


U.S. Fish and Wildlife Service
Columbia–Pacific Northwest
Interior Region 9

In collaboration with Bureau of Land Management, Bureau of Reclamation, National Marine Fisheries Service, U.S. Forest Service, Oregon Department of Agriculture, Oregon Department of Environmental Quality, Oregon Department of Fish and Wildlife, Oregon Water Resources Department, Crook County, Deschutes County, Jefferson County, and the Confederated Tribes of Warm Springs of Oregon

Final
Environmental Impact Statement

FOR THE DESCHUTES BASIN HABITAT CONSERVATION PLAN
VOLUME II PART B: APPENDICES 3.2-A THROUGH 3.10-A

October 2020

Estimated lead agency & applicant total costs associated with developing and producing this EIS $2,402,000

FINAL ENVIRONMENTAL IMPACT STATEMENT

FOR THE DESCHUTES BASIN
HABITAT CONSERVATION PLAN

VOLUME II, PART B:
APPENDICES 3.2-A THROUGH 3.10-A

OCTOBER 2020

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List of Appendices – Part B

- Appendix 3.2-A, Water Resources Technical Supplement
- Appendix 3.4-A, Vegetation and Wildlife Technical Supplement
- Appendix 3.4-B, Oregon Spotted Frog Technical Supplement
- Appendix 3.4-C, Fish and Mollusks Technical Supplement
- Appendix 3.5-A, Agricultural Uses and Agricultural Economics Technical Supplement
- Appendix 3.10-A, Cultural Resource Technical Supplement

Appendix 3.2-A
Water Resources Technical Supplement

Appendix 3.2-A
Water Resources Technical Supplement

Introduction

This appendix provides the technical supplement to the EIS. In general, the format follows that of the Water Resources EIS section, but not all subsections are addressed.

The study area for water resources is illustrated in Figure 1.

RiverWare Model

The analysis of effects on water resources was based on the review of RiverWare model outputs. RiverWare (Zagona et al. 2001) is a multifunctional river basin modeling tool. The Bureau of Reclamation (Reclamation) developed a daily timestep RiverWare model for the Upper Deschutes Basin[1] (2019) to analyze water distribution, streamflow, reservoir storage, water supply, reservoir water surface elevation and flood storage capacity, and flood flows in the study area. RiverWare model simulations were generated for a 38-water-year period from 1981 to 2018.[2] The selected model time period has a representative range of wet, medium, and dry years for the study area (Johnson pers. comm.).

The model representation of the water resources, infrastructure, and water demands in the basin is a simplification of the physical system, and as such, not every process and element in the physical system is represented in the model. However, the model is informed by existing data sets, water management regimes, and knowledge of the natural system. Appendix 3.1-A, *RiverWare Model Technical Memorandum*, documents the model representation of the alternatives and summarizes a selection of the results.

Model inputs included historical hydrology represented by over 25 streamflow, diversion, and reservoir gauges, water use at 21 surface water diversions, gain/loss flows associated with 12 reaches, properties for 5 reservoirs, and operational rules associated with the proposed action and alternatives. Model output for the proposed action and two action alternatives are compared to the no-action alternative to determine effects on water supply, surface water, and groundwater resources. The no-action alternative is compared to existing conditions. In addition to surface water data, model input included point locations representing groundwater gain and loss, diversions, and control points used to correct flows in the model.

The model-based water use in the basin on actual water use averaged over the 2010 to 2017 period for five of the eight irrigation districts. Water use for the three remaining irrigation districts was averaged over varying time periods (2013 to 2017 was used for Swalley Irrigation District [ID], 2009 was used for Three Sisters ID, and 2009 to 2011, 2013, and 2014 were averaged for Tumalo ID; Bureau of Reclamation 2019). A calibration model with a calibration period of October 1, 1984,

[1] Upper Deschutes Basin is defined as the basin upstream from Lake Billy Chinook.

[2] The original model period of water years 1981 through 2009 was established for the Upper Deschutes River Basin Study and extended through 2018 following updates to the RiverWare model completed in late 2019 and 2020.

through September 30, 2000, was used to test the operational logic written into the model rules (Bureau of Reclamation 2017). The 38-year simulation period is from October 1, 1980 through September 30, 2018.

Reclamation developed and ran the RiverWare model and provided model output to ICF in Microsoft Excel formatted files. ICF summarized model output using the Python Programming Language. Summarized data were exported to Excel for additional data manipulation and to MatLab for visualization.

One potentially significant difference between modeled water supply operations and real-time operational decisions made by water managers is the capability of managers to change operational decisions based on changing conditions. For example, the timing of stored water releases for downstream irrigation diversions is necessarily simplified in the RiverWare model to follow a set of defined assumptions that can affect the timing of reservoir releases and streamflows in the Crooked and Deschutes Rivers. For this EIS, for example, the model anticipates that North Unit ID will manage Wickiup Reservoir releases to extend demands throughout the season, but generally prioritizes meeting demands early in the irrigation season, in some cases at the expense of retaining stored water supplies for late season use. Depending on a number of factors, including the potential for water conservation efforts throughout the Upper Deschutes Basin to alleviate North Unit ID water shortages, actual management of Wickiup Reservoir releases may place a greater priority on extending the irrigation season at the expense of meeting maximum demands for a portion of the season.

Because of these differences between modeled operations and real-time operations, this EIS uses RiverWare as a tool to provide the best available information to provide a fair comparison across all of the alternatives. Therefore, although this analysis presents direct RiverWare model results as precise numbers, use of these results is not intended to imply unrealistic accuracy. Although RiverWare is a precise simulation model, the accuracy of model output is influenced by input data quality, model assumptions, and the model's ability to simulate complex interactions.

Figure 1. Water Resources Study Area Sheet 1

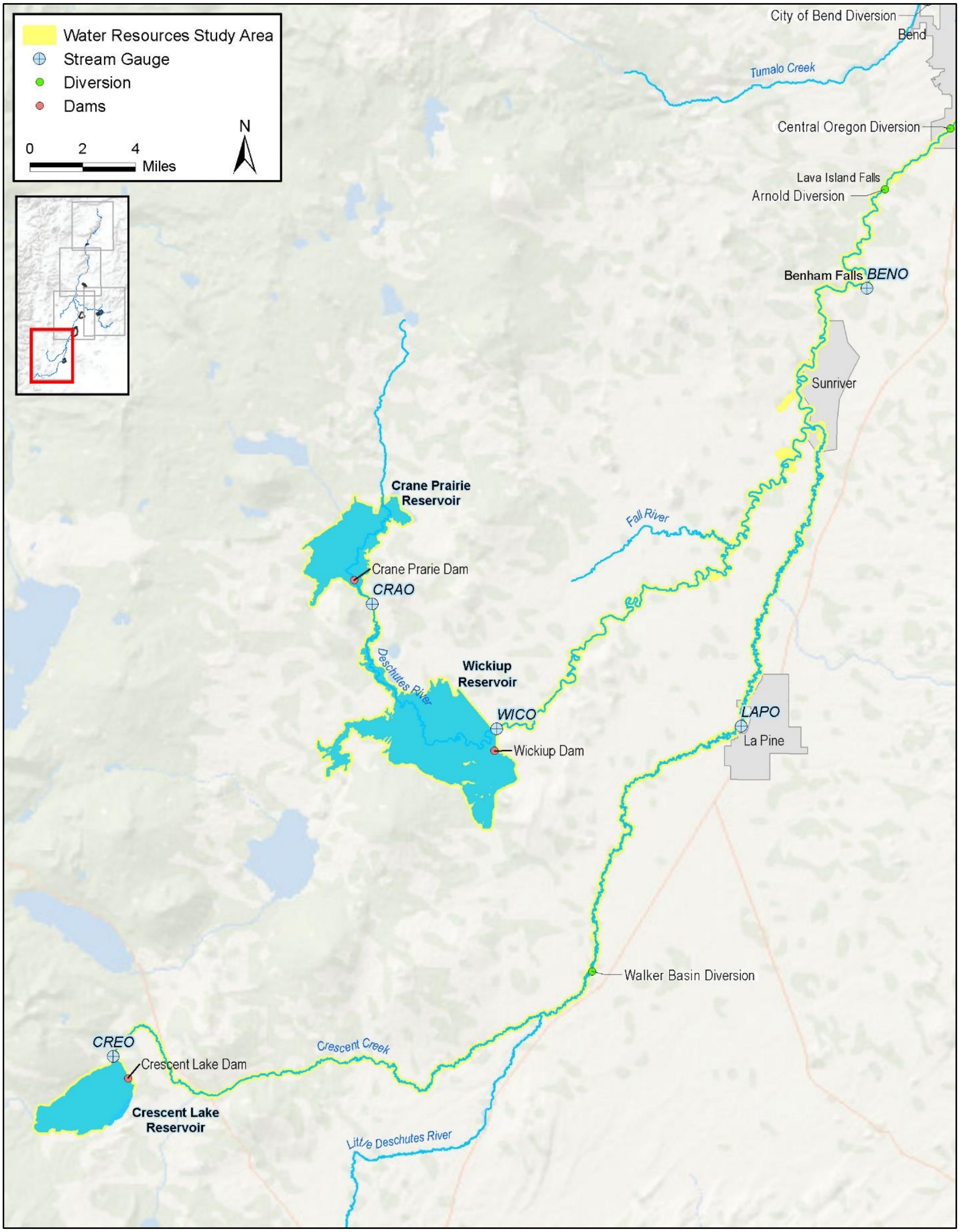


Figure 1. Water Resources Study Area Sheet 2

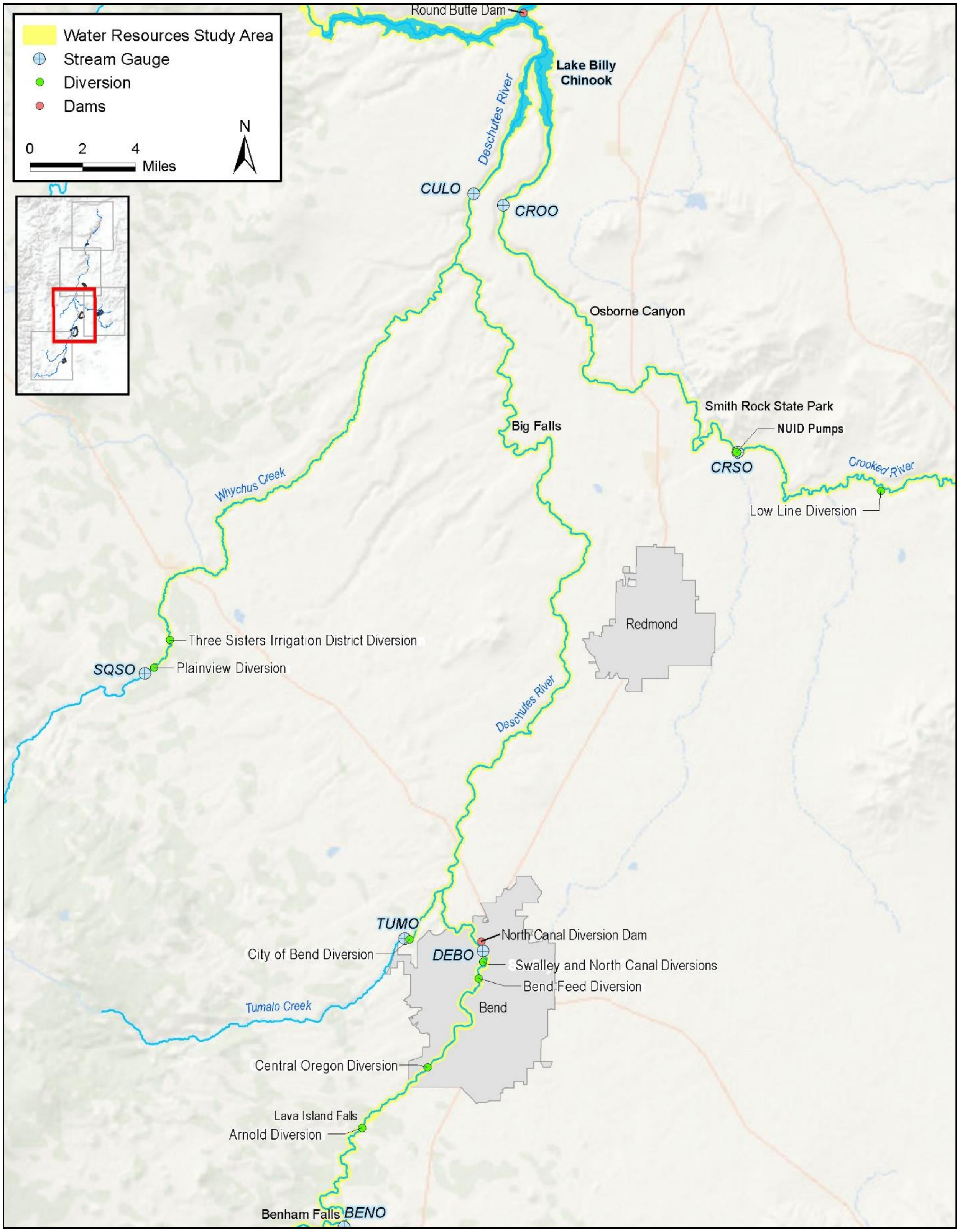


Figure 1. Water Resources Study Area Sheet 3

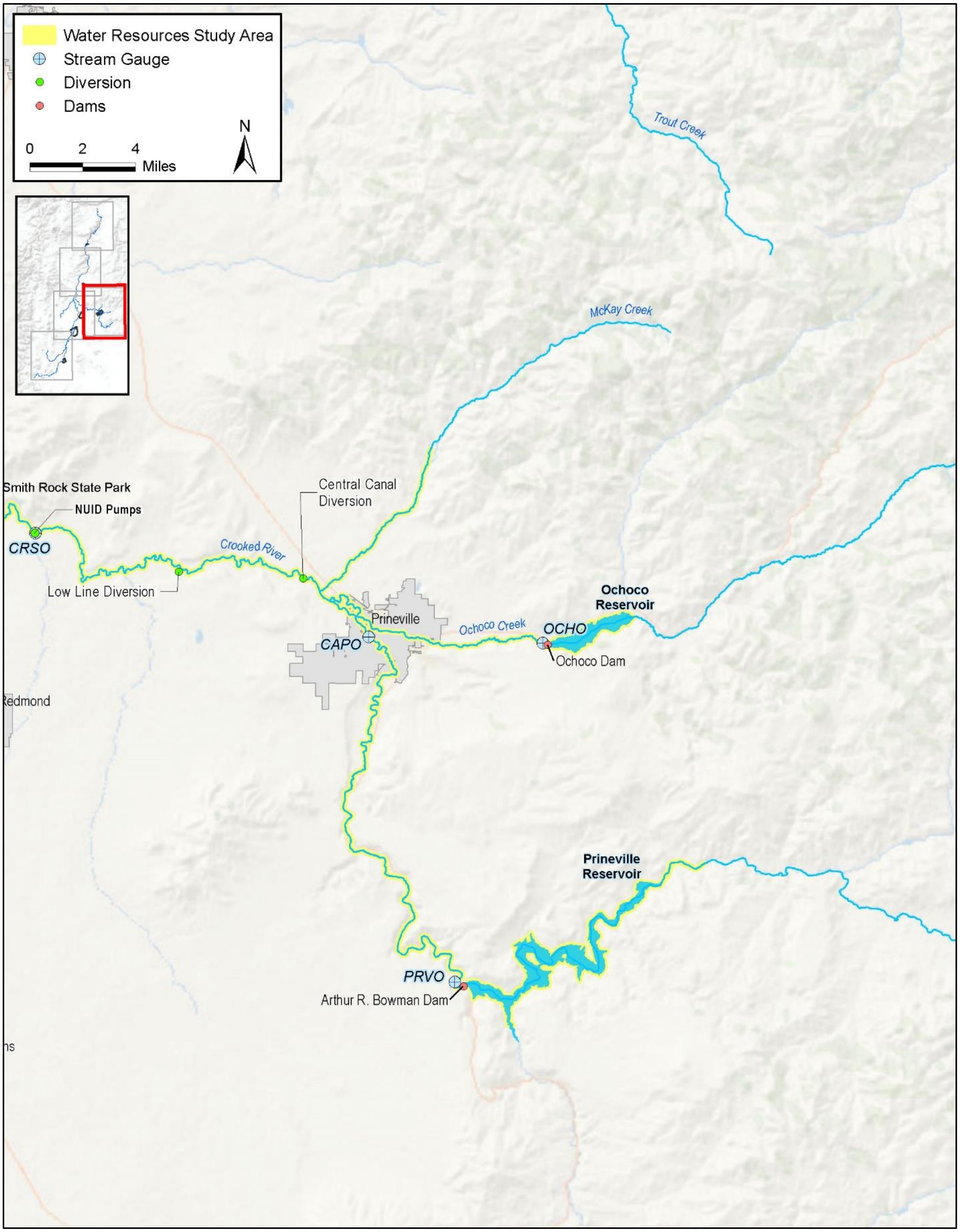


Figure 1. Water Resources Study Area Sheet 4

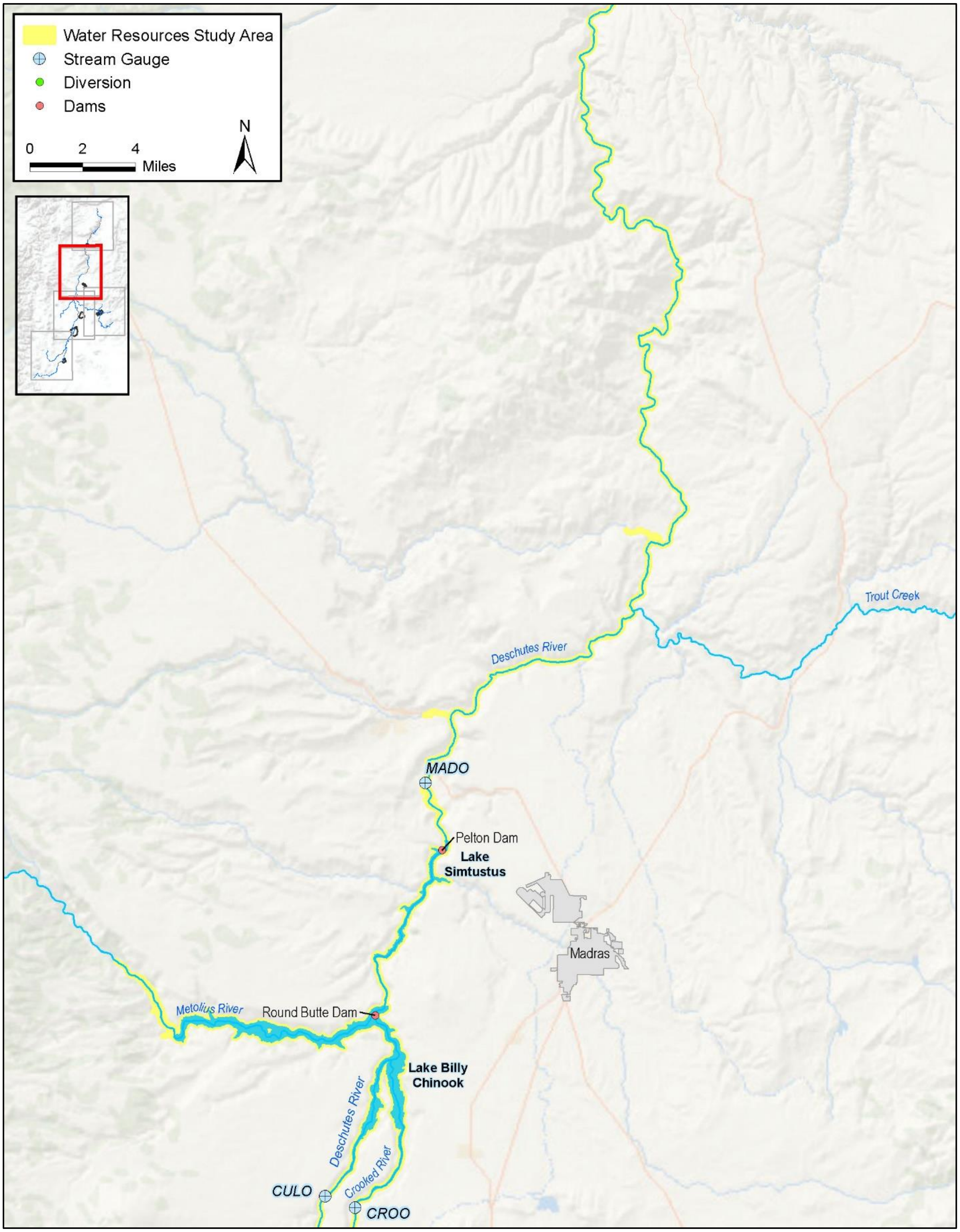
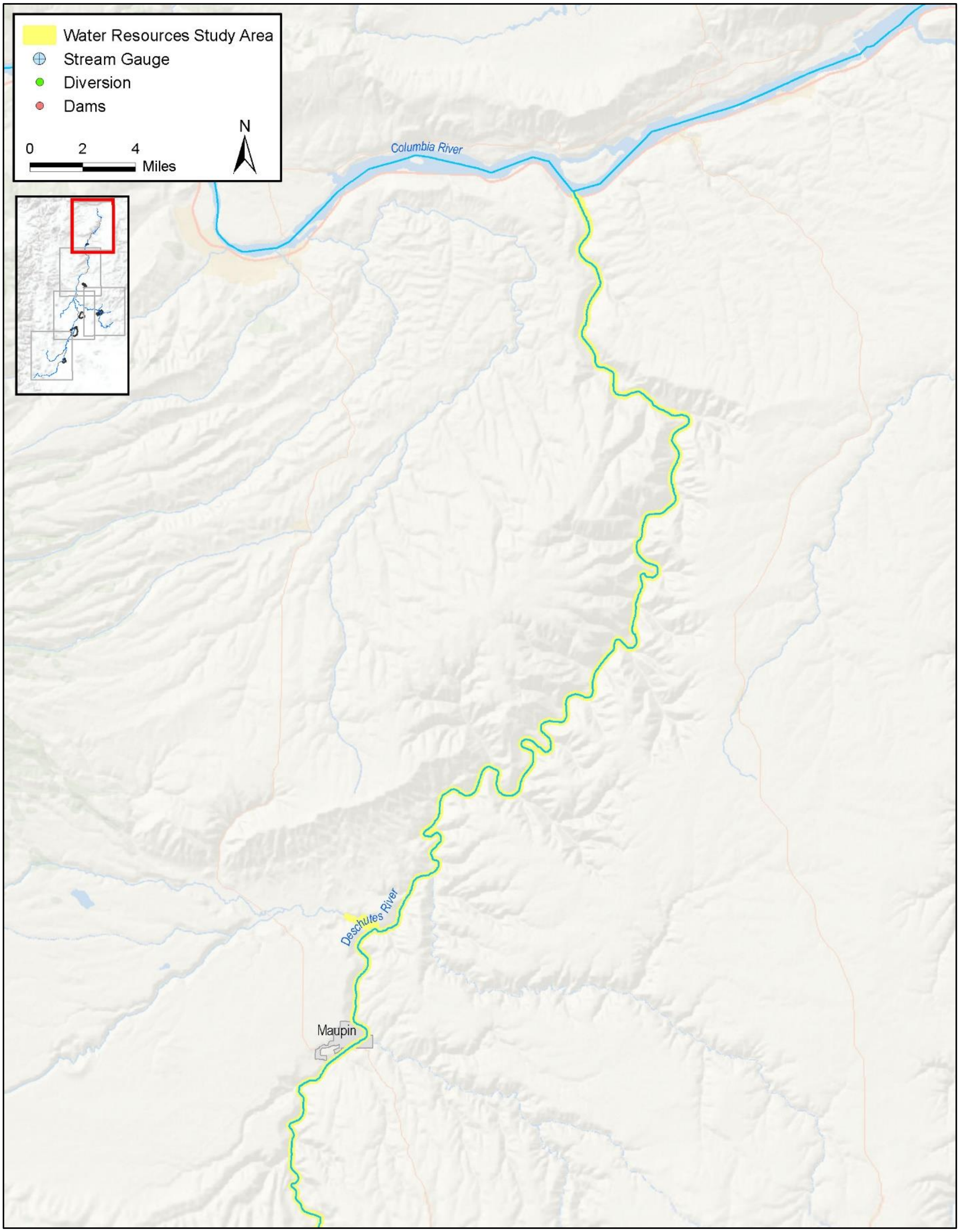


Figure 1. Water Resources Study Area Sheet 5



Affected Environment

Water Uses and Water Rights Administration

Under Oregon water law, with a few exceptions, the use of public water requires a water right from the Oregon Water Resources Department (OWRD). A water right is required to store water in a reservoir, which is referred to as a "primary" water right. Similarly, the use of stored water from a reservoir also requires a water right, which is referred to as a "secondary" water right and is different than the water right authorizing the storage of water. Secondary water rights can authorize the use of stored water for consumptive uses or for instream purposes.

Water rights describe the source of water, priority date, amount of water that can be used, point of diversion, type of water use, season of use, and place of use. The priority date is typically based on the date that the water right application was filed with OWRD.

When there is insufficient water to meet the needs of all water rights, OWRD regulates water rights by relative priority. In other words, senior water rights have priority so the upstream water rights with the most junior (recent) priority dates are the first ones required to cease water use to increase water supply available for senior (older) water rights. OWRD will continue the process of regulating off progressively more senior water rights until sufficient water is available for the most senior water right holders.

Regulation of live flow water rights in a river does not affect secondary water rights for the use of stored water. If stored water is released into a stream, the stored water is considered to be a different source than the live flow in the stream. Consequently, secondary water rights with junior priority dates can continue to divert water when more senior live flow water rights are regulated off.

Regulation can be initiated by OWRD, such as to protect an existing instream water right, or can result from a "call" from a water right holder who is not receiving all of the water to which they are entitled. When a call is made, OWRD validates the call by confirming that the senior right holder is using water as authorized by the water right, and that water is not available from the authorized source. After validating the call, OWRD considers the existing water rights on the stream, and then will identify the priority date to which they will regulate. OWRD then regulates off the water rights junior to that date (and any unauthorized water users). After the junior water users cease using water, the water supply will be re-evaluated and any necessary adjustments made, such as regulating back to a later date. OWRD will not regulate off a junior water user if it would be a "futile call" (i.e. regulating off the junior water users would result in no or an inadequate amount of water reaching the senior water user.)

The reservoirs in the Upper Deschutes Basin are generally filled during the period outside of the irrigation season through the early irrigation season.[3] A description of the water rights authorizing storage of water in these reservoirs (the primary water rights) is provided in Table 1.

[3] The water rights authorizing storage of water in these reservoirs do not include a stated storage season. Further, there is not an identified storage season in the Deschutes Basin.

Table 1. Covered Storage Reservoirs, Capacities, and Water Rights

Reservoir	Capacity (af)[a]	Water Right Volume (af)	Primary Water Right Holder	Secondary Water Right Holder
Crane Prairie	55,300	50,000	Central Oregon Irrigation District	Central Oregon Irrigation District Arnold Irrigation District Lone Pine Irrigation District
Wickiup	200,000	200,000	North Unit Irrigation District	North Unit Irrigation District Oregon Water Resources Department (Instream Water Rights)
Crescent Lake	86,900	51,050; 35,000	Tumalo Irrigation District	Tumalo Irrigation District Oregon Water Resources Department (Instream Water Rights)
Prineville	148,640	155,000	Bureau of Reclamation	Bureau of Reclamation and Prineville Reservoir Contract Holders
Ochoco	44,247	47,600	Ochoco Irrigation District	Ochoco Irrigation District

af = acre-feet

[a] This is the capacity listed on Reclamation's Deschutes Hydromet page http://www.usbr.gov/pn/hydromet/destea.html (retrieved February 29, 2016). Note that the listed capacity may be inconsistent with Hydromet data on reservoir storage volume and may vary from the maximum volume listed on the water right.

[b] An inter-district agreement between Central Oregon, Arnold, Lone Pine, and North Unit Irrigation Districts dictates fill order and water allocation between Wickiup and Crane Prairie Reservoirs.

Tables 2 and 3 present live flow and primary storage water rights associated with surface waters of the Deschutes River and Crooked River, respectively.

Table 2. Water Rights for Hydraulically Connected Surface Waters of the Deschutes River and tributaries above the BENO Gauge on the Deschutes River Listed in Order of Priority

Owner	Priority	Source	Irrigation Acres (or character of use, if not Irrigation)	Rate (cfs) or Volume (af)	Certificate
Priority Senior or Equal to Central Oregon and Lone Pine Irrigation District (10/31/1900)					
Private Irrigation	12/31/1893	Little Deschutes River	110	2.75 cfs	13602
Private Irrigation	12/31/1897	Little Deschutes River	29.3	0.73 cfs	68722
Walker Basin Diversion [a]	12/31/1897	Little Deschutes River	699.9	17.498 cfs	90239
Private Irrigation	12/31/1898	Big Marsh Creek	22.02	0.551 cfs	91836
Private Irrigation	12/31/1898	Crescent Creek	176.4	4.41 cfs	13641
Private Irrigation	12/31/1898	Crescent Creek	220.5	5.51 cfs	13640
Private Irrigation	12/31/1898	Crescent Creek	183.6	4.59 cfs	13637
Swalley Irrigation District [a]	9/1/1899	Deschutes River	4561.105	87 cfs	74145

Owner	Priority	Source	Irrigation Acres (or character of use, if not Irrigation)	Rate (cfs) or Volume (af)	Certificate
Central Oregon Irrigation District [a]	10/31/1900	Deschutes River	44627	978.297 cfs	83571
Lone Pine Irrigation District [a]	10/31/1900	Deschutes River	2369	29.1 cfs	72197
Priority Junior to Central Oregon and Lone Pine Irrigation District (10/31/1900), but Senior to North Unit (2/28/1913)					
Walker Basin Diversion	12/31/1900	Little Deschutes River	48.9	1.223 cfs	90239
Walker Basin Diversion	4/30/1902	Little Deschutes River	326.15	8.154 cfs	90239
Tumalo Irrigation District [a]	1905	Deschutes River	Supplemental to All Tumalo ID acres	9.5 cfs	74149
Arnold Irrigation District [a]	2/1/1905	Deschutes River	4384.05	150 cfs	74197
Walker Basin Diversion	12/31/1907	Little Deschutes River	63.1	1.58 cfs	68721
Tumalo Irrigation District [a]	3/20/1911	Crescent Creek	6590.6	35,000 af	76683
Swalley Irrigation District [a]	4/5/1911	Deschutes River	60	0.85 cfs	509
Private Irrigation	4/19/1911	Little Deschutes River	15	0.19 cfs	3383
North Unit Irrigation District [a]	2/28/1913	Deschutes River	Storage	200,000 af	51229
North Unit Irrigation District [a]	2/28/1913	Deschutes River	133.9	3.35 cfs	72280
North Unit Irrigation District [a]	2/28/1913	Deschutes River	49916	1101 cfs	72279
Central Oregon Irrigation District [a]	2/28/1913	Deschutes River	Storage	50,000 af	76685
Priority Junior to North Unit Irrigation District (2/28/1913)					
U.S. Forest Service Irrigation	5/7/1914	Little Deschutes River	55	0.7 cfs	1064
Private Irrigation	6/24/1915	Long Prairie Slough	20	0.25 cfs	12300
Private Irrigation	7/10/1916	Little Deschutes River	123	1.54 cfs	3368
Private Irrigation	1/30/1923	Little Deschutes River	87	1.25 cfs	9823
Private Irrigation	10/6/1924	Crescent Creek	44	0.85 cfs	7862
Private Irrigation	10/6/1924	Crescent Creek	70	0.88 cfs	6769

Owner	Priority	Source	Irrigation Acres (or character of use, if not Irrigation)	Rate (cfs) or Volume (af)	Certificate
Private Irrigation	3/15/1926	Crescent Creek	58	0.73 cfs	7873
Private Irrigation	3/15/1926	Crescent Creek	40	0.5 cfs	6792
Private Manufacturing	9/4/1929	Little Deschutes River	Manufacturing	2 cfs	12239
Private Water Supply	9/4/1929	Little Deschutes River	Municipal/ Fire Protection	2 cfs	12240
Private Irrigation	8/31/1931	Crescent Creek	35	0.44 cfs	11005
North Unit Irrigation District [a]	7/12/1955	Deschutes River	Storage	5650 af	51230
Tumalo Irrigation District [a]	12/8/1961	Crescent Creek	Storage	51,050 af	76637

[a] Water rights held by applicant irrigation districts.

Table 3. Summary of Water Rights for Hydraulically Connected Surface Waters of the Mainstem Crooked River from Bowman Dam to Osborne Canyon and Ochoco Creek below Ochoco Reservoir*

<table>
<tr><th>Diversion</th><th>Sources of Water</th><th>Maximum Flow Rate (cfs)</th><th>Maximum Storage Volume (af)</th></tr>
<tr><td>Ochoco Irrigation District - Crooked River Feed Canal, Ochoco Feed Canal, and Other Small Diversions</td><td>Live Flow, Prineville Reservoir Storage, and Ochoco Reservoir Storage</td><td>170</td><td>60,640</td></tr>
<tr><td>People's Canal and Other Small Private Diversions</td><td>Live Flow and Prineville Reservoir Storage</td><td rowspan="2">33.498</td><td>3,497</td></tr>
<tr><td>Crooked River Central Canal and Other Small Private Diversions</td><td>Live Flow and Prineville Reservoir Storage</td><td rowspan="3">6,547</td></tr>
<tr><td>Rice Baldwin and Other Small Private Diversions</td><td>Live Flow and Prineville Reservoir Storage</td><td>35.123</td></tr>
<tr><td>Small Diversions Below Lowline Canal</td><td>Live Flow and Prineville Reservoir Storage</td><td>11.63</td></tr>
<tr><td>Lowline Canal and Other Small Private Diversions</td><td>Live Flow and Prineville Reservoir Storage</td><td>9.54</td><td>330</td></tr>
<tr><td>North Unit Irrigation District Crooked River Pumping Station</td><td>Live Flow and Prineville Reservoir Storage</td><td>200</td><td>10,000</td></tr>
</table>

Table 4. Detailed List of Water Rights for natural flow of the Mainstem Crooked River and stored water from Bowman Dam to Lake Billy Chinook

Owner	Priority	Irrigation Acres (or character of use, if not Irrigation)	Rate (cfs) or Volume (af)	Certificate / Transfer
Crooked River Central	1880	79	0.988	72947
Private	1885	20	0.25	523
Private	1891	88.7	1.48	80794
Private	1891	104.8	1.75	83442
Private	1891	6.5	0.11	T-6969
Peoples Irrigation Company	1892	19	0.2375	89538
Peoples Irrigation Company	1892	10	0.125	90397
Private	1892	11	0.137	83732
Peoples Irrigation Company	1893	335.8	4.1985	87547
Peoples Irrigation Company	1893	22.6	0.2825	90381
Crooked River Central	1893	13.2	0.165	72947
Crooked River Central	1893	21.8	0.2725	72947
Private	1893	65	0.81	80855
Private	1893	29.5	0.37	T-9171
Private	1893	10	0.125	T-8548
Private	1893	34.8	0.434	T-6969
Private	1893	49.3	0.616	T-6969
Private	1893	12.8	0.16	80793
Peoples Irrigation Company	1895	40	0.5	90397
Peoples Irrigation Company	1895	6.7	0.084	90381
Peoples Irrigation Company	1895	20	0.25	90383
Peoples Irrigation Company	1897	76	0.95	90397
Crooked River Central	1897	74.8	0.935	72947
Peoples Irrigation Company	1898	3.5	0.044	90397
Peoples Irrigation Company	1900	47.6	0.595	87547
Private	1900	404	5.05	52015
Private	1903	14	0.18	42158
Low Line Ditch Company	1903	120.09	1.5	87058
Low Line Ditch Company	1903	34.2	0.43	T-10732
Peoples Irrigation Company	1904	32	0.4	87547
Private	1904/1910	15	0.19	T-11740
Peoples Irrigation Company	1904/1910	337.8	4.22	90397
Private	1904/1910	225.1	2.81	T-10233
Crooked River Central	1904	17.3	0.216	72947
Crooked River Central	1906	159.8	1.998	72947
Private	1908	100	1.25	610

Owner	Priority	Irrigation Acres (or character of use, if not Irrigation)	Rate (cfs) or Volume (af)	Certificate / Transfer
Private	1909	263.2	3.29	51322
Private	1909	6.4	0.08	68326
Private	1909	39.3	0.5	83851
Private	1909	44	0.55	86518
Private	1909	4.3	0.05	T-9172
Peoples Irrigation Company	1910	40	0.5	87547
Crooked River Central	1910	84.7	1.059	72947
Crooked River Central	1910	11.7	0.146	72947
Private	1910	26	0.33	57742
Private	1911	146.5	1.83	2734
Private	1912	187.5	2.33	1327
Private	1913	34	0.43	2114
Ochoco ID	1914	3087.3	77.183	82247
Ochoco ID	1914	12011.9	112.817	82247
Private	1914	75	0.94	82262
Bureau of Reclamation & Crooked River Central	1914	169.7	4.242	72948
Bureau of Reclamation & Crooked River Central	1914	47	1.175	72948
Bureau of Reclamation & Crooked River Central	1914	22.5	0.563	72948
Bureau of Reclamation	1914	761.20	19.03	83850
Bureau of Reclamation	1914	918.00	23.4	83850
Private	1914	0.80	0.01	83850
Private	1914	80.00	2.02	T-9171
Private	1914	4.30	0.11	T-9171
Bureau of Reclamation & Peoples Irrigation Company	1914	289.4	7.23	76013
Bureau of Reclamation & Peoples Irrigation Company	1914	577.2	14.43	76013
Private	1914	14.8	0.365	80854
Private	1914	65	1.625	80854
Private	1914	2.7	0.0675	T-8548
Private	1914	10	0.25	T-8548
Private	1914	62.2	1.55	T-6969
Private	1914	37.1	0.93	T-6969
Private	1914	76.1	1.9	T-6969
Bureau of Reclamation	1914	Storage	155,000 AF	57612
Private	1916	8	0.2	8969

Owner	Priority	Irrigation Acres (or character of use, if not Irrigation)	Rate (cfs) or Volume (af)	Certificate / Transfer
Private	1916	22.5	0.28	82251
Private	1917	99.8	1.24	83858
Private	1917	246	3.06	T-10233
Crooked River Central	1919	20.9	0.264	72946
Crooked River Central	1919	35.7	0.446	72946
Private	1920	20	0.25	45870
Private	1920	30	0.38	52180
Private	1921	Hydro	48.2	10851
Peoples Irrigation Company	1921	7	0.1	75484
Private	1927	100.25	1.25	10854
Crooked River Central	1927	16.7	0.28	72945
Crooked River Central	1927	12	0.25	72949
Crooked River Central	1927	77.6	0.97	72950
Crooked River Central	1927	70.6	0.93	72950
Private	1929	30	0.38	11698
Private	1930	93	1.17	52181
Peoples Irrigation Company	1934	79.7	1	75485
Private	1934	20	0.25	75486
Peoples Irrigation Company	1934	12.4	0.16	75487
Private	1935	17	0.21	75488
Peoples Irrigation Company	1935	25	0.31	90380
Private	1940	29.4	0.37	76618
Private	1946	205.4	3.89	87331
Bureau of Reclamation	1947	Hydro	175	17362
City of Prineville	1947	30.4	0.38	T-7488
Private	1948	11.2	0.14	21681
Deschutes Valley Water District	1948	Hydro	21.3	27796
Private	1950	17.5	0.22	23999
Private	1950	85.4	1.068	33012
Private	1952	100	1.25	82265
Private	1954	56	0.7	24147
Private	1955	43.5	1.09	81134
Private	1955	19.8	0.5	30934
North Unit ID	1955	49,866	200	72281
North Unit ID	1955	133.9	3.35	72282
Private	1955	105.9	1.39	75490
Peoples Irrigation Company	1955	83.5	1.09	75491
Deschutes Valley Water District	1967	Hydro	60	46049

Owner	Priority	Irrigation Acres (or character of use, if not Irrigation)	Rate (cfs) or Volume (af)	Certificate / Transfer
North Unit ID	1968	8,530.80	200	72283
North Unit ID	1968	286.9	7.17	72284
Deschutes Valley Water District	1977	Hydro	140	65840
Private	1982	30.3	0.76	62542
Deschutes Valley Water District	1982	Hydro	1772.5	P-47591
North Unit ID	1982	124	3.09	P-47284
Private	1983	22.4	0.56	60930
Private	1986	3.5	0.088	82624
Private	1987	Fire Protection	0.99	66175

* The Services acknowledge that the Confederated Tribes of the Warm Springs claim to have off-reservation water rights in the Deschutes Basin, including the Crooked River within the Plan area, as well as its tributaries. However, these claims have not been adjudicated or otherwise quantified.

Prineville Reservoir water use is affected by the Crooked River Collaborative Water Security and Jobs Act of 2014. Under the Act, 83,987 acre-feet (af) of previously uncontracted water was made available for irrigation and to benefit fish and wildlife. This includes the release of up to 5,100 af of stored water from the reservoir annually to serve as mitigation for City of Prineville groundwater pumping, to be released for the benefit of downstream fish and wildlife; the release of up to approximately 62,000 af of uncontracted storage in Prineville Reservoir to benefit downstream fish and wildlife; and the release of up to 10,000 af for irrigation in North Unit ID or fish and wildlife use.

Crooked River minimum streamflows below North Unit ID's Crooked River Pumping Plant are mandated by an agreement between North Unit ID and the Deschutes River Conservancy (DRC) as part of North Unit ID's conserved water projects. The agreement is intended to limit North Unit ID's exercise of its Crooked River water rights to protect minimum instream flows in the Crooked River below the pumping plant. The agreement includes scenarios for both dry and non-dry years based on the Prineville Reservoir storage and outflows in late March. The minimum streamflow protected in the Lower Crooked River is based on the volume of water conserved through North Unit ID's conserved water project and the district's historical pattern of use from the Crooked River.

Surface Water

The following hydrologic description of the study area is largely adapted from the Chapter 4 of the Deschutes Basin HCP, *Current Conditions of the Covered Lands and Waters* (Deschutes Basin Board of Control and City of Prineville 2020).

Upper and Middle Deschutes River

The headwaters of the Upper Deschutes Basin (the watershed area located upstream from Lake Billy Chinook Reservoir where the Deschutes, Crooked, and Metolius Rivers join) are located within the Cascade Range and Newberry Volcano and Quaternary Sediment deposits, both units are characterized by highly-permeable materials with rapid infiltration rates (Lite and Gannett 2002). Most precipitation that falls in the upper basin becomes groundwater before reemerging at multiple springs and seeps. Direct surface runoff makes up a relatively small percentage of the flow in the Upper Deschutes River. The net effect of this is an unregulated flow regime that shows considerably less seasonal variation than most other Oregon streams that are surface runoff-dominated.

The Upper Deschutes River is generally defined as upstream of the City of Bend ID diversions. The Middle Deschutes River begins below Bend, extending to upstream of Lake Billy Chinook. Current streamflows are heavily influenced by irrigation activities and show considerably more seasonal variation than unregulated flows. The storage, release and diversion of irrigation water results in flows upstream of Bend that are generally high in the late spring and summer and low in the fall, winter and early spring. Flows downstream of Bend are low during the late spring and summer irrigation season because most flow (natural and released storage) is diverted. Peak diversion rates typically occur between May 16 and September 15. During the fall, winter and early spring, flows in the Middle Deschutes River, located between the City of Bend and Lake Billy Chinook, are also reduced from natural conditions by irrigation storage, but natural inflow from tributaries and springs downstream of the reservoirs moderates the influence of storage somewhat and winter flows are not nearly as low at Bend as they are between Wickiup Dam and Fall River. Middle Deschutes River flows fluctuate periodically during the winter when water is diverted into four of the canals (Central Oregon, Pilot Butte, Swalley and Tumalo) for periods of one week or less each month to supply water for livestock.

Crescent Creek and Little Deschutes River

Crescent Creek and the Little Deschutes River have a combined drainage area of 1,050 mi^2. The drainages are located within the La Pine Subbasin, a geologic formation characterized by several hundred feet of low-permeability, fine grained sediment (Lite and Gannett 2002). Unlike other streams within the Upper Deschutes Basin, where flows are supported largely by spring discharge, Crescent Creek and the Little Deschutes show strong seasonal variation driven by surface runoff that is also influenced by operation of Crescent Lake Reservoir. Unregulated surface flows typically peak for short periods during winter storm events and spring runoff, and drop to prolonged annual lows in mid- to late summer. Operation of Crescent Lake Reservoir causes a minor reduction in monthly median flow during the storage season and a pronounced increase in flow during the irrigation season from immediately downstream of Crescent Dam, to 60 miles downstream on the Little Deschutes River.

Tumalo Creek

The entire Tumalo Creek watershed lies within the Cascade Range and Newberry Volcano Deposits hydrogeologic unit described by Lite and Gannett (2002). Although there are large springs (>10 cfs) in the upper portion of Tumalo Creek, the subsurface permeability in Tumalo Creek is less than in other portions of the Upper Deschutes Basin. With less permeable geology, Tumalo Creek has a greater contribution of surface runoff and a more pronounced seasonal fluctuation in flow relative to more groundwater-dominated streams in the basin. Upstream of the Tumalo ID diversion at RM 2.8, the unregulated Tumalo Creek shows a substantial and predictable peak during spring runoff, moderate flows during the summer, and annual low flows during the winter. Downstream of the diversion, the lower 2.8 miles of creek experience substantially reduced spring and summer flows, but fall and winter flows are relatively unaffected.

Whychus Creek

Natural flows in Whychus Creek are influenced predominantly by snowmelt. Upstream of the irrigation diversions, flows consistently peak at 200 to 400 cfs in June and drop to 60 cfs or less in late winter. Extreme peak flows as high as 1,000 cfs have been reported during episodic winter storms and rain-on-snow events. Downstream of the Three Sisters ID diversion at RM 25.8, flows are considerably reduced from April through October and slightly reduced from November through March. Flows increase downstream of Sisters due to a number of sources, including, multiple small springs near Camp Polk Road (RM 17) and Alder Springs (RM 1.4).

Lower Deschutes River

Flows in the Deschutes River increase more than fourfold between Culver (RM 120) and Madras (RM 100), mostly due to inflow that originates as spring discharge to the Metolius River and lower Crooked River. Inputs to the Lower Deschutes River include approximately 800 cfs of groundwater inputs, 1,000 cfs on the Crooked River, and 1,500 cfs on the Metolius River. The net effects of this large, relatively constant inflow are a reduction in the relative influence of upstream irrigation activities and less seasonal fluctuation in flow compared to the Middle Deschutes River.

Crooked River, Ochoco Creek, and McKay Creek

The hydrology of the Crooked River Subbasin upstream from Smith Rock State Park, is distinct from the western portions of the Upper Deschutes Basin for two reasons. First, the Crooked River Subbasin receives substantially less precipitation than tributaries in the Cascade Mountains to the west of the Deschutes River. Average annual precipitation in Prineville, near the lower end of the Crooked River Subbasin, is only 9.9 inches, to 17.0 inches at Rager Ranger Station, located at 4,000 feet elevation (Western Regional Climate Center 2017). In contrast, average annual precipitation at Santiam Pass on the Cascade crest is 85.6 inches.

The second reason for the difference in hydrology for the Crooked River Subbasin upstream of Smith Rock State Park, is the absence of deep, highly-permeable geologic surface deposits of the type present in other portions of the Deschutes Basin. Much of the Crooked River Subbasin is in close contact with the John Day Formation, which is older and much less permeable than the Newberry Volcanic Deposits and Quaternary Sediments that overlie it to the south and west (Lite and Gannett 2002). The result is limited interchange between surface and ground water in the Crooked River Subbasin. Rather than recharging groundwater, most precipitation that falls in the subbasin becomes surface runoff that peaks rapidly and briefly during storm events and spring snowmelt. Unlike the Deschutes River, which receives relatively constant groundwater discharge throughout the year, the Crooked River and its tributaries receive little groundwater support and tend to drop dramatically after the end of snowmelt in early spring. Groundwater discharge (originating from the Upper Deschutes Basin, including irrigation canal leakage) only becomes a significant source of streamflow in the lower 10 miles of the Crooked River above Lake Billy Chinook, where the canyon is of sufficient depth to intersect the regional groundwater table and the river gains as much as 1,100 cfs (Gannett and Lite 2004).

Current hydrologic conditions in the Crooked River and Ochoco Creek are illustrated by flow data for five locations with significance to ongoing irrigation activities. Flow above Prineville Reservoir typically peaks in spring during snowmelt, and falls close to zero by late summer. In many years, storm events and/or heavy snowpack can result in short-term runoff events upstream of the reservoir well in excess of 3,000 cfs. Downstream of Bowman Dam, the combination of irrigation storage and flood control eliminates flows over 3,000 cfs, reduces average winter flow, and increases average summer flow compared to unregulated conditions. At Terrebonne, which is downstream of all irrigation diversions, the cumulative effects of diversions and tributary inflow are apparent. Peak winter flow in the Crooked River at Terrebonne again exceeds 3,000 cfs in some years due to flow inputs from Prineville Reservoir, Ochoco Creek, and McKay Creek, but summer flow is much less than below Bowman Dam due to multiple irrigation diversions. Further downstream at Opal Springs, groundwater discharge increases flow in the Crooked River by more than 1,000 cfs during all seasons.

Flow in Ochoco Creek below Ochoco Dam shows a seasonal pattern similar to the Crooked River below Bowman Dam, though much smaller in magnitude. Ochoco Creek flow is high immediately below the dam during the irrigation season when water is released, and low during the winter when water is stored. In 13 of 23 years between 1994 and 2016, it was necessary to release additional water from Ochoco Reservoir during the storage season to maintain flood storage capacity. Between Ochoco Dam and the mouth of Ochoco Creek, summer flow is reduced by multiple irrigation diversions covered by the Final Deschutes Basin HCP.

McKay Creek flows into the Crooked River 0.5 mile downstream of Ochoco Creek, also within the City of Prineville. The lower 9 miles of the river pass through the Crooked River Gorge, which is up to 500 feet deep in places. McKay Creek does not have storage facilities although there are a number of diversions and returns that affect streamflow. Ochoco ID manages diversions downstream from Jones Dam (RM 5.8).

Historically low flows in the Crooked River downstream of Bowman Dam have been improved in recent years by two actions. The Crooked River Collaborative Water Security and Jobs Act of 2014 (Crooked River Act) made over 62,000 af of previously-uncontracted storage in Prineville Reservoir available for fish and wildlife use. This water is released from storage at various times of year to increase instream flow in the reach from Bowman Dam to Lake Billy Chinook. In addition, summer flows at Terrebonne have been increased through an agreement between North Unit ID and the Deschutes River Conservancy (DRC) that ensures North Unit ID will not operate the Crooked River pump station to divert water unless minimum flows of 43 cfs to 181 cfs can be maintained at the Terrebonne gauge (CRSO). The result of this agreement is that Crooked River flow at Terrebonne will not drop appreciably below the historical median in non-dry years or below the historical 80% exceedance level in dry years during the driest months of July and August.

Groundwater discharge to the Crooked River contributes to streamflow downstream from Terrabonne. In excess of 1,000 cfs enters the Crooked River year-round through groundwater inputs between Osborne Canyon and Opal Springs Dam.

Groundwater

Basin Hydrogeology

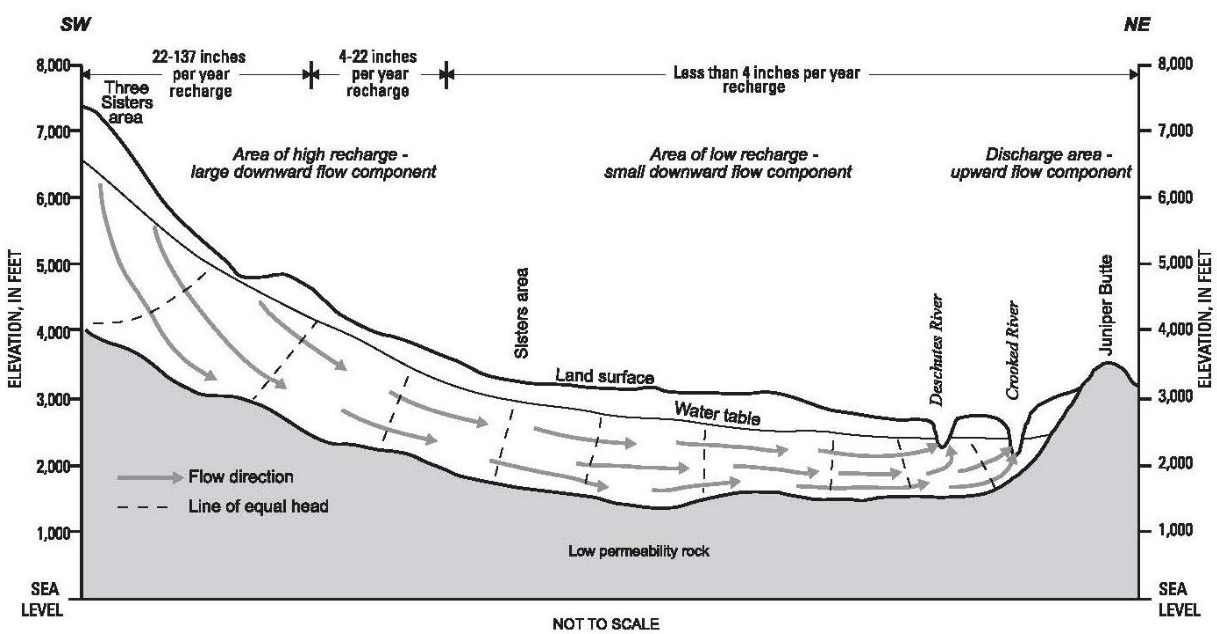
The permeable rock underlying the Deschutes River Basin, combined with the large annual precipitation in the Cascades, results in a substantially large aquifer system that is highly productive and a river system that is influenced by groundwater–surface water interactions. Due to the porous geology of the area, water can move relatively easily between the surface and groundwater systems depending on the relative elevations of the groundwater levels and stream channels and local hydrogeologic conditions.

The study area includes groundwater within the Upper Deschutes Basin, which is bound on the north by Jefferson Creek, the Metolius River, the Deschutes River, and Trout Creek; the east by the geological change between the Deschutes Formation and the much less permeable John Day Formation; on the south by the drainage divides between the Deschutes Basin and the Fort Rock and Klamath Basins; and on the west by the Cascade Mountain Range.

USGS, in conjunction with OWRD, published the study Groundwater Hydrology of the Upper Deschutes Basin in 2001 that documents the groundwater system and its interactions with the rivers in the upper basin (Gannett et al. 2001). An update of the original study that evaluates the groundwater level changes observed in the basin was published in 2013 (Gannett and Lite 2013). These studies define the hydrology and hydrogeologic interactions in the Deschutes Basin regional groundwater system that are summarized below.

The groundwater system and its interactions with the rivers in the Upper Deschutes Basin is primarily controlled by the distribution of recharge, the geology, and the location and elevation of streams relative to the groundwater table. Groundwater flows from the recharge areas in the Cascade Range and Newberry Volcano through the younger porous Cascade and Deschutes Formation deposits within the basin. Beneath these permeable deposits is the older, low permeability John Day Formation deposits. The top of the John Day Formation forms the bottom of the groundwater system (Figure 2).

Figure 2. Diagrammatic Section of Water Movement through the Groundwater System in the Upper Deschutes Basin (Source: Gannett et al. 2001: 62)

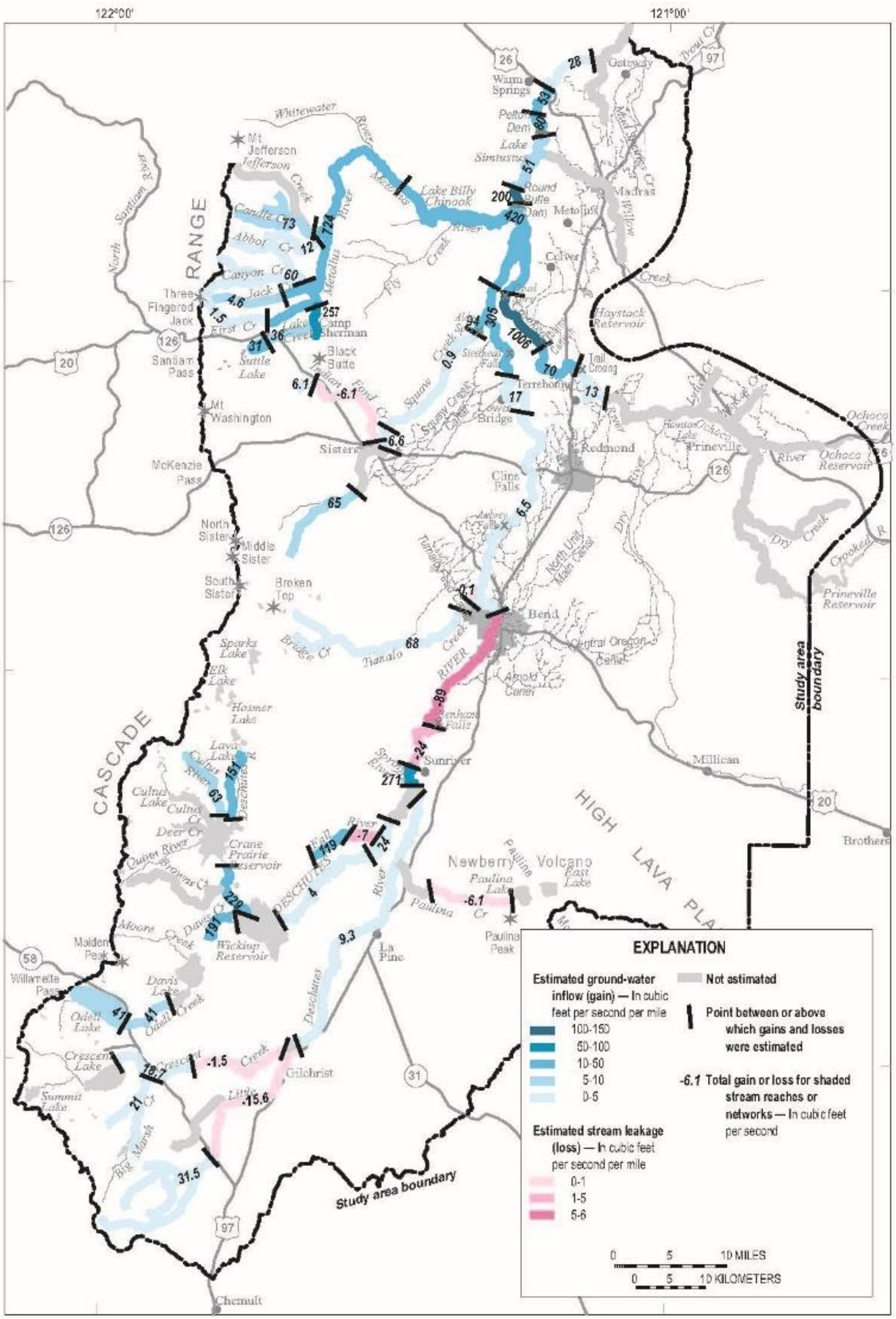


Water moves through the groundwater system toward the discharge areas along the margin of the Cascade Range and near the confluence of the Deschutes, Crooked, and Metolius Rivers. Approximately 10 to 15 miles upstream of the confluence of these rivers, the river canyons are sufficiently deep to intersect the groundwater table, and the groundwater system discharges into the rivers (Figure 2). The exposure of the older deposits in the bottom of the incised river canyons approximately 10 miles north of Lake Billy Chinook (near the Pelton Dam) marks the northern extent of the permeable groundwater system in the study area. There is no appreciable discharge of groundwater to the Deschutes River downstream of this point. Therefore, the groundwater system evaluation is limited to the Upper Deschutes Basin from the confluence of the Deschutes, Crooked, and Metolius Rivers.

Annual recharge to the groundwater system includes precipitation, inter-basin flows, and irrigation canal leakage. Precipitation in the Cascade Range provides an average of 3,800 cfs of recharge (2.45 billion gallons per day or approximately 2.7 million af per year) based on data from 1962 to 1997 (Gannett et al. 2001:22). Interbasin groundwater flows from outside the Upper Deschutes provide an additional 850 cfs of recharge. Canal leakage provides an additional approximately 490 cfs of recharge (1994 dataset) (Gannett et al. 2001:1 and 26), which has recently been reduced in localized areas by canal lining and piping projects. (Gannett and Lite 2013: 13). At the basin-scale, fluctuations in the groundwater levels generally follow the climate cycles, with periods of high groundwater levels generally corresponding to high precipitation, and lower water levels corresponding to low precipitation periods. This effect dampens going eastward and away from the recharge area.

Areas where groundwater discharges into surface waters through springs, increasing streamflow, are *gaining reaches*; areas where water leaks from a stream, recharging the groundwater system, are *losing reaches*. Figure 3 depicts average gains and losses across segments of the river systems and shows that within the Upper Deschutes Basin, the groundwater system is generally discharging water into the river systems with a few notable exceptions described below (Gannett et al. 2001:34-37).

Figure 3. Estimated Gains and Losses from Select Stream Reaches in the Upper Deschutes Basin (Source: Gannett et al. 2001:37)



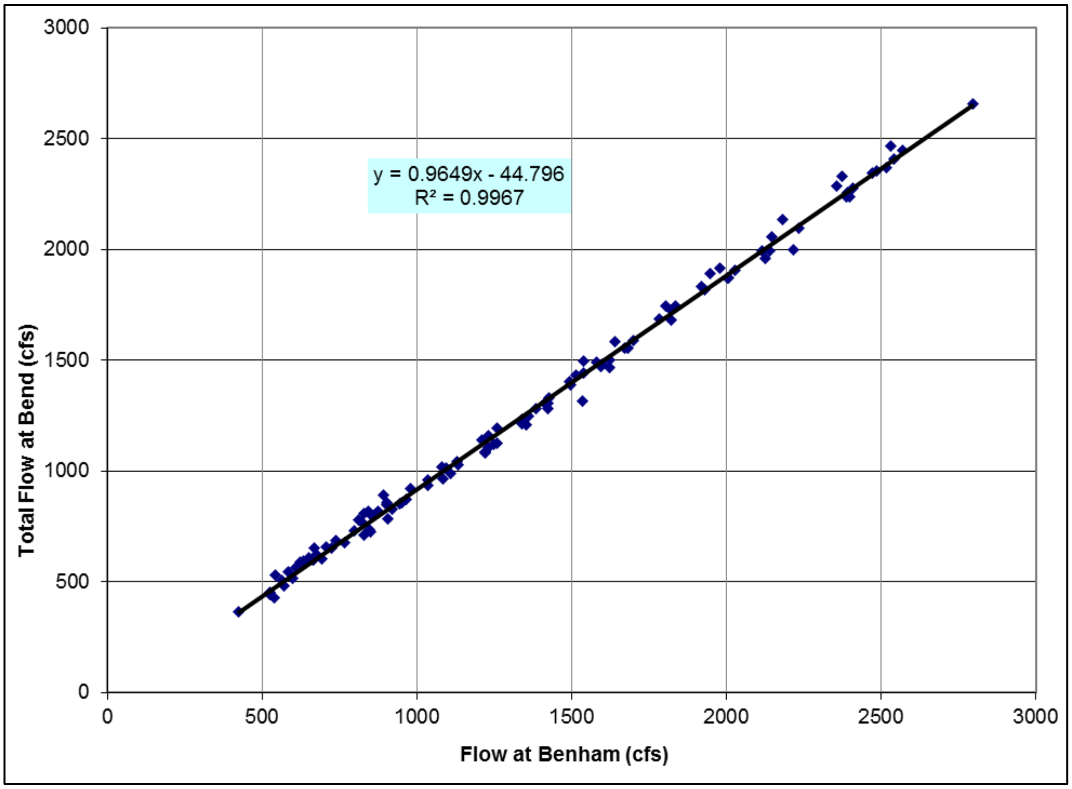
River–Groundwater System Interactions

In the upper portions of the Deschutes River and its tributaries, numerous springs supply water to the headwaters of the river systems and reservoirs along the edge of the Cascade Mountains. According to Gannett et al. (2001), seepage losses from Crane Prairie Reservoir to the groundwater system are dependent on reservoir stage, with the rate of loss increasing with higher reservoirs stages. On average the reservoir loses 60,000 af per year, or approximately 83 cfs based on 1939 through 1950 data (Gannett et al. 2001: 29). It is thought a large fraction of these losses are returned to the system through the springs located just below Crane Prairie Reservoir and along the edges of Wickiup Reservoir, and some of this likely contributes to the groundwater system recharge. Wickiup Reservoir is not as well understood, but generally has a net inflow of water through springs and rivers with some seepage occurring from periodic development of sinkholes.

In the La Pine area the groundwater table elevation is near land surface. Stream gains and losses along most of these reaches of the Deschutes and Little Deschutes Rivers area are small, indicating relatively little net exchange of water between the groundwater and river systems (Figure 3) (Gannett et al. 2017:12). The exception is the significant inflow to the Deschutes River from the Spring River area near Sunriver. There also is one notable area in this upper basin where the losing reach of stream on the Little Deschutes River and Crescent Creek is likely recharging the local groundwater system.

At approximately Sunriver and northwards the groundwater table elevation begins dropping below the land surface (and stream system) due to changes in the geologic deposits and faulting. The only significant losing reach along the Deschutes River occurs between Sunriver and Bend (Figure 3) where the river crosses a highly porous and recent lava flow losing approximately 113 cfs on average, up to 7% of river flow (Gannett et al. 2001: 73). Historical data indicate a correlation between seepage rate (water loss) and river flows, with higher river flows resulting in higher seepage rates. Figure 4 presents the relationship of flow between Benham Falls and Bend and OWRD’s estimation of the relationship of the river losses to the flow (LaMarche pers. comm. [a, b]; Gannett et al. 2001: 38).

Figure 4. Relationship of Flow between Benham Falls and Bend and Resulting Relationship between River Flow and Channel Loss (Source: LaMarche pers. comm. [a, b]; Gannett 2001:38) (monthly data from 1932 to 1999; Lag-7 dataset)



From Bend to Lower Bridge (Figure 3) is considered a neutral reach where there is little net exchange of water between the groundwater and river systems. From Lower Bridge to the confluence of the Metolius, Deschutes, and Crooked Rivers, the groundwater system becomes exposed to the incising river canyons and begins discharging large volumes of groundwater to the river system (Gannett et al. 2001:44–46).

The Whychus Creek system is generally a gaining river system with the exception of the short segment just upstream of Sisters. This short segment of the creek flows through a braided stream restoration project just upstream of Sisters and loses approximately 10 cfs (LaMarche pers. comm. [a, b]), which appears to recharge the groundwater system and not discharge back to the creek locally. Groundwater discharges into the creek significantly increase near the Deschutes River confluence.

Based on the OWRD seepage run data from 2007, the Crooked River generally interacts with a shallow alluvial aquifer in the upper deposits of the valley and not with the regional groundwater system until downriver below Smith Rocks. The river gains small amounts of groundwater from the shallow alluvial aquifer throughout the Prineville valley until the incising river canyon intersects the regional groundwater table approximately 5 miles downstream of Smith Rocks State Park (LaMarche pers. comm. [a, b]). At this point, significant gains in flow result from the discharge of groundwater from the regional aquifer system, continuing down to the confluence of the Metolius, Deschutes, and Crooked Rivers.

Other Groundwater System Influences

Groundwater levels fluctuate within the Upper Deschutes Basin based on a number of factors with the degree of change based on the location, duration, and magnitude of the influencing factor. At the basin-scale, fluctuations in the groundwater levels mimic the larger-scale basin-wide/regional precipitation cycles, with periods of high groundwater level generally corresponding to high precipitation, and lower water levels corresponding to low precipitation periods. Water level measurements across the basin indicate the magnitude of these basin-scale stresses on the groundwater system within the study area are diminished (attenuated), delayed, and diffused with distance from the recharge source because of the highly permeable nature of the system combined with the size of the aquifer (Gannett et al. 2001:65). Similar attenuation effects on water levels can occur on a more local-scale as one moves farther away from a large agricultural or municipal well. Conversely, small-scale changes associated with variations in river stage at different flows result in only minor localized effects that are attenuated and absorbed by the local groundwater system and do not affect overall basin-wide groundwater levels.

The effects of canal leakage on the lower portions of the river system are documented in the historical hydrograph in the lower Crooked River, near the confluence with the Deschutes River, which shows an overall increase in groundwater discharge to the river August mean discharge rate) of 400 to 500 cfs/year between 1918 and the early 1960s. This value peaked in the late 1950s at about 600 cfs/year and was estimated a 520 cfs/year in 1994 (Gannett et al. 2001: 26, 52). This increase in groundwater discharge (baseflow) to the river in the lower portions of the basin is similar to the estimated annual mean canal losses of this same period in the study area (Gannett et al. 2001: 26, 52; Gannett and Lite 2013:4). Therefore, current groundwater discharges downstream of the canals near the confluence of the river systems have been artificially increased in an amount similar to the irrigation canals annual leakage rate. Canal piping and lining projects between 1994 and 2013 further reduced the canal losses by about 100 cfs/year (Gannet et al. 2017:24)

The aquifers in the Upper Deschutes Basin have been affected by a general drying trend since the 1950s (Gannett and Lite 2013:2). Climate oscillations remain the largest influence on water level fluctuations (Gannett et al. 2001:2; Gannett and Lite 2013:1) with increases in groundwater pumping and decreases in recharge due to canal lining also contributing to declines within the central part of the Upper Deschutes Basin (between Benham Falls and Lower Bridge) (Gannett and Lite 2013:1). Groundwater levels in the central part of the groundwater system declined by approximately 5 to 14 feet between 1997 and 2008 (Gannett and Lite 2013:1), with 60 to 70% of the measured decline associated with climate cycles, 20 to 30% with increased groundwater pumping, and 10% with canal lining and piping. In general, water-level declines are dominated by climatic variability. Therefore, these basin-scale natural fluctuations in groundwater levels will largely mask small or minor changes in the study area groundwater levels caused by changes in river flows, while the central part of the basin is also susceptible to additional groundwater level fluctuations associated with increases in pumping and canal lining (Gannett and Lite 2013:33).

Supporting Analysis for Environmental Consequences

The presentation of direct RiverWare outputs (without rounding) is not intended to imply exact predictions of future conditions, but provide a basis for comparing among alternatives.

Alternative 1: No Action

Water Conservation Activities

Recent and reasonably foreseeable water conservation projects[4] will affect the study area hydrology over the analysis period by changing the timing and amount of water diverted, instream flow, and as seepage for irrigation networks.

Water saved as a result of water conservation projects can be protected instream under the State of Oregon's Allocation of Conserved Water (ACW) process[5] (Oregon Administrative Rule [OAR] 690-18), reduce demand for the entity completing the project (typically where available water supply is not meeting existing demand), or potentially increase water supply for another water user(s). The potential effects of these three scenarios are described further.

If water saved through conservation projects are protected instream through an ACW, water would be expected to be protected from the point of diversion to Lake Billy Chinook. Thus, for conservation projects for Deschutes River water supply, streamflow in the Middle Deschutes River would be higher during the irrigation season compared to existing conditions. If the saved water were used to reduce the demands of the entity completing the project or made available to another water user, saved water may change the amount and timing of water supply shortages and streamflow in the Upper Deschutes Basin. If the saved water were not protected instream during the irrigation season, the saved water would potentially provide managers with additional flexibility to meet fish and wildlife flow needs. For example, if less stored water is needed to meet irrigation needs during the irrigation season, more water could be released during the winter period to meet fish and wildlife needs. Water released during the storage season may be able to be legally protected instream.

Whether water saved through conservation is protected instream or used to reduce water supply deficits depends in part on State of Oregon rules and statutes governing the use and instream protection of water rights. Prior to the implementation of water conservation projects, the outcome of State of Oregon review of proposed water right transactions is not certain. The allocations by source and by season presented in Tumalo ID's watershed EA are estimates based on conserved water applications that were associated with similar, completed projects in Tumalo ID that have already completed the State of Oregon's administrative process for the allocation of conserved water (see ORS 545.470). The allocations presented in the Plan-EA may change following a thorough review of the application by OWRD who may order a different allocation in attempt to avoid impacting other water users at either source (Farmers Conservation Alliance 2018a).

Three water conservation projects are assumed under the no-action alternative: the Swalley ID Irrigation Modernization Project, the Tumalo ID Irrigation Modernization Project, and the Central

[4] RiverWare includes instream water rights at gauges throughout the study area, including instream water rights originating from conserved water projects. Tumalo ID's Conserved Water Project 37 (CW-37) is currently in progress. RiverWare accounts for instream water rights at the TUMO gauge through increment 3 of CW-37. Two additional increments have added to the instream water rights at the TUMO gauge and will result in an increase in instream flows below Tumalo ID relative to the RiverWare model. It is anticipated that Tumalo ID will complete CW-37 within the next two years, then initiate a new conserved water project (or projects) to allocate water saved through piping of Tumalo ID's laterals. The projected streamflow impact of these conserved water projects is shown in Table 5.

[5] Under an ACW, water allocated to instream use would be protected under an instream water right with a priority date equivalent to or 1minute junior to that of the irrigation district rights used to divert water. OWRD must find that the ACW does not "harm" other water users.

Oregon ID Smith Rock-King Way Infrastructure Modernization Project. Water saved through the Swalley ID and Tumalo ID projects would be protected instream under the ACW process, and would thereby increase instream flow below irrigation diversions in the Deschutes River, and Tumalo Creek as shown in Table 5. Flows would increase incrementally over the first 10 years of the analysis period as projects are completed. As noted in the table, some of the water presented as saved through piping may be discharged to surface water on the Deschutes River above the CULO gauge and below the DEBO and TUMO gauges. Table 5 also includes flows from the recent Tumalo ID piping project that is not reflected in the diversions assumed in the RiverWare model. These flow values are included under years 1 through 5. The flow increases are reflected in the streamflow analysis (Impact WR-4) in Alternatives 2 through 4 for the affected reaches.

Table 5. Instream Flow Increases during Peak Irrigation Season from Water Conservation Projects assumed under the No-Action Alternative

Irrigation District	Streamflow Impact - Years 1 through 5			Streamflow Impact - Years 6 through 10			Streamflow Impact - Years 11 through 30		
	DEBO	CULO[c]	TUMO	DEBO	CULO[c]	TUMO	DEBO	CULO[c]	TUMO
Tumalo ID[a]	0	12.35	12.35	0	19.83	19.83	0	30.91	30.91
Swalley ID[b]	7.6	7.6	0	15.2	15.2	0	0	0	0

Source: Farmers Conservation Alliance 2018a, 2018b

[a] Planned piping began in October 2018 and has an anticipated 12-year timeline. Flow values also reflect completion of conserved water 37 project.

[b] Piping is planned to begin in 2019 and has an 8- to 9-year timeline.

[c] The table shows all water gauged at TUMO and CULO would be saved through water conservation projects, but some of the water saved through piping may have discharged to surface water on the Deschutes River above the CULO gauge and below the DEBO and TUMO gauges.

The Central Oregon ID project has been incorporated into the RiverWare model. The hydrologic and water supply impacts of the project, as described in the final Watershed Plan-Environmental Assessment are reflected in the RiverWare outputs for all alternatives. The Central Oregon ID project anticipates that water saved through piping will continued to be diverted at the Powell Butte Canal and spilled to North Unit ID during the irrigation season. This water supply impact, and associated minor differences in the timing and location of flows between Wickiup and the Powell Butte Canal have been incorporated into the River Ware model. In exchange for Central Oregon ID's natural flow water made available during the irrigation season, North Unit ID would increase storage season flows at the WICO gauge by an equivalent volume, with the additional volume available for release at the discretion of the U.S. Fish and Wildlife Service. This increase in WICO gauge flows during the storage season is not reflected in RiverWare.

Groundwater

This section provides supporting information on groundwater fluctuations due to conservation activities, climate change, future groundwater demands, and City of Prineville future groundwater pumping and associated mitigation. Based on the historical record, basin-scale groundwater levels will continue to fluctuate in response to precipitation cycles that affect the overall recharge to the system (Gannett and Lite 2013:2). The magnitude of water level changes will vary across the basin depending upon the distances from the basin's primary recharge source (the Cascade Range) as well as localized changes resulting from district water conservation projects (Tumalo ID and Swalley ID Irrigation Modernization Projects), groundwater pumping, and other conservation assumed under the no-action alternative. The basin-scale fluctuations in groundwater levels driven by precipitation cycles will likely mask any localized changes in water levels. The exception is groundwater levels in wells immediately adjacent to planned district water conservation projects, where declines in water levels may exceed the precipitation driven fluctuations.

Under the no-action alternative, the three proposed conservation projects combined could result in slightly lower groundwater levels and subsequent spring discharge in the lower portion of the basin above the confluence of the rivers at Lake Billy Chinook. The canal losses in 2013 are estimated to be 420 cfs/year (Gannet et al. 2017: 24). The projects are projected to reduce canal losses an additional 44 cfs/year. This 10% change in canal loss would likely result in an equivalent change in groundwater discharge in the lower portion of the basin as the artificially elevated discharges return to their natural discharges.

However, it is anticipated there will be no change to the ongoing basin-scale groundwater level fluctuations over the 30-year analysis period, which will mask the impacts of the conservation projects. If climate change conditions significantly modify the annual precipitation to the region (beyond the current cycles) the basin groundwater levels could be affected. Therefore, there would be no effect on groundwater recharge under the no-action alternative with the exception of a negative effect on localized groundwater levels adjacent to planned piping projects.

The Deschutes Basin is administratively closed to new surface water appropriations and therefore the water needs of new development in the Upper Deschutes Basin are anticipated to be met using groundwater. Any new groundwater permit in the basin requires mitigation under the Deschutes Groundwater Mitigation Program rules established in 2002. The mitigation program created a system for developing and obtaining mitigation credits that is designed to offset the potential impacts of future groundwater withdrawals on surface water flows.

It is expected that during the permit term the City of Prineville will continue to grow and obtain additional water supply from groundwater production from the Prineville Valley. Because groundwater wells pull water radially from the aquifer, depending upon the locations of the well(s), impacts from pumping can range from a partial connection to the Crooked River, to a more delayed and attenuated impact on the surface water system.

The Deschutes Basin Groundwater Mitigation Rules (Oregon Administrative Rules 690-505-0600 through 690-505-0630) require that new groundwater rights in the vicinity of the City of Prineville be accompanied by mitigation to offset the impact on surface water from groundwater pumping. Therefore, as the City obtains new groundwater supply and water rights, the City must annually provide mitigation equal to the volume of the groundwater used consumptively (the quantity of water that is not returned to the river through municipal wastewater plants).

In December 2018, the City obtained a new authorization (water use permit) for use of the Prineville Valley aquifer. This new water use permit will likely be the majority of the City's additional groundwater supply through the permit period.[6] The required mitigation for this new water use permit is stored water released from Prineville Reservoir.

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[6] The City's *2018 Water Master Plan* (WMP) estimates that by 2037, the City will need a total of 5,303 gallons per minute (gpm) of production for a period of 18 hours a day. With current capacity of 3,765 gpm (prior to the new well field and water right), this means that an additional 1,538 gpm of new supply will be needed to meet the City's needs in 2037 (Anderson Perry 2018:2-21). Assuming the permit will extend to 2049 (for 30 years) the City's water

OWRD has assumed that the wells under the City's new permit are hydraulically connected to the Crooked River and that 40% of the annual volume of groundwater pumped will be consumed. As a result, OWRD has required up to 1,292 af of mitigation[7] in the Crooked River annually.[8]

Under the Crooked River Act, the City of Prineville secured 5,100 af of stored water from Prineville Reservoir for mitigation for future groundwater production, which is equivalent to an annual flow rate of approximately 7 cfs. However under the Crooked River Act, Reclamation, in consultation with the National Marine Fisheries Service and the U.S. Fish and Wildlife Service, can develop release schedules for the 5100 af of mitigation water that maximizes benefits to downstream fish and wildlife. Therefore, the City's likely additional groundwater pumping through the permit period, combined with the 5,100 af of stored water released annually for mitigation, is likely to result in a net positive benefit to streamflow.

Alternative 2: Proposed Action

Under the proposed action, the applicants would implement the Final Deschutes Basin HCP conservation strategy. The conservation strategy consists of a series of conservation measures to reduce the adverse effects of covered activities on the covered species. Proposed conservation measures include actions that would change the timing and volume of water released from covered reservoirs and streamflow in covered rivers and creeks. Key measures that would affect water resources are summarized below.

The proposed action would increase fall and winter flows in the Deschutes River below Wickiup Dam as shown below and cap irrigation period maximum daily flows starting in year 8 of the permit term.

- Years 1–7: 100 cfs
- Years 8–12: 300 cfs
- Years 13–30: 400–500 cfs

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supply needs in 2049 can be estimated from the existing data. Annualizing the 1,538 gpm per year of additional needs over the WMP's 20 year planning window indicates an annual increase of 76.9 gpm; therefore, the City will need approximately an additional 932 gpm by 2049 (76.9 x 12 years = 932 gpm). The City's total new water supply needs beyond the current supply is 1,538 gpm + 932 gpm = 2,461 gpm (pumping 18 hours per day). Required mitigation under OWRD's Deschutes Basin Groundwater Mitigation Rules for 2,461 gpm for 18 hour a day at a consumptive use rate of 40% is approximately 1,190 af of water, much less than the 5,100 af of stored water mitigation the City has already secured and is protected instream annually.

[7] Providing 1,292 af of mitigation assumes the City is pumping 2,000 gpm 24 hours a day all year long.

[8] The two separate 5-day aquifer tests on the City's recently installed wells under the new water use permit, which authorizes wells adjacent to the Crooked River, do not indicate an immediate direct connection to the river based on the low production capacity of each well (85 and 100 gpm) and the shape of the drawdown curves which after 5 days were not flat as would be expected with a direct connection to the river (Newton 2018: Appendix C). Additional macro-particulate analysis (MPA) testing results (collected at the end of each 5-day test) for the Oregon Health Authority indicates limited direct connection between the wells and the adjacent river, and water quality testing results from the end of each test show significant ammonia, and dissolved iron and manganese in the water suggesting reducing conditions, and not the oxygen rich conditions that would be associated with the river water. Although the new production is from groundwater that is hydraulically connected to the Crooked River, the current data indicates that the full impact from pumping may not be seen in an immediate corresponding decrease in the adjacent Crooked River flows, but the impact on streamflow will likely be spread out over a larger area.

On Crescent Creek, the proposed action would decrease minimum flows but include an Oregon spotted frog stored water account to provide water management flexibility.

The presentation of direct RiverWare outputs (without rounding) is not intended to imply exact predictions of future conditions, but provide a basis for comparing among alternatives.

WR-1: Change Reservoir Storage

This section describes the impact and mechanism of impact for changes in reservoir water supply storage as a result of the proposed action.

Crane Prairie Reservoir

Measure CP-1 would adjust the range and timing of reservoir storage and drawdown rate for Crane Prairie Reservoir, and establish a recommended minimum instream flow of 75 cfs in the Deschutes River below the reservoir. This minimum instream flow requirement is the same as under the no-action alternative, however narrower limits on the range of surface elevations (water levels) in the reservoir under the proposed action would have a variable effect on water supply storage in Crane Prairie Reservoir. Storage would generally be higher from approximately late September through early May and lower from mid-May through mid-September compared to the no-action alternative (Table 6, Figure 5).

Because Crane Prairie is above Wickiup Reservoir, any water stored in Crane Prairie early in the storage season would otherwise be available to store in Wickiup. So although the timing of storage would be altered under the proposed action, the total combined storage in Crane Prairie and Wickiup Reservoirs is relatively unchanged in years 1 through 7 of the permit term (Figures 6 and 7), when winter releases from Wickiup Reservoir are the same as under the no-action alternative. Beginning in year 8 of the permit term, increased winter releases from Wickiup Reservoir would result in a reduction in combined storage. Given the high seepage loss from Crane Prairie Reservoir, as reservoir elevation increases, the increased September through May storage would likely result in an increased volume of seepage loss on an annual basis, compared to the no-action alternative, but the effect is relatively small (see WR-5).

Table 6. Modeled Crane Prairie Storage at the 20th, 50th, and 80th Percentiles in August and December under the No-Action Alternative and Proposed Action

		Crane Prairie Storage (af)			
		No-Action Alternative	Proposed Action		
	Water Year		Years 1–7	Years 8–12	Years 13–30
August (Reduction)	Dry	45,550	43,625	43,625	43,625
	Normal	46,995	43,677	43,674	43,645
	Wet	47,165	43,724	43,724	43,715
December (Increase)	Dry	35,000	42,136	42,136	42,136
	Normal	35,000	45,035	45,033	45,033
	Wet	35,000	47,568	47,568	47,569

af = acre-feet; cfs = cubic feet per second

Figure 5. Modeled Storage in Crane Prairie Reservoir under Proposed Action in Years 1–7 Compared to the No-Action Alternative

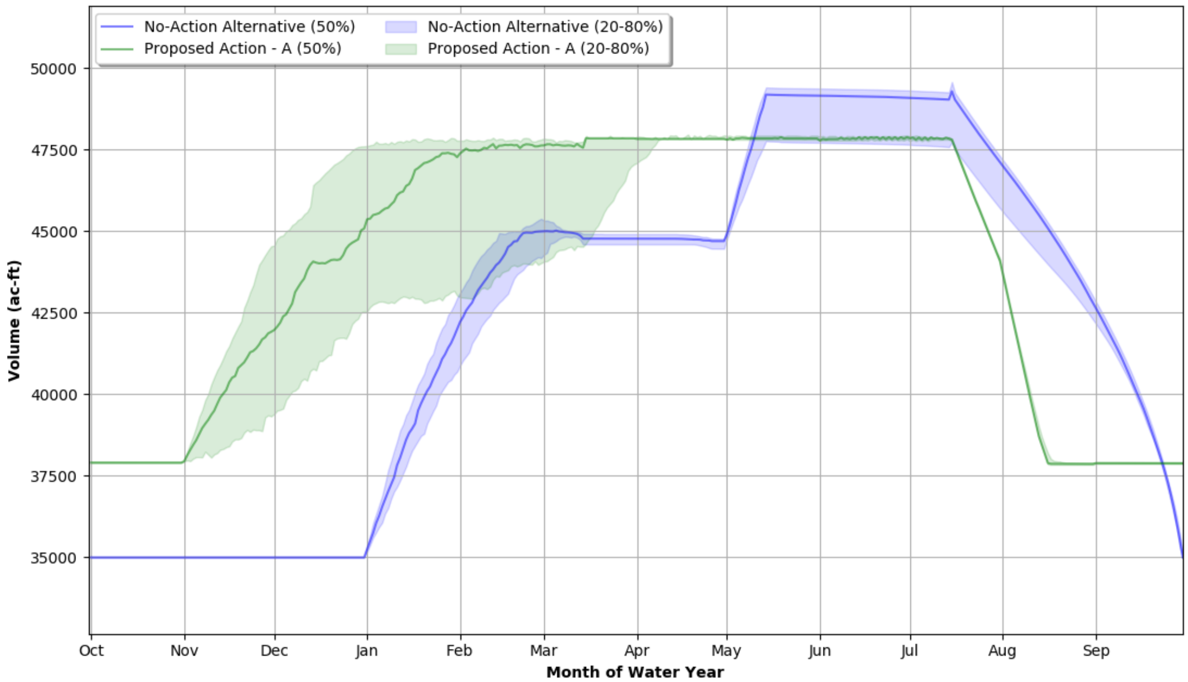
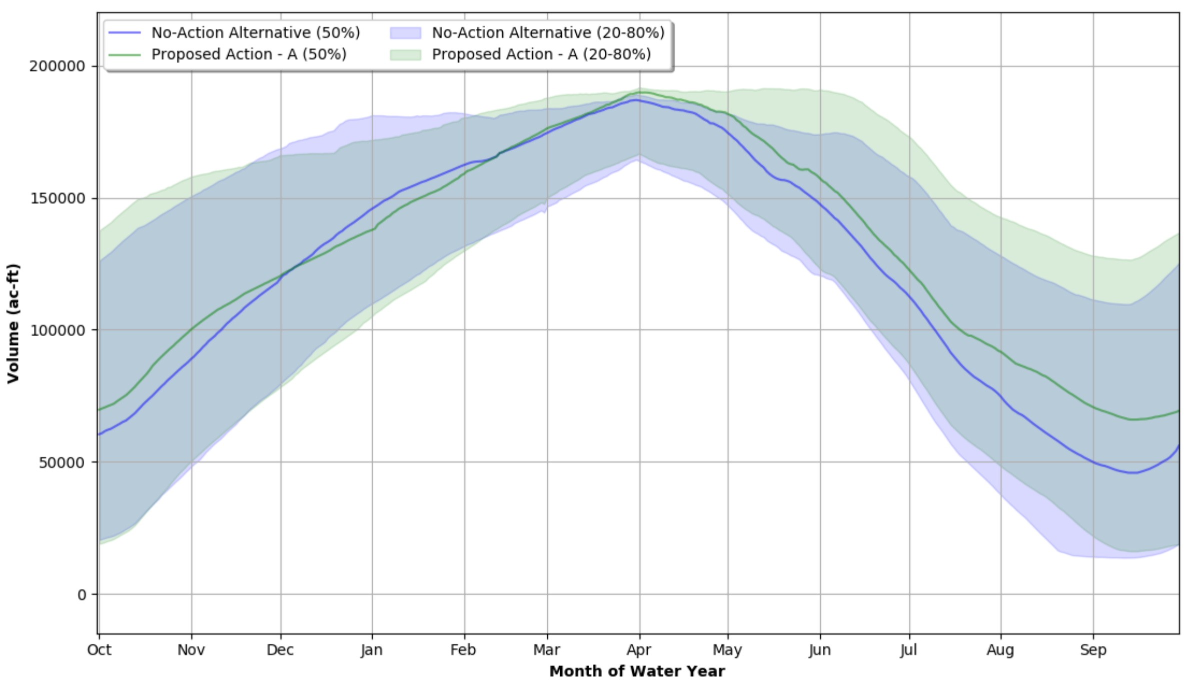


Figure 6. Modeled Storage in Wickiup Reservoir under Proposed Action in Years 1–7 Compared to the No-Action Alternative



Wickiup Reservoir

As winter flow releases from Wickiup begin to increase above the 100 cfs flow required under the no-action alternative, Wickiup Reservoir storage declines, with the greatest declines observed in years 13 through 30 of the permit term (Table 7; Figure 7). Compared to the no-action alternative, the reduction in maximum storage on or after April 1 is expected to occur in a normal year during years 13 through 30 of the permit term would be 75,017 af. However, Wickiup Reservoir would still fill to over 175,000 af in one out of every three years, when conditions are wet or very wet (Table 8). The frequency of filling Wickiup Reservoir to a maximum annual volume of at least 100,000 af—approximately half of the total capacity of Wickiup Reservoir—declines from 100 to 53% (Table 8), indicating that the effects of reduced reservoir storage would be concentrated in normal, dry, and very dry years.

Tables 7 and 8, show modeled Wickiup storage and the frequency of achieving various storage thresholds under the no action and proposed action. Figure 7 compares Wickiup storage under the no action and years 13 through 30 of the proposed action.

Table 7. Modeled Wickiup Reservoir Storage under the No-Action Alternative and Proposed Action

Water Year Conditions	No-Action Alternative (af)	Proposed Action (af)		
		Years 1–7	Years 8–12	Years 13–30
Very Dry	133,737	136,224	65,084	31,066
Dry	162,246	161,105	89,497	56,556
Normal	186,930	190,473	151,471	111,913
Wet	189,063	195,408	191,170	189,974
Very Wet	195,434	200,125	200,105	200,278

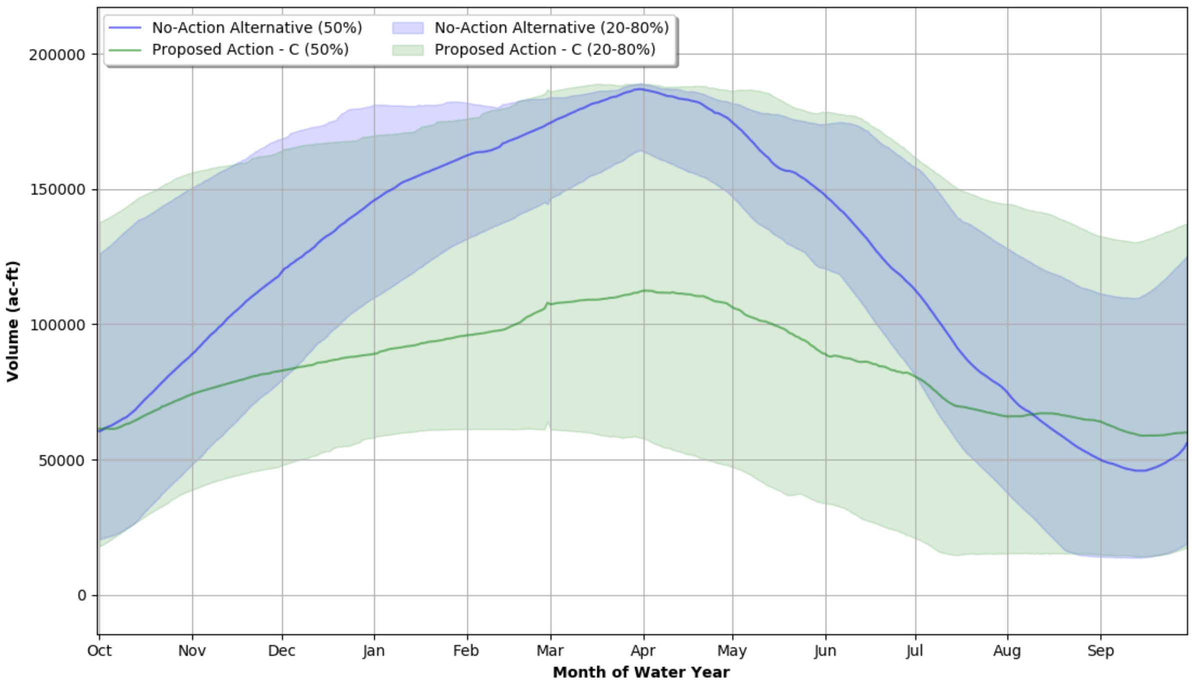
af = acre-feet; cfs = cubic feet per second

Table 8. Frequency of Wickiup Reservoir Fill under the No-Action Alternative and Proposed Action

Maximum Fill Volume April–August (af)	No-Action Alternative	Proposed Action		
		Years 1–7	Years 8–12	Years 13–30
25,000	100%	100%	100%	100%
50,000	100%	100%	100%	89%
75,000	100%	100%	95%	71%
100,000	100%	100%	74%	53%
125,000	100%	100%	58%	47%
150,000	89%	92%	53%	39%
175,000	68%	76%	42%	34%

af = acre-feet; cfs = cubic feet per second

Figure 7. Modeled Storage in Wickiup Reservoir under the Proposed Action in Years 13–30 Compared to the No-Action Alternative



Crescent Lake Reservoir

The proposed action would reduce minimum flows downstream from Crescent Lake Dam as compared to the no-action alternative. Under the no-action alternative the minimum flow below Crescent Lake Dam would be 30 cfs from March 15 through November 30 and 20 cfs during the rest of the year. Under the proposed action Conservation Measure CC-1, water set aside each year from the Crescent Lake Reservoir storage would be used to affect flows in Crescent Creek and the Little Deschutes downstream from its confluence with Crescent Creek. This "OSF storage" is to be used specifically to benefit Oregon spotted frogs and its volume would increase over the lifetime of the proposed action. Four phases of increasing OSF storage do not precisely track the three phases of overall proposed action implementation, but instead follow the timeline outlined in Conservation Measure CC-1 and shown below in Table 9.

Table 9. Storage for Oregon Spotted Frog under Conservation Measure CC-1 of the Proposed Action

	Volume of Crescent Lake Reservoir Storage (acre-feet) to be Available for Oregon Spotted Frog Conservation		
Implementation Phases under Proposed Action	When Total Storage Volume on July 1 is <45,000 acre-feet	When Total Storage Volume on July 1 is 45,000 - 75,000 acre-feet	When Total Storage Volume on July 1 is >75,000 acre-feet
1–10	5,264	7,264	8,764
11–15	6,464	8,464	9,964
16–20	7,664	9,664	11,164
21–30	8,864	10,864	12,364

Each year, the OSF storage volume available for the following water year would be set depending on the phase of the proposed action and on the storage volume detected in Crescent Lake Reservoir as of July 1. OSF storage would first be used to fulfill the minimum winter flow in Crescent Creek during the overwinter and spring seasons (October 1–June 30). After fulfilling the minimum winter flow, any remaining OSF storage can be used to manage flows in Crescent Creek to further increase winter flows, increase instream flow levels in spring, or delay and draw out the ramp down of irrigation releases in the fall. Neither the no-action alternative nor the other action alternatives (Alternatives 3 or 4) include this conservation measure.

Conservation measure CC-1 allows for substantial discretion in the timing of Crescent storage releases for Oregon spotted frog conservation. These releases may still be diverted for irrigation at Tumalo ID's diversion in the Middle Deschutes River depending upon water supply conditions for Tumalo ID, especially water supply available from Tumalo Creek. As such, the model is sensitive to changes in the timing of releases for irrigation and the Oregon spotted frog. However, this does not change the general trend toward an increase in Crescent Lake storage, under the proposed action.

Because Tumalo ID is typically releasing 50 cfs from July through September anyway to meet irrigation demands, the primary impact of the proposed action would be to reduce minimum outflows during the storage season compared to the no action alternative. As a result, the proposed action would generally result in an increase in Crescent Lake storage (Figure 8).

In years 1 through 7 of the permit term, the maximum storage volume attained between April and August would increase compared to the No Action alternative (Table 10). As winter releases from Wickiup increase to 400 cfs during years 13 through 30 of the permit term, the increase in Crescent Lake storage compared to the no action declines by approximately 2,000 to 6,000 af compared to the proposed action at 100 cfs of Wickiup releases, reflecting the increasing frequency of regulatory calls on junior water rights. Tumalo ID holds two water rights for storage in Crescent Reservoir, certificate 76683 for storage of 35,000 af with a March 20, 1911, priority, and certificate 76637 for storage of 51,050 af with a 1961 priority. Because certificate 76637 is junior to North Unit ID's 1913 live flow water right, under rare circumstances, it may be subject to regulatory calls when North Unit ID experiences shortages.

Tumalo ID's water right to store water in Crescent Lake Reservoir beyond 35,000 af per year is junior to live flow water rights on the main stem Deschutes, including North Unit ID's 1913 live flow water rights. Additionally, the RiverWare model anticipates increased regulation of Tumalo ID's 1905 live flow priority date on the main stem Deschutes River, which may lead to further reliance on Crescent Lake storage releases to make up for the reduced availability of live flow, and a commensurate reduction in storage. In years 13 through 30, reductions in maximum Crescent storage may not reflect reductions in end of year storage, as maximum storage may be reduced through mid-July by regulation of Deschutes natural flow water rights to maintain Crane Prairie elevations.

Figure 8. Modeled Storage in Crescent Lake Reservoir under Proposed Action in Years 13–30 Compared to the No-Action Alternative

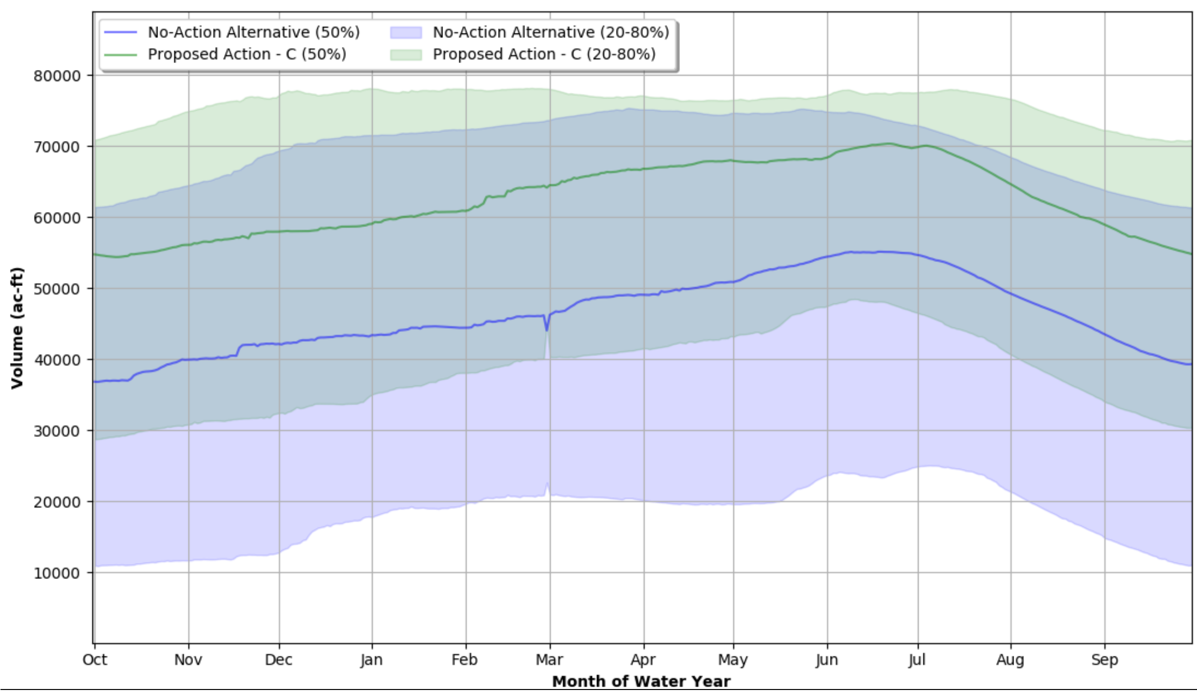


Table 10. Change in Crescent Lake Storage under the No-Action Alternative and Proposed Action

Water Year Conditions	No-Action Alternative	Proposed Action		
		Years 1–7	Years 8–12	Years 13–30
Very Dry	10,318	25,840	23,699	23,906
Dry	27,006	54,003	53,799	51,627
Normal	55,345	76,633	75,514	70,680
Wet	74,371	78,704	79,192	79,339
Very Wet	79,608	80,565	80,458	80,380

af = acre-feet; cfs = cubic feet per second

Prineville Reservoir

North Unit ID is expected to increase use of its Crooked River Pumping Station to address the declining reliability of stored water supply from Wickiup Reservoir storage as described above. North Unit uses the Crooked River Pumping Station to divert both Crooked River live flow and up to 10,000 af of stored water from Prineville Reservoir. Additionally, increased winter minimum flows in the Crooked River lead to reduced storage in Prineville Reservoir in dry and very dry years. Under the proposed action, North Unit ID would use its available stored water from Prineville Reservoir (up to 10,000 af) more frequently and to a greater extent, and increased winter minimum flows in the Crooked River would reduce Prineville Reservoir storage in most years. The RiverWare model shows that in years 13 through 30, the proposed action would generally result in a reduction of Prineville Reservoir storage compared to the no-action alternative in normal to very dry years, with changes ranging from a decrease of 177 af in a normal year to a reduction of 14,328 af in a very dry year (Table 11). Although the reduction in Prineville storage is high during very dry years, the change in storage in a normal year is minimal. Figure 9 shows the impacts of the proposed action on Prineville Reservoir storage during years 13 through 30 of the permit term.

Figure 9. Modeled Storage in Prineville Reservoir under the Proposed Action in Years 13–30 Compared to the No-Action Alternative

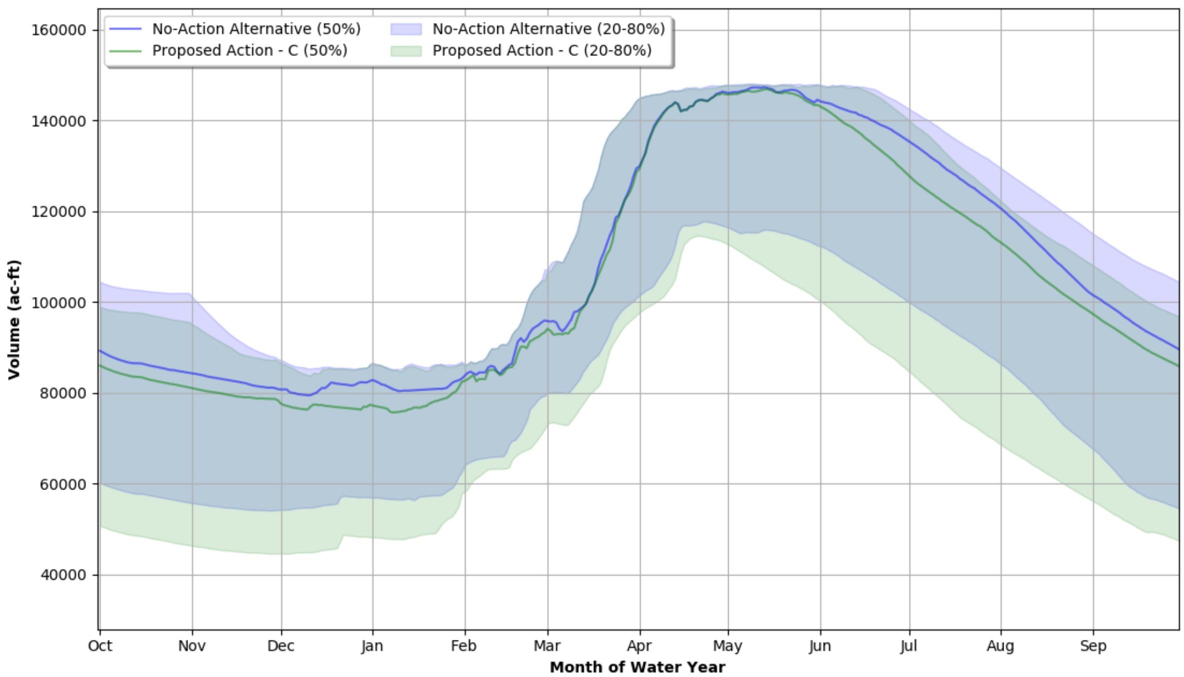


Table 11. Change in Prineville Reservoir Storage under the No-Action Alternative and Alternative 4

Water Year Conditions	No-Action Alternative	Alternative 4	
		Years 1–5	Years 6–20
Very Dry	65,548	46,543	46,139
Dry	125,244	117,803	115,508
Normal	148,326	147,916	147,864
Wet	148,482	148,170	148,158
Very Wet	151,001	150,998	150,995

af = acre-feet; cfs = cubic feet per second

Ochoco Reservoir

The proposed action (Conservation Measure CR-2) provides for release of additional flow from the Ochoco Main Canal downstream of Ochoco Reservoir to contribute to flow increases in Ochoco Creek during the irrigation season and non-irrigation season, subject to limitations. Historically, flows at gauge 14085300 below Ochoco Reservoir have regularly dropped below 3.0 cfs. Maintaining a flow of 3.0 cfs during the non-irrigation season and 5.0 cfs during the irrigation season would likely reduce water supply storage 0 af to 1,500 af compared to historical conditions.[9] This

[9] This analysis assumes that a minimum flow of 3.0 cfs would be maintained below Ochoco Reservoir from October through April and a minimum flow of 5.0 cfs would be maintained from May through September.

analysis did not consider the effect of bypassing additional flows associated with instream water rights (regardless of priority date as compared to Ochoco ID storage) originating above Ochoco Reservoir, but such measures would be expected to further reduce Ochoco Reservoir storage compared to the historical baseline.

Measure CR-3 provides for minimum flows in McKay Creek during the active irrigation season, to be achieved through bypass or release of water into McKay Creek, as needed. Similar to measure CR-2, historical data suggests that bypass flows will not be sufficient to maintain the identified flow in McKay Creek, requiring Ochoco ID to release additional flow into McKay Creek to maintain the specified minimum flows. During times when some part of Ochoco ID's water supply comes from Prineville or Ochoco Reservoir, water released into McKay Creek will be at least partly made up of stored water. Compared to the historical baseline, measure CR-3 would likely have an effect on Ochoco Reservoir water supply storage because Ochoco ID would need to release and divert more stored water to maintain minimum flows on McKay Creek.

Measure CR-4 provides funding for the Crooked River Conservation Fund to support conservation measures and benefit covered species in the Crooked River Subbasin. Possible uses of the Crooked River conservation fund include temporary instream leasing of secondary irrigation rights supplied by stored water in Prineville and Ochoco Reservoirs. Measure CR-4 specifies that such water rights may be released at any time from February 1 through November 30, which may result in a reduction of Prineville and Ochoco Reservoir storage, depending upon the timing of water releases and how instream leases are administered and accounted for.

The results of the RiverWare model show that Ochoco Reservoir storage does not change under the proposed action. However, RiverWare assumed that Ochoco Creek minimum flows proposed under measure CR-2 would be met under the no-action alternative. When compared to the historical baseline, measures CR-2, CR-3, and CR-4 are expected to have a small impact on Ochoco Reservoir water supply storage.

WR-2: Change in Water Supply for Irrigation Districts and Other Surface Water Users

Changes in stored water supply described under impact WR-1 have direct and indirect effects on water supply for irrigation districts and other surface water users. Modeling results show that as stored water supplies decrease, the frequency and duration of regulatory calls on live flow water rights and of water shortages for water users with water rights junior to Central Oregon ID's October 31, 1900, priority date increase.[10] Changes in annual and monthly diversions for irrigation districts under the proposed action indicate that supply shortages would tend to be concentrated during June through September rather than evenly distributed throughout the irrigation season. This analysis considers water supply shortfalls on the basis of reduced irrigation district diversions during the full irrigation season of April through October and peak irrigation season of June through September.[11]

[10] Lone Pine ID's water right certificate (72197) also has a priority date of October 31, 1900, but it is junior to Central Oregon ID's October 31, 1900 under certificate 83571.

[11] This metric is intended to capture substantial water supply shortfalls caused by a lack of water available under a district's water rights for live flow or supplemental stored water.

Figures 10 through 13 and 17 through 19 compare irrigation season diversions under the proposed action (years 1–7 and years 13–30) in normal, dry, and very dry years as a percentage of the diversion under the no-action alternative. North Unit, Central Oregon, Arnold, Lone Pine, and Ochoco IDs are expected to experience reductions in diversions as a result of the proposed action. Tumalo ID is expected to experience an increase in diversions. Three Sisters ID is not shown and are discussed in greater detail below. Swalley ID is not affected by the proposed action.

Figures 15 and 16 compare diversions in normal, dry, and very dry years between the no-action alternative and the proposed action (in years 1 through 7 and years 13 through 30 of the permit term) from April through October as volumes. Supply shortages under the proposed action from June through September are more pronounced than for the entirety of the irrigation season.

The analysis shown in the figures does not capture changes expected to occur under the no-action alternative during the permit term.

The impacts of the proposed action on the water supply of the applicants and other water users is described below.

North Unit Irrigation District

As described under WR-1, the proposed action will reduce Wickiup Reservoir storage. North Unit ID is dependent on Wickiup Reservoir storage when live flow in the Deschutes River is insufficient to meet North Unit ID demands under their February 28, 1913 water right certificates (72279, 72280, 80936, 94079). This will reduce water supply available to North Unit ID (Figures 10 and 15) and increase the frequency that North Unit ID would make regulatory calls for Deschutes River live flow. While there have been regulatory calls on water rights junior to North Unit ID in previous years (Giffin pers. comm. [a, b]), the declining likelihood of filling Wickiup Reservoir (Table 8) and increased value of entering the storage season with more water in Wickiup Reservoir mean that regulatory calls on Upper Deschutes River water rights junior to 1913 would be expected to occur with much greater frequency.

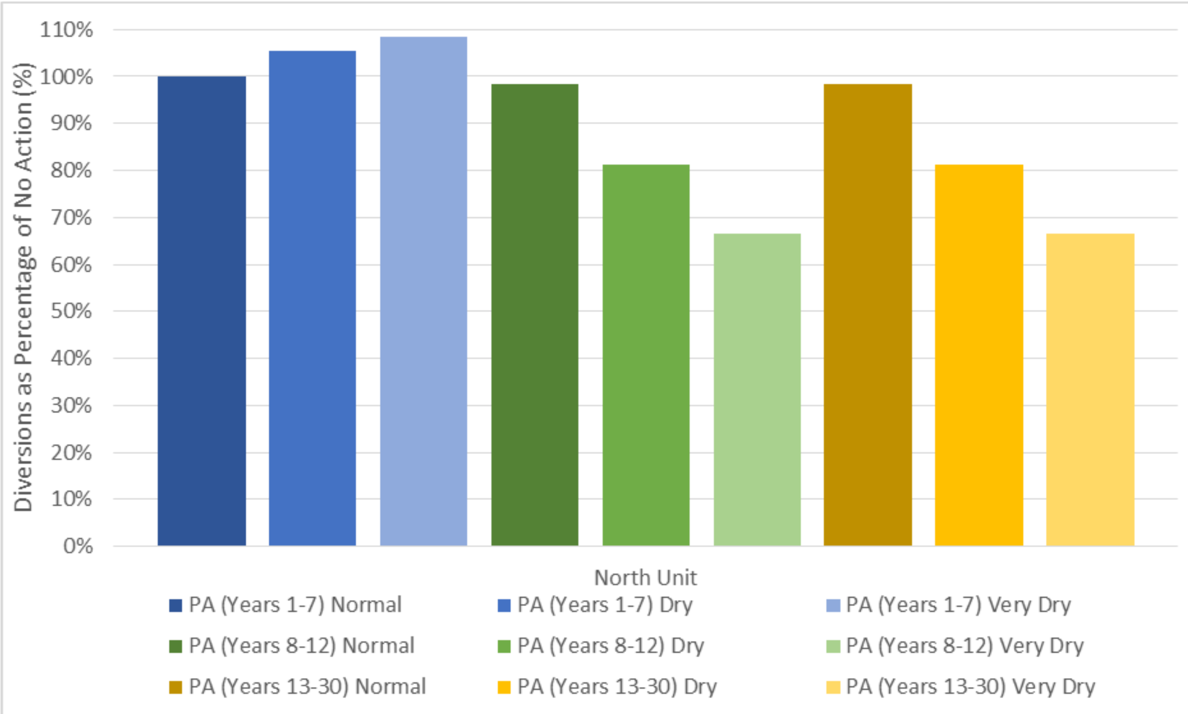
By year 13 under the proposed action, when the required fall/winter flow at WICO is 400 cfs, North Unit ID diversion would be reduced by over 20,000 af in a normal year compared to the no-action alternative (Figures 10 and 15).[12] In a dry year, North Unit ID diversions would be reduced by over 56,000 af. In wet years, there would be a minimal reduction in North Unit ID diversions, and in very wet years, there would be no reduction in North Unit ID diversions.

In general, the RiverWare model shows that North Unit ID would increase use of its Crooked River pumping plant to offset some of the loss of Deschutes River water supply. Under the proposed action, during years 13 through 30 of the permit term, North Unit ID would increase use of the Crooked River pumping plant in all water year types except in very dry years (e.g., 1992) for which RiverWare shows that North Unit ID pumping from the Crooked River would decline by 2,315 af, further exacerbating Deschutes River water supply shortages. The decline in the utilization of the Crooked River pumping plant in a very dry year is attributable to increased winter releases from

[12] In general, the model results show that North Unit ID will increase use of its Crooked River pumping plant to offset some of the loss of Deschutes River water supply. However, in a very dry year (1991 and 1992), the model shows that water available from the Crooked River declined by approximately 2,000 af, exacerbating Deschutes River water supply shortages.

Prineville Reservoir under the proposed action, which would cause a decrease in Prineville Reservoir storage and Crooked River water supply available to North Unit ID.

Figure 10. Modeled Diversions for North Unit Irrigation District (April–October) under the Proposed Action as a Percentage of Diversions under the No-Action Alternative



Arnold, Lone Pine, and Central Oregon Irrigation Districts

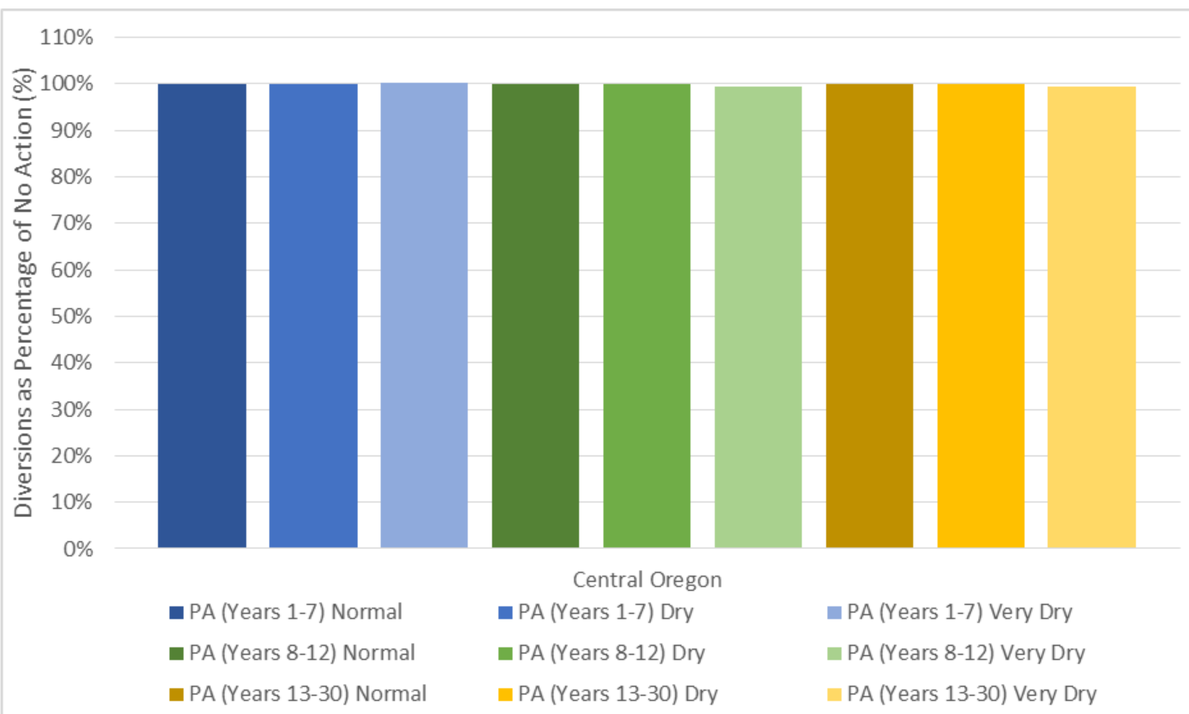
The proposed action would reduce water supply available to the entities with water rights to Crane Prairie Storage: Arnold ID, Lone Pine ID, and Central Oregon ID. Crane Prairie's active storage would effectively be reduced 5,000 af; from approximately 15,000 af under the no-action alternative to 10,000 af under the proposed action. Furthermore, because Crane Prairie must be held above 46,800 af through July 15 (Conservation Measure CP-1A), supply shortages prior to July 15 cannot be addressed by release of Crane Prairie stored water. As described above under Water Uses and Water Rights Administration, under Oregon Law, when there is insufficient water to meet the needs of all water users, OWRD can regulate water rights by relative priority. As a result of this regulatory framework, RiverWare modeling indicates that the frequency of regulatory calls on live flow water rights and of water shortages for water users with water rights junior to Central Oregon ID's October 31, 1900, priority date, including Arnold and Lone Pine ID, and other water users shown in Table 2, would increase (Figures 12 and 13).[13] It is important to note that the reason for the curtailment shown in Figures 12 and 13 is that the modeling results anticipate that senior water right holders, including Central Oregon ID, would make regulatory calls on more junior water right holders, and that OWRD would validate that call. If no senior water right holder makes a valid, regulatory call affecting live flow water rights with more junior priority dates, even during very dry

[13] Lone Pine ID's water right certificate (72197) also has a priority date of October 31, 1900, but it is junior to Central Oregon ID's October 31, 1900 priority date under certificate 83571.

years, Arnold ID, Central Oregon ID, and Lone Pine ID may instead share demand shortfalls during summer low flow periods.

In years where Crane Prairie storage would not be available, a comparison of demand and diversion for Arnold ID, Lone Pine ID, and Central Oregon ID in RiverWare anticipates regulation of water right priority dates as senior as 1900. Using Lone Pine ID as an example, RiverWare model output for a very dry year (2005) shows that Lone Pine's water right will be regulated with greater frequency, and for longer durations during years 13 through 30 of the permit term, when minimum winters flow releases from Wickiup are 400 cfs. Under the no-action alternative, modeling results do not show any regulation of Lone Pine ID's water right until late July. Under the proposed action, during years 13 through 30 of the permit term, Lone Pine ID's live flow water right is regulated throughout the year, including from mid-June through mid-July. Therefore, Conservation Measure CP-1 results in more frequent water shortages prior to July 15 for Lone Pine ID and all other water users with rights junior to Lone Pine ID.[14] Figure 14 shows regulation of Lone Pine ID's water right as a reduction in Lone Pine ID's diversion under the no-action alternative and the proposed action (during years 21 through 30 of the permit term). As described above, in the absence of a regulatory call affecting Lone Pine ID's water rights, and cessation of deliveries to Lone Pine ID through the Central Oregon ID distribution system, demand shortfalls may be shared amongst Lone Pine ID, Central Oregon ID, and Arnold ID. Additionally, it should be noted that reductions in available live flow that RiverWare simulates for Lone Pine ID and Arnold ID are small compared to Central Oregon ID's total diversion.

Figure 11. Modeled Diversions for Central Oregon Irrigation District (April–October) under the Proposed Action as a Percentage of Diversions under the No-Action Alternative



[14] It is important to note that the reason for the curtailment shown is that the modeling results anticipate that senior water right holders, including Central Oregon ID, will make a regulatory call on junior water right holders, and that OWRD will validate that call.

Figure 12. Modeled Diversions for Arnold Irrigation District (April–October) under the Proposed Action as a Percentage of Diversions under the No-Action Alternative

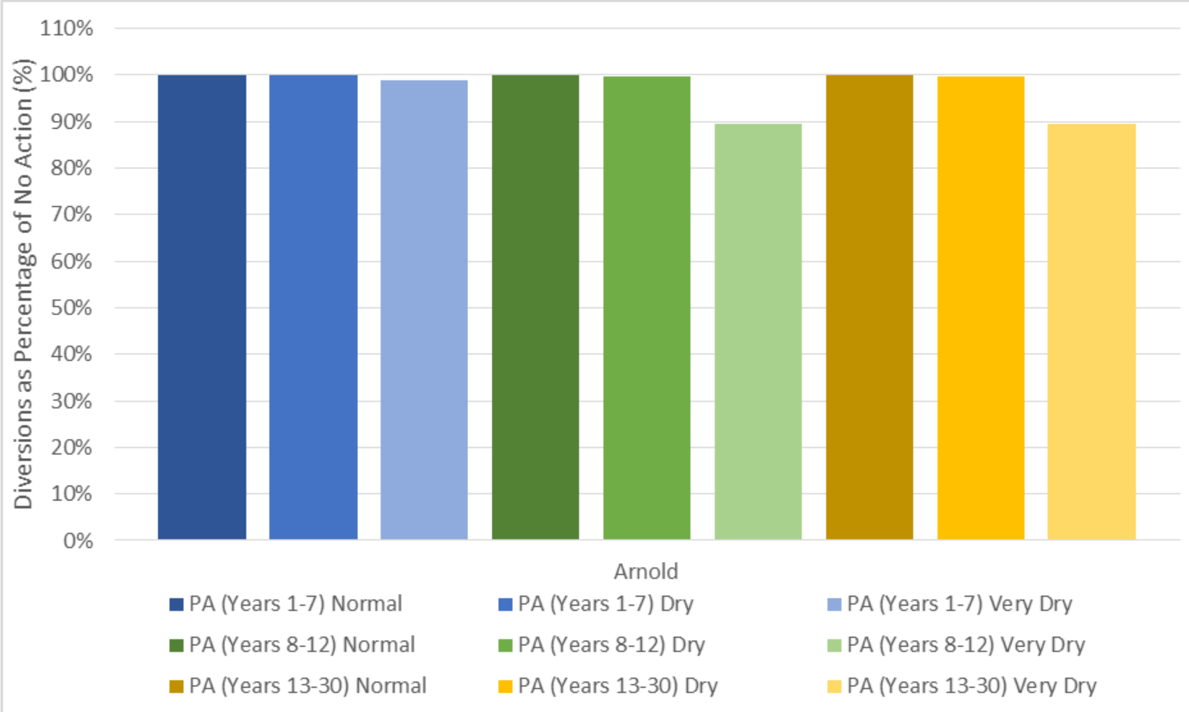


Figure 13. Modeled Diversions for Lone Pine Irrigation District (April–October) under the Proposed Action as a Percentage of Diversions under the No-Action Alternative

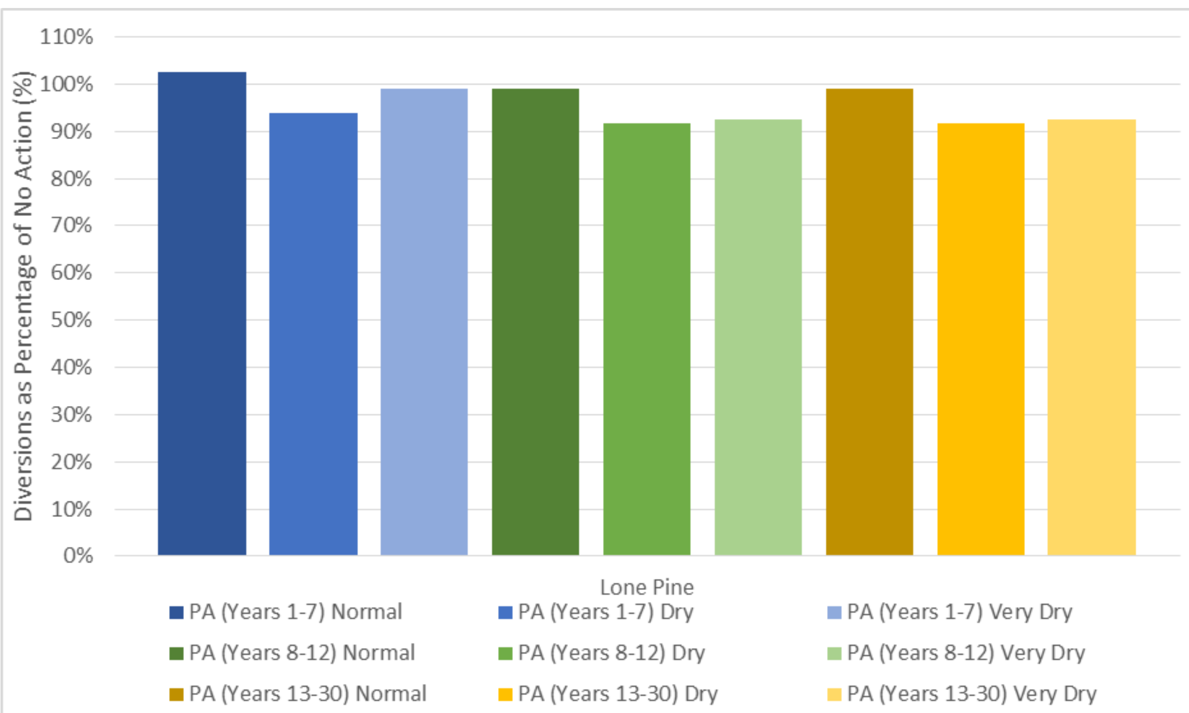


Figure 14. Regulation of Lone Pine Irrigation District's Water Rights under the Proposed Action in Years 13–30 Compared to the No-Action Alternative in a Very Dry Water Year

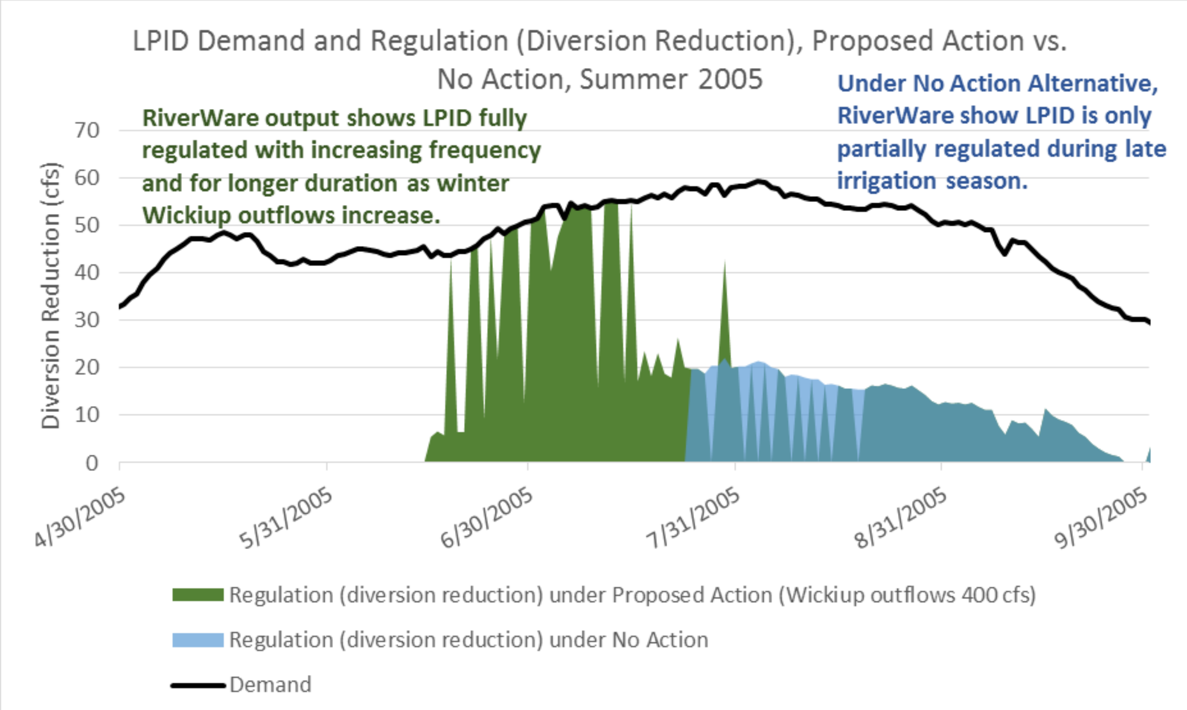


Figure 15. Central Oregon and North Unit Irrigation District Diversions (April–October)— Proposed Action during Years 1–7 and 13–30 Compared to the No-Action Alternative

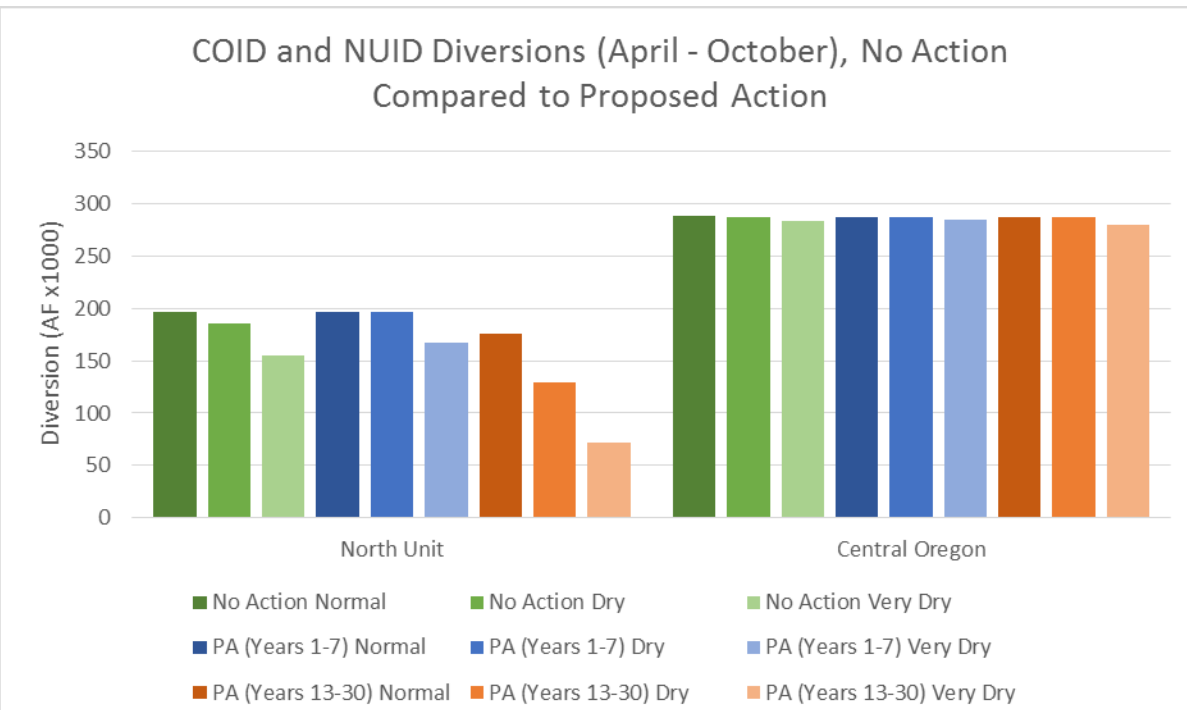
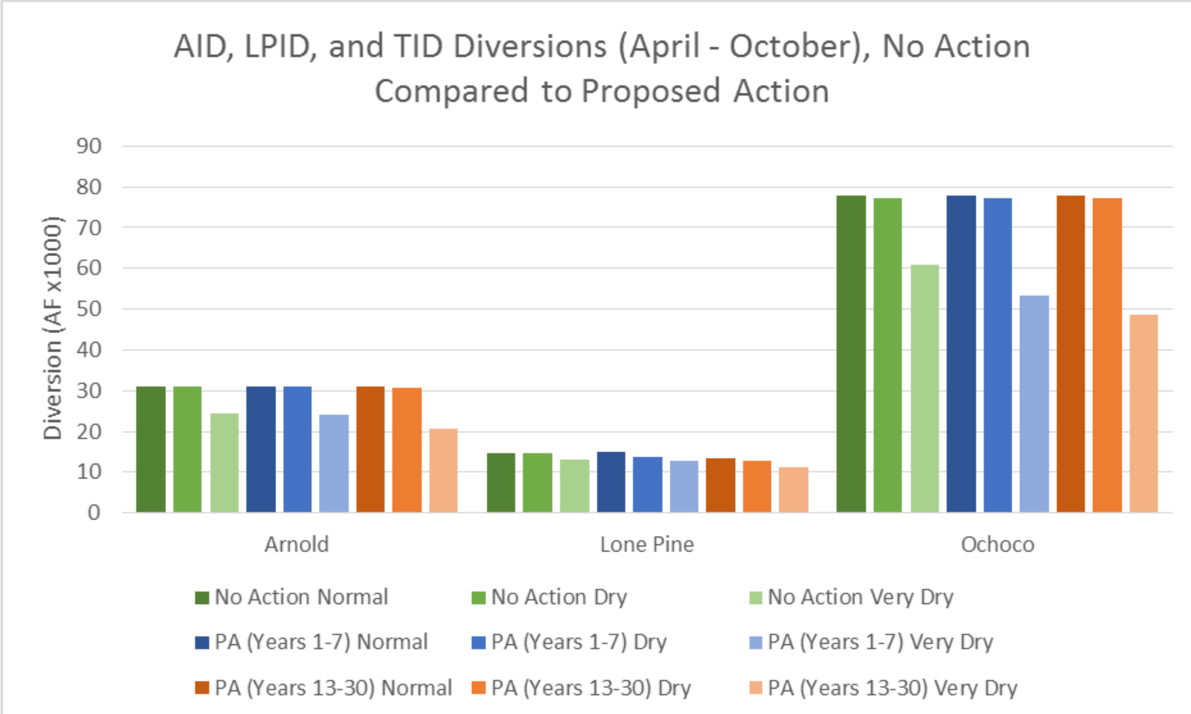


Figure 16. Arnold, Lone Pine, and Ochoco Irrigation District Diversions (April–October)— Proposed Action Years 1–7 and 13–30 Compared to the No-Action Alternative



Ochoco Irrigation District

Modeling results show that under the proposed action, increased winter releases from Prineville Reservoir, combined with North Unit ID's increased utilization of the Crooked River would result in a reduction of approximately 12,318 af of irrigation water supply for Ochoco ID in a very dry year scenario (Figure 16) in years 13 through 30 of the permit term.

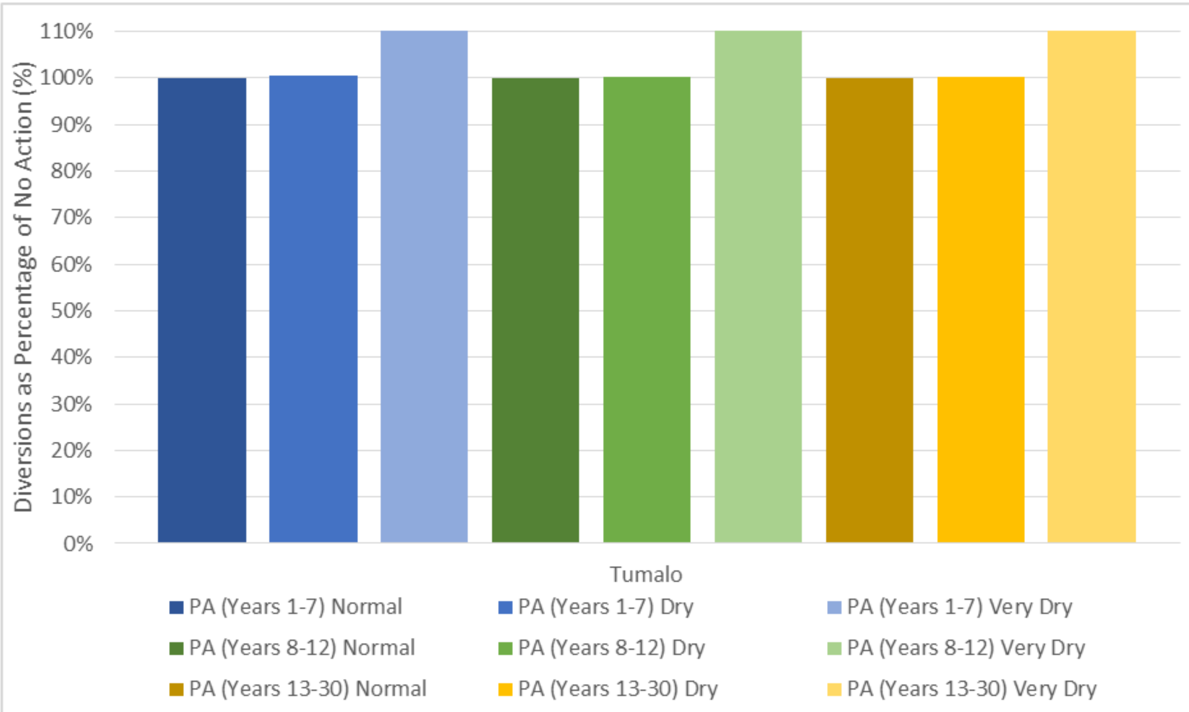
Historical data suggests that bypass flows in Ochoco Creek and McKay Creek under the proposed action could not be maintained without release and spill of additional supply. During times when some part of Ochoco ID's water supply comes from Prineville or Ochoco Reservoir, water released into McKay Creek would at least partly be made up of stored water.

The proposed action also specifies that water protected under temporary instream leases by Ochoco ID patrons with water rights for supplemental stored water in Prineville and Ochoco Reservoirs may be released at any time from February 1 through November 30. This could result in a decline of Prineville and Ochoco Reservoir storage, depending upon the timing of water releases and how instream leases are administered and accounted for. As a result, the proposed action could result in a decline in water supply available to Ochoco ID and other water users.

Tumalo Irrigation District

Overall, the proposed action would increase water supply available to Tumalo ID as a result of decreased minimum winter flows below Crescent Reservoir. Winter releases from Crescent Lake would be reduced from 30 cfs to a minimum of 10 to 12 cfs, with additional volume of water available for flexible management of Crescent Creek flow as described in the discussion of Crescent Lake flows, above. As a result, Crescent Lake storage and Tumalo ID's water supply increase compared to the No Action. As described under the no-action alternative, RiverWare does not reflect recent and planned conservation projects that have reduced Tumalo ID's demand. Although all water conserved through these projects was protected instream through an allocation of conserved water, improvements in operational flexibility are anticipated to alleviate short-term water supply challenges. RiverWare shows Tumalo ID's April through October diversion would increase by approximately 7,800 af in a very dry year. Figure 17 shows Tumalo ID diversions under the proposed action (100 through 400 cfs) in normal, dry, and very dry years as a percentage of the diversion under the no-action alternative.

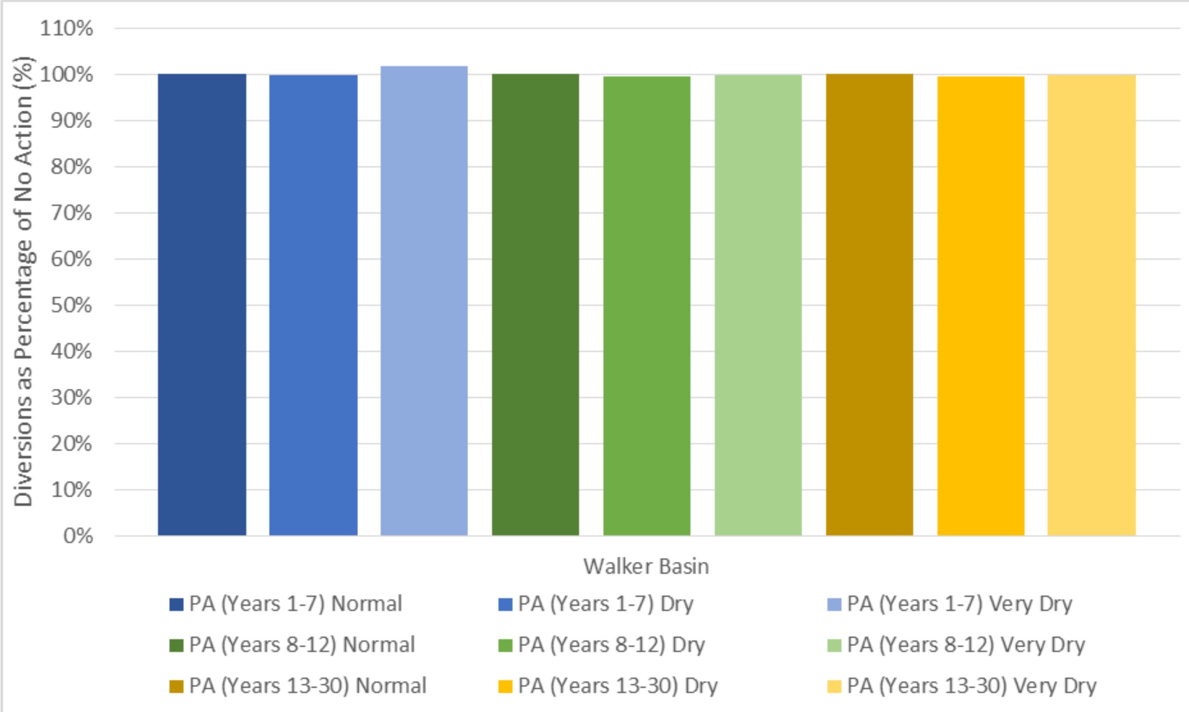
Figure 17. Modeled Diversions for Tumalo Irrigation District (April–October) under the Proposed Action as a Percentage of Diversions under the No-Action Alternative



Other Deschutes Water Users

RiverWare indicates that the proposed action would result in more frequent regulatory calls on live flow water rights in the Upper Deschutes Basin beginning in year 8, when winter flows below Wickiup Reservoir begin to increase above 100 cfs due to release of stored water. With the reduction in Crane Prairie Reservoir supply for Arnold ID, Lone Pine ID, and Central Oregon ID, it is anticipated that there would be spillover effects on other water users who have historically benefited indirectly from Arnold ID's, Lone Pine ID's, and Central Oregon ID's supply of stored water during dry years. Table 2 shows water rights in the Deschutes Basin above the BENO gauge with priority dates junior to October 31, 1900, who may experience a reduction in water supply due to increased regulatory calls. RiverWare includes modeled diversions for the Walker Basin ditch (also known as La Pine Cooperative Water Association diversion), which has water rights with priorities of 1897, 1900, and 1902. Figure 18 shows diversions under the proposed action (100 through 400 cfs) in normal, dry, and very dry years as a percentage of the diversion under the no-action alternative for the Walker Basin diversion. RiverWare indicates that changes in Walker Basin diversions as a result of the proposed action will be minimal.

Figure 18. Modeled Diversions for Walker Basin (April–October) under the Proposed Action as a Percentage of Diversions under the No-Action Alternative



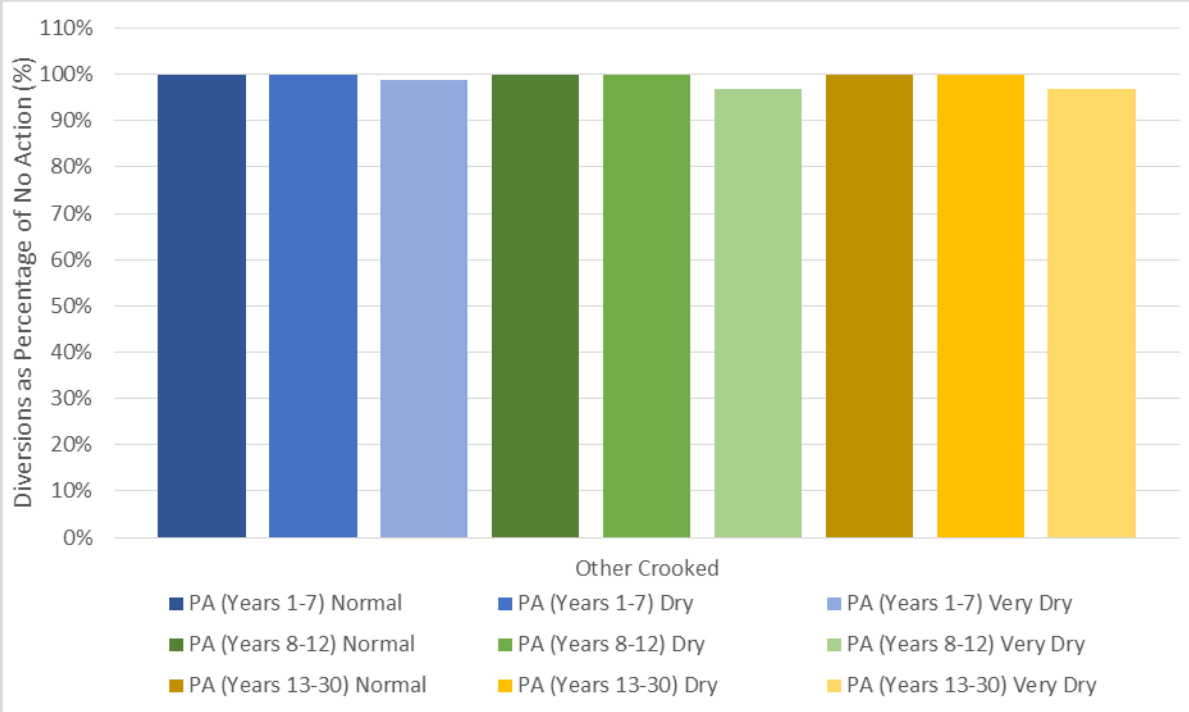
Similarly, while there have been regulatory calls on water rights junior to North Unit ID in previous years, the proposed action would be expected to increase the frequency of regulatory calls, resulting in a reduction in water supply for junior water users in the Upper Deschutes Basin.

Other Crooked River Water Users

Similar to Ochoco ID, increased winter storage releases on the Crooked River and North Unit ID's increased use of the Crooked River, Crooked River water users other than Ochoco ID, including small irrigation districts, private irrigators using shared conveyance systems, and private irrigators with individual diversions,[15] could experience reduced supply in very dry years beginning in year 1 of the permit term. Table 3 lists major diversions between Prineville Reservoir and the North Unit ID Crooked River Pumping Plant. Table 4 is a detailed list of water right holders in the Lower Crooked River from Bowman Dam to Lake Billy Chinook. Figure 19 shows diversions under the proposed action (100 through 400 cfs) in normal, dry, and very dry years as a percentage of the diversion under the no-action alternative for of Crooked River water users listed in Table 3, excluding Ochoco and North Unit IDs. The figure shows the change from the no-action alternative to the proposed action in years 1 through 7 of the permit term (to show effects of Conservation Measure CR-1) and years 13 through 30 of the permit term (to show effects of Conservation Measures CR-1 and WR-1 combined). In the worst year for water supply (1992), the RiverWare model indicates that there would be small reduction in diversions of approximately 3%. RiverWare did not model the impacts on all irrigators, and others with more junior water rights may also be affected by the proposed action.

[15] RiverWare includes modeled diversions for Crooked River irrigators above the Crooked River Feed Canal, Lowline Irrigation District, People's Irrigation District, the Rice Baldwin ditch, and Crooked River Central ditch.

Figure 19. Modeled Diversions for Other Crooked River Irrigators (April–October) under the Proposed Action as a Percentage of Diversions under the No-Action Alternative



WR-3: Changes in Reservoir Water Surface Elevations and Flood Storage Capacity

This section describes changes in reservoir water surface elevation as it relates to flood storage capacity under the proposed action. Changes in reservoir flood storage capacity are likely to occur in response to reservoir management intended to improve study area habitat for Oregon spotted frog and other species. Modeled reservoir storage volumes and associated water surface elevations for Crane Prairie, Wickiup, Crescent Lake, Prineville, and Ochoco Reservoirs were compared to the 90% total storage capacity of each reservoir (Table 12) during the October through June period (when rain-on-snow and spring runoff floods typically occur) to compare the number of days when the reservoir storage would exceed 90% of flood storage capacity. Modeled data include the median and maximum daily water surface elevations. Exceedance of 90% of reservoir storage capacity was set as the threshold for effect on flood storage capacity. Only Prineville and Ochoco reservoirs have Congressionally-mandated flood control operations. Managers may operate Crane Prairie, Wickiup, and Crescent Lake reservoirs to reduce downstream flood risk, but these reservoirs are not Congressionally-authorized flood control facilities. Although the aforementioned reservoirs are not flood control facilities, changes to reservoir flood storage capacity is reviewed in the context of potential proposed action effects on flood storage.

Table 12. Total and 90% Reservoir Storage Volumes and Elevations for the Covered Reservoirs

	Crane Prairie Reservoir	Wickiup Reservoir	Crescent Lake Reservoir	Prineville Reservoir[1]	Ochoco Reservoir[2]
Total Reservoir Storage Volume (af)	55,300	200,000	86,500	148,633	44,248
Total Reservoir Storage Water Surface Elevation[3] (ft)	4,445.00	4,337.65	4,845.43	3,234.80	3,130.70
90% Storage Volume (af)	49,770	180,000	77,850	133,770	39,823
90% Storage Water Surface Elevation (ft)	4,443.86	4,335.79	4,843.21	3,234.80	3,126.41

af = acre-feet; ft = feet

1 An incomplete station capacity curve is available for Prineville Reservoir. An elevation of 3,234.80 ft is the normal water surface elevation when the outlet works are at capacity.

2 Data provided by Ochoco Irrigation District (B. Scanlon, Ochoco Irrigation District, personal communication, February 5, 2019).

3 Elevations taken from station storage capacity curves posted to OWRD station webpages (OWRD 2018a, 2018b, 2018c, 2018d, 2018e).

Crane Prairie Reservoir

By Congressional authorization, Crane Prairie Dam and Reservoir are operated solely for storage of irrigation water. The dam may be operated informally for flood storage in anticipation of abnormally high inflow according to operating rules developed by Reclamation, but only to the extent that flood control does not compromise the storage of irrigation water. There is also a state-imposed minimum instream flow water right of 30 cfs downstream of Crane Prairie Dam.

Crane Prairie Reservoir median water surface elevations over the permit term would be higher during the storage season (November 1 through March 31) and lower through most of the irrigation season (early May through October 31) (Figure 20). Increased winter storage would start in October to meet Oregon spotted frog overwintering habitat targets (Conservation Measure CP-1). In contrast to median water surface elevations, maximum water surface elevations would be lower except from September through November, when reservoir storage would be prioritized for Oregon spotted frog overwintering habitat (Figure 21). Average median and maximum water surface elevations would be approximately 0.4 feet higher and 0.8 feet lower, respectively, over the permit term.

Figure 20. Modeled Monthly Median Water Surface Elevations for Crane Prairie Reservoir under the Proposed Action and No-Action Alternative (The reference elevation associated with 90% flood storage capacity is 4,443.86 ft [red line]. The 90% flood storage capacity is based on a total reservoir capacity of 55,300 af.)

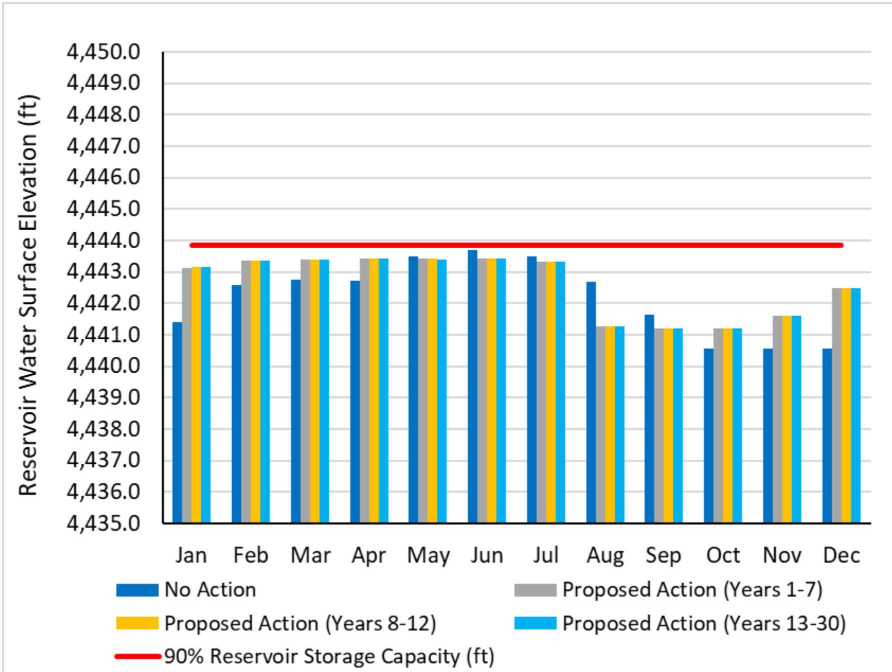
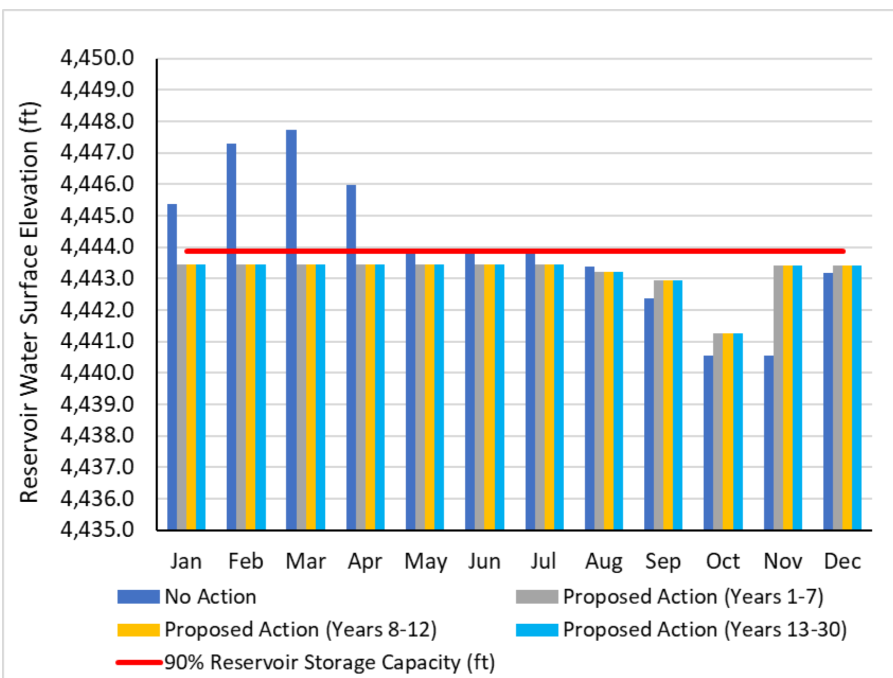


Figure 21. Modeled Monthly Maximum Water Surface Elevations for Crane Prairie Reservoir under the Proposed Action and No-Action Alternative (The reference elevation associated with 90% flood storage capacity is 4,443.86 ft [red line]. The 90% flood storage capacity is based on a total reservoir capacity of 55,300 af.)



Wickiup Reservoir

By Congressional authorization, Wickiup Reservoir is operated solely for storage of irrigation water. The dam may be operated informally for flood storage in anticipation of abnormally high inflow according to operating rules developed by Reclamation, but only to the extent that flood control does not compromise the storage of irrigation water.

Wickiup Reservoir would experience the greatest change from increased prioritization of Crane Prairie Reservoir water levels and increased minimum winter instream downstream from Wickiup Dam (Conservation Measures CP-1 and WR-1). These measures would result in Wickiup Reservoir median water surface elevations becoming more variable, especially in years 13 through 30 as less water would be stored year-round compared to earlier periods of the permit term (Figure 22). Median reservoir water surface elevations would, on average, be 4 feet lower during the storage season and 0.8 feet lower during the irrigation season. Maximum reservoir water surface elevations are similar with minor water surface elevation increases from June through September (Figure 23).

Figure 22. Modeled Monthly Median Water Surface Elevations for Wickiup Reservoir under the Proposed Action and No-Action Alternative (The reference elevation associated with 90% flood storage capacity is 4,335.79 ft [red line]. The 90% flood storage capacity is based on a total reservoir capacity of 200,000 af.)

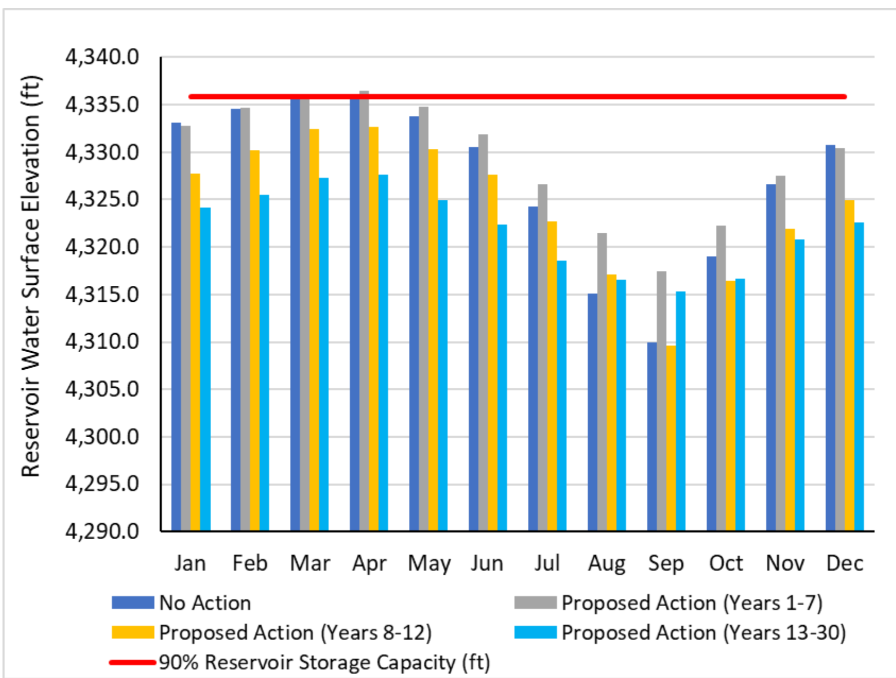
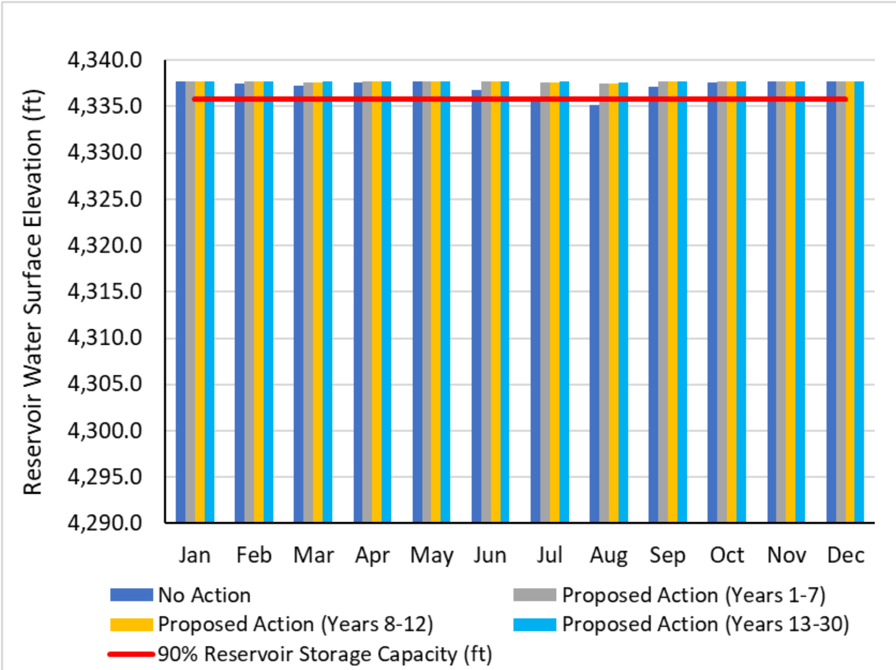


Figure 23. Modeled Monthly Maximum Water Surface Elevations for Wickiup Reservoir under the Proposed Action and No-Action Alternative (The reference elevation associated with 90% flood storage capacity is 4,335.79 ft [red line]. The 90% flood storage capacity is based on a total reservoir capacity of 200,000 af)



Crescent Lake Reservoir

Crescent Lake Reservoir would experience higher median water surface elevations due to lower minimum flows downstream from Crescent Lake Dam from March 15 through November 30 (Conservation Measure CC-1) (Figure 24). Water surface elevation differences relative to the no-action alternative would be greatest during the storage season, and least during irrigation season when water is released to meet irrigation demand. Water surface elevations would be approximately 5 feet higher over the permit term relative to the no-action alternative. There would be minor differences in maximum water surface elevations over the permit term (Figure 25).

Figure 24. Modeled Monthly Median Water Surface Elevations for Crescent Lake Reservoir under the Proposed Action and No-Action Alternative (The reference elevation associated with 90% flood storage capacity is 4,843.21 ft [red line]. The 90% flood storage capacity is based on a total reservoir capacity of 86,500 af.)

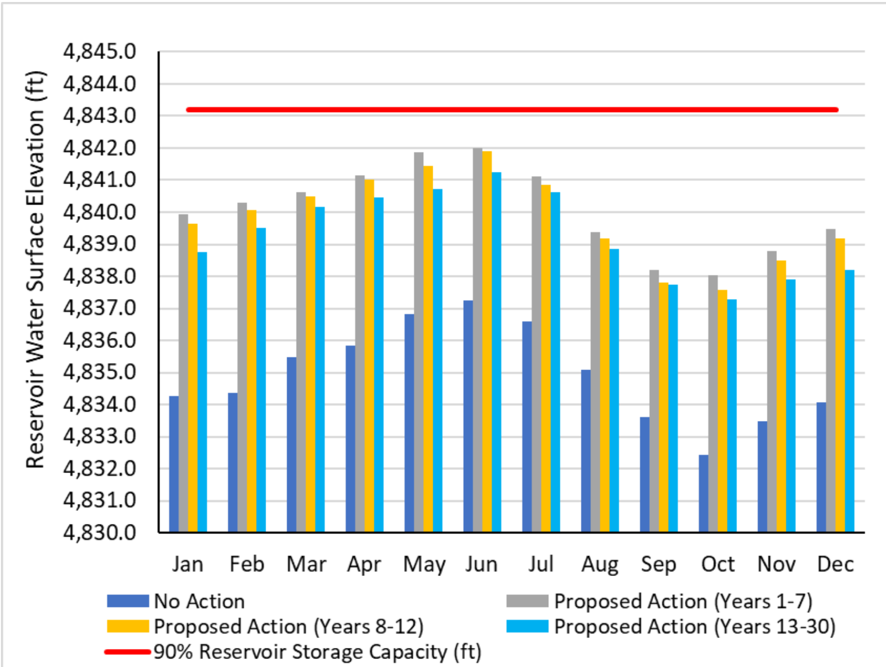
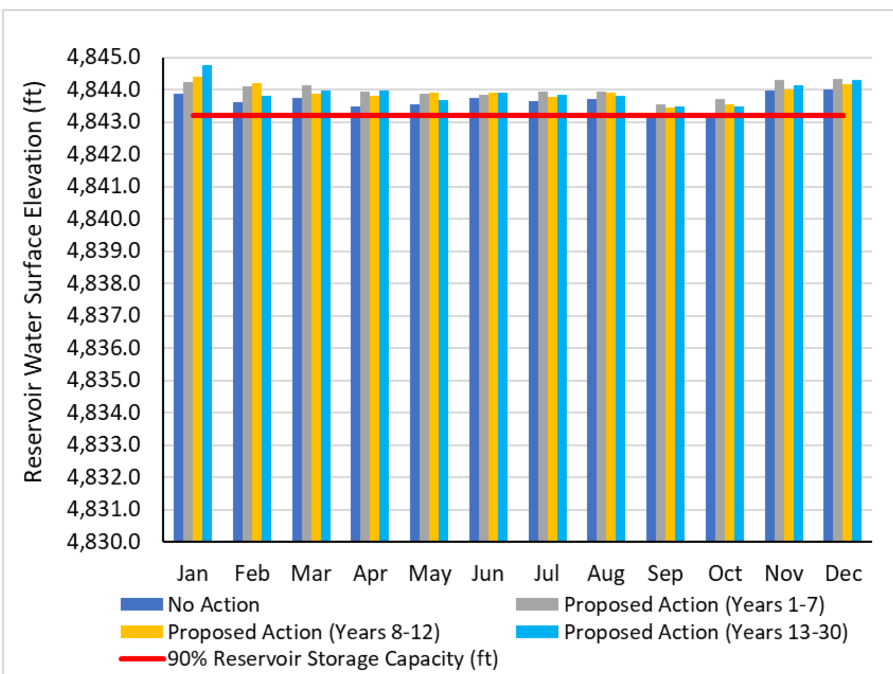


Figure 25. Modeled Monthly Maximum Water Surface Elevations for Crescent Lake Reservoir under the Proposed Action and No-Action Alternative (The reference elevation associated with 90% flood storage capacity is 4,843.21 ft [red line]. The 90% flood storage capacity is based on a total reservoir capacity of 86,500 af.)



Prineville Reservoir

Ochoco Reservoir and Prineville Reservoir are managed jointly for irrigation and flood control. Reservoir filling is based on Reclamation runoff forecasts and guided by the U.S. Army Corps of Engineers' rule curves to balance demands for irrigation and flood control. At least 16,500 af of evacuated space (flood storage capacity) are retained in Ochoco Reservoir from November 15 through January 31, and at least 60,000 af of flood storage capacity are retained in Prineville Reservoir from November 15 through February 15. After these dates, additional storage occurs according to established rule curves to limit flood flows to 3,000 cfs downstream from Prineville Reservoir and 1,100 cfs downstream from Ochoco Reservoir. Both reservoirs typically reach annual maximum storage elevations during April or May (Deschutes Basin Board of Control and City of Prineville 2019).

Prineville Reservoir would experience similar median water surface elevations late in winter storage through spring, but lower median water surface elevations would occur through irrigation season and early in winter storage (June through January) (Figure 26). Lower median reservoir water surface elevations in year 13 of the permit term, would result from releasing stored water to meet North Unit ID's water needs and meeting minimum instream flow requirements downstream from Prineville Reservoir (Conservation Measure CR-1). Maximum reservoir water surface elevations would be similar except in late winter, when the proposed action water surface elevations would be lowered to meet minimum flow requirements downstream from Bowman Dam (Figure 27). Average median and maximum water surface elevations would be approximately 0.4 foot lower and 0.2 foot higher, respectively, over the permit term.

Days of 90% reservoir capacity exceedance would increase from 0 days under the no-action alternative, to 1 day under the proposed action. However, because Ochoco and Prineville Reservoirs are operated in tandem to reduce flood potential on the Crooked River, reservoir managers would continue to operate the reservoirs for flood control. Based on the proposed action's minimal influence on flood storage, the proposed action is not expected to affect reservoir flood storage capacity.

Figure 26. Modeled Monthly Median Water Surface Elevations for Crescent Lake Reservoir under the Proposed Action and No-Action Alternative (The reference elevation associated with 90% flood storage capacity is 4,843.21 ft [red line]. The 90% flood storage capacity is based on a total reservoir capacity of 86,500 af.)

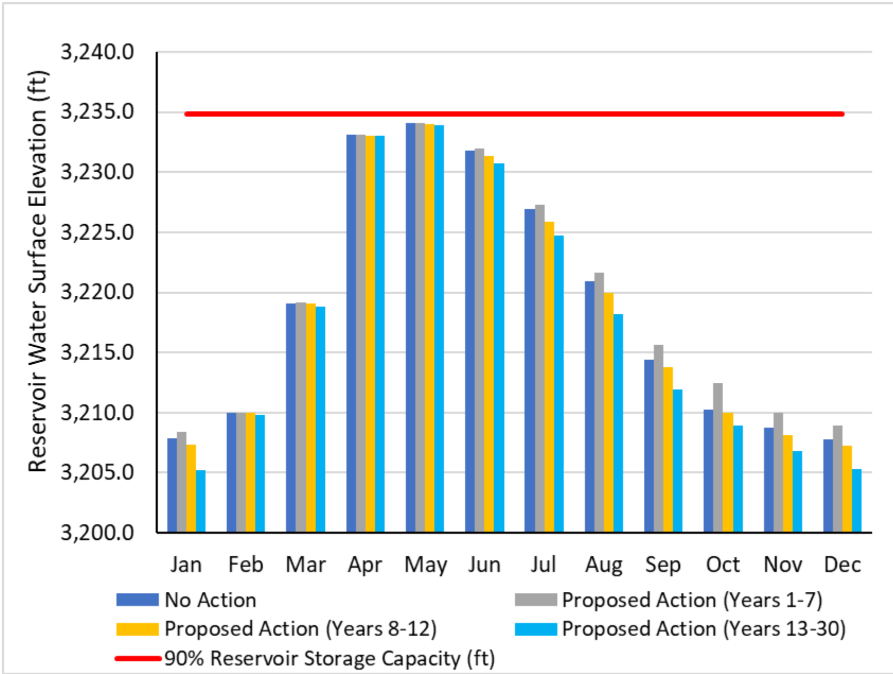
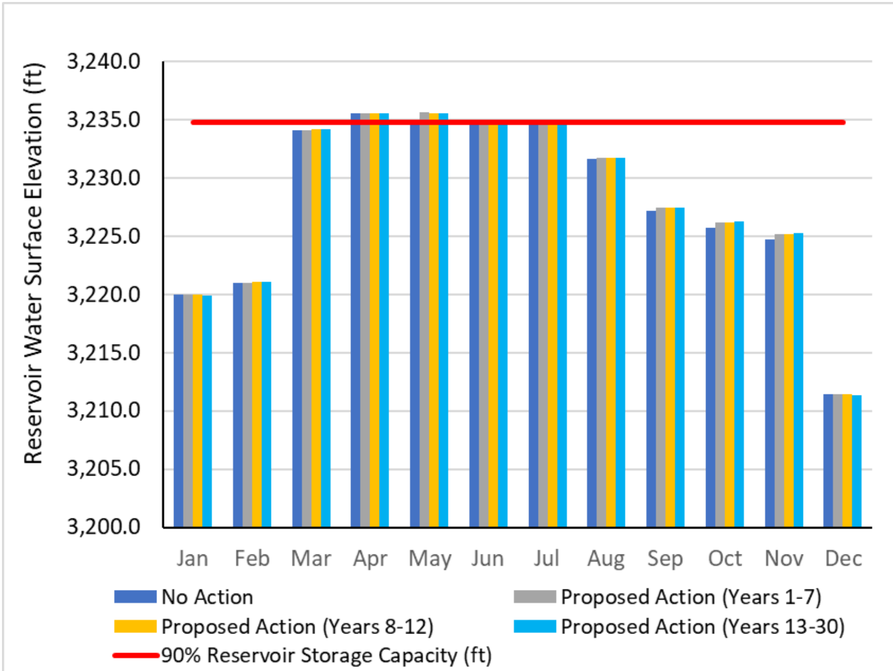


Figure 27. Modeled Monthly Maximum Water Surface Elevations for Prineville Reservoir under the Proposed Action and No-Action Alternative (The reference elevation associated with the outlet works is 3,234.80 ft [red line]. The 90% flood storage capacity is based on a total reservoir capacity of 148,633 af.)



Ochoco Reservoir

Ochoco Reservoir median and maximum water surface elevations would be similar to the no-action alternative over the permit term. Conservation Measures CR-2, CR-3, and CR-4 would have minimal influence over median (Figure 28) and maximum (Figure 29) reservoir water surface elevations. Modeling results suggest there would be no difference in the proposed action's average median and maximum water surface elevations over the permit term.

Figure 28. Modeled Monthly Median Water Surface Elevations for Ochoco Reservoir under the Proposed Action and No-Action Alternative (The reference elevation associated with the outlet works is 3,130.06 ft [red line]. The 90% flood storage capacity is based on a total reservoir capacity of 44,248 af.)

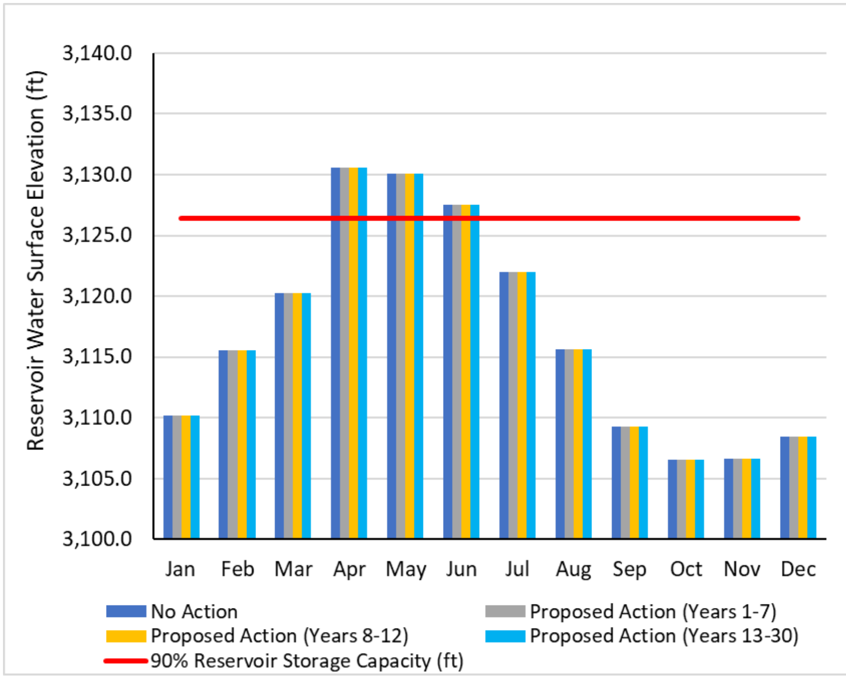
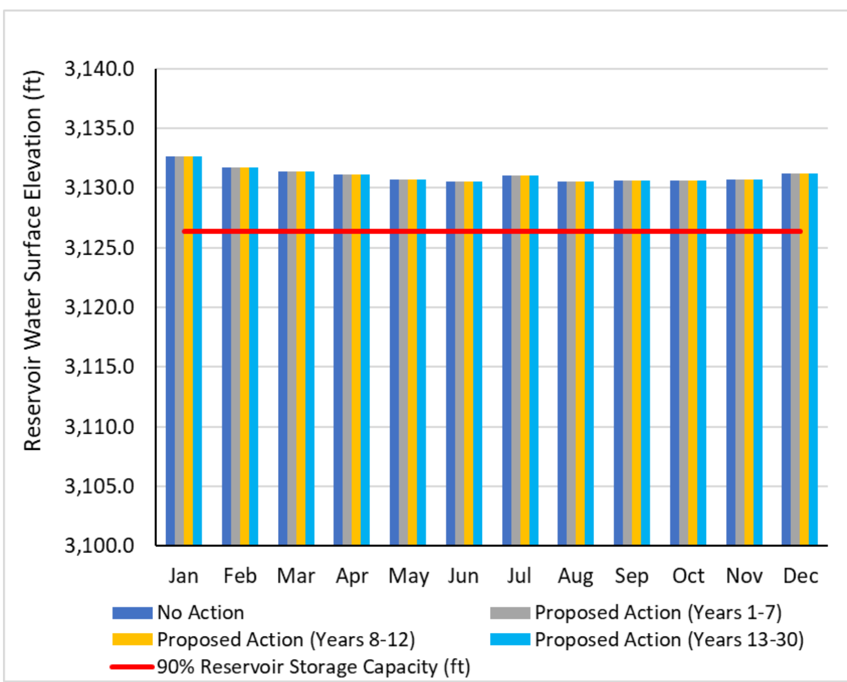


Figure 29. Modeled Monthly Maximum Water Surface Elevations for Ochoco Reservoir under the Proposed Action and No-Action Alternative (The reference elevation associated with the outlet works is 3,130.06 ft [red line]. The 90% flood storage capacity is based on a total reservoir capacity of 44,248 af.)



WR-4: Change Seasonal River and Creek Flows

Seasonal river and creek flows in the study area would generally respond to changes in the proposed action's water management regime. Anticipated changes include higher winter flows on the Upper Deschutes River and Crooked River in response to higher minimum winter flows in both rivers. Conversely, irrigation period flows will decrease due to the reduction in reservoir storage associated with the increasing minimum flows in winter. Although the analysis includes wet, normal, an dry years, additional evaluation was completed for normal and dry years since these are periods when water availability may be limited.

Deschutes River from Crane Prairie Reservoir to Wickiup Reservoir

Implementation of Conservation Measures CP-1 and WR-1 would cause a more variable flow regime in this reach. Conservation Measure CP-1 would establish a minimum year-round instream flows that are subordinate in priority to maintaining consistent storage in Crane Prairie Reservoir. The minimum instream flow target of 75 cfs is less than the no-action alternative target of 100 cfs (January through August) and the same as the 75 cfs target established for September through December under the no-action alternative.

Generally, flows at the CRAO gauge downstream from Crane Prairie Reservoir would be higher during 4 months of the year (January through February, the first half of May, and then July through mid-August), lower during 5 months of the year (November through December, mid-March through mid-April, and mid-August through the end of September), and similar during 3 months of the year (October and mid-May to mid-July) (Figure 30). Minimum flow requirements for the Deschutes River downstream from Wickiup Reservoir would not affect flow levels in this reach since water surface elevations in Crane Prairie Reservoir are prioritized for Oregon spotted frog habitat.

Figure 30. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Deschutes River at the CRAO Gauge between Crane Prairie Reservoir and Wickiup Reservoir under the Proposed Action Years 1-7 (upper) and Years 13-30 (lower) Compared to the No-Action Alternative

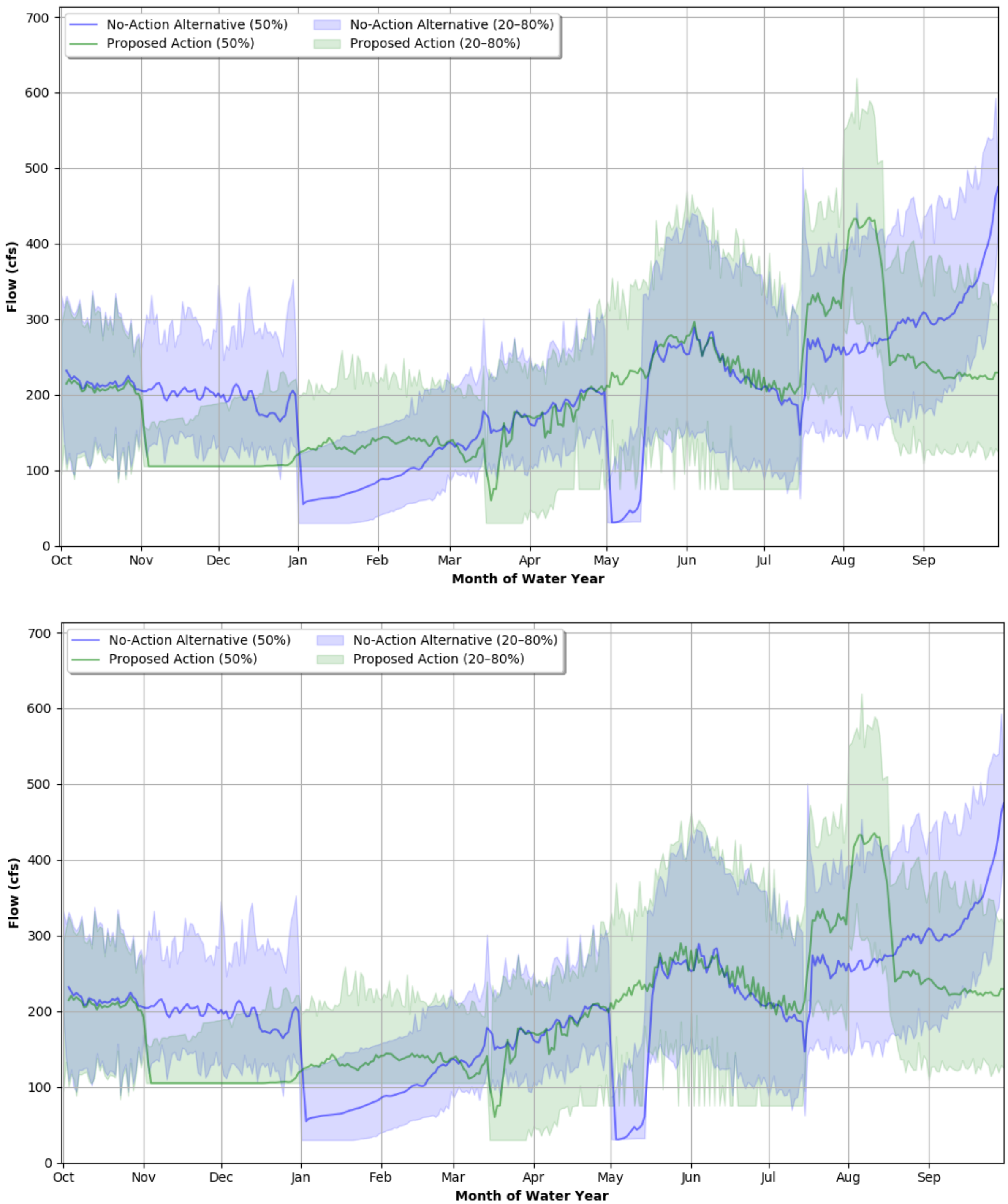


Table 13 includes a comparison of seasonal differences in minimum and maximum median flows for the permit term based on RiverWare output for the CRAO gauge. The proposed action has lower minimum and maximum median flows during the winter period. Minimum and maximum median daily flows remain consistent through the permit term since there are no additional operational requirements. The proposed action's narrower range between minimum and maximum flows suggests less variable outflows from Crane Prairie Reservoir since reservoir storage would be managed to meet Oregon spotted frog habitat goals.

Table 13. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Deschutes River between Crane Prairie Reservoir and Wickiup Reservoir by Season for the No-Action Alternative and Proposed Action over the Permit Term

Alternative	Winter (Nov 1–Mar 31) Minimum (cfs)	Winter (Nov 1–Mar 31) Maximum (cfs)	Irrigation (Apr 1–Oct 31) Minimum (cfs)	Irrigation (Apr 1–Oct 31) Maximum (cfs)
No-Action	49.3	225.4	30.5	500.4
Proposed Action (Years 1–7)	30.0	183.3	75.0	445.8
Proposed Action (Years 8-12)	30.0	183.3	75.0	445.8
Proposed Action (Years 13-30)	30.0	183.3	75.0	445.8

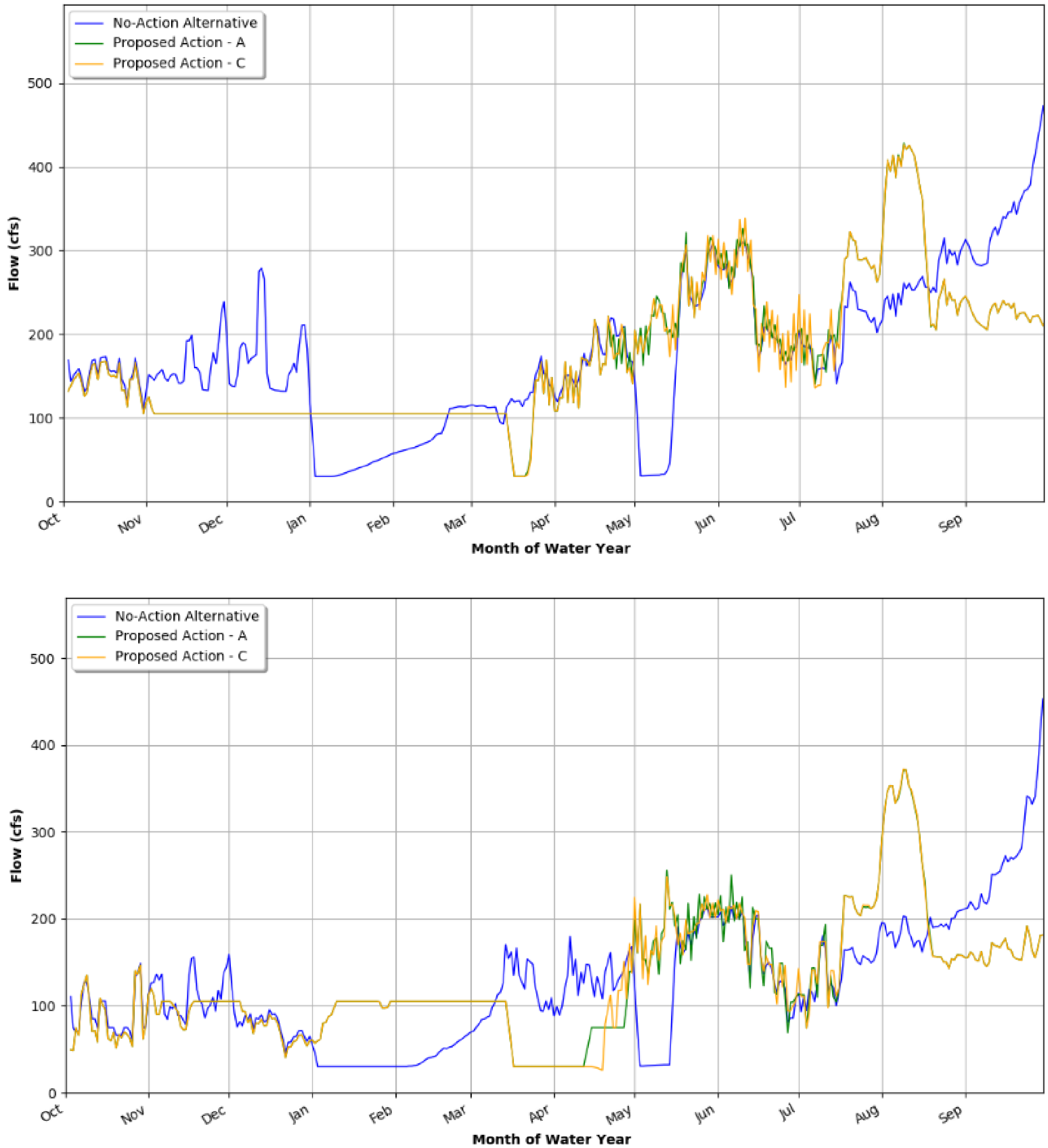
Total monthly streamflow volume (af) for representative wet, normal, and dry years was evaluated to assess changes in seasonal streamflow. Proposed action results are presented as the percent difference from the no-action alternative (Table 14). Total streamflow volume decreases between 3% and 4% in a normal and dry year, respectively, in years 13 through 30 compared to the no-action alternative. Winter storage period flows are variable, decreasing by 11% and 8% in wet and dry years, respectively, and decreasing by 18% in a normal year. Irrigation period flows increase a small amount in wet and normal years, and decrease by 1% in dry years in years 13 through 30 of the permit term. Dry year flows are least variable while wet year flows are the most variable. Flow differences remain the same over the permit term for each of the water year types.

Table 14. Percent Differences in Streamflow Volume between the No-Action Alternative and Proposed Action for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal and Dry Years at the CRAO Gauge

Water Year Type	Time Period	Proposed Action Years 1–7	Proposed Action Years 8–12	Proposed Action Years 13–30
Wet	Irrigation Period	2%	2%	2%
	Winter/Storage Period	-11%	-11%	-11%
	Annual	-3%	-3%	-3%
	1 SD	41%	41%	41%
Normal	Irrigation Period	3%	3%	2%
	Winter/Storage Period	-18%	-18%	-18%
	Annual	-3%	-3%	-3%
	1 SD	-6%	-6%	-6%
Dry	Irrigation Period	-2%	-1%	-1%
	Winter/Storage Period	-8%	-8%	-8%
	Annual	-4%	-4%	-4%
	1 SD	-30%	-30%	-30%

Figure 31 includes the representative normal and dry year hydrographs for the CRAO gauge under the proposed action in years 1 through 5 and years 13 through 30 of the permit term in normal and dry years. Proposed action flows increase from mid-July through mid-August and then decrease as Crane Prairie Reservoir filling begins in mid-August. In a dry year, the proposed action reaches minimum flow levels between mid-March and mid-May, likely in response to low reservoir elevations and the need to minimize reservoir fluctuations. Increasing flows beginning in mid-July take place after the Oregon spotted frog reservoir water surface prioritization time period for Crane Prairie Reservoir, and to meet downstream irrigation demand. Flows less than 100 cfs in the dry year hydrograph indicate the reservoir volume is below fill targets and therefore, less flow is released from Crane Prairie Reservoir. Anticipated normal year peak flows exceed the 400 cfs maximum flow criterion for a short period in early August. Fall flows decrease relative to the no-action alternative as water storage begins to meet Oregon spotted frog water surface elevation guidelines.

Figure 31. Modeled flows for the Deschutes River at the CRAO Gauge between Crane Prairie Reservoir and Wickiup Reservoir under Proposed Action in Years 1–7 (A) and Years 13–30 (C) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative



Deschutes River from Wickiup Dam to the Little Deschutes River

Conservation measures for the Deschutes River downstream from Wickiup Dam (Conservation Measure WR-1) are intended to increase minimum winter and spring flows and cap summer maximum flows over the permit term. The no-action alternative and proposed action in years 1 through 7 of the permit term would have a similar influence on flow levels at the WICO gauge downstream from Wickiup Dam (Figure 32). As minimum flows increase and irrigation period maximum flows are capped through the permit term, flows become less variable. In years 13 through 30, minimum storage flows are 400 cfs and irrigation period maximum flows are capped at 1,200 cfs. Higher winter releases result in lower irrigation period flows which are also affected by the maximum flow cap especially in years 13 through 30.

Figure 32. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Deschutes River at the WICO Gauge Downstream from Wickiup Reservoir under the Proposed Action for Years 1–7 (upper) and Years 13–30 (lower) Compared to the No-Action Alternative

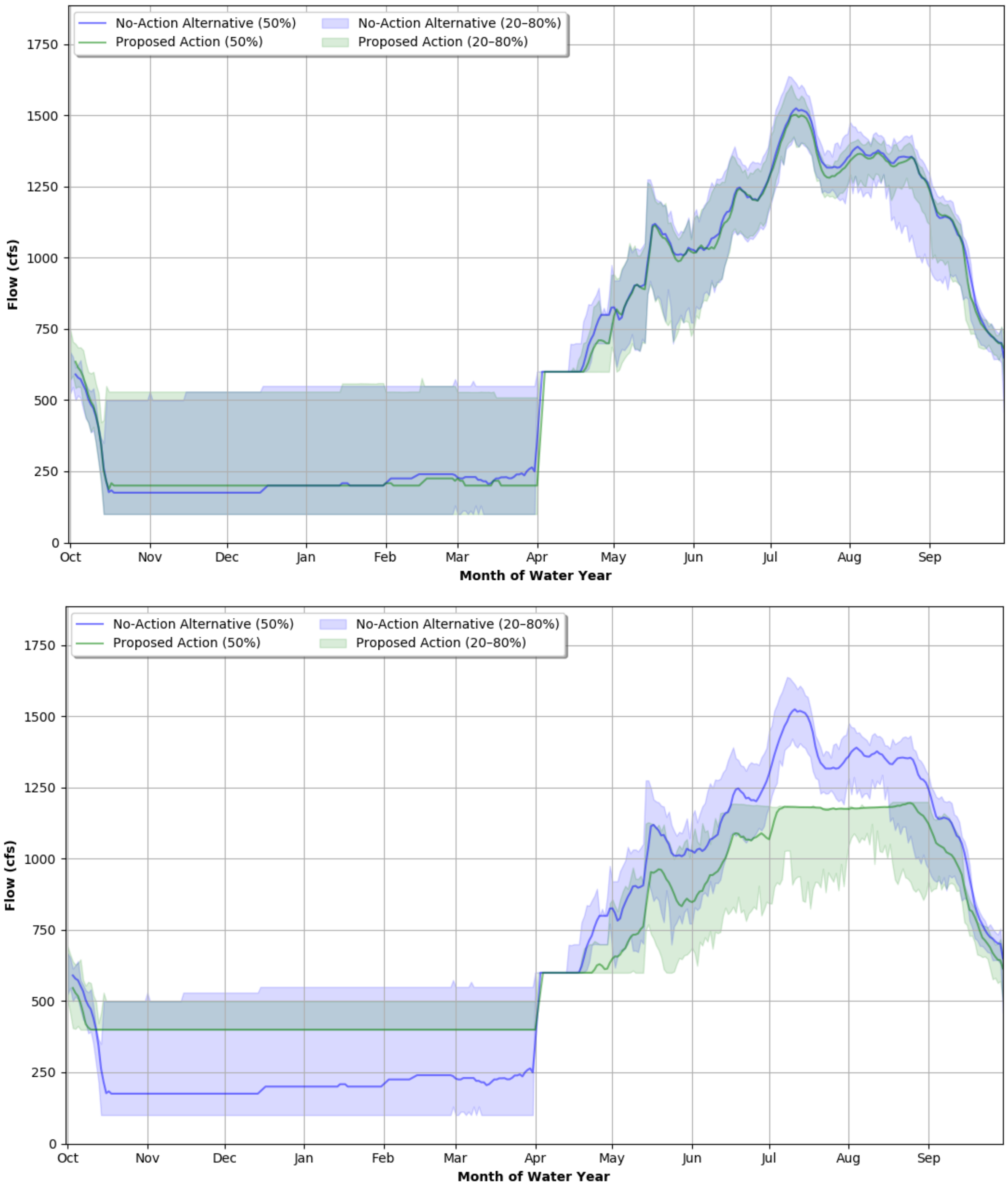


Table 15 includes a comparison of seasonal differences in minimum and maximum median flows based on WICO gauge data. Storage period flows increase over the permit term as the minimum winter flow releases from Wickiup Reservoir increase. Alternatively, maximum flows during the irrigation period decline due to higher winter season flows and as irrigation season maximum flows are capped in years 8 through 12 and years 13 through 30 of the permit term.

Table 15. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Deschutes River Downstream from Wickiup Reservoir by Season for the No-Action Alternative and Proposed Action over the Permit Term

	Winter (Nov 1–Mar 31)		Irrigation (Apr 1–Oct 31)	
Alternative	Minimum (cfs)	Maximum (cfs)	Minimum (cfs)	Maximum (cfs)
No-Action	175.0	279.5	155.3	1,532.0
Proposed Action (Years 1–7)	200.0	250.0	136.4	1,515.1
Proposed Action (Years 8-12)	300.0	300.0	300.0	1,383.0
Proposed Action (Years 13-30)	400.0	400.0	400.0	1,200.0

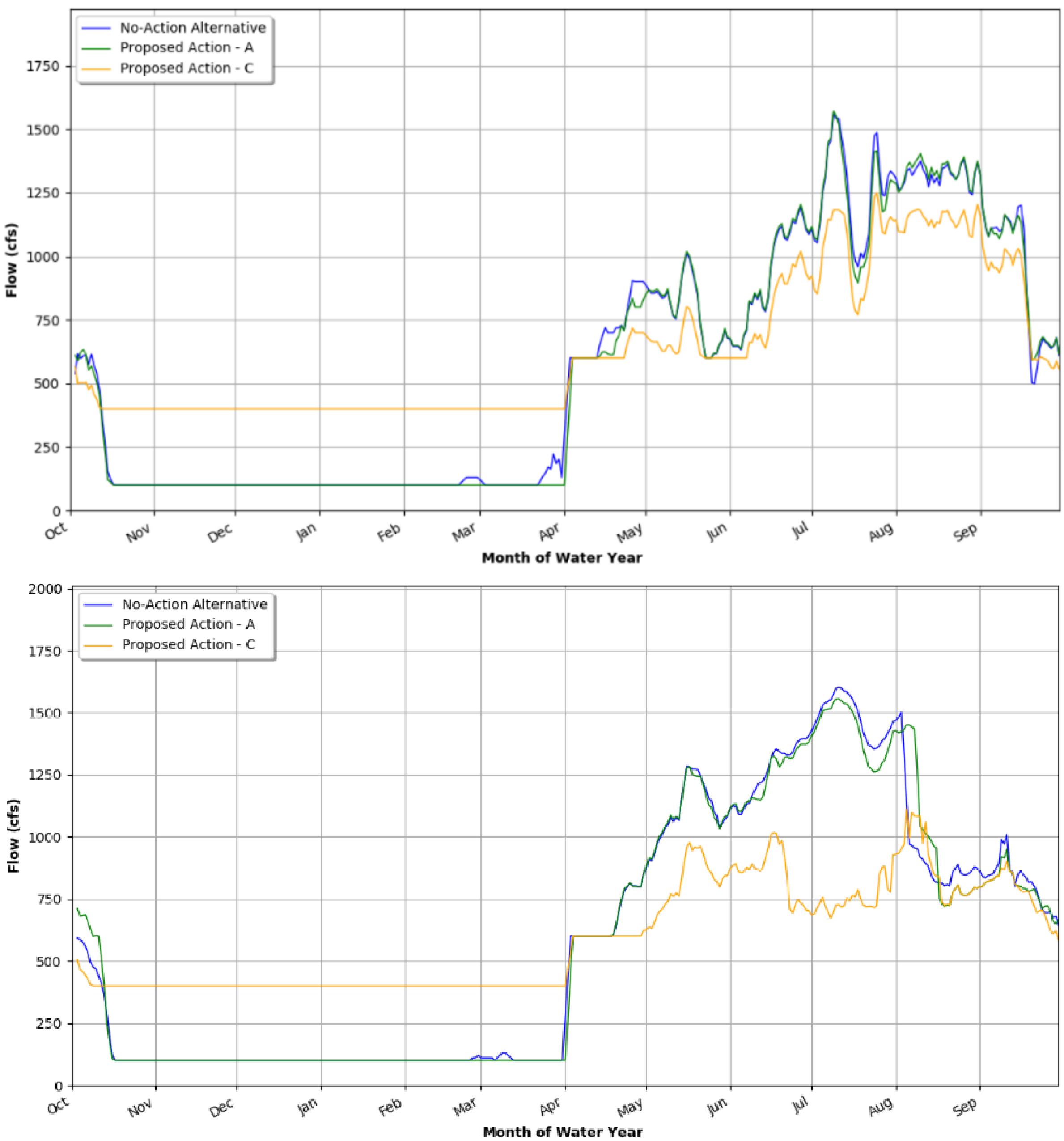
Total monthly streamflow volume (af) for representative wet, normal, and dry years was evaluated to assess changes in seasonal streamflow. Proposed action results are presented as the percent difference from the no-action alternative (Table 16). Total streamflow volume is 4% greater in wet years, 4% less in normal years, and unchanged in dry years during years 13 through 30 of the permit term. Storage flows increase over the permit term and are substantially greater than the no-action alternative flows. Irrigation period flows have a contrasting trend to the winter storage flows, with irrigation period flows increasingly constrained through the permit term and from wet to dry years. Minimum winter flow releases have the greatest effect on dry year irrigation period releases. Monthly flows are also less variable under the proposed action with decreasing variability from a wet year to a dry year as the difference between irrigation and storage period flows tightens.

Table 16. Percent Differences in Streamflow Volume between the No-Action Alternative and Proposed Action for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years at the WICO Gauge

		Proposed Action		
Water Year Type	Time Period	Years 1–7	Years 8–12	Years 13–30
Wet	Irrigation Period	-2%	-2%	-6%
	Winter/Storage Period	3%	24%	49%
	Annual	-1%	3%	4%
	1 SD	-3%	-15%	-32%
Normal	Irrigation Period	-1%	-7%	-15%
	Winter/Storage Period	-2%	24%	42%
	Annual	-1%	-1%	-4%
	1 SD	0%	-20%	-38%
Dry	Irrigation Period	-1%	-15%	-23%
	Winter/Storage Period	-1%	196%	295%
	Annual	-1%	0%	0%
	1 SD	-1%	-40%	-60%

Figure 33 includes the representative normal and dry year hydrographs for the WICO gauge under the proposed action in years 13 through 30 of the permit term. Under both scenarios, flows during the first period of the permit term resemble the no-action alternative. However, during the final period of the permit term, storage flows are set at 400 cfs and peak at 1,200 cfs. Irrigation period flows in years 13 through 30 are lower than the no-action alternative and the first period of the proposed action as storage is depleted by the higher winter releases from Wickiup Reservoir. Streamflow differences are accentuated in dry years when irrigation period flows are generally between 750 cfs and 1,000 cfs.

Figure 33. Modeled Flows for the Deschutes River at the WICO Gauge Downstream from Wickiup Reservoir under the Proposed Action Years 1–7 (A) and Years 13–30 (C) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative



Deschutes River from the Little Deschutes River to Benham Falls

Implementation of Conservation Measure WR-1 influences flows in the Little Deschutes River to Benham Falls reach. Generally, flows are similar between the proposed action in years 1 through 7, and the no-action alternative as the reservoir management rules are similar (Figure 34). In later periods of the permit term, streamflow at the BENO gauge illustrates the effects of higher minimum winter storage flows. Although this trend is apparent through the permit term periods, the winter minimum flow effects are most prominent in years 13 through 30. Irrigation period difference are most apparent from mid-May through mid-September as stored water in upstream reservoirs is depleted.

Figure 34. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Deschutes River at the BENO Gauge under the Proposed Action Years 1–7 (upper) and Years 13–30 (lower) Compared to the No-Action Alternative

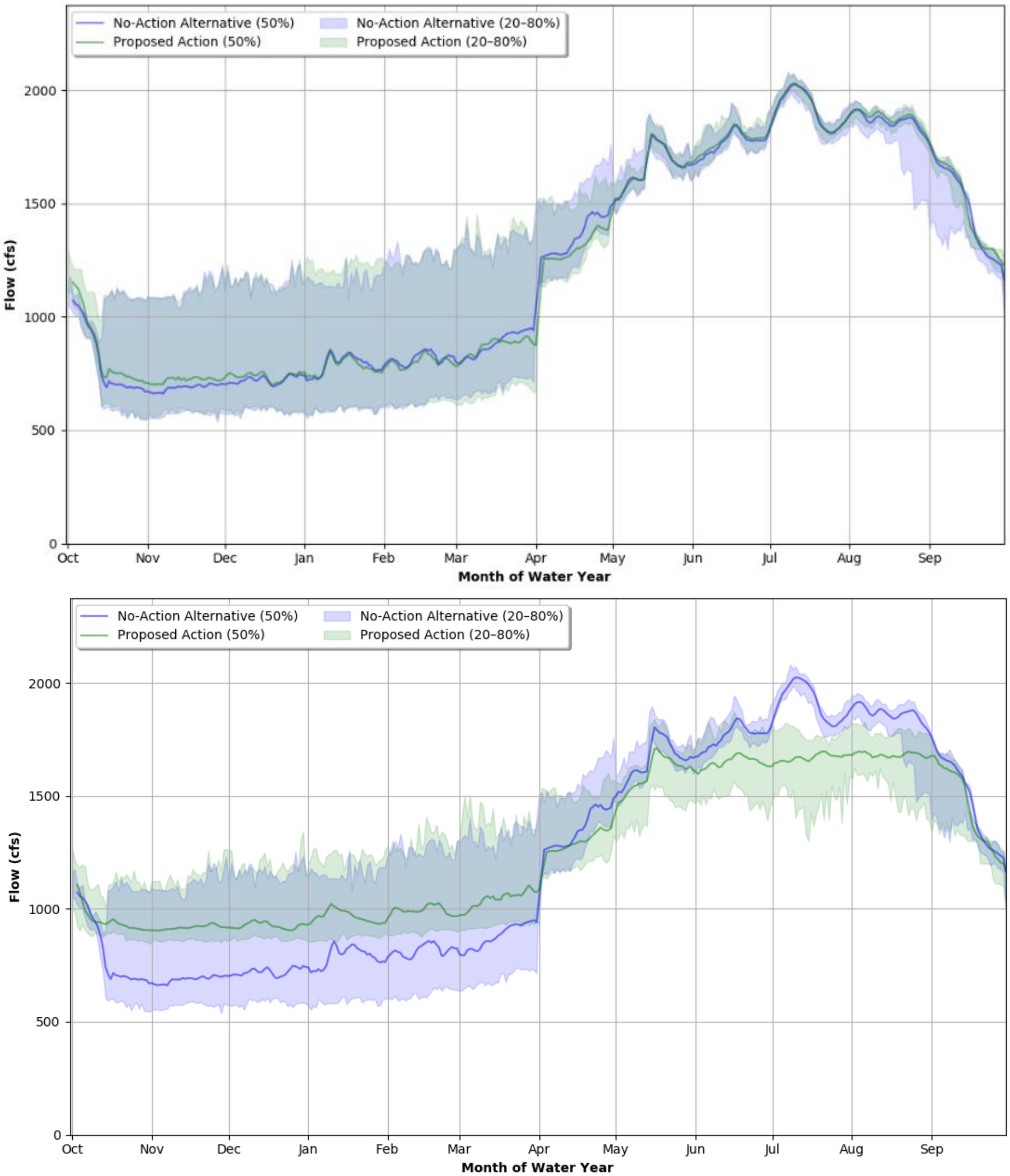


Table 17 includes a comparison of seasonal differences in minimum and maximum median flows for the permit term based on RiverWare output for the BENO gauge. The flow data show the increasing minimum and maximum median flows that would occur during the winter storage period over the permit term related to the implementation of Conservation Measure WR-1. Due to the increasing winter minimum flows, irrigation period flows experience an inverse relationship with decreasing maximum median flows especially beginning in years 8 through 12 when minimum winter flows on the Upper Deschutes River are set at 300 cfs and summer maximum flows are capped at 1,400 cfs.

Table 17. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Deschutes River at the BENO Gauge by Season for the No-Action Alternative and Proposed Action

	Winter (Nov 1–Mar 31)		Irrigation (Apr 1–Oct 31)	
Alternative	Minimum (cfs)	Maximum (cfs)	Minimum (cfs)	Maximum (cfs)
No-Action	651.3	960.4	637.5	2,029.6
Proposed Action (Years 1–7)	691.0	923.9	651.5	2,035.6
Proposed Action (Years 8-12)	798.5	1,011.0	801.3	1,877.4
Proposed Action (Years 13-30)	900.4	1,109.4	902.7	1,726.2

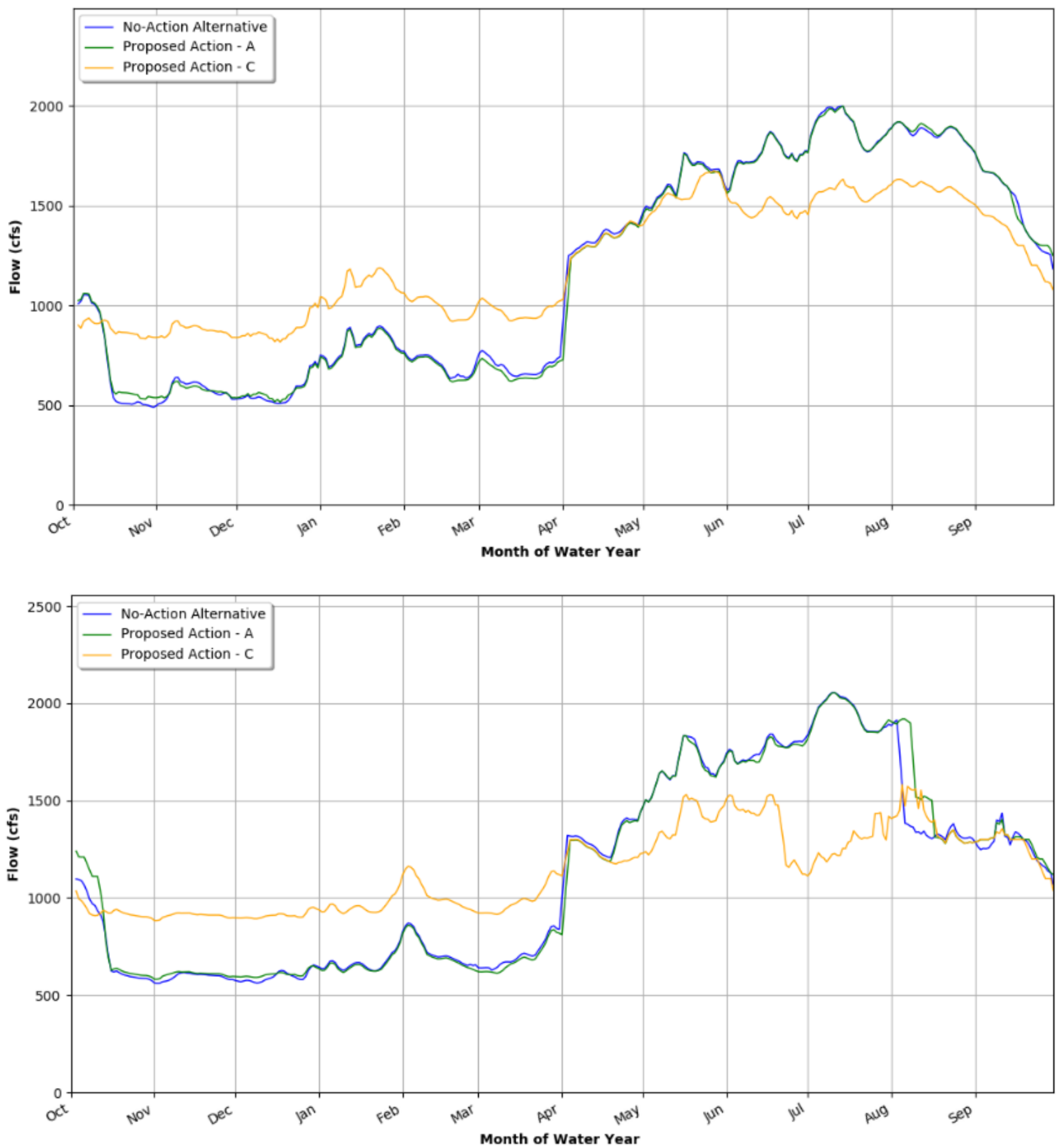
Total monthly streamflow volume (af) for representative wet, normal, and dry years were evaluated to assess changes in seasonal streamflow. Proposed action results were compared to the no-action alternative and proposed action results are reported as the percent difference from the no-action alternative (Table 18). Although annual flows would experience minimal change over the water year types, winter storage and irrigation period flows differ by water year type and over the periods of the permit term. From a wet year to a dry year, there would be winter storage period flow changes ranging from a decrease of 3% in a wet year, to an increase of 46% in a dry year. Similarly, there would be a reduction in irrigation period flows of between 10% and 13% for a normal year and dry year, respectively.

Table 18. Percent Differences between the No-Action Alternative and Proposed Action for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years for the BENO Gauge

		Proposed Action		
Water Year Type	Time Period	Years 1–7	Years 8–12	Years 13–30
Wet	Irrigation Period	1%	1%	1%
	Winter/Storage Period	-4%	-3%	-3%
	Annual	-1%	0%	0%
	1 SD	0%	0%	-3%
Normal	Irrigation Period	0%	-6%	-10%
	Winter/Storage Period	-2%	16%	29%
	Annual	-1%	0%	0%
	1 SD	1%	-24%	-42%
Dry	Irrigation Period	1%	-8%	-13%
	Winter/Storage Period	-1%	30%	46%
	Annual	0%	1%	1%
	1 SD	1%	-38%	-58%

Figure 35 includes the representative normal and dry year hydrographs for the BENO gauge under the proposed action in years 13 through 30 of the permit term. Hydrographs for representative normal and dry years have similar patterns with the proposed action daily flows being higher from mid-October to April 1, similar from April 1 to mid-May (dry year) and early July (normal year), and lower through the remainder of the irrigation season. Flow declines occur about a month and half earlier in a dry year compared to a normal year.

Figure 35. Modeled Flows for the Deschutes River at the BENO Gauge under the Proposed Action Years 1–7 (A) and Years 13–30 (C) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative



Deschutes River from Benham Falls to Bend

Surface water diversions located between Lava Island and the DEBO gauge, and streamflow losses to groundwater, influence the amount of water remaining in the Deschutes River at the DEBO gauge (#14070500). Like the WICO and BENO gauges, the no-action and proposed action in years 1 through 7 yield similar median flows over the hydrograph (Figure 36). Flow variability marked by the 20 to 80% flow range is similar for both alternatives. In years 13through 30, higher winter flows are related to minimum releases from Wickiup Reservoir. Irrigation period flows are similar to the no-action alternative except for lower flows from mid-May to early June.

Figure 36. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Deschutes River at the DEBO Gauge Under the Proposed Action Years 1–7 (upper) and Years 13–30 (lower) Compared to the No-Action Alternative

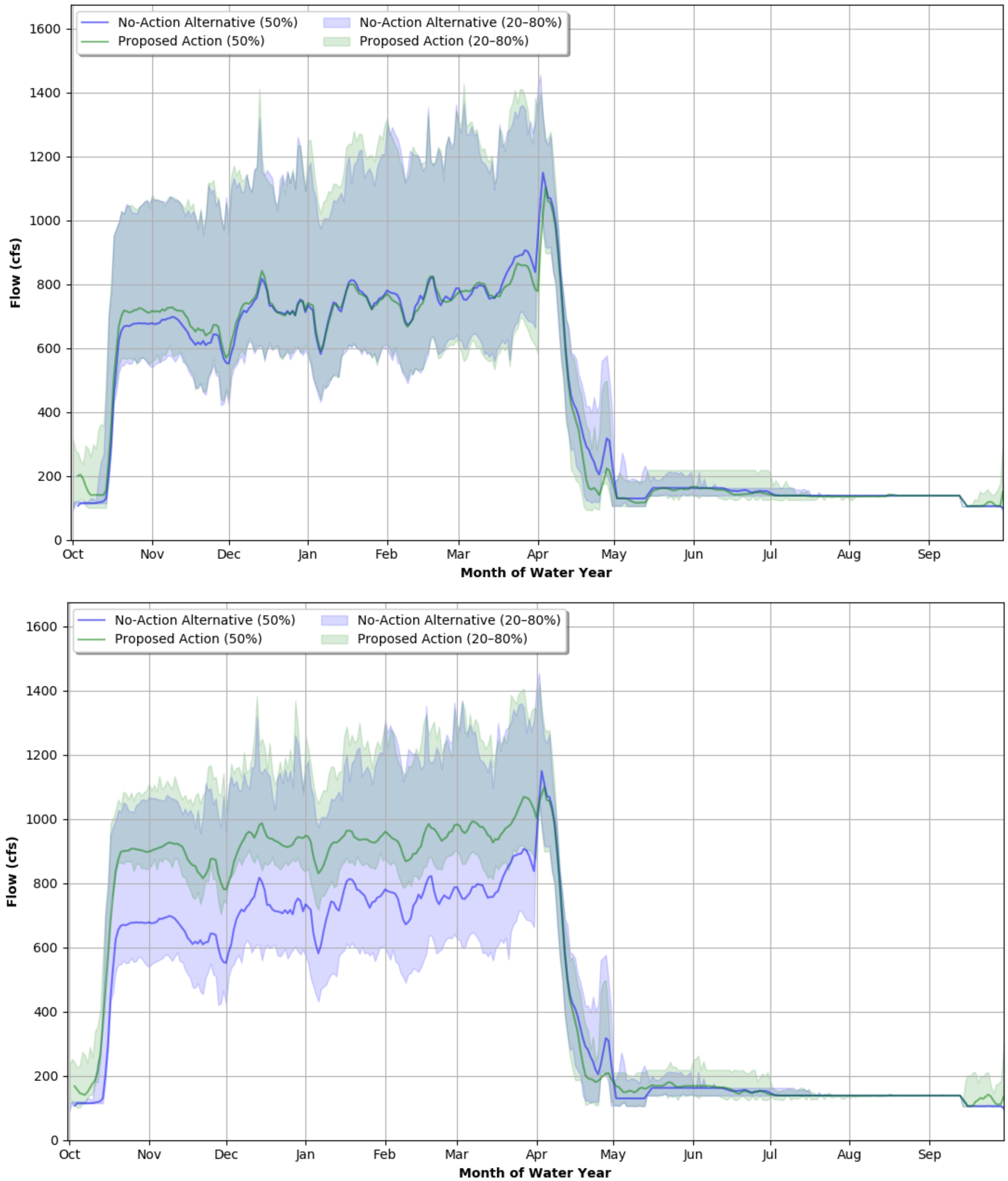


Table 19 includes a comparison of seasonal differences in minimum and maximum median flows based on DEBO gauge data. The proposed action in years 13 through 30 has the highest minimum and maximum median flows during winter due to the higher minimum flow target included in Conservation Measure WR-1. Conservation measures approved for Tumalo ID and Swalley ID will increase diversion network efficiency. However, instream flow benefits associated with these improvements were not included in the RiverWare model logic. Conservation measures are anticipated to result in additional instream flow during irrigation season of 7.5 cfs during the first period of the permit term, increasing to 5.2 cfs in the second period.

Table 19. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Deschutes River at the DEBO Gauge by Season for the No-Action Alternative and Proposed Action over the Permit Term[1]

Alternative	Winter (Nov 1–Mar 31) Minimum (cfs)	Winter (Nov 1–Mar 31) Maximum (cfs)	Irrigation (Apr 1–Oct 31)[2] Minimum (cfs)	Irrigation (Apr 1–Oct 31)[2] Maximum (cfs)
No-Action	535.0	913.8	89.8	1,183.1
Proposed Action (Years 1–7)	559.5	880.4	105.0	1,174.3
Proposed Action (Years 8-12)	668.6	987.8	105.0	1,174.3
Proposed Action (Years 13-30)	766.2	1,075.9	105.0	1,174.3

[1] Tumalo ID and Swalley ID water conservation projects would result in an additional 7.6 cfs of instream water during the irrigation season in years 1 through 5 and 15.2 cfs in years 6 through 30 under the no-action alternative and proposed action that were not modeled in RiverWare.

[2] Minimum instream flow based on conserved water and instream leasing is 125.8 cfs.

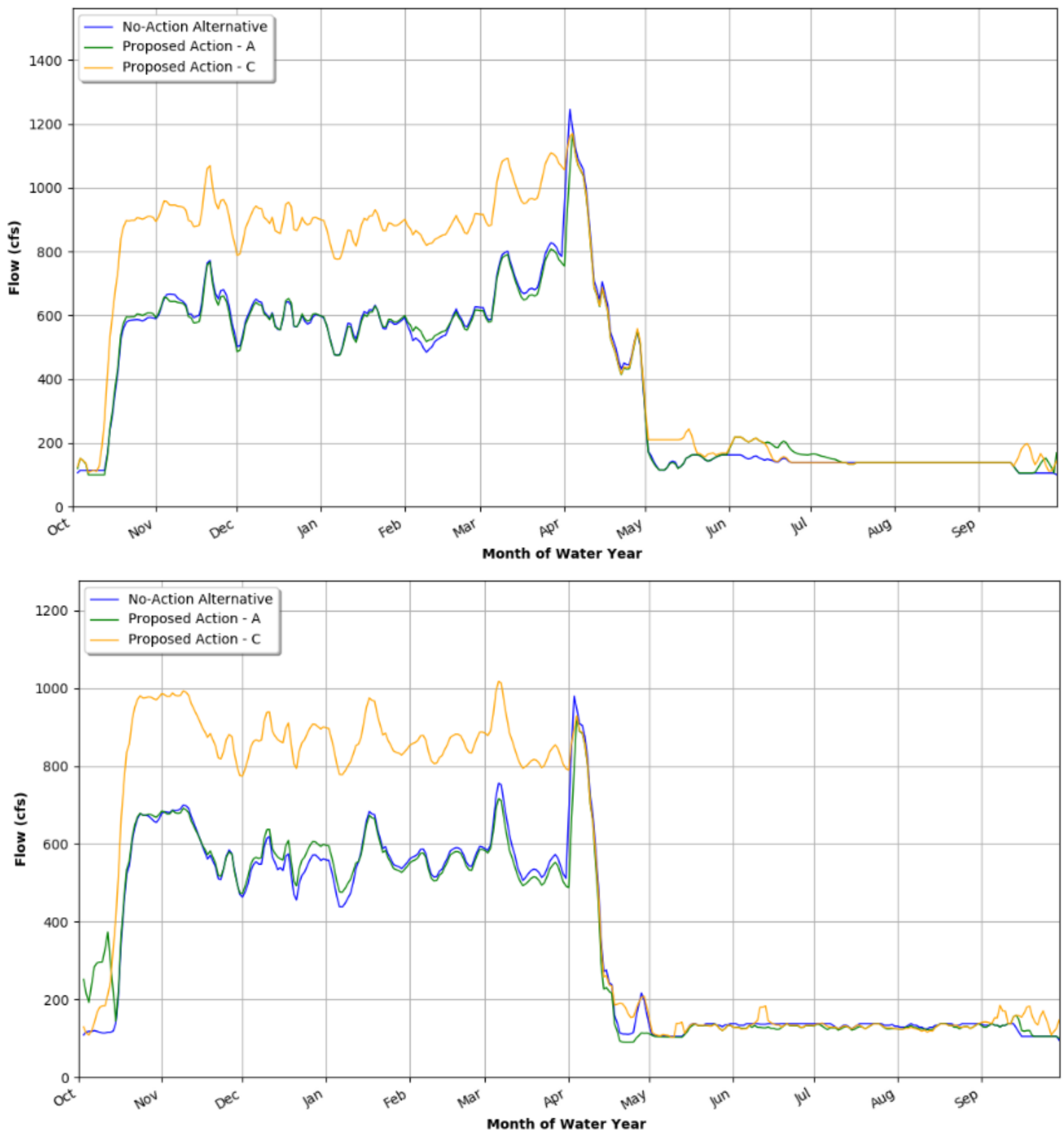
Total monthly streamflow volume (af) for representative wet, normal, and dry years was evaluated to assess changes in seasonal streamflow. Proposed action results were compared to the no-action alternative and proposed action results are reported as the percent difference from the no-action alternative (Table 20). Annual flow at the DEBO gauge would increase by up to 40% under normal and dry years, as more flow is released during the winter. Higher winter storage period flows are reflected in the 46% and 52% increases under normal and dry years, respectively. Irrigation period flows range from an increase of 1% under a wet year, to increases of 14% and 17% under normal and dry years, respectively.

Table 20. Percent Differences between the No-Action Alternative and Proposed Action for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years for the DEBO Gauge

Water Year Type	Time Period	Proposed Action Years 1–7	Proposed Action Years 8–12	Proposed Action Years 13–30
Wet	Irrigation Period	-1%	-1%	1%
	Winter/Storage Period	-1%	0%	2%
	Annual	-1%	0%	2%
	1 SD	-2%	-1%	1%
Normal	Irrigation Period	4%	9%	14%
	Winter/Storage Period	3%	29%	46%
	Annual	3%	22%	34%
	1 SD	-1%	25%	43%
Dry	Irrigation Period	-5%	6%	17%
	Winter/Storage Period	-2%	34%	52%
	Annual	-3%	25%	40%
	1 SD	-2%	43%	65%

Figure 37 includes the representative normal and dry year hydrographs for the DEBO gauge under the proposed action in years 1 through 7 and years 13 through 30 of the permit term. In a dry year, proposed action flows decrease rapidly as flows are diverted by diversions upstream of the DEBO gauge. Proposed action years 1 through 7 flows are similar to the no-action alternative flows in a normal year while flows in years 13 through 30 are substantially higher during winter compared to the no-action alternative. In a dry year, winter flows remain under 1,000 cfs and flows rapidly decline in mid-April in response to the onset of irrigation season. Irrigation season flows are similar for the proposed action periods and the no-action alternative in a dry year as stored water in Wickiup Reservoir is depleted.

Figure 37. Modeled Flows for the Deschutes River at the DEBO Gauge under the Proposed Action Years 1–7 (A) and Years 13–30 (C) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative



Crescent Creek from Crescent Lake to the Little Deschutes River

Crescent Creek conservation measures maintain minimum instream flows (CC-1), and address reservoir ramping rates (CC-2) and drawdown timing (CC-3). Year-round minimum flows are set at 10 cfs and a water account will allow flexible management during low flow periods. Relative to the no-action alternative, the proposed action has lower winter median flows and higher median flows during the early irrigation season. The proposed action flows are slightly lower during the irrigation season, but follow a similar pattern as the no-action alternative (Figure 38). RiverWare output suggests not all of the Oregon spotted frog account's augmentation water is used in most years, allowing for adaptive management and operational flexibility.

Figure 38. Modeled Flows (median flow and 20 to 80% exceedance flow range) for Crescent Creek at the CREO Gauge Downstream from Crescent Lake Reservoir under the Proposed Action Years 1–7 (upper) and Years 13–30 (lower) Compared to the No-Action Alternative

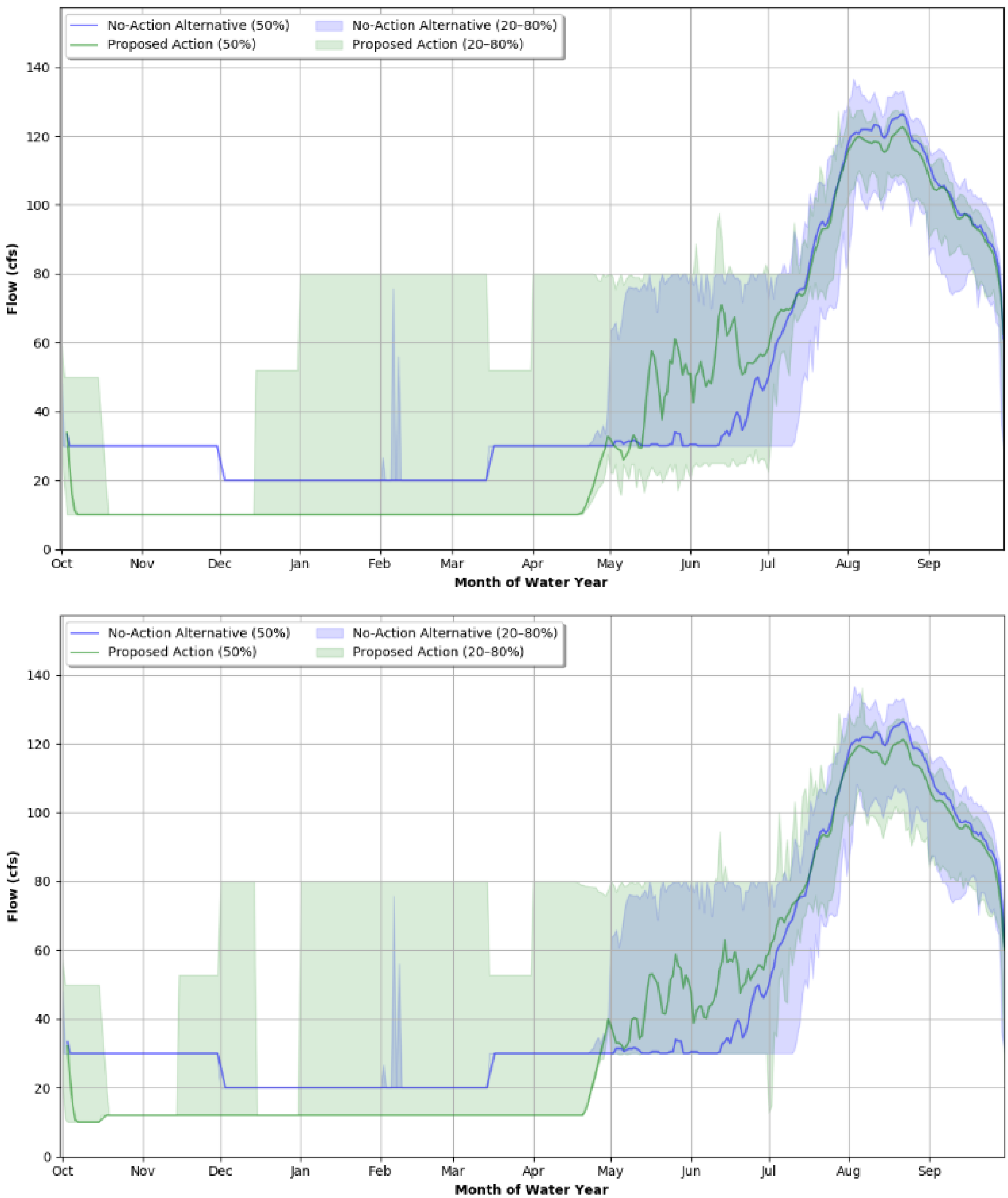


Table 21 includes a comparison of seasonal differences in minimum and maximum median flows based on CREO gauge data. Proposed action year-round minimum flows are limited to 10 cfs, less than the no-action alternative flows in both the winter and irrigation seasons. Maximum daily median flows remain consistent over the permit term and are similar to the no-action alternative.

Proposed action winter flows are similar over the permit term, while irrigation period flows increase later in the permit term relative to the no-action alternative.

Table 21. Comparison of Minimum and Maximum Median (50%) Daily Flows on Crescent Creek Downstream from Crescent Lake Reservoir by Season for the No-Action Alternative and Proposed Action over the Permit Term

	Winter (Nov 1–Mar 31)		Irrigation (Apr 1–Oct 31)	
Alternative	Minimum (cfs)	Maximum (cfs)	Minimum (cfs)	Maximum (cfs)
No-Action	20.0	30.0	30.0	126.9
Proposed Action (Years 1–7)	10.0	10.0	10.0	123.0
Proposed Action (Years 8-12)	10.0	10.0	10.0	122.4
Proposed Action (Years 13-30)	12.0	12.0	10.0	121.7

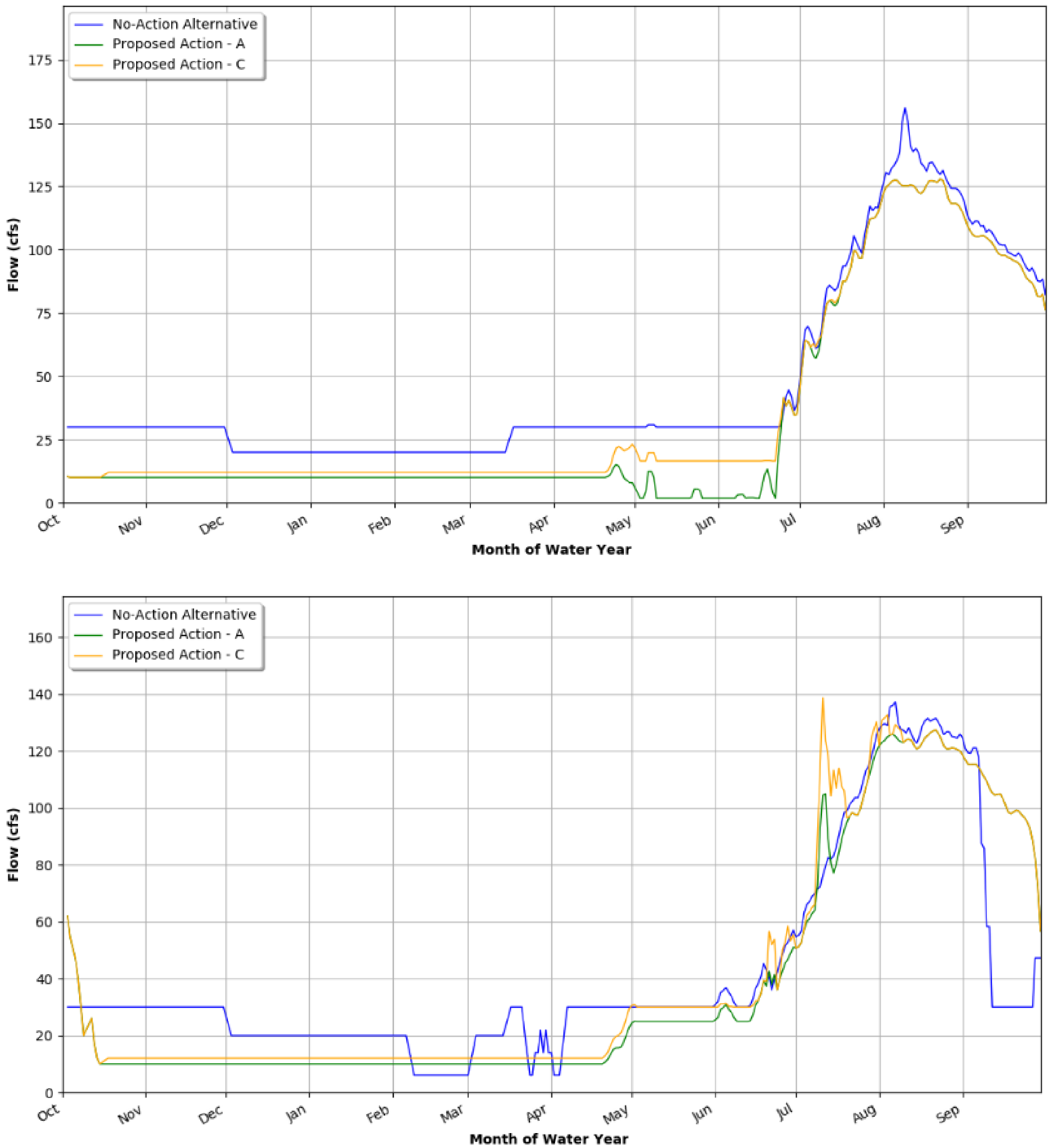
Total monthly streamflow volume (af) for representative wet, normal, and dry years was evaluated to assess changes in seasonal streamflow. Proposed action results are presented as the percent difference in streamflow from the no-action alternative (Table 22). Total streamflow volume varies from a 4% decrease during a dry year, to a 19% decrease in a normal year in years 13 through 30 compared to the no-action alternative. In a wet year, there is a 3% reduction in total streamflow. Winter storage period flows are nearly 50% less than the no-action alternative as minimum flows are decreased from 30 cfs to 10 cfs during the irrigation season. Flows are most variable in a dry year due to the lower minimum flows.

Table 22. Percent Differences in Streamflow Volume between the No-Action Alternative and Proposed Action for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years for the CREO Gauge

		Proposed Action		
Water Year Type	Time Period	Years 1–7	Years 8–12	Years 13–30
Wet	Irrigation Period	-6%	-3%	-5%
	Winter/Storage Period	8%	3%	8%
	Annual	-3%	-2%	-3%
	1 SD	-4%	-4%	-5%
Normal	Irrigation Period	-19%	-18%	-12%
	Winter/Storage Period	-57%	-57%	-48%
	Annual	-26%	-26%	-19%
	1 SD	9%	9%	4%
Dry	Irrigation Period	-2%	1%	4%
	Winter/Storage Period	-50%	-50%	-40%
	Annual	-11%	-9%	-4%
	1 SD	19%	22%	20%

Figure 39 includes the representative normal and dry year hydrographs for the CREO gauge under the proposed action in years 1 through 7 and in years 13 through 30 of the permit term. The representative normal year hydrograph illustrates the lower minimum flows from October through July for the propose action in the early period. The proposed action's additional augmentation water influences the ramp down rate in September of dry years. In short, Crescent Creek flows increase later in the irrigation season under a dry year scenario in order to meet later season irrigation demand with Crescent Lake Reservoir stored water.

Figure 39. Modeled Flows for Crescent Creek at the CREO Gauge Downstream from Crescent Lake Reservoir under the Proposed Action Years 1–7 (A) and Years 13–30 (C) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative



Little Deschutes River from Crescent Creek Confluence to the Deschutes River

While there are no conservation measures outlined for the Little Deschutes River, Crescent Creek conservation measures influence Little Deschutes River flows. Median flows for the proposed action are slightly greater than the no-action alternative flows during the irrigation season as Crescent Lake Reservoir water is released to meet water user demand and reservoir releases are ramped down more slowly as flow is augmented with the water account. Median proposed action flows are less during winter (30 cfs versus 10 to 12 cfs) due to lower proposed action flow releases from Crescent Lake Reservoir (Figure 40). Since flows change very little under the proposed action between years 1 through 7 and years 13 through 30, only the hydrograph for years 13 through 30 is presented.

Figure 40. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Little Deschutes River at the LAPO Gauge under the Proposed Action Years 13–30 (lower) Compared to the No-Action Alternative

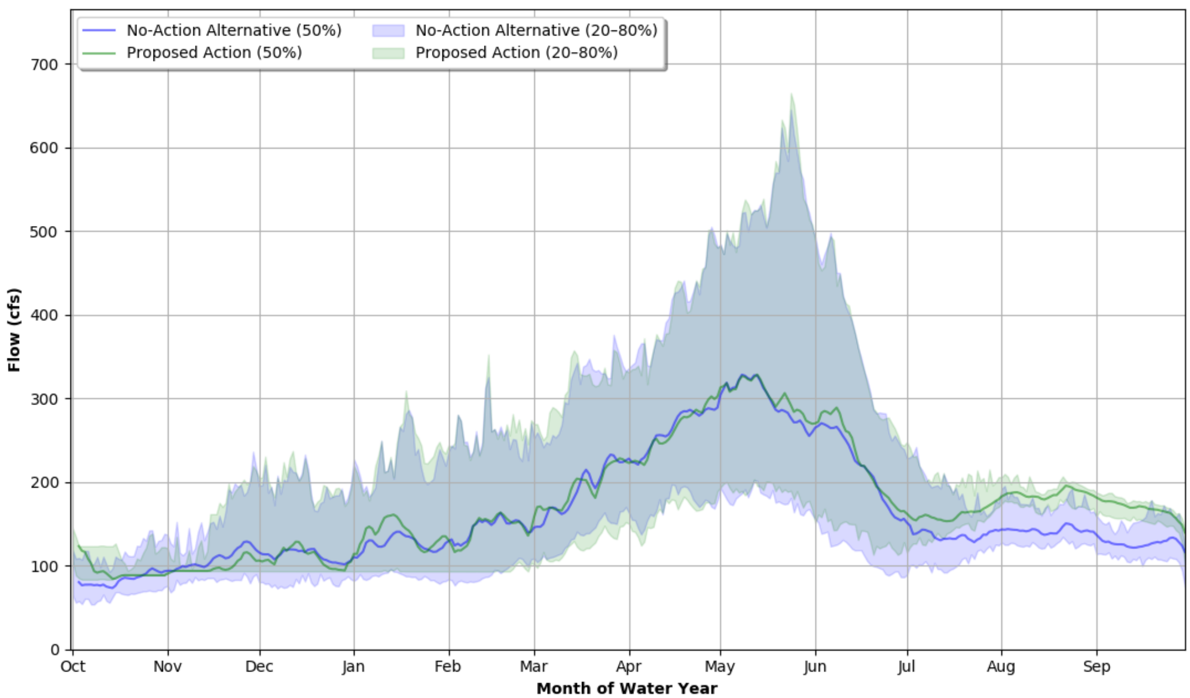


Table 23 includes a comparison of seasonal differences in minimum and maximum median flows based on LAPO gauge data. The proposed action's lower year-round releases increase storage and operational flexibility of Crescent Reservoir. The increased storage is reflected in the higher minimum median daily flows at the LAPO gauge. Maximum median daily flows remain consistent in both the winter and irrigation periods.

Table 23. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Little Deschutes River by Season for the No-Action Alternative and Proposed Action over the Permit Term

Alternative	Winter (Nov 1–Mar 31) Minimum (cfs)	Winter (Nov 1–Mar 31) Maximum (cfs)	Irrigation (Apr 1–Oct 31) Minimum (cfs)	Irrigation (Apr 1–Oct 31) Maximum (cfs)
No-Action	92.4	238.2	69.6	334.3
Proposed Action (Years 1–7)	91.4	239.3	83.3	327.3
Proposed Action (Years 8-12)	91.4	229.7	83.3	328.5
Proposed Action (Years 13-30)	93.4	231.7	83.2	332.4

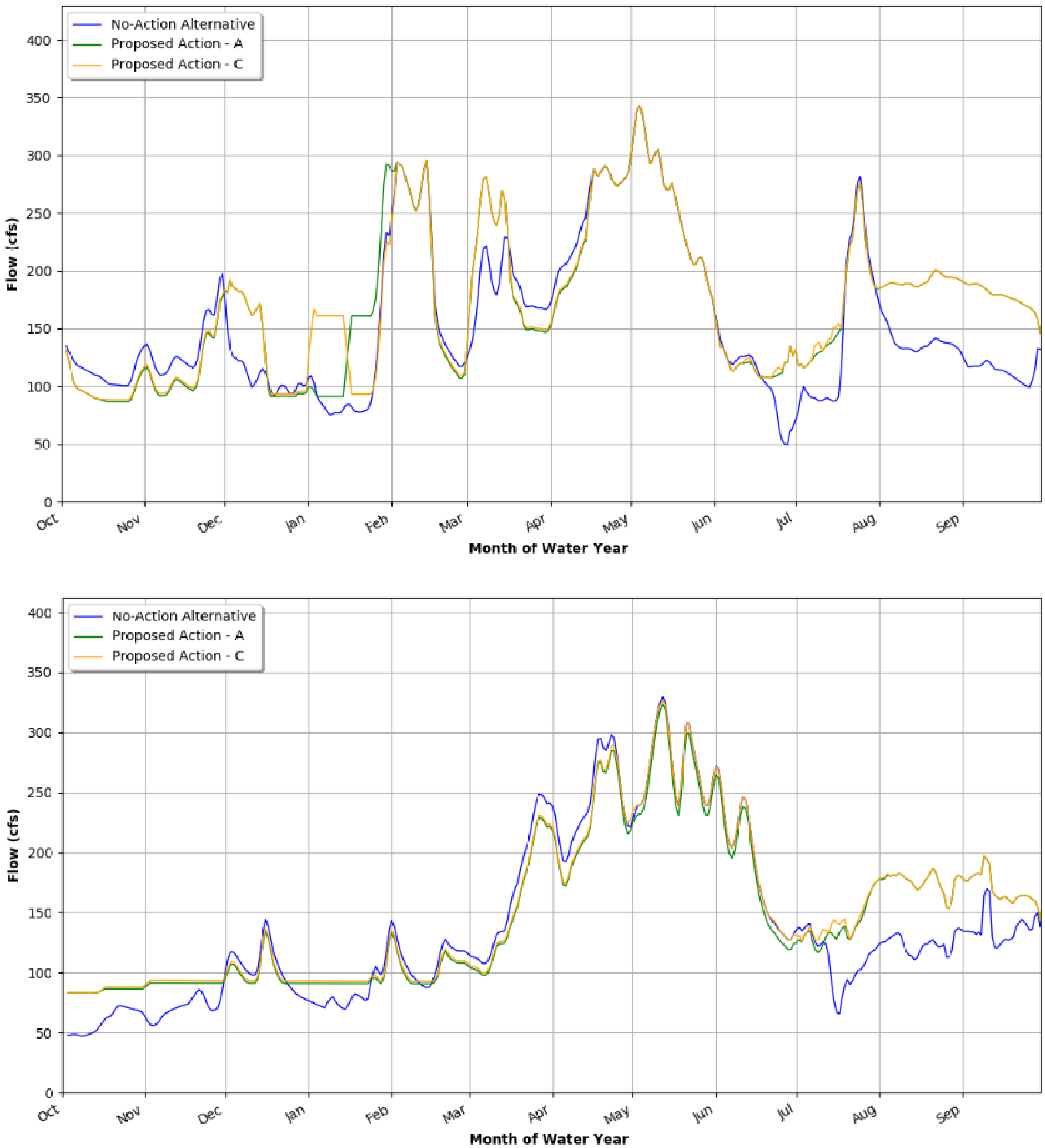
There are minimal differences in streamflow on the Little Deschutes River over the water year types, over the permit term periods, and over the seasonal periods (Table 24). Annual flows differ slightly from wet year (-1%) to normal year (1%). Winter storage period flows will experience decreases of 1% to 2% due to lower minimum outflows from Crescent Lake Reservoir. Irrigation period flows increase 2% in normal and dry years to meet downstream Tumalo ID water demands.

Table 24. Percent Differences in Streamflow Volume between the No-Action Alternative and Proposed Action for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years for the LAPO Gauge

Water Year Type	Time Period	Proposed Action Years 1–7	Proposed Action Years 8–12	Proposed Action Years 13–30
Wet	Irrigation Period	2%	2%	2%
	Winter/Storage Period	5%	5%	5%
	Annual	3%	3%	3%
	1 SD	-2%	-2%	-3%
Normal	Irrigation Period	16%	18%	17%
	Winter/Storage Period	9%	8%	9%
	Annual	14%	14%	14%
	1 SD	-18%	-20%	-18%
Dry	Irrigation Period	10%	10%	12%
	Winter/Storage Period	-1%	-1%	1%
	Annual	6%	7%	8%
	1 SD	-13%	-12%	-11%

Figure 41 includes the representative normal and dry year hydrographs for the LAPO gauge under the proposed action in years 1 through 7 and years 13 through 30 of the permit term. Proposed action winter storage flows are slightly less as minimum outflows from Crescent Lake Reservoir are reduced under Conservation Measure CC-1. Late irrigation season releases from Crescent Lake Reservoir in August and September under the proposed condition, elevate streamflow at the LAPO gauge in normal and dry years.

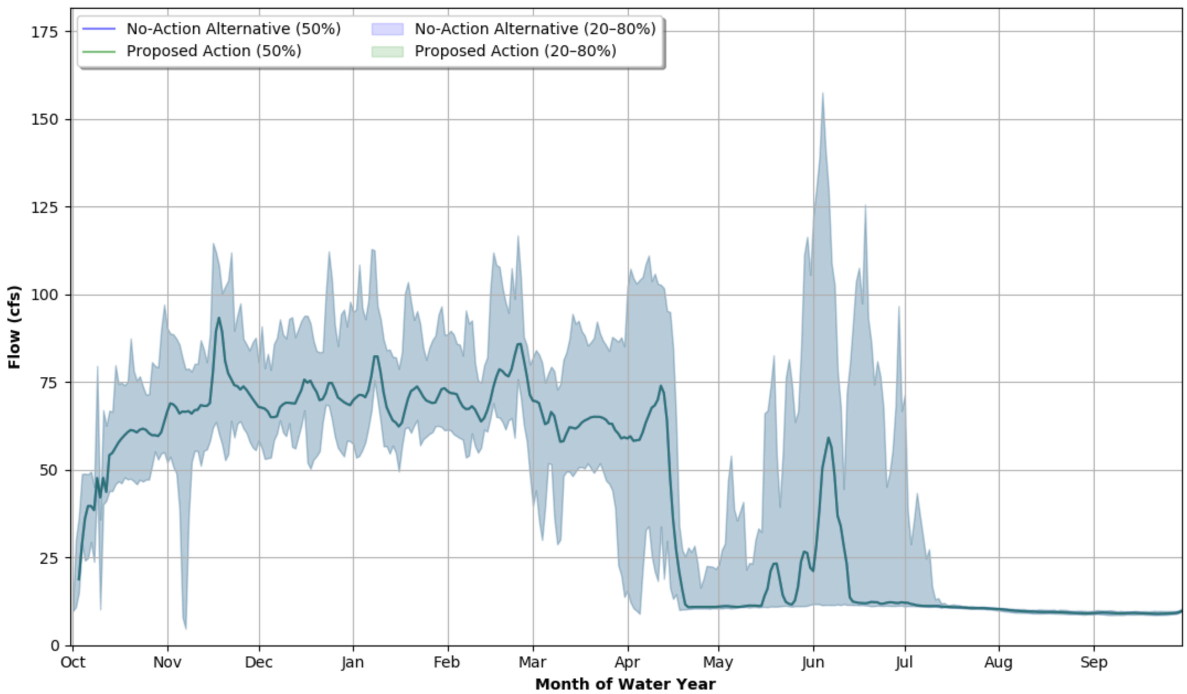
Figure 41. Modeled Flows for the Little Deschutes River at the LAPO Gauge under the Proposed Action Years 1–7 (A) and Years 13–30 (C) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative



Tumalo Creek

The no-action alternative and proposed action yield the same flow results for Tumalo Creek based on the hydrograph developed for the TUMO gauge, located at river mile 2.8 on Tumalo Creek (Figure 42). Since flows change very little under the proposed action between years 1 through 7 and years 13 through 30, only the hydrograph for years 13 through 30 is presented.

Figure 42. Modeled Flows for Tumalo Creek at the TUMO Gauge under the Proposed Action Years 13–30 (lower) Compared to the No-Action Alternative

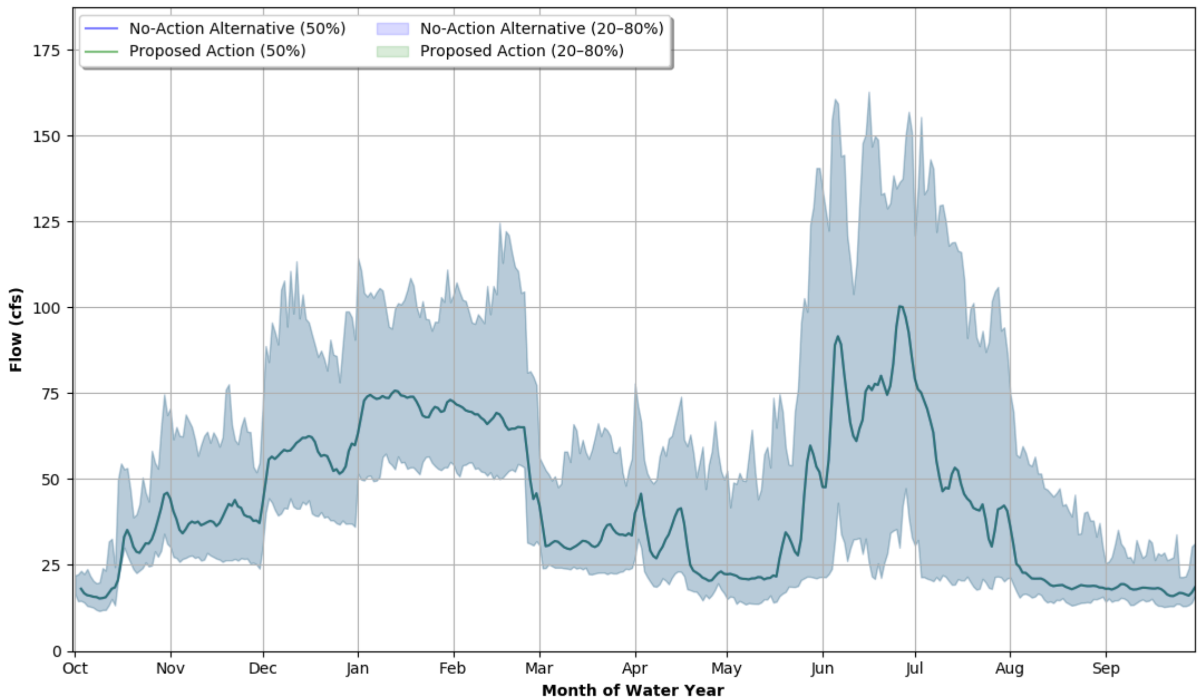


There were no differences in seasonal streamflow under the proposed action for the TUMO gauge compared to the no-action alternative. With the exception of increased winter minimum flows at the CREO gauge, and resulting effects on Crescent Lake Reservoir storage, increased instream flows associated with the Tumalo ID Irrigation Modernization Project, assumed under the no-action alternative (Chapter 2, *Proposed Action and Alternatives*), were not incorporated into the RiverWare logic. Therefore, increased flows at the TUMO gauge as a result of the Tumalo ID Irrigation Modernization Project are not reflected in Figure 42. This project would result in additional instream flow in Tumalo Creek (TUMO gauge) during the irrigation season of 12.35 cfs in first years 1 through 5 of the permit term, 19.83 cfs in years 6 through 10, and 30.91 cfs in years 11 through 30 (Table 5).

Whychus Creek

Since there are no water management differences between the no-action alternative and the proposed action in the RiverWare model, there are no flow differences at the SQSO gauge (Figure 43).

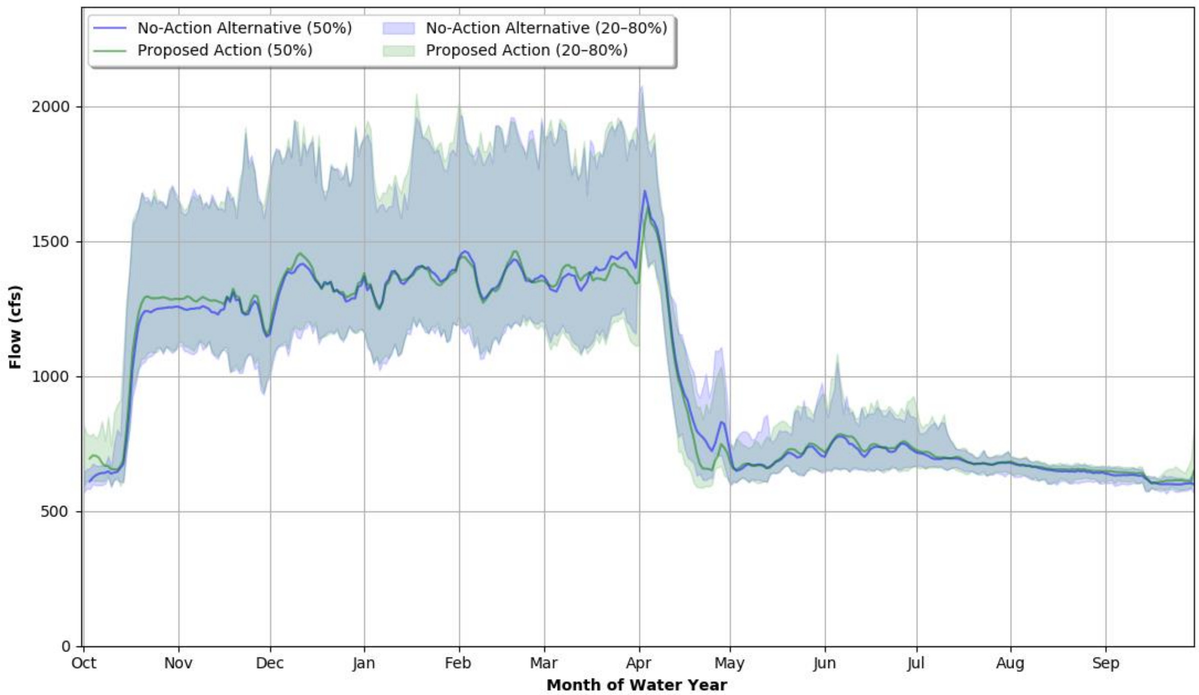
Figure 43. Modeled Flows for Whychus Creek at the SQSO Gauge under the Proposed Action Years 13–30 Compared to the No-Action Alternative



Deschutes River from Bend to Culver

Like the DEBO gauge, the Culver gauge (CULO) shows the effects of higher winter minimum flows associated with the proposed action (Figure 44). Increasing minimum flows over the permit term, primarily influences winter flows. Proposed action irrigation period flows are similar over the permit term. Groundwater inputs to the Deschutes River in the Culver reach also contribute to streamflow, increasing the year-round magnitude of flows.

Figure 44. Modeled flows (median flow and 20 to 80% exceedance flow range) for the Deschutes River at the CULO Gauge at Culver under the Proposed Action Years 1–7 (upper) and Years 13–30 (lower) Compared to the No-Action Alternative



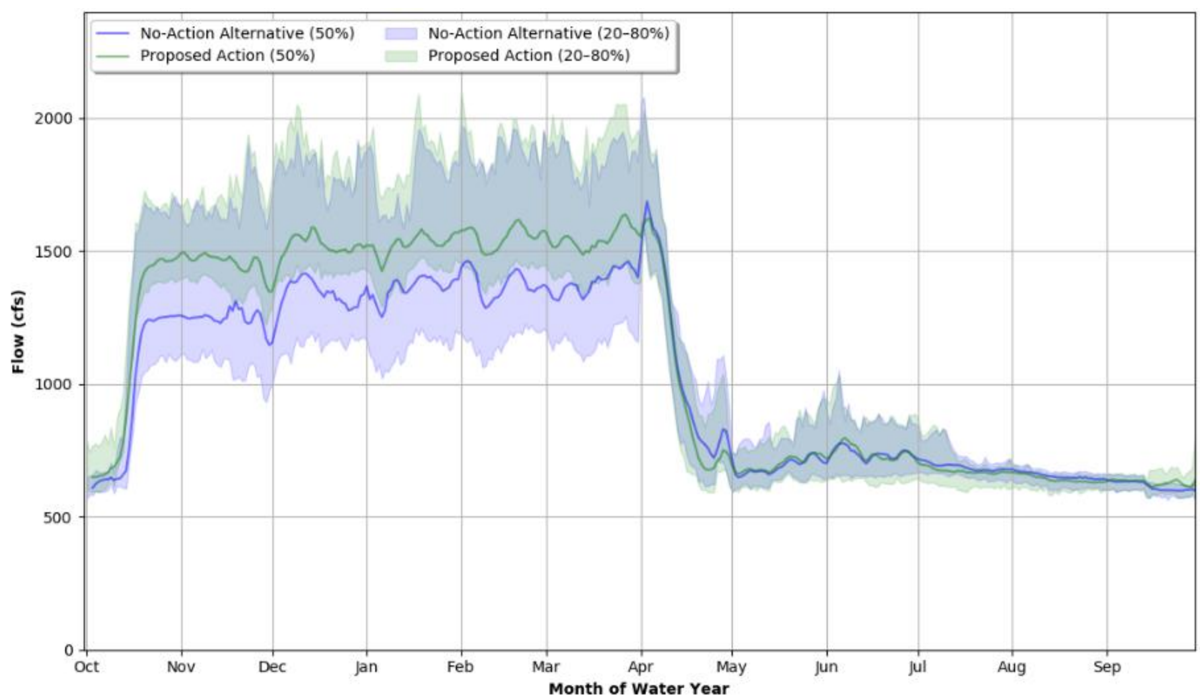


Table 25 includes a comparison of seasonal differences in minimum and maximum median flows based on CULO gauge data. Winter storage period flows increase with increasing minimum flows for the Upper Deschutes River. Irrigation period flows are similar over the permit term and are only marginally different from the no-action alternative. Conservation measures approved for Tumalo ID and Swalley ID will increase diversion network efficiency. However, instream flow benefits associated with these improvements were not included in the RiverWare model logic. Conservation measures are anticipated to result in additional instream flow of 19.95 cfs in years 1 through 5, and 35.03 cfs in years 6 through 10, and 46.11 cfs in years 11 through 30 during the irrigation season at the CULO gauge.

Table 25. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Deschutes River at the CULO Gauge by Season for the No-Action Alternative and Proposed Action over the Permit Term

	Winter (Nov 1–Mar 31)		Irrigation (Apr 1–Oct 31)	
Alternative	**Minimum (cfs)**	**Maximum (cfs)**	**Minimum (cfs)**	**Maximum (cfs)**
No-Action	1,134.5	1,515.3	589.1	1,730.5
Proposed Action (Years 1–7)	1,124.7	1,509.3	599.1	1,731.2
Proposed Action (Years 8–12)	1,244.0	1,568.7	601.8	1,731.2
Proposed Action (Years 13–30)	1,333.8	1,662.5	604.8	1,721.1

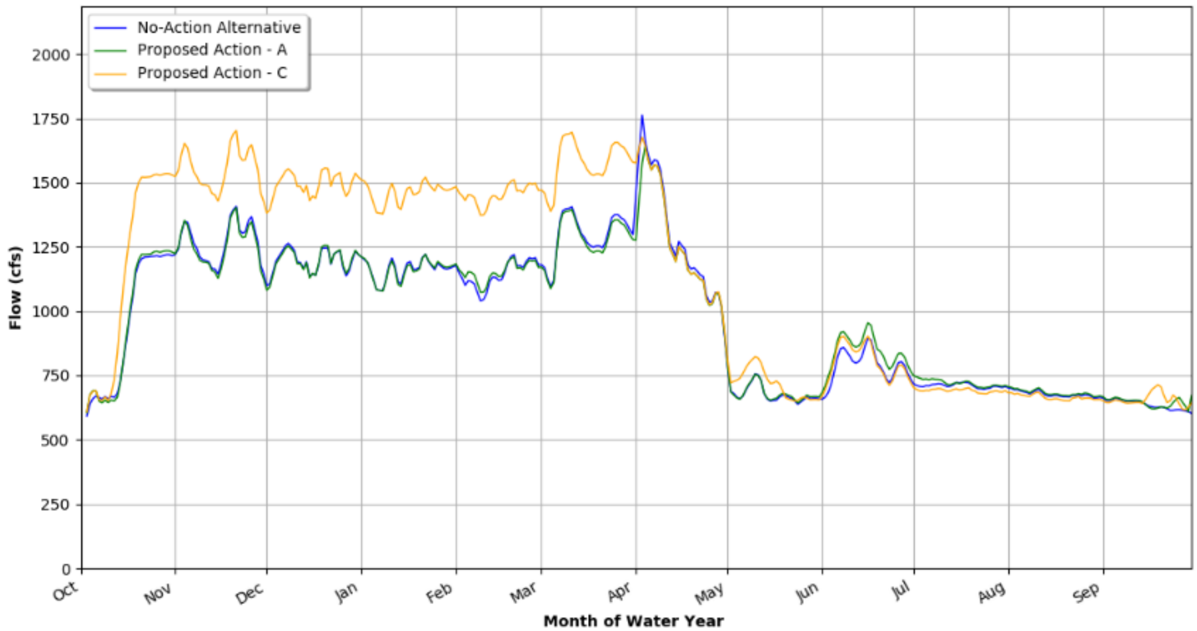
Total monthly streamflow volume (af) for representative wet, normal, and dry years was evaluated to assess changes in seasonal streamflow. Proposed action results were compared to the no-action alternative and proposed action results are reported as the percent difference from the no-action alternative (Table 26). Total streamflow volume increases 1% in a wet year, 13% and 14% in a normal and dry years, respectively as winter storage period flows increase up to 25% in a dry year. Irrigation period flows increase in normal and dry years by 3% and 2%, respectively. Monthly flow variability increases from wet to dry years, with the greatest variability associated with a dry year in years 13 through 30 of the permit term due to the influence of minimum winter flows on the Upper Deschutes River.

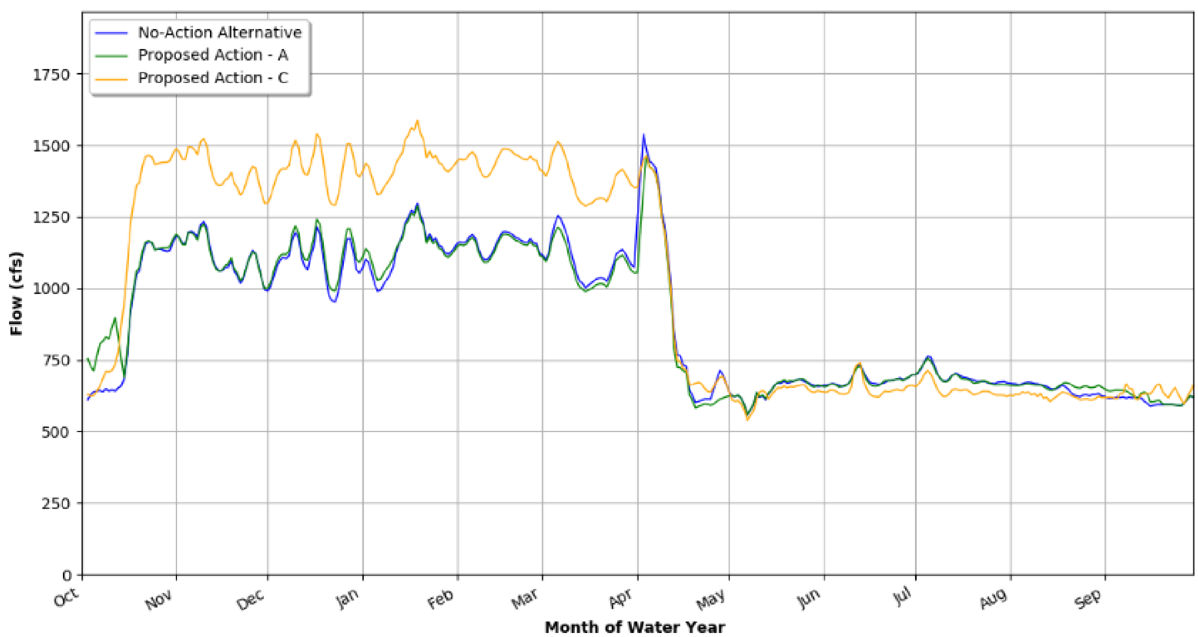
Table 26. Percent Differences in Streamflow Volume between the No-Action Alternative and Proposed Action for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years for the CULO Gauge

		Proposed Action		
Water Year Type	**Time Period**	**Years 1–7**	**Years 8–12**	**Years 13–30**
Wet	Irrigation Period	-5%	0%	0%
	Winter/Storage Period	1%	0%	1%
	Annual	-1%	0%	1%
	1 SD	4%	-1%	1%
Normal	Irrigation Period	1%	2%	3%
	Winter/Storage Period	2%	15%	23%
	Annual	2%	9%	13%
	1 SD	-1%	24%	42%
Dry	Irrigation Period	-1%	0%	2%
	Winter/Storage Period	-1%	16%	25%
	Annual	-1%	9%	14%
	1 SD	-2%	41%	62%

Figure 45 includes the representative normal and dry year hydrographs for the CULO gauge under the proposed action in years 1 through 7 and years 13 through 30 of the permit term. Streamflow patterns are similar to the DEBO gauge results with proposed action flows higher in the winter and lower or similar to the no-action alternative during the irrigation period. Flows decline faster in a dry year as water is diverted at upstream locations for irrigation.

Figure 45. Modeled flows for the Deschutes River at the CULO Gauge at Culver under the Proposed Action Years 1–7 (A) and Years 13–30 (C) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative

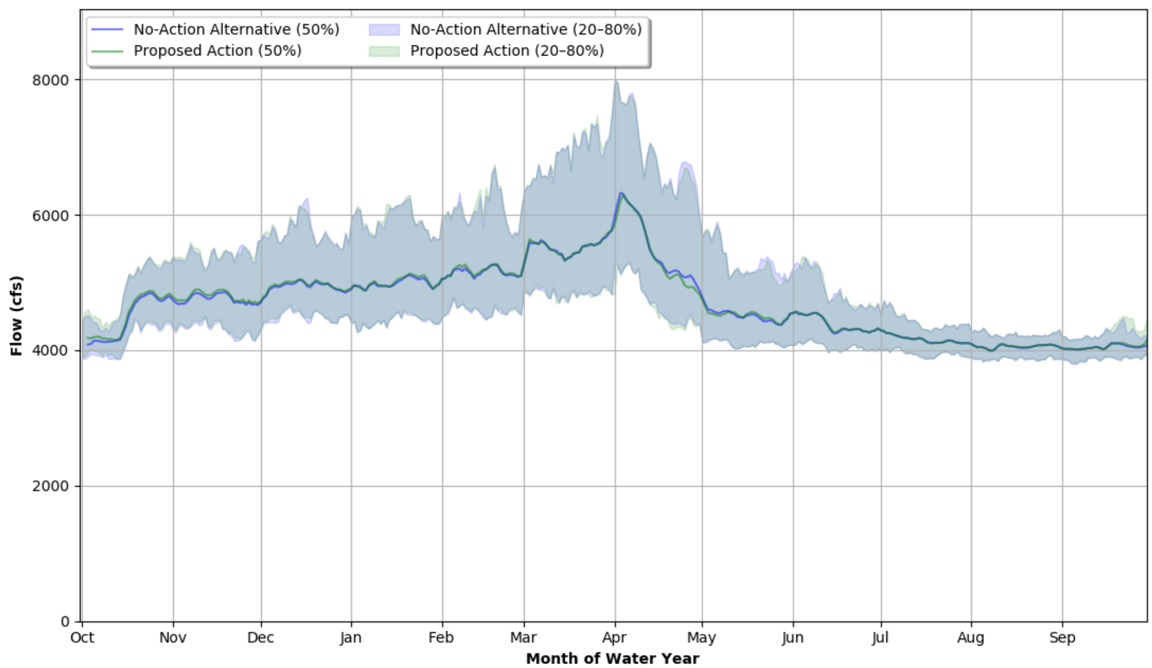




Deschutes River from Pelton Round Butte Dam to Madras

The Deschutes River at the Madras (MADO) gauge has similar median flows and flow variability for the no-action alternative and proposed action (Figure 46). Proposed action median winter flows slightly increase as minimum flows increase on the Upper Deschutes River over the permit term. Likewise, irrigation period median flows decrease with increasing minimum winter flows.

Figure 46. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Deschutes River at the MADO Gauge Downstream from Lake Billy Chinook under the Proposed Action Years 1–7 (upper) and Years 13–30 (lower) Compared to the No-Action Alternative



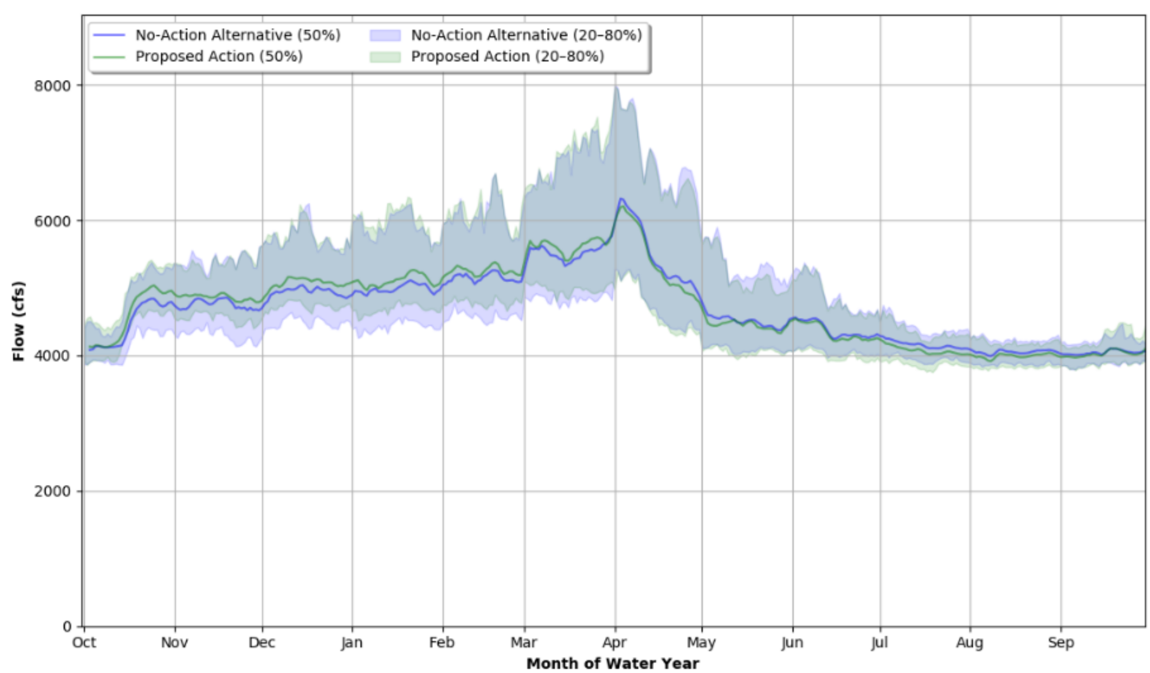


Table 27 includes a comparison of seasonal differences in minimum and maximum median flows based on MADO gauge data. The proposed action in years 13 through 30 has marginally higher minimum and maximum median winter flows, suggesting the effects of the higher minimum winter flow prescription. Irrigation period flows are similar for the no-action alternative and proposed action.

Table 27. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Deschutes River at the MADO Gauge by Season for the No-Action Alternative and Proposed Action over the Permit Term

	Winter (Nov 1–Mar 31)		Irrigation (Apr 1–Oct 31)	
Alternative	Minimum (cfs)	Maximum (cfs)	Minimum (cfs)	Maximum (cfs)
No-Action	4,603.0	5,802.0	3,986.7	6,364.5
Proposed Action (Years 1–7)	4,646.1	5,793.2	3,984.3	6,345.8
Proposed Action (Years 8-12)	4,678.2	5,825.0	3,932.7	6,276.9
Proposed Action (Years 13-30)	4,739.8	5,902.4	3,906.5	6,266.9

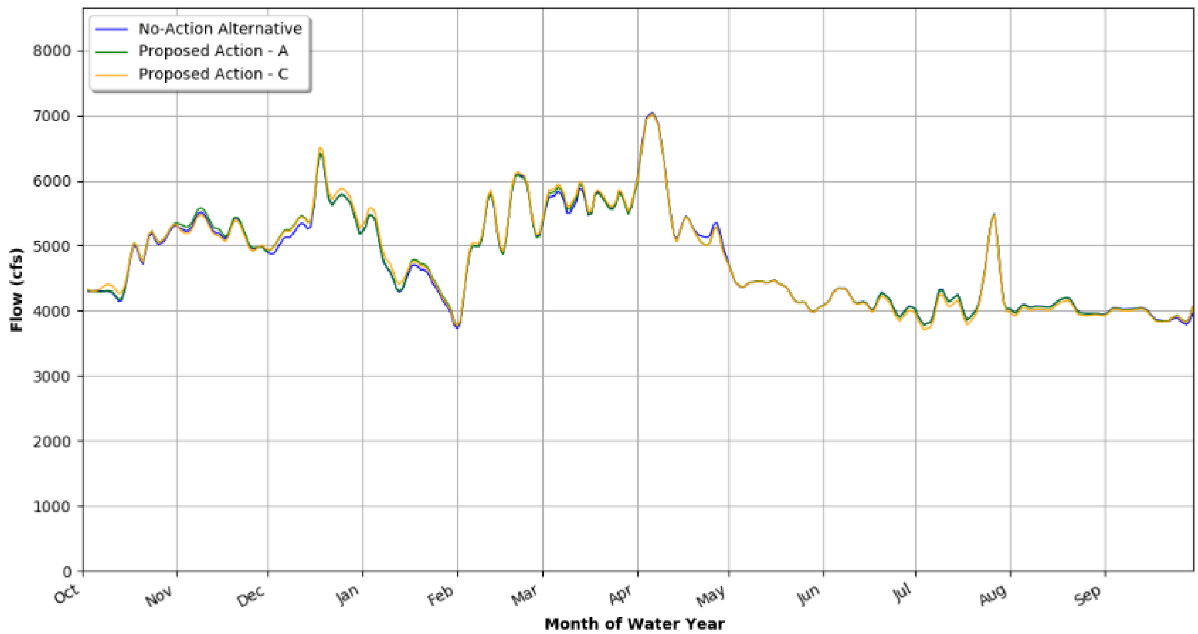
Total monthly streamflow volume (af) for representative wet, normal, and dry years was evaluated to assess changes in seasonal streamflow. Proposed action results were compared to the no-action alternative and proposed action results are reported as the percent difference from the no-action alternative (Table 28). Streamflow changes are minimal in wet and normal years over the permit term. Flows are more variable in dry years as minimum winter flows increase over the permit term.

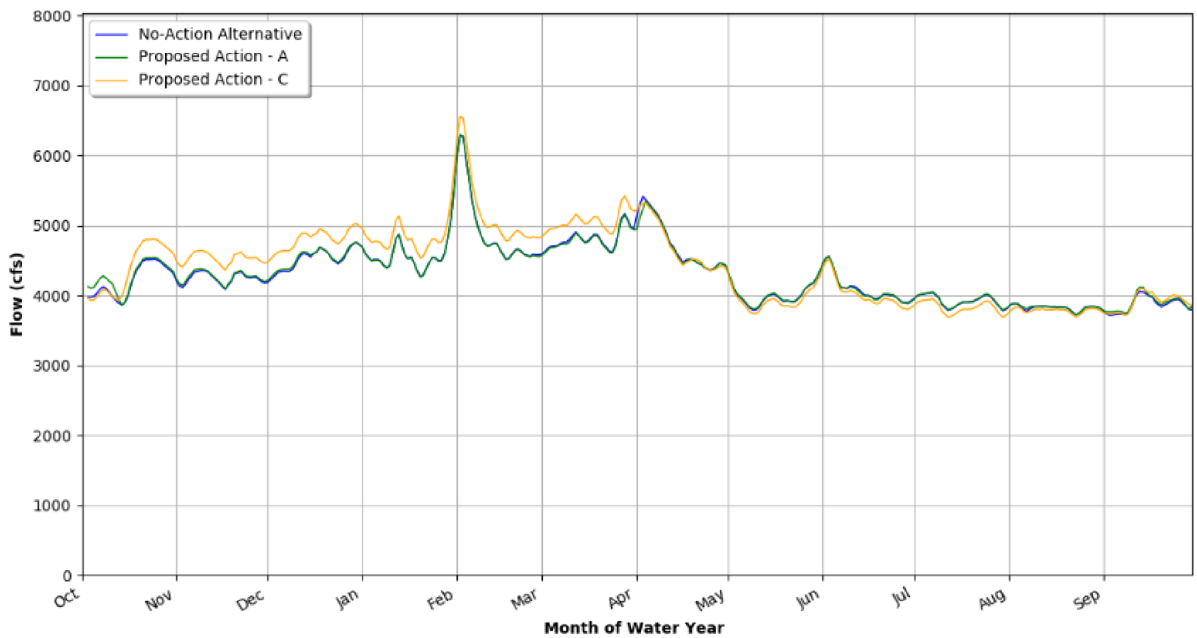
Table 28. Percent Differences in Streamflow Volume between the No-Action Alternative and Proposed Action for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years for the MADO Gauge

		Proposed Action		
Water Year Type	Time Period	Years 1–7	Years 8–12	Years 13–30
Wet	Irrigation Period	0%	0%	0%
	Winter/Storage Period	1%	0%	0%
	Annual	0%	0%	0%
	1 SD	0%	0%	0%
Normal	Irrigation Period	0%	0%	0%
	Winter/Storage Period	1%	2%	3%
	Annual	0%	1%	1%
	1 SD	-1%	2%	6%
Dry	Irrigation Period	0%	0%	0%
	Winter/Storage Period	0%	4%	6%
	Annual	0%	2%	2%
	1 SD	-3%	19%	30%

Figure 47 includes the representative normal and dry year hydrographs for the MADO gauge under the proposed action in years 1 through 7 and years 13 through 30 of the permit term. Streamflow patterns are similar to the CULO gauge results with proposed action flows higher in the winter and lower or similar to the no-action alternative during the irrigation period. Flows are generally lower during the representative dry year.

Figure 47. Modeled flows for the Deschutes River at the MADO Gauge Downstream from Lake Billy Chinook under the Proposed Action Years 1–7 (A) and Years 13–30 (C) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative





Deschutes River Flood Flows

The Deschutes River flood flow analysis assessed effects of the proposed action on the magnitude of the regulatory base flood (1%, 100-year flood) and 500-year (0.2% flood) floods, and more frequent floods associated with shallow floodplain inundation.

The base flood and the 500-year flood were evaluated for the Benham Falls (BENO) gauge. The base flood associated with the proposed action would be essentially the same as the no-action alternative, the base flood and the 500-year event would have a small reduction in the predicted flow.

To assess the proposed action's influence on more frequent, low magnitude floods, recent flood reports for the Deschutes River between La Pine and Sunriver and near Tumalo were used to determine threshold flood flows for the WICO, BENO, DEBO, and TUMO gauges (Hendricks 2014; Kato 2017; Shumway 2017; Gorman pers. comm; LaMarche pers. comm [c]). The sum of flows recorded at the DEBO and TUMO gauges was used to assess potential flooding near the town of Tumalo. Localized flooding may be influenced by Deschutes River flows, tributary contributions, aquatic vegetation growth in the Deschutes River channel, and diversion operation. Peak flows alone may not cause flooding, while lower flows on the Deschutes River combined with elevated tributary flows and dense aquatic vegetation in the river channel may cause flooding.

Table 29 includes the threshold flood flows and the average number of days per year the threshold flood flows were exceeded under the no-action alternative and proposed action based on daily mean flows over the permit term.

The number of days that flows exceed flood flow thresholds varies by gauge location and timing within the permit term. The number of days of flood flow exceedance remains the same or decreases over the permit term for each of the reviewed gauges, although the number of days of exceedance increases slightly for the DEBO+TUMO results when a flood flow threshold of 1,400 cfs is applied during the early and middle periods. Flooding in the La Pine to Sunriver reach typically occurs late in the irrigation season when irrigation flows are released from Wickiup Reservoir and aquatic vegetation densities in the Deschutes River channel are at their peak. Since irrigation period flows would decrease over the permit term, include a cap on maximum flows of 1,400 cfs in years 8 through 12 and 1,200 cfs in years 13 through 30, modeling results suggest there would be fewer days when the WICO gauge exceeds 1,600 cfs. Table 30 includes the percent change in flood flow exceedance for each gauge over the permit term. The reduction in flood flows on the Upper Deschutes River is due to increased winter storage season flows, which decrease stored water availability during irrigation season. Proposed action irrigation season peak flow caps instituted in year 8 (1,400 cfs cap) and in year 13 (1,200 cfs cap) result in fewer days of flows exceeding the respective flow cap target values at the WICO gauge.

Table 29. Flood Flow Thresholds and Days of Flow Exceedance for the No-Action Alternative and Proposed Action averaged over the Permit Term (Two flood flow thresholds are included for the DEBO+TUMO gauge data.)

Gauge	Flood Flow Threshold (cfs)	Average Number of Days of Flood Flow Threshold Exceedance per Year			
			Proposed Action		
		No-Action	Years 1–7	Years 8-12	Years 13–30
WICO	1,600	3.1	1.6	0.1	0.0
BENO	2,000	12.2	12.3	6.4	3.9
DEBO+TUMO	1,400	25.8	27.3	26.7	0.0
DEBO+TUMO	2,000	1.1	1.1	1.1	0.0

Table 30. Percent Change in Days of Flow Exceedance for the No-Action Alternative and Proposed Action averaged over the Permit Term (Two flood flow thresholds are included for the DEBO+TUMO gauge data.)

Gauge	Flood Flow Threshold (cfs)	Days of Exceedance	Percent Change in the Average Number of Days of Flood Flow Threshold Exceedance per Year		
			Proposed Action		
		No-Action	Years 1–7	Years 8-12	Years 13–30
WICO	1,600	3.1	-49%	-98%	-99%
BENO	2,000	12.2	1%	-48%	-68%
DEBO+TUMO	1,400	25.8	6%	3%	-100%
DEBO+TUMO	2,000	1.1	5%	5%	-100%

Crooked River Outflow from Bowman Dam

Conservation Measure CR-1 provides guidance for Crooked River flow downstream from Bowman Dam. Conservation Measure CR-1 is intended to maintain minimum winter flows of 50 cfs at the PRVO gauge. The no-action alternative and proposed action for years 1 through 7 of the permit term have similar influence on flow levels at the PRVO gauge downstream from Bowman Dam (Figure 48). Increasing minimum flows from 100 cfs (years 1 through 7 of the permit term) to 400 cfs (years 13 through 30 of the permit term) on the Upper Deschutes River results in water delivery shortage for North Unit ID, which in turn requires North Unit ID to rely more heavily on Crooked River water. To meet North Unit ID demand, additional water is released from Prineville Reservoir and higher Crooked River flows are marked by elevated median and 20% exceedance flows from mid-June through mid-July under the proposed action in years 13 through 30.

Figure 48. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Crooked River at the PRVO Gauge Downstream from Bowman Dam under the Proposed Action Years 1–7 (upper) and Years 13–30 (lower) Compared to the No-Action Alternative

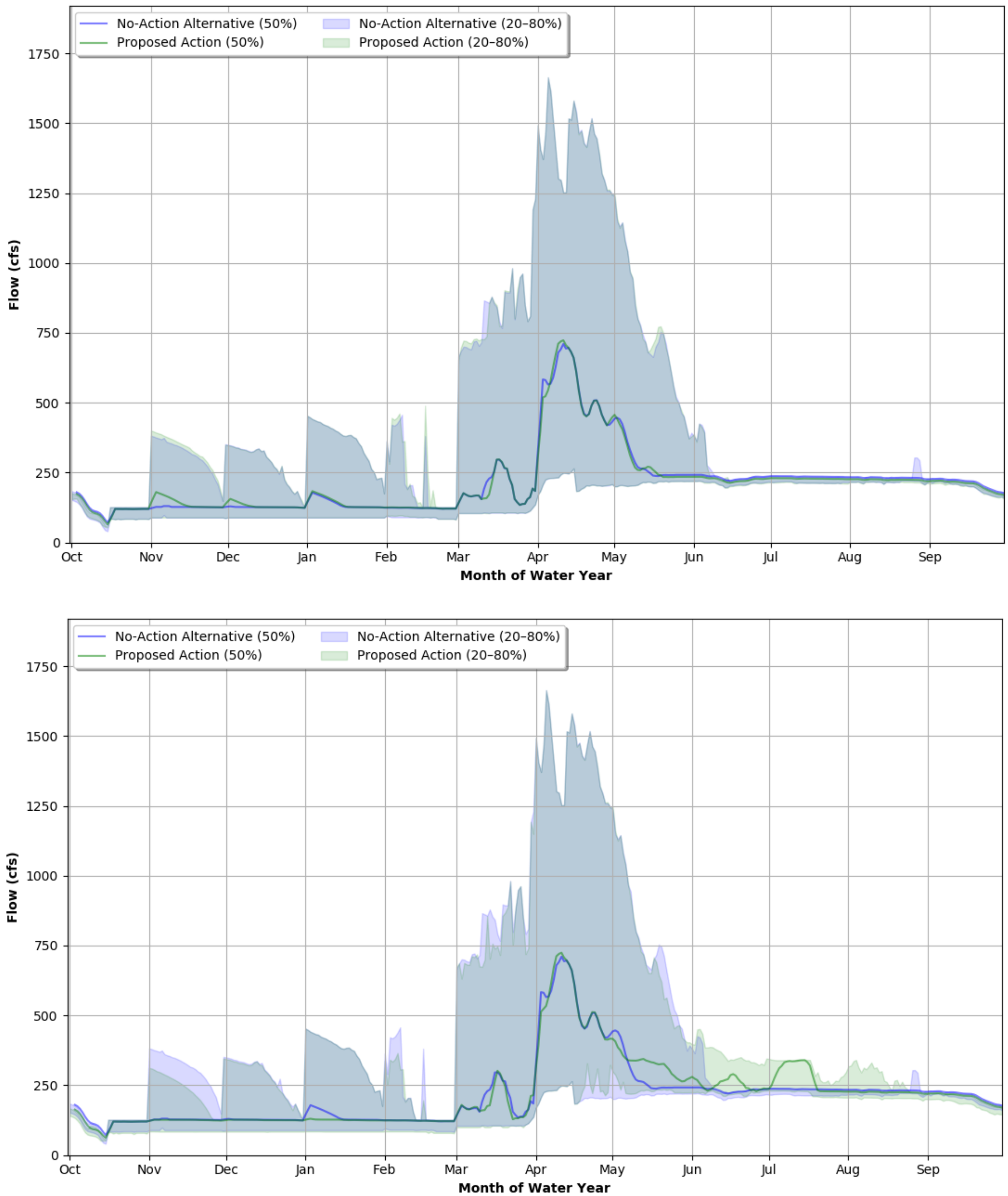


Table 31 includes a comparison of seasonal differences in minimum and maximum median flows based on PRVO gauge data. There are minor differences in the minimum and maximum flows during the winter storage and irrigation periods since the proposed action follows the model logic included in the no-action alternative.

Table 31. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Crooked River at the PRVO Gauge by Season for the No-Action Alternative and Proposed Action over the Permit Term

Alternative	Winter (Nov 1–Mar 31) Minimum (cfs)	Winter (Nov 1–Mar 31) Maximum (cfs)	Irrigation (Apr 1–Oct 31) Minimum (cfs)	Irrigation (Apr 1–Oct 31) Maximum (cfs)
No-Action	119.6	304.4	62.7	734.6
Proposed Action (Years 1–7)	119.6	305.4	56.0	737.4
Proposed Action (Years 8-12)	120.6	309.9	56.0	739.0
Proposed Action (Years 13-30)	120.7	309.8	55.9	739.3

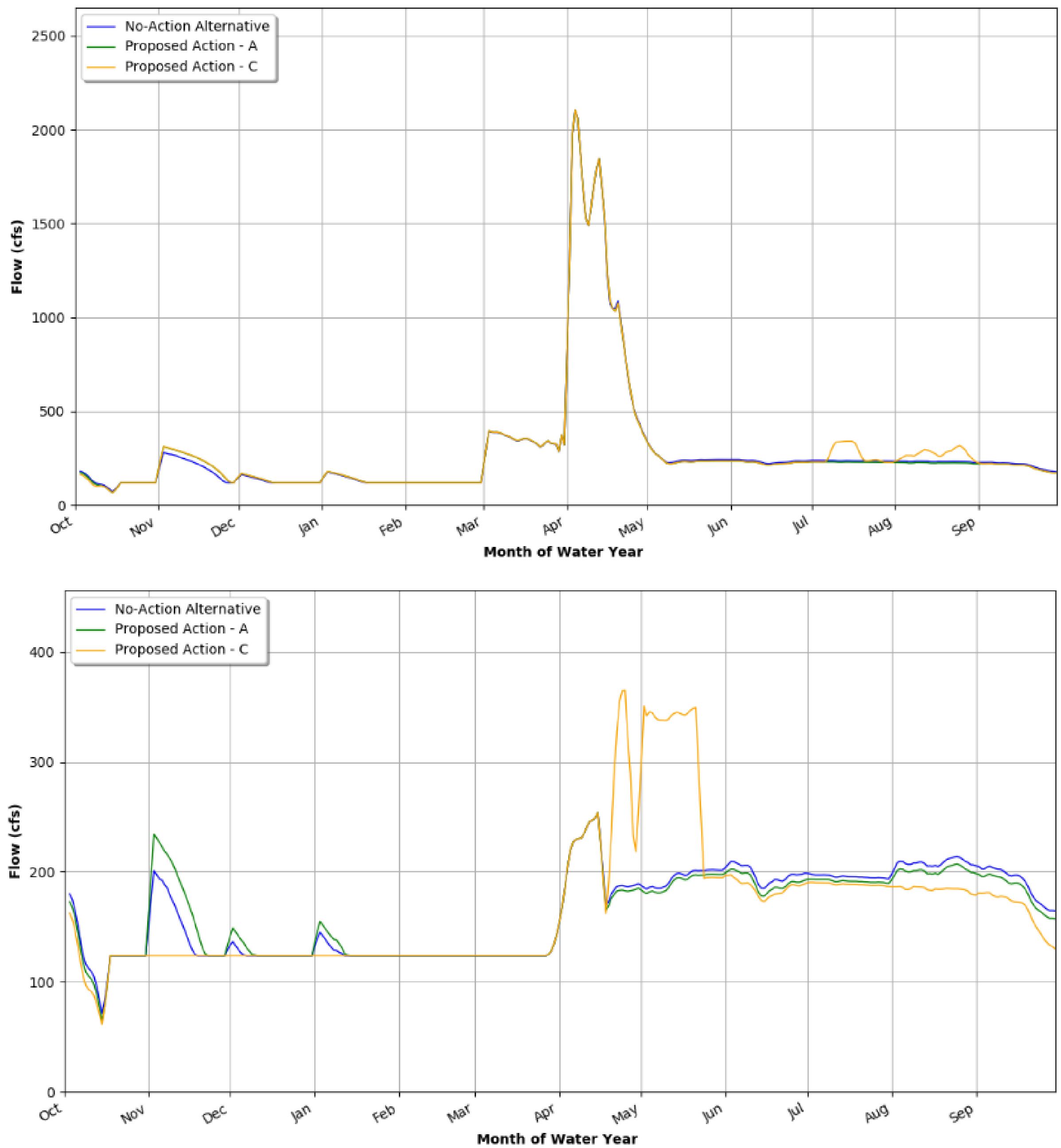
Total monthly streamflow volume (af) for representative wet, normal and dry years was evaluated to assess changes in seasonal streamflow (Table 32). Irrigation period flows would increase in years 8 through 12 and years 13 through 30 to compensate for decreased flows on the Deschutes River associated with higher winter minimum flows and capped maximum irrigation season flows.

Table 32. Percent Differences in Streamflow Volume between the Proposed Action and the No-Action Alternative for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years for the PRVO Gauge

Water Year Type	Time Period	Proposed Action Years 1–7	Proposed Action Years 8–12	Proposed Action Years 13–30
Wet	Irrigation Period	-1%	3%	3%
	Winter/Storage Period	-2%	-10%	-10%
	Annual	-1%	-1%	-1%
	1 SD	-3%	-3%	-3%
Normal	Irrigation Period	-2%	-2%	2%
	Winter/Storage Period	0%	0%	0%
	Annual	-1%	-1%	2%
	1 SD	0%	0%	0%
Dry	Irrigation Period	-2%	5%	5%
	Winter/Storage Period	3%	-3%	-3%
	Annual	-1%	3%	3%
	1 SD	-7%	18%	28%

Figure 49 includes the representative normal and dry year hydrographs for the PRVO gauge under the proposed action in years 13 through 30. Normal year flows are substantially higher than dry year flows, although minimum winter flows are similar in both year types. In a dry year, stored water is released between mid-April and late May for downstream diversions. Following the release, streamflow declines through September.

Figure 49. Modeled Flows for the Crooked River at the PRVO Gauge under the Proposed Action Years 1–7 (A) and Years 13–30 (C) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative. (Note flow scale differences.)



Crooked River from Bowman Dam to Highway 126 Crossing

Several diversions draw water from the Crooked River between Bowman Dam and the Highway 126 bridge (location of the CAPO gauge). Diversions including Rice Baldwin, Peoples, and the Crooked River Feed Canal are the primary diversions; smaller secondary diversions are also located in the reach. Comparative hydrographs for the no-action alternative and proposed action in years 1 through 7 and years 13 through 30 suggest similar flows at the CAPO gauge (Figure 50). In years 13 through 30, higher flows from early June through mid-August suggest flow releases to meet North Unit ID demands associated with the depletion of stored water in Wickiup Reservoir.

Figure 50. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Crooked River at the CAPO Gauge at the Highway 126 Bridge under the Proposed Action for Years 1–7 (upper) and Years 13–30 (lower) Compared to the No-Action Alternative

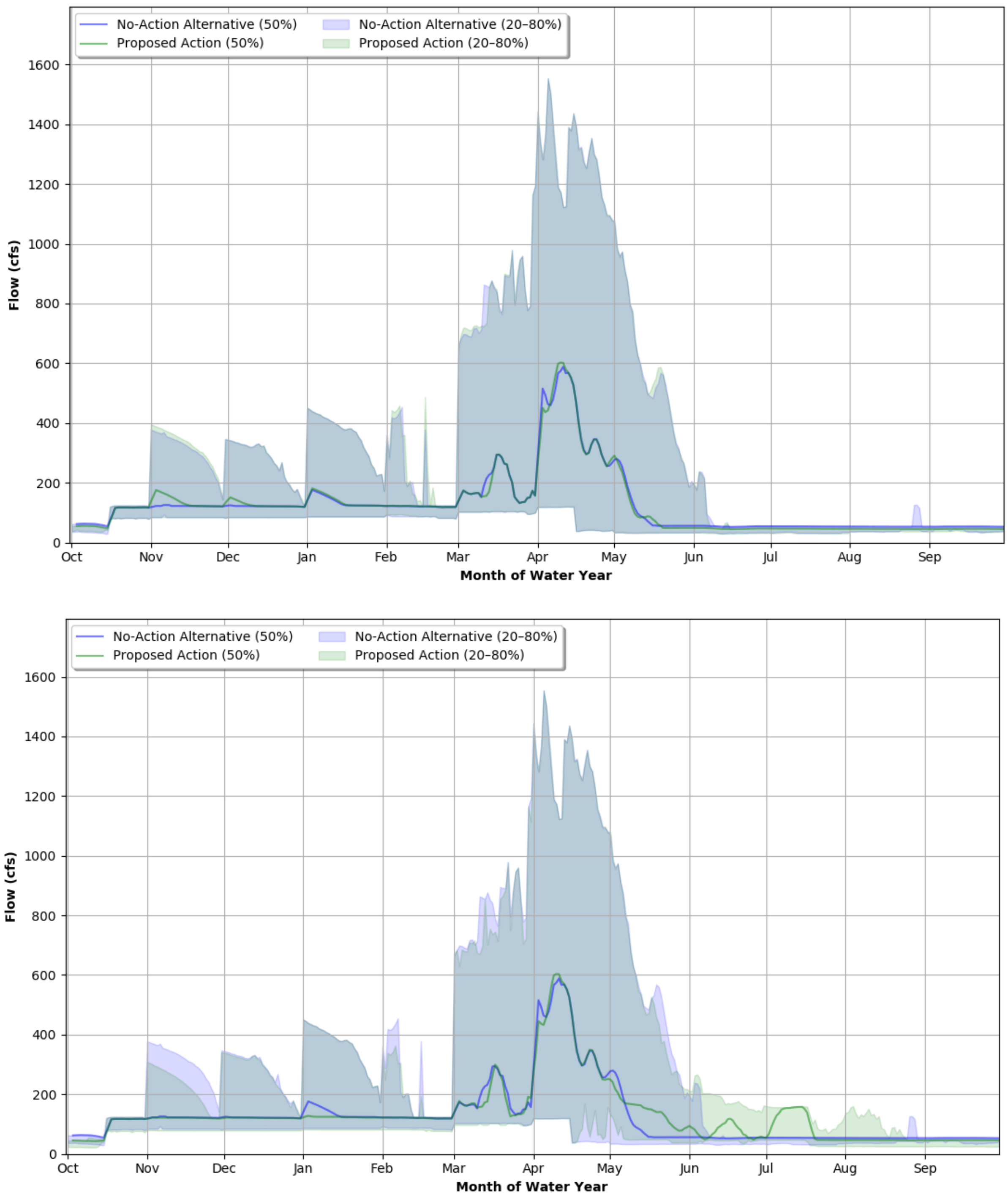


Table 33 includes a comparison of seasonal differences in minimum and maximum median flows based on CAPO gauge data. There are minimal differences in the minimum and maximum flow values for the winter and irrigation periods. Minimum median daily irrigation period flows suggest the effect of low water years.

Table 33. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Crooked River at the CAPO Gauge by Season for the No-Action Alternative and Proposed Action over the Permit Term

	Winter (Nov 1–Mar 31)		Irrigation (Apr 1–Oct 31)	
Alternative	Minimum (cfs)	Maximum (cfs)	Minimum (cfs)	Maximum (cfs)
No-Action	117.2	302.0	51.5	621.1
Proposed Action (Years 1–7)	117.2	303.0	44.6	623.9
Proposed Action (Years 8-12)	118.2	307.5	44.6	625.5
Proposed Action (Years 13-30)	117.3	307.4	41.8	625.7

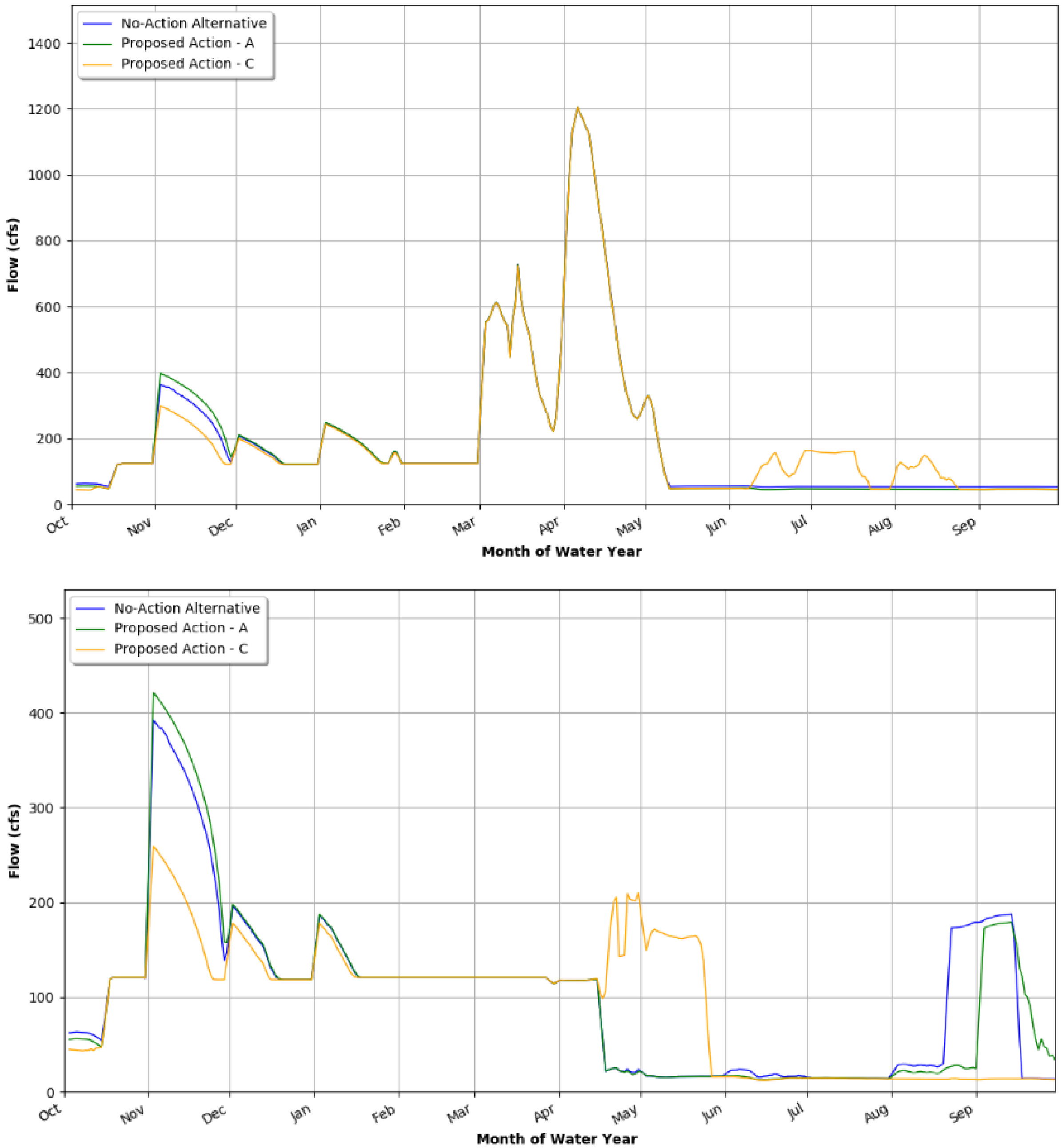
Total monthly streamflow volume (af) for representative wet, normal, and dry years was evaluated to assess changes in seasonal streamflow. Proposed action results were compared to the no-action alternative and proposed action results are reported as the percent difference from the no-action alternative (Table 34). Flow changes are greatest in a dry year and approximately the same as the no-action alternative in a normal year.

Table 34. Percent Differences in Streamflow Volume between the No-Action Alternative and Proposed Action for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years for the CAPO Gauge

		Proposed Action		
Water Year Type	Time Period	Years 1–7	Years 8–12	Years 13–30
Wet	Irrigation Period	-1%	4%	4%
	Winter/Storage Period	-2%	-10%	-10%
	Annual	-1%	-1%	-1%
	1 SD	-3%	-4%	-4%
Normal	Irrigation Period	-3%	0%	11%
	Winter/Storage Period	3%	0%	-6%
	Annual	0%	0%	3%
	1 SD	1%	0%	-2%
Dry	Irrigation Period	-10%	8%	10%
	Winter/Storage Period	0%	-1%	-1%
	Annual	-4%	2%	3%
	1 SD	8%	2%	25%

Figure 51 includes the representative normal and dry year hydrographs for the CAPO gauge under the proposed action in years 1 through 7 and years 13 through 30. During a dry year, minimum flows are maintained during winter storage and a flow release to meet North Unit ID demand occurs from mid-June to mid-August in a normal year and from mid-April to June in a dry year during years 13 through 30 of the permit term. Irrigation period flows are otherwise similar under the proposed action.

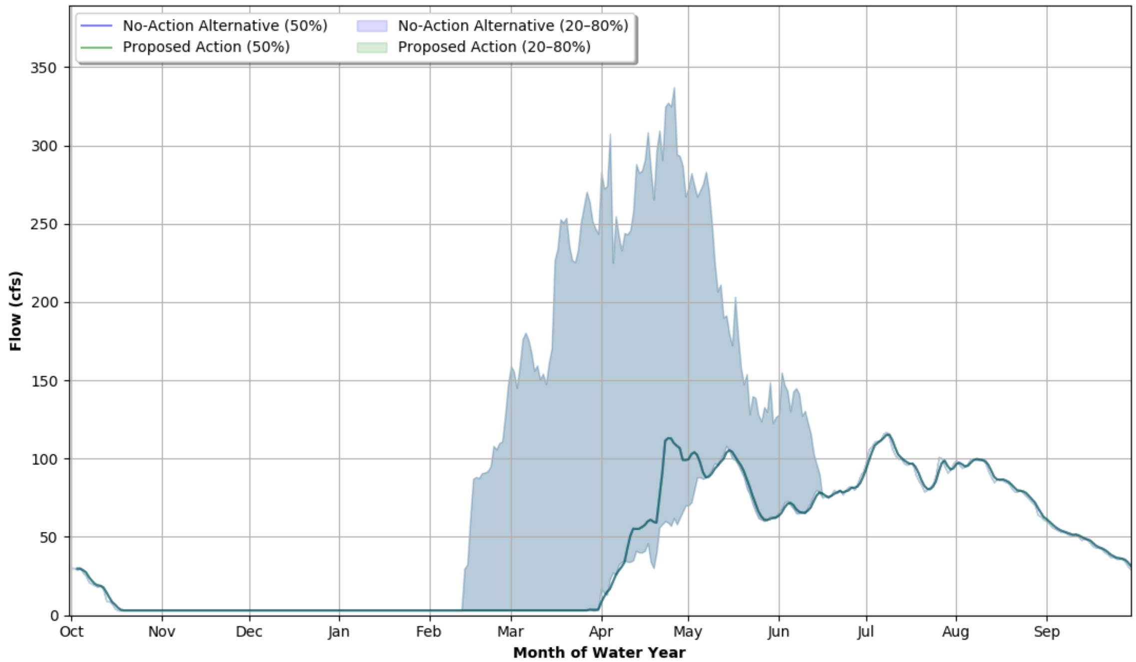
Figure 51. Modeled Flows for the Crooked River at the CAPO Gauge at the Highway 126 Bridge under the Proposed Action Years 1–7 (A) and Years 13–30 (C) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative. (Note flow scale differences.)

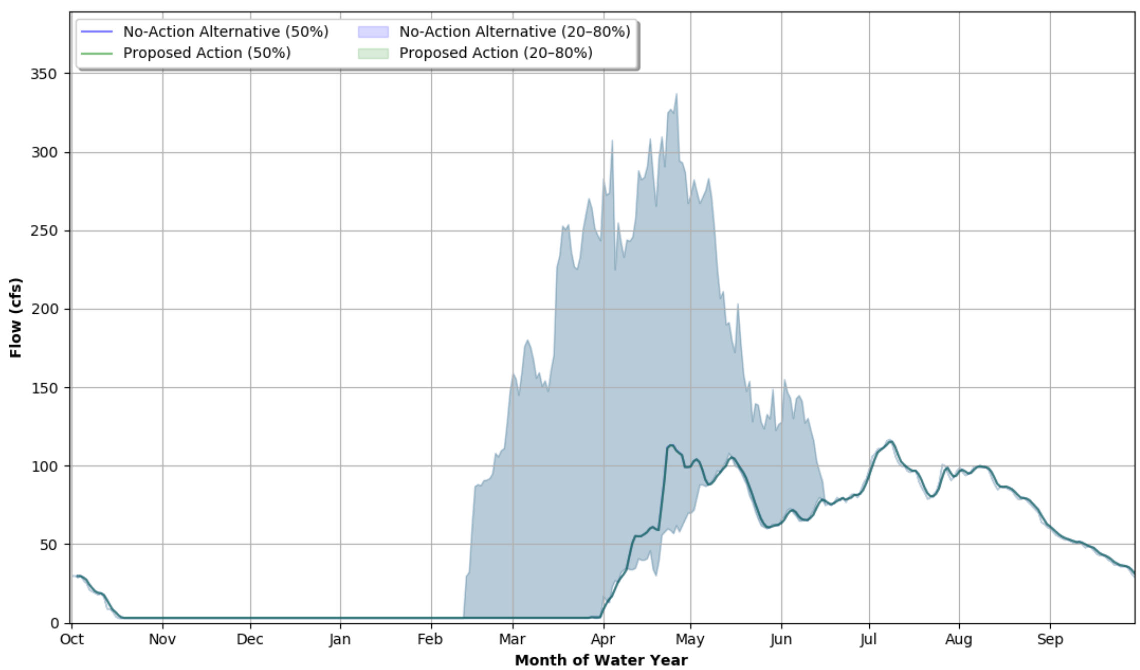


Ochoco Creek from Ochoco Dam to Crooked River

The no-action alternative and proposed action have similar flow results for Ochoco Creek based on the hydrographs developed for the OCHO gauge (Figure 52). Conservation Measure CR-2 will eliminate extreme low flows (historically as low as 0 cfs) by establishing minimum flows of up to 5 cfs for the entire reach between Ochoco Dam and the mouth.

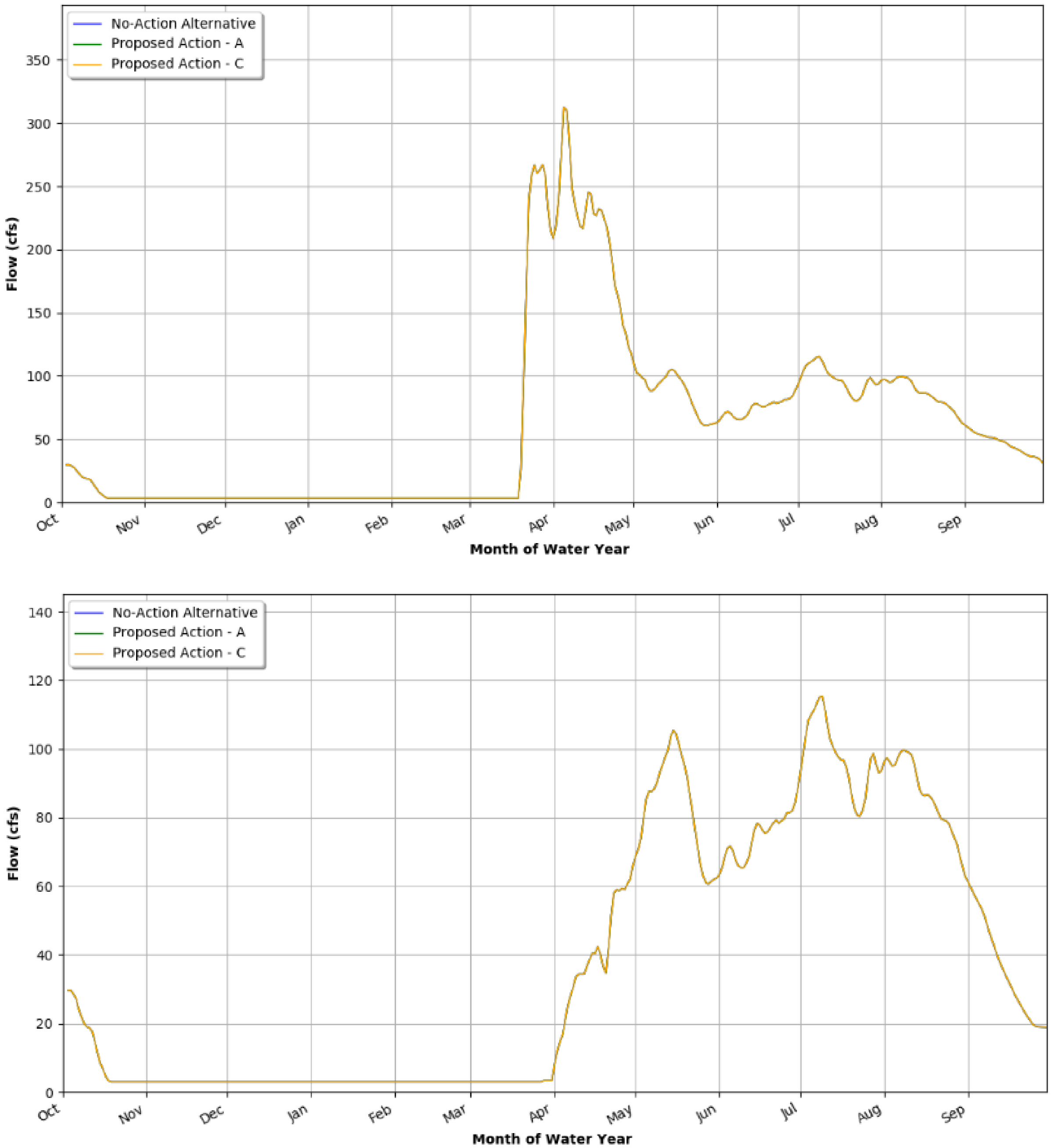
Figure 52. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Ochoco Creek at the OCHO Gauge Downstream from Ochoco Reservoir under the Proposed Action Years 1–7 (upper) and Years 13–30 (lower) Compared to the No-Action Alternative





There were no summary flow differences between the proposed action and no-action alternative for wet, normal, and dry years, although minimum flows will increase from approximately 0 cfs to 5 cfs during the irrigation season with implementation of Conservation Measure CR-2. Figure 53 includes normal year and dry year hydrographs for the OCHO gauge.

Figure 53. Modeled Flows for the Ochoco Creek at the OCHO Gauge Downstream from Ochoco Reservoir under the Proposed Action Years 1–7 (A) and Years 13–30 (C) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative



McKay Creek from Jones Dam to Crooked River

Conservation Measure CR-3 would result in increased minimum flows in McKay Creek during the irrigation season. Minimum flows would be between 2 and 5 cfs, depending on the reach, compared to as low as 1 cfs under the no-action alternative. Streamflow outside of the irrigation season would be unchanged.

Crooked River from North Unit Irrigation District Pump Station to Smith Rock State Park

Crooked River streamflow at the Smith Rock gauge (CRSO) located downstream from the North Unit ID pump station is shown in hydrographs for the proposed action in years 1 through 7 and years 13 through 30 of the permit term (Figure 54). The hydrographs are similar although median flows are lower from early June through early August as water is diverted by the North Unit ID pump station to meet water user demand in a representative dry year.

Figure 54. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Crooked River at the CRSO Gauge Downstream from the North Unit ID Pump Station under the Proposed Action Years 1–7 (upper) and Years 13–30 (lower) Compared to the No-Action Alternative

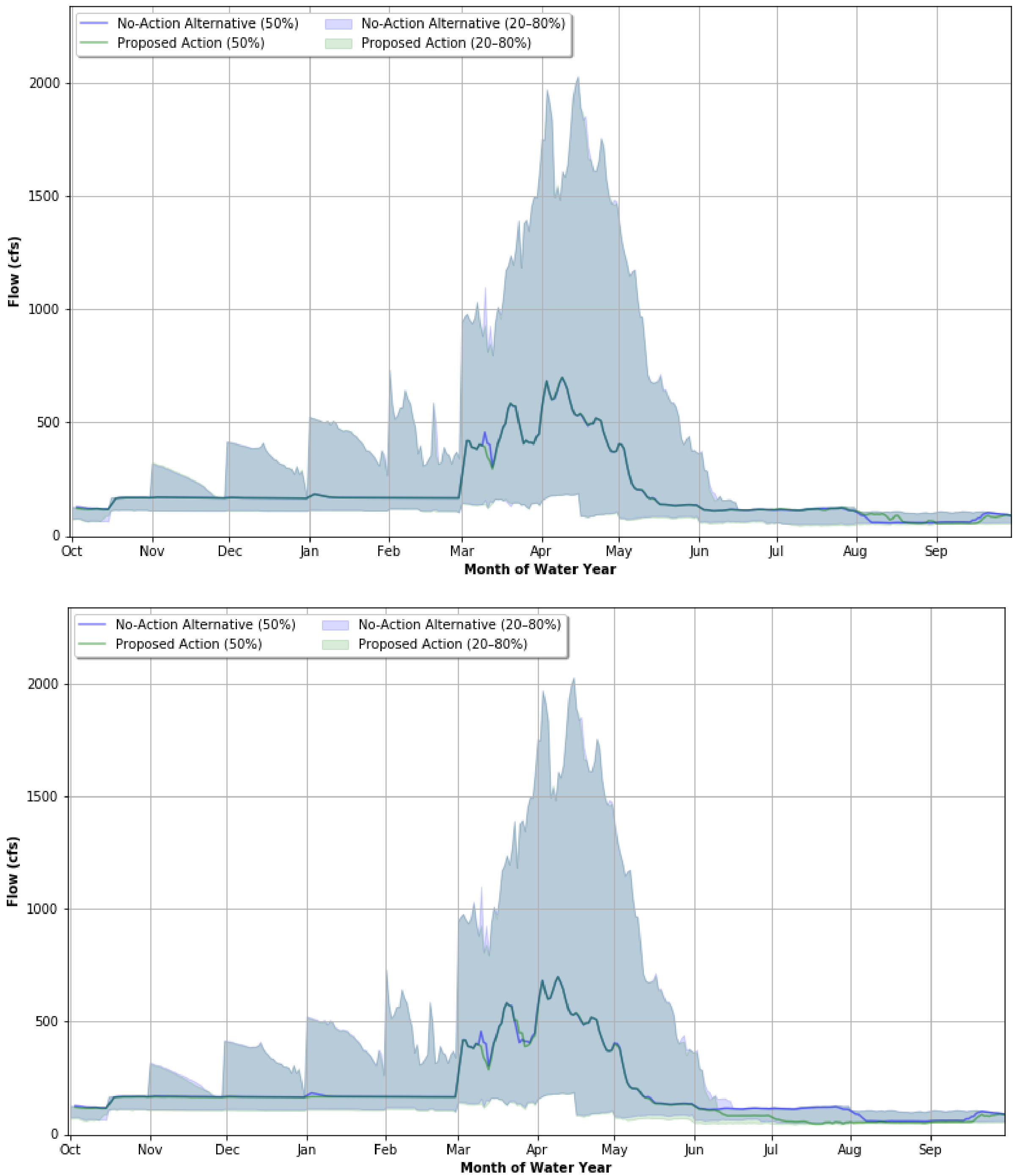


Table 35 includes a comparison of seasonal flow volume differences in minimum and maximum median flows based on CRSO gauge data. There are minimal flow differences over the permit term in both the winter storage and irrigation periods although minimum irrigation period flows decrease over time due to the additional pumping at the North Unit ID pump station.

Table 35. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Crooked River at the CRSO Gauge Downstream from the North Unit Irrigation District Pump Station by Season for the No-Action Alternative and Proposed Action

	Winter (Nov 1–Mar 31)		Irrigation (Apr 1–Oct 31)	
Alternative	**Minimum (cfs)**	**Maximum (cfs)**	**Minimum (cfs)**	**Maximum (cfs)**
No-Action	163.6	359.6	73.5	695.2
Proposed Action (Years 1–7)	163.6	360.8	66.9	740.8
Proposed Action (Years 8-12)	162.4	361.0	49.0	739.0
Proposed Action (Years 13-30)	160.9	359.7	49.0	738.1

Total monthly streamflow volume (af) for representative wet, normal, and dry years were evaluated to assess changes in seasonal streamflow. Proposed action results were compared to the no-action alternative and proposed action results are reported as the percent difference from the no-action alternative (Table 36). Annual flows decrease up to 9% in all three water year types. Winter flows decrease in wet (10%) and normal (2%) years as reservoir releases are reduced in favor of storage, but also decrease 4% in dry years. Irrigation period flows decrease in all three water year types with the greatest reduction (18%) during normal years as the North Unit ID pumps divert more water to satisfy water user needs.

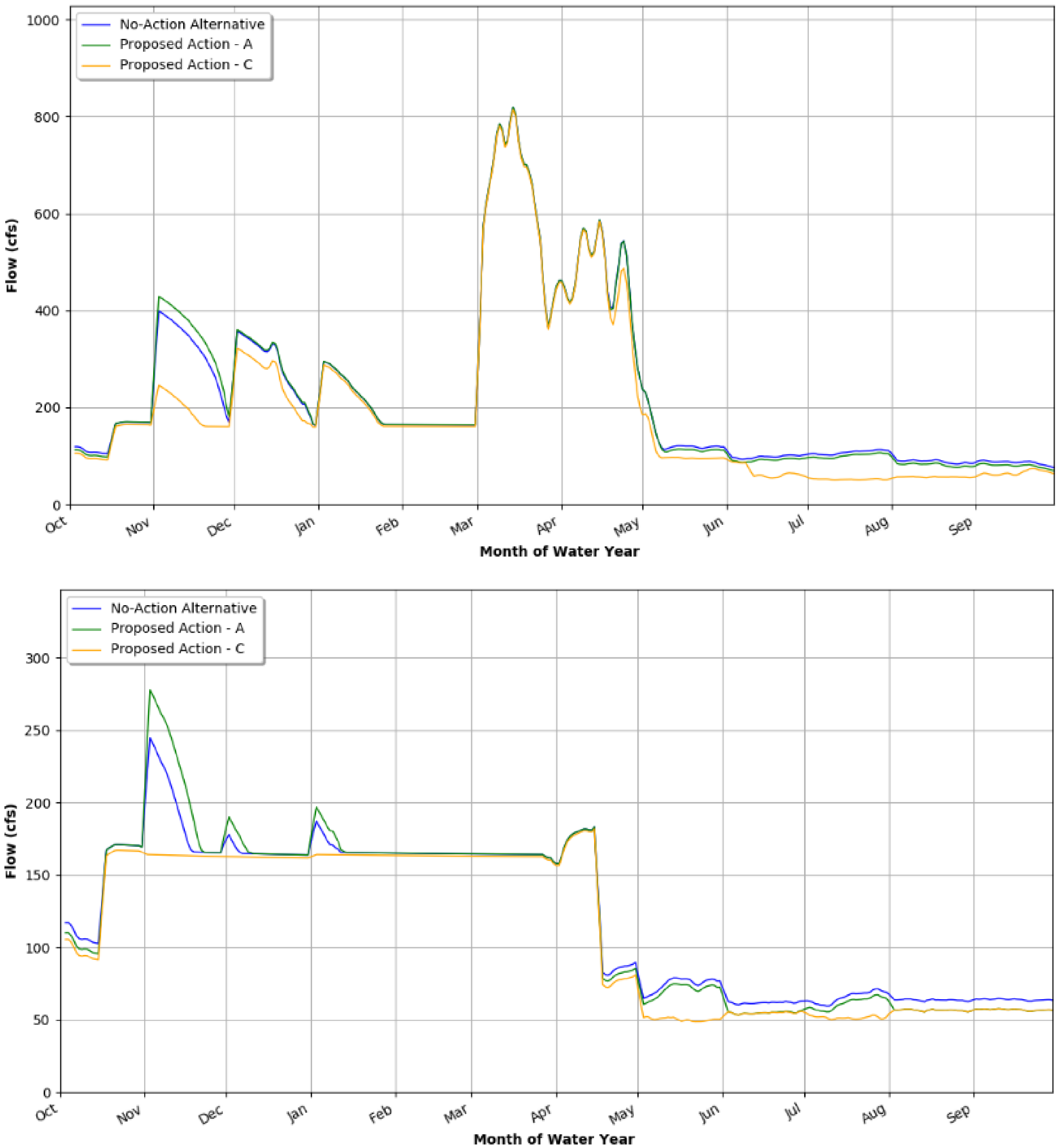
Table 36. Percent Differences between the Proposed Action and the No-Action Alternative for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years for the CRSO Gauge

		Proposed Action		
Water Year Type	**Time Period**	**Years 1–7**	**Years 8–12**	**Years 13–30**
Wet	Irrigation Period	-1%	-8%	-8%
	Winter/Storage Period	-2%	-9%	-10%
	Annual	-1%	-9%	-9%
	1 SD	-3%	-3%	-3%
Normal	Irrigation Period	-3%	-8%	-18%
	Winter/Storage Period	0%	-1%	-2%
	Annual	-1%	-4%	-9%
	1 SD	1%	3%	4%
Dry	Irrigation Period	97%	-13%	-13%
	Winter/Storage Period	97%	-3%	-4%
	Annual	97%	-7%	-8%
	1 SD	311%	10%	9%

Figure 55 presents the representative normal and dry year hydrographs for the CRSO gauge under the proposed action in years 1 through 7 and years 13 through 30. The hydrographs show the influence of the North Unit ID pump station flow diversion during the irrigation period in both normal and dry years. In a dry year, Crooked River flows are used to meet North Unit ID water needs as stored water in Wickiup Reservoir on the Upper Deschutes River is depleted. Proposed action irrigation flows are lower than the no-action alternative from mid-April through the end of

September in years 13 through 30 in a normal year. Irrigation flow differences between the proposed action and no-action alternative diminish in dry years.

Figure 55. Modeled Flows for the Crooked River at the CRSO Gauge Downstream from the North Unit ID Pump Station under the Proposed Action in Years 1–7 (A) and Years 13–30 (C) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative. (Note flow scale differences.)



Crooked River from Smith Rock State Park to Opal Springs Dam

Groundwater inputs between the Smith Rocks State Park gauge (CRSO) and the Crooked River below Opal Springs gauge (CROO), substantially increase Crooked River flows, especially in the winter when flows may increase tenfold between the CRSO and CROO gauges (Figure 56). Winter and irrigation period flows decrease relative to the no-action alternative beginning in year 6 of the permit term. With increasing minimum winter flows on the Upper Deschutes River, flow at the CROO gauge decreases slightly between mid-June and mid-September as flow is diverted at the North Unit ID pump station.

Figure 56. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Crooked River at the CROO Gauge Downstream from Opal Springs Dam under the Proposed Action for Years 1–7 (upper) and Years 13–30 (lower) Compared to the No-Action Alternative

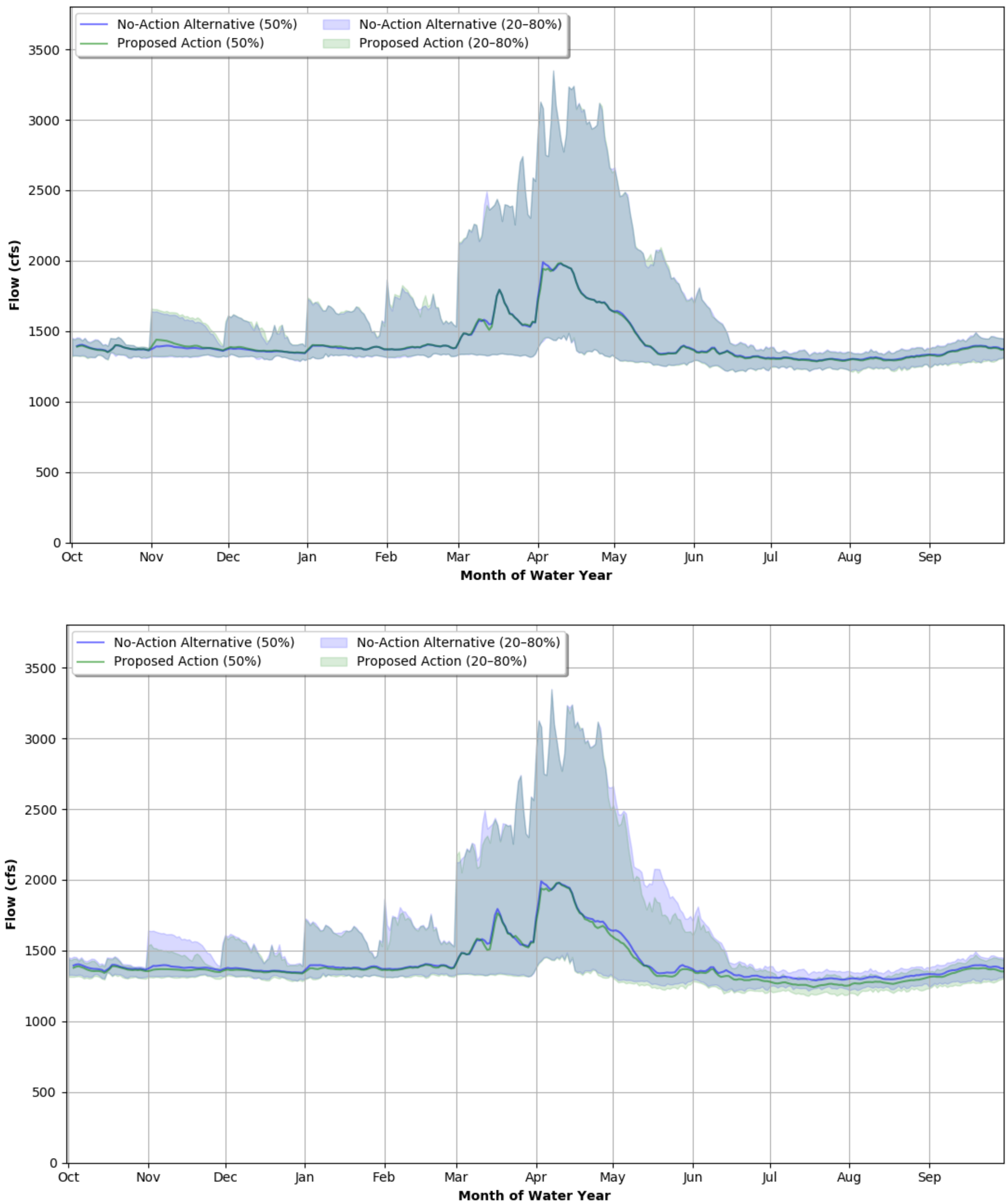


Table 37 includes a comparison of seasonal differences in minimum and maximum median flows based on CROO gauge data. The no-action alternative and proposed action have similar minimum and maximum median flows in the winter and summer suggesting the influence of groundwater inputs.

Table 37. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Crooked River at the CROO Gauge by Season for the No-Action Alternative and Proposed Action over the Permit Term

	Winter (Nov 1–Mar 31)		Irrigation (Apr 1–Oct 31)	
Alternative	Minimum (cfs)	Maximum (cfs)	Minimum (cfs)	Maximum (cfs)
No-Action	1,340.4	1,821.8	1,286.3	2,038.0
Proposed Action (Years 1–7)	1,344.0	1,819.2	1,281.1	1,996.6
Proposed Action (Years 8-12)	1,337.0	1,818.0	1,262.0	1,994.6
Proposed Action (Years 13-30)	1,334.6	1,771.5	1,240.3	1,993.4

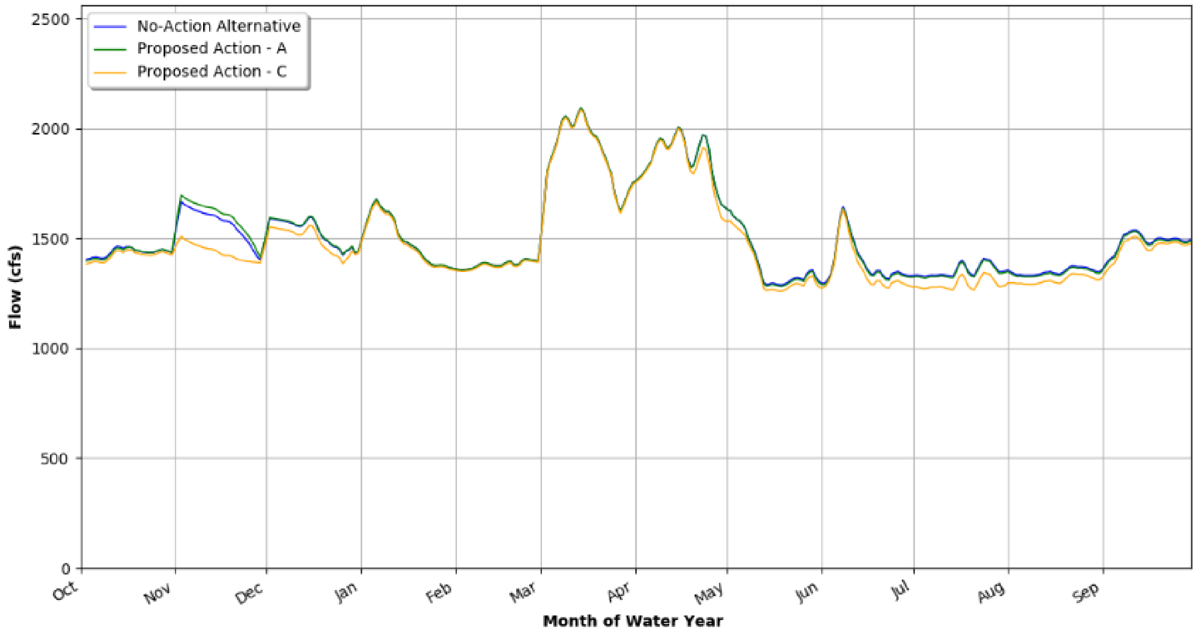
There are small differences in streamflow volumes in all water year types and over the permit term (Table 38). Differences relate to reduced winter storage flows as excess flow above minimum flow targets is stored in Prineville Reservoir, and the North Unit ID pump station diverts water to compensate for the effects of minimum flow targets on the Upper Deschutes River. The influence of the North Unit ID pump station diversion is less influential at the CROO gauge due to the large volume of groundwater inputs between the pump station and the CROO gauge.

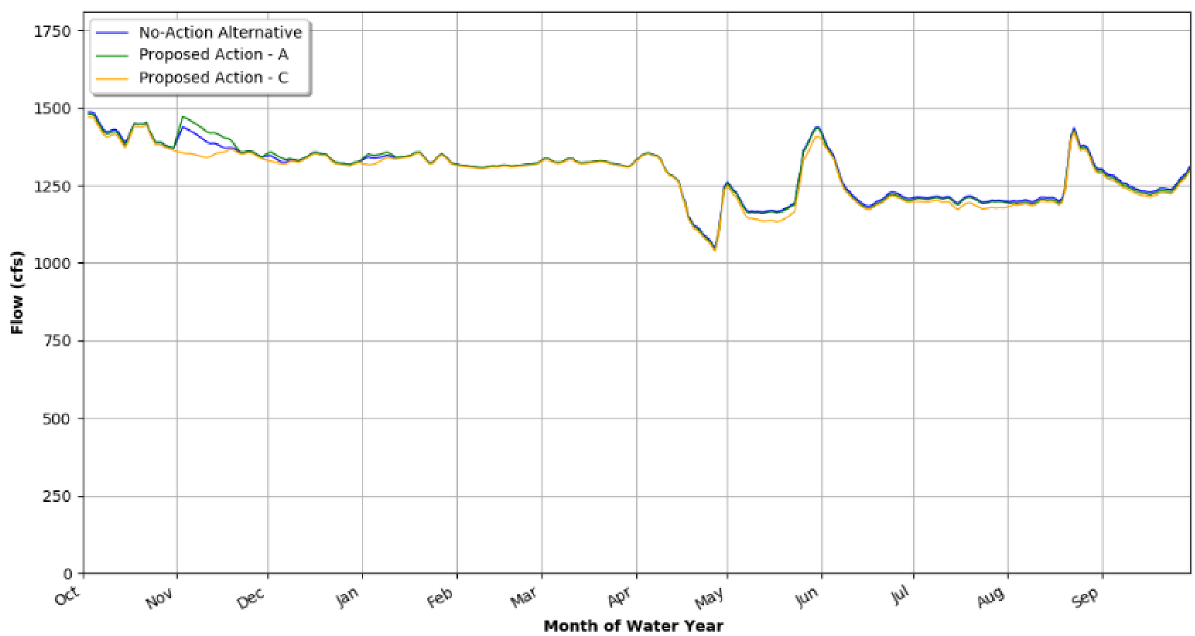
Table 38. Percent Differences between the No-Action Alternative and Proposed Action for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years for the CROO Gauge

		Proposed Action		
Water Year Type	Time Period	Years 1–7	Years 8–12	Years 13–30
Wet	Irrigation Period	0%	-3%	-3%
	Winter/Storage Period	0%	-3%	-3%
	Annual	0%	-3%	-3%
	1 SD	-3%	-3%	-3%
Normal	Irrigation Period	0%	-1%	-2%
	Winter/Storage Period	0%	0%	0%
	Annual	0%	-1%	-2%
	1 SD	1%	2%	2%
Dry	Irrigation Period	0%	-1%	-1%
	Winter/Storage Period	0%	0%	-1%
	Annual	0%	-1%	-1%
	1 SD	5%	3%	3%

Figure 57 includes the representative normal and dry year hydrographs for the CROO gauge under the proposed action in years 13 through 30. In a normal year, the proposed action has lower flows from November through mid-January and from late July through mid-September. In a dry year, proposed action flows are lower in July, but otherwise similar to the no-action alternative.

Figure 57. Modeled Flows for the Crooked River at the CROO Gauge Downstream from Opal Springs Dam under the Proposed Action Years 1–7 (A) and Years 13–30 (C) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative





Crooked River Flood Flows

The Crooked River flood flow analysis assessed effects on the magnitude of the regulatory base flood (100-year) and 500-year floods, and more frequent floods associated with shallow floodplain inundation.

The base flood (1%, 100-year event) and the 500-year (0.2%) event were evaluated for the CAPO gauge (OR 126 crossing) to capture flood risk areas between the CAPO gauge and the City of

Prineville. The base flood flow would increase by approximately 5% and the 500-year event would increase by approximately 8%. Because Ochoco Reservoir and Crooked River Reservoir are operated in tandem to reduce flood potential on the Crooked River, reservoir managers would continue to operate the reservoirs for flood control. Based on the proposed action's minimal influence on the base flood and 500-year flood, the proposed action is not expected to affect flood risk for properties in the Crooked River portion of the study area.

To assess the proposed action's influence on more frequent, low magnitude floods, recent flood reports from March 2017 (West 2017) for the Crooked River upstream from Prineville were used to determine a threshold flood flow of 2,500 cfs. The maximum flow for each day of the water year was calculated from the RiverWare model output. The proposed action resulted in an increase of 2% in the number of days per year when flows exceed the flood flow threshold compared to the no-action alternative. The proposed action is therefore anticipated to result in a minor increase in the frequency of shallow floodplain inundation relative to the no-action alternative.

WR-5: Affect Groundwater Recharge

Reservoirs and Deschutes River

Changes to the operation of Crane Prairie Reservoir could result in a change in seepage losses that vary with reservoir stage. Narrower limits on the range of surface elevations in Crane Prairie Reservoir under the proposed action would result in generally higher reservoir stages from approximately late September through early May and relatively lower reservoir stages from mid-May through mid-September. Seepage losses from this reservoir increase with higher reservoir stages. Although a large portion of this seepage loss from Crane Prairie Reservoir returns to the river system just downstream of the reservoir at the Sheep Springs complex, some small portion could be reaching the basin's groundwater system. The proposed action at the Crane Prairie Reservoir could have a small beneficial effect on the regional groundwater system water levels. However, the resulting small increase in groundwater recharge from the reservoir would likely be *de minimis* compared to the average annual groundwater recharge of 3,800 cfs (Gannett et al. 2001: 29).

Adjustments to the timing and flow in the Deschutes below Wickiup Dam would have no effect on the groundwater system with the exception of the river segment downstream of Sunriver. In this river segment, seepage from the river to the groundwater system is proportional to the flow rate. Increases in winter flows under the proposed action would result in an increase of recharge to the groundwater system after the first 5 years of implementing the proposed action, resulting in a small beneficial effect on the groundwater system. However, based on the relationship of seepage to flow described in the Affected Environment section, at the proposed action's peak winter discharge rate of 400 cfs, the resulting increase to groundwater recharge would be less than 0.3% of the average annual groundwater recharge of 3,800 cfs (Gannett et al. 2001: 29) and would likely be masked by the naturally occurring basin-scale groundwater level fluctuations associates with climatic cycles (Gannett and Lite:33).

Additional changes to the flows in the Middle Deschutes River during the winter period for livestock diversions are not expected to affect the groundwater system because the stream reaches downstream of Bend are either neutral or are gaining reaches. Impacts on the regional groundwater system from increases in streamflow within gaining reaches would only result in potential minor localized effects on groundwater levels that would be attenuated and absorbed by the regional groundwater system and, therefore, would not affect the overall system.

Crescent Creek and Little Deschutes River

Changes in the release, and rate of releases from Crescent Lake are not expected to affect the regional groundwater system. The water table elevation in this portion of the study area is near land surface and the stream gains and losses along most of reaches of Crescent Creek are small, indicating relatively little net exchange of water between the groundwater and river systems.

Whychus Creek

Whychus Creek is either a neutral or gaining stream (with a short losing reach just upstream of Sisters), therefore the minor localized effects on the groundwater system from additional flow provided to Whychus Creek and modifications to the Three Sisters ID diversion would be attenuated and absorbed by the regional groundwater system. There would be no change to the regional groundwater system from increased flows.

Crooked River

Changes in the scheduled release of water from Prineville Reservoir are not expected to affect the regional groundwater system because the Crooked River is either a neutral or gaining stream (LaMarche pers. comm. [a, b]). Potential minor localized impacts on the water levels from increases in streamflow will be attenuated and absorbed by the regional groundwater system.

Impact Summary

The proposed action could result in minor changes in groundwater recharge within the study area. However, these minor changes in groundwater recharge would likely be *de minimis* compared to the average annual groundwater recharge and likely masked by the naturally occurring basin-scale groundwater level fluctuations associates with climatic cycles. The potential for City of Prineville groundwater pumping to affect Crooked River streamflow would be mitigated by the current groundwater pumping mitigation program. Therefore, there would be no adverse effect on the groundwater recharge under the proposed action.

Alternative 3: Enhanced Variable Streamflows

Under Alternative 3, the applicants would implement the Final Deschutes Basin HCP conservation strategy, as described for the proposed action, but modified as summarized below.

Alternative 3 would increase fall and winter flows in the Deschutes River below Wickiup Dam 2 years earlier than under the proposed action, as shown below, and would include variable increase above minimum flows in all years during above-normal and wet years, but would not include the irrigation period maximum daily flow caps.

- Years 1–5: 200 cfs
- Years 6–10: 300 cfs
- Years 11–30: 400 to 500 cfs

In Crescent Creek and the Little Deschutes River, minimum flow requirements under Alternative 3 would be higher than under the proposed action from October 1 through June 30 (20 cfs vs. 10–12 cfs) and lower from July 1 through September 30 (20 cfs vs. 50 cfs), and Alternative 3 does not include the Oregon spotted frog stored water account that provides water management flexibility under the proposed action.

On the Crooked River, Alternative 3 would protect uncontracted storage releases from Prineville River instream to Lake Billy Chinook.

The presentation of direct RiverWare outputs (without rounding) is not intended to imply exact predictions of future conditions, but provide a basis for comparing among alternatives.

WR-1: Change Reservoir Storage

This section describes the impact and mechanism of impact for changes in reservoir water supply storage as a result of Alternative 3.

Crane Prairie Reservoir

Modeled changes in reservoir storage for Crane Prairie Reservoir under Alternative 3 compared to the no-action alternative would be the same as described for the proposed action.

Wickiup Reservoir

As winter flow releases from Wickiup begin to increase above the 100 cfs flow required under the no-action alternative, Wickiup Reservoir storage declines, with the greatest declines observed in years 11 through 30 of the permit term (Table 39; Figure 58). Compared to the no-action alternative, the reduction in maximum storage on or after April 1 is expected to occur in a normal year during years 11 through 30 of the permit term would be 99,986 af. However, Wickiup Reservoir would still fill to over 175,000 af in one out of every four years, when conditions are wet or very wet (Table 40). The frequency of filling Wickiup Reservoir to a maximum annual volume of at least 100,000 af—approximately half of the total capacity of Wickiup Reservoir—declines from 100 to 43% (Table 40), indicating that the effects of reduced reservoir storage would be concentrated in normal, dry, and very dry years.

Under Alternative 3, reservoir releases may be reduced below what is required to ensure that adequate flows are maintained at the WICO gauge. Depending on how outflows are managed, this may lead to an increase in Wickiup Reservoir storage relative to the modeled storage levels shown in Tables 38 and 39, and Figure 7.

Table 39. Modeled Wickiup Reservoir Storage under the No-Action Alternative and Alternative 3

Water Year Conditions	No-Action Alternative (af)	Alternative 3 (af)		
		Years 1–5	Years 6–10	Years 11–30
Very Dry	133,737	102,082	70,976	37,287
Dry	162,246	119,605	84,747	57,896
Normal	186,930	147,953	112,446	87,261
Wet	189,063	189,302	171,463	182,070
Very Wet	195,434	200,135	200,135	200,129

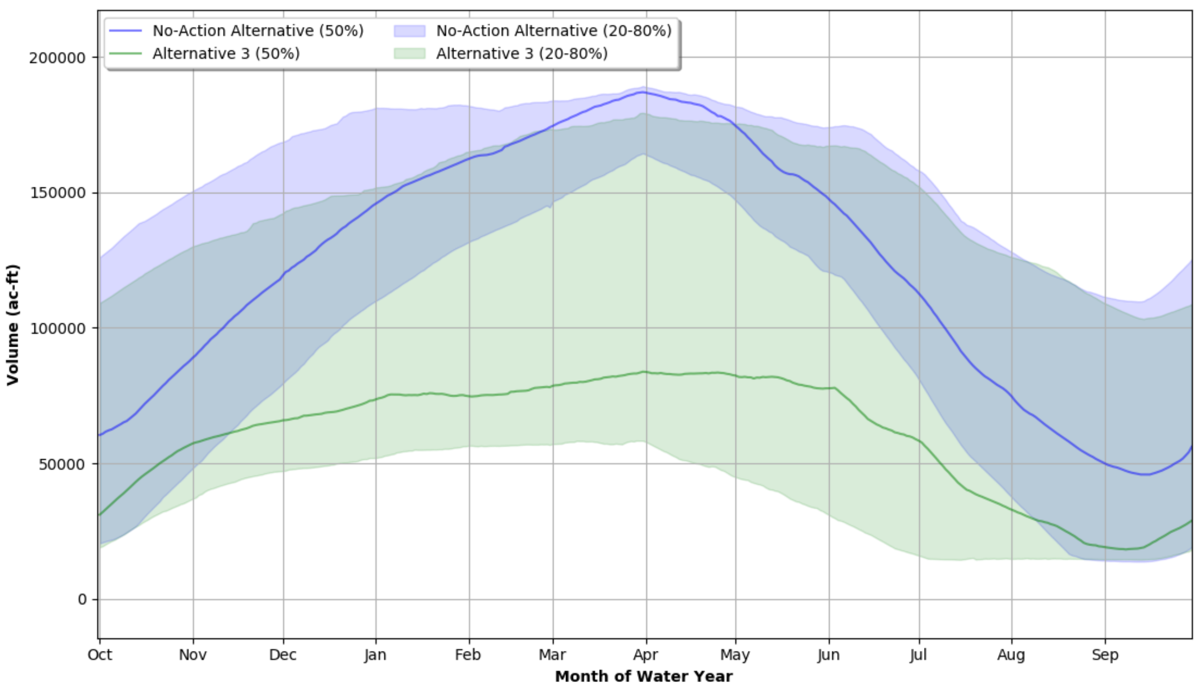
af = acre-feet; cfs = cubic feet per second

Table 40. Frequency of Wickiup Reservoir Fill under the No-Action Alternative and Alternative 3

Maximum Fill Volume April–August (af)	No-Action Alternative	Alternative 3		
		Years 1–5	Years 6–10	Years 11–30
25,000	100%	100%	100%	100%
50,000	100%	100%	100%	89%
75,000	100%	100%	92%	57%
100,000	100%	100%	54%	43%
125,000	100%	68%	43%	35%
150,000	89%	49%	30%	35%
175,000	68%	32%	19%	24%

af = acre-feet; cfs = cubic feet per second

Figure 58. Modeled Storage in Wickiup Reservoir under Alternative 3 in Years 11–30 Compared to the No-Action Alternative



Crescent Lake Reservoir

Alternative 3 would reduce minimum flows downstream from Crescent Lake Dam as compared to the no-action alternative. Under the no-action alternative the minimum flow below Crescent Lake Dam would be 30 cfs from March 15 through November 30 and 20 cfs during the rest of the year. Under the Alternative 3 Conservation Measure CC-1, the minimum flow below Crescent Lake Dam would be 20 cfs during the storage season. Therefore, Alternative 3 would generally result in an increase in Crescent Lake storage (Figure 59) compared to the no action, but not as much of an increase as under the proposed action. During very dry years, there would be a limited increase or a slight decline in Crescent Lake storage.

In years 1 through 5 of the permit term, the maximum storage volume attained between April and August would stay approximately the same or slightly increase compared to the no-action alternative (Table 41). As winter releases from Wickiup increase to 400 cfs during years 13 through 30 of the permit term, the increase in Crescent Lake storage declines by approximately 1,000 af compared to years 1 through 5 when Wickiup outflows are 200 cfs. Tumalo ID holds two water rights for storage in Crescent Reservoir, certificate 76683 for storage of 35,000 af with a March 20, 1911, priority, and certificate 76637 for storage of 51,050 af with a 1961 priority. Because certificate 76637 is junior to North Unit ID's 1913 live flow water right, under rare circumstances, it may be subject to regulatory calls when North Unit ID experiences shortages.

Tumalo ID's water right to store water in Crescent Lake Reservoir beyond 35,000 af per year is junior to live flow water rights on the main stem Deschutes, including North Unit ID's 1913 live flow water rights. Additionally, the RiverWare model anticipates increased regulation of Tumalo ID's 1905 live flow priority date on the main stem Deschutes River, which may lead to further reliance on Crescent Lake storage releases to make up for the reduced availability of live flow, and a commensurate reduction in storage. In years 21 through 30, reductions in maximum Crescent storage may not reflect reductions in end of year storage, as maximum storage may be reduced through mid-July by regulation of Deschutes natural flow water rights to maintain Crane Prairie elevations, but Tumalo ID's storage account may be rebalanced with Crane Prairie storage accounts later in the year.

Figure 59. Modeled Storage in Crescent Lake Reservoir under Alternative 3 in Years 11–30 Compared to the No-Action Alternative

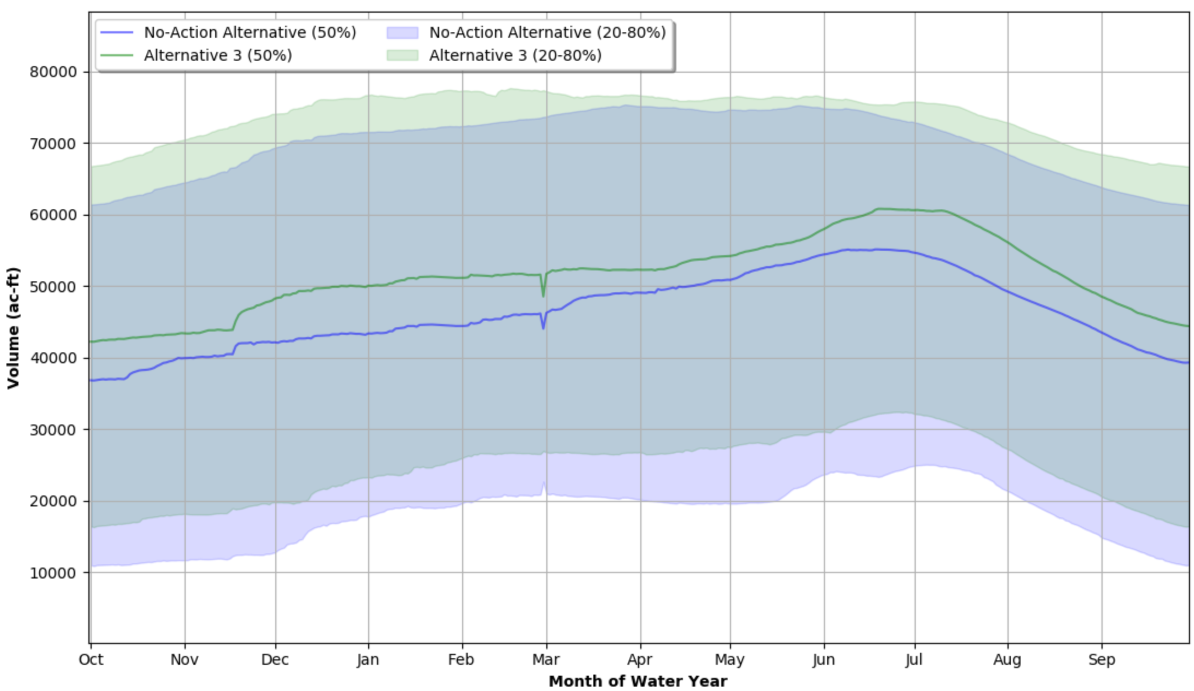


Table 41. Crescent Lake Storage under the No-Action Alternative and Alternative 3.

Water Year Conditions	No-Action Alternative	Alternative 3		
		Years 1–5	Years 6-10	Years 11–30
Very Dry	10,318	11,015	10,742	10,093
Dry	27,006	33,327	32,346	32,730
Normal	55,345	62,124	61,716	61,276
Wet	74,371	77,952	77,920	78,019
Very Wet	79,608	79,944	80,248	80,784

af = acre-feet; cfs = cubic feet per second

Prineville Reservoir

As winter flow releases out of Wickiup Reservoir increase starting in year 1 of the permit term, reducing North Unit ID's stored water supply in the Deschutes, North Unit ID would use its available stored water from Prineville Reservoir (up to 10,000 af) more frequently and to a greater extent.. This, combined with increased winter minimum flows in the Crooked River (Conservation Measure CR-1), would result in reduced Prineville Reservoir storage in most years. Changes in storage would range from a reduction of 460 af during normal years to a reduction of 19,367 af during a very dry year during years 11 through 30 of the permit term (Table 42). Figure 60 compares Prineville Reservoir storage under the no-action alternative to years 11 through 30 of the permit term under Alternative 3. Additionally, increasing bypass flows in McKay Creek and Ochoco Creek and protecting stored water under temporary instream leases for Ochoco ID patrons (Conservation Measures CR-2, CR-3, and CR-4) may contribute to a decline in Prineville Reservoir storage by increasing Ochoco ID stored water releases in years that Prineville Reservoir does not fill.

Figure 60. Modeled Storage in Prineville Reservoir under Alternative 3 during Years 11–30 Compared to the No-Action Alternative

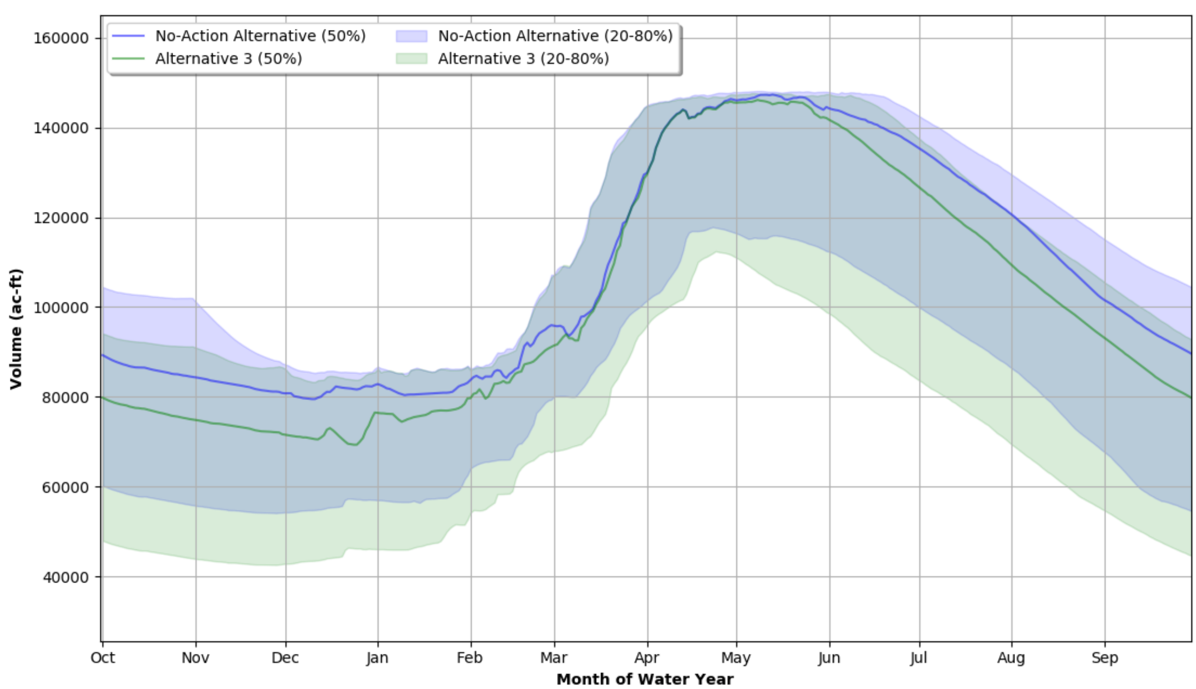


Table 42. Prineville Reservoir Storage under the No-Action Alternative and Alternative 3.

Water Year Conditions	No-Action Alternative	Alternative 3		
		Years 1–5	Years 6-10	Years 11–30
Very Dry	65,548	51,177	46,543	46,181
Dry	125,244	118,440	117,803	120,486
Normal	148,326	148,089	147,916	147,867
Wet	148,482	148,217	148,170	148,161
Very Wet	151,001	150,998	150,998	150,995

af = acre-feet; cfs = cubic feet per second

Ochoco Reservoir

Modeled changes in reservoir storage for Ochoco Reservoir under Alternative 3 would be the same as described for the proposed action.

WR-2: Change in Water Supply for Irrigation Districts and Other Surface Water Users

Similar to the proposed action, changes in stored water supply for Alternative 3, described under Impact WR-1, have direct and indirect effects on water supply for irrigation districts and other surface water users. With the exception of Tumalo ID, the causes and timing of changes in diversions for water users are the same as under the proposed action, but changes would generally occur earlier in the permit term and reductions in water supply would be greater than under the proposed action.

Figures 61 through 64, and 67 through 69 compare irrigation season diversions under Alternative 3 (years 1–5 and years 11–30) in normal, dry, and very dry years as a percentage of the diversion under the no-action alternative. North Unit, Central Oregon, Arnold, Lone Pine, and Ochoco IDs are expected to experience reductions in diversions as a result of the proposed action. Tumalo ID is expected to experience a slight increase in supply compared to the No Action, but the increase in supply is expected to be significantly less than under the proposed action. Swalley ID is not affected by the proposed action.

Figures 65 and 66 compare diversions in normal, dry, and very dry years between the no-action alternative and Alternative 3 (in years 1 through 5 and years 11 through 30 of the permit term) from April through October as volumes. Supply shortages under the proposed action from June through September are more pronounced than for the entirety of the irrigation season.

The analysis shown in the figures does not capture changes expected to occur under the no-action alternative during the permit term.

The impacts of Alternative 3 on the water supply of the applicants and other water users are described below.

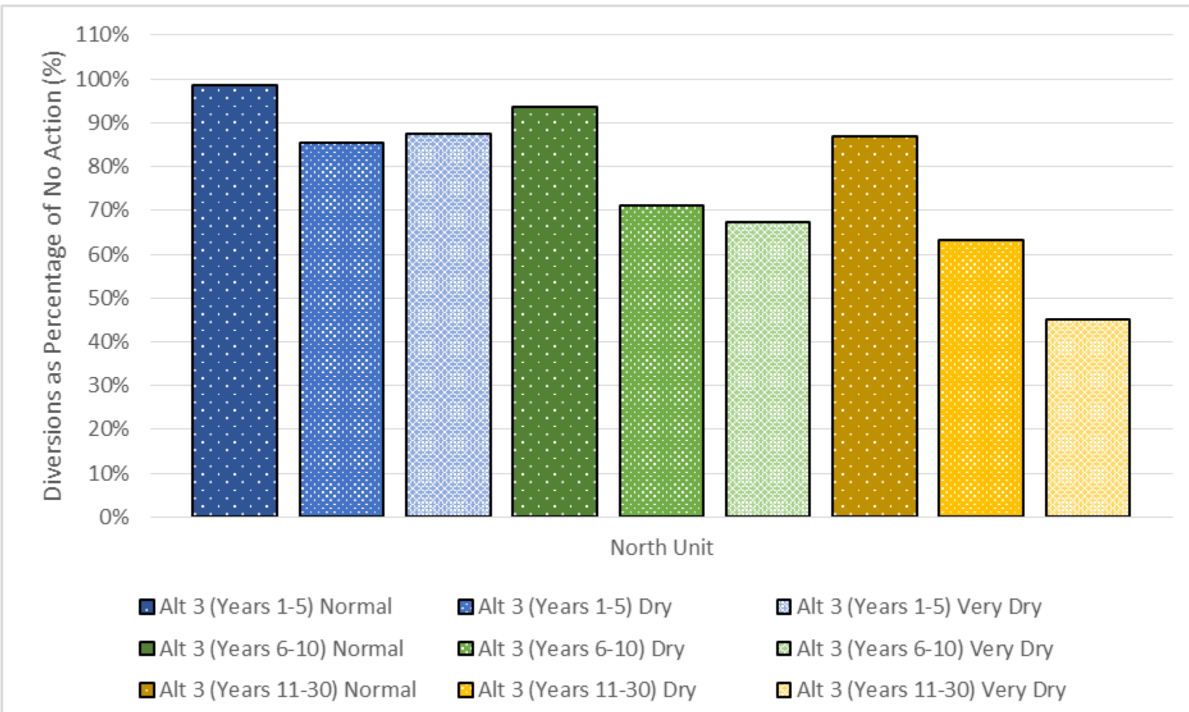
North Unit Irrigation District

Similar to the proposed action, reductions in Wickiup Reservoir storage will reduce North Unit ID water supply under Alternative 3. However, reductions in North Unit ID water supply will be greater under Alternative 3 than under the proposed action.

By year 11 under Alternative 3, when the required fall/winter flow at WICO is 400 cfs, North Unit ID's diversion would be reduced by over 25,000 af in a normal year compared to the no-action alternative (Figures 61 and 65).[16] In a dry year, North Unit ID diversions would be reduced by over 68,000 af. In wet and very wet years, there would be no reduction in North Unit ID diversions.

Under Alternative 3, during years 11 through 30 of the permit term, North Unit ID would increase use of the Crooked River pumping plant in all water year types, except very dry years (e.g., 1992), for which RiverWare shows that North Unit ID pumping from the Crooked River would decline by approximately 2,800 af. The decline in the utilization of the Crooked River pumping plant in a very dry year is attributable to increased releases from Prineville Reservoir under Alternative 3 compared to the proposed action, which would cause a decrease in Prineville Reservoir storage and Crooked River water supply available to North Unit ID.

Figure 61. Modeled Diversions for North Unit Irrigation District (April–October) under Alternative 3 as a Percentage of Diversions under the No-Action Alternative



Arnold, Lone Pine, and Central Oregon Irrigation Districts

Similar to the proposed action, Alternative 3 would reduce water supply available to the entities with water rights to Crane Prairie Storage: Arnold ID, Lone Pine ID, and Central Oregon ID. Compared to the proposed action, reductions in water supply would generally be greater under Alternative 3 and would occur earlier in the permit term. (Figures 62 through 67). Arnold ID diversions would be reduced by 7,753 af in a very dry year and 1,781 af in a dry year under

[16] In general, the model results show that North Unit ID will increase use of its Crooked River pumping plant to offset some of the loss of Deschutes River water supply. However, in a very dry year (1991 and 1992), the model shows that water available from the Crooked River declined by approximately 2,000 af, exacerbating Deschutes River water supply shortages.

Alternative 3, compared to reductions of 3,501 af and 135 af under the Proposed Action. Reductions in Central Oregon and Lone Pine ID diversions would be similar or only slightly greater than under the Proposed Action.

Figure 62. Modeled Diversions for Central Oregon Irrigation District (April–October) under the Alternative 3 as a Percentage of Diversions under the No-Action Alternative

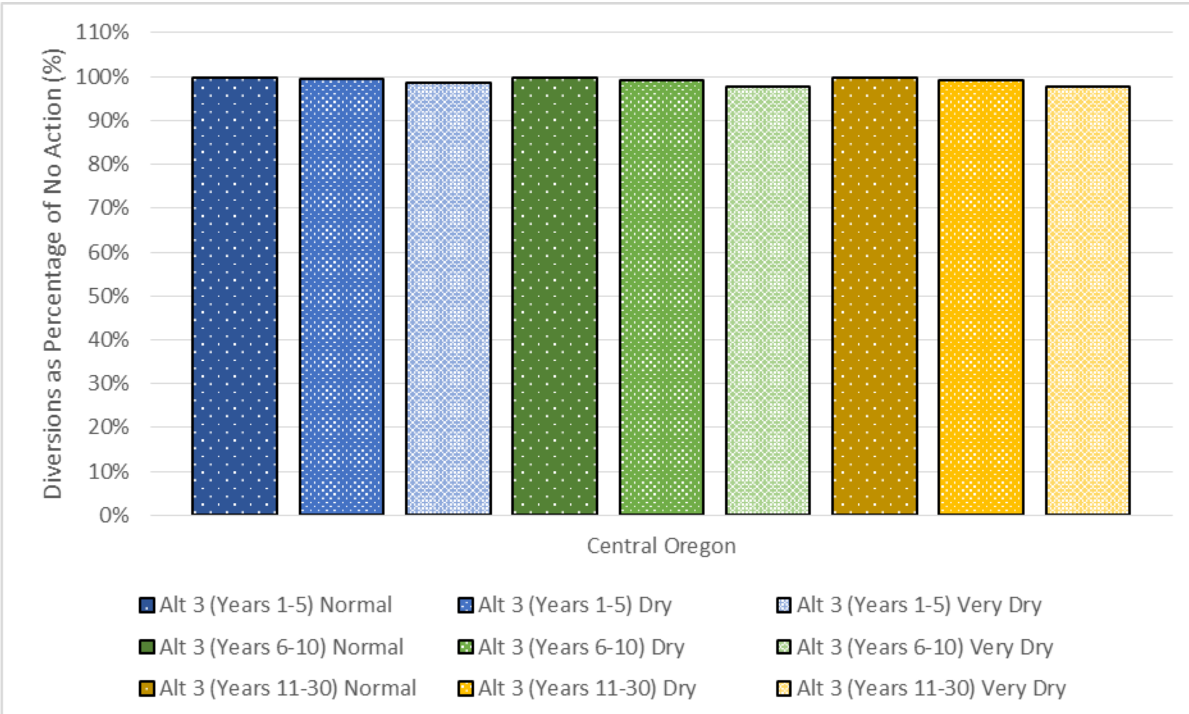


Figure 63. Modeled Diversions for Arnold Irrigation District (April–October) under Alternative 3 as a Percentage of Diversions under the No-Action Alternative

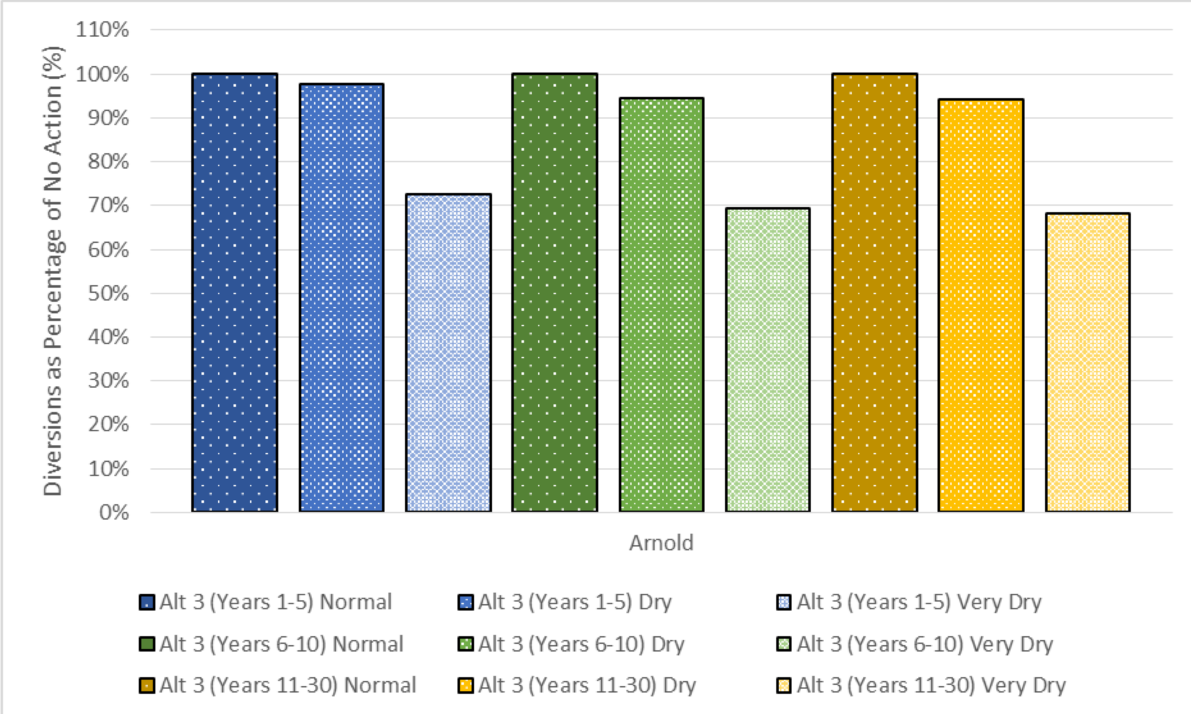


Figure 64. Modeled Diversions for Lone Pine Irrigation District (April–October) under Alternative 3 as a Percentage of Diversions under the No-Action Alternative

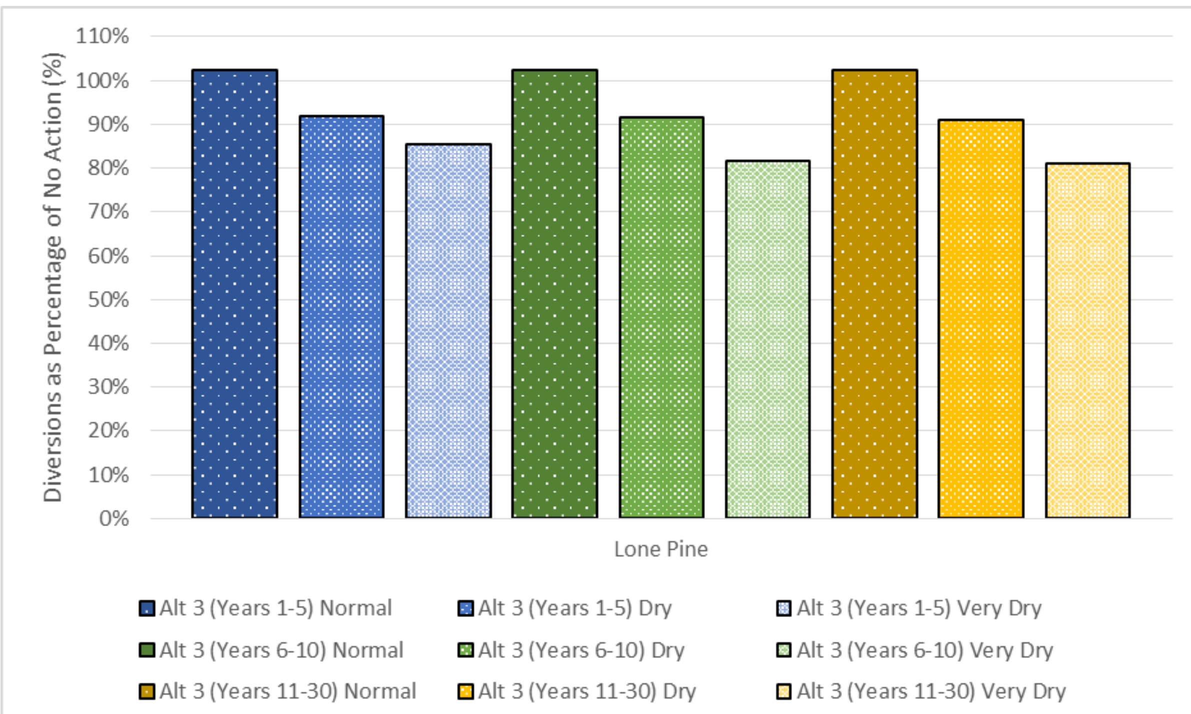


Figure 65. Central Oregon and North Unit Irrigation District Diversions (April–October)—under Alternative 3 in Years 1–5 and 11–30 Compared to the No-Action Alternative

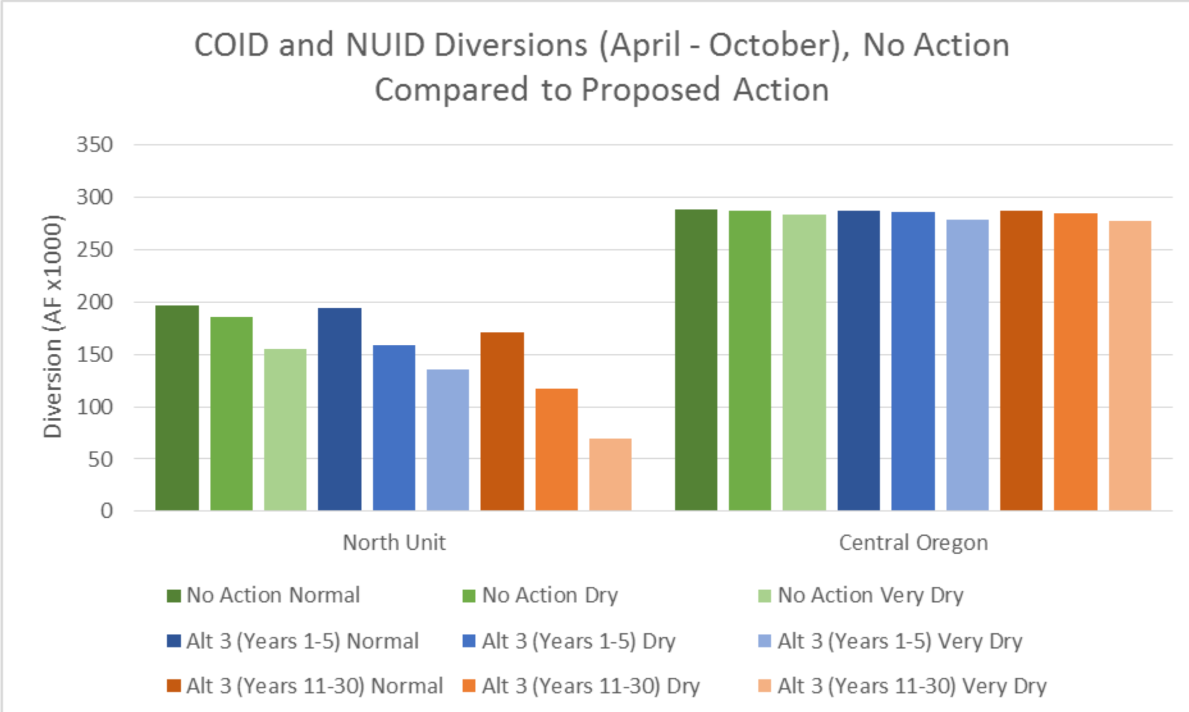
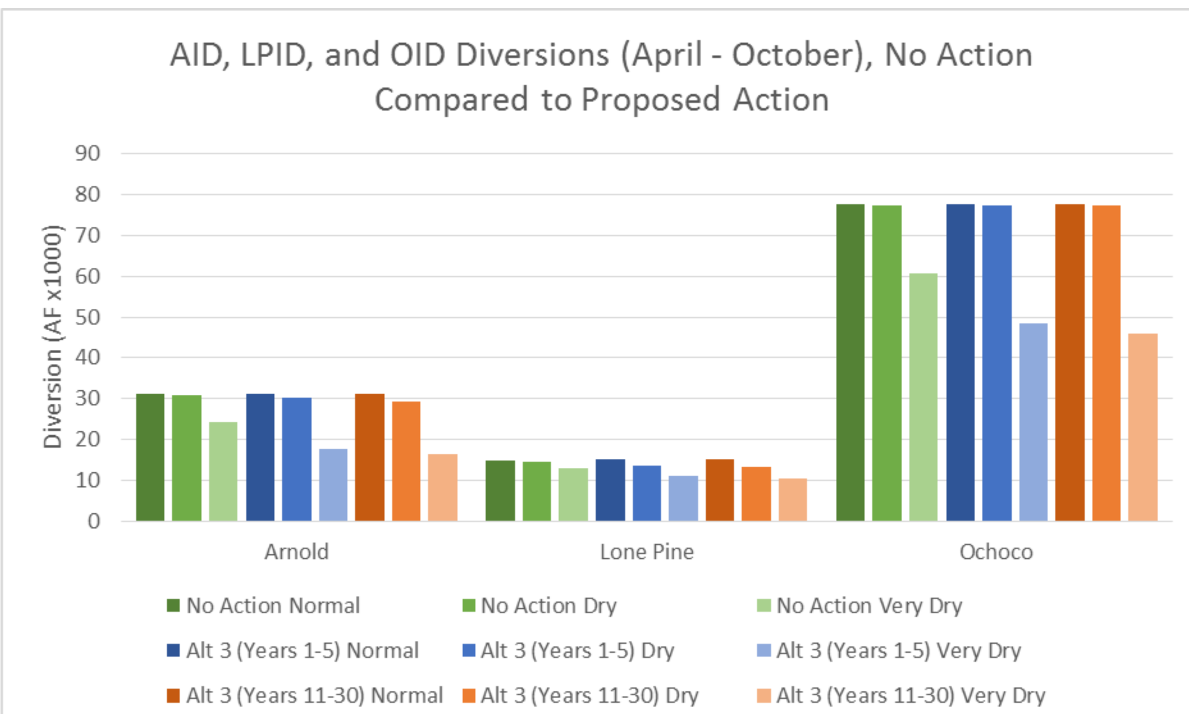


Figure 66. Arnold, Lone Pine, and Ochoco Irrigation District Diversions (April–October)—under and Alternative 3 in Years 1–5 and 11–30 Compared to the No-Action Alternative



Ochoco Irrigation District

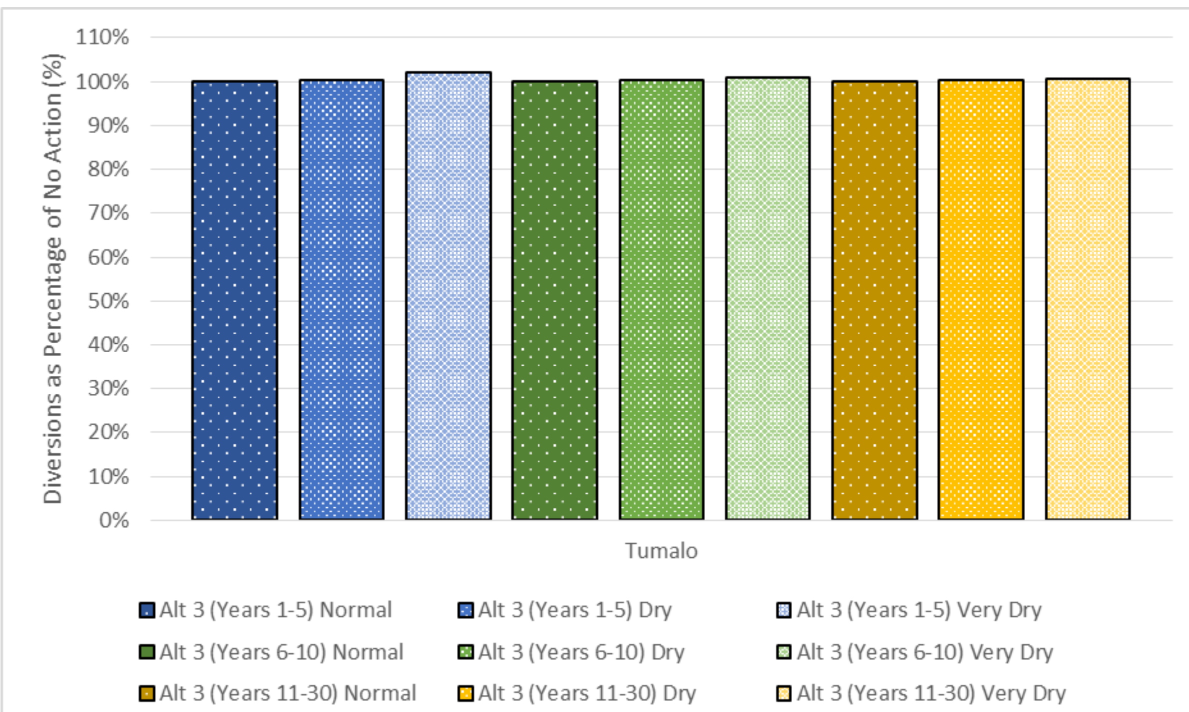
Modeling results show that under Alternative 3, increased winter releases from Prineville Reservoir, combined with North Unit ID's increased utilization of the Crooked River would result in a reduction of approximately 14,834 af of irrigation water supply for Ochoco ID in a very dry year scenario (Figure 66) in years 11 through 30 of the permit term. The reduction is slightly greater than under the proposed action.

The effect of conservation measures addressing Ochoco and McKay Creek minimum flows and instream leasing by Ochoco ID patrons would be the same or nearly the same as described for the proposed action.

Tumalo Irrigation District

Under Alternative 3 there would be a slight increase in Tumalo ID water supply during dry and very dry years due to decreased minimum winter flows below Crescent Reservoir compared to the no-action alternative. Winter releases from Crescent Lake would be reduced from 30 cfs to 20 cfs from March 15 through November 30. As a result, Crescent Lake storage and Tumalo ID's water supply increase compared to the no-action alternative. RiverWare shows Tumalo ID's April through October diversion would increase by approximately 192 af in a very dry year. Figure 67 shows Tumalo ID diversions under the three phases of Alternative 3 in normal, dry, and very dry years as a percentage of the diversion under the no-action alternative.

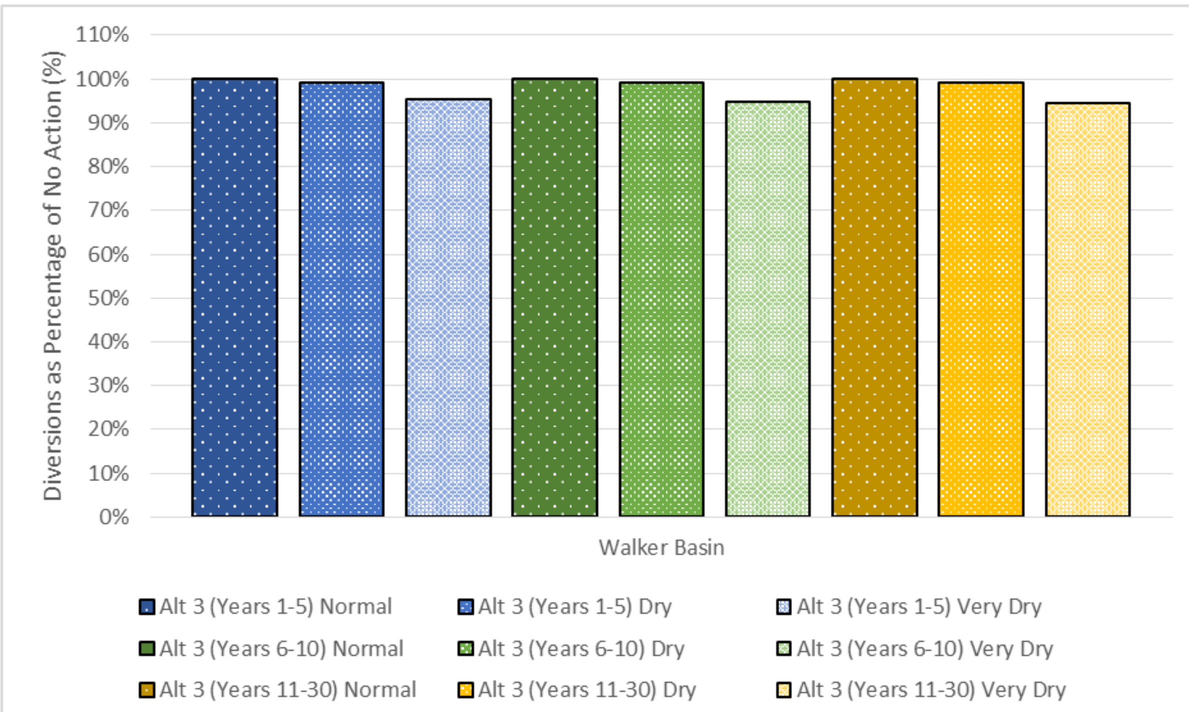
Figure 67. Modeled Diversions for Tumalo Irrigation District (April–October) under Alternative 3 as a Percentage of Diversions under the No-Action Alternative



Other Deschutes Water Users

RiverWare indicates that the reduction in supply under Alternative 3 would result in more frequent regulatory calls on live flow water rights in the Upper Deschutes Basin. Regulatory calls would also begin to occur earlier, in year 1 of the permit term, compared to the proposed action. RiverWare includes modeled diversions for the Walker Basin ditch (also known as La Pine Cooperative Water Association diversion), which has water rights with priorities of 1897, 1900, and 1902. Figure 68 shows diversions under the proposed action (100 through 400 cfs) in normal, dry, and very dry years as a percentage of the diversion under the no-action alternative for the Walker Basin diversion. RiverWare indicates that Walker Basin diversions will be reduced by 5% under Alternative 3 compared to the no-action alternative, greater than the minimal, 1% reduction anticipated under the proposed action.

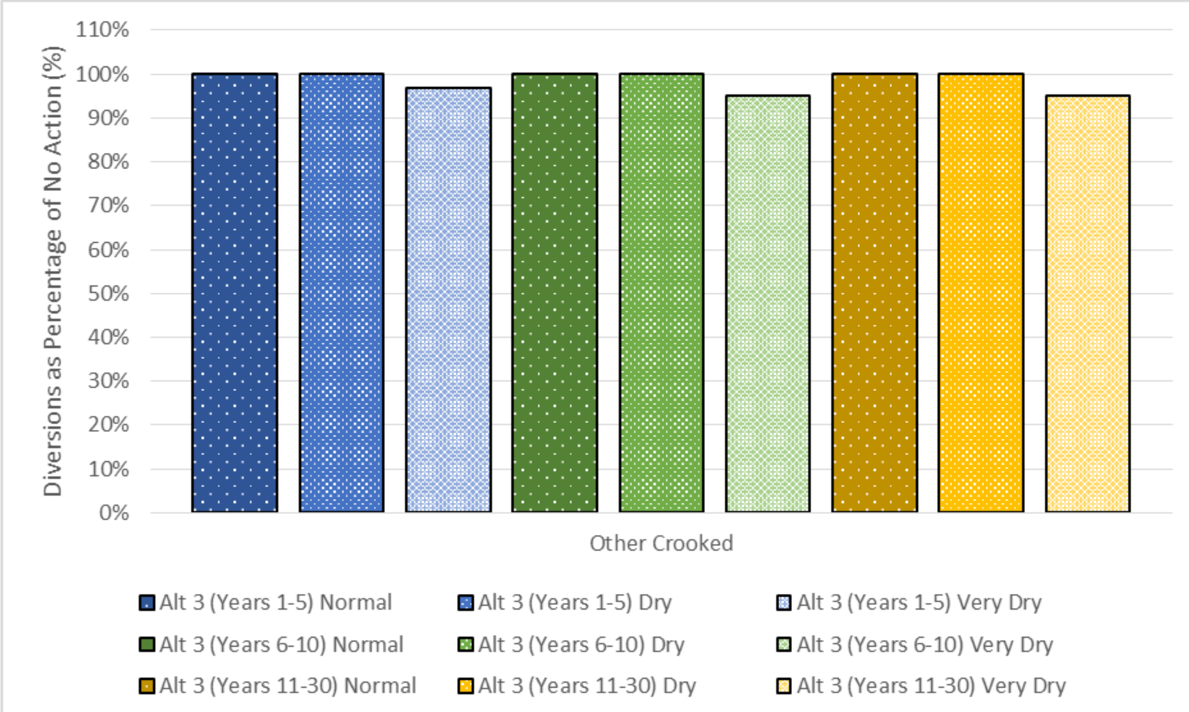
Figure 68. Modeled Diversions for Walker Basin (April–October) under Alternative 3 as a Percentage of Diversions under the No-Action Alternative



Other Crooked River Water Users

Under Alternative 3, reductions for Crooked River water users other than Ochoco ID (as shown in tables 3 and 4), would be slightly greater than under the proposed action (Figure 69). Under alternative 3 diversions would be The RiverWare model indicates that there reductions in water supply in very dry years in years 11 through 30 of the permit term would be approximately 5% compared to approximately 3% under the same conditions under the no action. RiverWare did not model the impacts on all irrigators, and others with more junior water rights may also be affected by the proposed action.

Figure 69. Modeled Diversions for Other Crooked River Irrigators (April–October) under Alternative 3 as a Percentage of Diversions under the No-Action Alternative



WR-3: Changes in Reservoir Water Surface Elevations and Flood Storage Capacity

Modeled changes in reservoir water surface elevation and related flood storage capacity would be the same as described for the proposed action for Crane Prairie Reservoir and Ochoco Reservoir. Median water surface elevations in Prineville Reservoir, Wickiup Reservoir, and Crescent Lake Reservoir would vary from the proposed action due to changes in water management for Oregon spotted frog habitat.

Modeled changes in Wickiup Reservoir compared to the proposed action include:

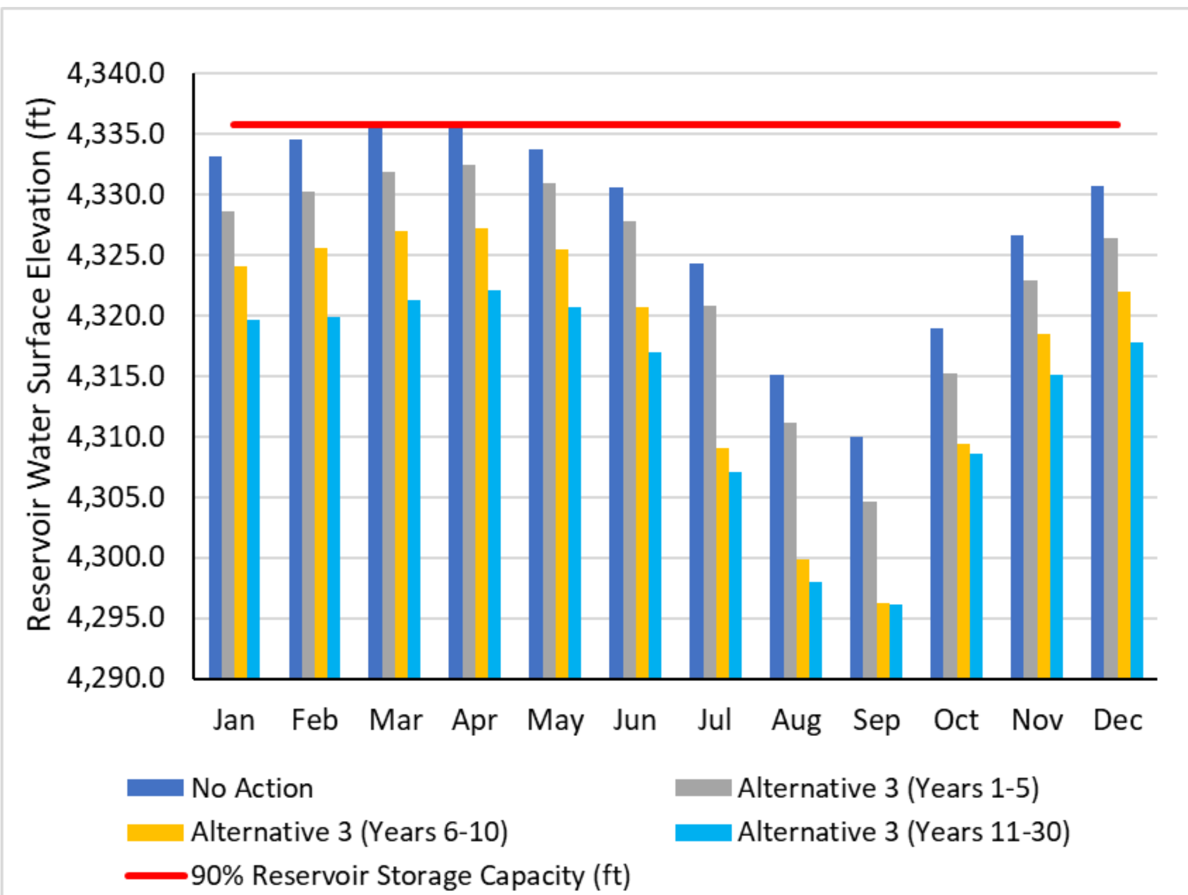
- Alternative 3 years 1 through 5 have minimum winter outflow of 200 cfs versus the proposed action minimum flows of 100 cfs in years 1 through 7.
- Alternative 3 years 6 through 10 would be equivalent to proposed action years 8 through 12. Alternative 3 does not have the 1,400 cfs maximum irrigation season cap included in the proposed action.
- Alternative 3 years 11 through 30 would be equivalent to proposed action years 13 through 30. Alternative 3 does not have the 1,200 cfs maximum irrigation season cap included in the proposed action.
- Modeled changes in Crescent Lake Reservoir compared to the proposed action include:
- Alternative 3 includes minimum instream flow of 20 cfs below Crescent Dam versus a minimum flow of 10 cfs for the proposed action.
- Alternative 3 does not include the Oregon spotted frog water account that provides operational flexibility under the proposed action.

Instream protection of released uncontracted storage water from Bowman Dam to Lake Billy Chinook, as part of Conservation Measure CR-1 under Alternative 3, would result in slightly lower median and maximum Prineville Reservoir elevations under Alternative 3 compared to both the no-action alternative and proposed action. Differences in reservoir elevation between Alternative 3 and the no-action alternative are greatest early in the winter storage period (October through December). Under Alternative 3, median monthly water surface elevations are less than the 90% flood storage capacity.

Wickiup Reservoir

Wickiup Reservoir median water surface elevations would be drawn down more under Alternative 3 over all years due higher minimum flows in years 1 through 5, and an absence of a maximum flow cap during the irrigation season in years 6 through 10 and years 11 through 30. Monthly median water surface elevations are less than the no-action alternative in every month (Figure 70). Water surface elevation differences are greatest during the irrigation season when Alternative 3 water surface elevations are more than 15 ft lower than the no-action water surface elevation. Alternative 3 maximum water surface elevations are similar to the no-action alternative results.

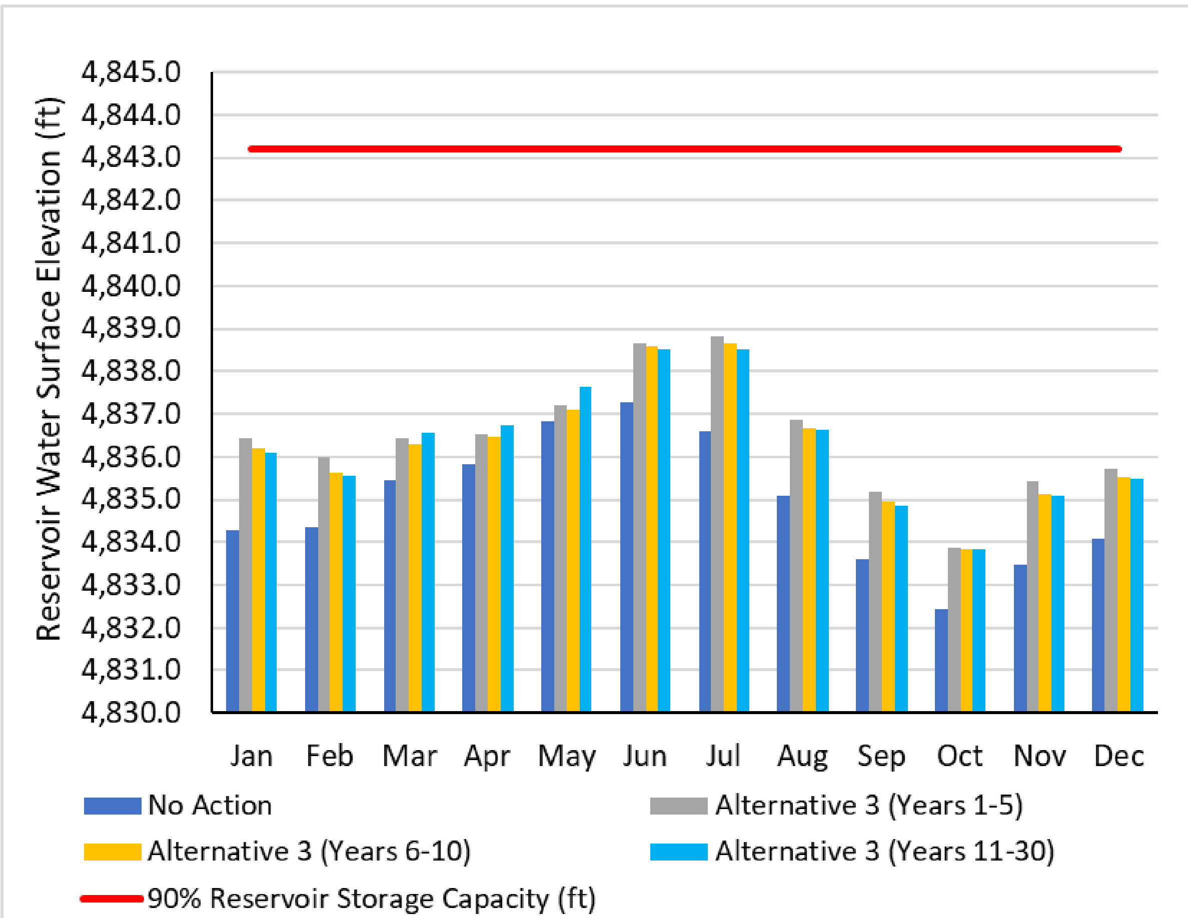
Figure 70. Modeled Monthly Median Water Surface Elevations for Wickiup Reservoir under Alternative 3 and the No-Action Alternative (The reference elevation associated with 90% flood storage capacity is 4,335.79 ft [red line]. The 90% flood storage capacity is based on a total reservoir capacity of 200,000 af.)



Crescent Lake Reservoir

Crescent Lake Reservoir would experience higher median water surface elevations due to lower minimum flows downstream from Crescent Lake Dam relative to the proposed action (Figure 71). Alternative 3 median water surface elevations would be lower relative to the no-action since the no-action alternative has a lower minimum flow requirement downstream from Crescent Lake Dam. Average median water surface elevation differences are slightly greater than the no-action alternative results during the storage season (1.5 feet) and during the irrigation season (1.3 feet). Alternative 3 has marginally higher maximum water surface elevations compared to the no-action and generally similar, if not lower, water surface elevations compared to the proposed action alternative.

Figure 71. Modeled Monthly Median Water Surface Elevations for Crescent Lake Reservoir under Alternative 3 and the No-Action Alternative (The reference elevation associated with 90% flood storage capacity is 4,843.21 ft [red line]. The 90% flood storage capacity is based on a total reservoir capacity of 86,500 af.)

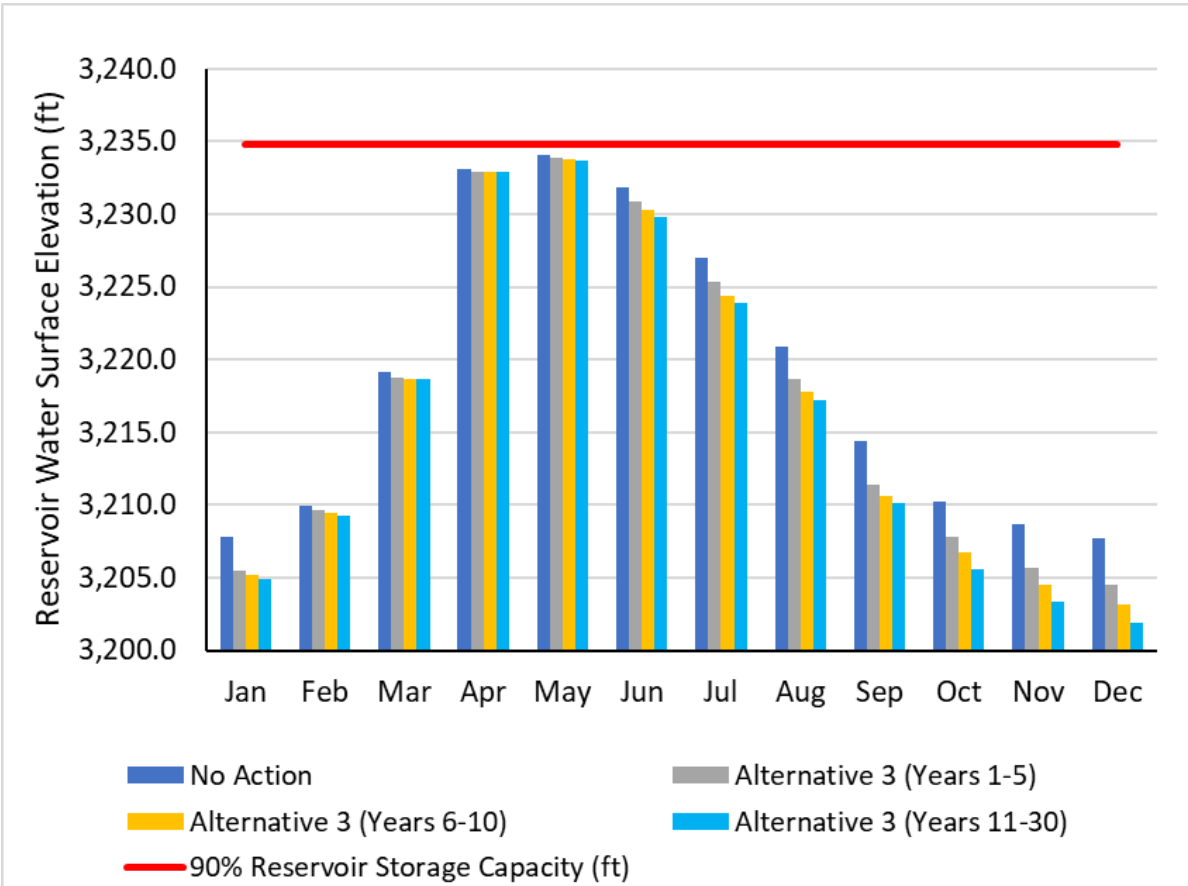


Prineville Reservoir

Prineville Reservoir would experience increasingly large differences in median water surface elevation over 30-year period as minimum flows on the Deschutes River require North Unit ID to increasingly rely on Prineville Reservoir releases and North Unit ID pump station operation to satisfy irrigation needs. Median water surface elevation differences are greatest in November and

December in years 11 through 30 when Alternative 3 water surface elevations are 5 feet lower than the no-action alternative (Figure 72). The maximum differences occur following irrigation season and before spring runoff contributions to reservoir storage. Alternative 3 maximum water surface elevations are marginally lower than the no-action from September through November, and are likewise lower than the proposed action maximum water surface elevations during the same period.

Figure 72. Modeled Monthly Median Water Surface Elevations for Prineville Reservoir under Alternative 3 and the No-Action Alternative (The reference elevation associated with the outlet works is 3,234.80 ft [red line]. The 90% flood storage capacity is based on a total reservoir capacity of 148,633 af.)



WR-4: Change Seasonal River and Creek Flow and Flood Flows

Modeled changes in streamflows are the same as described for the proposed action for all reaches except for the Crooked River, described below. In addition, modeled changes for the Deschutes River downstream of Wickiup Reservoir and for Crescent Creek would occur earlier in the permit term, and proposed action irrigation season flow caps do not apply to Alternative 3. Differences between Alternative 3 and the proposed action include:

- Alternative 3 years 1 through 5 have minimum Upper Deschutes River winter flows of 200 cfs versus the proposed action minimum flows of 100 cfs in years 1 through 7.

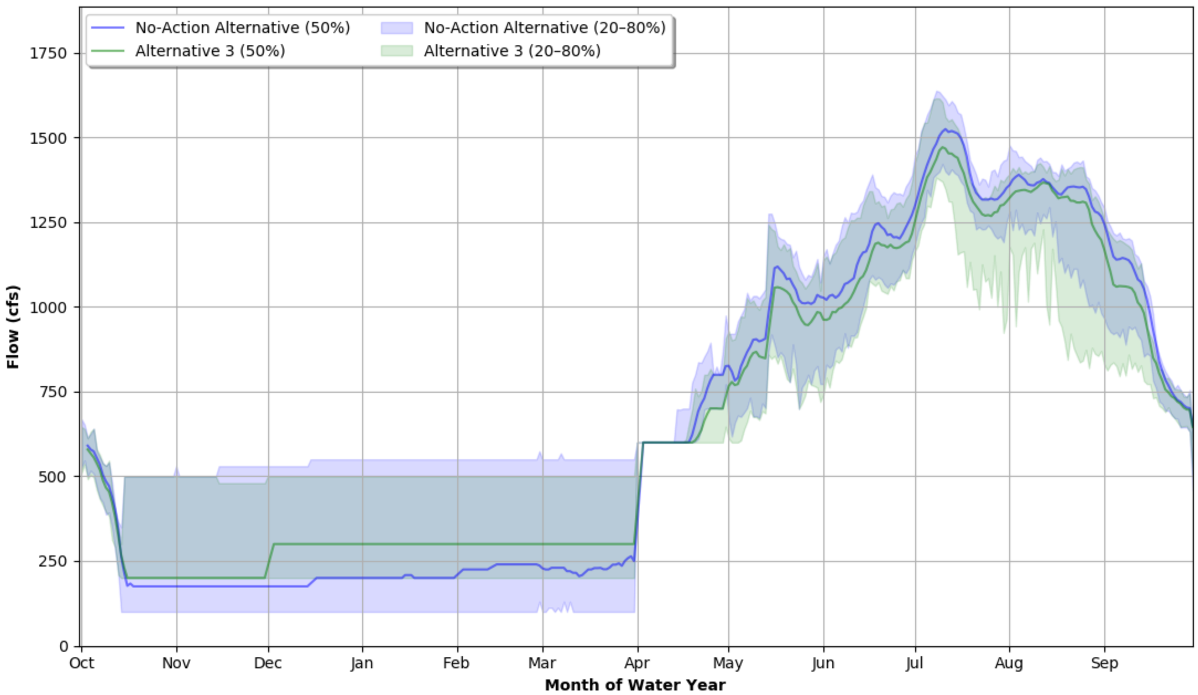
- Alternative 3 years 6 through 10 would be equivalent to proposed action years 8 through 12. Alternative 3 does not have the Upper Deschutes River 1,400 cfs maximum irrigation season cap included in the proposed action.
- Alternative 3 years 11 through 30 would be equivalent to proposed action years 13 through 30. Alternative 3 does not have the 1,200 cfs maximum irrigation season cap included in the proposed action.

Flood flow magnitude and number of days exceeding the flood flow threshold would be the same as described for the Crooked River. The Deschutes River would experience marginally different days of flood flow exceedance due to differences in minimum and maximum flows on the Deschutes River compared to the proposed action.

Deschutes River from Wickiup Dam to the Little Deschutes River

Conservation measures for the Deschutes River downstream from Wickiup Dam (Conservation Measure WR-1) are intended to increase minimum winter and spring flows downstream from the dam. Alternative 3 includes winter minimum flows of 200 cfs in years 1 through 5, 300 cfs in years 6 through 10, and variable minimum flows of 400 cfs to 500 cfs in years 11 through 30 depending on Wickiup Reservoir storage. Increasing minimum flows results in higher flows during winter and lower irrigation season flow compared to the no-action alternative (Figure 73). Irrigation season flows in years 11 through 30 are also more variable suggesting the impact of the minimum 400 cfs winter storage season flows on the irrigation period.

Figure 73. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Deschutes River at the WICO Gauge Downstream from Wickiup Reservoir under Alternative 3 in Years 1–5 (upper) and Years 11–30 (lower) Compared to No-Action Alternative



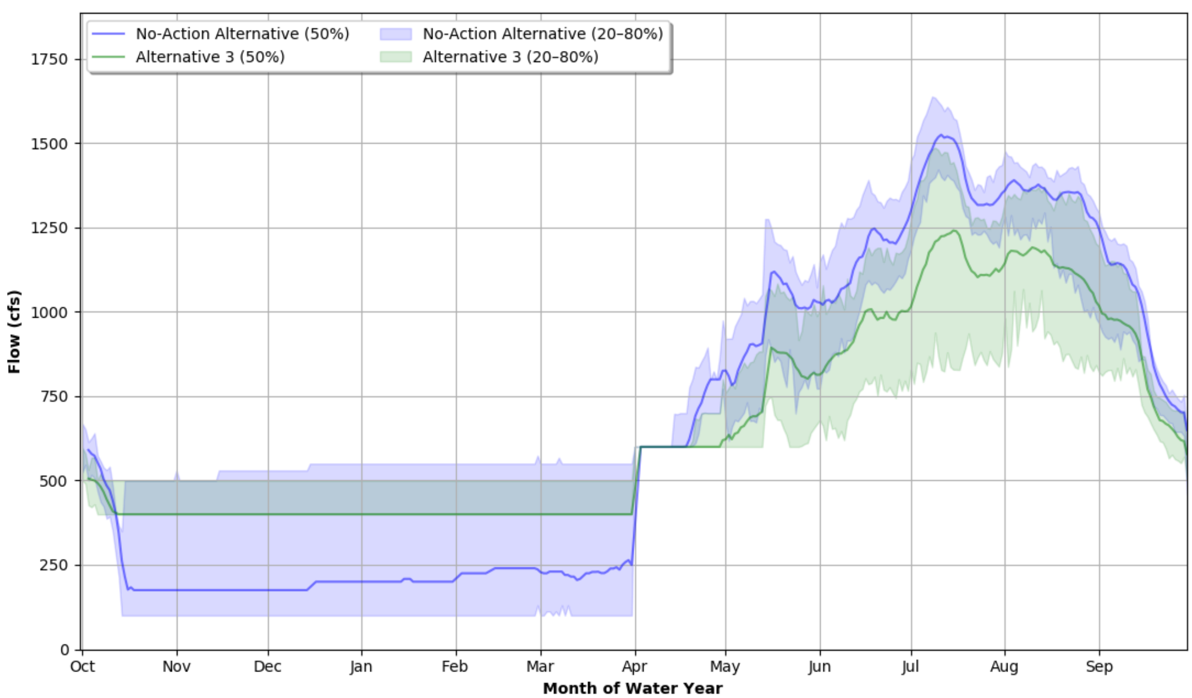


Table 43 includes a comparison of seasonal differences in minimum and maximum median flows based on WICO gauge data. Alternative 3 has higher winter storage flows, and higher minimum and lower maximum irrigation season flows compared to the no-action alternative. Flow characteristics are influenced by the progressively higher minimum winter storage flows over the permit term.

Table 43. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Deschutes River Downstream from Wickiup Reservoir by Season for the No-Action Alternative and Alternative 3 over the Permit Term

	Winter (Nov 1–Mar 31)		Irrigation (Apr 1–Oct 31)	
Alternative	**Minimum (cfs)**	**Maximum (cfs)**	**Minimum (cfs)**	**Maximum (cfs)**
No-Action	175.0	279.5	155.3	1,532.0
Alternative 3 (Years 1-5)	200.0	300.0	200.0	1,479.0
Alternative 3 (Years 6-10)	300.0	400.0	300.0	1,352.3
Alternative 3 (Years 11-30)	400.0	400.0	400.0	1,245.4

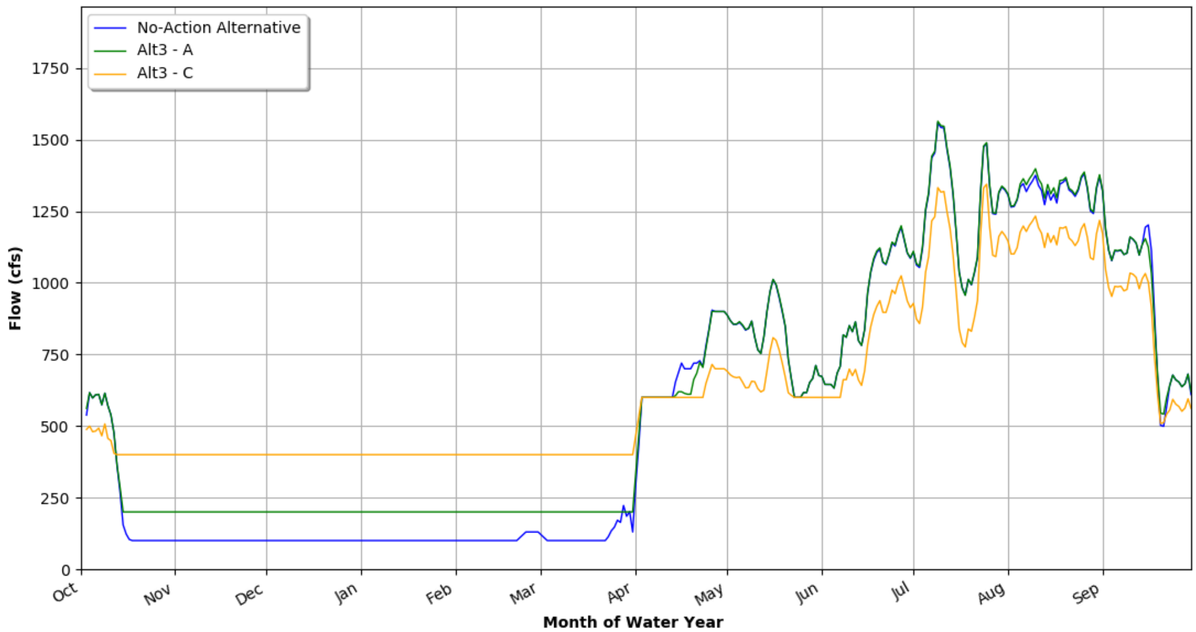
Total monthly streamflow volume (af) for representative wet, normal, and dry years was evaluated to assess changes in seasonal streamflow. Alternative 3 results are presented as the percent difference from the no-action alternative (Table 44). Winter storage season flows exhibit the greatest differences, especially in a dry year, relative to the no-action alternative.

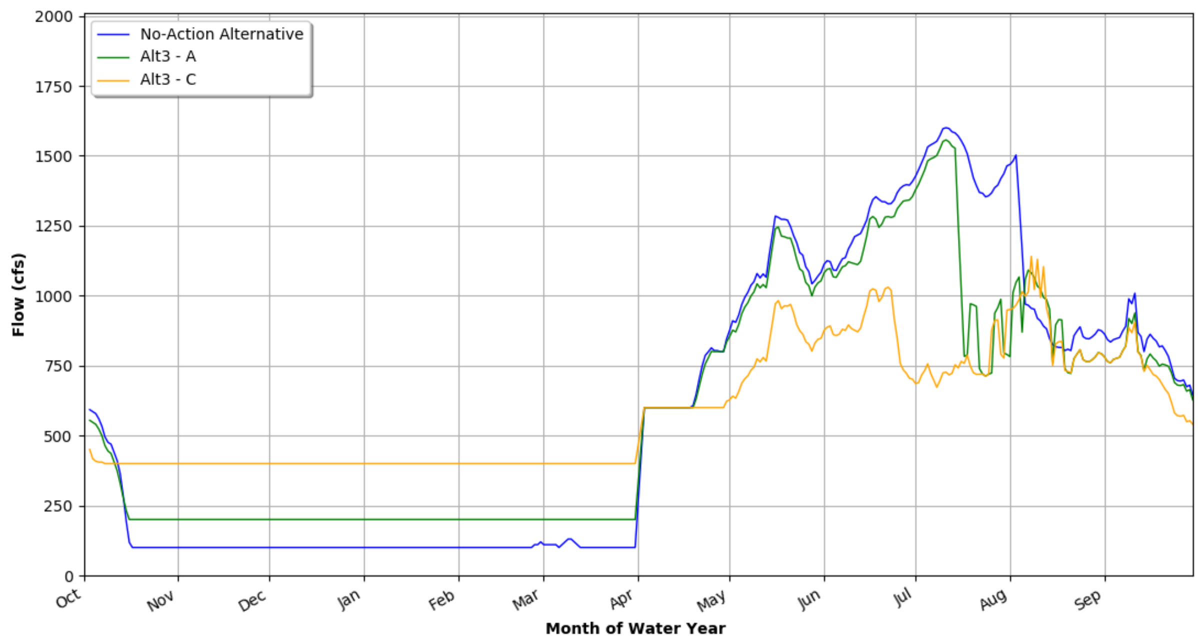
Table 44. Percent Differences in Streamflow Volume between the No-Action Alternative and Alternative 3 for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years at the WICO Gauge

		Alternative 3		
Water Year Type	**Time Period**	**Years 1–5**	**Years 6–10**	**Years 11–30**
Wet	Irrigation Period	1%	1%	3%
	Winter/Storage Period	29%	36%	49%
	Annual	6%	7%	11%
	1 SD	-9%	-12%	-17%
Normal	Irrigation Period	-1%	-6%	-13%
	Winter/Storage Period	6%	31%	43%
	Annual	0%	1%	-2%
	1 SD	-5%	-19%	-36%
Dry	Irrigation Period	-8%	-15%	-23%
	Winter/Storage Period	97%	196%	295%
	Annual	0%	0%	0%
	1 SD	-21%	-40%	-60%

Figure 74 includes the representative normal and dry year hydrographs for the WICO gauge under Alternative 3 in years 1 through 5 and years 11 through 30 of the permit term. Hydrographs for representative normal and dry years have similar patterns with winter storage flows higher and irrigation season flows lower than the no-action alternative.

Figure 74. Modeled Flows for the Deschutes River at the WICO Gauge under Alternative 3 in Years 1–5 (A) and Years 11–30 (C) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative





Deschutes River from the Little Deschutes River to Benham Falls

Implementation of Conservation Measure WR-1 influences Deschutes River flows in the Little Deschutes River to Benham Falls reach (Figure 75). Flow differences during the winter storage and irrigation seasons are magnified from years 1 through 5 to years 11 through 30 at the BENO gauge as minimum winter storage season flows increase.

Figure 75. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Deschutes River at the BENO Gauge under Alternative 3 Years 1–5 (upper) and Years 11–30 (lower) Compared to the No-Action Alternative

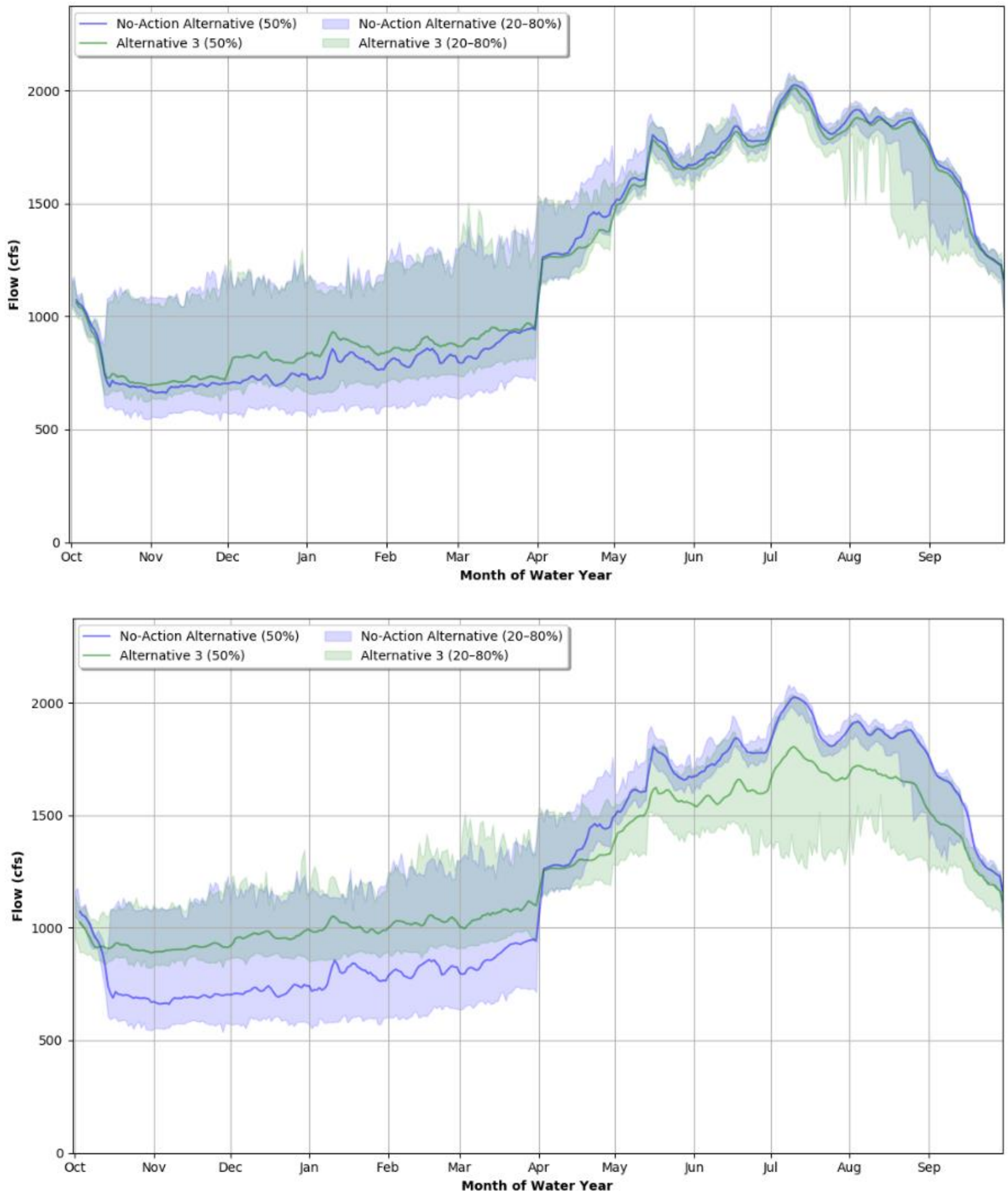


Table 45 includes a comparison of seasonal differences in minimum and maximum median flows for the permit term based on RiverWare output for the BENO gauge. The flow data show the increasing minimum and maximum median flows that would occur during the winter storage period over the permit term related to the implementation of Conservation Measure WR-1. Due to the increasing winter minimum flows, irrigation period flows experience an inverse relationship with decreasing maximum median daily flows.

Table 45. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Deschutes River at the BENO Gauge by Season for the No-Action Alternative and Alternative 3

	Winter (Nov 1–Mar 31)		Irrigation (Apr 1–Oct 31)	
Alternative	**Minimum (cfs)**	**Maximum (cfs)**	**Minimum (cfs)**	**Maximum (cfs)**
No-Action	651.3	960.4	637.5	2,029.6
Alternative 3 (Years 1-5)	695.3	976.5	693.2	2,015.5
Alternative 3 (Years 6-10)	790.5	1,051.3	787.8	1,910.8
Alternative 3 (Years 11-30)	890.5	1,123.3	887.8	1,811.8

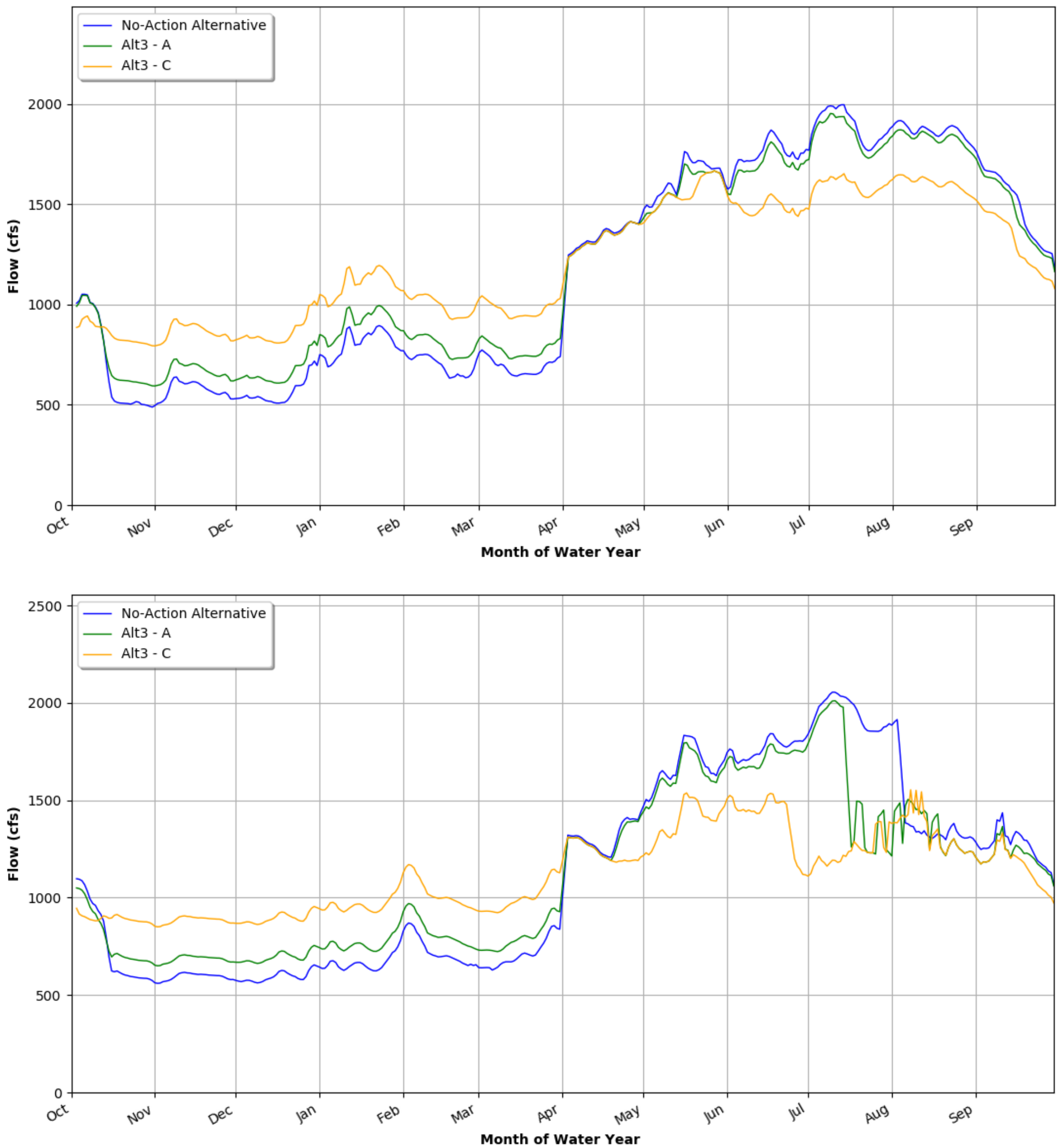
Total monthly streamflow volume (af) for representative wet, normal, and dry years were evaluated to assess changes in seasonal streamflow. Alternative results were compared to the no-action alternative and Alternative 3 results are reported as the percent difference from the no-action alternative (Table 46). Winter storage period flows in normal and dry years exhibit the greatest differences relative to the no-action.

Table 46. Percent Differences between the No-Action Alternative and Alternative 3 for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years for the BENO Gauge

		Alternative 3		
Water Year Type	**Time Period**	**Years 1–5**	**Years 6–10**	**Years 11–30**
Wet	Irrigation Period	0%	-2%	-1%
	Winter/Storage Period	-2%	0%	-2%
	Annual	-1%	-1%	-1%
	1 SD	-11%	-15%	-12%
Normal	Irrigation Period	-2%	-6%	-10%
	Winter/Storage Period	7%	20%	30%
	Annual	0%	1%	1%
	1 SD	-8%	-26%	-41%
Dry	Irrigation Period	-10%	-10%	-15%
	Winter/Storage Period	30%	30%	46%
	Annual	0%	0%	0%
	1 SD	-39%	-39%	-58%

Figure 76 includes the representative normal and dry year hydrographs for the BENO gauge under Alternative 3 in years 1 through 5 and years 11 through 30 of the permit term. Hydrographs for representative normal and dry years have similar patterns with the Alternative 3 flows higher during the winter storage season and lower during the irrigation season.

Figure 76. Modeled Flows for the Deschutes River at the BENO gauge under Alternative 3 Years 1–5 (A) and Years 11–30 (C) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative



Deschutes River from Benham Falls to Bend

Surface water diversions located between Lava Island and the DEBO gauge, and streamflow losses to groundwater, influence the amount of water remaining in the Deschutes River at the DEBO gauge (#14070500). Alternative 3 flows are higher than the no-action during the winter storage period, but flows are similar during the irrigation period as diversions above the DEBO gauge reduce instream flows. Alternative 3 median flows decline at a faster rate in mid to late April before tracking at similar flow levels compared to the no-action for the remainder of the irrigation season.

Figure 77. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Deschutes River at the DEBO Gauge under Alternative 3 Years 1–5 (upper) and Years 11–30 (lower) Compared to the No-Action Alternative

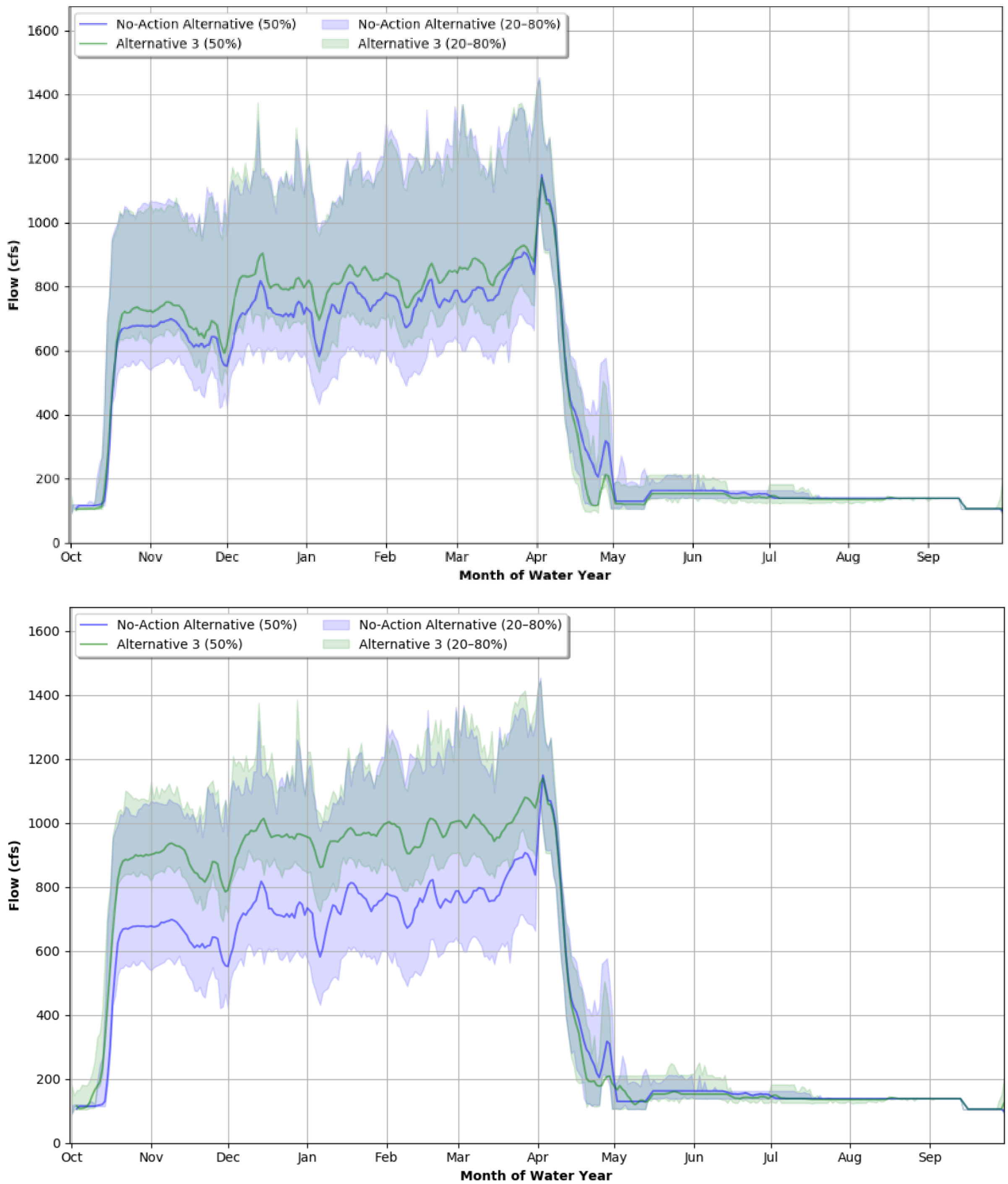


Table 47 includes a comparison of seasonal differences in minimum and maximum median flows based on DEBO gauge data. Median winter flows increase over the permit term as winter storage season minimum flows increase below Wickiup Dam. Irrigation season minimum median daily flows increase slightly and maximum median daily flows remain consistent over the permit term.

Table 47. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Deschutes River at the DEBO Gauge by Season for the No-Action Alternative and Alternative 3 over the Permit Term[1]

	Winter (Nov 1–Mar 31)		Irrigation (Apr 1–Oct 31)[2]	
Alternative	**Minimum (cfs)**	**Maximum (cfs)**	**Minimum (cfs)**	**Maximum (cfs)**
No-Action	535.0	913.8	89.8	1,183.1
Alternative 3 (Years 1-5)	575.4	942.4	95.6	1,173.1
Alternative 3 (Years 6-10)	670.4	1,032.3	103.8	1,173.1
Alternative 3 (Years 11-30)	770.4	1,092.7	105.0	1,173.1

1 Tumalo ID and Swalley ID water conservation projects would result in an additional 7.6 cfs of instream water during the irrigation season in years 1 through 5 and 15.2 cfs in years 6 through 30 under the no-action alternative and proposed action that were not modeled in RiverWare.

2 Minimum instream flow based on conserved water and instream leasing is 125.8 cfs.

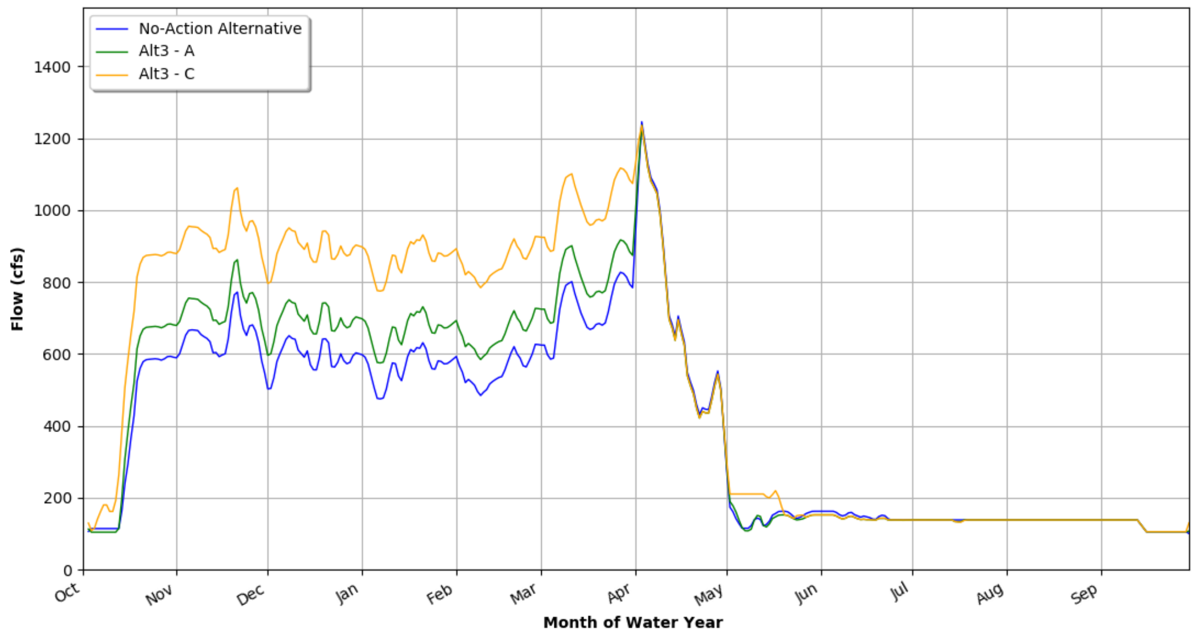
Like upstream gauges, Alternative 3 winter storage period flows in normal and dry years increase 45% and 52%, respectively compared to the no-action alternative. Irrigation period flows increase a smaller amount under both year types. Alternative 3 flows become more variable as winter storage flows increase a greater amount compared to the irrigation season flows.

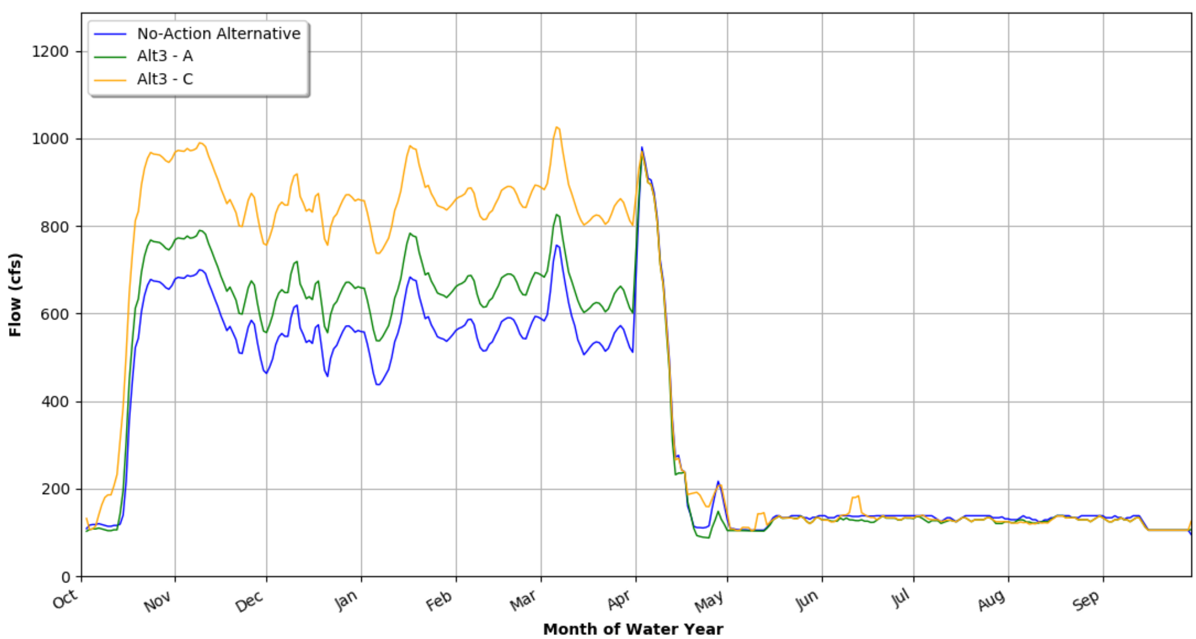
Table 48. Percent Differences between the No-Action Alternative and Alternative 3 for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years for the DEBO Gauge

		Alternative 3		
Water Year Type	**Time Period**	**Years 1–5**	**Years 6–10**	**Years 11–30**
Wet	Irrigation Period	-2%	1%	3%
	Winter/Storage Period	-1%	4%	1%
	Annual	-1%	3%	2%
	1 SD	-2%	4%	-1%
Normal	Irrigation Period	0%	6%	11%
	Winter/Storage Period	16%	32%	45%
	Annual	10%	22%	32%
	1 SD	16%	32%	45%
Dry	Irrigation Period	0%	6%	13%
	Winter/Storage Period	17%	34%	52%
	Annual	11%	25%	39%
	1 SD	22%	45%	67%

Figure 78 includes the representative normal and dry year hydrographs for the DEBO gauge under Alternative 3 in years 1 through 5 and years 11 through 30. In both time periods, winter flows are higher than the no-action alternative due to minimum flow requirements downstream from Wickiup Dam.

Figure 78. Modeled Flows for the Deschutes River at the DEBO Gauge under Alternative 3 in Years 1–5 (A) and Years 11–30 (C) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative

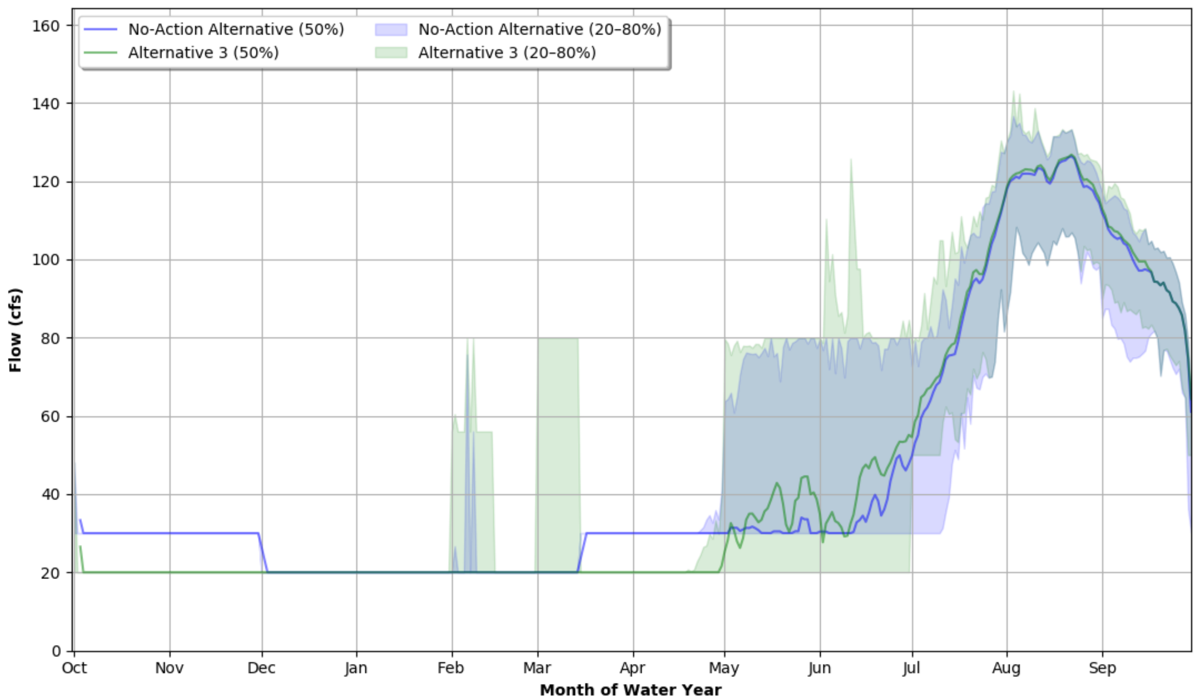




Crescent Creek from Crescent Lake to the Little Deschutes River

Crescent Creek conservation measures maintain minimum instream flows (CC-1), and address reservoir ramping rates (CC-2) and drawdown timing (CC-3). The RiverWare model only accounts for CC-1 and CC-3, ramping rates are not included in the RiverWare model. The lower winter storage flows associated with Alternative 3, provides more irrigation season storage. Alternative 3 flows from early May through the beginning of July are higher than the no-action alternative flows in both the early and later periods of the permit term. After mid-July, Alternative 3 and no-action alternative irrigation period median flows track similarly.

Figure 79. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Crescent Creek at the CREO Gauge Downstream from Crescent Lake Reservoir under Alternative 3 in Years 1–5 (upper) and Years 11–30 (lower) Compared to the No-Action Alternative



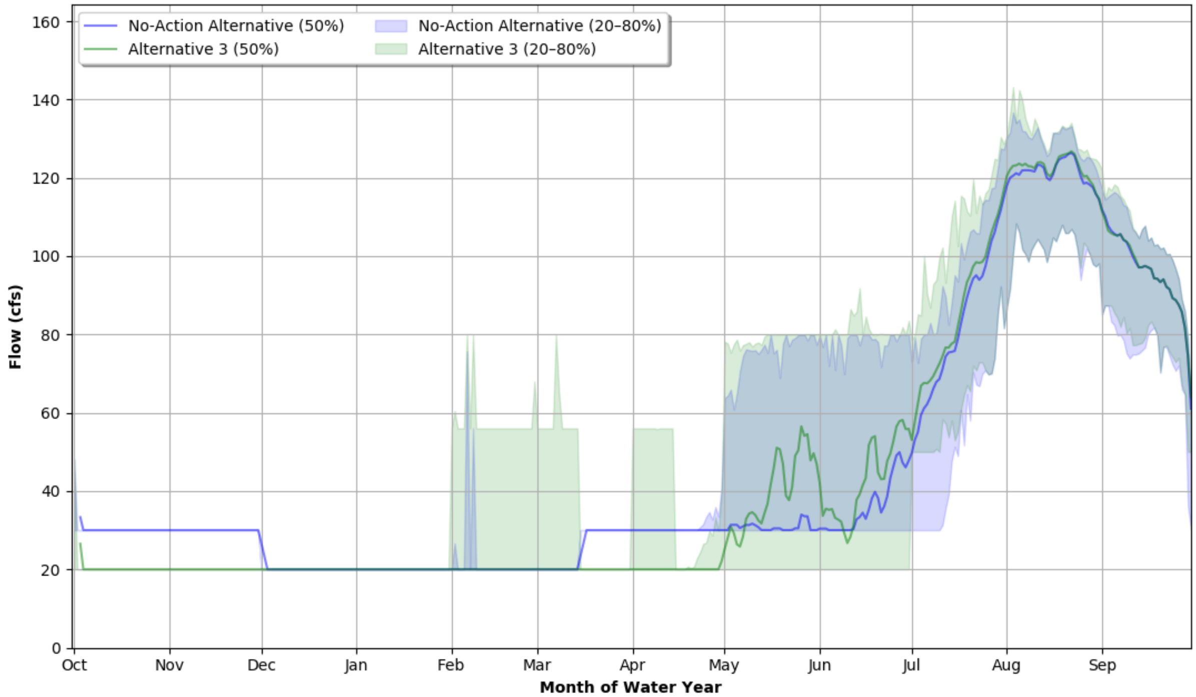


Table 49 includes a comparison of seasonal differences in minimum and maximum median daily flows based on CREO gauge data. Alternative 3 management has lower maximum median daily flows during the winter storage season, and lower minimum median daily flows during the irrigation season.

Table 49. Comparison of Minimum and Maximum Median (50%) Daily Flows on Crescent Creek Downstream from Crescent Lake Reservoir by Season for the No-Action Alternative and Alternative 3 over the Permit Term

	Winter (Nov 1–Mar 31)		Irrigation (Apr 1–Oct 31)	
Alternative	**Minimum (cfs)**	**Maximum (cfs)**	**Minimum (cfs)**	**Maximum (cfs)**
No-Action	20.0	30.0	30.0	126.9
Alternative 3 (Years 1-5)	20.0	20.0	20.0	127.7
Alternative 3 (Years 6-10)	20.0	20.0	20.0	127.7
Alternative 3 (Years 11-30)	20.0	20.0	20.0	127.7

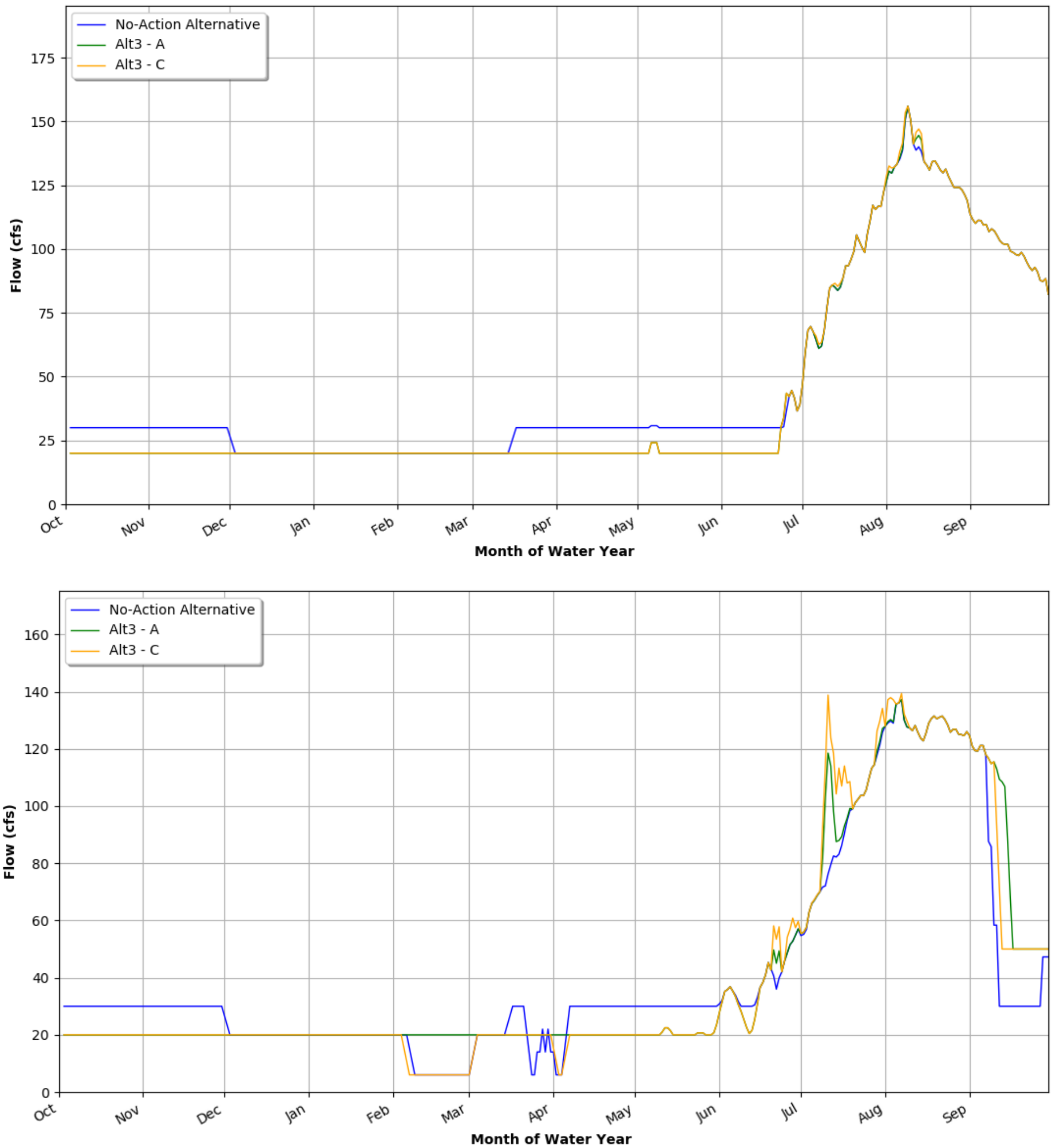
Total monthly streamflow volume (af) for representative wet, normal, and dry years was evaluated to assess changes in seasonal streamflow. Alternative 3 results are presented as the percent difference in streamflow from the no-action alternative (Table 50). Winter storage flows decline under normal and dry years, but increase 28% during wet years. Irrigation period flows decline 4% and 8% in wet and normal years, respectively, while remaining about the same in dry years.

Table 50. Percent Differences in Streamflow Volume between the No-Action Alternative and Alternative 3 for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years for the CREO Gauge

		Alternative 3		
Water Year Type	**Time Period**	**Years 1–5**	**Years 6-10**	**Years 11-30**
Wet	Irrigation Period	-4%	-2%	-4%
	Winter/Storage Period	28%	13%	28%
	Annual	2%	1%	2%
	1 SD	2%	1%	2%
Normal	Irrigation Period	-8%	-8%	-8%
	Winter/Storage Period	-13%	-13%	-13%
	Annual	-9%	-9%	-9%
	1 SD	6%	6%	7%
Dry	Irrigation Period	1%	0%	1%
	Winter/Storage Period	1%	-4%	-11%
	Annual	1%	-1%	-2%
	1 SD	8%	10%	12%

Figure 80 includes the representative normal and dry year hydrographs for the CREO gauge under Alternative 3 in years 1 through 5 and years 11 through 30 of the permit term. Alternative 3 lower winter storage minimum flows are apparent in the normal year plot. Irrigation season flows are similar for Alternative 3. Under the dry year scenario, Alternative 3 flows are generally less than no-action flows during winter storage, although no-action and Alternative 3 years 11–30 flows are more variable. Lower minimum flows associated with Alternative 3 result in more stored water in Crescent Lake Reservoir, extending flow levels slightly later into September compared to the no-action alternative.

Figure 80. Modeled Flows for Crescent Creek at the CREO Gauge Downstream from Crescent Lake Reservoir under Alternative 3 in Years 1–5 (A) and Years 11–30 (C) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative



Little Deschutes River from Crescent Creek Confluence to the Deschutes River

While there are no conservation measures outlined for the Little Deschutes River, Crescent Creek conservation measures influence Little Deschutes River flows. Alternative 3 median flows are less than the no-action alternative during winter storage due to the lower Alternative 3 minimum flows. Flows are marginally different compared to the no-action alternative for most of the irrigation season.

Figure 81. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Little Deschutes River at the LAPO Gauge under Alternative 3 Years 11-30 (C) Compared to the No-Action Alternative

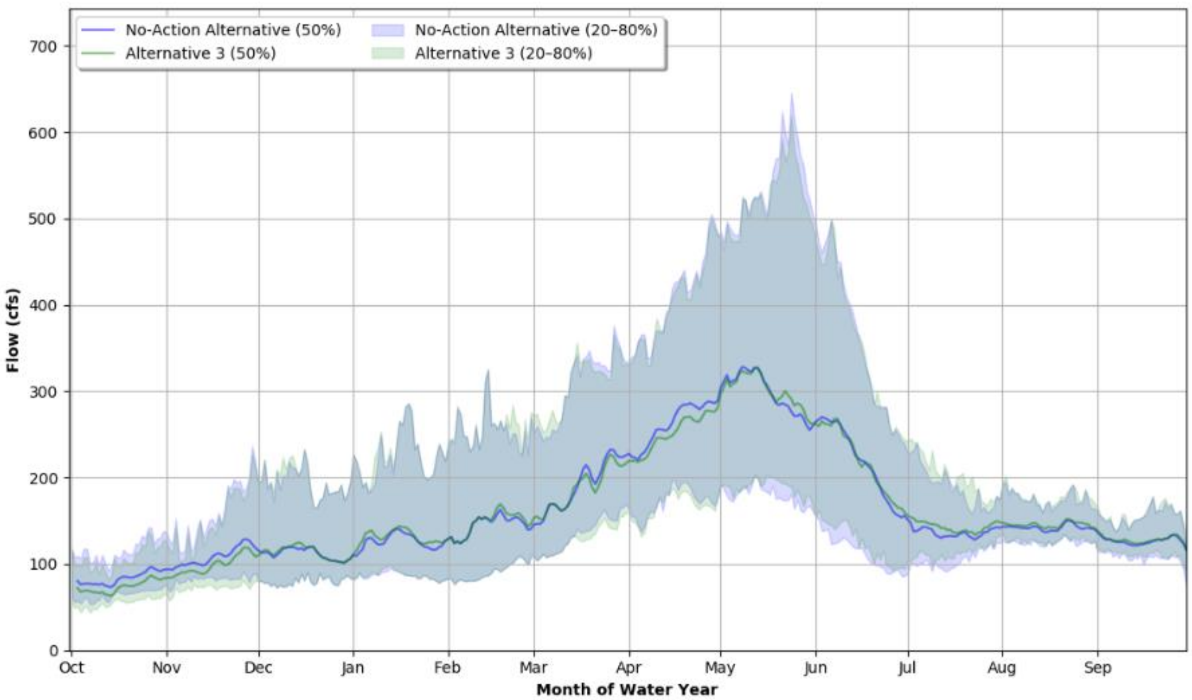


Table 51 includes a comparison of seasonal differences in minimum and maximum median flows based on LAPO gauge data. Alternative 3 minimum winter and irrigation period flows are influenced by the lower minimum flow releases (20 cfs instead of 30 cfs) from Crescent Lake Reservoir. Maximum flows during both periods are similar to the no-action alternative.

Table 51. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Little Deschutes River by Season for the No-Action Alternative and Alternative 3 over the Permit Term

	Winter (Nov 1–Mar 31)		Irrigation (Apr 1–Oct 31)	
Alternative	Minimum (cfs)	Maximum (cfs)	Minimum (cfs)	Maximum (cfs)
No-Action	92.4	238.2	69.6	334.3
Alternative 3 (Years 1-5)	83.6	241.6	59.6	330.3
Alternative 3 (Years 6-10)	83.6	233.2	59.6	330.3
Alternative 3 (Years 11-30)	83.6	233.2	59.6	330.3

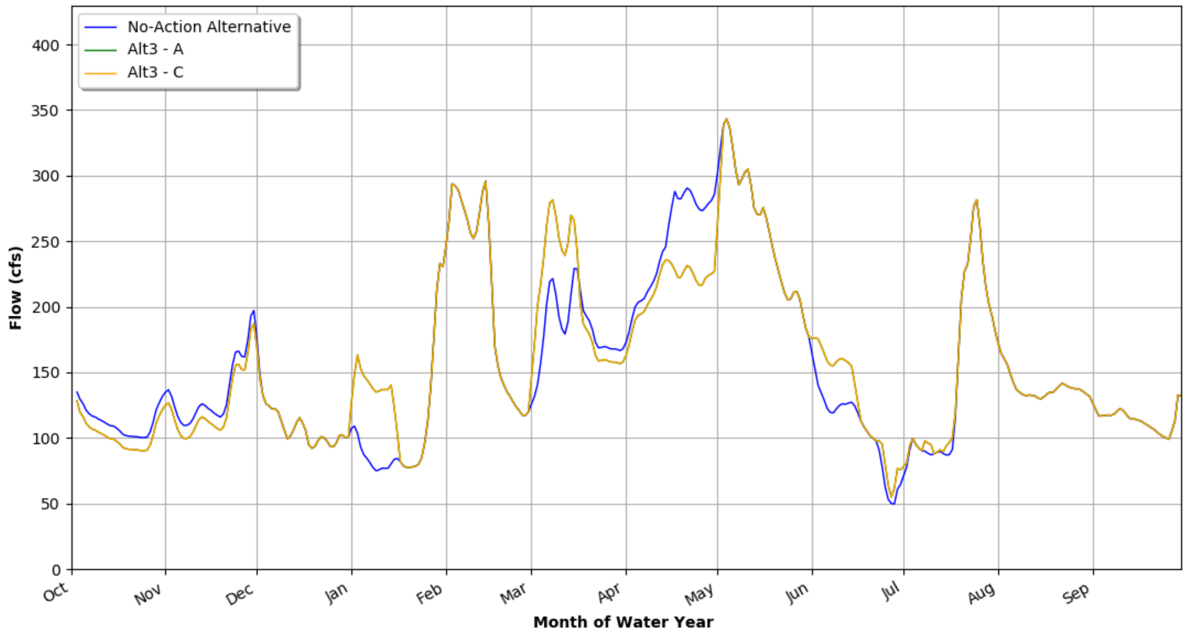
There are minimal differences in streamflow on the Little Deschutes River over the water year types, over the permit term periods, and over the seasonal periods (Table 52).

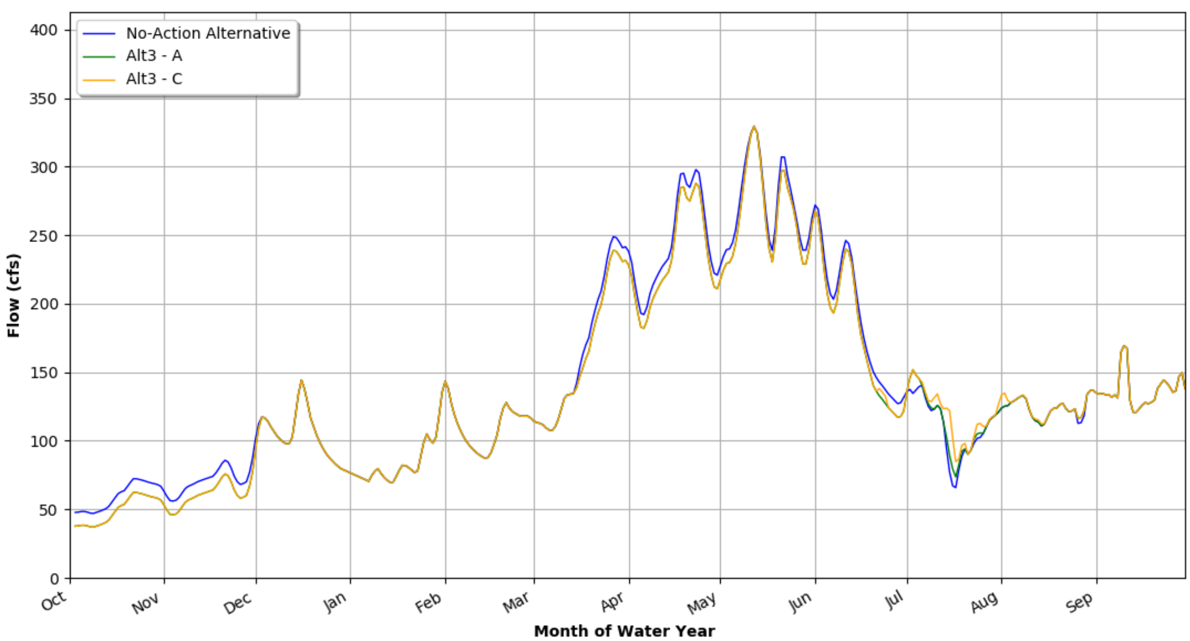
Table 52. Percent Differences in Streamflow Volume between the No-Action Alternative and Alternative 3 for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years for the LAPO Gauge

		Alternative 3		
Water Year Type	**Time Period**	**Years 1–5**	**Years 6-10**	**Years 11–30**
Wet	Irrigation Period	-1%	-1%	-1%
	Winter/Storage Period	-1%	-1%	1%
	Annual	-1%	-1%	0%
	1 SD	1%	1%	0%
Normal	Irrigation Period	-2%	-1%	-2%
	Winter/Storage Period	6%	3%	6%
	Annual	1%	1%	1%
	1 SD	-4%	0%	-4%
Dry	Irrigation Period	-3%	-2%	-2%
	Winter/Storage Period	-3%	-3%	-3%
	Annual	-3%	-3%	-2%
	1 SD	-3%	-3%	-3%

Figure 82 includes the representative normal and dry year hydrographs for the LAPO gauge under Alternative in years 1 through 5 and years 11 through 30 of the permit term. Proposed action winter storage flows are slightly less as minimum outflows from Crescent Lake Reservoir are reduced under Conservation Measure CC-1. Streamflow differences between Alternative 3 and the no-action alternative are related to Tumalo ID irrigation demand.

Figure 82. Modeled Flows for the Little Deschutes River at the LAPO Gauge under Alternative 3 Years 1–5 (A) and Years 11–30 (C) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative





Deschutes River from Bend to Culver

Like the DEBO gauge, the Culver gauge (CULO) shows the effects of higher winter minimum flows associated with Alternative 3 (Figure 83). Increasing minimum flows over the permit term, primarily influences winter flows. Irrigation period flows are similar under the proposed action in years 1 through 5 and years 11 through 30. Groundwater inputs to the Deschutes River in the Culver reach also contribute to streamflow, increasing the year-round magnitude of flows.

Figure 83. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Deschutes River at the CULO Gauge at Culver under Alternative 3 Years 1–5 (upper) and Years 11–30 (lower) Compared to the No-Action Alternative

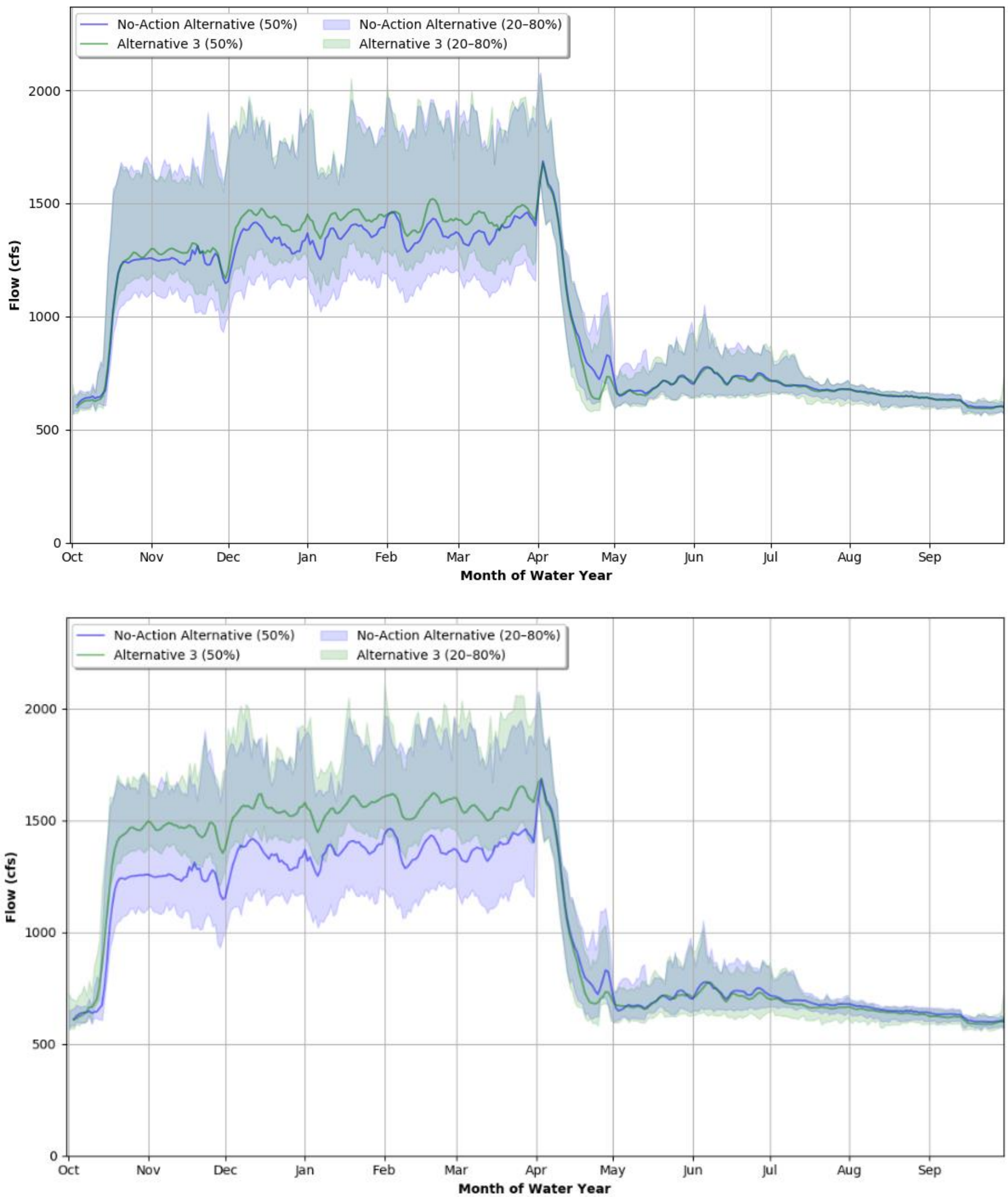


Table 53 includes a comparison of seasonal differences in minimum and maximum median flows based on CULO gauge data. Winter storage flows increase with increasing minimum flows for the Upper Deschutes River. Irrigation period flows are similar over the permit term and are only marginally different from the no-action alternative.

Table 53. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Deschutes River at the CULO Gauge by Season for the No-Action Alternative and Alternative 3 over the Permit Term

	Winter (Nov 1–Mar 31)		Irrigation (Apr 1–Oct 31)	
Alternative	**Minimum (cfs)**	**Maximum (cfs)**	**Minimum (cfs)**	**Maximum (cfs)**
No-Action	1,134.5	1,515.3	589.1	1,730.5
Alternative 3 (Years 1-5)	1,154.6	1,527.0	586.0	1,719.5
Alternative 3 (Years 6-10)	1,236.0	1,609.4	587.5	1,726.2
Alternative 3 (Years 11-30)	1,334.6	1,669.4	585.4	1,725.0

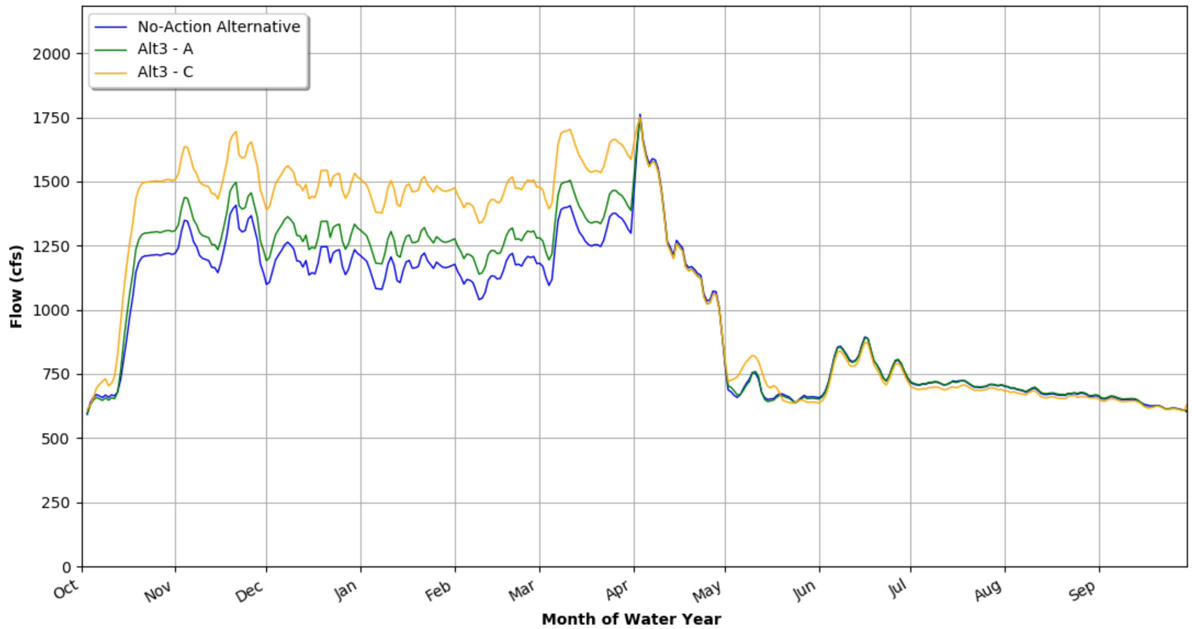
Total monthly streamflow volume (af) for representative wet, normal, and dry years was evaluated to assess changes in seasonal streamflow. Alternative 3 results were compared to the no-action alternative and Alternative 3 results are reported as the percent difference from the no-action alternative (Table 54). Total streamflow volume increases 1% in a wet year, but increases 13% and 14% in a normal and dry years, respectively as winter storage period flows increase up to 25% in a dry year. Irrigation period flows increase in normal and dry years by 1% and 2%, respectively. Monthly flow variability increases from wet to dry years, with the greatest variability associated with a dry year in years 11 through 30 of the permit term due to the influence of minimum winter flows on the Upper Deschutes River.

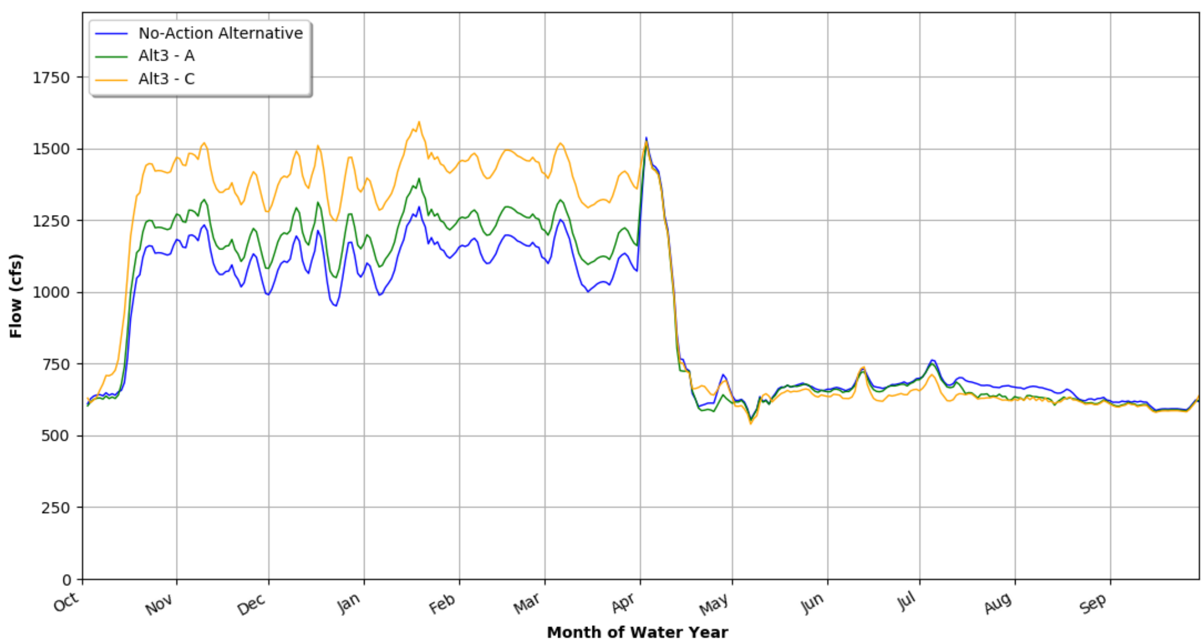
Table 54. Percent Differences in Streamflow Volume between the No-Action Alternative and Alternative 3 for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years for the CULO Gauge

		Alternative 3		
Water Year Type	**Time Period**	**Years 1–5**	**Years 6-10**	**Years 11–30**
Wet	Irrigation Period	-1%	0%	1%
	Winter/Storage Period	-1%	3%	1%
	Annual	-1%	2%	1%
	1 SD	-2%	3%	-1%
Normal	Irrigation Period	0%	1%	2%
	Winter/Storage Period	8%	16%	23%
	Annual	4%	9%	13%
	1 SD	15%	31%	44%
Dry	Irrigation Period	-1%	0%	1%
	Winter/Storage Period	8%	17%	25%
	Annual	4%	9%	14%
	1 SD	21%	43%	64%

Figure 84 includes the representative normal and dry year hydrographs for the CULO gauge under Alternative 3 in years 11 through 30 of the permit term. Streamflow patterns are similar to the DEBO gauge results with Alternative 3 flows higher in the winter and lower or similar to the no-action alternative during the irrigation period.

Figure 84. Modeled Flow for the Deschutes River at the CULO Gauge at Culver under Alternative 3 Years 1–5 (A) and Years 11–30 (C) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative





Deschutes River from Pelton Round Butte Dam to Madras

The Deschutes River at the Madras (MADO) gauge has similar median flows and flow variability for Alternative 3 (Figure 85). Alternative 3 median winter flows slightly increase as minimum flows increase on the Upper Deschutes River over the permit term. Likewise, irrigation period median flows decrease with increasing minimum winter flows and depleted reservoir storage.

Figure 85. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Deschutes River at the MADO Gauge Downstream from Lake Billy Chinook under Alternative 3 Years 1–5 (upper) and Years 11–30 (lower) Compared to the No-Action Alternative

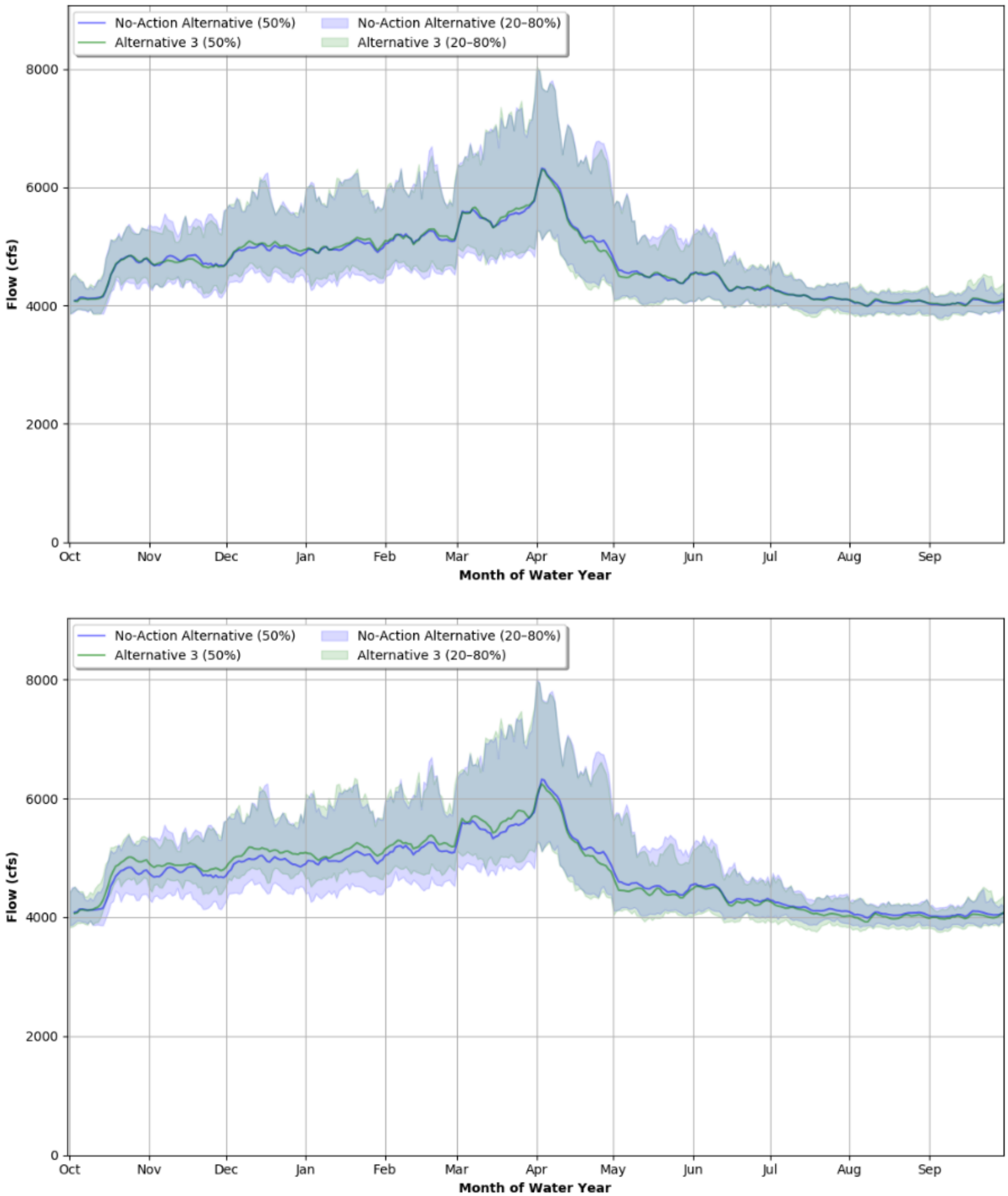


Table 55 includes a comparison of seasonal differences in minimum and maximum median flows based on MADO gauge data. Alternative 3 has progressively higher winter storage flows after years 1 through 5. Irrigation season flows marginally decrease over the permit term in response to the minimum winter storage flows.

Table 55. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Deschutes River at the MADO Gauge by Season for the No-Action Alternative and Alternative 3 over the Permit Term

	Winter (Nov 1–Mar 31)		Irrigation (Apr 1–Oct 31)	
Alternative	**Minimum (cfs)**	**Maximum (cfs)**	**Minimum (cfs)**	**Maximum (cfs)**
No-Action	4,603.0	5,802.0	3,986.7	6,364.5
Alternative 3 (Years 1-5)	4,582.6	5,838.1	3,955.7	6,347.5
Alternative 3 (Years 6-10)	4,646.0	5,863.1	3,934.6	6,282.2
Alternative 3 (Years 11-30)	4,735.6	5,936.5	3,908.8	6,272.3

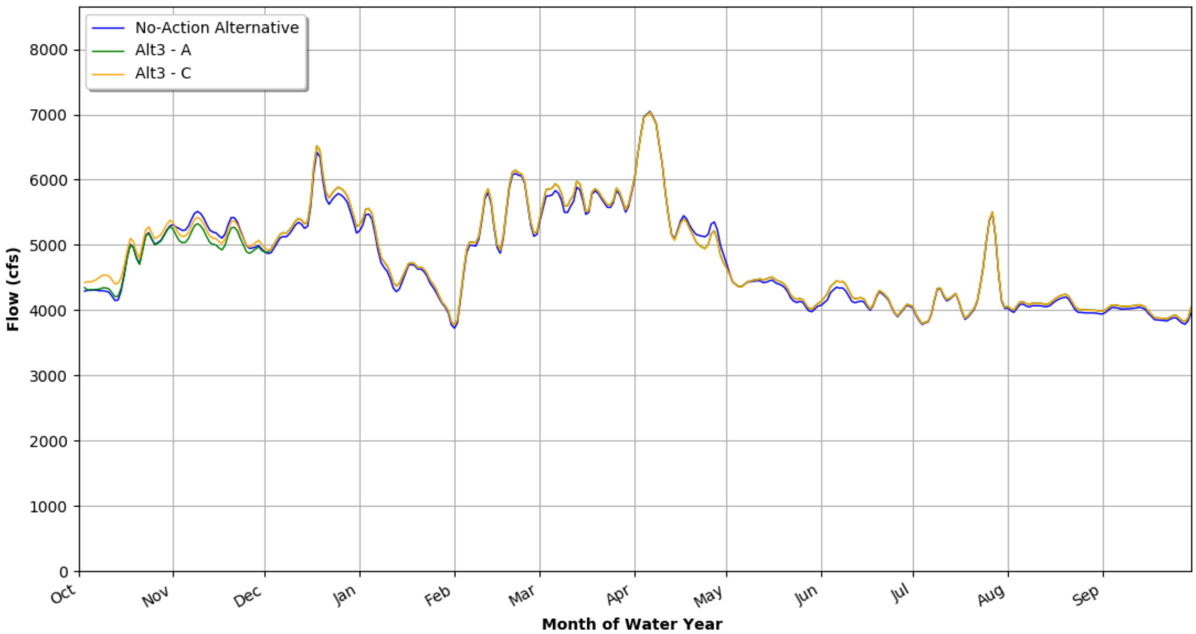
Total monthly streamflow volume (af) for representative wet, normal, and dry years was evaluated to assess changes in seasonal streamflow. Alternative 3 results were compared to the no-action alternative and Alternative 3 results are reported as the percent difference from the no-action alternative (Table 56). Streamflow changes are minimal in wet and normal years over the permit term. Flows are more variable in dry years as minimum winter flows increase and irrigation season flows decrease over the permit term.

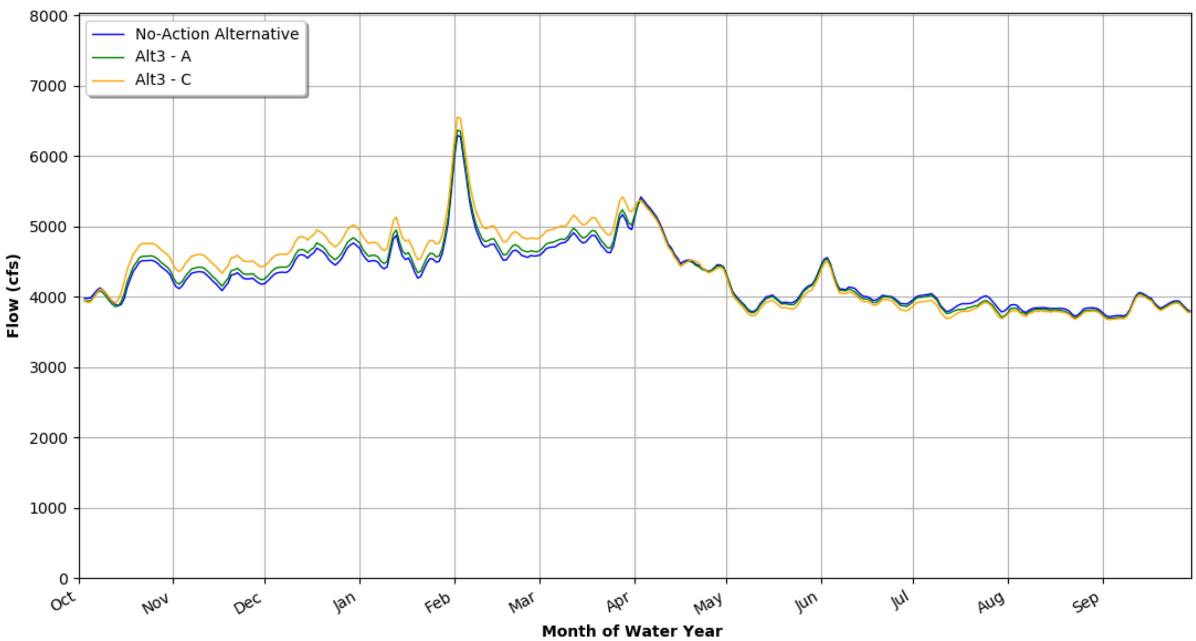
Table 56. Percent Differences in Streamflow Volume between the No-Action Alternative and Alternative 3 for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years for the MADO Gauge

		Alternative 3		
Water Year Type	**Time Period**	**Years 1–5**	**Years 6-10**	**Years 11–30**
Wet	Irrigation Period	1%	0%	0%
	Winter/Storage Period	-1%	-1%	-1%
	Annual	0%	0%	0%
	1 SD	-4%	-4%	-4%
Normal	Irrigation Period	0%	1%	1%
	Winter/Storage Period	1%	2%	3%
	Annual	1%	1%	2%
	1 SD	1%	1%	3%
Dry	Irrigation Period	-1%	-1%	-1%
	Winter/Storage Period	2%	4%	6%
	Annual	0%	1%	2%
	1 SD	20%	20%	32%

Figure 86 includes the representative normal and dry year hydrographs for the MADO gauge under Alternative 3 in years 1 through 5 and years 11 through 30 of the permit term. Alternative 3 streamflow is similar to the no-action alternative in a normal year. In a dry year, Alternative 3 flows are higher during the winter storage season, and similar to the no-action alternative during the irrigation season.

Figure 86. Modeled Flows for the Deschutes River at the MADO Gauge Downstream from Lake Billy Chinook under Alternative 3 Years 1–5 and Years 11–30 in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative





Deschutes River Flood Flows

Alternative 3 results in a reduction of days exceeding respective flood flow thresholds for the WICO, BENO, and DEBO+TUMO gauges (when 2,000 cfs is applied as the DEBO+TUMO gauge data threshold) (Table 57). When the lower flood flow threshold of 1,400 cfs is used, one additional day exceeds the flood threshold.

Table 57. Flood Flow Thresholds and Days of Flow Exceedance for the No-Action Alternative and Alternative 3 averaged over the Permit Term (Two flood flow thresholds are included for the DEBO+TUMO gauge data.)

Gauge	Flood Flow Threshold (cfs)	Average Number of Days of Flood Flow Threshold Exceedance per Year			
			Alternative 3		
		No-Action	Years 1–5	Years 6-10	Years 11-30
WICO	1,600	3.1	2.2	1.2	0.7
BENO	2,000	12.2	8.7	6.6	5.5
DEBO+TUMO	1,400	25.8	26.5	26.9	27.4
DEBO+TUMO	2,000	1.1	1.0	1.1	0.9

Crooked River Outflow from Bowman Dam

As under the proposed action, if uncontracted storage water is insufficient to meet the 50 cfs storage season minimum flow, Ochoco ID would release contracted water or bypass live flow to meet the minimum flow. Increasing minimum flows from 200 cfs (years 1–5 of the permit term) to 400 cfs (years 11–30 of the permit term) on the Upper Deschutes River results in water delivery shortage for North Unit ID, which in turn requires North Unit ID to rely more heavily on Crooked River water. To meet North Unit ID demand, additional water is released from Prineville Reservoir and higher Crooked River flows at the PRVO gauge are marked by elevated median flows from early-May through late June under Alternative 3 (Figure 87). Higher flows are released in years 11 through 30 to meet the higher demand associated with the 400 cfs minimum winter flows on the Upper Deschutes River.

Figure 87. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Crooked River at the PRVO Gauge under Alternative 3 for Years 1-7 (upper) and Years 11–30 (lower) Compared to the No-Action Alternative

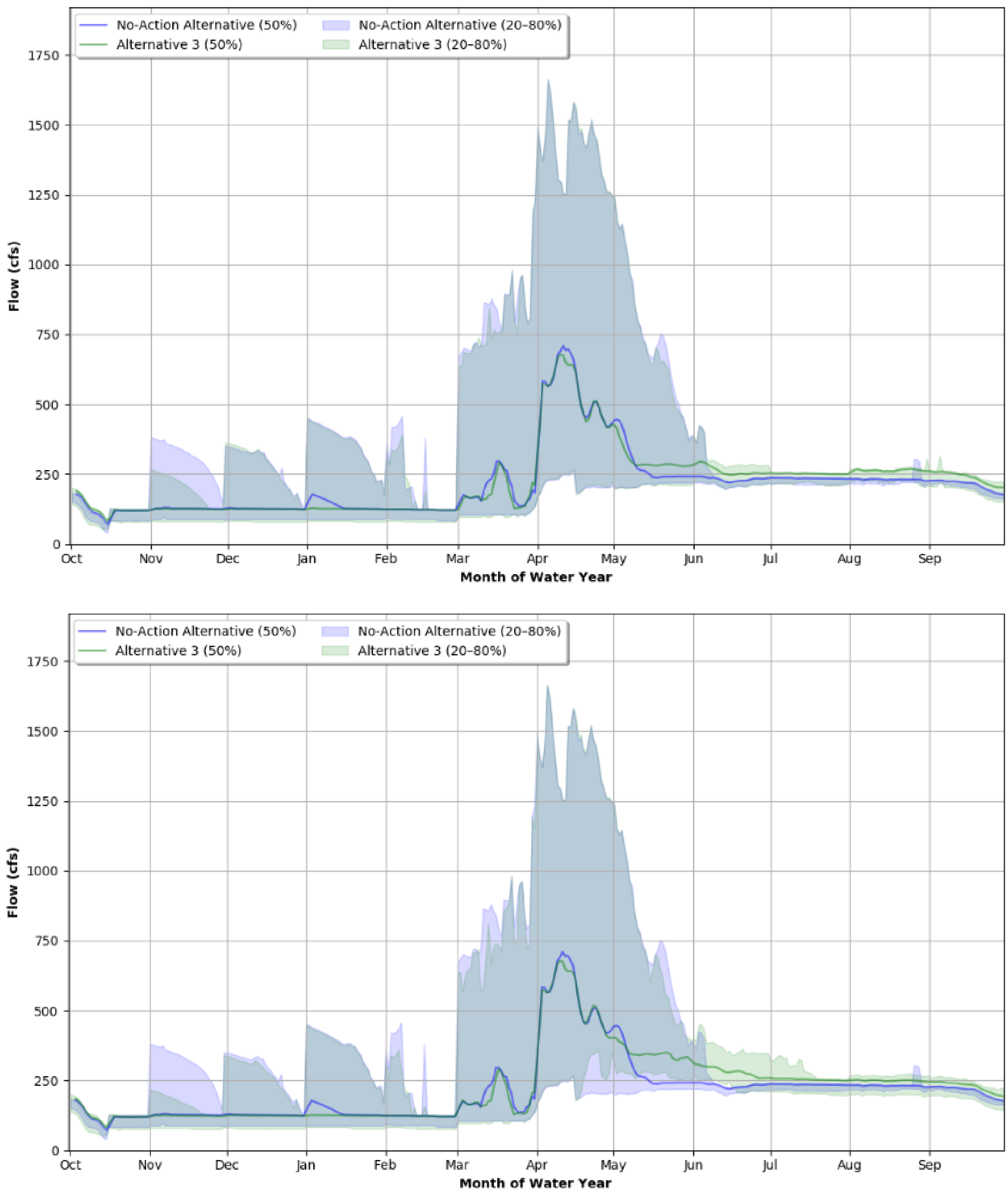


Table 58 includes a comparison of seasonal differences in minimum and maximum median flows based on PRVO gauge data. There are minor differences in the winter storage flows over the permit term. Minimum irrigation period flows are related to increased releases to meet North Unit ID irrigation demand.

Table 58. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Crooked River at the PRVO Gauge by Season for the No-Action Alternative and Alternative 3 over the Permit Term

	Winter (Nov 1–Mar 31)		Irrigation (Apr 1–Oct 31)	
Alternative	**Minimum (cfs)**	**Maximum (cfs)**	**Minimum (cfs)**	**Maximum (cfs)**
No-Action	119.6	304.4	62.7	734.6
Alternative 3 (Years 1-5)	120.6	300.0	75.6	701.1
Alternative 3 (Years 6-10)	120.6	299.4	75.6	701.4
Alternative 3 (Years 11-30)	120.6	299.1	75.6	701.4

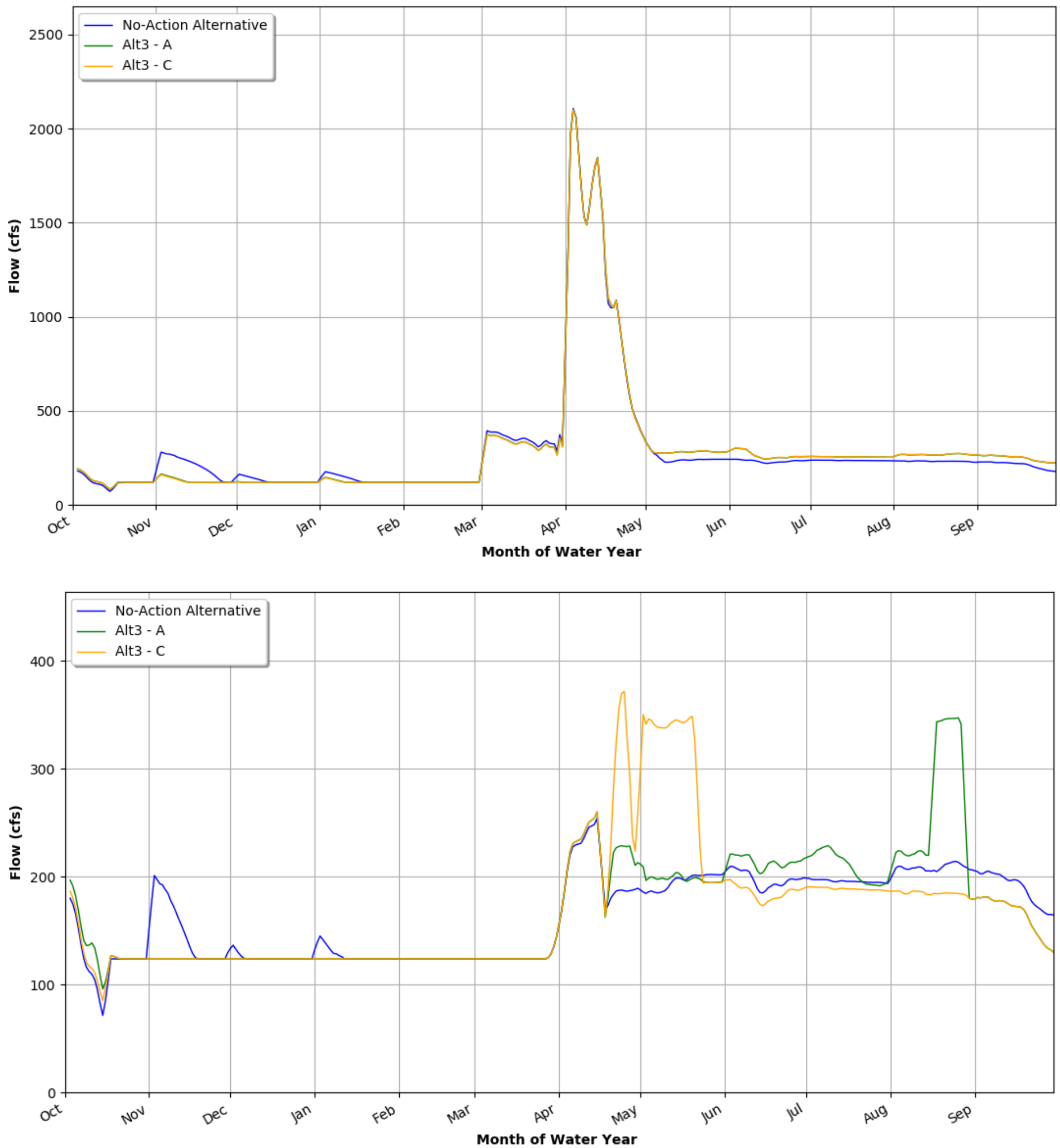
Total monthly streamflow volume (af) for representative wet, normal and dry years was evaluated to assess changes in seasonal streamflow (Table 59). Alternative 3 irrigation period flows increase 5% to 7% across the three water year types. Winter storage period flows decrease from 4% to 13% as reservoir storage is prioritized over live flow releases from Bowman Dam. Flows during a dry year are most variable as irrigation flows increase to satisfy North Unit ID demand.

Table 59. Percent Differences in Streamflow Volume between the No-Action Alternative and Alternative 3 for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years at the PRVO Gauge

		Alternative 3		
Water Year Type	**Time Period**	**Years 1–5**	**Years 6–10**	**Years 11–30**
Wet	Irrigation Period	4%	5%	5%
	Winter/Storage Period	-11%	-13%	-13%
	Annual	-1%	-1%	-1%
	1 SD	-4%	-3%	-3%
Normal	Irrigation Period	7%	7%	7%
	Winter/Storage Period	-4%	-4%	-4%
	Annual	4%	4%	4%
	1 SD	-1%	-1%	-1%
Dry	Irrigation Period	6%	5%	5%
	Winter/Storage Period	-3%	-4%	-4%
	Annual	3%	3%	3%
	1 SD	21%	29%	29%

Figure 88 includes the representative normal and dry year hydrographs for the PRVO gauge under Alternative 3 in years 1 through 5 and years 11 through 30. In a representative normal year, flows associated with Alternative 3 and the no-action alternative are very similar although Alternative 3 has higher irrigation season flows. In a representative dry year in years 11 through 30 of Alternative 3, Bowman Dam releases begin in mid-June to meet irrigation demand.

Figure 88. Modeled Flows for the Crooked River at the PRVO Gauge under Alternative 3 Years 1–5 and Years 11–30 in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative



Crooked River from Bowman Dam to Highway 126 Crossing

A similar pattern of lower maximum median winter storage period flows, and similar irrigation period flows occur at the CAPO gauge under Alternative 3. Like the results for the PRVO gauge, Alternative 3 median flows increase in years 1 through 5 from early May through the end of September to meet North Unit ID water demand (Figure 89). Flows during this time period increase in years 11 through 30 when more of North Unit ID's demand is met by Crooked River flows due to depleted stored water Wickiup Reservoir on the Upper Deschutes River.

Figure 89. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Crooked River at the CAPO Gauge under Alternative 3 Years 1–5 (upper) and Years 11–30 (lower) Compared to the No-Action Alternative

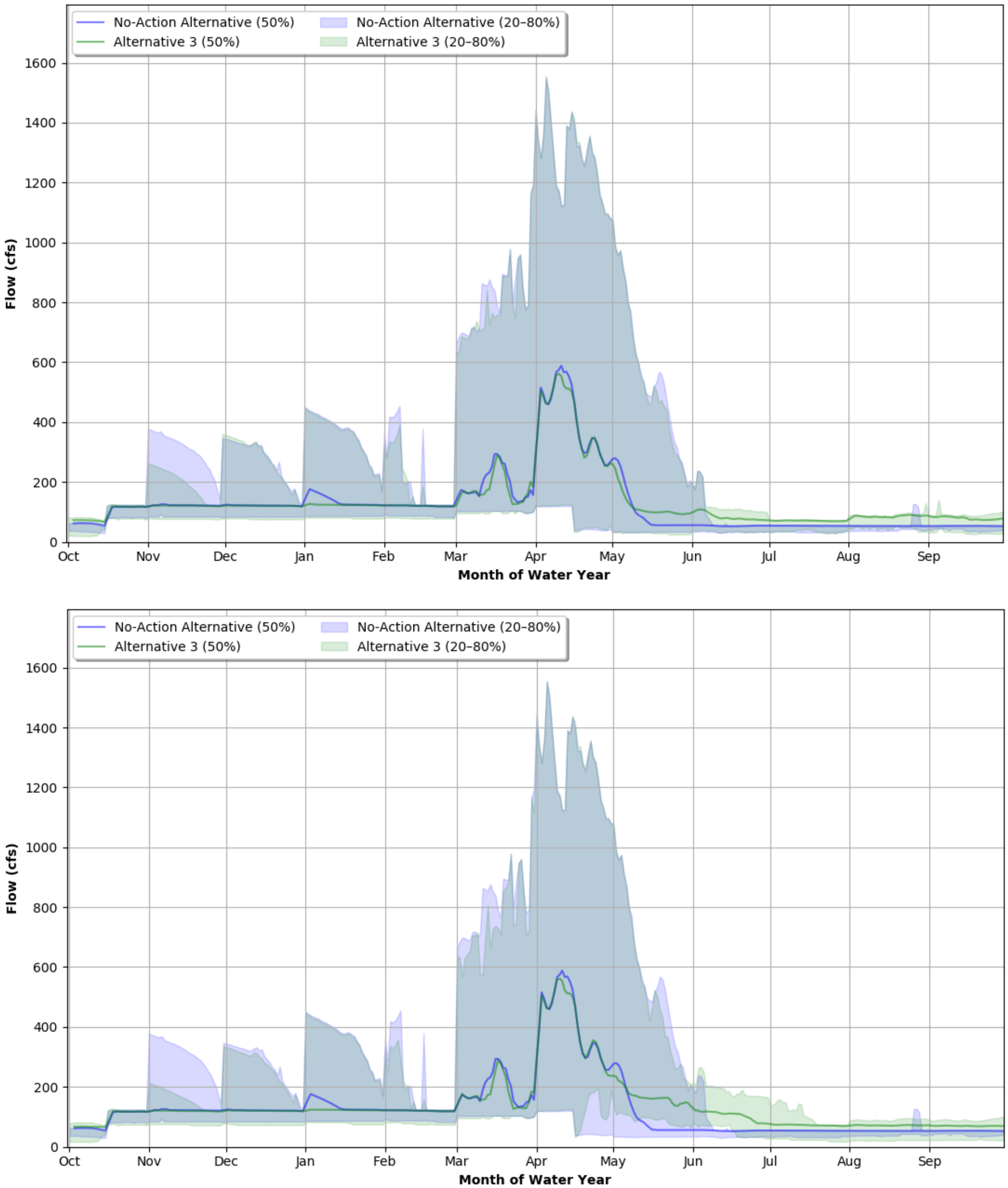


Table 60 includes a comparison of seasonal differences in minimum and maximum median flows based on CAPO gauge data. There are minimal differences in the minimum and maximum flow values for the winter and irrigation periods.

Table 60. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Crooked River at the CAPO by Season for the No-Action Alternative and Alternative 3 over the Permit Term

	Winter (Nov 1–Mar 31)		Irrigation (Apr 1–Oct 31)	
Alternative	**Minimum (cfs)**	**Maximum (cfs)**	**Minimum (cfs)**	**Maximum (cfs)**
No-Action	117.2	302.0	51.5	621.1
Alternative 3 (Years 1–5)	117.3	297.6	64.2	587.6
Alternative 3 (Years 6–10)	117.3	297.0	64.2	587.9
Alternative 3 (Years 11–30)	117.3	296.7	64.2	587.9

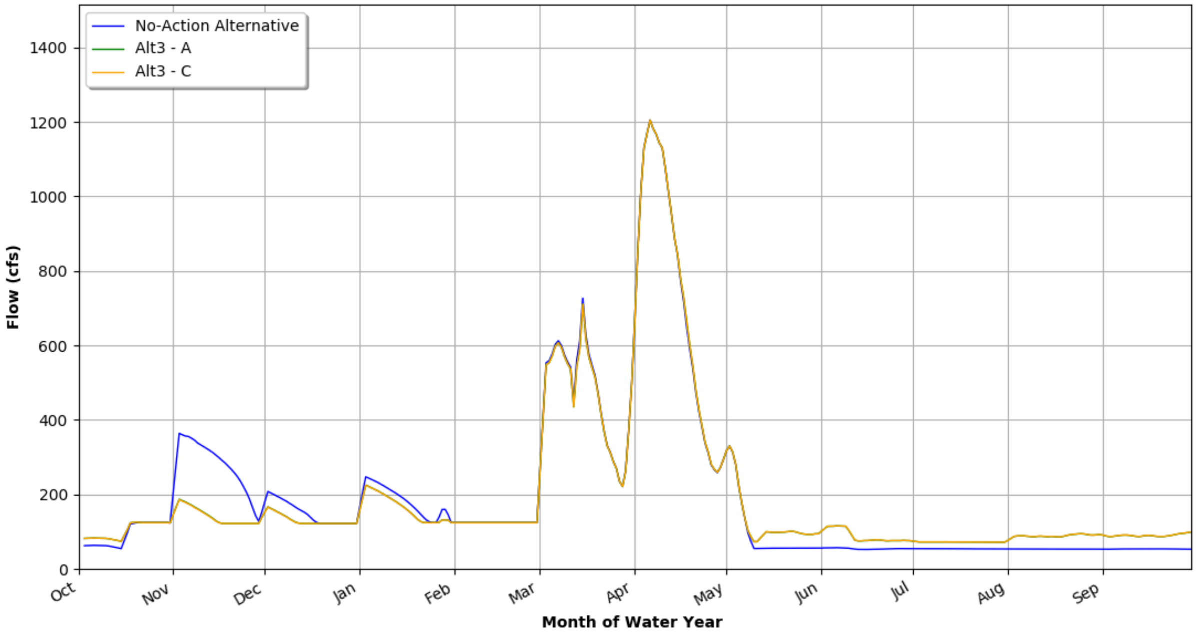
Total monthly streamflow volume (af) for representative wet, normal and dry years was evaluated to assess changes in seasonal streamflow (Table 61). Under Alternative 3. Irrigation period flows increase and winter storage period flows decrease as water is stored to meet later irrigation demand.

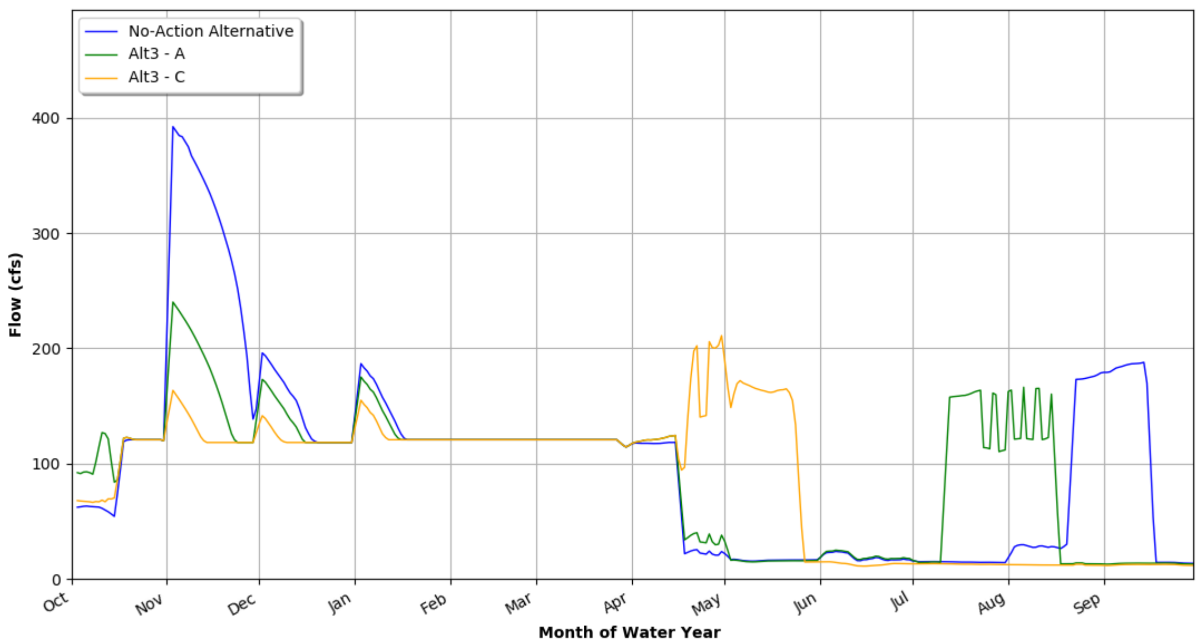
Table 61. Percent Differences in Streamflow Volume between the No-Action Alternative and Alternative 3 for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years at the CAPO Gauge

		Alternative 3		
Water Year Type	**Time Period**	**Years 1–5**	**Years 6–10**	**Years 11–30**
Wet	Irrigation Period	5%	7%	7%
	Winter/Storage Period	-11%	-13%	-13%
	Annual	-1%	-1%	-1%
	1 SD	-4%	-4%	-4%
Normal	Irrigation Period	15%	17%	15%
	Winter/Storage Period	-8%	-8%	-8%
	Annual	4%	5%	4%
	1 SD	-3%	-4%	-3%
Dry	Irrigation Period	3%	8%	8%
	Winter/Storage Period	-1%	-3%	-3%
	Annual	0%	1%	1%
	1 SD	0%	15%	24%

Figure 90 includes the representative normal and dry year hydrographs for the CAPO gauge under Alternative 3 in years 1 through 5 and years 11 through 30. In a representative normal year, flows associated with Alternative 3 and the no-action alternative are very similar although since more water is stored in Prineville Reservoir during the winter time, winter flows are more consistent compared to the no-action alternative. Month-long flow releases from Bowman Dam are called for from mid-May to mid-June in years 11 through 30, and from mid-June to mid-July in years 1 through 5. The earlier release in years 11 through 30 is in response to depleted storage in Wickiup Reservoir and North Unit ID's increasing reliance on Crooked River flows.

Figure 90. Modeled Flows for the Crooked River at the CAPO Gauge under Alternative 3 Years 1–5 (A) and Years 11–30 (C) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative





Ochoco Creek from Ochoco Dam to Crooked River

No additional conservation measures are associated with Ochoco Creek under Alternative 3. Ochoco ID would be required to release or bypass flow from Ochoco Reservoir to meet minimum flows in Ochoco Creek. Based on the RiverWare modeling results, Alternative 3 flows are the same as the no-action alternative and proposed action.

Crooked River from North Unit Irrigation District Pump Station to Smith Rock State Park

Crooked River streamflow at the Smith Rock gauge (CRSO) located downstream from the North Unit ID pump station is shown in hydrographs for the no-action alternative and Alternative 3 in years 1 through 5 and years 11 through 30 (Figure 91). The hydrographs are similar although median flows are lower from mid-June through early August as water is diverted by the North Unit ID pump station to meet water user demand. The difference between Alternative 3 and no-action alternative irrigation period flows increases in years 11 through 30 as more water is pumped at the North Unit ID pump station to meet water demand not met by the Upper Deschutes River. Under Alternative 3, releases of uncontracted storage from Prineville Reservoir would be protected instream year-round from Bowman Dam to Lake Billy Chinook.

Figure 91. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Crooked River at the CRSO Gauge under Alternative 3 Years 1–5 (upper) and Years 11–30 (lower) Compared to the No-Action Alternative

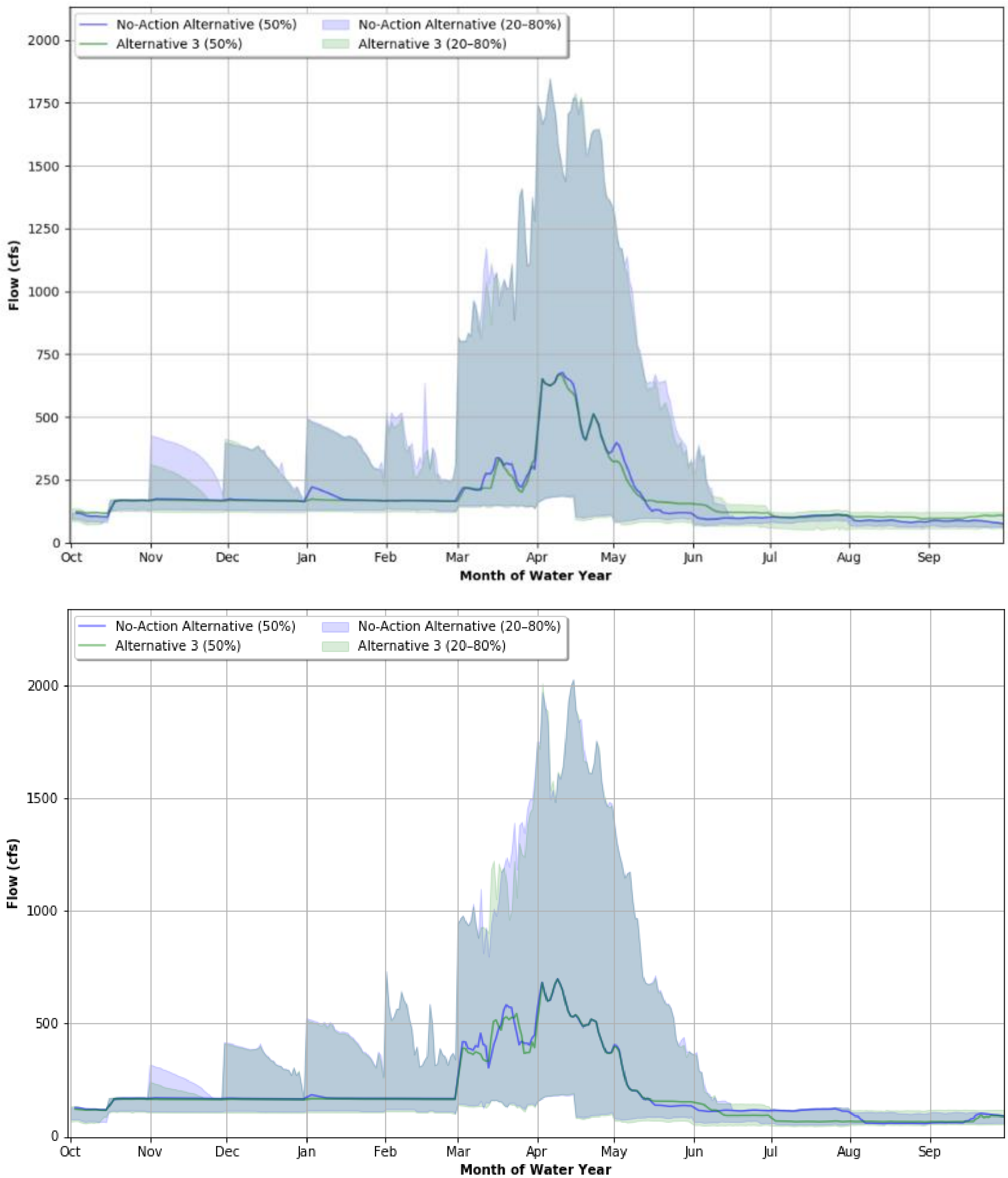


Table 62 includes a comparison of seasonal flow volume differences in minimum and maximum median flows based on CRSO gauge data. There are minimal flow differences over the permit term in both the winter storage and irrigation periods although maximum median winter storage flows decrease slightly for Alternative 3 relative to the no-action alternative. Minimum median irrigation period flows are lower than the winter storage flows, reflecting increasing North Unit ID pump station withdrawals by period of the permit term. Maximum median daily flows which are established early in the irrigation window, remain consistent over the permit term and flows are marginally different from the no-action alternative results.

Table 62. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Crooked River at the CRSO Gauge Downstream from the North Unit Irrigation District Pump Station by Season for the No-Action Alternative and Alternative 3 over the Permit Term

	Winter (Nov 1–Mar 31)		Irrigation (Apr 1–Oct 31)	
Alternative	**Minimum (cfs)**	**Maximum (cfs)**	**Minimum (cfs)**	**Maximum (cfs)**
No-Action	163.6	359.6	73.5	695.2
Alternative 3 (Years 1–5)	162.4	361.7	93.5	694.0
Alternative 3 (Years 6–10)	161.1	350.6	52.1	692.9
Alternative 3 (Years 11–30)	159.9	349.7	49.8	692.1

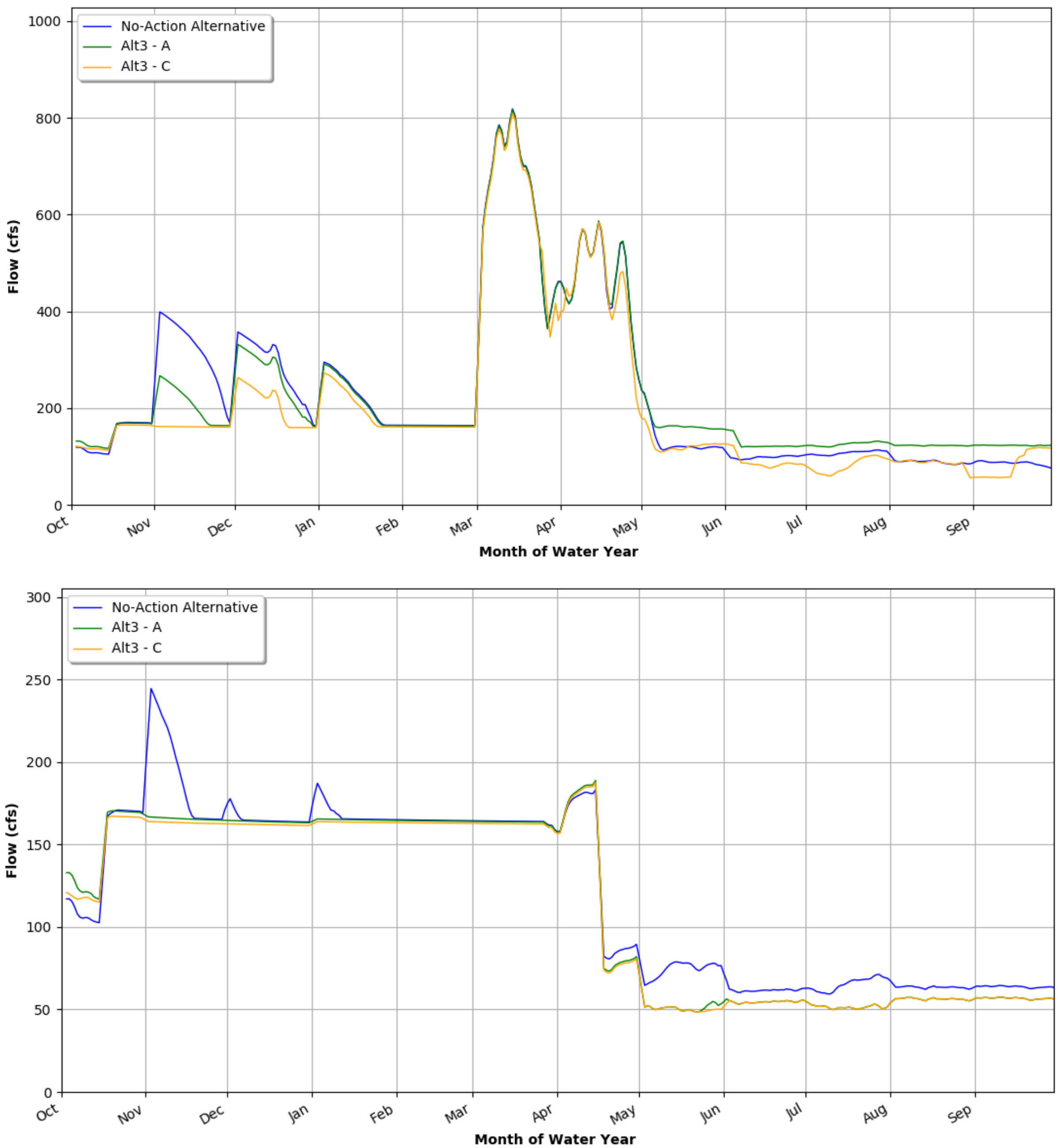
Total monthly streamflow volume (af) for representative wet, normal, and dry years were evaluated to assess changes in seasonal streamflow (Table 63). Irrigation period and winter storage period flows decline over the three year types and permit term periods. Irrigation period flows decline the most in a dry year when the North Unit ID pump station withdraws more water from the Crooked River to meet irrigation demand.

Table 63. Percent Differences in Streamflow Volume between the No-Action Alternative and Alternative 3 for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years at the CRSO Gauge

		Alternative 3		
Water Year Type	**Time Period**	**Years 1–5**	**Years 6–10**	**Years 11–30**
Wet	Irrigation Period	-4%	-8%	-8%
	Winter/Storage Period	-10%	-13%	-13%
	Annual	-6%	-10%	-10%
	1 SD	-3%	-2%	-2%
Normal	Irrigation Period	15%	11%	-2%
	Winter/Storage Period	-1%	-3%	-4%
	Annual	6%	3%	-3%
	1 SD	-5%	-5%	-5%
Dry	Irrigation Period	-12%	-13%	-13%
	Winter/Storage Period	-3%	-4%	-4%
	Annual	-7%	-8%	-8%
	1 SD	10%	10%	9%

Figure 92 presents the representative normal and dry year hydrographs for the CRSO gauge under Alternative 3. The hydrographs show the influence of the North Unit ID pump station flow diversion during the irrigation period in both normal and dry years, although the effect is more persistent lasting from May through September in a dry year.

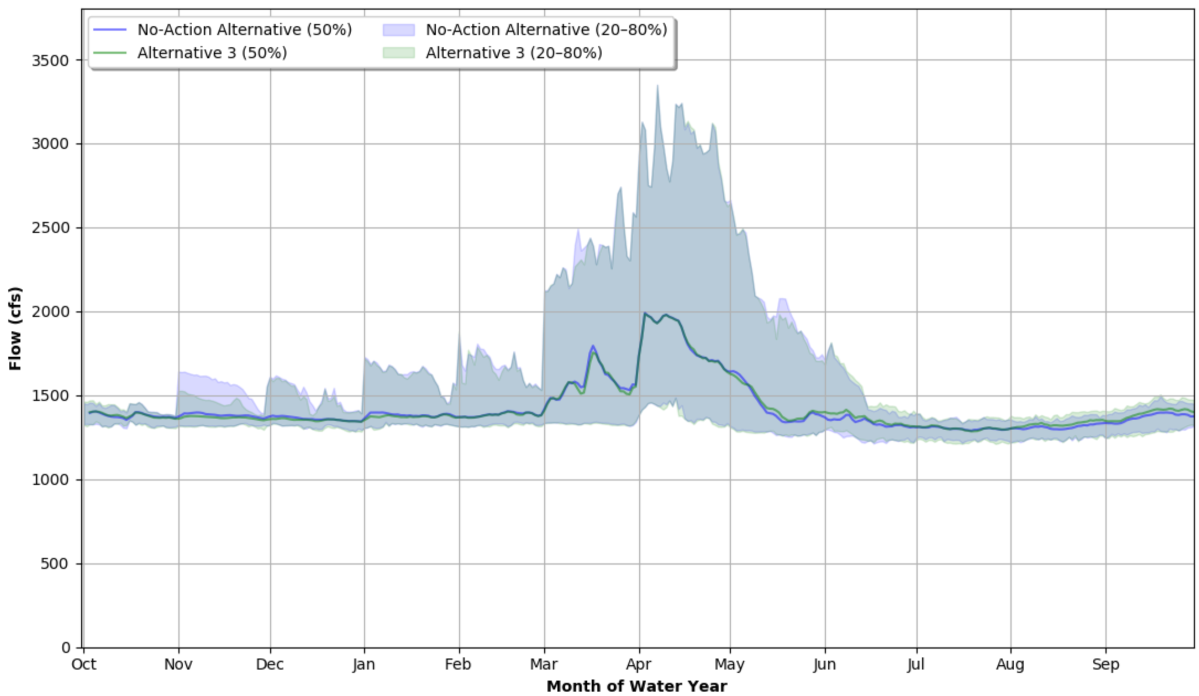
Figure 92. Modeled Flows for the Crooked River at the CRSO Gauge under Alternative 3 Years 1–5 (A) and Years 11–30 (C) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative. (Note flow scale differences.)



Crooked River from Smith Rock State Park to Opal Springs Dam

There are minor differences between no-action alternative and Alternative 3 flows at the CROO gauge downstream from Opal Springs Dam. Substantial groundwater inputs in this reach mask water management-related changes to Crooked River flows. Compared to the no-action alternative, there is a slight decrease in streamflow from late July through early August in years 11 through 30 of Alternative 3 (Figure 93). Otherwise, there are minor differences in the median flow values.

Figure 93. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Crooked River at the CROO Gauge Downstream from Opal Springs Dam under Alternative 3 Years 1–5 (upper) and Years 11–30 (lower) Compared to the No-Action Alternative



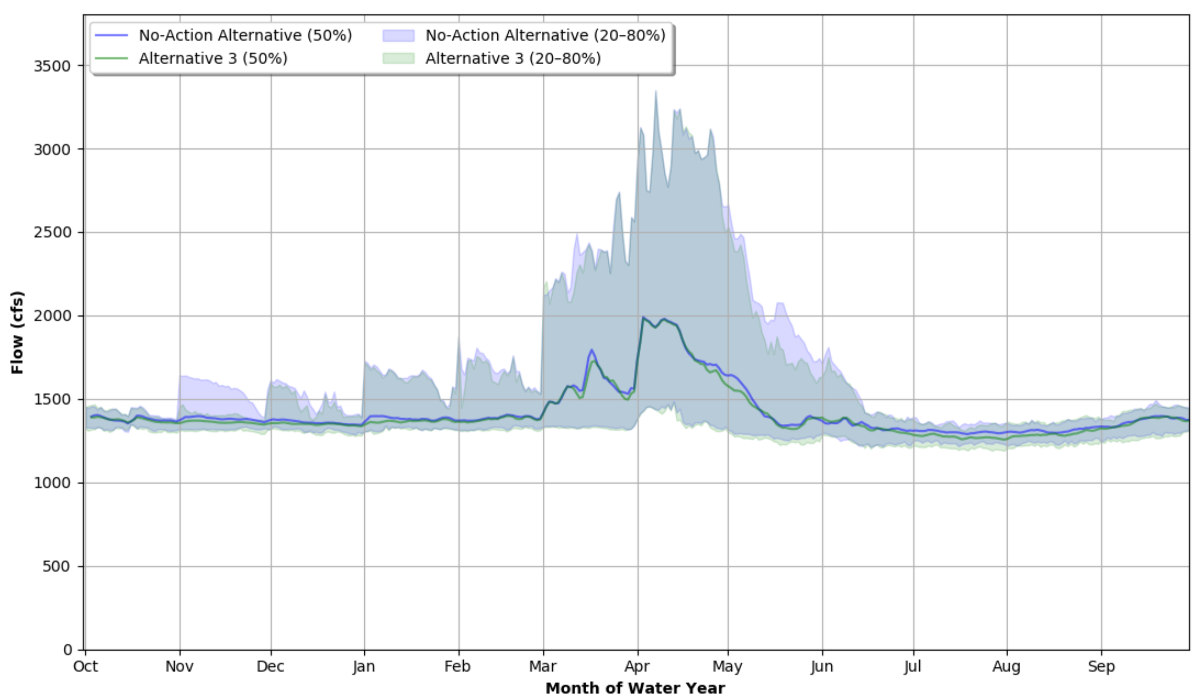


Table 64 includes a comparison of seasonal differences in minimum and maximum median flows based on CROO gauge data. The no-action alternative and Alternative 3 have similar minimum and maximum median flows in the winter and summer suggesting the influence of groundwater inputs.

Table 64. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Crooked River at the CROO Gauge for the No-Action Alternative and Alternative 3 over the Permit Term

	Winter (Nov 1–Mar 31)		Irrigation (Apr 1–Oct 31)	
Alternative	**Minimum (cfs)**	**Maximum (cfs)**	**Minimum (cfs)**	**Maximum (cfs)**
No-Action	1,340.4	1,821.8	1,286.3	2,038.0
Alternative 3 (Years 1–5)	1,338.8	1,761.3	1,278.6	2,025.0
Alternative 3 (Years 6–10)	1,336.3	1,745.5	1,264.9	2,022.9
Alternative 3 (Years 11–30)	1,333.8	1,743.6	1,249.8	2,021.1

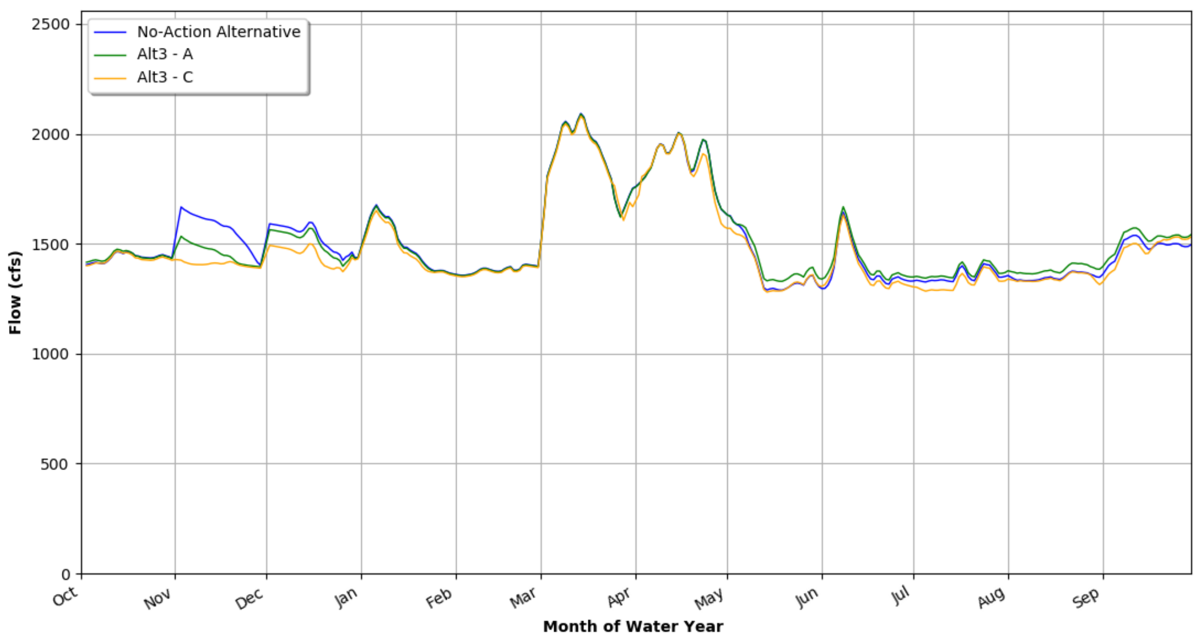
There are small differences in streamflow volumes in all water year types and over the permit term (Table 65). Differences relate to reduced winter storage flows as excess flow above minimum flow targets is stored in Prineville Reservoir, and the North Unit ID pump station diverts water to compensate for the effects of minimum flow targets on the Upper Deschutes River. The influence of the North Unit ID pump station diversion is less influential at the CROO gauge due to the large volume of groundwater inputs between the pump station and the CROO gauge. In short, flow differences related to Alternative 3 conservation measures have little influence on flows at the CROO gauge.

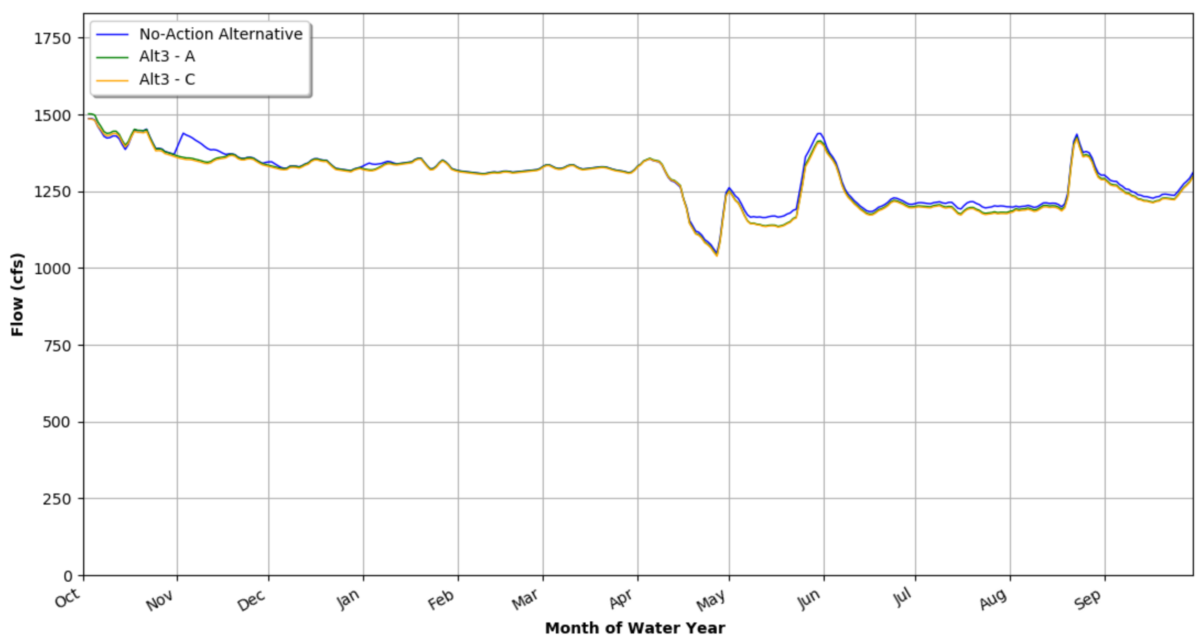
Table 65. Percent Differences in Streamflow Volume between the No-Action Alternative and Alternative 3 for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years at the CROO Gauge

		Alternative 3		
Water Year Type	**Time Period**	**Years 1–5**	**Years 6–10**	**Years 11–30**
Wet	Irrigation Period	-1%	-3%	-3%
	Winter/Storage Period	-3%	-4%	-4%
	Annual	-2%	-3%	-3%
	1 SD	-3%	-3%	-2%
Normal	Irrigation Period	2%	1%	-1%
	Winter/Storage Period	0%	-1%	-1%
	Annual	1%	0%	-1%
	1 SD	-3%	-3%	-2%
Dry	Irrigation Period	-1%	-1%	-1%
	Winter/Storage Period	0%	-1%	-1%
	Annual	-1%	-1%	-1%
	1 SD	2%	2%	2%

Figure 94 includes the representative normal and dry year hydrographs for the CROO gauge under Alternative 3 in normal and dry years. Similar to the preceding analyses, there are minimal flow differences between the no-action alternative and Alternative 3.

Figure 94. Modeled Flows for the Crooked River at the CROO Gauge under Alternative 3 Years 1–5 (A) and Years 11–30 (C) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative





WR-5: Affect Groundwater Recharge

Effects under Alternative 3 compared to the no-action alternative would be the same or nearly the same as described for the proposed action except that changes in the increase in seepage associate with the Deschutes River segment downstream of Sunriver would occur earlier in the permit term. There would be no meaningful adverse effect on the regional groundwater system.

Alternative 4: Enhanced and Accelerated Variable Streamflows

Alternative 4 would be the same as Alternative 3, with the following exceptions.

The permit term is 20 years rather than 30 years

Fall/winter releases from Wickiup Reservoir would increase at a faster rate and reach a higher minimum flow, as shown below.

- Years 1–5: 300 cfs
- Years 6–20: 400–600 cfs

Storage season minimum flows on the Crooked River would increase to 80 cfs from 50 cfs. The values presented in the effects analysis are direct RiverWare model outputs (without rounding). They are not intended as exact predictions of future conditions, but and are used for purposes of comparing among alternatives.

WR-1: Change Reservoir Storage

Crane Prairie Reservoir

Modeled changes in reservoir storage for Crane Prairie Reservoir under Alternative 4 compared to the no-action alternative would be the same as described for the proposed action.

Wickiup Reservoir

Under Alternative 4, as under the proposed action and Alternative 3, increased fall/winter releases from Wickiup Reservoir would result in decreased water supply storage in Wickiup Reservoir. Alternative 4 would accelerate the implementation of those changes and reach at a higher fall/winter minimum compared to the proposed action and Alternative 3. In years 1 to 5, Wickiup releases and associated storage would be the same as years 8 through 12 of the proposed action. In years 6 through 20,[17] the higher minimum fall/winter flow target would further decrease storage compared to the proposed action years 13 through 30.

As winter flow releases from Wickiup Reservoir increase above no-action levels beginning in year 1 (Conservation Measure WR-1), Wickiup Reservoir storage would decline, with the greatest declines observed in years 6 through 20 of the permit term (Table 66, Table 67, and Figure 95). In a normal water year during years 6 through 20, water supply storage would be reduced by 104,364 af compared to the no-action alternative.

[17] Alternative 4 considers a shorter permit term than the proposed action and Alternative 3.

Table 66. Wickiup Reservoir Storage under the No-Action Alternative and Alternative 4

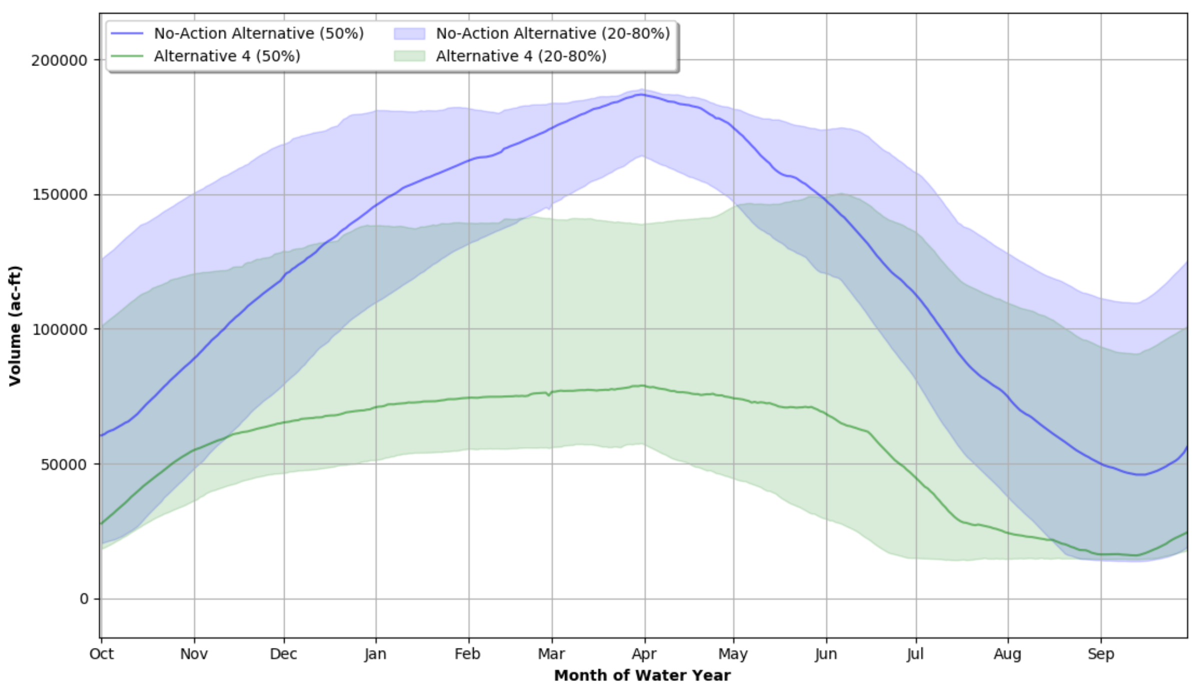
Water Year Conditions	No-Action Alternative (af)	Alternative 4 (af)	
		Years 1–5	Years 6–20
Very Dry	133,737	70,976	37,726
Dry	162,246	84,747	57,087
Normal	187,247	112,446	82,883
Wet	189,100	171,463	161,263
Very Wet	200,066	200,135	200,126

af = acre-feet; cfs = cubic feet per second

Table 67. Frequency of Wickiup Reservoir Fill under the No-Action Alternative and Alternative 4

Maximum Fill Volume April–August (af)	No-Action Alternative	Alternative 4	
		Years 1–5	Years 6–20
25,000	100%	100%	100%
50,000	100%	100%	86%
75,000	100%	92%	57%
100,000	100%	54%	41%
125,000	100%	43%	32%
150,000	89%	30%	22%
175,000	70%	19%	14%

Figure 95. Modeled Storage in Wickiup Reservoir under Alternative 4 in Years 6–20 Compared to the No-Action Alternative



Crescent Lake Reservoir

Reduced minimum flows below the Crescent Lake Dam from March 15 through November 30 (Conservation Measure CC-1) would generally result in an increase in Crescent Lake Reservoir storage (Figure 96) In years 6 through 20 of the permit term, the maximum storage volume attained would increase by 4,212 af and 5,631 af in dry and normal years, respectively. However, there would be a slight decrease in storage in a very dry year (Table 68). Changes in all water year types would be similar to Alternative 3.

Figure 96. Modeled Storage in Crescent Lake Reservoir under Alternative 4 in Years 6–20 Compared to the No-Action Alternative

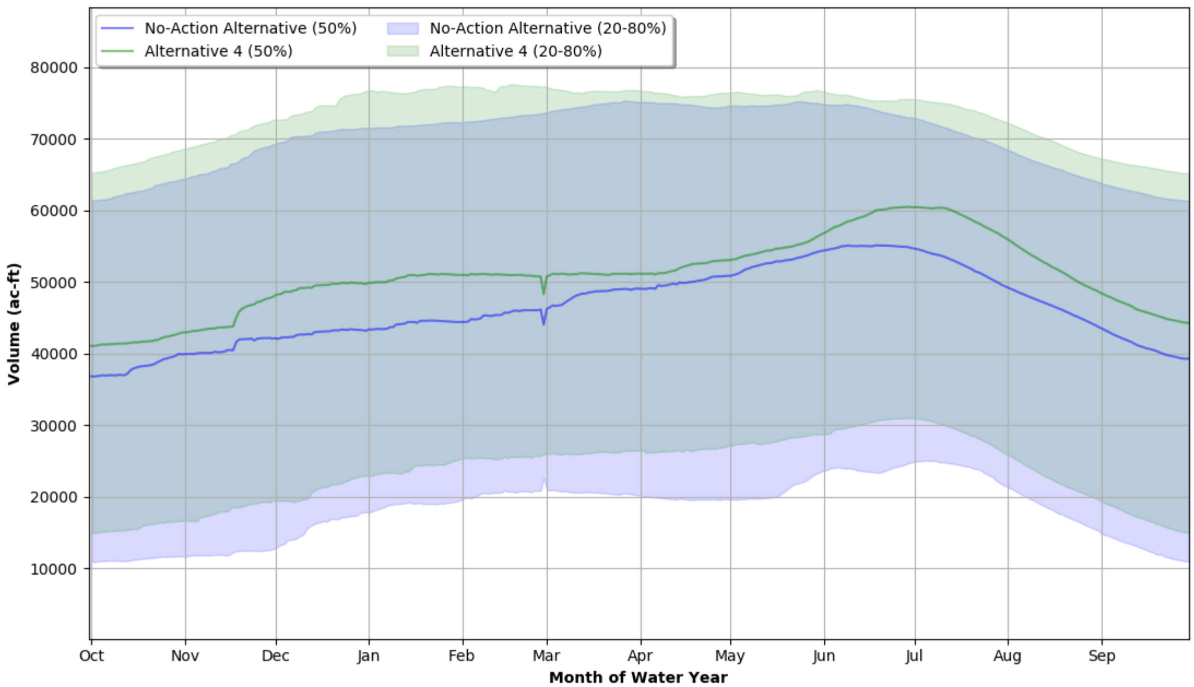


Table 68. Change in Crescent Lake Storage under the No-Action Alternative and Alternative 4

Water Year Conditions	No-Action Alternative	Alternative 4	
		Years 1–5	Years 6–20
Very Dry	11,015	10,742	10,093
Dry	33,327	32,346	32,730
Normal	62,124	61,716	61,276
Wet	77,952	77,920	78,019
Very Wet	79,944	80,248	80,784

af = acre-feet; cfs = cubic feet per second

Prineville Reservoir

As winter flow releases out of Wickiup Reservoir increase starting in year 1 of the permit term, reducing North Unit ID's stored water supply in the Deschutes, North Unit ID would use its available stored water from Prineville Reservoir (up to 10,000 af) more frequently and to a greater extent.. This, combined with increased winter minimum flows in the Crooked River (Conservation Measure

CR-1), would result in reduced Prineville Reservoir storage in most years. Changes in storage would range from a reduction of 462 af during normal years to a reduction of 19,409 af during a very dry year during years 11 through 20 of the permit term (Table 69). The reduction in storage compared to the no action in years 6 through 20 of the permit term would be 9,736 af during dry years. Figure 97 compares Prineville Reservoir storage under Alternative 4 in years 6 through 20 to the no-action alternative. Additionally, increasing bypass flows in McKay Creek and Ochoco Creek and protecting stored water under temporary instream leases for Ochoco ID patrons (Conservation Measures CR-2, CR-3, and CR-4) may contribute to a decline in Prineville Reservoir storage by increasing Ochoco ID stored water releases in years that Prineville Reservoir does not fill.

Figure 97. Modeled Storage in Prineville Reservoir under Alternative 4 in Years 6–20 Compared to the No-Action Alternative

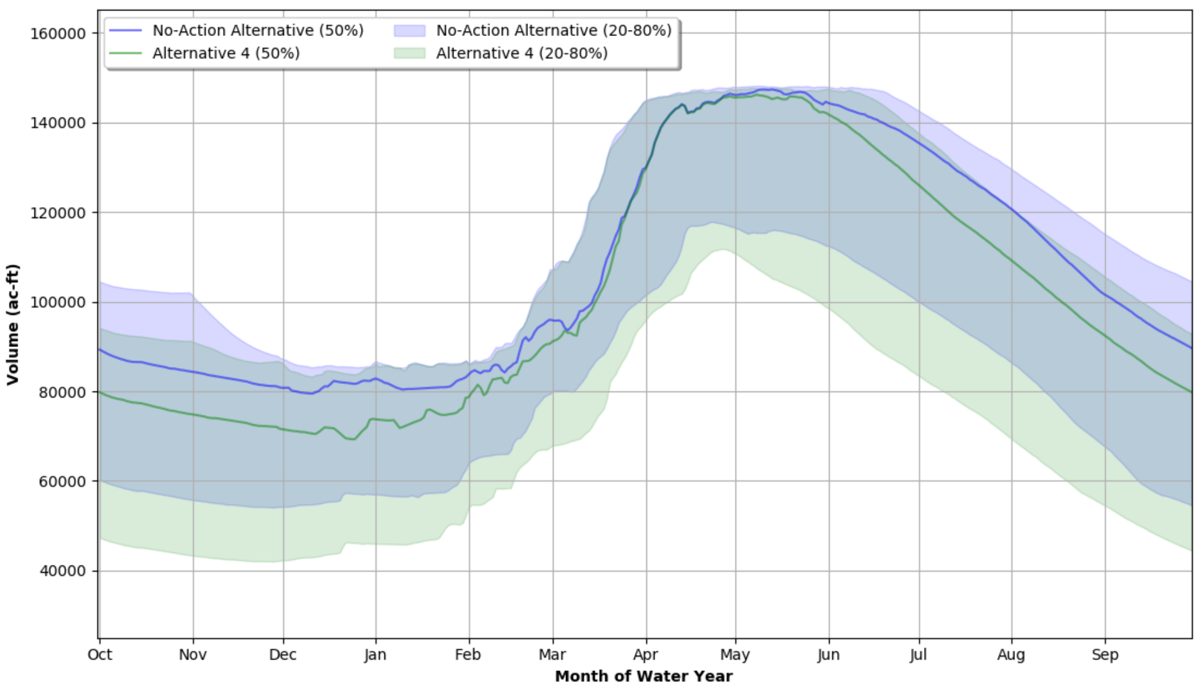


Table 69. Change in Prineville Reservoir Storage under the No-Action Alternative and Alternative 4

Water Year Conditions	No-Action Alternative	Alternative 4 Years 1–5	Alternative 4 Years 6–20
Very Dry	65,548	46,543	46,139
Dry	125,244	117,803	115,508
Normal	148,326	147,916	147,864
Wet	148,482	148,170	148,158
Very Wet	151,001	150,998	150,995

af = acre-feet; cfs = cubic feet per second

Ochoco Reservoir

Modeled changes in reservoir storage Ochoco Reservoir under Alternative 4 compared to the no-action alternative would be the same as described for the proposed action.

WR-2: Change in Water Supply for Irrigation Districts and Other Surface Water Users

As for WR-1, above, the most significant difference between Alternative 4 and the proposed action would be an accelerated schedule for increasing releases from Wickiup Reservoir. With the exception of North Unit ID, the change in water supply under Alternative 4 would be the same or nearly the same as the change in water supply under Alternative 3 at equivalent storage season Wickiup outflows (e.g., years 1 through 5 under Alternative 4 and years 11 through 20 of the proposed action).

For North Unit ID, change in water supply under Alternative 4 would be greater than under the proposed action and Alternative 3 as a result of increased fall/winter releases from Wickiup Reservoir. The change in water supply for these districts is discussed in greater detail below. Table 70 compares the no-action alternative, proposed action, Alternative 3, and Alternative 4 to show the impact of accelerating the timetable for storage season Wickiup outflows and highlights the water users and scenarios in which water supply is different under Alternative 4 than under Alternative 3.

As described under WR-1, alternative 4 will reduce Wickiup Reservoir storage. North Unit ID is dependent on Wickiup Reservoir storage when live flow in the Deschutes River is insufficient to meet North Unit ID demands under their February 28, 1913 water right certificates (72279, 72280, 80936, 94079). This will reduce water supply available to North Unit ID (Figure 98) and increase the frequency that North Unit ID would make regulatory calls for Deschutes River live flow.

By year 6 under Alternative 4, when the required fall/winter flow at WICO is 400 cfs, North Unit ID's diversion would be reduced by over 35,000 af in a normal year compared to the no-action alternative (Figures 98). In a dry year, North Unit ID diversions would be reduced by over 79,000 af. In wet and very wet years, there would be no reduction in North Unit ID diversions.

In general, the RiverWare model shows that North Unit ID would increase use of its Crooked River pumping plant to offset some of the loss of Deschutes River water supply. Under Alternative 4, during years 6 through 20 of the permit term, North Unit ID would increase use of the Crooked River pumping plant in all water year types, except very dry years (e.g., 1992), for which RiverWare shows that North Unit ID pumping from the Crooked River would decline by approximately 2,800 af. The decline in the utilization of the Crooked River pumping plant in a very dry year is attributable to increased winter releases from Prineville Reservoir under the proposed action, which would cause a decrease in Prineville Reservoir storage and Crooked River water supply available to North Unit ID.

Figure 98. Modeled Diversions for North Unit Irrigation District (April–October) under Alternative 4 as a Percentage of Diversions under the No-Action Alternative

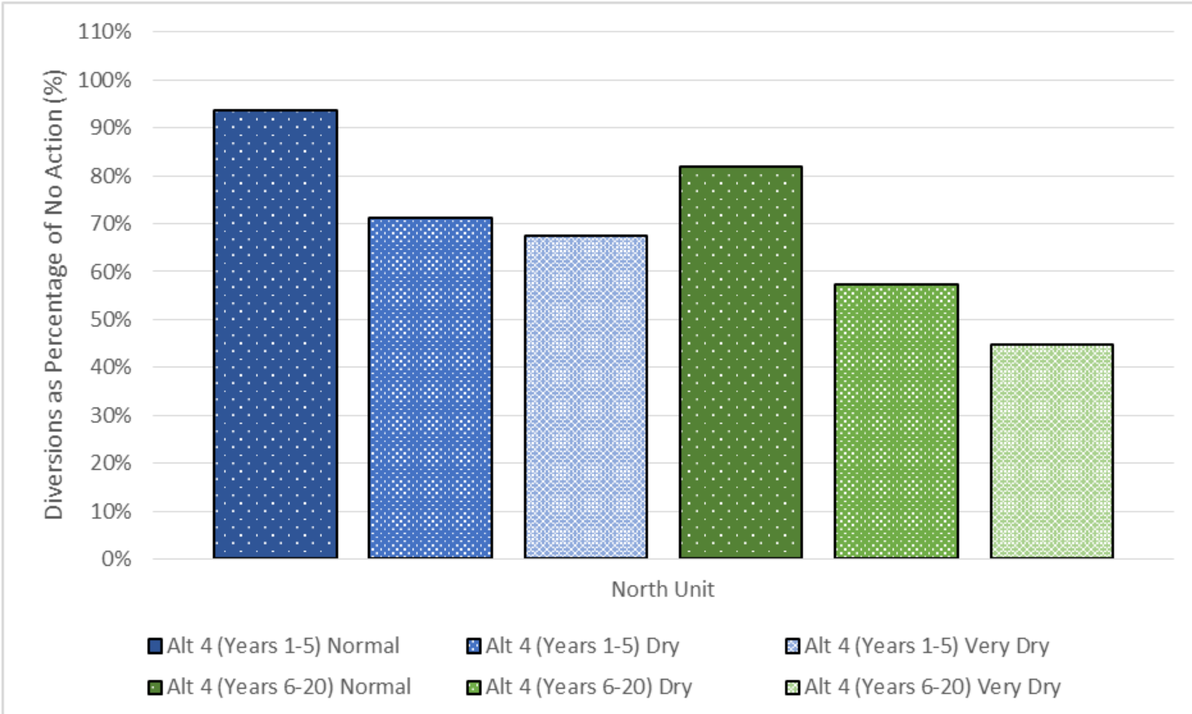


Table 70. Comparison of Irrigation Diversion (thousands of acre-feet) under the No-Action Alternative, Proposed Action, Alternative 3, and Alternative 4 at Varying Storage Season Wickiup Outflows (Regardless of the timetable for increasing outflows, water supply is the same under equivalent water conditions and at equivalent Wickiup outflow levels. The impact of higher variable outflows on North Unit, Arnold and Central Oregon IDs compared to the Proposed Action and Alternative 3 are highlighted in the table below if the impact exceeds 1% of water supply under the No-Action Alternative.)

Water Year Type	Scenario	Wickiup Outflows (cfs)	North Unit	Central Oregon	Arnold	Lone Pine	Ochoco	Tumalo	Swalley	Three Sisters	Walker Basin	Other Crooked
Normal	No Action	100	196.8	287.7	31.1	14.7	77.7	50.1	24.6	29.1	5.2	22.8
	PA (Years 1–7)	100	196.8	287.2	31.1	15.1	77.7	50.1	24.6	29.1	5.2	22.8
	Alt 3 (Years 1–5)	200	193.8	287.2	31.1	15.1	77.7	50.1	24.6	29.1	5.2	22.8
	PA (Years 8–12)	300	193.3	287.2	31.1	14.6	77.7	50.1	24.6	29.1	5.2	22.8
	Alt 3 (Years 6–10)	300	184.3	287.2	31.1	15.1	77.7	50.1	24.6	29.1	5.2	22.8
	Alt 4 (Years 1–5)	300	184.3	287.2	31.1	15.1	77.7	50.1	24.6	29.1	5.2	22.8
	PA (Years 13–30)	400	176.1	287.2	31.1	13.4	77.7	50.1	24.6	29.1	5.2	22.8
	Alt 3 (Years 11–30)	400–500	171.1	287.2	31.1	15.1	77.7	50.1	24.6	29.1	5.2	22.8
	Alt 4 (Years 6–20)	400–600	161.2	287.2	31.1	15.1	77.7	50.1	24.6	29.1	5.2	22.8
Dry	No Action	100	185.9	287.0	31.0	14.7	77.3	49.9	24.6	27.6	5.2	22.8
	PA (Years 1–7)	100	196.3	287.0	31.0	13.7	77.3	50.1	24.6	27.6	5.2	22.8
	Alt 3 (Years 1–5)	200	159.0	285.6	30.3	13.4	77.3	50.1	24.6	27.6	5.1	22.8
	PA (Years 8–12)	300	151.2	286.8	30.9	13.4	77.3	50.1	24.6	27.6	5.2	22.8
	Alt 3 (Years 6–10)	300	132.3	284.7	29.3	13.4	77.3	50.1	24.6	27.6	5.1	22.8
	Alt 4 (Years 1–5)	300	132.3	284.7	29.3	13.4	77.3	50.1	24.6	27.6	5.1	22.8
	PA (Years 13–30)	400	129.4	286.5	30.9	12.9	77.3	50.1	24.6	27.6	5.1	22.8
	Alt 3 (Years 11–30)	400–500	117.7	284.8	29.2	13.3	77.3	50.1	24.6	27.6	5.1	22.8
	Alt 4 (Years 6–20)	400–600	106.7	284.3	28.9	13.3	77.3	50.1	24.6	27.6	5.1	22.8

Water Year Type	Scenario	Wickiup Outflows (cfs)	North Unit	Central Oregon	Arnold	Lone Pine	Ochoco	Tumalo	Swalley	Three Sisters	Walker Basin	Other Crooked
Very Dry	No Action	100	154.7	283.2	24.3	13.1	60.8	30.4	24.6	23.5	4.8	20.9
	PA (Years 1–7)	100	167.7	283.9	24.1	12.9	53.4	44.2	24.6	23.5	4.9	20.6
	Alt 3 (Years 1–5)	200	135.1	278.9	17.7	11.1	48.5	31.1	24.6	23.5	4.6	20.2
	PA (Years 8–12)	300	102.9	281.5	21.8	12.1	48.6	40.4	24.6	23.5	4.8	20.2
	Alt 3 (Years 6–10)	300	104.4	276.9	16.9	10.6	46.0	30.8	24.6	23.5	4.6	19.9
	Alt 4 (Years 1–5)	300	104.4	276.9	16.9	10.6	46.0	30.8	24.6	23.5	4.6	19.9
	PA (Years 13–30)	400	72.0	279.9	20.8	11.3	48.5	38.3	24.6	23.5	4.8	20.2
	Alt 3 (Years 11–30)	400–500	69.7	276.7	16.6	10.6	46.0	30.6	24.6	23.5	4.6	19.9
	Alt 4 (Years 6–20)	400–600	69.3	276.3	16.5	10.6	46.0	30.6	24.6	23.5	4.6	19.9

WR-3: Changes in Reservoir Water Surface Elevations and Flood Storage Capacity

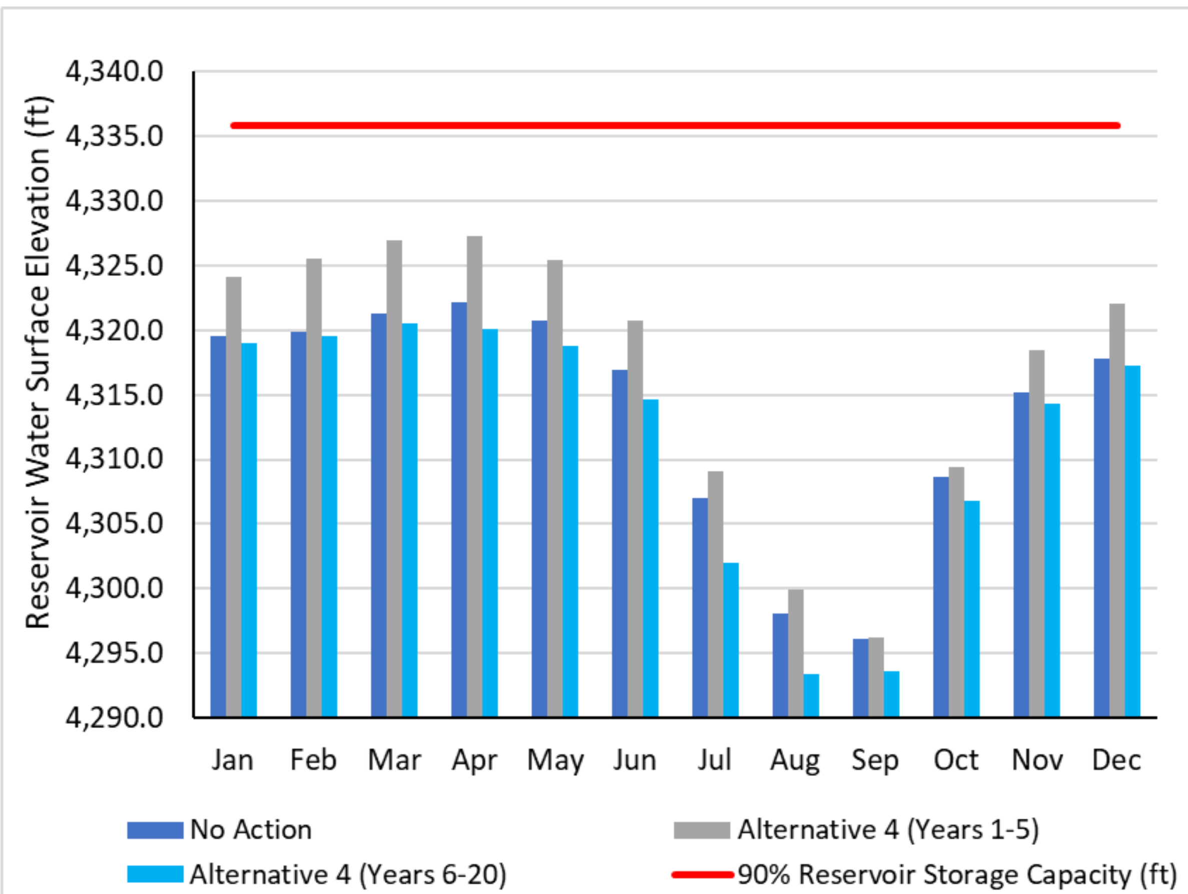
Modeled changes in Crane Prairie and Ochoco Reservoir water surface elevation and related flood storage capacity are the same as described for the proposed action. Changes in Wickiup, Crescent Lake, and Prineville Reservoir are described below.

Exceedance of 90% of reservoir storage capacity was set as the threshold for proposed action changes to flood storage capacity.

Wickiup Reservoir

Wickiup Reservoir water management under Alternative 4 results in lower median and similar maximum reservoir levels compared to the no-action alternative and proposed action (Figure 99). Lower median water surface elevations are due to the accelerated minimum winter flows on the Upper Deschutes River and how the minimum flows affect reservoir storage. Median water surface elevations differences are greatest from April to June (7 to 8 feet lower) in years 6 through 20 for Alternative 4 relative to the proposed action in years 21 through 30.

Figure 99. Modeled Monthly Median Water Surface Elevations for Wickiup Reservoir under Alternative 4 and the No-Action Alternative (The reference elevation associated with 90% flood storage capacity is 4,335.79 ft [red line]. The 90% flood storage capacity is based on a total reservoir capacity of 200,000 af.)



WR-4: Changes in Seasonal River and Creek Flow

Modeled changes in streamflows are the same as described for the proposed action for the Upper Deschutes River between Crane Prairie and Wickiup Reservoirs and in Ochoco, Whychus and Tumalo Creeks. Modeled changes in streamflow for the Deschutes River at Culver and Madras, Crescent Creek and the Little Deschutes River, and Crooked River, are the same or nearly the same for Alternative 4 as presented for Alternative 3.

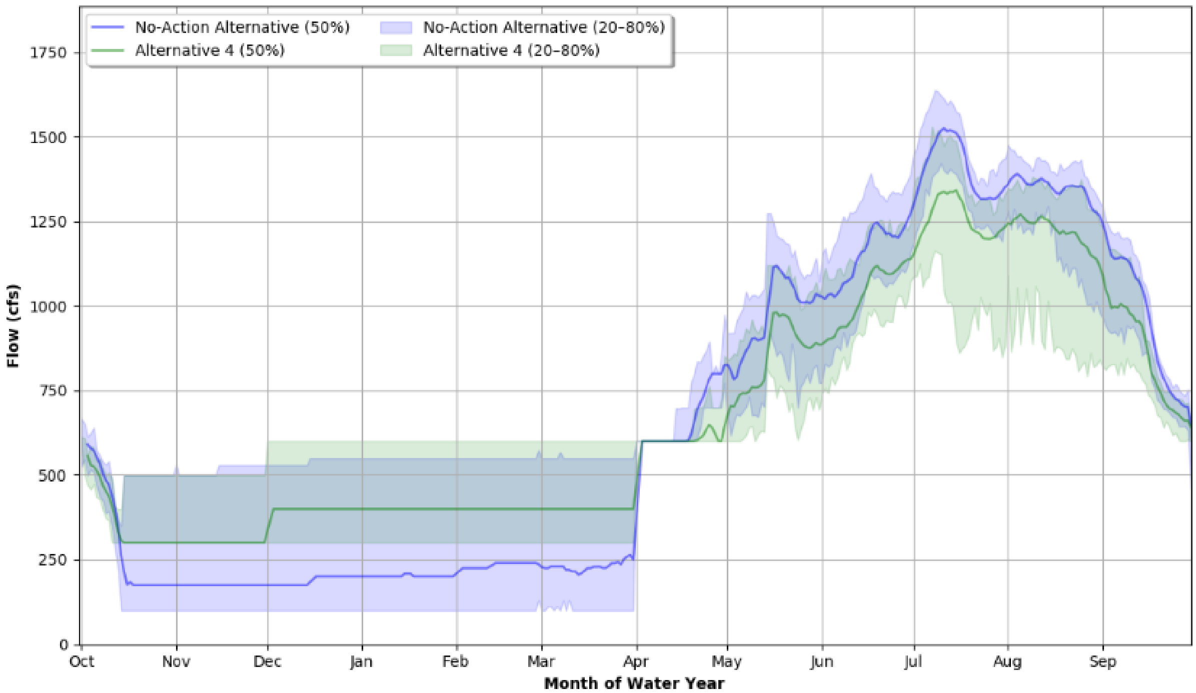
Minimum winter storage season flows for the Deschutes River downstream of Wickiup Reservoir in years 1 through 5 would be the same as under the proposed action in years 8 through 12, although the proposed action includes an irrigation season maximum daily flow cap of 1,400 cfs. Minimum winter storage season flows in years 6 through 20 have the same minimum target of 400 cfs, but Alternative 4 includes a higher variable minimum flow range up to 600 cfs compared to the proposed action's 500 cfs. Alternative 4 does not have the 1,200 cfs irrigation season maximum daily flow cap included in the proposed action.

Under Alternative 4, Upper Deschutes River summer flows would decrease and winter flows would increase compared to the no-action alternative. The hydrologic changes would be implemented in two stages, the first in years 1 to 5 (300 cfs) and the second in years 6 to 20 (400 to 600 cfs) of the permit term. Higher minimum fall/winter flows would also correspond with lower irrigation period flows due to the reduction in reservoir storage.

Deschutes River from Wickiup Dam to the Little Deschutes River

In years 1 through 5, minimum winter flows downstream of Wickiup Dam would be 300 cfs, higher than the no-action, but the same as the proposed action in years 11 through 20 and Alternative 3 in years 6 through 10. This represents higher winter storage season flows and lower irrigation season flows compared to the proposed action and no-action alternative (Figure 102). In years 6 through 20, minimum winter flows would increase to a variable 400 to 600 cfs, which results in the same median flows through winter, but the 80% exceedance flows after December 1 increase from 500 cfs for the proposed action and Alternative 3, to 600 cfs for Alternative 4. The higher flow after December 1 has a marginal effect on irrigation season median flows, but the higher winter flow creates more a broader flow range through the irrigation season. As minimum winter flows increase, Wickiup Reservoir storage volumes decrease and there is less stored water available to meet irrigation season demand.

Figure 100. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Deschutes River at the WICO Gauge under Alternative 4 Years 1–5 (upper) and Years 6–20 (lower) Compared to the No-Action Alternative



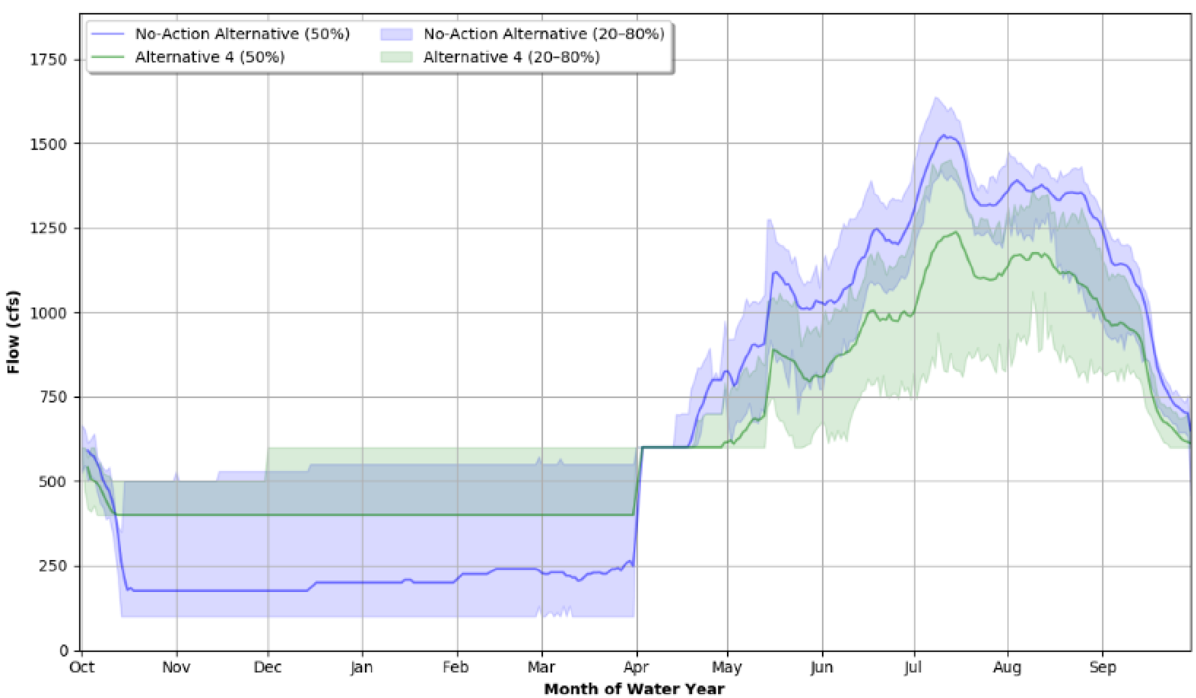


Table 71 includes a comparison of seasonal differences in minimum and maximum median flows based on WICO gauge data. Alternative 4 would have higher minimum and maximum median winter flows and higher minimum median irrigation period flows relative to the no-action alternative. Maximum median irrigation period flows would be lower for Alternative 4 due to the higher winter flow releases. Alternative 4 would have the same irrigation period flows as Alternative 3, higher maximum median daily irrigation flows compared to the proposed action and no-action alternatives. Irrigation period flows are similar among Alternative 4, Alternative 3, and the proposed action, and lower than the no-action alternative maximum median daily flows.

Table 71. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Deschutes River Downstream from Wickiup Reservoir by Season for the No-Action Alternative and Alternative 4 over the Permit Term

	Winter (Nov 1–Mar 31)		Irrigation (Apr 1–Oct 31)	
Alternative	Minimum (cfs)	Maximum (cfs)	Minimum (cfs)	Maximum (cfs)
No-Action	175.0	279.5	155.3	1,532.0
Alternative 4 (Years 1–5)	300.0	400.0	300.0	1,352.3
Alternative 4 (Years 6–20)	400.0	400.0	400.0	1,245.4

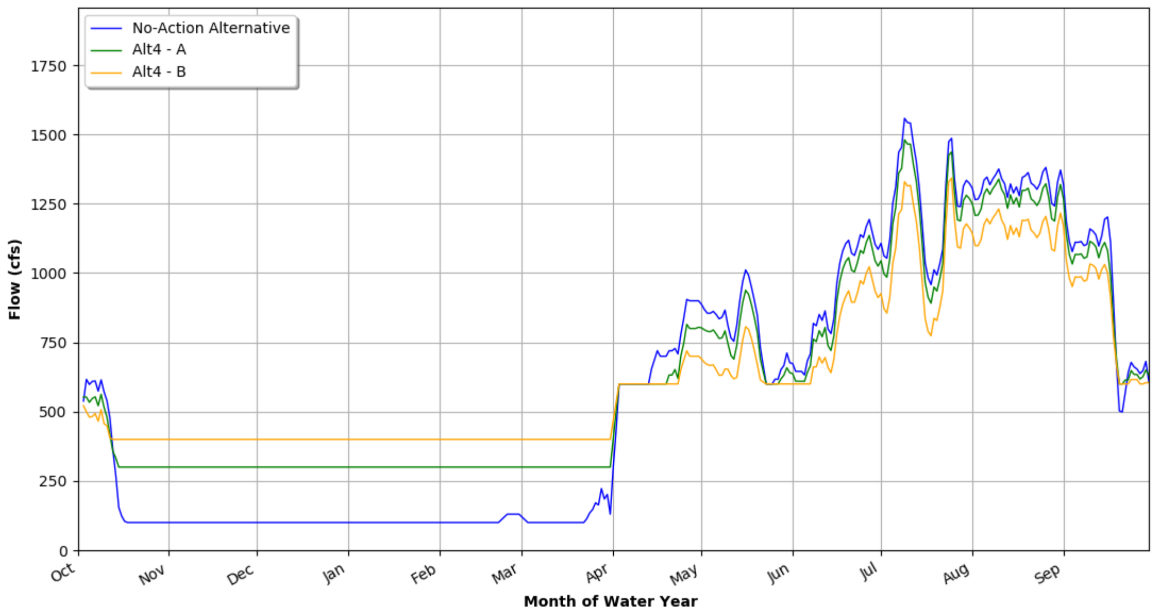
Total monthly streamflow volume (af) for representative wet, normal, and dry years was evaluated to assess changes in seasonal streamflow. Alternative 4 results are presented as the percent difference from the no-action alternative (Table 72). Irrigation period flows decreased in all three water year types and from years 1 through 5 to years 6 through 20. Winter storage period flows increased each of the three water year types with the greatest increase in years 6 through 20 in a dry year. Flows were also the least variable in years 6 through 20 of a dry year due to the higher winter storage flows and lower irrigation period flows which are more similar than under other water year types.

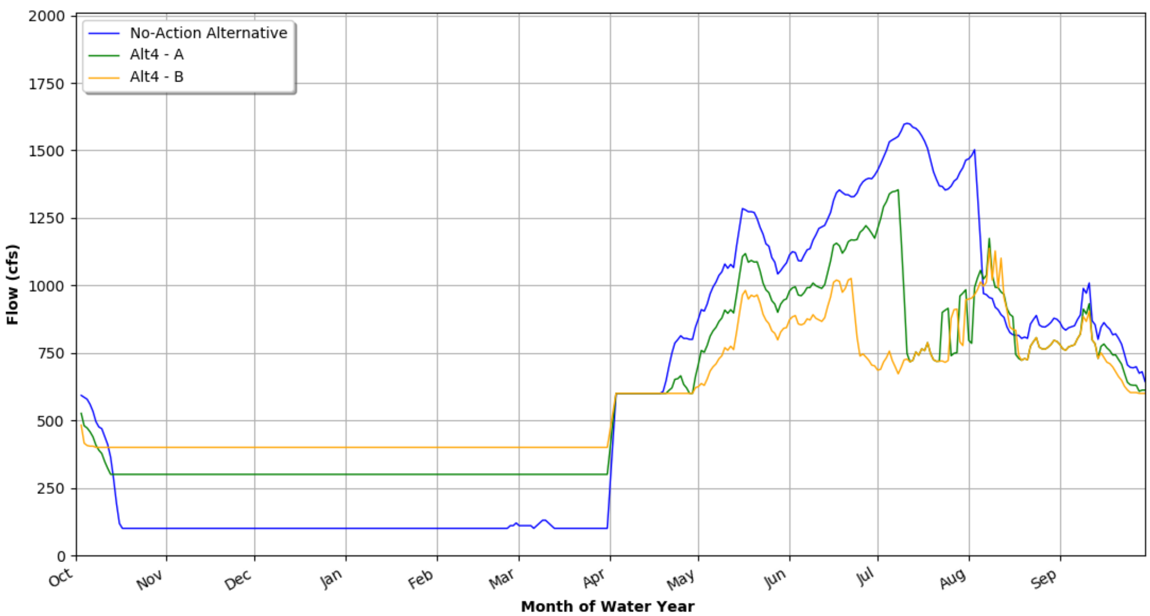
Table 72. Percent Differences in Streamflow Volume between the No-Action Alternative and Alternative 4 for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years at the WICO Gauge

		Alternative 4	
Water Year Type	Time Period	Years 1–5	Years 6–20
Wet	Irrigation Period	1%	-10%
	Winter/Storage Period	36%	68%
	Annual	7%	4%
	1 SD	-12%	-36%
Normal	Irrigation Period	-6%	-13%
	Winter/Storage Period	31%	50%
	Annual	1%	-1%
	1 SD	-19%	-37%
Dry	Irrigation Period	-15%	-23%
	Winter/Storage Period	196%	295%
	Annual	0%	0%
	1 SD	-40%	-60%

Figure 103 includes the representative normal and dry year hydrographs for the WICO gauge under Alternative 4. In both normal and dry years, median flows are higher during the winter storage period and generally lower during the irrigation period for the Alternative 4 flow scenarios relative to the no-action alternative. Irrigation period flow decrease faster during a representative dry year compared to a representative normal year.

Figure 101. Modeled Flows for the Deschutes River at the WICO Gauge under Alternative 4 in Years 1–5 (A) and Years 6–20 (B) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative





Deschutes River from the Little Deschutes River to Benham Falls

Implementation of Conservation Measure WR-1 influences flows in the Deschutes River from the Little Deschutes River confluence downstream to Benham Falls. Similar to the WICO gauge results, Alternative 4 flows are higher relative to the proposed action and no-action alternative during the winter storage period and lower during the irrigation period (Figure 104). Lower irrigation period flows are due to the higher winter storage period minimum flows. Irrigation period flows also decline faster during years 6 through 20, marked by declining flows in early July.

Figure 102. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Deschutes River at the BENO Gauge under Alternative 4 Years 1–5 (upper) and Years 6–20 (lower) Compared to the No-Action Alternative

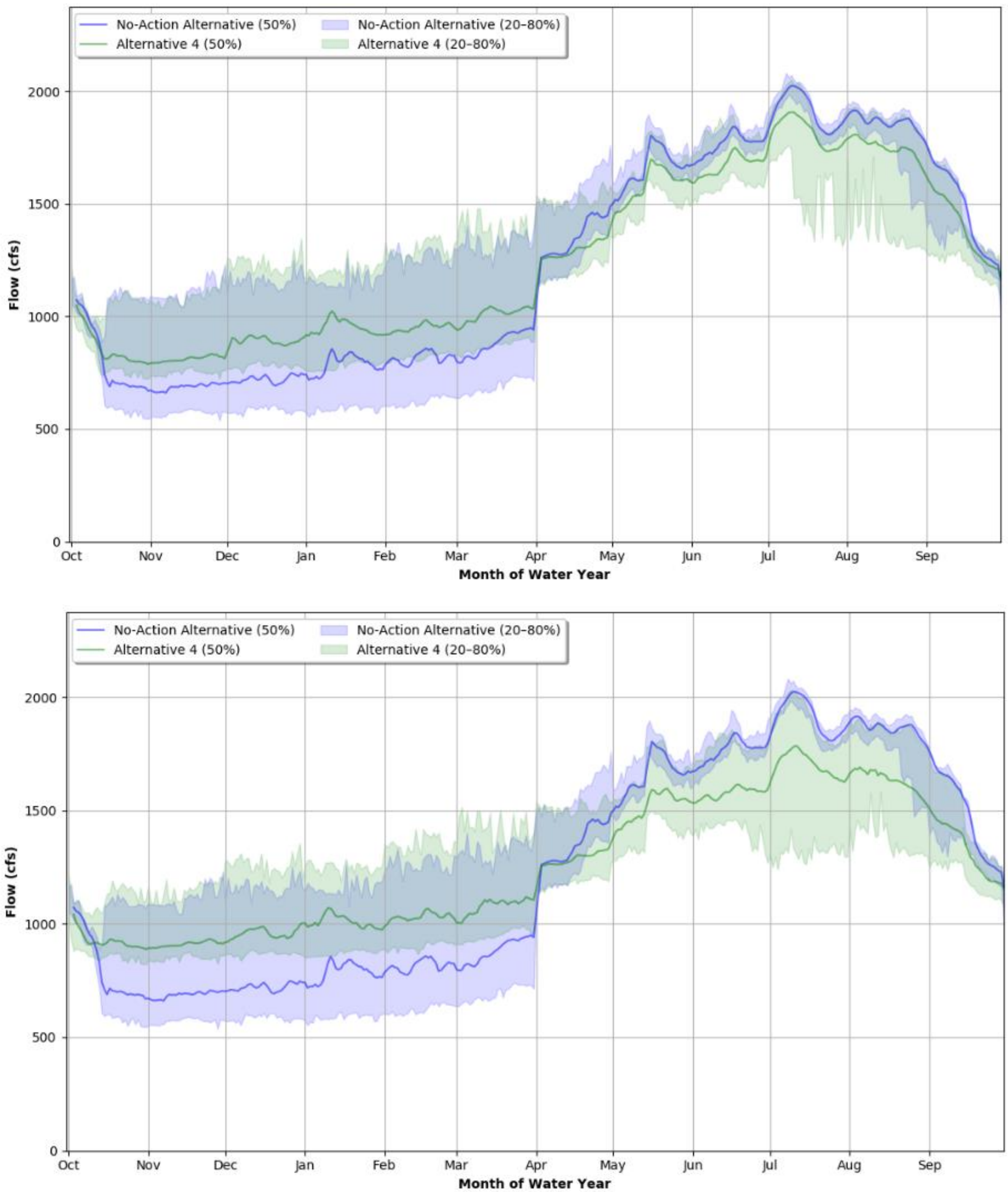


Table 73 includes a comparison of seasonal differences in minimum and maximum median flows based on BENO gauge data. Alternative 4 would have higher minimum and maximum median winter flows and higher minimum median irrigation period flows relative to the no-action alternative. Maximum median irrigation period flows would be lower for Alternative 4 due to the higher winter flow releases. Winter flows are higher in years 1 through 5 for Alternative 4 compared to proposed action in years 11 through 20 when the minimum flows are the same (300 cfs). During the irrigation season, Alternative 4 in years 1 through 5 has higher minimum flows (30 cfs higher) but lower maximum flows (90 cfs lower) relative to the proposed action in years 11 through 20 when minimum winter flows are the same. There is a similar result when Alternative 4 in years 6 through 20 is compared to the proposed action in years 21 through 30.

Table 73. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Deschutes River at the BENO Gauge by Season for the No-Action Alternative and Alternative 4 over the Permit Term

	Winter (Nov 1–Mar 31)		Irrigation (Apr 1–Oct 31)	
Alternative	Minimum (cfs)	Maximum (cfs)	Minimum (cfs)	Maximum (cfs)
No-Action	651.3	960.4	637.5	2,029.6
Alternative 4 (Years 1–5)	790.5	1,051.3	787.8	1,910.8
Alternative 4 (Years 6–20)	890.5	1,121.2	887.8	1,797.7

Total monthly streamflow volume (af) for representative wet, normal, and dry years was evaluated to assess changes in seasonal streamflow. Alternative 4 results are presented as the percent difference from the no-action alternative (Table 74). Irrigation period flows decreased the most in years 6 through 20 of a dry year. Winter storage period flows increased in normal and dry years and are progressively greater in years 6 through 20 than in years 1 through 5. Annual flows are also less variable in a dry year as winter storage and irrigation period flows narrow in magnitude. Compared to the proposed action in years 13 through 30,

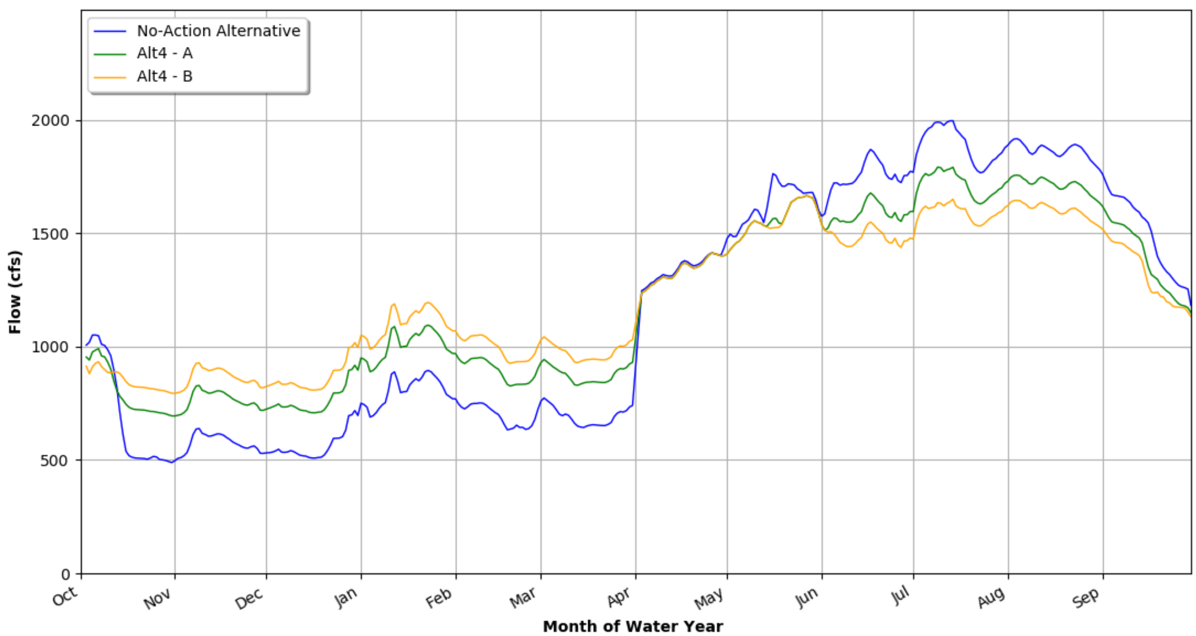
Table 74. Percent Differences in Streamflow Volume between the No-Action Alternative and Alternative 4 for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years at the BENO Gauge

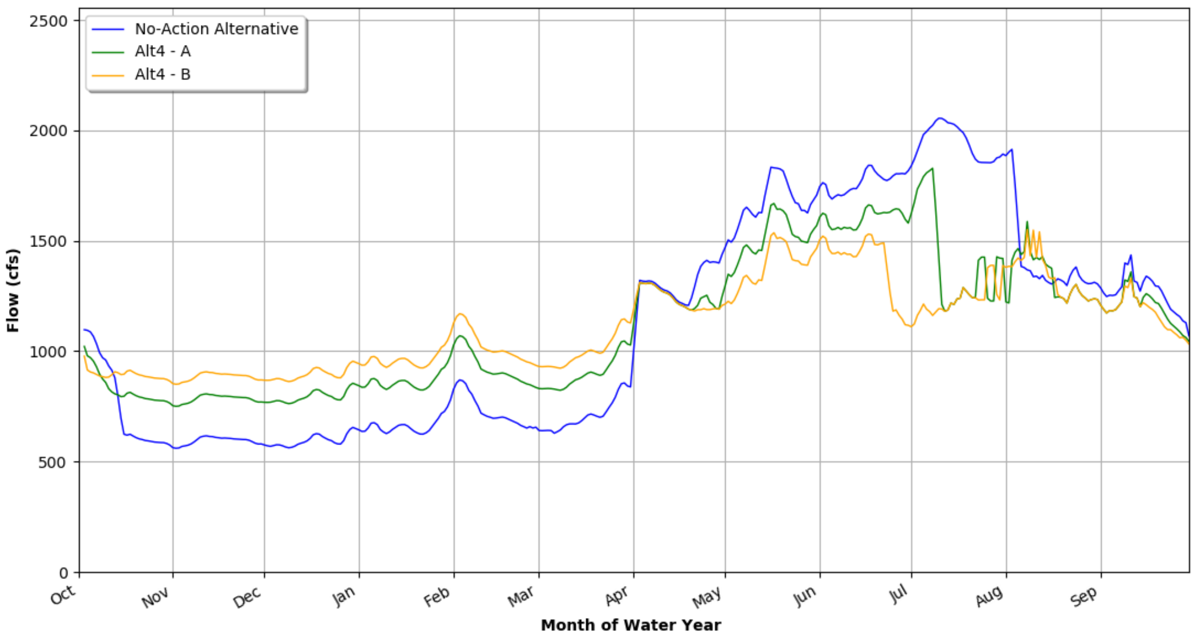
		Alternative 4	
Water Year Type	Time Period	Years 1–5	Years 6–20
Wet	Irrigation Period	-2%	-4%
	Winter/Storage Period	0%	2%
	Annual	-1%	-2%
	1 SD	-15%	-19%
Normal	Irrigation Period	4%	-3%
	Winter/Storage Period	-11%	9%
	Annual	-1%	0%
	1 SD	24%	-21%

Water Year Type	Time Period	Alternative 4	
		Years 1–5	Years 6–20
Dry	Irrigation Period	-10%	-15%
	Winter/Storage Period	30%	46%
	Annual	0%	0%
	1 SD	-39%	-59%

Figure 105 includes the representative normal and dry year hydrographs for the BENO gauge under Alternative 4. In both normal and dry years, Alternative 4 median flows are higher during the winter storage period and generally lower during the irrigation period relative to the no-action alternative. Irrigation period flow decrease more rapidly during a dry year compared to a normal year, and flows decline faster in years 6 through 20 compared to years 1 through 5.

Figure 103. Modeled Flows for the Deschutes River at the BENO Gauge under Alternative 4 in Years 1–5 (A) and Years 6–20 (B) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative





Deschutes River from Benham Falls to Bend

Surface water diversions located between Lava Island and the DEBO gauge, and streamflow losses to groundwater, influence the amount of water remaining in the Deschutes River at the DEBO gauge (#14070500). Like the WICO and BENO gauges, winter storage period flows are higher under Alternative 4 compared to the no-action alternative (Figure 106). Winter flows are also greater for Alternative 4 in years 6 through 20 compared to years 1 through 5. Irrigation period flows between the no-action alternative and Alternative 4 are very similar.

Figure 104. Modeled Flows (median flow and 20 to 80% exceedance flow range) for the Deschutes River at the DEBO Gauge under Alternative 4 Years 1–5 (upper) and Years 6–20 (lower) Compared to the No-Action Alternative

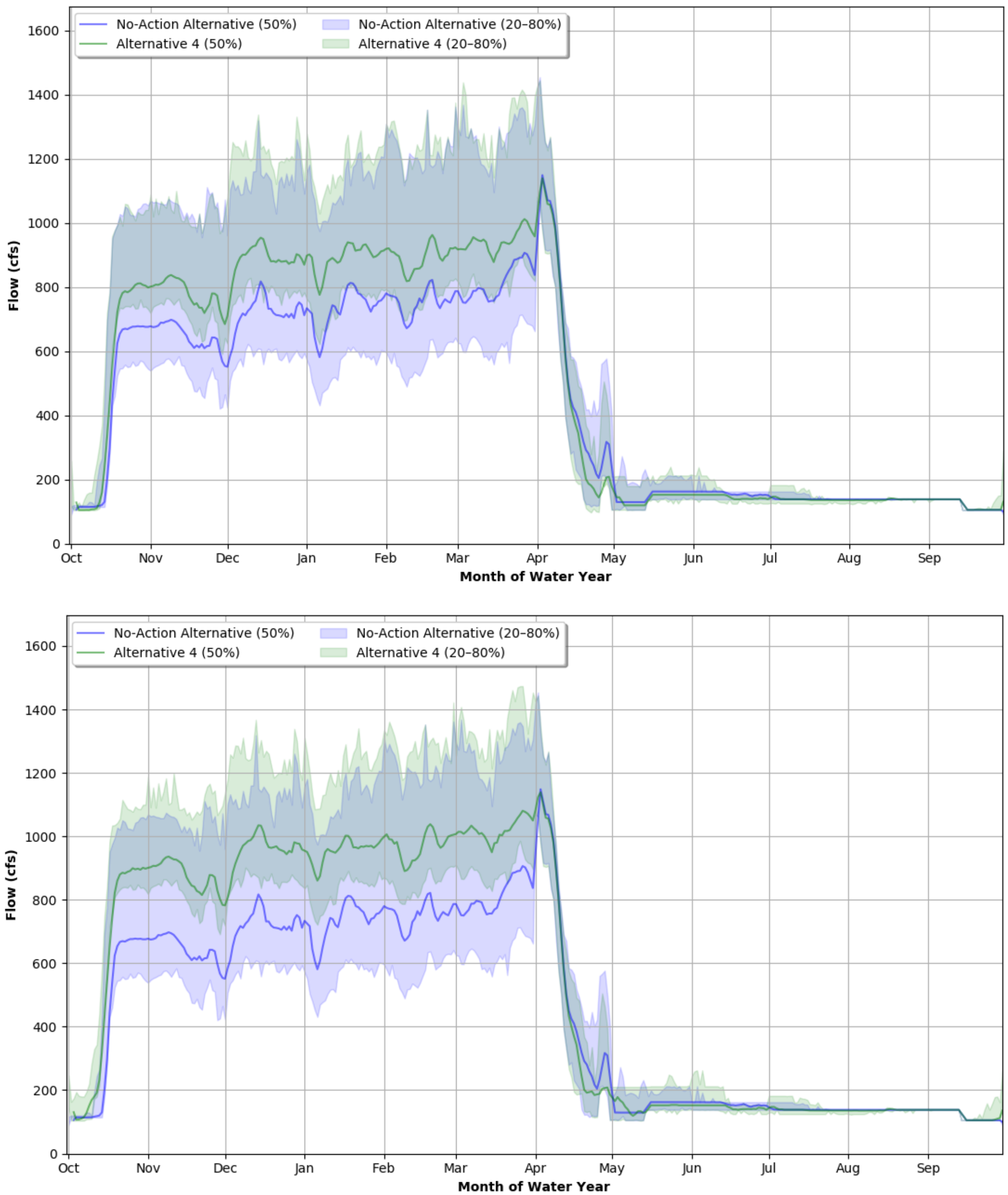


Table 75 includes a comparison of seasonal differences in minimum and maximum median flows based on DEBO gauge data. Alternative 4 would have higher minimum and maximum median winter flows and lower maximum median irrigation period flows relative to the no-action alternative. Minimum median irrigation period flows are higher relative to the no-action alternative.

Table 75. Comparison of Minimum and Maximum Median (50%) Daily Flows on the Deschutes River at the DEBO Gauge by Season for the No-Action Alternative and Alternative 4 over the Permit Term

	Winter (Nov 1–Mar 31)		Irrigation (Apr 1–Oct 31)	
Alternative	**Minimum (cfs)**	**Maximum (cfs)**	**Minimum (cfs)**	**Maximum (cfs)**
No-Action	535.0	913.8	89.8	1,183.1
Alternative 4 (Years 1–5)	670.4	1,032.3	103.8	1,173.1
Alternative 4 (Years 6–20)	765.2	1,087.7	105.0	1,173.1

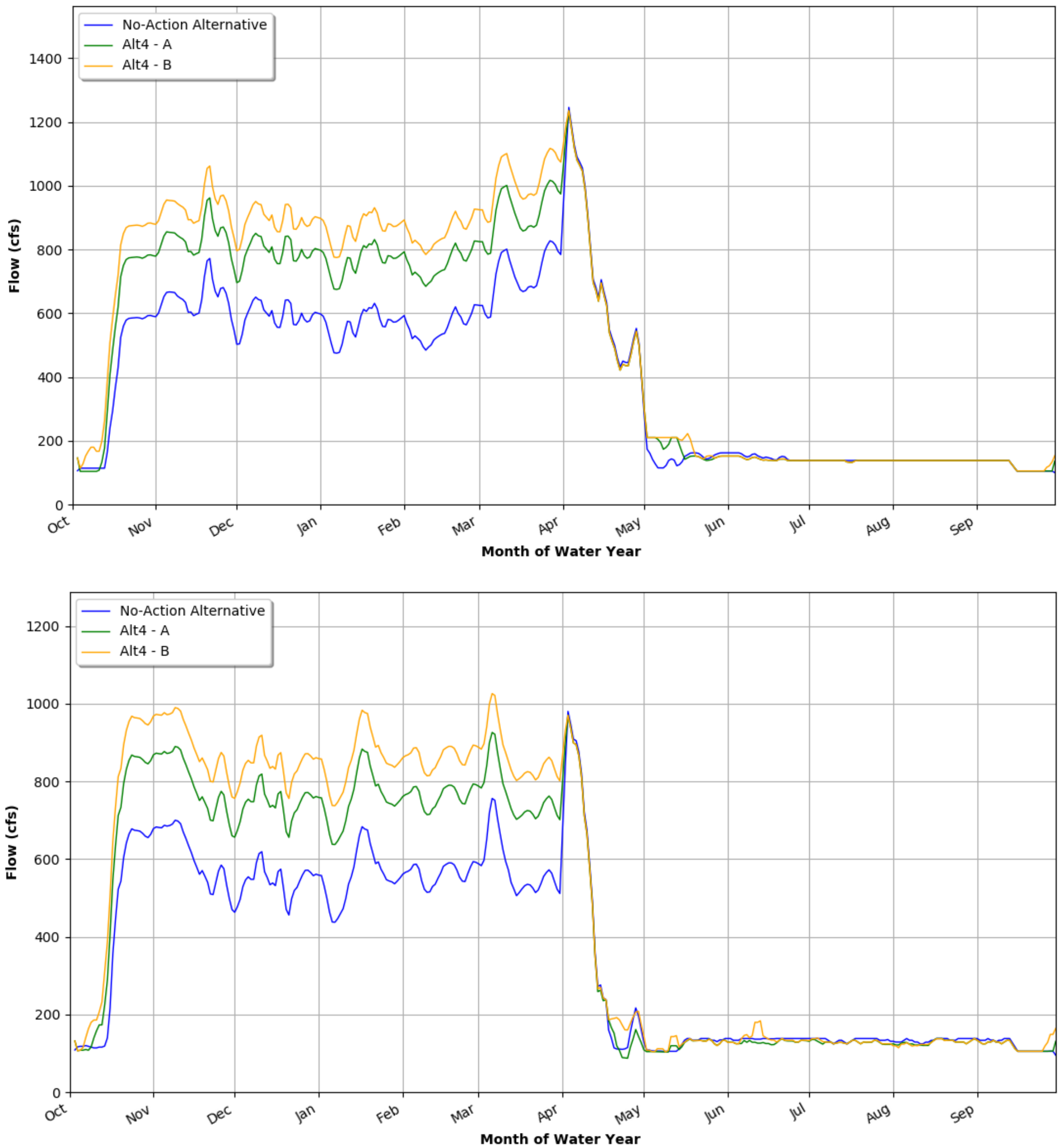
Total monthly streamflow volume (af) for representative wet, normal, and dry years was evaluated to assess changes in seasonal streamflow. Alternative 4 results are presented as the percent difference from the no-action alternative (Table 76). Winter storage and irrigation period flows increase relative to the no-action alternative in normal and dry years and from years 1 through 5 to year 6 through 20 of the flow scenarios. Annual flow variation also increases as winter storage period flows increase relative to the irrigation period flows. Alternative 4 has more variable flows, higher winter flows, and similar irrigation period flows compared to the proposed action.

Table 76. Percent Differences in Streamflow Volume between the No-Action Alternative and Alternative 4 for the Irrigation Period (April 1 to October 31), Winter Storage Period (November 1 to March 31), and the Entire Year for Representative Wet, Normal, and Dry Years at the DEBO Gauge

		Alternative 4	
Water Year Type	**Time Period**	**Years 1–5**	**Years 6–20**
Wet	Irrigation Period	1%	5%
	Winter/Storage Period	4%	8%
	Annual	3%	7%
	1 SD	4%	6%
Normal	Irrigation Period	6%	11%
	Winter/Storage Period	32%	45%
	Annual	22%	32%
	1 SD	32%	45%
Dry	Irrigation Period	6%	14%
	Winter/Storage Period	34%	52%
	Annual	25%	40%
	1 SD	45%	67%

Figure 107 includes the representative normal and dry year hydrographs for the DEBO gauge under the no-action alternative and Alternative 4. Hydrographs for representative normal and dry years have similar patterns with the Alternative 4 scenarios having higher median flows during the winter storage season and similar flows to the no-action alternative during the irrigation period. There is a spike in streamflow that occurs from early to mid-May in a normal year compared to the no-action alternative.

Figure 105. Modeled Flows for the Deschutes River at the DEBO Gauge under Alternative 4 Years 1–5 (A) and Years 6–20 (B) in Normal (upper) and Dry (lower) Years Compared to the No-Action Alternative



Deschutes River Flood Flows

Alternative 4 results in fewer days of flood flow exceedance at the WICO and BENO gauges due to higher winter flows and since irrigation period flows are capped at 1,200 cfs. The number of days of exceedance at Tumalo increase by 2 days based on a 1,400 cfs threshold and decrease slightly based on the 2,000 cfs threshold.

Table 77. Flood Flow Thresholds and Daily Flow Exceedance for the No-Action Alternative and Alternative 4 over the Permit-Term (Two flood flow thresholds are included for the DEBO+TUMO gauge data.)

Gauge	Flood Flow Threshold (cfs)	Average Number of Days of Flood Flow Threshold Exceedance per Year		
			Alternative 4	
		No-Action	Years 1–5	Years 6–20
WICO	1,600	2.3	1.4	0.8
BENO	2,000	27.4	19.3	17.7
DEBO+TUMO	1,400	26.8	29.9	29.2
DEBO+TUMO	2,000	1.9	1.3	1.2

WR-5: Affect Groundwater Recharge

Effects under Alternative 4 compared to the no-action alternative would be the same or nearly the same as described for the proposed action. There would be no meaningful effect on the regional groundwater system compared to the no action alternative.

References Cited

Printed References

Anderson Perry. 2018. *Water System Master Plan for the City of Prineville, Oregon.* Prepared for the City of Prineville.

Bureau of Reclamation (Reclamation). 2017. Development of a daily Water Management Model of the Deschutes River, Oregon, using RiverWare. 54 pp.

Deschutes Basin Board of Control and City of Prineville. 2020. *Final Deschutes Basin Habitat Conservation Plan.* Submittal to U.S. Fish and Wildlife Service and National Marine Fisheries Service in support of application for Endangered Species Act section 10 incidental take permits. Deschutes Basin Board of Control, Madras, OR.

Farmers Conservation Alliance. 2018a. *Tumalo Irrigation District Irrigation Modernization Project. Final Watershed Plan. Environmental Assessment*. Available: https://img1.wsimg.com/blobby/go/4c8b915d-c9c0-4a10-86d6-3ac6eb749f65/downloads/1clcnlqs7_469853.pdf.

Farmers Conservation Alliance. 2018b. *Swalley Irrigation District Irrigation Modernization Project. Final Watershed Plan. Environmental Assessment*. Available: https://img1.wsimg.com/blobby/go/4c8b915d-c9c0-4a10-86d6-3ac6eb749f65/downloads/1ctqfim5f_920261.pdf.

Gannett, M.W., and Lite, K.E., Jr. 2004. *Simulation of regional ground-water flow in the upper Deschutes Basin, Oregon*: U.S. Geological Survey Water-Resources Investigations Report 03–4195, 84 p.

Gannett, M.W., and Lite, K.E., Jr. 2013. *Analysis of 1997–2008 groundwater level changes in the upper Deschutes Basin, Central Oregon*: U.S. Geological Survey Scientific Investigations Report 2013-5092, 34 p. Available: http://pubs.usgs.gov/sir/2013/5092.

Gannett, M.W., Lite, Jr., K.E., Morgan, D.S., and Collins, C.A., 2001. *Ground-water hydrology of the upper Deschutes Basin, Oregon*: U.S. Geological Survey Water-Resources Investigations Report 00-4162, 74 p.

Gannett, M.W., Lite, K.E., Jr., Risley, J.C., Pischel, E.M., and La Marche, J.L. 2017. *Simulation of groundwater and surface-water flow in the upper Deschutes Basin, Oregon:* U.S. Geological Survey Scientific Investigations Report 2017–5097, 68 p. Available: https://doi.org/10.3133/sir20175097.

Hendricks, J. 2014. "Rivers still high; Tumalo flood water continues,". Available: https://www.ktvz.com/news/bend/rivers-still-high-tumalo-flood-watch-continues/68720688. Accessed: March 3, 2019.

Kato, A.J. 2017. 'Tumalo residents watching Deschutes waters rise,". Available: https://www.ktvz.com/news/tumalo-residents-watching-deschutes-waters-rise/425646215. Accessed: March 3, 2019.

Lite, K.E., Jr., and Gannett, M.W. 2002. *Geologic framework of the regional ground-water flow system in the upper Deschutes Basin, Oregon*: U.S. Geological Survey Water-Resources Investigations Report 02–4015, p. 44.

Newton, Jim. 2018. *Summary of Groundwater Source Investigation – City of Prineville ASR Feasibility Project; Crook County Oregon.* Technical Memorandum prepared for the City of Prineville.

Shumway, J. 2017. "Sunriver-area residents struggle with Deschutes flooding," accessed March 3, 2019. Available: https://www.bendbulletin.com/localstate/5570060-151/sunriver-area-residents-struggle-with-deschutes-flooding.

West, A. 2017. "Crooked River flooding eases – for now," accessed March 3, 2019, Available: https://www.bendbulletin.com/localstate/5193704-151/crooked-river-flooding-eases-for-now.

Western Regional Climate Center. 2017. *Western US Climate Summaries–Oregon*. Available: http://www.wrcc.dri.edu/. Accessed July 26, 2017.

Zagona, E. A., T. J. Fulp, R. Shane, T. M. Magee, H. M. Goranflo. 2001. "RiverWare: A Generalized Tool for Complex Reservoir System Modeling." *Journal of the American Water Resources Association* 37(4), 913–929.

Personal Communications

Giffin, Jeremy (a). District 11 Watermaster, Oregon Water Resources Department, Bend, OR. January 28, 2018—Email with Owen McMurtrey, GSI Water Solutions, Inc., regarding surface water regulation in the Deschutes basin.

Giffin, Jeremy (b). District 11 Watermaster, Oregon Water Resources Department, Bend, OR. January 29, 2018—Meeting with Owen McMurtrey, GSI Water Solutions, Inc., regarding surface water regulation in the Deschutes basin.

Gorman, Kyle, Manager, Oregon Water Resources Department, Bend, OR. November 27, 2018—email with Troy Brandt, River Design Group, Inc., regarding surface water flooding in the Deschutes Basin.

Johnson, Jennifer, PE, Hydrologic Engineer, U.S. Bureau of Reclamation, Boise, ID. June 13, 2019—email with Troy Brandt, River Design Group, Inc. regarding RiverWare model period.

La Marche (a), Jonathan, Hydrologist, Oregon Water Resources Department, Bend, OR. October 9, 2018—Meeting with Bruce Brody-Heine, GSI Water Solutions, Inc., regarding surface water–groundwater interactions across entire basin.

La Marche (b), Jonathan, Hydrologist, Oregon Water Resources Department, Bend, OR. February 1, 2019—Phone call with Bruce Brody-Heine, GSI Water Solution, regarding surface water–groundwater interactions in Tumalo and Ochoco Creeks.

La Marche (c), Jonathan, Hydrologist, Oregon Water Resources Department, Bend, OR. November 27, 2018—email with Troy Brandt, River Design Group, Inc., regarding surface water flooding in the Deschutes Basin.

Appendix 3.4-A
Vegetation and Wildlife Technical Supplement

Appendix 3.4-A
Plant and Wildlife Technical Supplement

Purpose

This appendix addresses the following topics.

- The approach and results of screening to determine which plant and wildlife species to address in the effects analysis.
- Delineation and description of stream reaches used in the plant and wildlife effects analysis.
- Analysis of RiverWare outputs.

Plant and Wildlife Species Screening

Special-Status Plants

Special-status plants and fungi were determined through reference to the following sources.

- Species listed by the Oregon Department of Agriculture as threatened, endangered, or candidates for such listing. These species are listed by name in Oregon Administrative Rules (OAR) 603-703-0070 and are listed by county in a searchable database (Oregon Department of Agriculture 2018a).
- Plants listed as special status species on the U.S. Forest Service (USFS) Region 6 special-status species list, filtered to include only species potentially present in Deschutes National Forest (U.S. Forest Service 2019).
- Plants identified by USFS as potentially present in riparian areas within the Deschutes Basin, and sensitive to hydrologic changes

The results of these searches are as follows.

- Plant species listed by Oregon Department of Agriculture as potentially present in Crook, Deschutes, or Jefferson Counties: *Astragalus peckii* and *Botrychium pumicola*.
- Plant and fungal species listed by the USFS as potentially present in Region 6, which includes the Deschutes National Forest: *Anastrophyllum minutum, Blepharostoma arachnoideum, Brachydontium olympicum, Campylium stellatum, Cephaloziella spinigera, Conostomum tetragonum, Encalypta brevipes, Entosthodon fascicularis, Gymnomitrion concinnatum, Haplomitrium hookeri, Harpanthus flotovianus, Jungermannia polaris, Lophozia gillmanii, Marsupella sparsifolia, Nardia japonica, Polytrichastrum sexangulare* var. *vulcanicum, Preissia quadrata, Pseudocalliergon trifarium, Rivulariella gemmipara, Schistidium cinclidodonteum, Schofieldia monticola, Splachnum sphaericum, Trematodon asanoi, Tritomaria exsecta, Gastroboletus vividus, Helvella crassitunicata, Pseudorhizina californica, Rhizopogon alexsmithii, Texosporium sancti-jacobi, Tholurna dissimilis, Agoseris elata, Arnica viscosa, Astragalus peckii, Botrychium pumicola, Calamagrostis breweri, Carex capitata, Carex diandra, Carex lasiocarpa,*

Carex livida, Carex retrorsa, Carex vernacula, Castilleja chlorotica, Cheilanthes feei, Collomia mazama, Cyperus acuminatus, Cyperus lupulinus ssp. *lupulinus, Diphasiastrum complanatum, Elatine brachysperma, Eucephalus gormanii, Gentiana newberryi* var. *newberryi, Heliotropium curassavicum, Lipocarpha aristulata, Lobelia dortmanna, Lycopodiella inundata, Muhlenbergia minutissima, Ophioglossum pusillum, Penstemon peckii, Pilularia americana, Pinus albicaulis, Potamogeton diversifolius, Rorippa columbiae, Rotala ramosior, Scheuchzeria palustris* ssp. *americana, Schoenoplectus subterminalis,* and *Utricularia minor*.

Potential presence of special-status plants in the study area was determined through reference to the collections database maintained by the Consortium of Pacific Northwest Herbaria (2018). This is a comprehensive regional database listing the full collection catalogs of all major herbaria based in Washington, Oregon, and Idaho, and some neighboring areas. Potential presence of special-status plants in the study area was also determined using a GIS shapefile provided by Deschutes National Forest, listing occurrences of special-status plants on the forest. This shapefile was filtered to only identify occurrences within the study area. None of the Oregon or USFS Region 6 listed species was found to have ever been observed in the study area.

Invasive Plants

Potential invasive plants in the study area were determined through reference to the following sources.

- Species listed by the Oregon Department of Agriculture as invasive in (Oregon Department of Agriculture 2018b). The distribution of these weeds in the study area was analyzed using the Weedmapper database (Oregon Department of Agriculture 2018c).
- Plants known to be invasive in Deschutes and Ochoco National Forests, and Crooked River National Grassland, were identified using a GIS shapefile of invasive plant occurrences provided by Deschutes National Forest. This shapefile was filtered to only identify occurrences within the study area, representing a total of 1,750 records. Species recorded within the study area include *Bromus tectorum* (cheatgrass), *Cardaria draba* (whitetop), *Cardaria pubescens* (hairy whitetop), *Centaurea* sp. (knapweed), *Centaurea biebersteinii* (spotted knapweed), *Centaurea diffusa* (diffuse knapweed), *Centaurea solstitialis* (yellow star-thistle), *Centaurea stoebe* ssp. *micranthos* (spotted knapweed), *Cirsium arvense* (Canada thistle), *Cirsium vulgare* (bull thistle), *Convolvulus arvensis* (field bindweed), *Cytisus scoparius* (Scotch broom), *Elymus repens* (quackgrass), *Euphorbia esula* (leafy spurge), *Hieracium aurantiacum* (orange hawkweed), *Hypericum perforatum* (common St. Johnswort), *Iris pseudacorus* (paleyellow iris), *Isatis tinctoria* (Dyer's woad), *Kochia scoparia* (burningbush), *Lepidium* (pepperweed), *Leucanthemum vulgare* (oxeye daisy), *Linaria dalmatica* (Dalmatian toadflax), *Linaria vulgaris* (butter and eggs), *Melilotus officinalis* (sweetclover), *Myriophyllum spicatum* (Eurasian watermilfoil), *Onopordum acanthium* (Scotch cottonthistle), *Phalaris arundinacea* (reed canarygrass), *Salsola kali* (Russian thistle), *Senecio jacobaea* (stinking willie), *Solanum triflorum* (cutleaf nightshade), *Taeniatherum caput-medusae* (medusahead), *Tribulus terrestris* (puncturevine), and *Verbascum thapsus* (common mullein).

The Oregon Department of Agriculture classifies weeds as A, B, or T weeds, defined as follows (Oregon Department of Agriculture 2018b).

- **A Listed Weed (A):** A weed of known economic importance that occurs in the state in small enough infestations to make eradication or containment possible; or is not known to occur, but its presence in neighboring states make future occurrence in Oregon seem imminent. Recommended action: Infestations are subject to eradication or intensive control when and where found.
- **B Listed Weed (B):** A regionally abundant weed of economic importance that may have limited distribution in some counties. Recommended action: Limited to intensive control at the state, county, or regional level as determined on a site-specific, case-by-case basis. Where implementation of a fully integrated statewide management plan is not feasible, biological control (when available) is be the primary control method.
- **T Designated Weed (T):** A focal species for prevention and control by the Oregon Noxious Weed Control Program. Action against these weeds will receive priority. T-designated noxious weeds are determined by the Oregon State Weed Board, which directs the Oregon Department of Agriculture to develop and implement a statewide management plan. T-designated noxious weeds are species selected from either the A or B list.

USFS does not have a weed classification system, but all listed weeds are subject to control.

The great majority of invasive plant species potentially present in the study area are habitat generalists that may occur in riparian or wetland settings, but are also commonly found in varied upland settings, including both forest and nonforest communities. As such the proposed action has limited potential to affect their distribution. However, several of the less common species have a riparian or wetland association, and reed canarygrass is a very common species that has riparian and wetland associations. This analysis therefore particularly addresses potential effects of the proposed action on reed canarygrass, while acknowledging that similar affects will accrue to other riparian- and wetland-associated invasive plants. The analysis also focuses on the potential for the proposed action and alternatives to alter site vulnerability to the invasion and persistence of invasive weeds by changing hydrological factors that influence the availability of bare soil substrates where weeds can readily establish. Alternatives that reduce seasonal hydrologic fluctuations, flooding, and sedimentation would tend to develop persistent native-dominated plant communities that have reduced presence of invasive weeds. Alternatives that increase seasonal hydrologic fluctuations, flooding, and sedimentation would tend to develop areas of exposed unvegetated soil or sediment that are highly vulnerable to weed infestation.

Special-Status Wildlife

An inventory of special-status wildlife species potentially present in the study area was created through reference to the following sources.

- A special-status species list published by the Oregon Department of Fish and Wildlife (ODFW), listing all special-status species potentially present in the East Cascades ecoregion as defined by the Oregon Conservation Strategy; this ecoregion includes the entire study area (Oregon Department of Fish and Wildlife 2016).
- A special-status species list provided by Deschutes National Forest in response to a query as to which special-status species should be assessed in this EIS (U.S. Forest Service 2016).

- A special-status species list provided by the Prineville District, U.S. Bureau of Land Management (Ashton pers. comm.).

These species lists included many different listing classifications. Some of these special-status species are imperiled, but many others are not rare and have large, healthy populations in the study area. The special-status classification codes used in the EIS are defined in Table 1.

Table 1. Special-Status Species Classifications Defined

Classification	Definition
BG	A species protected under the Bald and Golden Eagle Protection Act.
BLM	A species identified by BLM as a species of concern for this EIS.
DBC	Species identified by Deschutes National Forest as Birds of Conservation Concern, referencing a larger FWS list (U.S. Fish and Wildlife Service 2008).
DCS	Species identified by Deschutes National Forest as part of the Conservation Strategy for the East Slope of the Cascade Mountains.
DNF	Species identified by the Deschutes National Forest part of the Northwest Forest Plan.
DO	Species identified by the Deschutes National Forest as Other Required Species.
DS	Species identified by the Deschutes National Forest as Regional Forester Sensitive
FE	A species listed as endangered by FWS. An endangered species is defined in the ESA as a species "in danger of extinction throughout all or a significant portion of its range."
FT	A species listed as threatened by FWS. A threatened species is defined in the ESA as a species "likely to become endangered within the foreseeable future throughout all or a significant portion of its range.”
FPT	A species that FWS has proposed for listing as threatened.
MIS	A species identified by Deschutes National Forest as a Management Indicator Species. Management Indicators are defined in FSM 2620.5-1 as “Plant and animal species, communities, or special habitats selected for emphasis in planning, and which are monitored during forest plan implementation in order to assess the effects of management activities on their populations and the populations of other species with similar habitat needs which they may represent” (U.S. Forest Service 1991).
SC	A species that is being reviewed by ODFW for as a candidate for listing as threatened or endangered on the state Threatened and Endangered Species List (OAR 625-100-040(1).
ST	A species listed by ODFW as threatened. *Threatened* means an animal that could become endangered in the near future within all or a portion of its range (OAR 625-100-0001(3)).
SS	A species listed as an Oregon Sensitive Species. *Sensitive* refers to wildlife species, subspecies, or populations that are facing one or more threats to their populations, habitat quantity or habitat quality or that are subject to a decline in number of sufficient magnitude such that they may become eligible for listing on the state Threatened and Endangered Species List (OAR 625-100-040(1)).
SSC	A species listed as an Oregon Sensitive Species-Critical. These sensitive species are also of particular conservation concern. Sensitive-Critical species have current or legacy threats that are significantly affecting their abundance, distribution, diversity, and/or habitat (Oregon Department of Fish and Wildlife 2016).

EIS = environmental impact statement; FWS = U.S. Fish and Wildlife Service; ESA = Endangered Species Act; OAR = Oregon Administrative Rules; ODFW = Oregon Department of Fish and Wildlife

The inventory of special-status wildlife species potentially present in the study area was screened according to two criteria.

1. Is the species likely to occur in the study area?
2. Does the species have a primary association with aquatic, wetland, or riparian habitats?

Criterion 1 was resolved by reference to online databases of species occurrence. The principal sources used were eBird.org for birds, and VertNet.org for all other vertebrate species. The eBird (2018) site is a "citizen science" site that maintains records of sightings of birds; most records have been acquired since 2001. The database is very complete for species occurring in the United States. VertNet.org is a database frequently used by vertebrate biologists researching specimen collections, especially within the United States, and is frequently cited in peer-reviewed publications in vertebrate biology. Published literature was also used for some species and was the sole source used to address Criterion 1 for invertebrate species. Species that have never been recorded anywhere in the study area were assumed to not occur in the study area and are not otherwise analyzed in the EIS. Species that have been recorded in the study area were additionally assessed under Criterion 2.

Criterion 2 was resolved by reference to published literature addressing all special-status species that have been recorded anywhere in the study area. For most species, this review used the online database NatureServe.org (2018), which is a standard database recommended by the U.S. Fish and Wildlife Service (FWS) and widely referenced in conservation analyses. For some species, NatureServe data were not sufficient to assess likely habitat associations of the species where it occurs within the study area, and published literature was referenced.

All species found to pass both criteria are addressed in the EIS.

Table 2 lists all species evaluated and the outcome of evaluation under the two criteria. Descriptions of the columns listed in Table 2 are as follows.

- **Taxonomic group:** Each species is assigned to the invertebrates, or to a class of vertebrates (amphibians, reptiles, birds, or mammals).
- **Species common and scientific names:** Scientific names correspond to the usage of the listing authority (FWS, USFS, or ODFW).
- **Species status:** Uses the classification codes defined in Table 1.
- **Criterion 1:** Whether the species has been recorded in the study area. If yes, additionally listed as *low, moderate,* or *high. Low* indicates the species has occasionally been recorded, typically with years between successive records. Often such infrequent records indicate a migratory or accidental occurrence. *Moderate* indicates the species has frequently been recorded in at least some portions of the study area, suggesting the presence of a persistent population of the species. *High* indicates the species is abundant in at least some portions of the study area, suggesting a large population and possibly a significant ecological role.
- **Criterion 2:** Whether the species has a primary association with aquatic, wetland, or riparian habitats; yes or no.
- **Determination:** either a negligible impact risk, meaning the species is not otherwise addressed in this EIS; or a potential impact risk, meaning the species is addressed in Chapter 3, *Affected Environment and Environmental Consequences*, of this EIS.
- **Rationale**: The justification underlying the determination.

Table 2. Species Evaluated for Inclusion in the EIS

Taxonomic Group	Species Common Name	Species Scientific Name	Status[a]	Criterion 1	Criterion 2	Determination	Rationale
Amphibian	Cascades frog	*Rana cascadae*	FSSS, SS	Low	Yes	Potential impact risk	Potentially in hydrologically connected waters in upper elevations of watershed.
Amphibian	Columbia spotted frog	*Rana luteiventris*	DS	No	Yes	Negligible impact risk	Not known to occur in study area: nearest occurrences are east, in Great Basin ecoregion.
Amphibian	Cope's giant salamander	*Dicamptodon copei*	SS	No	Yes	Negligible impact risk	Not known to occur in study area; occurs at higher elevations than study area.
Amphibian	Western toad	*Anaxyrus boreas*	SS	High	Yes	Potential impact risk	Uses riverine and reservoir habitats, and is known to occur in study area.
Bird	American peregrine falcon	*Falco peregrinus anatum*	DBC, DS, MIS	Moderate	No	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Bald eagle	*Haliaeetus leucocephalus*	BG, DBC, DS, MIS, SS	Moderate	Yes	Potential impact risk	Commonly forages in riparian forests.
Bird	Black swift	*Cypseloides niger*	DBC	Low	No	Negligible impact risk	The rare occurrences in the Deschutes Basin do not show association with riparian or wetland habitats.
Bird	Black-chinned sparrow	*Spizella atrogularis*	DBC	No	No	Negligible impact risk	Not known to occur in study area. Nearest known occurrences are south of Upper Klamath Lake.
Bird	Black-crowned rosy finch	*Leucostichte atrata*	DBC	No	No	Negligible impact risk	Not known to occur in study area. Nearest known occurrences are in southeastern Oregon.

Taxonomic Group	Species Common Name	Species Scientific Name	Status[a]	Criterion 1	Criterion 2	Determination	Rationale
Bird	Black-throated sparrow (BR and OW only)	*Amphispiza bilineata*	DO	Low	No	Negligible impact risk	No primary association with habitat subject to impacts and rare in study area (most occurrences are to the east, in the Basin and Range ecoregion).
Bird	Bobolink (GB and OW only)	*Dolychonix ozyvorus*	DO	Low	No	Negligible impact risk	No primary association with habitat subject to impacts and rare in study area (most occurrences are to the east, in the Basin and Range ecoregion).
Bird	Brewer's sparrow	*Spizella breweri*	DBC, DO	Moderate	No	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Brown creeper	*Certhia americana*	DCS	High	Yes	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Bullock's oriole	*Icterus bullockii*	DO	High	Yes	Potential impact risk	Uses riparian habitat and is known to occur in study area.
Bird	Burrowing owl	*Athene cunicularia*	DO	Low	No	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Calliope hummingbird	*Selasphorus calliope*	DBC	Moderate	Yes	Potential impact risk	Uses riparian (and upland) habitat and is known to occur in study area.
Bird	Caspian tern	*Hydroprogne caspia*	SS	Moderate	Yes	Potential impact risk	Forages on larger, fish-bearing waters.
Bird	Chipping sparrow	*Spizella passerina*	DCS	High	No	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Clark's nutcracker	*Nucifraga columbiana*	DCS	High	No	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Cooper's hawk	*Accipiter cooperii*	MIS	High	No	Negligible impact risk	No primary association with habitat subject to impacts.

Taxonomic Group	Species Common Name	Species Scientific Name	Status[a]	Criterion 1	Criterion 2	Determination	Rationale
Bird	Dusky grouse	*Dendragapus obscurus*	DCS	No	No	Negligible impact risk	No primary association with habitat subject to impacts, and not known to occur in study area; nearest occurrences are east, in Ochoco Mountains.
Bird	Ferruginous hawk	*Buteo regalis*	DBC, DO	Moderate	No	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Flammulated owl	*Psiloscops flammeolus*	DBC, DCS, DNF, SS	Low	No	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Golden eagle	*Aquila chrysaetos*	BG, DBC, MIS, SS	Moderate	No	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Grasshopper sparrow	*Ammodrammus savannarum*	DO	No	No	Negligible impact risk	No primary association with habitat subject to impacts, and not known to occur in study area: nearest occurrences are south, in Klamath area.
Bird	Gray flycatcher	*Empidonax wrightii*	DO	Moderate	Yes	Potential impact risk	Uses riparian (and upland) habitat and is known to occur in study area.
Bird	Great blue heron	*Ardea herodias*	MIS	High	Yes	Potential impact risk	Commonly forages near water bodies and nests in riparian or wetland forests.
Bird	Great gray owl	*Strix nebulosa*	BLM, DNF, MIS, SS	Low	No	Negligible impact risk	No primary association with habitat subject to impacts, and occurs at higher elevations than study area.
Bird	Greater (western) sage grouse	*Centrocercus urophasianus phaeios*	DBC, DO, DS	Moderate	No	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Greater sandhill crane	*Antigone canadensis tabida*	DCS, SS	Moderate	Yes	Potential impact risk	May forage or roost in wetlands in areas with long sight lines.
Bird	Green-tailed towhee	Pipio chlorulus	DBC	Moderate	Yes	Potential impact risk	Uses riparian habitat and is known to occur in study area.

Taxonomic Group	Species Common Name	Species Scientific Name	Status[a]	Criterion 1	Criterion 2	Determination	Rationale
Bird	Green-winged teal	*Anas crecca*	MIS	High	Yes	Potential impact risk	Uses lake and river habitat and is known to occur in study area.
Bird	Hairy woodpecker	*Dryobates villosus*	MIS	High	No	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Hermit thrush	*Catharus guttatus*	DCS	High	No	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Lark sparrow	*Chondestes grammacus*	DO	Moderate	No	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Lazuli bunting	*Passerina amoena*	DO	Moderate	Yes	Potential impact risk	Uses riparian habitat and is known to occur in study area.
Bird	Lesser scaup	*Aythya affinis*	MIS	Moderate	Yes	Potential impact risk	Uses lake and river habitat and is known to occur in study area.
Bird	Loggerhead shrike	*Lanius ludovicianus*	DBC, DO	Moderate	No	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Long-billed curlew	*Numenius americanus*	DBC, SS	Moderate	Yes	Potential impact risk	Associated with wetland and riparian habitats.
Bird	Mallard	*Anas platyrhynchos*	MIS	High	Yes	Potential impact risk	Uses lake, river, and wetland habitat and is known to occur in study area.
Bird	Marbled godwit	*Limosa fedoa*	DBC	Low	Yes	Potential impact risk	Uses lake (including reservoir) habitat and is known to occur in study area.
Bird	Neotropical migrant birds	(not applicable)	BLM	High	Yes	Potential impact risk	Many neotropical migrant birds have a primary association with riparian habitat; some also use wetland, lake, and river habitat; many species are known to occur in the study area.
Bird	Northern flicker	*Colaptes auratus*	MIS	High	No	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Northern goshawk	*Accipiter gentilis atricapillus*	BLM, MIS, SS	Low	No	Negligible impact risk	No primary association with habitat subject to impacts.

Taxonomic Group	Species Common Name	Species Scientific Name	Status[a]	Criterion 1	Criterion 2	Determination	Rationale
Bird	Northern pintail	*Anas acuta*	MIS	Moderate	Yes	Potential impact risk	Uses lake and river habitat and is known to occur in study area.
Bird	Northern spotted owl	*Strix occidentalis caurina*	MIS, FT, ST	Low	No	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Northern waterthrush	*Parkesia noveboracensis*	BLM, DS	Low	Yes	Negligible impact risk	Occurrences in study area are upstream and at higher elevations than the affected waters.
Bird	Olive-sided flycatcher	*Contopus cooperi*	DCS, SSC	Moderate	Yes	Potential impact risk	Uses riparian habitats and is known to occur in study area.
Bird	Osprey	*Pandion haliaetus*	MIS	Moderate	Yes	Potential impact risk	Forages on fish-bearing waters and is known to occur in study area.
Bird	Pileated woodpecker	*Dryocopus pileatus*	MIS	Moderate	No	Negligible impact risk	No primary association with habitat subject to impacts, and primarily occurs at higher elevations than study area.
Bird	Pinyon jay	*Gymnorhinus cyanocephalus*	DBC	High	No	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Prairie falcon	*Falco mexicanus*	DO	Moderate	No	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Pygmy nuthatch	*Sitta pygmaea*	DCS, DNF	High	No	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Red-tailed hawk	*Buteo jamaicensis*	MIS	High	No	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Sage sparrow	*Artemisiospiza nevadensis*	DBC, DO	Low	No	Negligible impact risk	No primary association with habitat subject to impacts, and most occurrences in central Oregon have been east of study area.

Taxonomic Group	Species Common Name	Species Scientific Name	Status[a]	Criterion 1	Criterion 2	Determination	Rationale
Bird	Sage thrasher	*Oreoscoptes montanus*	DBC, DO	Low	No	Negligible impact risk	No primary association with habitat subject to impacts, and most occurrences in central Oregon have been east of study area.
Bird	Sharp-shinned hawk	*Accipiter striatus*	MIS	Low	No	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Sharp-tailed grouse	*Tympanuchus phasianellus*	DO	No	No	Negligible impact risk	Not known to occur in study area: nearest occurrences are far east, in Columbia Basin and Wallowa Mountains.
Bird	Snowy plover	*Charadrius nivosus*	DBC	Low	Yes	Negligible impact risk	Rarely recorded in study area, and not at waters potentially affected by any of the alternatives.
Bird	Swainson's hawk	*Buteo swainsoni*	SS	Low	No	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Tricolored blackbird	*Agelaius tricolor*	DBC, DS	Low	Yes	Potential impact risk	Uses wetland and riparian habitat and is known to occur in study area.
Bird	Tule goose	*Anser albifrons elgasi*	DS, MIS	Low	No	Negligible impact risk	The rare occurrences in the Deschutes Basin do not show association with riparian or wetland habitats.
Bird	Virginia's warbler	*Oreothlypis virginiae*	DBC, DO	No	Yes	Negligible impact risk	Not known to occur in study area; nearest occurrences far to south and east.
Bird	Western grebe	*Aechmophorus occidentalis*	MIS	Moderate	Yes	Potential impact risk	Uses lake and river habitat and is known to occur in study area.
Bird	White-headed woodpecker	*Picoides albolarvatus*	DBC, DCS, DNF, DS, MIS, SSC	Low	No	Negligible impact risk	No primary association with habitat subject to impacts.
Bird	Willow flycatcher	*Empidonax traillii*	DBC, DO	Moderate	Yes	Potential impact risk	Uses riparian habitat and is known to occur in study area.

Taxonomic Group	Species Common Name	Species Scientific Name	Status[a]	Criterion 1	Criterion 2	Determination	Rationale
Bird	Wood duck	*Aix sponsa*	MIS	Moderate	Yes	Potential impact risk	Uses lake and river habitat and is known to occur in study area.
Bird	Yellow rail	*Coturnicops noveboracensis*	DBC, DS, SSC	Low	Yes	Potential impact risk	USFS states species is present in study area (Turner pers. comm.).
Bird	Yellow warbler	*Setophaga petechia*	DO	High	Yes	Potential impact risk	Uses riparian habitat and is known to occur in study area.
Bird	Yellow-billed cuckoo	Coccyzus americanus	DBC, DO, FT	No	Yes	Negligible impact risk	Not known to occur in study area.
Bird	Yellow-breasted chat	*Icteria virens*	DO	Low	Yes	Potential impact risk	Uses riparian and wetland habitat and is known to occur in study area.
Invertebrate	Crater Lake tightcoil	*Pristiloma crateris*	DNF, DS	Moderate	Yes	Potential impact risk	Known to occur in streams within the study area.
Invertebrate	Evening field slug	*Deroceras hesperium*	DNF	Low	Yes	Potential impact risk	Duncan (2005) indicates it may occur in forested, perennially wet areas within the study area.
Invertebrate	Johnson's hairstreak	*Callophrys [Mitoura] johnsoni*	DS	No	No	Negligible impact risk	No primary association with habitat subject to impacts and not known to occur in study area.
Invertebrate	Silver-bordered fritillary	*Boloria selene atrocostalis*	DS	Low	Yes	Negligible impact risk	Not known to occur in study area (U.S. Forest Service 2015).
Invertebrate	Western bumblebee	*Bombus occidentalis*	DS, MIS	Low	No	Negligible impact risk	Not known to occur in study area – found at higher elevations immediately to the west (Turner 2015).
Mammal	American marten	*Martes americana*	MIS	No	Yes	Negligible impact risk	Not known to occur in study area.
Mammal	American pika	*Ochotona princeps*	SS	Low	No	Negligible impact risk	No primary association with habitat subject to impacts.
Mammal	California myotis	*Myotis californicus*	SS	Moderate	No	Negligible impact risk	No primary association with habitat subject to impacts.

Taxonomic Group	Species Common Name	Species Scientific Name	Status[a]	Criterion 1	Criterion 2	Determination	Rationale
Mammal	Elk	*Cervus canadensis*	BLM, MIS	Moderate	Yes	Potential impact risk	Seasonal association with riparian and some wetland habitats in study area.
Mammal	Fringed myotis	*Myotis thysanodes*	DS, SS	Moderate	Yes	Potential impact risk	Forages and may roost in riparian areas.
Mammal	Gray wolf	*Canis lupus*	BLM, FE, FSSS	No	No	Negligible impact risk	No primary association with habitat subject to impacts and not known to occur in study area.
Mammal	Hoary bat	*Lasiurus cinereus*	SS	No	Yes	Negligible impact risk	Not known to occur in study area.
Mammal	Long-legged myotis	*Myotis volans*	SS	Moderate	Yes	Potential impact risk	Forages and may roost in riparian areas.
Mammal	Mule deer	*Odocoileus hemionus*	BLM, MIS	Moderate	Yes	Potential impact risk	Seasonal association with riparian and some wetland habitats in study area.
Mammal	Mule deer	*Odocoileus hemionus*	BLM, MIS	Moderate	Yes	Potential impact risk	Seasonal association with riparian habitats in study area.
Mammal	Pacific fisher	*Pekania pennanti (pennantia)*	DS	Low	Yes	Potential impact risk	Associated with riparian habitats, although no recent records in the study area.
Mammal	Pacific marten	*Martes caurina*	SS	Low	Yes	Potential impact risk	Associated with riparian habitats, although no recent records in the study area.
Mammal	Pallid bat	*Antrozous pallidus*	DS, SS	Moderate	Yes	Potential impact risk	Forages in riparian areas.
Mammal	Sierra Nevada red fox	*Vulpes vulpes necator*	DS, SS	Low	No	Negligible impact risk	No primary association with habitat subject to impacts.
Mammal	Silver-haired bat	*Lasionycteris noctivagans*	SS	Low	Yes	Potential impact risk	Forages in riparian areas.
Mammal	Spotted bat	*Euderma maculatum*	DS, SS	No	Yes	Negligible impact risk	Not known to occur in study area.
Mammal	Townsend's big-eared bat	*Corynorhinus townsendii*	DS, MIS, SS	Low	Yes	Potential impact risk	Forages in riparian areas.

Taxonomic Group	Species Common Name	Species Scientific Name	Status[a]	Criterion 1	Criterion 2	Determination	Rationale
Mammal	Wolverine	*Gulo gulo*	MIS, FTP, ST	Low	No	Negligible impact risk	No primary association with habitat subject to impacts, and occurs at higher elevations than study area.
Mollusk	Shiny tightcoil	*Pristiloma wascoense*	DS	Low	No	Negligible impact risk	No primary association with habitat subject to impacts.
Reptile	California mountain kingsnake	*Lampropeltis zonata*	FSSS, SS	Low	Yes	Negligible impact risk	Not known to occur in study area.
Reptile	Western painted turtle	*Chrysemys picta bellii*	SSC	No	Yes	Negligible impact risk	Not known to occur in study area, and occurs at lower elevations than study area.
Reptile	Western pond turtle	*Actinemys marmorata*	SSC	Low	Yes	Potential impact risk	Known to occur in study area (Wray pers. comm.).
Bird	Redhead	*Aythya americana*	MIS	Moderate	Yes	Potential impact risk	Uses lake and river habitat and is known to occur in study area.
Bird	Ring-necked duck	*Aythya collaris*	MIS	High	Yes	Potential impact risk	Uses lake and river habitat and is known to occur in study area.
Bird	Canvasback	*Aythya valisneria*	MIS	Moderate	Yes	Potential impact risk	Uses lake and river habitat and is known to occur in study area.
Bird	Canada goose	*Branta canadensis*	MIS	High	Yes	Potential impact risk	Uses lake, river, and wetland habitat and is known to occur in study area.
Bird	Bufflehead	*Bucephala albeola*	DS, MIS	Moderate	Yes	Potential impact risk	Commonly forages on fish-bearing water bodies.
Bird	Common goldeneye	*Bucephala clangula*	MIS	Moderate	Yes	Potential impact risk	Uses lake and river habitat and is known to occur in study area.
Bird	Barrow's goldeneye	*Bucephala islandica*	MIS	Moderate	Yes	Potential impact risk	Uses lake and river habitat and is known to occur in study area.
Bird	Trumpeter swan	*Cygnus buccinator*	SS	Moderate	Yes	Potential impact risk	Associated with wetland and riparian habitats and known to occur in study area.

Taxonomic Group	Species Common Name	Species Scientific Name	Status[a]	Criterion 1	Criterion 2	Determination	Rationale
Bird	Common loon	*Gavia immer*	MIS	High	Yes	Potential impact risk	Uses lake habitat, including reservoirs in study area.
Bird	Harlequin duck	*Histrionicus histrionicus*	DS, MIS	Low	Yes	Potential impact risk	Forages and nests along high-energy mountain streams.
Bird	Hooded merganser	*Lophodytes cucullatus*	MIS	Moderate	Yes	Potential impact risk	Uses lake and river habitat and is known to occur in study area.
Bird	American wigeon	*Mareca americana*	MIS	High	Yes	Potential impact risk	Uses lake and river habitat and is known to occur in study area.
Bird	Gadwall	*Mareca strepera*	MIS	Moderate	Yes	Potential impact risk	Uses lake and river habitat and is known to occur in study area.
Bird	Common merganser	*Mergus merganser*	MIS	High	Yes	Potential impact risk	Uses lake and river habitat and is known to occur in study area.
Bird	Ruddy duck	*Oxyura jamaicensis*	MIS	Moderate	Yes	Potential impact risk	Uses lake and river habitat and is known to occur in study area.
Bird	American white pelican	*Pelecanus erythrorhynchos*	SS	Moderate	Yes	Potential impact risk	Habitat includes larger rivers, lakes, and reservoirs.
Bird	Horned grebe	*Podiceps auritus*	DS, MIS	Moderate	Yes	Potential impact risk	Forages on streams and lakes.
Bird	Red-necked grebe	*Podiceps grisegena*	MIS, SSC	Moderate	Yes	Potential impact risk	Uses lake and river habitat.
Bird	Eared grebe	*Podiceps nigricollis*	DBC, MIS	Moderate	Yes	Potential impact risk	Uses lake and river habitat and is known to occur in study area
Bird	Pied-billed grebe	*Podilymbus podiceps*	MIS	Moderate	Yes	Potential impact risk	Uses lake and river habitat and is known to occur in study area.
Bird	Northern shoveler	*Spatula clypeata*	MIS	Moderate	Yes	Potential impact risk	Uses lake and river habitat and is known to occur in study area.
Bird	Cinnamon teal	*Spatula cyanoptera*	MIS	High	Yes	Potential impact risk	Uses lake and river habitat and is known to occur in study area.
Bird	Blue-winged teal	*Spatula discors*	MIS	Moderate	Yes	Potential impact risk	Uses lake, river, and wetland habitat and is known to occur in study area.

Taxonomic Group	Species Common Name	Species Scientific Name	Status[a]	Criterion 1	Criterion 2	Determination	Rationale
Bird	Downy woodpecker	*Dryobates pubescens*	MIS	High	Yes	Potential impact risk	Commonly forages in riparian forests and is known to be common in study area.
Bird	Lewis's woodpecker	*Melanerpes lewis*	DBC, DCS, DO, DS, MIS, SSC	Moderate	Yes	Potential impact risk	Commonly forages in forests with recent burn mortality.
Bird	Black-backed woodpecker	*Picoides arcticus*	DCS, DNF, MIS, SS	Moderate	Yes	Potential impact risk	Commonly nests and forages near water bodies.
Bird	American three-toed woodpecker	*Picoides dorsalis*	MIS, SS	Moderate	Yes	Potential impact risk	Commonly forages in riparian forests.
Bird	Red-naped sapsucker	*Sphyrapicus nuchalis*	DCS, DO, MIS	Moderate	Yes	Potential impact risk	Uses riparian (and upland) habitat and is known to occur in study area.
Bird	Red-breasted sapsucker	*Sphyrapicus ruber*	MIS	Moderate	Yes	Potential impact risk	Uses riparian (and upland) habitat and is known to occur in study area.
Bird	Williamson's sapsucker	*Sphyrapicus thyroides*	DBC, DCS, MIS	Moderate	Yes	Potential impact risk	Uses riparian (and upland) habitat and is known to occur in study area.

[a] Classification codes are defined in Table 1.

Species Guilds

Species selected for analysis in the EIS were assigned to guilds, defined for the purposes of this analysis as groups of species having similar life history requirements for their principal use of riparian and wetland vegetation communities in the study area. Table 3 identifies and defines the guilds, and identifies the species included in each guild.

Table 3. Species Guilds Used in the Wildlife Analysis

Guild	Guild definition and component species
Elk–deer	Large ungulates that seasonally forage in both forest and nonforest riparian habitats, and in some (shallow water, firm bottom) wetlands: Elk, mule deer (Oregon Compass 2018).
Fish-eater	Bird and mammal species that primarily forage on fishes and thus are sensitive to the available extent of fish-bearing waters, regardless of vegetation community: American white pelican, bald eagle, Barrow's goldeneye, bufflehead, Caspian tern, common goldeneye, common loon, common merganser, eared grebe, harlequin duck, hooded merganser, horned grebe, osprey, Pacific fisher, Pacific marten, pied-billed grebe, red-necked grebe, western grebe.
Forest	Birds that primarily or exclusively forage, roost, and breed in riparian forests: American three-toed woodpecker, black-backed woodpecker, Bullock's oriole, calliope hummingbird, downy woodpecker, green-tailed towhee, lazuli bunting, Lewis's woodpecker, red-breasted sapsucker, red-naped sapsucker, Williamson's sapsucker, yellow warbler.
Generalist	Birds, a toad, and land snails that extensively use habitat outside the study area but are also potentially associated with a variety of riparian and wetland habitats: Crater Lake tightcoil, evening field slug, great blue heron, neotropical migrant birds, western toad.
Insect-eater	Bird and bat species that forage on airborne insects; may forage over or in riparian or wetland vegetation or open water, and typically roost, rest or breed in riparian forest: Gray flycatcher, olive-sided flycatcher, willow flycatcher, yellow-breasted chat, fringed myotis, long-legged myotis, pallid bat, silver-haired bat, Townsend's big-eared bat.
Open–wetland	Birds that extensively use habitat outside the study area but in the study area are mainly associated with unforested wetlands and wet agricultural areas: Canada goose, greater sandhill crane, long-billed curlew, marbled godwit, tricolored blackbird, trumpeter swan.
Shallow-water	Water birds that primarily forage on vegetation and benthic invertebrates in wetlands and shallow water areas of streams, lakes, and reservoirs, and largely roost and nest in those areas as well: American wigeon, blue-winged teal, canvasback, cinnamon teal, gadwall, green-winged teal, lesser scaup, mallard, northern pintail, northern shoveler, redhead, ring-necked duck, ruddy duck, wood duck, yellow rail.
Wetland–aquatic	A largely aquatic amphibian that primarily occurs in cold, shallow ponds and wetlands in Crescent Creek, the Cascades frog; and a largely aquatic reptile that primarily occurs in warmer, slow-moving waters in the Deschutes River from Bend to the Columbia River, the western pond turtle.

River Reach Delineation

The large and environmentally diverse study area was subdivided for the purposes of the effects analysis by separating it into river reaches. The demarcation of river reaches was performed according to the following principles.

- Reaches identified by FWS (2017, 2019).
- Reaches identified by Courter et al. (2014).
- Reach breaks located at dams and major diversions.
- Each reservoir containing one or more reaches.
- Reaches selected to have relatively uniform topography, channel conditions, hydrological gain or loss characteristics, and riparian and wetland vegetation.

The 47 reaches so designated are illustrated in Figure 1 and described in Table 4. The list of wildlife species potentially occurring in the study area, and their distribution in the river reaches, is shown in Table 5.

Figure 1. River Reaches in the Wildlife Study Area—Sheet 1

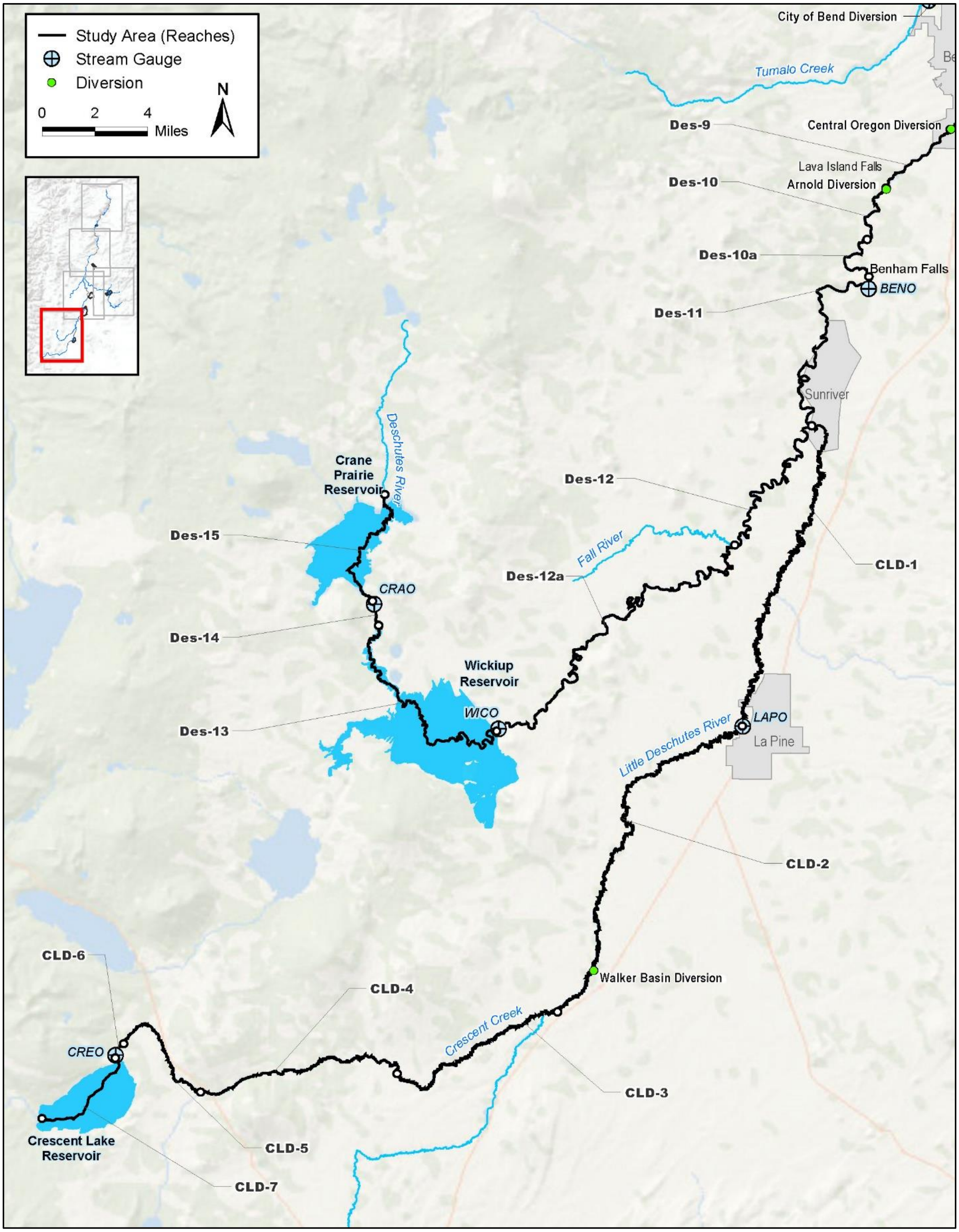


Figure 1. River Reaches in the Wildlife Study Area—Sheet 2

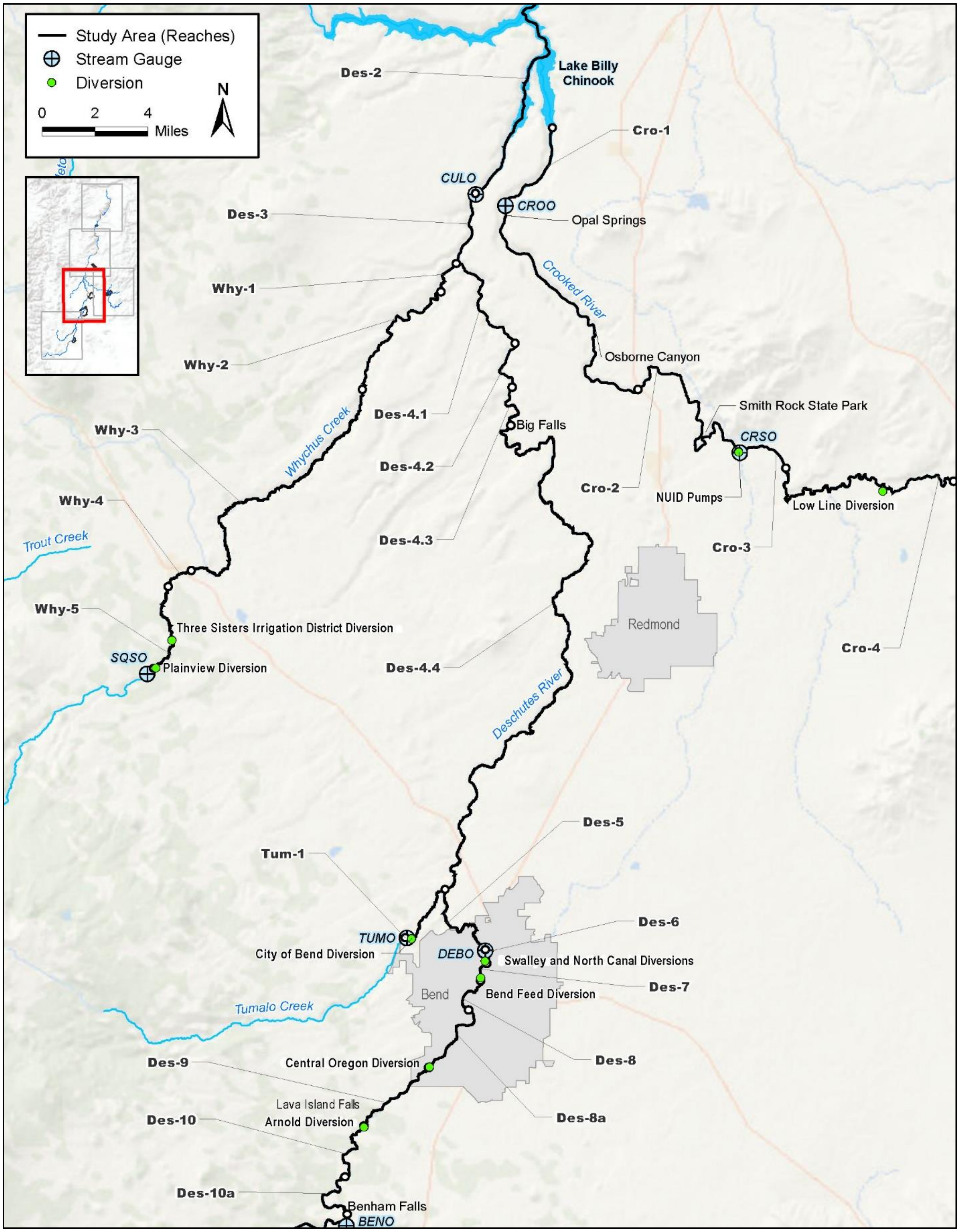


Figure 1. River Reaches in the Wildlife Study Area—Sheet 3

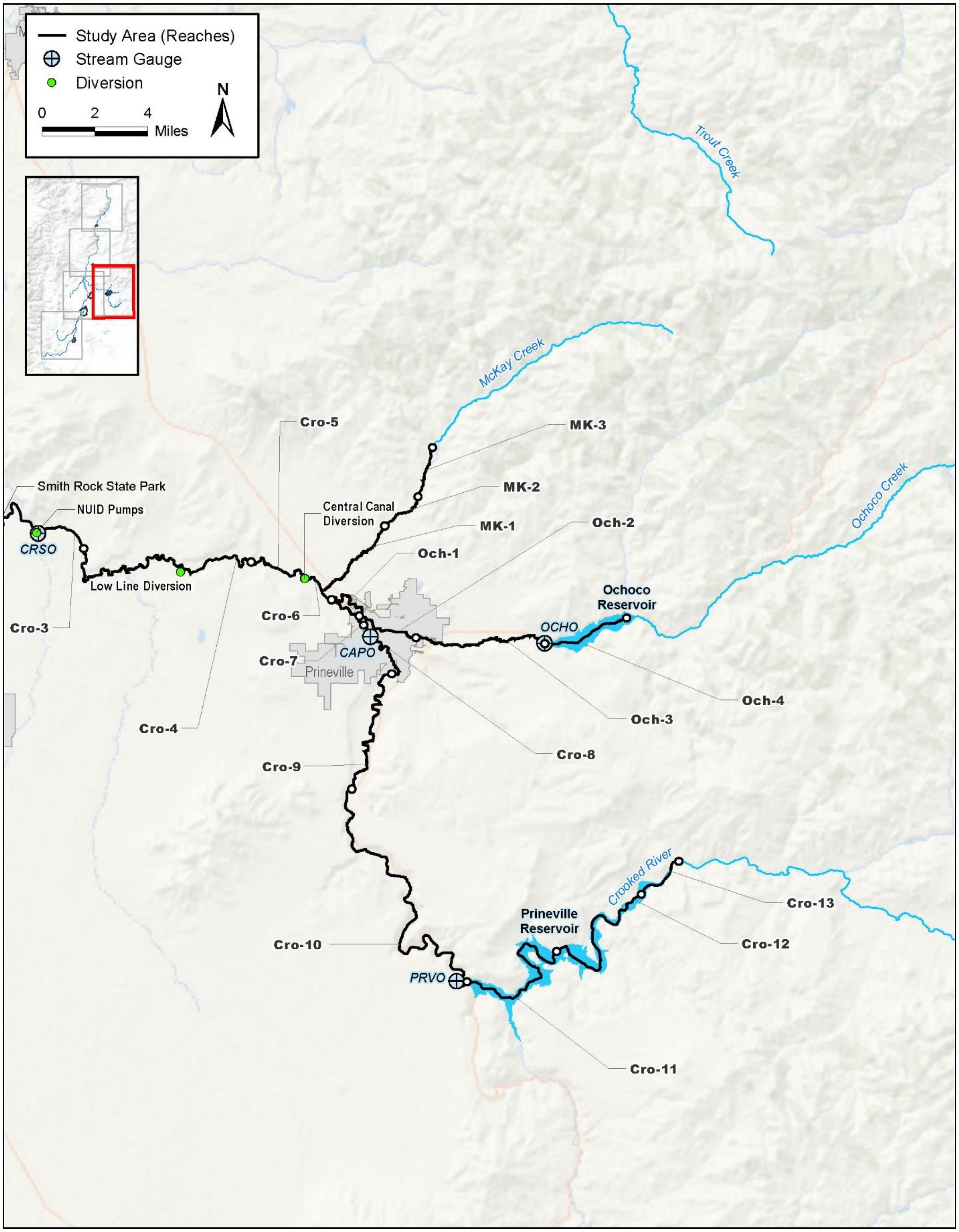


Figure 1. River Reaches in the Wildlife Study Area—Sheet 4

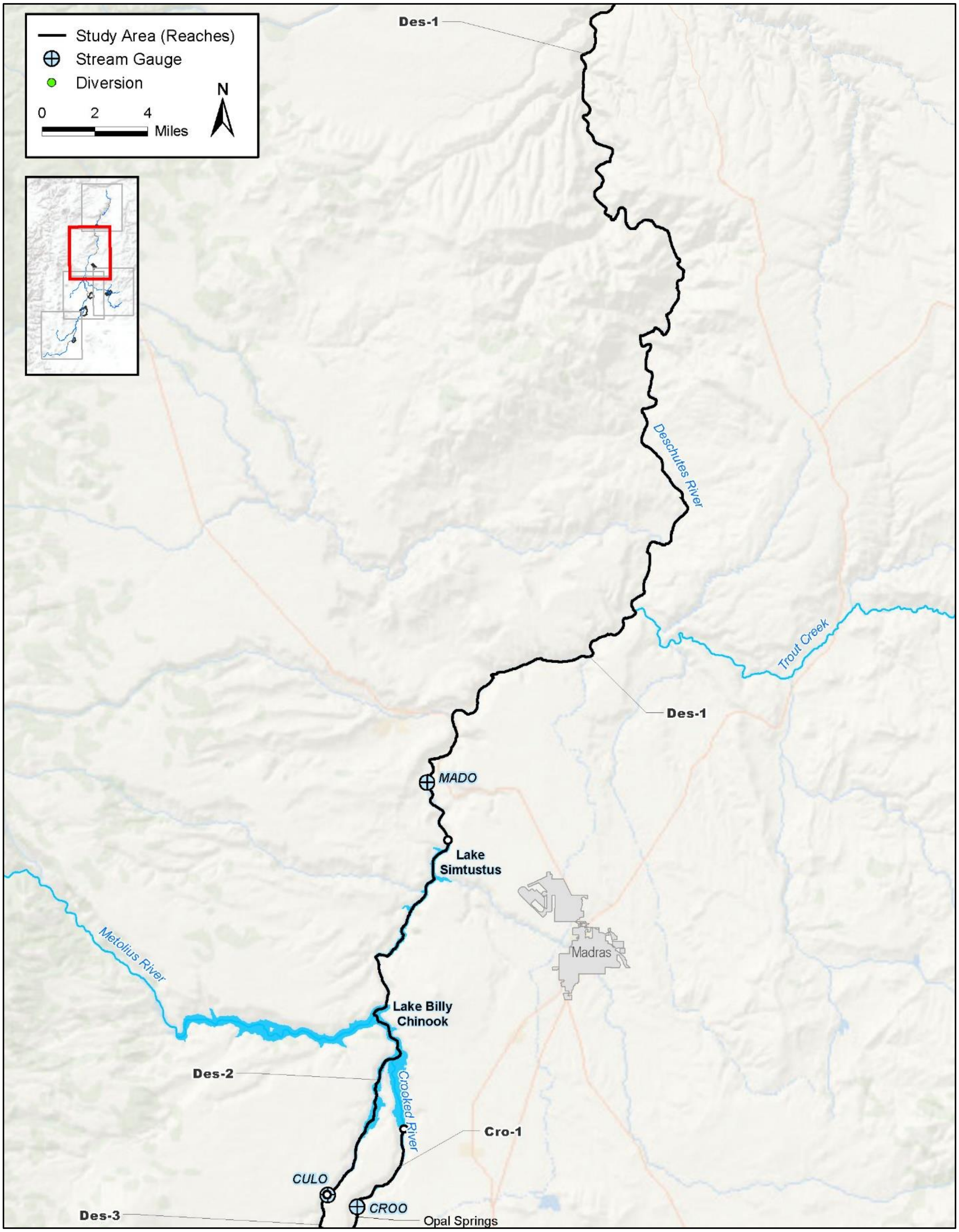


Figure 1. River Reaches in the Wildlife Study Area—Sheet 5

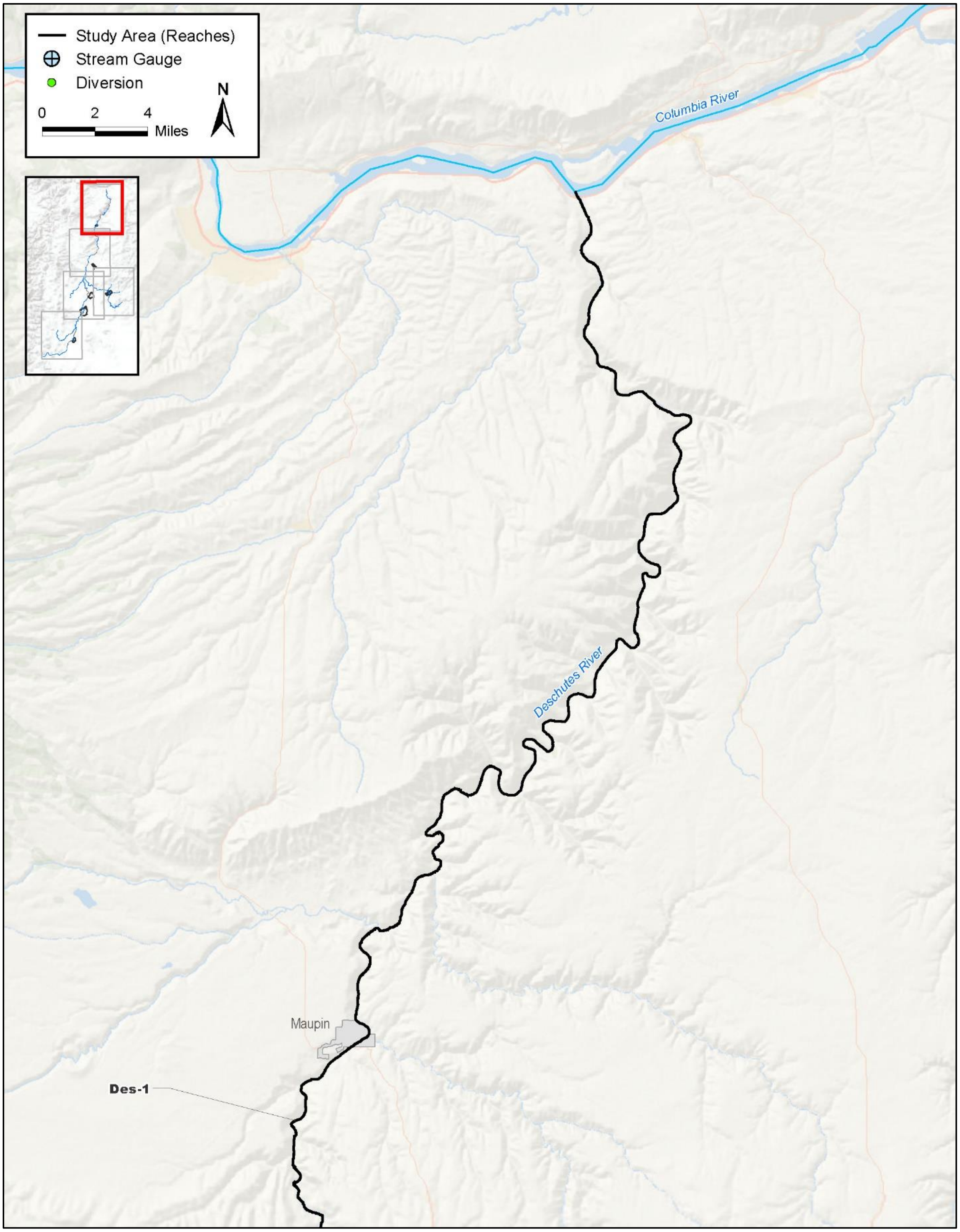


Table 4. Study Area Reaches

River	Reach	Length (mi)	Description
Deschutes	Des-15 Crane Prairie Reservoir	6.5	Crane Prairie Reservoir has locally extensive riparian/wetland vegetation on its margins and at its head. This is the upper limit of potential project effects on the Deschutes River.
Deschutes	Des-14 Crane Prairie Reservoir to Wickiup Reservoir	1.2	Pool-riffle reach with narrow bands of riparian vegetation, mostly located on point bars.
Deschutes	Des-13 Wickiup Reservoir	13.1	About 30% of Wickiup Reservoir has riparian/wetland vegetation, and it develops some localized herbaceous vegetation during draw-down. Uppermost Des-13 is less often inundated and has substantial areas of both herb and shrub wetland and riparian vegetation. Year-to-year water level variations are very large and the riparian/wetland vegetation is persistent despite this variability.
Deschutes	Des-12a Below Wickiup Dam to Fall River confluence	21.7	Same as Des-10a but is above the Fall River confluence.
Deschutes	Des-12 Fall River confluence to Little Deschutes River confluence	11.0	Same as Des-10a but is above the Little Deschutes River confluence.
Deschutes	Des-11 Little Deschutes River confluence to Benham Falls	11.4	Same as Des-10a but is above the BENO gauge.
Deschutes	Des-10a Benham Falls to Dillon Falls	3.1	Similar to Des-10, but moving upstream through the reach, the river gradually becomes steeper and more confined with fewer and smaller associated wetlands.
Deschutes	Des-10 Dillon Falls to Arnold Canal diversion	3.1	River has low gradient, glide morphology due to ancient damming by a lava flow at Lava Island Falls, which is the break between Des-9 and Des-10, and is the site of the Arnold Canal diversion. Some extensive wetland complexes flank the river or its former cut-off meanders; these include a mix of aquatic, wetland, and riparian vegetation, mostly in herbs and shrubs but locally in hardwood and mixed forest.
Deschutes	Des-9 Arnold Canal diversion to Central Oregon Canal diversion	3.7	River has glide morphology with some waterfalls related to lava flows. There are locally important riverine wetlands and floodplain riparian vegetation, mostly located on river bars. The Central Oregon Canal diversion is at the break between Des-8a and Des-9.

River	Reach	Length (mi)	Description
Deschutes	Des-8a Central Oregon Canal diversion to Bend Whitewater Park	3.4	Same as Des-8. Reach Des-8a is designated for consistency with the FWS (2017, 2019) analysis, which placed a reach break at the Colorado Avenue bridge.
Deschutes	Des-8 Bend Whitewater Park to Bend Feed Canal diversion	1.8	Same as Des-7, but is above the Bend Feed Canal diversion.
Deschutes	Des-7 Bend Feed Canal diversion to NUID diversions	0.9	River is confined variously by lava flows, development, and topography, with limited but locally important riparian or aquatic vegetation. River channel has a mixed pool-riffle, step-pool and glide morphology with occasional cascades. The largest diversion on the Deschutes River (North Unit ID and others) is located at the break between Des-6 and Des-7.
Deschutes	Des-6 NUID diversions to DEBO gauge	0.6	Same as Des-3 but is above the DEBO gauge.
Deschutes	Des-5 DEBO gauge to Tumalo Creek confluence	4	Same as Des-3 but is above the Tumalo Creek confluence.
Deschutes	Des-4 Tumalo Creek confluence to Whychus Creek confluence	37.1	Same as Des-3 but is above the Whychus Creek confluence.
Deschutes	Des-3 Whychus Creek confluence to CULO gauge	3.0	River has pool-riffle and step-pool morphology, and is confined within a canyon that experiences active groundwater inflow at or above the river surface elevation for most of its length, and which is the primary hydrology source for riparian and wetland vegetation found in this reach.
Deschutes	Des-2 CULO gauge to Pelton Dam	17.1	The reach includes the Regulating Reservoir, Lake Simtustus, and Lake Billy Chinook. There is negligible riparian or wetland vegetation. The Crooked River joins the Deschutes in Des-2.
Deschutes	Des-1 Pelton Dam to Columbia River	104.6	A desert canyon extends from the Columbia River up to the base of Pelton Dam. There is negligible groundwater inflow, outflow, or tributary contributions. There are very few wetlands, and riparian vegetation extends in a narrow band 0 to 197 feet wide, with an average total width (both river banks combined) of 61 feet.

River	Reach	Length (mi)	Description
Crescent–Little Deschutes	CLD-7 Crescent Lake Reservoir	4.5	Crescent Lake is a reservoir that has no riparian or wetland vegetation except in three large embayments (the inflow stream and two slack water areas) that support mixed wetland and riparian vegetation.
Crescent–Little Deschutes	CLD-6 Crescent Lake Reservoir to railroad crossing	0.9	A pool-riffle streamflows through a mostly unforested riverine wetland wetland/riparian vegetation corridor with a total width of 99 to 164 feet, flanked by ponderosa pine-dominated upland forest.
Crescent–Little Deschutes	CLD-5 Railroad crossing to Marsh Creek	5.9	CLD-5 has a low-gradient meandering stream within a mostly unforested riverine wetland corridor with a total width of 164 to 328 feet, flanked by ponderosa pine-dominated upland forest. At the upper end of CLD-5, the channel is constricted by development.
Crescent–Little Deschutes	CLD-4 Marsh Creek to geomorphic break at 4,380 feet elevation	11.0	River is a meandering underfit stream with glide morphology in an unforested wetland/riparian vegetation corridor with a total width of 164 to 328 feet.
Crescent–Little Deschutes	CLD-3 Geomorphic break at 4380 ft elevation to Walker Basin Canal	12.6	CLD-3 to CLD-6 are along Crescent Creek. The Little Deschutes River upstream of here would not be affected by the proposed action and alternatives. CLD-3 has the same morphology as CLD-1, but is upstream of the Walker Basin Canal diversion.
Crescent–Little Deschutes	CLD-2 Walker Basin Canal to northern outskirts of La Pine	29.2	Same as CLD-1, but upstream of the LAPO gauge.
Crescent–Little Deschutes	CLD-1 Northern outskirts of La Pine to Deschutes River	29.3	CLD-1 and CLD-2 are along the Little Deschutes River. CLD-1 has a low-gradient underfit stream with glide morphology in an unforested wetland/riparian vegetation corridor with a total width of 328 to 984 feet.
Tumalo	Tum-1 Tumalo Creek	2.8	Creek has no wetlands. Width of riparian vegetation is 33 feet, average, on each side of creek. Riparian growth may be supported by groundwater inflow. The upper limit of Tum-1 is the Tumalo Diversion, the upper limit of potential proposed action and alternatives effects.
Whychus	Why-5 SQSO diversion to Sokol pump station	4.1	Channel is confined, pool-riffle, flowing within conifer (ponderosa pine mostly) forest with an average riparian vegetation width of 20 feet along each streambank. There are no wetlands or nonforest areas. Consistent with reach W-4 of Courter et al. (2014). The upper limit of Why-5 is the Plainview diversion, the headward limit of potential project effects.

River	Reach	Length (mi)	Description
Whychus	Why-4 Sokol pump station to US-20	1.3	Creek is in Sisters, an area of intensive suburban development with negligible riparian and no wetland vegetation. Consistent with reach W-3 of Courter et al. (2014).
Whychus	Why-3 Open canyon with agricultural areas, below US-20	12.9	Creek is unconfined or loosely confined with a riparian vegetation width of 66 to 164 feet along each streambank. There is evidence of domestic pasturage, local evidence of groundwater inflow, and local areas of wetlands, irrigated agriculture, and exurban development. The floodplain includes oxbows and other alluvial features. The upper limit of Why-3 coincides with limit of reach W-2 of Courter et al. (2014).
Whychus	Why-2 Tightly confined canyon with narrow riparian strip	6.3	Creek is tightly confined in a canyon with a riparian vegetation width of about 20 feet along each streambank. There is little evidence of groundwater inflow. Includes lowermost portion of reach W-2 of Courter et al. (2014).
Whychus	Why-1 Lowermost confined canyon with more extensive riparian vegetation	1.6	Creek has pool-riffle and step-pool morphology, and is confined within a canyon that experiences active groundwater inflow at or above the river surface elevation for most of its length, and which is the primary hydrology source for riparian and wetland vegetation found in this reach. That vegetation which has an average width of about 66 feet along each streambank. Consistent with Courter et al. (2014) reach W-1.
Crooked	Cro-13 Prineville Reservoir above lower limit of seasonally inundated woody vegetation	2.2	The headwaters of Prineville Reservoir have a large wetland and benches or bars with shrub and herb riparian and wetland vegetation. This is upper limit of potential project effects on the Crooked River.
Crooked	Cro-12 Prineville Reservoir above marina	6.9	Upper Prineville Reservoir, where seasonally exposed areas have some riparian or wetland vegetation.
Crooked	Cro-11 Prineville Reservoir below marina	7.3	Lower Prineville Reservoir, which has no riparian or wetland vegetation.
Crooked	Cro-10 Prineville Reservoir to Rice-Baldwin diversion	14.4	River is below Prineville Reservoir and above Rice-Baldwind diversion, mostly in an open canyon with riparian vegetation about 33 feet wide on each bank, locally wider (on point bars). There are some small areas of agriculture (hayfields). Consistent with reach C-5 of Courter et al. (2014).

River	Reach	Length (mi)	Description
Crooked	Cro-9 Rice-Baldwin diversion to Peoples Canal diversion	6.8	Reach is between the Rice-Baldwin diversion and the Peoples Canal diversion. Morphology is similar to Cro-3, except some areas have steep desert upland on one side and irrigated agriculture on the other. Consistent with upper part of reach C-4 of Courter et al. (2014).
Crooked	Cro-8 City of Prineville	3.2	River is below the Peoples Canal diversion and within the City of Prineville; flanked by intensive development; there is negligible riparian or wetland vegetation. Consistent with lower part of reach C-4 of Courter et al. (2014).
Crooked	Cro-7 City of Prineville to Ochoco Creek	1.8	Same as Cro-4 but is above the Ochoco Creek confluence.
Crooked	Cro-6 Ochoco Creek to Central Canal diversion	1.6	Same as Cro-4 but is above the Central Canal diversion.
Crooked	Cro-5 Central Canal diversion to Low Line Canal diversion	3.0	Same as Cro-4 but is above the Low Line Canal diversion.
Crooked	Cro-4 Low Line Canal diversion to Lone Pine Road crossing	11.7	Unconfined, flanked almost continuously by irrigated agriculture. The river with its riparian zone is mostly 115 feet wide but in places is several times wider between the cultivated fields.
Crooked	Cro-3 Lone Pine Road crossing to North Unit ID pump station	2.3	Same as Cro-2 but is upstream of the NUID pumps.
Crooked	Cro-2 North Unit ID pump station to Crooked River railroad bridge	9.4	Partly in a deep canyon, but has a 33- to 99-foot-wide riparian zone on each bank of the river. The riparian vegetation is supported by a groundwater inflow. No wetlands. Consistent with reach C-2 of Courter et al. (2014).
Crooked	Cro-1 Crooked River railroad bridge to Lake Billy Chinook	15.0	River is tightly confined in deep canyon with no wetlands and almost no riparian vegetation. Lower end is at Deschutes River confluence in Lake Billy Chinook. Consistent with reach C-1 of Courter et al. (2014).
McKay	MK-3 McKay Creek headwaters	2.0	Similar to MK-2 with a somewhat steeper channel that is seasonally dry. Consistent with reach MK-3 of Courter et al. (2014).
McKay	MK-2 Ochoco Canal crossing to Amber Lane	1.9	Similar to MK-1, with some areas of predominately shrub or tree vegetation. Consistent with reach MK-2 of Courter et al. (2014).

River	Reach	Length (mi)	Description
McKay	MK-1 Amber Lane crossing to Crooked River	3.8	Unconfined low-gradient stream through cultivated fields. The riparian corridor width varies from 15 to 328 feet depending on how much land is left uncultivated along the stream. Vegetation is mostly herbs with some shrubs. Consistent with reach MK-1 of Courter et al. (2014).
Ochoco	Och-4 Ochoco Reservoir	3.6	The Ochoco Reservoir shoreline has negligible riparian or wetland vegetation.
Ochoco	Och-3 Ochoco Reservoir to City of Prineville	6.0	Is largely the same as Reach 1, but somewhat more heterogeneous with some desert upland and some residential areas and parks, and aquatic/riparian corridor width 20 to 30 meters.
Ochoco	Och-2 Ochoco Creek through City of Prineville	2.6	Creek is in developed city of Prineville, has riparian trees, but is essentially all developed as parks or residential. No wetlands.
Ochoco	Och-1 City of Prineville to Crooked River	2.5	Creek is unconfined, flanked almost continuously by irrigated agriculture. Combined width of aquatic and riparian vegetation averages 115 feet. Och-1, Och-2, and Och-3 are combined into one reach, O-1, by Courter et al. (2014).

ID = Irrigation District; FWS = U.S. Fish and Wildlife Service.

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Table 5. Correspondence between Species and Reaches in the Study Area

		Reaches																																																			
Guild	Species	Des-1	Des-2	Des-3	Des-4	Des-5	Des-6	Des-7	Des-8	Des-8a	Des-9	Des-10	Des-10a	Des-11	Des-12	Des-12a	Des-13	Des-14	Des-15	Why-1	Why-2	Why-3	Why-4	Why-5	Cro-1	Cro-2	Cro-3	Cro-4	Cro-5	Cro-6	Cro-7	Cro-8	Cro-9	Cro-10	Cro-11	Cro-12	Cro-13	Och-1	Och-2	Och-3	Och-4	Tum-1	CLD-1	CLD-2	CLD-3	CLD-4	CLD-5	CLD-6	CLD-7	MK-1	MK-2	MK-3	Source(s) & Comment
Elk-Deer	Elk	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X											X	X	X					X	X	X	X	X	X	X	X			X	Oregon Compass (2018) identified as important winter range.
Elk-Deer	Mule deer	X	X	X	X															X	X	X	X	X	X	X							X	X	X	X	X					X									X	X	Oregon Compass (2018) identified as important winter range.
Fish-eater	Bald eagle, Barrow's goldeneye, bufflehead, common goldeneye, common merganser, osprey, pied-billed grebe	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	eBird (2018) indicates species is very common in study area.
Fish-eater	Hooded merganser	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X							X	X	X	X	X					X	X	X	X	X	X	X	X	X	X	X	eBird (2018) indicates species is very common, especially in the Deschutes River basin above Bend.
Fish-eater	American white pelican, Caspian tern, common loon, eared grebe, horned grebe, red-necked grebe		X														X		X																X	X					X												eBird (2018) indicates species is almost exclusively at reservoirs.
Fish-eater	Harlequin duck																X		X																																		eBird (2018) indicates species is rare: only 3 records, seen at Crane Prairie and Wickiup.
Fish-eater	Western grebe		X											X			X		X																X	X					X												eBird (2018) indicates species is largely limited to reservoirs and at wetlands near Sunriver.
Fish-eater	Pacific fisher, Pacific marten										X	X	X	X	X	X	X	X	X				X	X																			X	X	X	X	X	X	X				NatureServe (2018) provides county occurrence data and habitat descriptors (conifer forest).
Forest	Bullock's oriole, calliope hummingbird, Downy woodpecker, Lewis's woodpecker, red-breasted sapsucker, red-naped sapsucker, yellow warbler	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	eBird (2018) indicates species is very common in both hardwood and conifer forests throughout study area.
Forest	American Three-toed Woodpecker, black-backed woodpecker, green-tailed towhee, Williamson's sapsucker					X	X	X	X	X	X	X	X	X	X	X	X	X	X				X	X																			X	X	X	X	X	X	X				eBird (2018) indicates species is generally associated with conifer forest.
Forest	Lazuli Bunting	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X							X	X	X	X	X					X	X	X	X	X	X	X	X	X	X	X	eBird (2018) indicates species is common, but sporadic across study area.
Generalist	Great blue heron, western toad	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	eBird (2018) indicates heron is very common in study area. Large toad aggregations reported from Crane Prairie Reservoir (Wray pers. Comm. 2019) but NatureServe (2018) indicates western toad is reported from counties throughout study area.
Generalist	Neotropical migrant birds	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	USFS (2016) provides no definition of "neotropical migrants" but assuming this is a reference to songbirds, they are assumed to be ubiquitous.
Generalist	Evening field slug										X	X	X	X	X	X	X	X	X					X																			X	X	X	X	X	X	X				Duncan (2005) states it occurs at "perennially wet meadows in forested habitats."
Generalist	Crater Lake Tightcoil																																																				Analysis for this species appears in the aquatic species section.
Insect-eater	Gray flycatcher	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	eBird (2018) indicates species is very common in study area.
Insect-eater	Yellow-breasted Chat	X	X	X	X	X	X	X	X	X	X	X													X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X												eBird (2018) indicates species is uncommon and, in study area, found at low elevations.
Insect-eater	Olive-sided flycatcher, willow flycatcher					X	X	X	X	X	X	X	X	X	X	X	X	X	X				X	X																			X	X	X	X	X	X	X				eBird (2018) indicates species is generally associated with conifer forest.
Insect-eater	Pallid bat, Townsend's big-eared bat	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	NatureServe (2018) habitat descriptors.

Guild	Species	Reaches																																																			Source(s) & Comment
		Des-1	Des-2	Des-3	Des-4	Des-5	Des-6	Des-7	Des-8	Des-8a	Des-9	Des-10	Des-10a	Des-11	Des-12	Des-12a	Des-13	Des-14	Des-15	Why-1	Why-2	Why-3	Why-4	Why-5	Cro-1	Cro-2	Cro-3	Cro-4	Cro-5	Cro-6	Cro-7	Cro-8	Cro-9	Cro-10	Cro-11	Cro-12	Cro-13	Och-1	Och-2	Och-3	Och-4	Tum-1	CLD-1	CLD-2	CLD-3	CLD-4	CLD-5	CLD-6	CLD-7	MK-1	MK-2	MK-3	
Insect-eater	Long-legged myotis, silver-haired bat										X	X	X	X	X	X	X	X	X				X	X																			X	X	X	X	X	X	X				NatureServe (2018) provides county occurrence data and habitat descriptors (conifer forest).
Insect-eater	Fringed myotis																																											X	X	X	X	X	X				NatureServe (2018) county occurrence data.
Open-wetland	Canada goose	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	eBird (2018) indicates species is very common in study area.
Open-wetland	Tricolored blackbird																								X	X	X	X	X	X	X	X						X	X	X	X									X	X	X	eBird (2018) indicates species is strongly concentrated on Ochoco and McKay creeks, and the Crooked River below Prineville.
Open-wetland	Trumpeter swan											X	X	X			X		X									X	X	X	X				X	X		X		X	X												eBird (2018) indicates species is uncommon, with sightings in agricultural land west of Prineville, at various reservoirs, and in wetlands northwest of Sunriver.
Open-wetland	Marbled godwit																X																		X	X																	eBird (2018) indicates species is rare, with sightings at Wickiup and Prineville Reservoirs.
Open-wetland	Greater sandhill crane																X		X																																		eBird (2018) shows no greater sandhill cranes in study area, but sandhill cranes not identified to subspecies have many records at Crane Prairie and Wickiup.
Open-wetland	Long-billed curlew																X																																				eBird (2018) indicates species is rare, with a few occurrences at Wickiup and Ochoco Reservoirs.
Shallow-water	American wigeon, green-winged teal, mallard, ring-necked duck	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	eBird (2018) indicates species is very common in study area.
Shallow-water	Blue-winged teal, wood duck			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	eBird (2018) indicates species is occasional in almost all of the study area upstream of Lake Billy Chinook.
Shallow-water	Canvasback		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	eBird (2018) indicates species is occasional in all of the study area except in reach Des-1.
Shallow-water	Cinnamon teal, gadwall, ruddy duck		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	eBird (2018) indicates species is very common, but almost exclusively at reservoirs.
Shallow-water	Lesser scaup, northern pintail, northern shoveler		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X							X	X	X	X	X					X	X	X	X	X	X	X	X	X	X	X	eBird (2018) indicates species is very common, but primarily at reservoirs.
Shallow-water	Redhead											X	X	X			X		X									X	X	X	X				X	X		X		X	X												eBird (2018) indicates species is uncommon, with sightings at reservoirs in in wetlands northwest of Sunriver.
Shallow-water	Yellow rail																		X																																		Turner (pers. comm. 2019) states species occurs in Big Marsh, which is upstream of Des-15.
Wetland-aquatic	Western pond turtle	X	X	X	X	X	X	X	X																																												Based on description by Wray (pers. comm. 2019).
Wetland-aquatic	Cascades frog																																														X	X	X				Based on description by Harrington (pers. comm. 2019).

Codes:
X = Species is potentially present in reach
[empty] = Species is not potentially present in reach, except as an occasional visitor (e.g., a migrant found in unsuitable habitat)

RiverWare Output Analysis

Table 6 summarizes the RiverWare output used to assess potential impacts on vegetation and wildlife. Flow or reservoir elevation metrics were calculated for each reach. Most, but not all reaches contained RiverWare output nodes. For reaches lacking output nodes, potential effects were inferred on the basis of model results for the closest upstream reach, combined with knowledge of hydrology, topography, and vegetation in the affected reach. Reservoir elevations are expressed as pool depths, i.e., the depth of water relative to the lowest pool elevation ever recorded at the reservoir. The metrics used to assess potential impacts were the mean and standard deviation of monthly average flow or reservoir elevation over the period of record. These metrics were chosen because shorter intervals (such as daily averages) are too short a timescale to materially affect vegetation patterns, and because standard deviation is a common and intuitive measure of variability in a time series. Use of standard deviation as a metric requires certain assumptions about the statistical properties of the data, primarily that they have a normal random distribution and that successive values are not correlated with each other. These asssumptions are met reasonably well by this data set, but these results were not used to make probabilistic statements about future variability due to the limitations regarding the validity of statistical assumptions.

RiverWare was run for a baseline interval, and for the implementation phases of each alternative.

- Proposed action years 1 through 7, 8 threough 12, and 13 through 30.
- Alternative 3 years 1 through 5, 6 through 10, and 11 through 30
- Alternative 4 years 1 through 5 and 6 through 20.

For each reach, for each period, within each alternative, changes in the monthly means and standard deviations were compared to the results for the baseline data, for preceding and following periods, for neighboring reaches, and for other alternatives, to identify potentially important differences. In general, differences of less than 10% were regarded as negligible, because this is smaller than the normal range of variation on a month-to-month or year-to-year basis; thus, any changes in vegetation would likely be too small to detect. Differences of more than 10% were regarded as potentially substantial, with a strong likelihood of vegetation community change in those river reaches where vegetation is sensitive to instream flows or reservoir levels. Similarly, substantial changes in standard deviation were regarded as potentially important even if not accompanied by changes in mean monthly flows, because increased variation has the potential to destabilize vegetation communities and make them more vulnerable to reduced vigor or increased presence of invasive species, whereas reduced variation has the opposite effect.

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Table 6a. RiverWare Model Output, Monthly Average Flow and Standard Deviation—Crescent Creek and Little Deschutes River

Alternative	Month	Reach CLD-1				Reach CLD-2				Reach CLD-3				Reach CLD-4				Reaches CLD-5, -6				Reach CLD-7			
		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Depth (ft)		Change vs No Action	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
No-Action Alternative	Jan	172	158			172	158			171	158			26	19			26	19			12.0	6.7		
	Feb	192	154			192	154			191	154			30	24			30	24			12.3	6.7		
	Mar	229	126			229	126			228	126			33	19			33	19			12.5	6.7		
	Apr	291	139			291	139			299	139			38	22			38	22			12.6	6.7		
	May	342	182			342	182			352	182			49	35			49	35			13.0	6.6		
	Jun	252	172			252	172			269	172			58	48			58	48			13.5	6.4		
	Jul	154	79			154	79			170	79			80	37			80	37			13.2	6.3		
	Aug	148	46			148	46			160	47			111	33			111	33			11.9	6.5		
	Sep	126	45			126	45			132	45			83	32			83	32			10.8	6.5		
	Oct	91	38			91	38			96	38			31	11			31	11			10.5	6.6		
	Nov	126	70			126	70			124	70			34	17			34	17			10.9	6.7		
	Dec	153	134			153	134			152	134			26	20			26	20			11.4	6.8		
Alternative 2 (Years 1–7)	Jan	185	173	8%	10%	185	173	8%	10%	184	173	8%	10%	32	37	22%	96%	32	37	22%	96%	16.5	5.0	38%	-26%
	Feb	199	152	4%	-1%	199	152	4%	-1%	198	152	4%	-1%	29	31	-3%	32%	29	31	-3%	32%	16.8	4.7	37%	-29%
	Mar	227	134	-1%	6%	227	134	-1%	6%	227	134	-1%	6%	30	37	-8%	95%	30	37	-8%	95%	17.0	4.6	36%	-31%
	Apr	286	140	-2%	1%	286	140	-2%	1%	293	140	-2%	1%	33	31	-15%	38%	33	31	-15%	38%	17.2	4.5	37%	-33%
	May	346	180	1%	-1%	346	180	1%	-1%	357	180	1%	-1%	53	44	7%	23%	53	44	7%	23%	17.6	4.3	35%	-35%
	Jun	269	174	7%	1%	269	174	7%	1%	285	174	6%	1%	68	56	16%	16%	68	56	16%	16%	17.9	4.0	33%	-37%
	Jul	180	64	17%	-19%	180	64	17%	-19%	196	64	15%	-20%	83	30	4%	-19%	83	30	4%	-19%	17.5	4.2	33%	-34%
	Aug	189	26	28%	-44%	189	26	28%	-44%	202	26	26%	-44%	114	19	3%	-41%	114	19	3%	-41%	16.2	4.6	36%	-28%
	Sep	166	26	32%	-43%	166	26	32%	-43%	173	26	31%	-43%	88	22	6%	-30%	88	22	6%	-30%	15.0	4.9	40%	-24%
	Oct	108	35	19%	-8%	108	35	19%	-8%	113	35	18%	-8%	25	25	-19%	139%	25	25	-19%	139%	14.7	5.3	41%	-20%
	Nov	126	68	0%	-4%	126	68	0%	-4%	124	68	0%	-4%	19	24	-43%	42%	19	24	-43%	42%	15.3	5.3	41%	-21%
	Dec	163	132	6%	-2%	163	132	6%	-2%	162	132	6%	-2%	25	34	-3%	68%	25	34	-3%	68%	16.0	5.2	40%	-23%
Alternative 2 (Years 8–12)	Jan	184	173	8%	9%	184	173	0%	9%	183	173	0%	9%	31	37	-3%	94%	31	37	-3%	94%	16.3	5.1	37%	-25%
	Feb	200	158	4%	2%	200	158	1%	2%	199	158	1%	2%	31	37	6%	56%	31	37	6%	56%	16.7	4.8	35%	-28%
	Mar	226	131	-1%	4%	226	131	-1%	4%	225	131	-1%	4%	28	31	-6%	61%	28	31	-6%	61%	16.9	4.7	35%	-30%
	Apr	285	142	-2%	2%	285	142	0%	2%	292	142	0%	2%	31	38	-4%	67%	31	38	-4%	67%	17.1	4.6	36%	-32%
	May	347	179	2%	-2%	347	179	0%	-2%	358	179	0%	-2%	54	38	2%	8%	54	38	2%	8%	17.4	4.4	34%	-34%
	Jun	270	173	7%	0%	270	173	0%	0%	286	173	0%	0%	69	54	1%	12%	69	54	1%	12%	17.8	4.2	32%	-34%
	Jul	182	69	18%	-12%	182	69	2%	-12%	198	69	1%	-12%	86	34	3%	-7%	86	34	3%	-7%	17.4	4.3	32%	-31%
	Aug	189	30	28%	-36%	189	30	0%	-36%	201	30	0%	-36%	114	24	0%	-27%	114	24	0%	-27%	16.0	4.8	35%	-26%
	Sep	163	30	29%	-33%	163	30	-2%	-33%	169	30	-2%	-33%	85	27	-4%	-16%	85	27	-4%	-16%	14.9	5.0	38%	-22%
	Oct	107	34	18%	-11%	107	34	-1%	-11%	112	34	-1%	-10%	24	24	-3%	133%	24	24	-3%	133%	14.6	5.3	39%	-19%
	Nov	128	68	2%	-3%	128	68	2%	-3%	126	68	2%	-3%	21	26	10%	54%	21	26	10%	54%	15.2	5.4	40%	-20%
	Dec	163	134	6%	0%	163	134	0%	0%	162	134	0%	0%	26	35	1%	74%	26	35	1%	74%	15.9	5.2	39%	-22%
Alternative 2 (Years 13–30)	Jan	187	177	9%	12%	187	177	1%	12%	186	177	1%	12%	33	41	7%	117%	33	41	7%	117%	16.0	5.2	34%	-23%
	Feb	199	152	4%	-1%	199	152	-1%	-1%	198	152	-1%	-1%	30	30	-4%	27%	30	30	-4%	27%	16.3	4.9	33%	-26%
	Mar	228	128	0%	2%	228	128	1%	2%	227	128	1%	2%	30	30	7%	59%	30	30	7%	59%	16.5	4.9	32%	-27%
	Apr	289	143	-1%	3%	289	143	1%	3%	296	143	1%	3%	35	35	13%	56%	35	35	13%	56%	16.7	4.7	33%	-29%
	May	351	180	3%	-1%	351	180	1%	-1%	361	180	1%	-1%	57	41	6%	15%	57	41	6%	15%	17.0	4.6	31%	-31%
	Jun	265	165	5%	-4%	265	165	-2%	-4%	281	165	-2%	-4%	63	46	-8%	-5%	63	46	-8%	-5%	17.4	4.4	29%	-30%
	Jul	181	67	18%	-15%	181	67	-1%	-15%	197	67	-1%	-15%	84	37	-2%	1%	84	37	-2%	1%	17.0	4.7	29%	-26%
	Aug	183	35	24%	-24%	183	35	-3%	-24%	195	36	-3%	-23%	108	31	-5%	-6%	108	31	-5%	-6%	15.7	5.1	32%	-22%
	Sep	160	32	28%	-29%	160	32	-1%	-29%	167	32	-1%	-29%	83	28	-3%	-10%	83	28	-3%	-10%	14.7	5.1	36%	-21%
	Oct	108	35	19%	-9%	108	35	1%	-9%	113	35	1%	-9%	25	24	4%	131%	25	24	4%	131%	14.4	5.4	37%	-18%
	Nov	129	68	2%	-4%	129	68	1%	-4%	127	68	1%	-4%	22	24	4%	44%	22	24	4%	44%	15.0	5.5	38%	-19%
	Dec	165	136	8%	1%	165	136	1%	1%	164	136	1%	1%	28	35	9%	72%	28	35	9%	72%	15.6	5.3	36%	-21%

Alternative	Month	Reach CLD-1				Reach CLD-2				Reach CLD-3				Reach CLD-4				Reaches CLD-5, -6				Reach CLD-7			
		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Depth (ft)		Change vs No Action	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
	Jan	174	159	2%	1%	174	159	2%	1%	174	159	2%	1%	29	22	11%	17%	29	22	11%	17%	13.1	6.6	10%	-2%
	Feb	194	155	1%	1%	194	155	1%	1%	193	155	1%	1%	32	25	6%	4%	32	25	6%	4%	13.5	6.5	9%	-2%
	Mar	228	127	0%	1%	228	127	0%	1%	227	127	0%	1%	32	24	-3%	25%	32	24	-3%	25%	13.6	6.5	9%	-3%
	Apr	284	140	-3%	1%	284	140	-3%	1%	292	140	-2%	1%	31	26	-19%	16%	31	26	-19%	16%	13.8	6.4	10%	-3%
	May	342	176	0%	-3%	342	176	0%	-3%	352	176	0%	-3%	49	38	0%	8%	49	38	0%	8%	14.2	6.3	10%	-4%
Alternative 3	Jun	256	173	2%	0%	256	173	2%	0%	273	173	1%	1%	62	55	7%	15%	62	55	7%	15%	14.7	6.0	9%	-5%
(Years 1–5)	Jul	162	78	5%	-1%	162	78	5%	-1%	178	78	4%	-1%	87	32	10%	-13%	87	32	10%	-13%	14.3	6.1	8%	-4%
	Aug	151	43	2%	-7%	151	43	2%	-7%	163	44	2%	-7%	115	30	3%	-8%	115	30	3%	-8%	12.9	6.3	9%	-2%
	Sep	130	43	3%	-5%	130	43	3%	-5%	137	43	3%	-5%	87	29	5%	-8%	87	29	5%	-8%	11.7	6.4	9%	-2%
	Oct	82	38	-10%	0%	82	38	-10%	0%	87	38	-9%	0%	22	11	-28%	7%	22	11	-28%	7%	11.5	6.5	10%	-1%
	Nov	117	72	-6%	3%	117	72	-6%	3%	116	72	-7%	3%	26	20	-24%	19%	26	20	-24%	19%	12.0	6.7	11%	-1%
	Dec	154	134	0%	0%	154	134	0%	0%	153	134	0%	0%	27	21	3%	4%	27	21	3%	4%	12.7	6.7	11%	-1%
	Jan	174	159	2%	1%	174	159	2%	1%	174	159	2%	1%	29	22	11%	17%	29	22	11%	17%	13.1	6.6	9%	-1%
	Feb	194	155	1%	1%	194	155	1%	1%	194	155	1%	1%	33	25	8%	7%	33	25	8%	7%	13.4	6.5	9%	-2%
	Mar	226	127	-1%	1%	226	127	-1%	1%	226	127	-1%	1%	30	23	-8%	18%	30	23	-8%	18%	13.5	6.5	8%	-2%
	Apr	285	138	-2%	0%	285	138	-2%	0%	293	139	-2%	0%	32	26	-16%	14%	32	26	-16%	14%	13.7	6.5	9%	-3%
	May	343	179	0%	-2%	343	179	0%	-2%	353	179	0%	-2%	50	39	2%	11%	50	39	2%	11%	14.1	6.4	9%	-4%
Alternative 3	Jun	256	170	1%	-1%	256	170	1%	-1%	272	171	1%	-1%	62	55	5%	14%	62	55	5%	14%	14.6	6.1	8%	-4%
(Years 6–10)	Jul	163	78	5%	-1%	163	78	5%	-1%	178	78	5%	-1%	88	33	10%	-9%	88	33	10%	-9%	14.2	6.1	8%	-3%
	Aug	152	44	3%	-6%	152	44	3%	-6%	164	44	2%	-5%	115	31	4%	-5%	115	31	4%	-5%	12.8	6.3	8%	-2%
	Sep	129	44	3%	-4%	129	44	3%	-4%	136	44	2%	-4%	86	29	4%	-7%	86	29	4%	-7%	11.6	6.4	8%	-1%
	Oct	82	38	-10%	0%	82	38	-10%	0%	87	38	-9%	0%	22	11	-28%	7%	22	11	-28%	7%	11.4	6.5	9%	0%
	Nov	117	72	-6%	3%	117	72	-6%	3%	116	72	-7%	3%	26	20	-24%	19%	26	20	-24%	19%	11.9	6.7	10%	-1%
	Dec	154	134	0%	0%	154	134	0%	0%	153	134	0%	0%	27	21	3%	4%	27	21	3%	4%	12.6	6.7	10%	-1%
	Jan	175	159	2%	1%	175	159	2%	1%	174	159	2%	1%	30	23	14%	21%	30	23	14%	21%	13.1	6.7	9%	-1%
	Feb	194	155	1%	1%	194	155	1%	1%	193	155	1%	1%	33	25	8%	8%	33	25	8%	8%	13.4	6.6	9%	-2%
	Mar	226	128	-1%	1%	226	128	-1%	1%	226	128	-1%	1%	30	23	-8%	18%	30	23	-8%	18%	13.6	6.5	9%	-2%
	Apr	285	139	-2%	0%	285	139	-2%	0%	292	139	-2%	0%	32	26	-18%	15%	32	26	-18%	15%	13.8	6.5	9%	-3%
	May	344	178	1%	-2%	344	178	1%	-2%	355	178	1%	-2%	52	39	5%	11%	52	39	5%	11%	14.2	6.4	9%	-3%
Alternative 3	Jun	253	168	0%	-2%	253	168	0%	-2%	270	169	0%	-2%	59	49	1%	2%	59	49	1%	2%	14.6	6.2	9%	-3%
(Years 11–30)	Jul	163	77	6%	-2%	163	77	6%	-2%	179	78	5%	-2%	89	33	11%	-10%	89	33	11%	-10%	14.2	6.2	8%	-2%
	Aug	151	44	3%	-6%	151	44	3%	-6%	164	44	2%	-6%	115	31	3%	-5%	115	31	3%	-5%	12.9	6.4	8%	-1%
	Sep	129	44	2%	-3%	129	44	2%	-3%	135	44	2%	-3%	86	29	4%	-7%	86	29	4%	-7%	11.7	6.5	9%	0%
	Oct	82	38	-10%	0%	82	38	-10%	0%	87	38	-9%	0%	22	11	-28%	7%	22	11	-28%	7%	11.5	6.6	9%	1%
	Nov	117	72	-6%	3%	117	72	-6%	3%	116	72	-7%	3%	26	20	-24%	19%	26	20	-24%	19%	12.0	6.7	10%	0%
	Dec	155	134	1%	0%	155	134	1%	0%	154	134	1%	0%	28	22	5%	8%	28	22	5%	8%	12.6	6.7	10%	0%
	Jan	174	159	2%	1%	174	159	2%	1%	174	159	2%	1%	29	22	11%	17%	29	22	11%	17%	13.1	6.6	9%	-1%
	Feb	194	155	1%	1%	194	155	1%	1%	194	155	1%	1%	33	25	8%	7%	33	25	8%	7%	13.4	6.5	9%	-2%
	Mar	226	127	-1%	1%	226	127	-1%	1%	226	127	-1%	1%	30	23	-8%	18%	30	23	-8%	18%	13.5	6.5	8%	-2%
	Apr	285	138	-2%	0%	285	138	-2%	0%	293	139	-2%	0%	32	26	-16%	14%	32	26	-16%	14%	13.7	6.5	9%	-3%
	May	343	179	0%	-2%	343	179	0%	-2%	353	179	0%	-2%	50	39	2%	11%	50	39	2%	11%	14.1	6.4	9%	-4%
Alternative 4	Jun	256	170	1%	-1%	256	170	1%	-1%	272	171	1%	-1%	62	55	5%	14%	62	55	5%	14%	14.6	6.1	8%	-4%
(Years 1–5)	Jul	163	78	5%	-1%	163	78	5%	-1%	178	78	5%	-1%	88	33	10%	-9%	88	33	10%	-9%	14.2	6.1	8%	-3%
	Aug	152	44	3%	-6%	152	44	3%	-6%	164	44	2%	-5%	115	31	4%	-5%	115	31	4%	-5%	12.8	6.3	8%	-2%
	Sep	129	44	3%	-4%	129	44	3%	-4%	136	44	2%	-4%	86	29	4%	-7%	86	29	4%	-7%	11.6	6.4	8%	-1%
	Oct	82	38	-10%	0%	82	38	-10%	0%	87	38	-9%	0%	22	11	-28%	7%	22	11	-28%	7%	11.4	6.5	9%	0%
	Nov	117	72	-6%	3%	117	72	-6%	3%	116	72	-7%	3%	26	20	-24%	19%	26	20	-24%	19%	11.9	6.7	10%	-1%
	Dec	154	134	0%	0%	154	134	0%	0%	153	134	0%	0%	27	21	3%	4%	27	21	3%	4%	12.6	6.7	10%	-1%
	Jan	175	159	2%	1%	175	159	2%	1%	174	159	2%	1%	30	23	14%	21%	30	23	14%	21%	13.0	6.7	8%	-1%
	Feb	194	155	1%	1%	194	155	1%	1%	193	155	1%	1%	33	26	8%	8%	33	26	8%	8%	13.3	6.6	8%	-1%
	Mar	226	127	-1%	1%	226	127	-1%	1%	226	127	-1%	1%	30	23	-8%	18%	30	23	-8%	18%	13.5	6.6	8%	-2%
	Apr	285	140	-2%	1%	285	140	-2%	1%	292	140	-2%	1%	32	26	-17%	18%	32	26	-17%	18%	13.6	6.5	8%	-2%
	May	343	179	0%	-2%	343	179	0%	-2%	353	179	0%	-1%	50	40	2%	13%	50	40	2%	13%	14.1	6.4	8%	-3%
Alternative 4	Jun	256	169	1%	-2%	256	169	1%	-2%	272	169	1%	-2%	62	52	5%	8%	62	52	5%	8%	14.5	6.2	8%	-3%
(Years 6–20)	Jul	163	78	5%	-1%	163	78	5%	-1%	178	78	5%	-1%	88	33	10%	-10%	88	33	10%	-10%	14.1	6.2	7%	-1%
	Aug	151	45	2%	-4%	151	45	2%	-4%	163	45	2%	-4%	115	32	3%	-2%	115	32	3%	-2%	12.8	6.4	7%	0%
	Sep	128	44	2%	-3%	128	44	2%	-3%	135	44	2%	-3%	86	29	3%	-7%	86	29	3%	-7%	11.6	6.5	8%	0%
	Oct	82	38	-10%	0%	82	38	-10%	0%	87	38	-9%	0%	22	11	-29%	7%	22	11	-29%	7%	11.3	6.6	8%	1%
	Nov	117	72	-6%	3%	117	72	-6%	3%	116	72	-7%	3%	26	20	-24%	19%	26	20	-24%	19%	11.9	6.8	9%	0%
	Dec	155	134	1%	0%	155	134	1%	0%	154	134	1%	0%	28	22	5%	8%	28	22	5%	8%	12.5	6.7	9%	0%

Table 6b. RiverWare Model Output, Monthly Average Flow and Standard Deviation—Crooked River

Alternative	Month	Reach Cro-3				Reach Cro-4				Reach Cro-9				Reach Cro-10				Reaches Cro-11, 12, 13			
		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Depth (ft)		Change vs No Action	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
	Jan	324	369			324	369			255	300			255	300			72.0	12.6		
	Feb	386	621			386	621			295	551			295	551			76.6	10.8		
	Mar	693	828			693	828			553	727			555	727			87.4	11.5		
	Apr	877	902			890	901			716	776			837	774			97.6	9.6		
	May	431	556			467	556			340	487			501	486			98.9	10.0		
No-Action Alternative	Jun	151	201			207	201			106	167			270	167			96.6	11.4		
	Jul	100	39			154	42			57	21			227	21			92.0	12.8		
	Aug	81	17			168	48			74	48			243	48			85.5	14.9		
	Sep	81	17			144	46			66	42			214	50			78.1	18.0		
	Oct	125	37			132	34			78	36			106	38			74.4	19.3		
	Nov	263	250			263	250			218	249			218	249			72.0	17.2		
	Dec	247	235			247	235			198	212			198	212			70.7	14.6		
	Jan	330	367	2%	-1%	330	367	2%	-1%	261	298	2%	-1%	261	298	2%	-1%	72.3	13.6	0%	7%
	Feb	393	621	2%	0%	393	621	2%	0%	302	552	2%	0%	302	552	2%	0%	76.7	12.1	0%	12%
	Mar	693	824	0%	0%	693	824	0%	0%	553	722	0%	-1%	555	722	0%	-1%	87.5	11.9	0%	4%
	Apr	879	902	0%	0%	892	902	0%	0%	718	777	0%	0%	839	775	0%	0%	97.7	10.0	0%	4%
	May	430	559	0%	1%	466	560	0%	1%	340	491	0%	1%	500	490	0%	1%	98.9	10.5	0%	5%
Alternative 2 (Years 1–7)	Jun	146	203	-3%	1%	202	203	-2%	1%	100	168	-5%	1%	264	168	-2%	1%	96.7	12.0	0%	5%
	Jul	95	38	-4%	-3%	148	38	-4%	-9%	51	13	-11%	-40%	221	13	-3%	-40%	92.2	13.6	0%	6%
	Aug	75	16	-7%	-1%	153	34	-9%	-28%	58	32	-21%	-32%	227	33	-6%	-31%	86.0	15.9	1%	6%
	Sep	74	18	-9%	5%	137	42	-5%	-10%	59	37	-10%	-12%	204	53	-5%	5%	79.3	18.0	1%	0%
	Oct	125	36	0%	-2%	132	31	0%	-6%	78	35	0%	-3%	106	34	0%	-10%	75.8	18.7	2%	-3%
	Nov	277	255	6%	2%	277	255	6%	2%	233	254	7%	2%	233	254	7%	2%	73.0	17.1	1%	0%
	Dec	255	240	3%	2%	255	240	3%	2%	205	216	4%	2%	205	216	4%	2%	71.3	15.1	1%	4%
	Jan	327	367	1%	0%	327	367	1%	0%	259	299	1%	-1%	259	299	1%	-1%	70.7	15.0	-2%	19%
	Feb	384	618	0%	0%	384	618	0%	0%	294	548	0%	-1%	294	548	0%	-1%	75.4	13.3	-2%	23%
	Mar	686	825	-1%	0%	686	825	-1%	0%	547	722	-1%	-1%	549	722	-1%	-1%	86.6	13.0	-1%	13%
	Apr	870	904	-1%	0%	897	897	1%	-1%	724	772	1%	-1%	844	770	1%	-1%	97.0	11.2	-1%	16%
	May	401	559	-7%	1%	471	553	1%	-1%	346	484	2%	-1%	506	483	1%	-1%	97.9	12.4	-1%	24%
Alternative 2 (Years 8–12)	Jun	138	201	-9%	0%	223	201	8%	0%	124	168	17%	1%	288	168	7%	1%	95.3	14.2	-1%	24%
	Jul	75	37	-25%	-6%	169	58	9%	37%	74	45	29%	110%	244	45	7%	109%	89.9	16.1	-2%	26%
	Aug	67	16	-17%	-5%	145	34	-14%	-28%	53	28	-28%	-41%	220	37	-9%	-23%	83.4	18.4	-3%	23%
	Sep	68	18	-15%	8%	125	33	-13%	-29%	50	25	-25%	-40%	194	43	-9%	-15%	76.9	19.6	-2%	9%
	Oct	122	37	-2%	0%	129	33	-2%	-1%	76	37	-2%	1%	105	35	-1%	-8%	73.6	20.4	-1%	5%
	Nov	261	254	-1%	2%	261	254	-1%	2%	218	253	0%	1%	218	253	0%	1%	71.0	18.8	-1%	10%
	Dec	249	236	1%	0%	249	236	1%	0%	201	213	2%	0%	201	213	2%	0%	69.6	16.6	-2%	14%
	Jan	318	369	-2%	0%	318	369	-2%	0%	251	300	-2%	0%	251	300	-2%	0%	69.6	15.3	-3%	21%
	Feb	379	619	-2%	0%	379	619	-2%	0%	291	548	-1%	-1%	291	548	-1%	-1%	74.5	13.6	-3%	26%
	Mar	679	822	-2%	-1%	679	822	-2%	-1%	541	718	-2%	-1%	543	718	-2%	-1%	86.0	13.3	-2%	16%
	Apr	860	905	-2%	0%	897	895	1%	-1%	725	770	1%	-1%	845	768	1%	-1%	96.5	11.4	-1%	19%
	May	383	550	-11%	-1%	477	548	2%	-1%	353	479	4%	-2%	514	478	3%	-2%	97.4	12.9	-2%	28%
Alternative 2 (Years 13–30)	Jun	128	195	-15%	-3%	239	200	16%	0%	141	168	34%	1%	305	168	13%	1%	94.4	14.6	-2%	28%
	Jul	61	31	-39%	-21%	189	69	23%	64%	96	59	68%	175%	266	59	17%	175%	88.4	16.4	-4%	28%
	Aug	59	8	-28%	-49%	156	51	-7%	6%	67	46	-10%	-3%	233	53	-4%	11%	81.2	18.5	-5%	24%
	Sep	65	18	-19%	5%	118	26	-18%	-45%	45	16	-32%	-62%	189	37	-11%	-27%	74.6	19.6	-5%	9%
	Oct	119	37	-4%	0%	123	34	-6%	3%	72	38	-7%	5%	101	34	-5%	-12%	71.4	20.4	-4%	6%
	Nov	233	243	-11%	-3%	233	243	-11%	-3%	192	241	-12%	-3%	192	241	-12%	-3%	69.1	19.1	-4%	11%
	Dec	243	233	-2%	-1%	243	233	-2%	-1%	196	209	-1%	-1%	196	209	-1%	-1%	68.1	17.0	-4%	17%

Alternative	Month	Reach Cro-3				Reach Cro-4				Reach Cro-9				Reach Cro-10				Reaches Cro-11, 12, 13			
		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Depth (ft)		Change vs No Action	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
	Jan	319	368	-2%	0%	319	368	-2%	0%	251	299	-2%	0%	251	299	-2%	0%	69.1	15.3	-4%	21%
	Feb	379	616	-2%	-1%	379	616	-2%	-1%	289	545	-2%	-1%	289	545	-2%	-1%	74.1	13.8	-3%	28%
	Mar	681	823	-2%	-1%	681	823	-2%	-1%	542	719	-2%	-1%	544	720	-2%	-1%	85.7	13.7	-2%	19%
	Apr	871	906	-1%	0%	889	903	0%	0%	716	778	0%	0%	837	776	0%	0%	96.3	11.7	-1%	21%
	May	422	554	-2%	0%	465	554	0%	0%	340	485	0%	0%	501	484	0%	0%	97.6	12.1	-1%	21%
Alternative 3	Jun	165	198	9%	-1%	227	198	10%	-2%	127	164	20%	-2%	291	164	8%	-2%	95.0	13.7	-2%	20%
(Years 1–5)	Jul	99	48	-1%	22%	173	52	12%	22%	77	38	34%	75%	247	38	9%	75%	89.6	15.8	-3%	23%
	Aug	93	32	14%	91%	182	49	9%	1%	90	44	22%	-7%	257	52	6%	9%	82.3	18.3	-4%	23%
	Sep	93	32	16%	92%	157	49	8%	7%	80	43	22%	2%	225	58	5%	15%	74.6	19.6	-5%	9%
	Oct	129	35	3%	-4%	136	33	3%	-1%	83	35	7%	-3%	112	39	5%	2%	70.7	20.3	-5%	5%
	Nov	227	230	-14%	-8%	227	230	-14%	-8%	183	229	-16%	-8%	183	229	-16%	-8%	68.5	19.0	-5%	10%
	Dec	241	227	-2%	-4%	241	227	-2%	-4%	192	204	-3%	-4%	192	204	-3%	-4%	67.7	17.0	-4%	16%
	Jan	317	368	-2%	0%	317	368	-2%	0%	249	299	-2%	0%	249	299	-2%	0%	68.2	16.2	-5%	28%
	Feb	376	616	-3%	-1%	376	616	-3%	-1%	287	545	-3%	-1%	287	545	-3%	-1%	73.4	14.6	-4%	35%
	Mar	675	821	-3%	-1%	675	821	-3%	-1%	537	716	-3%	-1%	539	716	-3%	-1%	85.2	14.3	-3%	24%
	Apr	864	907	-1%	1%	898	896	1%	-1%	725	770	1%	-1%	846	769	1%	-1%	95.9	12.4	-2%	29%
	May	393	555	-9%	0%	481	544	3%	-2%	357	476	5%	-2%	517	475	3%	-2%	96.7	13.7	-2%	36%
Alternative 3	Jun	148	196	-2%	-2%	243	196	18%	-3%	144	164	36%	-2%	308	164	14%	-2%	93.6	15.5	-3%	35%
(Years 6–10)	Jul	84	44	-16%	14%	173	58	12%	37%	79	44	38%	104%	249	44	10%	104%	87.9	17.2	-5%	34%
	Aug	82	32	1%	95%	173	51	3%	6%	82	45	11%	-6%	248	55	2%	15%	80.6	19.3	-6%	29%
	Sep	83	33	3%	97%	143	44	-1%	-5%	69	37	4%	-12%	213	52	0%	3%	73.1	20.6	-6%	15%
	Oct	126	36	1%	-2%	132	35	1%	4%	81	37	4%	0%	109	40	3%	4%	69.2	21.4	-7%	11%
	Nov	220	231	-16%	-8%	220	231	-16%	-8%	177	229	-19%	-8%	177	229	-19%	-8%	67.2	20.0	-7%	17%
	Dec	236	225	-5%	-4%	236	225	-5%	-4%	188	202	-5%	-5%	188	202	-5%	-5%	66.6	17.9	-6%	23%
	Jan	314	369	-3%	0%	314	369	-3%	0%	247	300	-3%	0%	247	300	-3%	0%	68.0	16.2	-6%	28%
	Feb	373	614	-3%	-1%	373	614	-3%	-1%	284	542	-4%	-2%	284	542	-4%	-2%	73.2	14.6	-4%	35%
	Mar	673	821	-3%	-1%	673	821	-3%	-1%	535	716	-3%	-1%	537	716	-3%	-1%	85.1	14.4	-3%	25%
	Apr	859	906	-2%	0%	901	892	1%	-1%	729	767	2%	-1%	850	765	2%	-1%	95.8	12.5	-2%	30%
	May	376	549	-13%	-1%	490	539	5%	-3%	366	471	8%	-3%	527	470	5%	-3%	96.4	13.9	-2%	38%
Alternative 3	Jun	138	187	-9%	-7%	252	196	22%	-3%	154	164	46%	-2%	319	164	18%	-2%	93.0	15.6	-4%	36%
(Years 11–30)	Jul	78	42	-22%	8%	174	61	13%	46%	81	49	42%	126%	251	49	11%	126%	87.1	17.3	-5%	35%
	Aug	77	30	-5%	81%	163	48	-3%	0%	74	41	0%	-13%	240	52	-1%	8%	80.0	19.2	-7%	29%
	Sep	78	33	-3%	97%	142	44	-2%	-5%	69	36	4%	-13%	213	52	0%	3%	72.5	20.5	-7%	14%
	Oct	125	36	0%	-1%	131	35	-1%	4%	80	37	4%	0%	109	40	2%	3%	68.7	21.3	-8%	10%
	Nov	213	228	-19%	-9%	213	228	-19%	-9%	171	226	-22%	-9%	171	226	-22%	-9%	66.8	19.9	-7%	16%
	Dec	233	223	-6%	-5%	233	223	-6%	-5%	186	200	-6%	-6%	186	200	-6%	-6%	66.2	17.9	-6%	23%
	Jan	317	368	-2%	0%	317	368	-2%	0%	249	299	-2%	0%	249	299	-2%	0%	68.2	16.2	-5%	28%
	Feb	376	616	-3%	-1%	376	616	-3%	-1%	287	545	-3%	-1%	287	545	-3%	-1%	73.4	14.6	-4%	35%
	Mar	675	821	-3%	-1%	675	821	-3%	-1%	537	716	-3%	-1%	539	716	-3%	-1%	85.2	14.3	-3%	24%
	Apr	864	907	-1%	1%	898	896	1%	-1%	725	770	1%	-1%	846	769	1%	-1%	95.9	12.4	-2%	29%
	May	393	555	-9%	0%	481	544	3%	-2%	357	476	5%	-2%	517	475	3%	-2%	96.7	13.7	-2%	36%
Alternative 4	Jun	148	196	-2%	-2%	243	196	18%	-3%	144	164	36%	-2%	308	164	14%	-2%	93.6	15.5	-3%	35%
(Years 1–5)	Jul	84	44	-16%	14%	173	58	12%	37%	79	44	38%	104%	249	44	10%	104%	87.9	17.2	-5%	34%
	Aug	82	32	1%	95%	173	51	3%	6%	82	45	11%	-6%	248	55	2%	15%	80.6	19.3	-6%	29%
	Sep	83	33	3%	97%	143	44	-1%	-5%	69	37	4%	-12%	213	52	0%	3%	73.1	20.6	-6%	15%
	Oct	126	36	1%	-2%	132	35	1%	4%	81	37	4%	0%	109	40	3%	4%	69.2	21.4	-7%	11%
	Nov	220	231	-16%	-8%	220	231	-16%	-8%	177	229	-19%	-8%	177	229	-19%	-8%	67.2	20.0	-7%	17%
	Dec	236	225	-5%	-4%	236	225	-5%	-4%	188	202	-5%	-5%	188	202	-5%	-5%	66.6	17.9	-6%	23%
	Jan	313	369	-3%	0%	313	369	-3%	0%	247	300	-3%	0%	247	300	-3%	0%	67.8	16.2	-6%	28%
	Feb	372	614	-3%	-1%	372	614	-3%	-1%	284	542	-4%	-2%	284	542	-4%	-2%	73.1	14.7	-5%	35%
	Mar	672	821	-3%	-1%	672	821	-3%	-1%	535	716	-3%	-1%	537	716	-3%	-1%	84.9	14.4	-3%	25%
	Apr	857	907	-2%	1%	902	892	1%	-1%	730	766	2%	-1%	851	765	2%	-1%	95.7	12.5	-2%	30%
	May	374	550	-13%	-1%	494	537	6%	-3%	371	469	9%	-4%	531	468	6%	-4%	96.2	14.0	-3%	39%
Alternative 4	Jun	136	187	-10%	-7%	250	197	21%	-2%	153	165	45%	-1%	317	165	18%	-1%	92.8	15.7	-4%	38%
(Years 6–20)	Jul	76	42	-24%	7%	173	63	12%	49%	80	50	40%	133%	250	50	10%	133%	87.0	17.4	-5%	35%
	Aug	75	29	-8%	76%	165	51	-2%	5%	76	44	4%	-8%	242	54	0%	13%	79.7	19.4	-7%	30%
	Sep	76	32	-6%	92%	139	44	-4%	-5%	66	36	0%	-13%	210	51	-2%	2%	72.2	20.6	-8%	15%
	Oct	124	36	0%	-1%	130	35	-1%	5%	80	37	3%	1%	108	40	2%	4%	68.5	21.3	-8%	10%
	Nov	212	228	-19%	-9%	212	228	-19%	-9%	171	226	-22%	-9%	171	226	-22%	-9%	66.5	20.0	-8%	16%
	Dec	233	223	-6%	-5%	233	223	-6%	-5%	186	200	-6%	-6%	186	200	-6%	-6%	66.1	17.9	-7%	23%

Table 6c. RiverWare Model Output, Monthly Average Flow and Standard Deviation—Deschutes River, Reaches Des-1 through Des-10a

Alternative	Month	Reach Des-1				Reach Des-5				Reaches Des-7, -8				Reach Des-8a				Reach Des-9				Reach Des-10				Reach Des-10a			
		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
No-Action Alternative	Jan	5246	1113			852	371			874	370			881	370			900	369			904	369			896	370		
	Feb	5510	1607			891	367			918	366			925	366			946	365			948	365			945	363		
	Mar	5922	1448			928	356			956	355			959	355			980	354			987	354			992	357		
	Apr	5804	1285			591	386			1163	200			1171	198			1365	190			1401	200			1406	202		
	May	4729	800			186	119			1180	127			1201	124			1593	139			1678	140			1693	163		
	Jun	4495	579			183	110			1208	113			1232	111			1678	113			1763	116			1792	133		
	Jul	4197	320			145	23			1237	111			1303	103			1781	99			1872	100			1910	119		
	Aug	4075	235			138	6			1091	166			1196	183			1682	189			1777	191			1795	211		
	Sep	4082	279			122	19			855	127			934	143			1324	186			1411	190			1410	207		
	Oct	4506	578			501	414			767	289			769	289			868	287			896	294			912	301		
	Nov	4908	789			810	380			835	379			842	379			863	378			867	378			856	373		
	Dec	5161	955			859	355			869	355			876	355			880	354			882	354			875	365		
Alternative 2 (Years 1–7)	Jan	5275	1125	1%	1%	874	394	3%	6%	896	393	3%	6%	903	393	3%	6%	922	392	2%	6%	927	392	2%	6%	919	392	2%	6%
	Feb	5521	1600	0%	0%	894	371	0%	1%	921	369	0%	1%	928	370	0%	1%	949	369	0%	1%	951	369	0%	1%	948	365	0%	0%
	Mar	5926	1451	0%	0%	931	379	0%	7%	959	379	0%	7%	961	379	0%	7%	983	378	0%	7%	990	378	0%	7%	995	383	0%	7%
	Apr	5764	1292	-1%	1%	546	397	-8%	3%	1120	220	-4%	10%	1128	217	-4%	10%	1322	210	-3%	11%	1358	218	-3%	9%	1364	219	-3%	9%
	May	4722	798	0%	0%	175	93	-6%	-22%	1169	102	-1%	-20%	1190	98	-1%	-21%	1582	115	-1%	-17%	1667	116	-1%	-17%	1684	144	0%	-12%
	Jun	4497	578	0%	0%	184	90	1%	-18%	1211	98	0%	-14%	1237	94	0%	-16%	1683	96	0%	-15%	1766	101	0%	-13%	1799	116	0%	-13%
	Jul	4198	326	0%	2%	144	27	0%	19%	1238	100	0%	-10%	1309	83	0%	-19%	1787	78	0%	-22%	1878	77	0%	-23%	1920	101	1%	-15%
	Aug	4076	235	0%	0%	136	6	-2%	11%	1127	131	3%	-21%	1241	133	4%	-28%	1726	138	3%	-27%	1821	140	2%	-27%	1845	166	3%	-22%
	Sep	4099	289	0%	4%	140	67	15%	260%	888	126	4%	-1%	978	133	5%	-7%	1365	177	3%	-5%	1452	181	3%	-5%	1453	194	3%	-6%
	Oct	4551	580	1%	0%	544	415	9%	0%	811	306	6%	6%	813	306	6%	6%	912	312	5%	9%	940	320	5%	9%	957	327	5%	8%
	Nov	4929	766	0%	-3%	814	350	1%	-8%	840	348	1%	-8%	847	348	1%	-8%	868	348	1%	-8%	871	348	1%	-8%	860	343	1%	-8%
	Dec	5183	956	0%	0%	872	350	1%	-2%	882	349	1%	-2%	889	349	1%	-2%	892	349	1%	-2%	895	349	1%	-2%	888	359	1%	-2%
Alternative 2 (Years 8–12)	Jan	5341	1087	2%	-2%	951	325	12%	-12%	973	324	11%	-12%	981	324	11%	-12%	1000	323	11%	-12%	1004	323	11%	-12%	996	320	11%	-13%
	Feb	5587	1578	1%	-2%	976	308	10%	-16%	1003	307	9%	-16%	1010	307	9%	-16%	1031	306	9%	-16%	1033	306	9%	-16%	1030	302	9%	-17%
	Mar	5988	1421	1%	-2%	1009	304	9%	-15%	1037	304	8%	-15%	1039	304	8%	-15%	1060	303	8%	-15%	1068	302	8%	-15%	1072	306	8%	-14%
	Apr	5748	1292	-1%	1%	548	394	-7%	2%	1107	221	-5%	10%	1115	218	-5%	10%	1310	202	-4%	6%	1345	207	-4%	4%	1350	207	-4%	2%
	May	4681	800	-1%	0%	175	78	-6%	-35%	1119	122	-5%	-4%	1140	118	-5%	-5%	1532	130	-4%	-6%	1617	131	-4%	-6%	1632	153	-4%	-6%
	Jun	4479	583	0%	1%	187	98	2%	-11%	1162	140	-4%	24%	1188	135	-4%	21%	1634	137	-3%	21%	1715	143	-3%	24%	1745	156	-3%	17%
	Jul	4158	343	-1%	7%	147	31	1%	33%	1099	211	-11%	90%	1169	198	-10%	91%	1644	205	-8%	107%	1730	220	-8%	120%	1763	226	-8%	90%
	Aug	4049	245	-1%	4%	136	10	-1%	81%	1037	187	-5%	13%	1149	189	-4%	3%	1632	197	-3%	4%	1726	202	-3%	6%	1744	213	-3%	1%
	Sep	4084	291	0%	4%	145	67	19%	262%	856	129	0%	2%	943	137	1%	-5%	1329	175	0%	-6%	1416	179	0%	-6%	1416	191	0%	-8%
	Oct	4585	573	2%	-1%	590	419	18%	1%	847	283	10%	-2%	849	283	10%	-2%	948	265	9%	-8%	976	269	9%	-9%	993	271	9%	-10%
	Nov	4989	711	2%	-10%	901	287	11%	-25%	926	285	11%	-25%	933	285	11%	-25%	954	285	11%	-25%	958	285	10%	-25%	947	277	11%	-26%
	Dec	5254	921	2%	-4%	957	287	11%	-19%	966	286	11%	-19%	974	286	11%	-19%	977	286	11%	-19%	979	286	11%	-19%	973	297	11%	-19%
Alternative 2 (Years 13–30)	Jan	5406	1080	3%	-3%	1032	305	21%	-18%	1054	304	21%	-18%	1062	303	20%	-18%	1081	303	20%	-18%	1085	303	20%	-18%	1077	300	20%	-19%
	Feb	5649	1569	3%	-2%	1051	276	18%	-25%	1077	275	17%	-25%	1084	275	17%	-25%	1105	274	17%	-25%	1107	274	17%	-25%	1104	269	17%	-26%
	Mar	6052	1406	2%	-3%	1086	274	17%	-23%	1114	273	17%	-23%	1117	273	16%	-23%	1138	272	16%	-23%	1145	272	16%	-23%	1150	275	16%	-23%
	Apr	5740	1293	-1%	1%	557	393	-6%	2%	1106	228	-5%	14%	1114	224	-5%	13%	1308	203	-4%	7%	1344	206	-4%	3%	1348	204	-4%	1%
	May	4660	797	-1%	0%	183	84	-1%	-30%	1077	166	-9%	31%	1098	161	-9%	30%	1490	170	-6%	23%	1574	172	-6%	23%	1586	185	-6%	14%
	Jun	4448	576	-1%	0%	182	83	-1%	-24%	1061	201	-12%	78%	1087	193	-12%	74%	1532	196	-9%	73%	1612	209	-9%	81%	1636	215	-9%	61%
	Jul	4124	339	-2%	6%	146	28	1%	23%	974	194	-21%	74%	1044	182	-20%	76%	1517	192	-15%	93%	1602	209	-14%	109%	1626	209	-15%	75%
	Aug	4025	241	-1%	2%	138	11	0%	104%	948	152	-13%	-8%	1054	165	-12%	-10%	1537	172	-9%	-9%	1632	177	-8%	-7%	1643	185	-8%	-12%
	Sep	4078	288	0%	3%	153	71	26%	283%	843	129	-1%	2%	928	139	-1%	-3%	1314	176	-1%	-6%	1400	179	-1%	-6%	1400	190	-1%	-8%
	Oct	4627	576	3%	0%	644	424	29%	2%	894	283	16%	-2%	896	282	16%	-2%	994	251	15%	-13%	1022	251	14%	-15%	1039	250	14%	-17%
	Nov	5023	670	2%	-15%	970	248	20%	-35%	995	246	19%	-35%	1002	246	19%	-35%	1023	246	19%	-35%	1027	245	18%	-35%	1016	235	19%	-37%
	Dec	5311	895	3%	-6%	1027	253	20%	-29%	1037	251	19%	-29%	1044	252	19%	-29%	1048	251	19%	-29%	1050	251	19%	-29%	1043	262	19%	-28%

Alternative	Month	Reach Des-1				Reach Des-5				Reaches Des-7, -8				Reach Des-8a				Reach Des-9				Reach Des-10				Reach Des-10a			
		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
	Jan	5299	1085	1%	-2%	915	338	7%	-9%	937	337	7%	-9%	945	336	7%	-9%	963	336	7%	-9%	968	336	7%	-9%	960	335	7%	-9%
	Feb	5548	1582	1%	-2%	941	324	6%	-12%	968	323	5%	-12%	975	323	5%	-12%	995	322	5%	-12%	997	322	5%	-12%	995	319	5%	-12%
	Mar	5962	1423	1%	-2%	985	325	6%	-9%	1013	325	6%	-9%	1015	325	6%	-9%	1036	324	6%	-9%	1044	324	6%	-9%	1048	327	6%	-9%
	Apr	5766	1304	-1%	2%	562	414	-5%	7%	1131	226	-3%	13%	1139	223	-3%	12%	1334	203	-2%	7%	1369	207	-2%	4%	1375	209	-2%	4%
	May	4700	795	-1%	-1%	169	87	-9%	-27%	1146	105	-3%	-18%	1167	102	-3%	-18%	1559	119	-2%	-15%	1643	120	-2%	-14%	1660	146	-2%	-10%
Alternative 3	Jun	4493	573	0%	-1%	169	77	-8%	-30%	1178	93	-2%	-18%	1203	91	-2%	-18%	1649	94	-2%	-17%	1730	100	-2%	-13%	1762	117	-2%	-13%
(Years 1–5)	Jul	4189	340	0%	6%	144	27	-1%	19%	1171	200	-5%	80%	1237	192	-5%	85%	1712	199	-4%	100%	1797	215	-4%	115%	1836	223	-4%	87%
	Aug	4079	256	0%	9%	136	11	-2%	90%	1039	207	-5%	25%	1145	219	-4%	19%	1625	232	-3%	22%	1714	243	-4%	27%	1733	260	-3%	23%
	Sep	4096	306	0%	10%	131	65	8%	250%	830	143	-3%	13%	912	156	-2%	9%	1297	187	-2%	0%	1382	192	-2%	1%	1381	207	-2%	0%
	Oct	4528	581	1%	1%	525	422	5%	2%	788	295	3%	2%	790	295	3%	2%	889	289	2%	1%	916	295	2%	0%	933	299	2%	-1%
	Nov	4882	714	-1%	-9%	825	321	2%	-16%	851	319	2%	-16%	857	318	2%	-16%	878	318	2%	-16%	882	318	2%	-16%	871	312	2%	-16%
	Dec	5213	920	1%	-4%	922	307	7%	-14%	932	306	7%	-14%	939	306	7%	-14%	942	305	7%	-14%	944	305	7%	-14%	938	317	7%	-13%
	Jan	5360	1071	2%	-4%	985	311	16%	-16%	1006	309	15%	-16%	1014	309	15%	-16%	1033	309	15%	-16%	1037	309	15%	-16%	1029	309	15%	-16%
	Feb	5606	1573	2%	-2%	1007	294	13%	-20%	1034	292	13%	-20%	1041	292	13%	-20%	1062	291	12%	-20%	1064	291	12%	-20%	1061	288	12%	-21%
	Mar	6015	1413	2%	-2%	1049	295	13%	-17%	1077	295	13%	-17%	1079	295	13%	-17%	1101	294	12%	-17%	1108	294	12%	-17%	1113	297	12%	-17%
	Apr	5754	1302	-1%	1%	563	408	-5%	6%	1116	232	-4%	16%	1124	228	-4%	15%	1318	203	-3%	7%	1354	205	-3%	3%	1359	203	-3%	1%
	May	4661	799	-1%	0%	169	78	-9%	-34%	1088	129	-8%	2%	1109	125	-8%	0%	1501	137	-6%	-1%	1585	138	-6%	-1%	1598	159	-6%	-2%
Alternative 3	Jun	4464	571	-1%	-1%	167	72	-8%	-35%	1117	127	-7%	13%	1143	125	-7%	12%	1588	128	-5%	13%	1668	137	-5%	18%	1697	149	-5%	12%
(Years 6–10)	Jul	4160	347	-1%	8%	144	27	0%	19%	1083	234	-12%	111%	1148	229	-12%	121%	1620	241	-9%	143%	1704	261	-9%	161%	1735	267	-9%	124%
	Aug	4055	261	-1%	11%	136	10	-2%	83%	973	214	-11%	29%	1079	223	-10%	21%	1557	236	-7%	25%	1645	248	-7%	30%	1660	267	-8%	27%
	Sep	4078	305	0%	9%	132	55	8%	196%	805	134	-6%	6%	885	147	-5%	3%	1270	178	-4%	-5%	1355	183	-4%	-4%	1354	197	-4%	-5%
	Oct	4561	578	1%	0%	568	421	13%	2%	820	285	7%	-1%	821	285	7%	-1%	920	264	6%	-8%	948	266	6%	-10%	964	267	6%	-11%
	Nov	4930	682	0%	-14%	886	282	9%	-26%	912	279	9%	-26%	919	279	9%	-26%	940	279	9%	-26%	943	279	9%	-26%	932	271	9%	-27%
	Dec	5267	899	2%	-6%	987	276	15%	-22%	997	275	15%	-23%	1004	275	15%	-23%	1007	274	15%	-23%	1010	274	14%	-23%	1003	287	15%	-21%
	Jan	5391	1047	3%	-6%	1023	270	20%	-27%	1045	268	20%	-28%	1053	268	19%	-28%	1072	267	19%	-28%	1076	267	19%	-28%	1068	266	19%	-28%
	Feb	5639	1561	2%	-3%	1048	260	18%	-29%	1075	258	17%	-29%	1082	258	17%	-29%	1103	257	17%	-30%	1105	257	17%	-30%	1102	253	17%	-30%
	Mar	6049	1397	2%	-4%	1090	257	17%	-28%	1118	257	17%	-28%	1120	257	17%	-28%	1141	256	16%	-28%	1149	255	16%	-28%	1153	258	16%	-28%
	Apr	5746	1299	-1%	1%	567	403	-4%	4%	1109	239	-5%	19%	1117	235	-5%	19%	1311	207	-4%	9%	1346	208	-4%	4%	1350	205	-4%	2%
	May	4642	792	-2%	-1%	175	79	-6%	-34%	1041	165	-12%	30%	1062	161	-12%	29%	1453	170	-9%	22%	1538	171	-8%	23%	1548	186	-9%	14%
Alternative 3	Jun	4442	567	-1%	-2%	168	69	-8%	-38%	1028	203	-15%	79%	1053	200	-15%	79%	1497	204	-11%	80%	1576	217	-11%	88%	1598	225	-11%	69%
(Years 11–30)	Jul	4142	347	-1%	8%	144	27	0%	19%	1017	249	-18%	124%	1083	244	-17%	136%	1553	256	-13%	159%	1635	277	-13%	177%	1662	284	-13%	139%
	Aug	4041	259	-1%	10%	135	11	-2%	94%	949	203	-13%	22%	1054	213	-12%	16%	1533	224	-9%	18%	1622	235	-9%	23%	1636	256	-9%	21%
	Sep	4066	305	0%	10%	132	63	8%	236%	780	143	-9%	13%	861	157	-8%	9%	1246	189	-6%	1%	1330	193	-6%	1%	1328	208	-6%	0%
	Oct	4607	579	2%	0%	620	427	24%	3%	865	283	13%	-2%	866	283	13%	-2%	965	245	11%	-15%	993	242	11%	-18%	1010	240	11%	-20%
	Nov	4992	655	2%	-17%	961	249	19%	-35%	987	246	18%	-35%	993	246	18%	-35%	1014	246	18%	-35%	1018	245	17%	-35%	1007	236	18%	-37%
	Dec	5301	881	3%	-8%	1029	239	20%	-33%	1038	238	19%	-33%	1046	238	19%	-33%	1049	237	19%	-33%	1051	237	19%	-33%	1044	251	19%	-31%
	Jan	5360	1071	2%	-4%	985	311	16%	-16%	1006	309	15%	-16%	1014	309	15%	-16%	1033	309	15%	-16%	1037	309	15%	-16%	1029	309	15%	-16%
	Feb	5606	1573	2%	-2%	1007	294	13%	-20%	1034	292	13%	-20%	1041	292	13%	-20%	1062	291	12%	-20%	1064	291	12%	-20%	1061	288	12%	-21%
	Mar	6015	1413	2%	-2%	1049	295	13%	-17%	1077	295	13%	-17%	1079	295	13%	-17%	1101	294	12%	-17%	1108	294	12%	-17%	1113	297	12%	-17%
	Apr	5754	1302	-1%	1%	563	408	-5%	6%	1116	232	-4%	16%	1124	228	-4%	15%	1318	203	-3%	7%	1354	205	-3%	3%	1359	203	-3%	1%
	May	4661	799	-1%	0%	169	78	-9%	-34%	1088	129	-8%	2%	1109	125	-8%	0%	1501	137	-6%	-1%	1585	138	-6%	-1%	1598	159	-6%	-2%
Alternative 4	Jun	4464	571	-1%	-1%	167	72	-8%	-35%	1117	127	-7%	13%	1143	125	-7%	12%	1588	128	-5%	13%	1668	137	-5%	18%	1697	149	-5%	12%
(Years 1–5)	Jul	4160	347	-1%	8%	144	27	0%	19%	1083	234	-12%	111%	1148	229	-12%	121%	1620	241	-9%	143%	1704	261	-9%	161%	1735	267	-9%	124%
	Aug	4055	261	-1%	11%	136	10	-2%	83%	973	214	-11%	29%	1079	223	-10%	21%	1557	236	-7%	25%	1645	248	-7%	30%	1660	267	-8%	27%
	Sep	4078	305	0%	9%	132	55	8%	196%	805	134	-6%	6%	885	147	-5%	3%	1270	178	-4%	-5%	1355	183	-4%	-4%	1354	197	-4%	-5%
	Oct	4561	578	1%	0%	568	421	13%	2%	820	285	7%	-1%	821	285	7%	-1%	920	264	6%	-8%	948	266	6%	-10%	964	267	6%	-11%
	Nov	4930	682	0%	-14%	886	282	9%	-26%	912	279	9%	-26%	919	279	9%	-26%	940	279	9%	-26%	943	279	9%	-26%	932	271	9%	-27%
	Dec	5267	899	2%	-6%	987	276	15%	-22%	997	275	15%	-23%	1004	275	15%	-23%	1007	274	15%	-23%	1010	274	14%	-23%	1003	287	15%	-21%
	Jan	5405	1047	3%	-6%	1038	272	22%	-27%	1060	271	21%	-27%	1068	271	21%	-27%	1087	270	21%	-27%	1091	270	21%	-27%	1083	270	21%	-27%
	Feb	5656	1565	3%	-3%	1067	268	20%	-27%	1093	266	19%	-27%	1100	266	19%	-27%	1121	265	19%	-27%	1123	265	18%	-27%	1120	261	19%	-28%
	Mar	6064	1401	2%	-3%	1107	267	19%	-25%	1135	267	19%	-25%	1137	267	19%	-25%	1159	266	18%	-25%	1166	266	18%	-25%	1171	268	18%	-25%
	Apr	5745	1299	-1%	1%	567	402	-4%	4%	1107	240	-5%	20%	1115	236	-5%	19%	1309	207	-4%	9%	1345	208	-4%	4%	1349	205	-4%	2%
	May	4637	794	-2%	-1%	174	79	-6%	-33%	1031	164	-13%	29%	1052	160	-12%	29%	1444	170	-9%	22%	1528	172	-9%	23%	1537	188	-9%	16%
Alternative 4	Jun	4440	569	-1%	-2%	170	71	-7%	-35%	1020	206	-16%	82%	1045	202	-15%	82%	1490	206	-11%	82%	1568	220	-11%	90%	1590	228	-11%	71%
(Years 6–20)	Jul	4138	347	-1%	8%	145	27	0%	19%	1004	248	-19%	123%	1069	243	-18%	135%	1540	256	-14%	158%	1621	276	-13%	176%	1647	284	-14%	138%
	Aug	4036	261	-1%	11%	135	10	-2%	88%	931	203	-15%	22%	1036	211	-13%	15%	1514	224	-10%	18%	1603	235	-10%	23%	1615	256	-10%	21%
	Sep	4064	304	0%	9%	134	55	10%	194%	776	131	-9%	3%	856	144	-8%	1%	1241	174	-6%	-6%	1326	179	-6%	-6%	1324	193	-6%	-7%
	Oct	4604	571	2%	-1%	620	419	24%	1%	864	272	13%	-6%	866	271	13%	-6%	964	232	11%	-19%	992	230	11%	-22%	1009	227	11%	-25%
	Nov	4993	656	2%	-17%	964	248	19%	-35%	989	245	18%	-35%	996	245	18%	-35%	1017	245	18%	-35%	1021	245	18%	-35%	1010	235	18%	-37%
	Dec	5315	881	3%	-8%	1045	245	22%	-31%	1054	244	21%	-31%	1062	244	21%	-31%	1065	243	21%	-31%	1067	243	21%	-31%	1060	257	21%	-29%

Table 6d. RiverWare Model Output, Monthly Average Flow and Standard Deviation—Deschutes River, Reaches Des-11 through Des-15

Alternative	Month	Reach Des-11				Reach Des-12				Reach Des-12a				Reach Des-13				Reach Des-14				Reach Des-15			
		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Depth (ft)		Change vs No Action		Flow (cfs)		Change vs No Action		Depth (ft)		Change vs No Action	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
No-Action Alternative	Jan	479	328			307	237			307	237			46.5	3.6			89	65			5.5	0.7		
	Feb	511	311			319	237			319	237			47.8	2.6			123	77			6.6	0.7		
	Mar	540	288			311	223			311	223			49.0	2.0			169	80			6.8	0.7		
	Apr	972	174			680	111			680	111			49.1	1.9			203	90			6.8	0.3		
	May	1284	158			941	203			941	203			47.1	2.9			187	146			7.4	0.3		
	Jun	1388	124			1135	199			1135	199			43.9	5.3			255	138			7.6	0.3		
	Jul	1538	134			1384	166			1384	166			36.4	10.8			238	131			7.4	0.3		
	Aug	1432	206			1284	200			1284	200			27.6	15.6			293	136			6.7	0.3		
	Sep	1024	221			898	217			898	217			24.1	17.1			357	136			5.6	0.5		
	Oct	481	261			390	244			390	244			31.4	14.3			218	105			4.5	0.5		
	Nov	436	314			310	273			310	273			39.4	8.7			216	101			4.5	0.2		
	Dec	460	308			307	249			307	249			44.0	5.3			211	113			4.6	0.3		
Alternative 2 (Years 1–7)	Jan	501	351	5%	7%	316	243	3%	3%	316	243	3%	3%	46.1	3.8	-1%	7%	165	89	86%	37%	6.8	0.7	25%	3%
	Feb	514	313	1%	1%	315	236	-1%	0%	315	236	-1%	0%	47.9	2.7	0%	4%	166	84	35%	10%	7.0	0.7	6%	-8%
	Mar	542	312	0%	8%	315	241	1%	8%	315	241	1%	8%	49.3	2.0	1%	1%	147	89	-13%	11%	7.1	0.6	4%	-23%
	Apr	930	188	-4%	8%	643	121	-5%	9%	643	121	-5%	9%	49.5	2.1	1%	7%	178	107	-12%	19%	7.3	0.2	9%	-38%
	May	1275	142	-1%	-10%	929	201	-1%	-1%	929	201	-1%	-1%	48.0	3.2	2%	8%	254	136	36%	-6%	7.4	0.0	0%	-91%
	Jun	1394	105	0%	-15%	1125	186	-1%	-7%	1125	186	-1%	-7%	45.1	5.5	3%	3%	259	149	2%	8%	7.4	0.0	-2%	-84%
	Jul	1549	120	1%	-11%	1369	146	-1%	-12%	1369	146	-1%	-12%	38.8	10.2	7%	-6%	272	142	14%	8%	7.2	0.3	-4%	-7%
	Aug	1482	164	4%	-20%	1293	167	1%	-16%	1293	167	1%	-16%	32.6	14.3	18%	-8%	344	160	18%	18%	5.6	0.5	-17%	41%
	Sep	1067	210	4%	-5%	901	204	0%	-6%	901	204	0%	-6%	28.3	16.6	17%	-3%	240	119	-33%	-13%	5.3	0.3	-5%	-46%
	Oct	525	286	9%	10%	417	264	7%	8%	417	264	7%	8%	32.9	14.6	5%	2%	211	105	-3%	1%	5.1	0.6	15%	21%
	Nov	441	284	1%	-10%	315	243	1%	-11%	315	243	1%	-11%	39.7	8.9	1%	3%	133	53	-38%	-47%	5.7	0.6	26%	205%
	Dec	473	302	3%	-2%	310	237	1%	-5%	310	237	1%	-5%	43.5	5.7	-1%	7%	149	66	-29%	-42%	6.4	0.7	41%	155%
Alternative 2 (Years 8–12)	Jan	578	285	21%	-13%	394	166	28%	-30%	394	166	28%	-30%	41.3	7.5	-11%	108%	165	89	86%	36%	6.8	0.7	25%	3%
	Feb	596	256	17%	-18%	395	163	24%	-31%	395	163	24%	-31%	43.0	6.7	-10%	154%	166	84	35%	10%	7.0	0.7	6%	-8%
	Mar	620	235	15%	-19%	394	160	27%	-28%	394	160	27%	-28%	44.2	6.3	-10%	212%	147	89	-13%	11%	7.1	0.6	4%	-23%
	Apr	916	171	-6%	-2%	631	95	-7%	-15%	631	95	-7%	-15%	43.9	7.1	-11%	268%	177	107	-13%	20%	7.3	0.2	9%	-38%
	May	1222	142	-5%	-10%	875	194	-7%	-4%	875	194	-7%	-4%	41.6	9.0	-12%	210%	254	136	36%	-7%	7.4	0.0	0%	-92%
	Jun	1341	134	-3%	8%	1070	181	-6%	-9%	1070	181	-6%	-9%	37.3	12.8	-15%	140%	259	149	2%	8%	7.4	0.0	-2%	-84%
	Jul	1391	208	-10%	55%	1208	215	-13%	30%	1208	215	-13%	30%	30.5	16.5	-16%	52%	272	143	14%	9%	7.2	0.3	-4%	-7%
	Aug	1381	203	-4%	-2%	1192	208	-7%	4%	1192	208	-7%	4%	26.5	16.9	-4%	8%	344	160	18%	18%	5.6	0.5	-17%	41%
	Sep	1030	201	1%	-9%	867	194	-4%	-10%	867	194	-4%	-10%	24.0	17.3	-1%	1%	240	119	-33%	-13%	5.3	0.3	-5%	-46%
	Oct	561	227	17%	-13%	454	203	16%	-17%	454	203	16%	-17%	29.8	14.9	-5%	4%	211	105	-3%	1%	5.1	0.6	15%	21%
	Nov	527	217	21%	-31%	399	171	29%	-38%	399	171	29%	-38%	35.7	10.9	-9%	25%	133	53	-38%	-47%	5.7	0.6	26%	205%
	Dec	558	241	21%	-22%	394	162	29%	-35%	394	162	29%	-35%	38.9	8.8	-12%	64%	149	66	-29%	-42%	6.4	0.7	41%	156%
Alternative 2 (Years 13–30)	Jan	659	268	38%	-18%	473	140	54%	-41%	473	140	54%	-41%	38.4	10.4	-17%	189%	165	89	86%	37%	6.8	0.7	25%	3%
	Feb	670	227	31%	-27%	470	133	48%	-44%	470	133	48%	-44%	39.3	10.2	-18%	286%	166	84	35%	9%	7.0	0.7	6%	-8%
	Mar	698	206	29%	-29%	469	128	51%	-43%	469	128	51%	-43%	39.7	10.4	-19%	416%	147	89	-13%	11%	7.1	0.6	4%	-23%
	Apr	914	163	-6%	-7%	625	73	-8%	-34%	625	73	-8%	-34%	38.5	12.1	-22%	527%	177	108	-13%	20%	7.3	0.2	9%	-38%
	May	1177	167	-8%	6%	826	189	-12%	-7%	826	189	-12%	-7%	36.0	14.3	-24%	389%	254	136	36%	-6%	7.4	0.0	0%	-94%
	Jun	1231	182	-11%	47%	966	195	-15%	-2%	966	195	-15%	-2%	32.3	16.7	-26%	214%	259	149	2%	8%	7.4	0.0	-2%	-84%
	Jul	1255	175	-18%	30%	1073	172	-22%	4%	1073	172	-22%	4%	27.8	18.0	-24%	66%	273	142	15%	9%	7.2	0.3	-4%	-6%
	Aug	1280	163	-11%	-21%	1097	153	-15%	-23%	1097	153	-15%	-23%	26.0	17.7	-6%	13%	344	160	18%	18%	5.6	0.5	-17%	41%
	Sep	1014	198	-1%	-10%	853	191	-5%	-12%	853	191	-5%	-12%	24.7	17.9	2%	4%	239	119	-33%	-13%	5.3	0.3	-6%	-46%
	Oct	607	204	26%	-22%	499	179	28%	-27%	499	179	28%	-27%	30.3	15.2	-3%	6%	211	105	-3%	1%	5.1	0.6	15%	21%
	Nov	596	175	37%	-44%	467	130	51%	-52%	467	130	51%	-52%	34.8	12.2	-12%	41%	133	53	-38%	-47%	5.7	0.6	26%	205%
	Dec	628	207	37%	-33%	463	120	51%	-52%	463	120	51%	-52%	36.9	11.0	-16%	105%	149	66	-29%	-42%	6.4	0.7	40%	155%

Alternative	Month	Reach Des-11				Reach Des-12				Reach Des-12a				Reach Des-13				Reach Des-14				Reach Des-15			
		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Flow (cfs)		Change vs No Action		Depth (ft)		Change vs No Action		Flow (cfs)		Change vs No Action		Depth (ft)		Change vs No Action	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
	Jan	542	295	13%	-10%	367	199	20%	-16%	367	199	20%	-16%	42.8	5.4	-8%	50%	165	89	86%	37%	6.8	0.7	25%	3%
	Feb	560	270	10%	-13%	366	191	15%	-19%	366	191	15%	-19%	44.7	4.4	-7%	65%	166	84	35%	10%	7.0	0.7	6%	-8%
	Mar	596	256	10%	-11%	368	193	18%	-14%	368	193	18%	-14%	45.9	3.7	-6%	85%	147	89	-13%	11%	7.1	0.6	4%	-22%
	Apr	940	172	-3%	-1%	656	98	-4%	-12%	656	98	-4%	-12%	45.8	4.0	-7%	110%	178	107	-12%	19%	7.3	0.2	9%	-38%
	May	1251	142	-3%	-10%	908	199	-4%	-2%	908	199	-4%	-2%	43.8	5.8	-7%	98%	254	136	36%	-7%	7.4	0.0	0%	-91%
Alternative 3 (Years 1–5)	Jun	1357	98	-2%	-21%	1100	194	-3%	-3%	1100	194	-3%	-3%	39.5	9.7	-10%	83%	259	149	2%	8%	7.4	0.0	-2%	-84%
	Jul	1464	220	-5%	64%	1302	230	-6%	39%	1302	230	-6%	39%	30.7	15.7	-16%	45%	273	142	14%	8%	7.2	0.3	-4%	-6%
	Aug	1370	250	-4%	21%	1219	246	-5%	23%	1219	246	-5%	23%	24.9	17.2	-10%	11%	344	160	18%	18%	5.6	0.5	-17%	41%
	Sep	995	208	-3%	-6%	865	202	-4%	-7%	865	202	-4%	-7%	22.2	17.7	-8%	3%	239	119	-33%	-13%	5.3	0.3	-6%	-46%
	Oct	502	257	4%	-2%	419	240	8%	-2%	419	240	8%	-2%	28.6	15.2	-9%	7%	211	105	-3%	1%	5.1	0.6	15%	21%
	Nov	451	252	4%	-20%	334	207	8%	-24%	334	207	8%	-24%	36.1	10.1	-8%	16%	133	53	-38%	-47%	5.7	0.6	26%	205%
	Dec	523	259	14%	-16%	368	192	20%	-23%	368	192	20%	-23%	40.1	7.2	-9%	35%	149	66	-29%	-42%	6.4	0.7	40%	155%
	Jan	612	269	28%	-18%	437	170	42%	-28%	437	170	42%	-28%	39.3	7.1	-16%	97%	165	89	86%	36%	6.8	0.7	25%	3%
	Feb	627	241	23%	-23%	432	160	36%	-32%	432	160	36%	-32%	40.8	6.2	-15%	136%	166	84	35%	9%	7.0	0.7	6%	-8%
	Mar	661	227	22%	-21%	434	159	40%	-29%	434	159	40%	-29%	41.8	5.8	-15%	186%	147	89	-13%	11%	7.1	0.6	4%	-23%
	Apr	924	162	-5%	-7%	639	79	-6%	-29%	639	79	-6%	-29%	41.2	6.6	-16%	243%	177	108	-13%	20%	7.3	0.2	9%	-38%
	May	1189	145	-7%	-8%	846	182	-10%	-10%	846	182	-10%	-10%	38.6	8.8	-18%	201%	254	135	36%	-7%	7.4	0.0	0%	-92%
Alternative 3 (Years 6–10)	Jun	1292	121	-7%	-2%	1036	188	-9%	-6%	1036	188	-9%	-6%	33.8	12.9	-23%	142%	259	150	2%	9%	7.4	0.0	-2%	-84%
	Jul	1364	251	-11%	87%	1201	249	-13%	50%	1201	249	-13%	50%	25.5	16.9	-30%	56%	273	143	14%	9%	7.2	0.3	-4%	-6%
	Aug	1297	245	-9%	19%	1145	237	-11%	18%	1145	237	-11%	18%	21.3	17.5	-23%	12%	344	160	18%	18%	5.6	0.5	-17%	41%
	Sep	968	195	-6%	-12%	838	187	-7%	-14%	838	187	-7%	-14%	19.9	17.5	-18%	2%	239	119	-33%	-13%	5.3	0.3	-6%	-46%
	Oct	533	222	11%	-15%	451	203	16%	-17%	451	203	16%	-17%	26.9	14.9	-14%	4%	211	105	-3%	0%	5.1	0.6	15%	21%
	Nov	512	212	18%	-32%	395	165	27%	-40%	395	165	27%	-40%	33.6	10.7	-15%	23%	133	53	-38%	-47%	5.7	0.6	26%	205%
	Dec	588	229	28%	-26%	434	160	41%	-36%	434	160	41%	-36%	37.0	8.5	-16%	59%	149	66	-29%	-42%	6.4	0.7	40%	155%
	Jan	651	231	36%	-30%	475	126	55%	-47%	475	126	55%	-47%	36.0	9.8	-23%	173%	165	89	86%	37%	6.8	0.7	25%	3%
	Feb	668	213	31%	-31%	473	118	48%	-50%	473	118	48%	-50%	36.9	9.7	-23%	267%	166	83	34%	8%	7.0	0.7	6%	-7%
	Mar	701	192	30%	-34%	475	116	53%	-48%	475	116	53%	-48%	37.3	10.0	-24%	395%	147	89	-13%	11%	7.1	0.6	4%	-22%
	Apr	916	161	-6%	-7%	631	70	-7%	-37%	631	70	-7%	-37%	35.8	11.8	-27%	510%	177	108	-13%	21%	7.3	0.2	9%	-38%
	May	1139	165	-11%	5%	794	175	-16%	-14%	794	175	-16%	-14%	33.1	14.1	-30%	384%	254	137	36%	-6%	7.4	0.0	0%	-94%
Alternative 3 (Years 11–30)	Jun	1194	193	-14%	56%	940	214	-17%	8%	940	214	-17%	8%	29.3	16.8	-33%	215%	259	149	2%	8%	7.4	0.0	-2%	-85%
	Jul	1291	262	-16%	95%	1127	258	-19%	55%	1127	258	-19%	55%	23.5	18.0	-35%	66%	273	143	14%	9%	7.2	0.3	-4%	-7%
	Aug	1273	232	-11%	12%	1121	222	-13%	11%	1121	222	-13%	11%	20.7	17.6	-25%	13%	344	160	18%	18%	5.6	0.5	-17%	41%
	Sep	942	203	-8%	-8%	814	195	-9%	-10%	814	195	-9%	-10%	20.0	17.4	-17%	1%	239	119	-33%	-13%	5.3	0.3	-6%	-46%
	Oct	578	192	20%	-27%	496	170	27%	-30%	496	170	27%	-30%	27.1	14.5	-14%	2%	211	105	-3%	0%	5.1	0.6	15%	21%
	Nov	587	176	35%	-44%	470	127	52%	-54%	470	127	52%	-54%	32.2	11.6	-18%	33%	133	53	-38%	-48%	5.7	0.6	26%	205%
	Dec	630	195	37%	-37%	474	116	55%	-53%	474	116	55%	-53%	34.4	10.4	-22%	94%	149	66	-29%	-42%	6.4	0.7	41%	156%
	Jan	612	269	28%	-18%	437	170	42%	-28%	437	170	42%	-28%	39.3	7.1	-16%	97%	165	89	86%	36%	6.8	0.7	25%	3%
	Feb	627	241	23%	-23%	432	160	36%	-32%	432	160	36%	-32%	40.8	6.2	-15%	136%	166	84	35%	9%	7.0	0.7	6%	-8%
	Mar	661	227	22%	-21%	434	159	40%	-29%	434	159	40%	-29%	41.8	5.8	-15%	186%	147	89	-13%	11%	7.1	0.6	4%	-23%
	Apr	924	162	-5%	-7%	639	79	-6%	-29%	639	79	-6%	-29%	41.2	6.6	-16%	243%	177	108	-13%	20%	7.3	0.2	9%	-38%
	May	1189	145	-7%	-8%	846	182	-10%	-10%	846	182	-10%	-10%	38.6	8.8	-18%	201%	254	135	36%	-7%	7.4	0.0	0%	-92%
Alternative 4 (Years 1–5)	Jun	1292	121	-7%	-2%	1036	188	-9%	-6%	1036	188	-9%	-6%	33.8	12.9	-23%	142%	259	150	2%	9%	7.4	0.0	-2%	-84%
	Jul	1364	251	-11%	87%	1201	249	-13%	50%	1201	249	-13%	50%	25.5	16.9	-30%	56%	273	143	14%	9%	7.2	0.3	-4%	-6%
	Aug	1297	245	-9%	19%	1145	237	-11%	18%	1145	237	-11%	18%	21.3	17.5	-23%	12%	344	160	18%	18%	5.6	0.5	-17%	41%
	Sep	968	195	-6%	-12%	838	187	-7%	-14%	838	187	-7%	-14%	19.9	17.5	-18%	2%	239	119	-33%	-13%	5.3	0.3	-6%	-46%
	Oct	533	222	11%	-15%	451	203	16%	-17%	451	203	16%	-17%	26.9	14.9	-14%	4%	211	105	-3%	0%	5.1	0.6	15%	21%
	Nov	512	212	18%	-32%	395	165	27%	-40%	395	165	27%	-40%	33.6	10.7	-15%	23%	133	53	-38%	-47%	5.7	0.6	26%	205%
	Dec	588	229	28%	-26%	434	160	41%	-36%	434	160	41%	-36%	37.0	8.5	-16%	59%	149	66	-29%	-42%	6.4	0.7	40%	155%
	Jan	666	231	39%	-30%	490	130	59%	-45%	490	130	59%	-45%	35.0	9.4	-25%	163%	165	89	86%	37%	6.8	0.7	25%	3%
	Feb	686	217	34%	-30%	491	130	54%	-45%	491	130	54%	-45%	35.8	9.2	-25%	250%	166	83	34%	8%	7.0	0.7	6%	-8%
	Mar	719	199	33%	-31%	492	127	58%	-43%	492	127	58%	-43%	36.1	9.4	-26%	366%	147	89	-13%	11%	7.1	0.6	4%	-23%
	Apr	915	161	-6%	-8%	630	69	-7%	-38%	630	69	-7%	-38%	34.6	11.1	-30%	478%	177	108	-13%	21%	7.3	0.2	9%	-38%
	May	1128	167	-12%	6%	785	170	-17%	-16%	785	170	-17%	-16%	31.8	13.5	-33%	364%	254	137	36%	-6%	7.4	0.0	0%	-94%
Alternative 4 (Years 6–20)	Jun	1185	192	-15%	55%	929	206	-18%	4%	929	206	-18%	4%	27.8	16.2	-37%	205%	259	149	2%	8%	7.4	0.0	-2%	-84%
	Jul	1275	261	-17%	94%	1112	254	-20%	53%	1112	254	-20%	53%	21.7	17.5	-40%	62%	273	143	14%	9%	7.2	0.3	-4%	-7%
	Aug	1252	232	-13%	13%	1100	221	-14%	10%	1100	221	-14%	10%	19.0	17.3	-31%	11%	344	160	18%	18%	5.6	0.5	-17%	41%
	Sep	938	187	-8%	-15%	809	178	-10%	-18%	809	178	-10%	-18%	18.7	17.1	-22%	-1%	240	119	-33%	-13%	5.3	0.3	-5%	-46%
	Oct	577	178	20%	-32%	495	156	27%	-36%	495	156	27%	-36%	26.0	14.4	-17%	1%	211	105	-3%	1%	5.1	0.6	15%	21%
	Nov	590	174	35%	-44%	472	126	52%	-54%	472	126	52%	-54%	31.3	11.4	-21%	31%	133	53	-38%	-48%	5.7	0.6	26%	205%
	Dec	646	199	40%	-36%	490	126	60%	-50%	490	126	60%	-50%	33.5	10.1	-24%	89%	149	66	-29%	-42%	6.4	0.7	41%	156%

Table 6e. RiverWare Model Output, Monthly Average Flow and Standard Deviation—Ochoco River and Whychus Creek

Alternative	Month	Reaches Och-1, -2, -3				Reach Och-4				Reach Why-5			
		Flow (cfs)		Change vs No Action		Depth (ft)		Change vs No Action		Flow (cfs)		Change vs No Action	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
No-Action Alternative	Jan	29	113			45.9	17			84	54		
	Feb	51	127			51	15			85	76		
	Mar	101	169			57	13			45	41		
	Apr	154	151			62	11			42	34		
	May	132	84			62	11			48	47		
	Jun	90	45			60	12			91	70		
	Jul	98	38			55	13			68	55		
	Aug	83	22			49	14			33	31		
	Sep	45	16			43	15			23	17		
	Oct	11	10			41	16			35	35		
	Nov	4	6			41	17			55	69		
	Dec	10	44			43	17			77	70		
Alternative 2 (Years 1–7)	Jan	29	113	0%	0%	46	17	0%	0%	84	54	0%	0%
	Feb	51	127	0%	0%	51	15	0%	0%	85	76	0%	0%
	Mar	101	169	0%	0%	57	13	0%	0%	45	41	0%	0%
	Apr	154	151	0%	0%	62	11	0%	0%	42	34	0%	0%
	May	132	84	0%	0%	62	11	0%	0%	48	47	0%	0%
	Jun	90	45	0%	0%	60	12	0%	0%	91	70	0%	0%
	Jul	98	38	0%	0%	55	13	0%	0%	68	55	0%	0%
	Aug	83	22	0%	0%	49	14	0%	0%	33	31	0%	0%
	Sep	45	16	0%	0%	43	15	0%	0%	23	17	0%	0%
	Oct	11	10	0%	0%	41	16	0%	0%	35	35	0%	0%
	Nov	4	6	0%	0%	41	17	0%	0%	55	69	0%	0%
	Dec	10	44	0%	0%	43	17	0%	0%	77	70	0%	0%
Alternative 2 (Years 8–12)	Jan	29	113	0%	0%	46	17	0%	0%	84	54	0%	0%
	Feb	51	127	0%	0%	51	15	0%	0%	85	76	0%	0%
	Mar	101	169	0%	0%	57	13	0%	0%	45	41	0%	0%
	Apr	154	151	0%	0%	62	11	0%	0%	42	34	0%	0%
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	Nov	4	6	0%	0%	41	17	0%	0%	55	69	0%	0%
	Dec	10	44	0%	0%	43	17	0%	0%	77	70	0%	0%
Alternative 2 (Years 13–30)	Jan	29	113	0%	0%	46	17	0%	0%	84	54	0%	0%
	Feb	51	127	0%	0%	51	15	0%	0%	85	76	0%	0%
	Mar	101	169	0%	0%	57	13	0%	0%	45	41	0%	0%
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	Oct	11	10	0%	0%	41	16	0%	0%	35	35	0%	0%
	Nov	4	6	0%	0%	41	17	0%	0%	55	69	0%	0%
	Dec	10	44	0%	0%	43	17	0%	0%	77	70	0%	0%

Alternative	Month	Reaches Och-1, -2, -3				Reach Och-4				Reach Why-5			
		Flow (cfs)		Change vs No Action		Depth (ft)		Change vs No Action		Flow (cfs)		Change vs No Action	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
	Jan	29	113	0%	0%	46	17	0%	0%	84	54	0%	0%
	Feb	51	127	0%	0%	51	15	0%	0%	85	76	0%	0%
	Mar	101	169	0%	0%	57	13	0%	0%	45	41	0%	0%
	Apr	154	151	0%	0%	62	11	0%	0%	42	34	0%	0%
	May	132	84	0%	0%	62	11	0%	0%	48	47	0%	0%
Alternative 3	Jun	90	45	0%	0%	60	12	0%	0%	91	70	0%	0%
(Years 1–5)	Jul	98	38	0%	0%	55	13	0%	0%	68	55	0%	0%
	Aug	83	22	0%	0%	49	14	0%	0%	33	31	0%	0%
	Sep	45	16	0%	0%	43	15	0%	0%	23	17	0%	0%
	Oct	11	10	0%	0%	41	16	0%	0%	35	35	0%	0%
	Nov	4	6	0%	0%	41	17	0%	0%	55	69	0%	0%
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	Jan	29	113	0%	0%	46	17	0%	0%	84	54	0%	0%
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	May	132	84	0%	0%	62	11	0%	0%	48	47	0%	0%
Alternative 3	Jun	90	45	0%	0%	60	12	0%	0%	91	70	0%	0%
(Years 6–10)	Jul	98	38	0%	0%	55	13	0%	0%	68	55	0%	0%
	Aug	83	22	0%	0%	49	14	0%	0%	33	31	0%	0%
	Sep	45	16	0%	0%	43	15	0%	0%	23	17	0%	0%
	Oct	11	10	0%	0%	41	16	0%	0%	35	35	0%	0%
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	May	132	84	0%	0%	62	11	0%	0%	48	47	0%	0%
Alternative 3	Jun	90	45	0%	0%	60	12	0%	0%	91	70	0%	0%
(Years 11–30)	Jul	98	38	0%	0%	55	13	0%	0%	68	55	0%	0%
	Aug	83	22	0%	0%	49	14	0%	0%	33	31	0%	0%
	Sep	45	16	0%	0%	43	15	0%	0%	23	17	0%	0%
	Oct	11	10	0%	0%	41	16	0%	0%	35	35	0%	0%
	Nov	4	6	0%	0%	41	17	0%	0%	55	69	0%	0%
	Dec	10	44	0%	0%	43	17	0%	0%	77	70	0%	0%
	Jan	29	113	0%	0%	46	17	0%	0%	84	54	0%	0%
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	Mar	101	169	0%	0%	57	13	0%	0%	45	41	0%	0%
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Alternative 4	Jun	90	45	0%	0%	60	12	0%	0%	91	70	0%	0%
(Years 1–5)	Jul	98	38	0%	0%	55	13	0%	0%	68	55	0%	0%
	Aug	83	22	0%	0%	49	14	0%	0%	33	31	0%	0%
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	Nov	4	6	0%	0%	41	17	0%	0%	55	69	0%	0%
	Dec	10	44	0%	0%	43	17	0%	0%	77	70	0%	0%
	Jan	29	113	0%	0%	46	17	0%	0%	84	54	0%	0%
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	May	132	84	0%	0%	62	11	0%	0%	48	47	0%	0%
Alternative 4	Jun	90	45	0%	0%	60	12	0%	0%	91	70	0%	0%
(Years 6–20)	Jul	98	38	0%	0%	55	13	0%	0%	68	55	0%	0%
	Aug	83	22	0%	0%	49	14	0%	0%	33	31	0%	0%
	Sep	45	16	0%	0%	43	15	0%	0%	23	17	0%	0%
	Oct	11	10	0%	0%	41	16	0%	0%	35	35	0%	0%
	Nov	4	6	0%	0%	41	17	0%	0%	55	69	0%	0%
	Dec	10	44	0%	0%	43	17	0%	0%	77	70	0%	0%

References Cited

Printed References

Consortium of Pacific Northwest Herbaria. 2018. Specimen data. Query for collection records for *Arabis macdonaldiana, Astragalus peckii, Botrychium pumicola, Fritillaria gentneri, Hackelia venusta, Howellia aquatilis, Lilium occidentale, Lomatium cookii, Lupinus oreganus, Mirabilis macfarlanei, Plagiobothrys hirtus, Sidalcea nelsoniana, Sidalcea oregana* var. *calva, Silene spaldingii*, and *Spiranthes diluvialis*. Last updated: November 1, 2018. Available: http://www.pnwherbaria.org/data/search.php. Accessed: November 1, 2018.

Courter, Ian, Kevin Ceder, Martin Vaughn, Ron Campbell, Forrest Carpenter, and Greg Engelgau. 2014. DBHCP Study 11 – Phase 2: *Evaluation of Steelhead Trout and Chinook Salmon Summer Rearing Habitat, Spawning Habitat, and Fish Passage in the Upper Deschutes Basin.* Available upon request.

Duncan, Nancy. 2005. *Conservation Assessment for* Deroceras hesperium, *Evening Fieldslug*. USDA Forest Service Region 6 and USDI Bureau of Land Management, Oregon and Washington. Available: https://www.blm.gov/or/plans/surveyandmanage/files/ca-ig-deroceras-hesperium-2005-10.pdf. Accessed: November 1, 2018.

eBird. 2018. Species-specific occurrence data. Available: https://ebird.org/hotspots?env.minX=-124.566925&env.minY=41.992463&env.maxX=-116.461639&env.maxY=46.29218&yr=all&m=. Accessed: December 11, 2018.

NatureServe. 2018. Species account. Available: http://explorer.natureserve.org/servlet/NatureServe?post_processes=PostReset&loadTemplate=nameSearchSpecies.wmt&Type=Reset. Accessed: December 11, 2018.

Oregon Compass. 2018. Online mapping utility, *ODFW Deer Winter Range* and *ODFW Elk Winter Range* themes, Available: http://compass.dfw.state.or.us/visualize/#x=-120.50&y=44.09&z=7&logo=true&dls%5B%5D=true&dls%5B%5D=0.5&dls%5B%5D=549&dls%5B%5D=true&dls%5B%5D=0.5&dls%5B%5D=470&dls%5B%5D=true&dls%5B%5D=0.5&dls%5B%5D=471&basemap=ESRI+Satellite&themes%5Bids%5D%5B%5D=37&themes%5Bids%5D%5B%5D=39&themes%5Bids%5D%5B%5D=40&themes%5Bids%5D%5B%5D=31&themes%5Bids%5D%5B%5D=35&themes%5Bids%5D%5B%5D=27&tab=data&print=false. Accessed: December 11, 2018.

Oregon Department of Agriculture. 2018a. *Oregon Listed Plants by County.* Available: https://www.oregon.gov/ODA/programs/PlantConservation/Pages/ListedPlants.aspx. Accessed: November 1, 2018.

Oregon Department of Agriculture. 2018b. *Noxious Weed Policy and Classification System 2018.* Noxious Weed Control Program, 635 Capitol Street NE Salem, Oregon 97301. Available: https://www.oregon.gov/ODA/shared/Documents/Publications/Weeds/NoxiousWeedPolicyClassification.pdf. Accessed: November 1, 2018.

Oregon Department of Agriculture. 2018c. Oregon Department of Agriculture Weedmapper. Query for weed occurrences in study area. Available:

http://geo.maps.arcgis.com/apps/webappviewer/index.html?id=54e9b0eaacb34bc4a146a33faa9f8966. Accessed: November 1, 2018.

Oregon Department of Fish and Wildlife. 2016. Sensitive Species List. Available: https://www.dfw.state.or.us/wildlife/diversity/species/docs/2016_Sensitive_Species_List.pdf. Accessed: November 1, 2018.

Turner, Laurie. 2015. 2014 *Western Bumble Bee Surveys Deschutes National Forest*. Available: https://www.fs.fed.us/r6/sfpnw/issssp/documents4/inv-rpt-iihy-bombus-occidentalis-des-201503.pdf. Accessed: November 1, 2018.

U.S. Fish and Wildlife Service. 2008. *Birds of Conservation Concern 2008*. Division of Migratory Bird Management, Arlington, VA. 85 pp. Available: https://www.fws.gov/migratorybirds/pdf/grants/BirdsofConservationConcern2008.pdf. Accessed: November 1, 2018.

U.S. Fish and Wildlife Service. 2017. *Biological Opinion: Approval of Contract Changes to the 1938 Inter-District Agreement for Operation of Crane Prairie and Wickiup Dams and Implementation of Review of Operations and Maintenance and Safety Evaluation of Existing Dams Programs at Crane Prairie and Wickiup Dames, Deschutes County, Oregon*. September 29. Bend Field Office, Bend, OR.

U.S. Fish and Wildlife Service. 2019. *Reinitiation of Formal Consultation on Bureau of Reclamation Approval of Contract Changes to the 1938 Inter-District Agreement for the Operation of Crane Prairie and Wickiup Dams, and Implementation of the Review of Operations and Maintenance (ROM) and Safety Evaluation of Existing Dams (SEED) Programs at Crane Prairie and Wickiup Dams, Deschutes Project, Oregon (2017–2019)*. July 26. Bend Field Office, Bend, OR.

U.S. Forest Service. 1991. *Forest Service Manual*. Title 2600, Amendment 2600-91-5. Available: https://www.fs.fed.us/im/directives/fsm/2600/2620.txt. Accessed: November 1, 2018.

U.S. Forest Service. 2015. *Species Fact Sheet*. Available: https://www.fs.fed.us/r6/sfpnw/issssp/documents/planning-docs/sfs-iile-boloria-selene-2010-10.doc. Accessed: November 1, 2018.

U.S. Forest Service. 2016. *Wildlife Species Required to Analyze for the Wildlife Report and Biological Evaluation.* Deschutes National Forest. August 18.

U.S. Forest Service. 2019. *FINAL Region 6 Regional Forester Special Status Species List, February 25, 2019.* Microsoft Excel spreadsheet "DES 201903013-2670-fs-final-sss-list-enc1-20190225.xlsx". Deschutes National Forest.

Personal Communications

Ashton, Larry. Wildlife biologist. U.S. Bureau of Land Management, Prineville District. Prineville, OR. October 19, 2018—email to Lisa Allen, wildlife biologist, ICF.

Turner, Lauri. Wildlife biologist. U.S. Forest Service, Deschutes National Forest. March 6, 2019—Comment on working draft EIS text.

Wray, Simon. Wildlife biologist. Oregon Department of Fish and Wildlife. March 26, 2019—Comment on working draft EIS text.

Appendix 3.4-B
Oregon Spotted Frog Technical Supplement

Appendix 3.4-B

Oregon Spotted Frog Technical Supplement

Introduction

This appendix addresses the following topics.

- Background material for the Oregon spotted frog affected environment.
- Delineation and description of stream reaches used in the impact.
- Approach and results of the reach-level analysis of impacts.

Methods

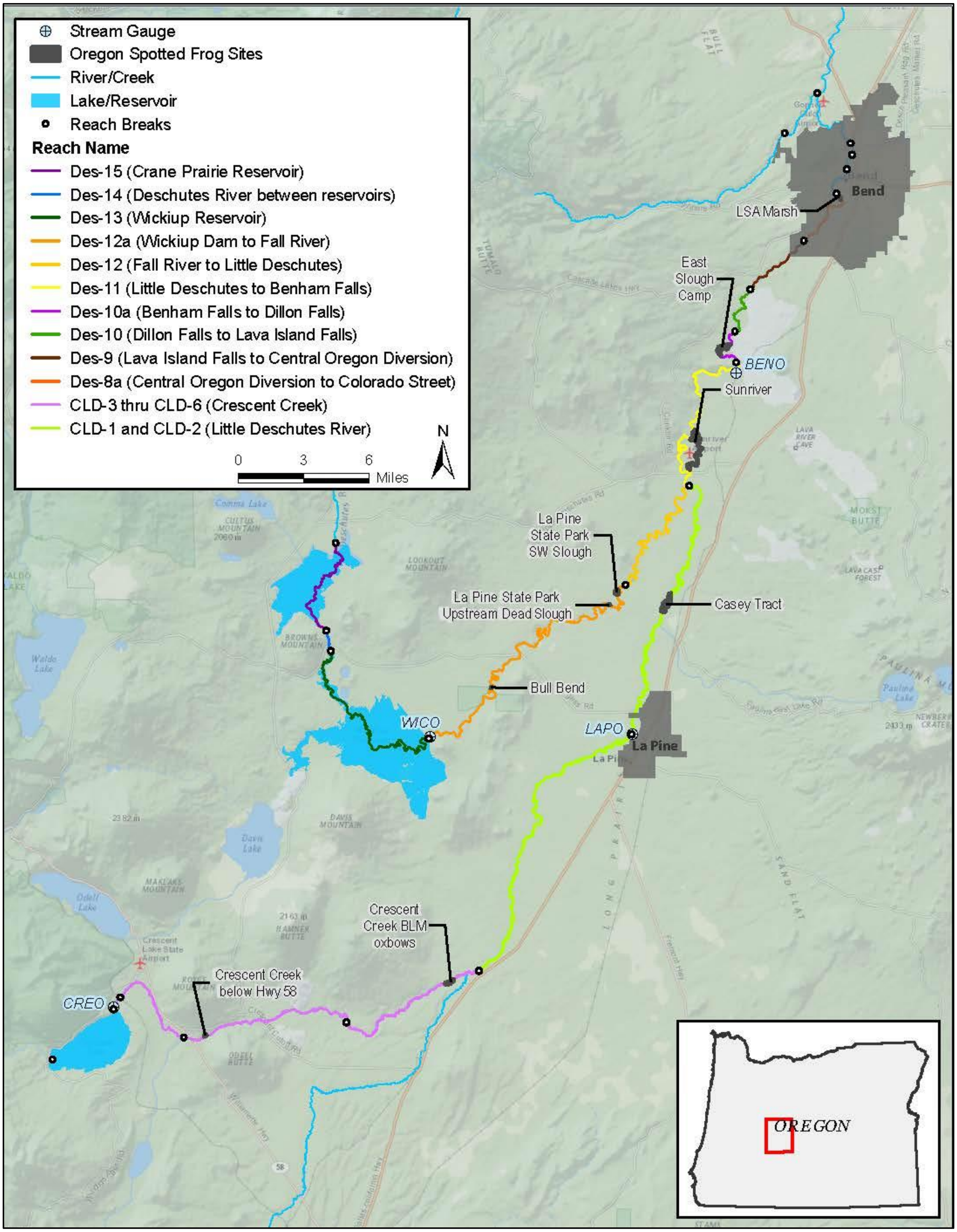
This analysis utilizes the RiverWare model to predict the volume of water flowing through the system throughout the year for each alternative. As discussed in the Deschutes Project Biological Opinion (BiOp) (U.S. Fish and Wildlife Service 2017, 2019), certain volumes of water flowing through the system result in water elevations that are known to inundate wetland vegetation that is also habitat for Oregon spotted frogs. The Deschutes Project BiOp, data used to develop the BiOp, and photographic records not associated with the BiOp provide baseline information on the vegetation community at some sites and inform the analysis of how the modeled flows, correlated water elevations, and the predicted inundation patterns under each alternative may affect Oregon spotted frog habitat components and seasonal suitability at the level of the reach. The analysis focuses on a daily time scale during Oregon spotted frog early spring (pre-breeding, March 1–March 31), breeding (April 1–April 30), summer rearing (April 15–August 31), fall (pre-winter, September 1–October 15), and overwintering (October 16–March 1) periods to assess how the modeled volumes of water flowing through the system may affect Oregon spotted frog habitat during these key life history periods. It is important to note that this analysis does not reach the site-specific depth of the analysis presented in the Deschutes Project BiOp.

This analysis does not reach the site-specific depth of the analysis presented in the Deschutes Project BiOp (Section 5.0, *Environmental Baseline*, and Section 6.0, *Effects of the Action*); rather, it provides a system-level comparison of environmental consequences of the alternatives on the Oregon spotted frog and its habitat in the study area. It is a reach-level assessment that relies primarily on the RiverWare model outputs of water flow volumes. These outputs are at a coarser spatial scale than required to assess impacts at individual sites. The assessment relied, in part, on known flow thresholds presented in the Deschutes Project BiOp as indicators of how sites in a particular reach may at least initially respond to the different flow regimes. Given the dynamic nature of this system and the expectation that habitat distribution and use by the frog will change over time, a reach-level analysis was deemed appropriate for purposes of comparing conditions across the alternatives.

Defining the Study Area

The study area for this analysis includes the portion of the Deschutes Basin that provides habitat for Oregon spotted frog and would potentially be affected by the alternatives. The study area extends from Crane Prairie Reservoir down the Upper Deschutes River to the LSA Marsh in Bend, Oregon, which is the lowest occupied site directly influenced by flows in the Deschutes River system (Figure 1). The study area also includes Crescent Creek downstream from the outlet of Crescent Lake to the confluence with the Little Deschutes River, and the Little Deschutes from this confluence downstream to the Deschutes River.

Figure 1. Oregon Spotted Frog Study Area Reaches and Sites (Seasonal and Breeding)



Stream and River Reach Delineation

To facilitate the effects analysis, the study area was divided into 12 stream and river reaches (Figure 1). These reaches overlap with the known distribution of the species. There are 10 reaches in the Upper Deschutes River (between Crane Prairie Reservoir and Bend) and 2 reaches in the Crescent Creek and the Little Deschutes River portion of the study area.

The study area reaches are described in Table 1.

Table 1. Description of Study Area Reaches

River	Reach	Length (mi)	Description
Little Deschutes	CLD-1 and CLD-2	58.5	CLD-1 to CLD-2 are along the Little Deschutes River. CLD-1 extends for 29.3 miles and has a low-gradient underfit stream with glide morphology in an unforested wetland/riparian vegetation corridor with a total width of 328 to 984 feet. CLD-2 has the same morphology as CLD-1, but upstream of the LAPO gauge.
Crescent-Creek	CLD-3 through CLD-6	30.4	CLD-3 through CLD-6 are along Crescent Creek. The Little Deschutes River upstream of here would not be affected by the alternatives. CLD-3 has the same morphology as CLD-1, but extends for 12.6 miles upstream of the Walker Basin Canal. CLD-4 is an 11.0-mile-long section where creek is a meandering underfit stream with glide morphology in an unforested wetland/riparian vegetation corridor with a total width of 164 to 328 feet. CLD-5 has a low-gradient meandering stream for 5.9 miles within a mostly unforested riverine wetland corridor with a total width of 164 to 328 feet, flanked by ponderosa pine-dominated upland forest. At the upper end of CLD-5, the channel is constricted by development. The upper 0.9 mile of the reach (CLD-6) is a pool-riffle stream that flows through a mostly unforested riverine wetland wetland/riparian vegetation corridor with a total width of 99 to 164 feet, flanked by ponderosa pine-dominated upland forest.
Deschutes	Des-8a	3.4	River is confined variously by lava flows, development, and topography, with limited but locally important riparian or aquatic vegetation. River channel has a mixed pool-riffle, step-pool and glide morphology with occasional cascades. Reach Des-8a is designated for consistency with the U.S. Fish and Wildlife Service (2017, 2019) analysis, which placed a reach break at the Colorado Avenue bridge.
Deschutes	Des-9	3.7	River has glide morphology with some waterfalls related to lava flows. There are locally important riverine wetlands and floodplain riparian vegetation, mostly located on river bars. The Central Oregon Canal diversion is at the break between Des-8a and Des-9.

River	Reach	Length (mi)	Description
Deschutes	Des-10	3.1	River has low gradient, glide morphology due to ancient damming by a lava flow at Lava Island Falls, which is the break between Des-9 and Des-10 and is the site of the Arnold Canal diversion. Wetlands are present in this reach, but the river is more confined in some locations and there are stretches of fast water, including Big Eddy rapids and other swift water sections.
Deschutes	Des-10a	3.1	Similar to Des-10, but some extensive wetland complexes flank the river or its former cut-off meanders; these include a mix of aquatic, wetland, and riparian vegetation, mostly in herbs and shrubs but locally in hardwood and mixed forest. The wetland complexes are distinctly influenced by groundwater, surface water, and/or pluvial inputs depending on the site. This reach includes the Slough Camp complex and Ryan Ranch, two very large and notable wetlands.
Deschutes	Des-11	11.4	Similar in river characteristics to Des-10a but is above the BENO gauge. Wetlands are more sparse than between Dillon and Benham, and in some sections, the valley walls extend down to the river's edge.
Deschutes	Des-12	11.0	Reach is above the Little Deschutes River confluence. The river is much more sinuous than Des-10a overall, with a fairly high frequency of cutoff meanders. There is more development with riverfront homes. Wetlands typically occur in meander scars and oxbows.
Deschutes	Des-12a	21.7	Reach is above the Fall River confluence. Lower part of the reach is similar to Des-12. Above the State Park, the river transitions to much less sinuosity with a relatively narrow riparian zone. Wetlands generally occur on the inside of meander bends.
Deschutes	Des-13 (Wickiup Reservoir)	13.1	Wickiup Reservoir has some riparian/wetland vegetation, and it develops some localized herbaceous vegetation during draw-down. There are some large areas of willow and rush/sedge communities at the southern lobe of the reservoir. These are inundated when storage level is high. Uppermost Des-13 is less often inundated and has substantial areas of both herb and shrub wetland and riparian vegetation.
Deschutes	Des-14	1.2	Pool-riffle reach with narrow bands of riparian vegetation, mostly located on point bars.
Deschutes	Des-15 (Crane Prairie Reservoir)	6.5	Crane Prairie Reservoir has locally extensive riparian/wetland vegetation on its margins and at its head. This is the upper limit of potential effects on the Deschutes River.

Life History Timeframes

The analysis assessed the effects among the alternatives by comparing how the differing flow regimes might affect the following five key life history periods of the Oregon spotted frog:

- Pre-breeding (March 1 through March 31): During this period frogs emerge from overwintering sites and move to breeding locations if habitat conditions do not support these life history periods in the same location.
- Breeding (April 1 through April 30): Frogs deposit egg masses in shallow wetland areas and during this period the egg masses are sensitive to changes in water levels that can result in less favorable conditions for development (exposure to predation, risk of desiccation).
- Rearing (April 15 through August 31): During this period frog eggs hatch and tadpoles develop throughout the summer, finally metamorphosing into juvenile frogs.
- Pre-wintering (September 1 through October 15): Juveniles and adults may move from wetlands associated with breeding and rearing to overwintering sites if habitat conditions do not support these life history periods in the same location.
- Overwintering (October 16 through March 1): Frogs remain relatively inactive during the winter and they are vulnerable to exposure and possible mortality via desiccation or freezing.

Relating Flow to Oregon Spotted Frog Habitat Impacts

The amount of water flowing through the Upper Deschutes River system affects the quality of the aquatic habitat used by Oregon spotted frogs based on time of year and the corresponding key life history periods described previously. General patterns of habitat sensitivity to flow include:

- During pre-breeding, frogs move from overwintering sites to breeding locations. Inundation of wetland vegetation during the latter part of this period prepares the breeding locations for the deposition of egg masses.
- Breeding and rearing habitats are supported in sites where flow volumes are sufficient to ensure emergent vegetation remains inundated with water during the breeding and rearing seasonal periods.
- During breeding, stable water elevation is important as egg masses develop. Egg masses are vulnerable to mortality through desiccation or predation if changing water levels move them to unsuitable habitat or strand them.
- During rearing, mobile tadpoles and metamorphic frogs can tolerate more water level fluctuation than egg masses. Flows need to maintain inundation of vegetation to facilitate movement and provide cover from predators and thermal refugia from summer heat.
- During the pre-winter, as juveniles and adults move from inundated wetland sites to overwintering locations in springs and creeks with refugia (e.g., mud banks, vegetation mats), and often with well-oxygenated flowing water, the distance traveled should be minimized. Inundation of vegetation early in this period provides shelter to Oregon spotted frogs from

predation. As water levels drop, the amount of water level change to which Oregon spotted frogs are exposed is also important to their successful movement and survival.

- Although Oregon spotted frogs may relocate during the overwintering period, general water level stability protects sedentary individuals from exposure and freezing.

Approach for Reach-Level Impact Analysis

RiverWare (Zagona et al. 2001) was modified and designed for the Deschutes Basin by the Bureau of Reclamation (Appendix 3.1-B, RiverWare Model Technical Memorandum). RiverWare model outputs and stream gauge flow data were related to Oregon spotted frog habitat conditions in reaches within the study area by assessing the amount of flow and patterns of change in flow depicted in modeled hydrographs, relative to flow thresholds that reflect some of the habitat sensitivity patterns described above. The reach-level impact assessment relied on the flow thresholds developed by the U.S. Fish and Wildlife Service (FWS) presented in Table 2,[1] as well as the hydrographs presented in the *Environmental Consequences* section.

Hydrographs used in this analysis included the earlier phases of each alternative, as well as fully implemented alternatives, meaning the flows predicted under each alternative when operating at their highest minimum instream fall and winter flow below Wickiup Dam.

Table 2. Minimum Fall/Winter Instream Flows below Wickiup Dam under Proposed Action, Alternative 3, and Alternative 4 Phases

	Proposed Action		Alternative 3		Alternative 4	
Phase	Years	Flows	Years	Flows	Years	Flows
1	1–7	100 cfs	1–5	200 cfs	1–5	300 cfs
2	8–12	300 cfs[a]	6–10	300 cfs	6–20	400–600 cfs[b]
3	13–30	400–500 cfs[b,c]	11–30	400–500 cfs[b]	N/A	N/A

[a] Includes a summer flow cap of 1,400 cfs.
[b] Variable minimum flow depending on amount of water stored in Wickiup Reservoir.
[c] Includes a summer flow cap of 1,200 cfs.
cfs = cubic feet per second; N/A = not applicable.

With some exceptions (e.g., Des-8a), the flow thresholds below were developed by FWS and are also presented in the Deschutes Project BiOp (U.S. Fish and Wildlife Service 2017: Table 32; 2019). FWS developed the thresholds by comparing the flow measured at gauges in the rivers or streams to the timing and duration of inundation patterns observed at sites. For sites associated with a gauge, when the flow threshold in Table 3 is observed at the gauge, the associated sites experience inundation levels that are deep enough to partially submerge emergent vegetation in the site, thereby providing sufficient cover and habitat function to support Oregon spotted frogs, particularly during breeding.

[1] Flow thresholds were developed by FWS based on habitat observation and they were used as "take" thresholds in the Deschutes Project BiOp (2017, 2019).

Table 3. Flow Thresholds

Reach	Associated Gauge	Flow Threshold (cfs)
Des-12a (Wickiup Dam to Fall River)	WICO	900[a]
Des-12 (Fall River to Little Deschutes)	WICO	900[a]
Des-11 (Little Deschutes to Benham Falls)	WICO	900[b]
Des-10a (Benham Falls to Dillon Falls)	BENO	1,200–1,600[a]
Des-10 (Dillon Falls to Lava Island Falls)	BENO	1,200–1,500[a]
Des-9 (Lava Island Falls to Central Oregon Diversion)	Modified from BENO *RiverWare Internode: Siphon2COIDInflow*	(none)
Des-8a (Central Oregon Diversion to Colorado Street)	Modified from BENO *RiverWare Internode: Siphon2COIDOutflow*	1,200[b]
CLD-3 through CLD-6 (Crescent Creek)	CREO	(none)
CLD-1 and CLD-2(Little Deschutes River)	LAPO	(none)

[a] U.S. Fish Wildlife Service 2017 and 2019.
[b] Developed by FWS for this analysis.

In addition to the wetland inundation thresholds in Table 3, the analysis applied some reach-specific flow thresholds to assess other reach conditions which do not represent wetland vegetation inundation but allow comparison of other physical attributes that are likely to affect habitat over time. An example of this is the flow threshold describing when water flow switches from flowing toward the wetlands to toward the river. These thresholds are described by reach in the *Environmental Consequences* section.

For reservoirs, RiverWare-modeled storage volumes (acre-feet [af]) and associated reservoir pool elevations (feet) were compared among the alternatives. The assessment relied on water elevation targets described in the Final Deschutes Basin HCP Chapter 6 (Deschutes Basin Board of Control and City of Prineville 2020) and storage volume targets or ranges described in the Deschutes Project BiOp (U.S. Fish and Wildlife Service 2017, 2019). These are detailed in the specific reach analysis sections for Crane Prairie and Wickiup reservoirs (Des-15 and Des-13).

Analysis of effects on general vegetation growth patterns within the study area considered the following growing season information. The growing season typically covers the period of time between the last and first freeze dates of a year. Based on data collected from 1971 through 2002 (Detweiler 2016), the median last frost date, or the beginning of the growing season for Bend, Oregon, is June 20, and the growing season extends to the median first frost date of September 2 (day 337 of water year). La Pine, Oregon also experiences its last frost on June 20, but the first frost typically happens on September 8 (day 343 of the water year). The growing season is approximately 11 weeks long and overlaps with the rearing period for Oregon spotted frogs.

Analysis of Other Threats to the Species

The assessment qualitatively addresses how proposed changes to the water management of the system may secondarily affect other known threats to the species in the study area. Primarily these threats include the proliferation of invasive species such as reed canarygrass (*Phalaris arundinacea*), which can affect the quality of the emergent vegetation at breeding sites, and nonnative predatory species such as the bullfrog (*Lithobates catesbeianus*), brown bullhead catfish (*Ictalurus nebulosus*), brown trout (*Salmo trutta*), and three-spined stickleback (*Gasterosteus aculeatus*).

Analysis of the OSF Storage Account

The proposed action includes Conservation Measure CC-1 that sets aside a portion of the water stored in Crescent Lake Reservoir to be used specifically to benefit Oregon spotted frogs. This storage would be used to manage flows in Crescent Creek to maintain or increase winter minimum flow levels, increase instream flow levels in spring, or delay and draw out the ramp down of irrigation releases in the fall. Conservation Measure CC-1 is analyzed as part of the proposed action; neither the no-action alternative nor the other action alternatives (Alternatives 3 or 4) include this conservation measure.

Considerations of the Upper Deschutes River Conservation Fund

The proposed action and Alternatives 3 and 4 include Conservation Measure UD-1: Upper Deschutes Basin Conservation Fund. The fund would be used to improve or enhance habitat in the Upper Deschutes Basin for the Oregon spotted frog and other aquatic species (to benefit the Oregon spotted frog), or otherwise address conditions in the Upper Deschutes Basin that affect the conservation and recovery of the Oregon spotted frog in the wild. This measure is not included in the no-action alternative. The effects of Conservation Measure UD-1 are not quantifiable; however, the assessment of environmental consequences considers it qualitatively because the measure will be used to support habitat restoration actions designed to respond to ongoing threats to the Oregon spotted frog and its habitat.

Comparing the Alternatives

This assessment compared how well the proposed action, Alternative 3, and Alternative 4 would perform relative to the no-action alternative and identified which alternative or group of alternatives would result in the most favorable conditions for Oregon spotted frogs and their habitat.

The RiverWare model was used to assess the performance of the alternatives by comparing the predicted number of days of habitat inundation during the following periods.

- Breeding, Oregon spotted frog's most sensitive life history period.
- Rearing, when frogs rely on inundated vegetation to facilitate movement and provide cover from predators and thermal refugia from summer heat. This is the least sensitive life history period for the frog.
- Pre-winter, when frogs move to overwintering sites.

- Overwintering, when frogs are relatively inactive and vulnerable to exposure and possible mortality via desiccation or freezing.
- Pre-breeding, when frogs move from their overwintering locations to breeding habitats.

The analysis focuses on the implementation phases of each alternative as described in Table 2. At the full implementation phase for each alternative, conditions affecting the Oregon spotted frog would be at their most beneficial or adverse level of effect. The proposed action and Alternatives 3 and 4 have different time frames (Table 2) for when they would operate at their highest minimum instream fall and winter flow below Wickiup Dam. The analysis also considers the length of time needed to reach full implementation as well as the duration at which the alternative would operate at full implementation when considering the overall effect of the alternative over its permit term.

If differences in the extent of habitat inundation were noted among the life history periods, the time required to reach full implementation (highest flow level) and duration of the full implementation timeframe were considered. Longer time needed to reach full implementation or shorter duration at full implementation would extend the negative effects of ongoing threats to the species as they exist under the current condition.

The patterns evident from the modeled hydrographs for each implementation phase of each alternative, including modeled flow changes, within-year, and then year-to-year variation among the alternatives, were also considered. The effect of Conservation Measure CC-1 was also considered, which is only included in the proposed action.

Effects of the proposed action and alternatives on Oregon spotted frog would be considered adverse if they directly or indirectly result in habitat conditions likely to cause a decline in the distribution, connectivity between habitats, abundance, and productivity of Oregon spotted frog.

Affected Environment

Biology of the Species

The Oregon spotted frog (*Rana pretiosa*) was listed as threatened under the Endangered Species Act (ESA) on August 29, 2014 (79 FR 168:51657). Critical habitat was designated on May 11, 2016 (81 FR 29336). Oregon spotted frogs have historically ranged from British Columbia to northeastern California, occupying 31 subbasins (Hayes 1997, McAllister and Leonard 1997). Currently, the Oregon spotted frog occupies 15 subbasins from southwestern British Columbia to at least southern Oregon (70 FR 51662-51663: Table 1). The spotted frog is likely extirpated from northeastern California (Hayes 1997). Within the study area, spotted frogs occupy two subbasins: the Upper Deschutes River and the Little Deschutes River. These subbasins are aquatically connected, unlike other subbasins in Oregon.

Oregon spotted frogs show a high affinity for aquatic habitat. They prefer perennially deep pools with moderate amounts of native vegetation, including grasses, sedges, and rushes, although they may also occupy mixes of reed canarygrass and native vegetation (Watson et al. 2003; McAllister and Leonard 1997). Reed canarygrass can reduce the quality of breeding habitat as it proliferates over time (Kapust et al. 2012). Aquatic plants are used by adults for basking and cover.

Oregon spotted frogs reach maturity by 1 to 3 years of age, varying by sex, elevation, and latitude. At lower elevations, breeding occurs in February or March while at higher elevations, it occurs between early April and early June (Leonard et al. 1993). Egg masses are laid communally, in groups of up to several hundred (Licht 1971, Nussbaum et al. 1983, Cook 1984, Hayes et al. 1997, Engler and Friesz 1998). Females deposit their eggs in shallow water such as temporary pools, gradually receding shorelines, benches of seasonal lakes and marshes, and in wet meadows. Egg-laying sites (oviposition habitat) tend to be only temporarily wet but are connected to permanently wetted areas through surface water. Eggs are often deposited in low and sparse aquatic vegetation situated to take advantage of solar exposure that warms the surrounding water. Due to the specific needs for ovipositional habitat and a limited flexibility to switch sites, Oregon spotted frogs may be especially affected by modification of existing egg-laying sites (Hayes 1994).

Eggs typically hatch within 3 weeks and tadpoles move into rearing habitat, such as streams, ponds, and wetlands. The tadpoles graze on plant tissue, bacteria, algae, detritus, and carrion. Tadpole survival is greatly affected by predation and is increased as tadpoles grow and with access to mature aquatic vegetation for cover (Licht 1974). Tadpoles metamorphose into froglets in their first summer.

Oregon spotted frogs are generally limited in their dispersal movements, averaging between 1,312 feet (400 meters) to 2,600 feet (800 meters) throughout the year, however individuals have been shown to disperse up to 1.7 miles (2.7 kilometers) (Cushman and Pearl 2007; Hallock and Pearson 2001; Watson et al*.* 1998). Frequency of movement is positively correlated with pool proximity (Watson et al. 2003). Spotted frogs in the Sunriver population routinely make annual migrations of 1,640 to 4,265 feet (500 to 1,300 meters) between a major egg-laying complex and an overwintering site. A recent study (Pearl et al. 2018) including some sites from the Upper Deschutes found that most frogs moved to overwintering habitats between mid-September and late October. Most frogs moved less than 250 meters, although some showed greater movement distances depending on habitat type. Those using ditches moved farther, up to 1,145 meters over the tracking period. Due to limited dispersal distance, all life history types are exhibited in the study area.

Limited dispersal distances and low habitat connectivity are thought to contribute to the low genetic diversity found in Oregon spotted frogs (Blouin et al. 2010). Blouin et al. (2010) demonstrated that gene flow is much higher if populations are less than 10 kilometers apart. FWS considers spotted frog habitat connected for the purposes of genetic exchange when occupied/suitable habitats fall within a maximum movement distance of 3.1 miles (5 kilometers) (U.S. Fish and Wildlife Service 2013).

For overwintering, adults generally require flowing streams for well-oxygenated water (Tattersall and Ultsch 2008) and refugia from predators and freezing (Watson et al. 2003). Where cold winters tend to ice over ponds, spotted frogs have been observed to remain active during the first month of freezing, appear dormant during January and February, and gradually increase activity by mid-March, even when ice cover remains (Hayes et al. 2001). Oregon spotted frogs have been observed using “semi-terrestrial” overwintering habitats, such as interstices in lava rock, beaver channels, and flooded beaver lodges along the Deschutes River in central Oregon (Pearl et al. 2018). Overwintering sites may contain multiple frogs, underscoring the importance of these habitat features for spotted frogs (Pearl et al. 2018).

Status in the Study Area

The proposed action would affect two subbasins: the Upper Deschutes from Bend to Crane Prairie Reservoir and the Little Deschutes Basin, including the Little Deschutes up to its confluence with Crescent Creek and Crescent Creek to Crescent Lake. Both subbasins include several riverine, palustrine, and lacustrine wetland locations known to be occupied by Oregon spotted frogs, and critical habitat has been designated for the species throughout these riverine reaches.

A *metapopulation* is a group of populations experiencing a measurable amount of gene flow. The Oregon spotted frogs within the study area belong to the Central Cascades metapopulation (Blouin et al. 2010). In the study area, patches of habitat conducive to Oregon spotted frog breeding are separated from each other by areas that are not suitable for breeding but may support other uses by Oregon spotted frogs (e.g., dispersal, foraging). For the purpose of this analysis, an Oregon spotted frog site is defined as a habitat patch where breeding has been confirmed (breeding site), or an area where multiple Oregon spotted frogs have been detected (seasonal habitat). Breeding sites and other seasonal habitat within the study area are shown on Figure 1. All habitats are important for connectivity between populations and influencing survival and recovery of Oregon spotted frog. These areas are all within critical habitat and considered to be occupied where there is suitable habitat for Oregon spotted frogs.

Above Wickiup Dam on the Upper Deschutes River, Crane Prairie Reservoir contains several breeding sites. The Deschutes River Arm and the southeast bay of Wickiup Reservoir are each known to support Oregon spotted frogs currently and within the recent past. Along the mainstem Deschutes River from below Wickiup Dam to the confluence with the Little Deschutes River, there are six known breeding sites, in two of which only occasional breeding has been detected. From below the confluence with the Little Deschutes River to Bend, there are six breeding sites (one of which is occasional) and one recently identified site with only juveniles detected (U.S. Fish and Wildlife Service 2017, 2019).

There are nine breeding sites that are monitored by FWS along the Little Deschutes River downstream of its confluence with Crescent Creek. The middle Little Deschutes, from Crescent Creek to the confluence with Long Prairie Creek, has three of these sites. The lower Little Deschutes, from Long Prairie Creek to the confluence with the Deschutes River, contains the other six. In 2011 and 2012, breeding counts found that spotted frogs were distributed throughout the entire reach of the Little Deschutes River, downstream of Crescent Creek (U.S. Fish and Wildlife Service 2017). Crescent Creek contains five known breeding sites. Surveys in 2011 and 2012 found Oregon spotted frogs distributed throughout 25 of the 30 miles of the reach. No Oregon spotted frogs were detected within 5 miles downstream of Crescent Lake Dam (U.S. Fish and Wildlife Service 2017, 2019).

Within the study area Oregon spotted frog site connectivity with the river and its associated flows are varied. Some sites are closely connected to the river (e.g., Bull Bend) whereas others function relatively independently from the fluctuations in the river flows (e.g., Sunriver, Old Mill/Casting Pond). Both the Sunriver (which hosts the Sunriver breeding site) and the Old Mill/Casting Pond sites are human-made so their independence from river flow fluctuations is probably the most extreme among the known Oregon spotted frog sites in the study area. In addition, groundwater inputs, and site-specific characteristics such as site topography, elevation, and substrate are known to affect the extent and timing of site-specific responses to changes in river flow (U.S. Fish and Wildlife Service 2017, 2019).

Threats to Oregon Spotted Frogs in the Deschutes Basin

In the 2014 Final Rule determining the ESA threatened species status of Oregon spotted frog (79 FR 51657), FWS identified threats to Oregon spotted frogs in the Deschutes Basin. Specifically, in the Upper Deschutes River Subbasin threats include wetland loss, reed canarygrass, shrub encroachment, and hydrological changes (water management). In the Little Deschutes River Subbasin, threats include habitat loss and/or modification due to land conversions (primarily agriculture), hydrologic changes (e.g., dams, ditches, and water control structures), shrub encroachment, invasive reed canarygrass, and introduced predators (bullfrogs and cold water fish).

Environmental Consequences

Reach Des-15: Crane Prairie Reservoir

Crane Prairie Reservoir supports a large breeding population of Oregon spotted frogs and is a key site for maintaining the species in the Upper Deschutes River subbasin.

In the Deschutes Project BiOp (U.S. Fish and Wildlife Service 2017, 2019), FWS found that storage volumes between 45,000 and 50,000 af ensure quality breeding habitat for Oregon spotted frogs because at these storage volumes the upper edge of the reservoir pool remains within the existing emergent vegetation.

Figure 2 depicts daily water volume hydrographs generated for Crane Prairie Reservoir (CRA) using RiverWare for the no-action alternative and the proposed action. The modeled hydrograph for this location is the same over the entire permit term under the proposed action and under Alternative 3 and Alternative 4, so only one hydrograph is presented for brevity.

Figure 2. Water Volume (acre-feet) in Crane Prairie Reservoir Flow Modeled Using RiverWare under Proposed Action Compared to No-Action Alternative

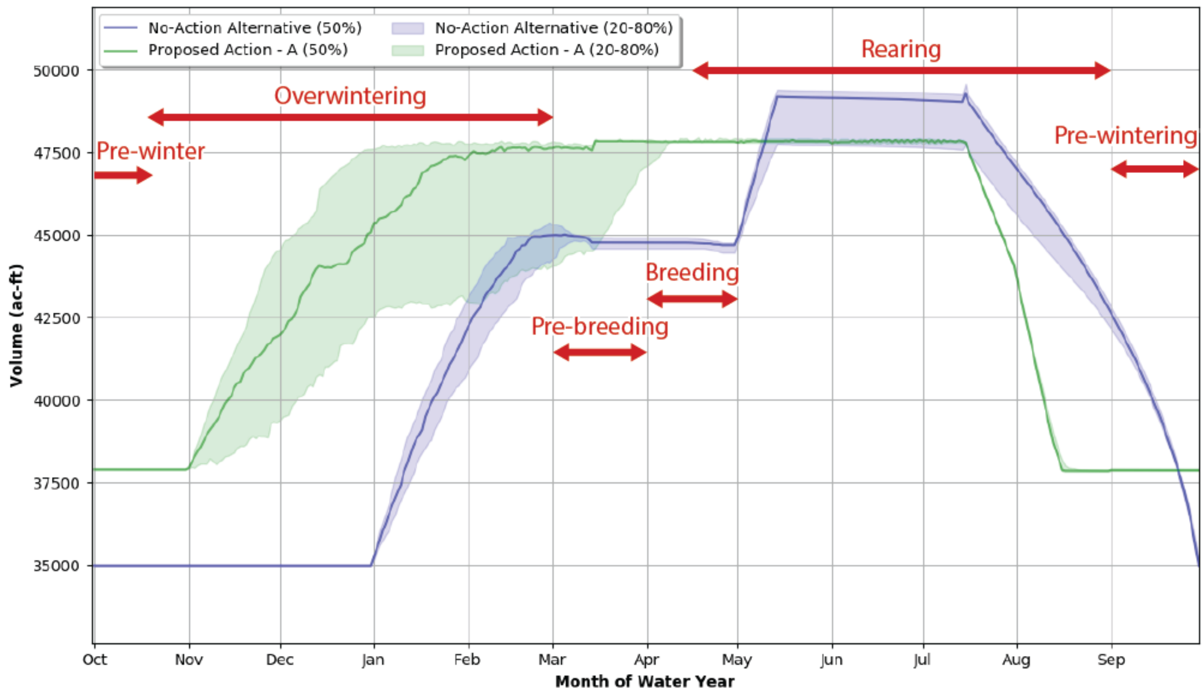


Table 4 and Table 5 provide comparisons among the alternatives of storage volume (af) and water elevation (feet) available in Crane Prairie during each of the key Oregon spotted frog life history periods. Data were calculated from the 20% (low flow years), 50% (median flow years), and 80% (high flow years) daily values for the 38-year model period, averaged over the key life history period days of the water year.

Table 4. Crane Prairie Reservoir Water Storage Volumes during Key Oregon Spotted Frog Seasons under the Proposed Action, Alternative 3, and Alternative 4 at Full Implementation Compared to the No-Action Alternative

	Dry Years				Median Years				Wet Years			
Crane Prairie Reservoir	No-Action Alternative (ac-ft)	Proposed Action % of No-Action Alternative	Alternative 3 % of No-Action Alternative	Alternative 4 % of No-Action Alternative	No-Action Alternative (ac-ft)	Proposed Action % of No-Action Alternative	Alternative 3 % of No-Action Alternative	Alternative 4 % of No-Action Alternative	No-Action Alternative (ac-ft)	Proposed Action % of No-Action Alternative	Alternative 3 % of No-Action Alternative	Alternative 4 % of No-Action Alternative
Breeding	44,563	107%	107%	107%	44,746	107%	107%	107%	44,869	107%	107%	107%
Rearing	46,229	99%	99%	99%	47,370	96%	96%	96%	47,578	96%	96%	96%
Pre-winter	37,882	100%	100%	100%	38,036	100%	100%	100%	38,156	99%	99%	99%
Overwintering	37,364	110%	110%	110%	37,776	116%	116%	116%	38,066	118%	118%	118%
Pre-breeding	44,634	101%	101%	101%	44,852	106%	106%	106%	44,997	106%	106%	106%

Table 5. Crane Prairie Reservoir Water Elevations during Key Oregon Spotted Frog Seasons under the Proposed Action, Alternative 3, and Alternative 4 at Full Implementation Compared to the No-Action Alternative (feet)

	Dry Years				Median Years				Wet Years			
Crane Prairie Reservoir	No-Action Alternative	Proposed Action difference from No-Action Alternative	Alternative 3 difference from No-Action Alternative	Alternative 4 difference from No-Action Alternative	No-Action Alternative	Proposed Action difference from No-Action Alternative	Alternative 3 difference from No-Action Alternative	Alternative 4 difference from No-Action Alternative	No-Action Alternative	Proposed Action difference from No-Action Alternative	Alternative 3 difference from No-Action Alternative	Alternative 4 difference from No-Action Alternative
Breeding	4,442.69	-0.70	-0.70	-0.70	4,442.73	-0.68	-0.68	-0.68	4,442.76	-0.67	-0.67	-0.67
Rearing	4,443.06	0.13	0.13	0.13	4,443.31	0.37	0.37	0.37	4,443.36	0.40	0.40	0.40
Pre-winter	4,441.20	-0.01	-0.01	-0.01	4,441.23	0.02	0.02	0.02	4,441.26	0.04	0.04	0.04
Overwintering	4,441.08	-0.83	-0.83	-0.83	4,441.17	-1.33	-1.33	-1.33	4,441.24	-1.53	-1.53	-1.53
Pre-breeding	4,442.70	-0.12	-0.12	-0.12	4,442.75	-0.64	-0.64	-0.64	4,442.78	-0.62	-0.62	-0.62

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Effects

At Crane Prairie Reservoir, from an operation standpoint the proposed action, Alternative 3, and Alternative 4 are indistinguishable, but they vary as a group from the no-action alternative.

Based on the storage volume calculations (Table 4):

- During all types of years (wet, dry, normal [median]), the no-action alternative provides about the same volume of water as the proposed action, Alternative 3, and Alternative 4 during rearing and pre-winter, but less water during pre-breeding and breeding and much less during overwintering.
- The proposed action, Alternative 3, and Alternative 4 show similar performance, and all outperform the no-action alternative.

Based on the storage elevation calculations (Table 5):

- The proposed action, Alternative 3, and Alternative 4 perform similarly during all key life history periods and under wet, normal, and dry year conditions.
- The no-action alternative provides slightly lower water elevations than the proposed action, Alternative 3, and Alternative 4 during rearing in all types of years, and during pre-wintering in normal (median) and wet years.

From the hydrograph (Figure 2):

- The modeled pattern shown in the hydrograph above (Figure 2) is similar for elevation, and the life history period effects described below are the same.
- The pool elevation and storage volume would be held at a consistent level with vegetation inundated throughout the breeding season under all alternatives.
- During pre-winter, the proposed action, Alternative 3, and Alternative 4 the volume of water in the reservoir would decrease but not be reduced below approximately 37,870 af, which is higher than the no-action alternative minimum storage level (35,000 af). This would make it easier for Oregon spotted frog to access overwintering sites because of the shorter travel distances between breeding and overwintering sites.
- Under the proposed action, Alternative 3, and Alternative 4, volume would be prevented from decreasing below 37,870 af during the winter. Smaller volume fluctuation would be expected to support Oregon spotted frog by increasing stability of a key abiotic component (water) that supports the vegetation community.
- The rate of fill would be smoothed, as water volumes increase between Nov 1 and April 1 (or earlier) and be held at an upper volume of 48,000 af. There would not be a jump in volume after May 1 for the proposed action, Alternative 3, and Alternative 4, as seen in the no-action alternative. The smoothing of the hydrograph would positively affect Oregon spotted frogs by maintaining a more stable water interface with the vegetation. Under the proposed action, Alternative 3, and Alternative 4, Oregon spotted frogs would experience fewer changes in volume and avoid a volume change that happens during the rearing period under the no-action alternative.

Summary Conclusion

Table 9 summarizes the overall results of this comparison of each alternative to the no-action. The proposed action, Alternative 3, and Alternative 4 would similarly improve Oregon spotted frog habitat and support the species compared to the no-action alternative.

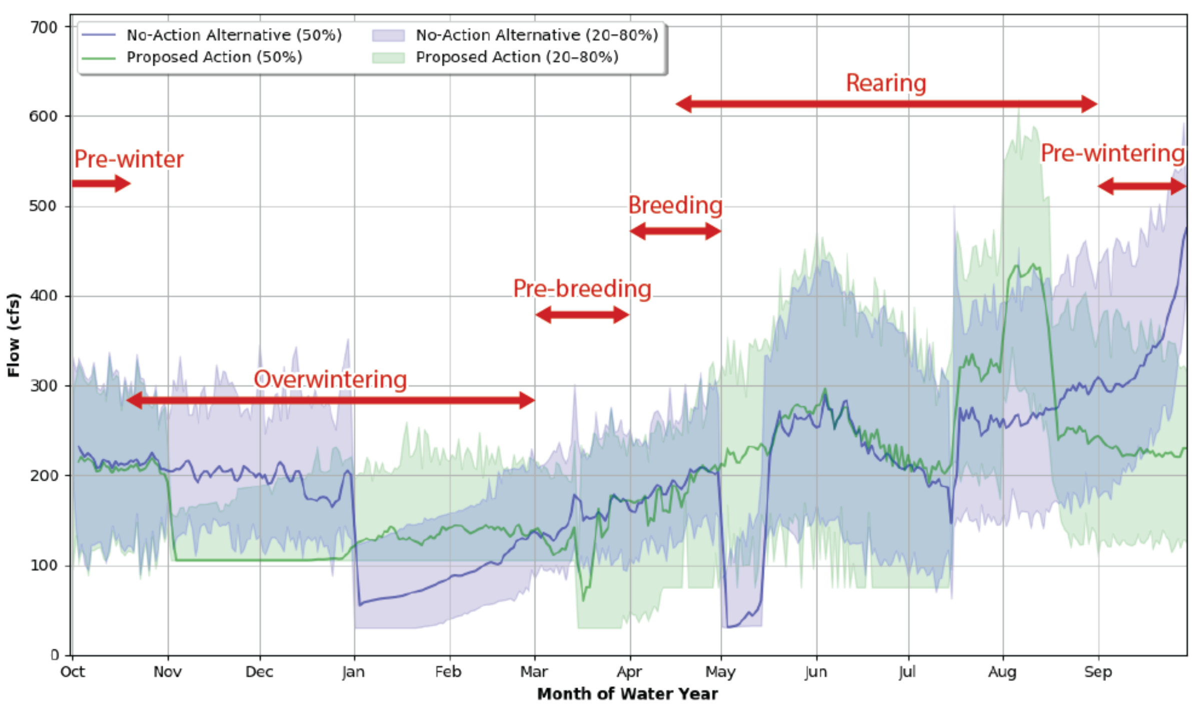
Reach Des-14

Oregon spotted frogs are known to occupy this short stretch of the Deschutes River between Crane Prairie Reservoir and Wickiup Reservoir; however, records of egg mass observation indicate the single confirmed breeding site appears to fail during most if not all years (U.S. Fish and Wildlife Service 2017, 2019). Oregon spotted frog egg masses were again detected within this area of the reach during 2019 (U.S. Fish and Wildlife Service 2019). Aside from potentially supporting breeding, the reach provides connectivity between Crane Prairie and Wickiup Reservoirs.

RiverWare Results

Figure 3 depicts daily Deschutes River flow hydrographs generated for the CRAO gauge location using RiverWare for the no-action alternative and the proposed action. The modeled hydrograph for this location is the same over the entire permit term under the proposed action and under Alternative 3 and Alternative 4, so only one hydrograph is presented for brevity.

Figure 3. Deschutes River Flow Modeled Using RiverWare at CRAO Gauge under Proposed Action Compared to No-Action Alternative



For each alternative, the graph presents the median modeled flow (50%; solid line) and a band capturing the 20% through 80% modeled flows, meaning the flows expected to occur 20% to 80% of the time.

Effects

The analysis for this reach was completed by comparing the RiverWare results for the CRAO gauge which is located on the Deschutes River just downstream from Crane Prairie Reservoir. It is important to note that the known breeding site located within this reach is heavily influenced by water level management in Wickiup Reservoir. The 2018 annual monitoring results for this wetland indicated that when Wickiup Reservoir storage exceeds approximately 179,000 af there is a surface connection as the water in the reservoir backs up into Reach Des-14 and inundates this site (Department of the Interior et al. 2019). Wickiup continues to influence this wetland with sub-surface flow when Wickiup storage volume exceeds 140,000 af. RiverWare also does not capture the effects of Conservation Measure CP-1 (H), which includes releases used to contribute flows to Wickiup and to manage invasive species in Crane Prairie. The CP-1(H) flows would move through this reach. Therefore, although this section provides a reach-level comparison of the alternatives based on the RiverWare modeling, it does not capture the site-specific conditions where Wickiup management affects the lower portions of the reach, including the vicinity of the known breeding site.

From the RiverWare hydrographs (Figure 3), this reach as modeled experiences erratic flows throughout the year; however, the erratic pattern is in part an artifact of the model as it adjusts flow to artificially maintain a minimum flow amount from the reservoir. The adjustments in the model occur more often than would realistically happen due to the operational maintenance of water elevation in Crane Prairie Reservoir.

Pre-breeding and Breeding (March 1–April 30; 31 days)

- Flow fluctuates throughout the pre-breeding and breeding periods under the no-action alternative and this pattern is amplified under the proposed action, Alternative 3, and Alternative 4.

The no-action alternative would outperform all implementation phases of the proposed action, Alternative 3, and Alternative 4; however, all alternatives offer erratic flow patterns. Flow fluctuations could strand or displace egg masses, resulting in increased egg mass mortality.

Rearing (April 15–August 31; 139 days)

- Flow patterns continue to display erratic swings but they are most extensive under the no-action alternative during early rearing as indicated by the large drop in flow during May. This is reversed in late rearing when the proposed action, Alternative 3, and Alternative 4 experience a large increase in flow relative to the no-action alternative.

All implementation phases of the proposed action, Alternative 3, and Alternative 4 would outperform the no-action alternative because the increase in flow later in the rearing season would occur at a time when frogs are more mobile and less vulnerable to flow fluctuation; however, all alternatives experience flow changes that are not conducive to supporting Oregon spotted frog habitat.

Pre-winter (September 1–October 15; 45 days)

- From the hydrographs (Figure 3), flows modeled for the proposed action, Alternative 3, and Alternative 4 experience a similar decrease in flow through the pre-winter season. The no-action alternative experiences a much larger flow fluctuation during the pre-winter.

The proposed action, Alternative 3, and Alternative 4 would perform similarly and would be much more stable compared to the no-action alternative. The less drastic change in inundation water elevation may prevent abrupt stranding of frogs as they migrate to overwintering sites. This more stable pattern could lead to an increase in the use of this reach by Oregon spotted frogs at least for dispersal and during overwintering. Therefore, the proposed action, Alternative 3, and Alternative 4 would outperform the no-action alternative.

Overwintering (October 16–March 1; 137 days)

From the hydrographs (Figure 3), flows under the proposed action, Alternative 3 and Alternative 4 maintain a relatively more stable flow pattern during winter than the no-action alternative, although they would experience a large drop in flow during early November; whereas, the no-action alternative would experience an even larger drop on average in January. Stability in flow later in the season would protect overwintering Oregon spotted frogs and could result in an increased use of the reach for overwintering, although the drop in flow early in the season could expose frogs already in overwintering locations. Therefore, the proposed action, Alternative 3, and Alternative 4 would outperform the no-action alternative, but would not necessarily produce conditions conducive to overwintering.

Summary Conclusion

Table 9 summarizes the overall results of this comparison of each alternative to the no-action alternative. The proposed action, Alternative 3, and Alternative 4 would outperform the no-action alternative during all key life history periods except pre-breeding and breeding. None of the alternatives provides high-quality stable flows that would maintain Oregon spotted frog habitat.

Reach Des-13 Wickiup Reservoir

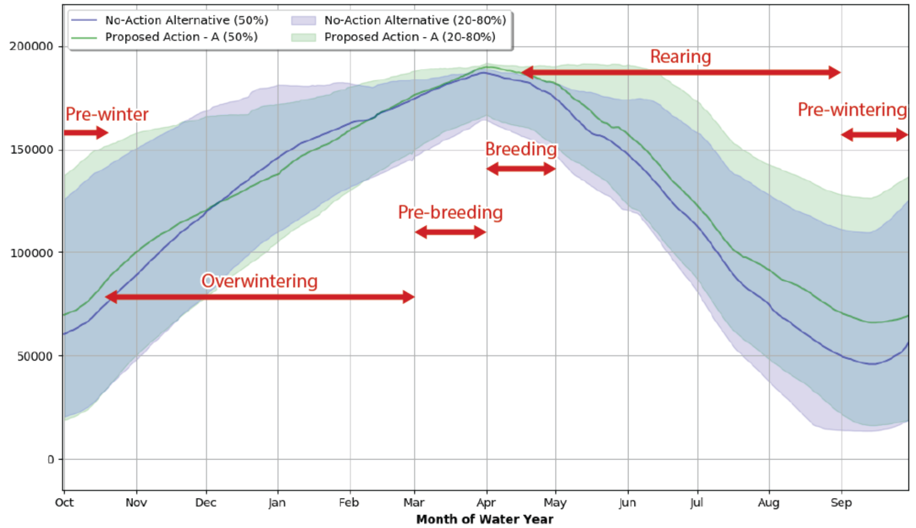
Oregon spotted frogs are known to occupy and breed in Wickiup Reservoir, although their distribution and use of the reservoir appears to be limited compared to that of Crane Prairie Reservoir (U.S. Fish and Wildlife Service 2017, 2019).

Figure 4 depicts daily water volume hydrographs generated for Wickiup Reservoir (WIC) using RiverWare for the no-action alternative, the proposed action, Alternative 3, and Alternative 4. The hydrographs represent a visual comparison of the storage volumes expected under the different alternatives during each phase of implementation.

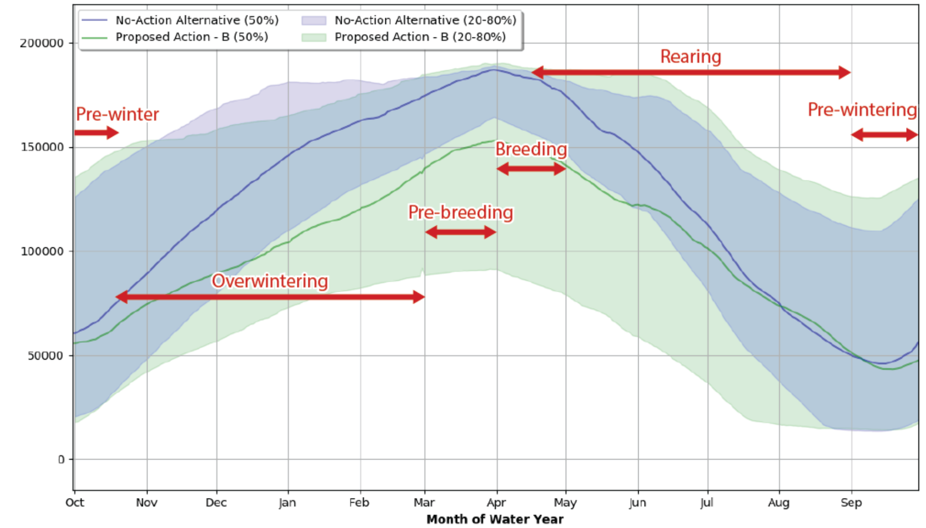
Table 6 and Table 7 provide comparisons among the alternatives (at full implementation) of storage volume (af) and water elevation (feet) available in Wickiup Reservoir during each of the key Oregon spotted frog life history periods. Data were calculated from the 20% (low flow years), 50% (median flow years), and 80% (high flow years) daily values for the 38-year model period, averaged over the key life history period days of the water year.

Figure 4. Water Volume (acre-feet) in Wickiup Reservoir Modeled Using RiverWare under Proposed Action, Alternative 3, and Alternative 4 Compared to No-Action Alternative

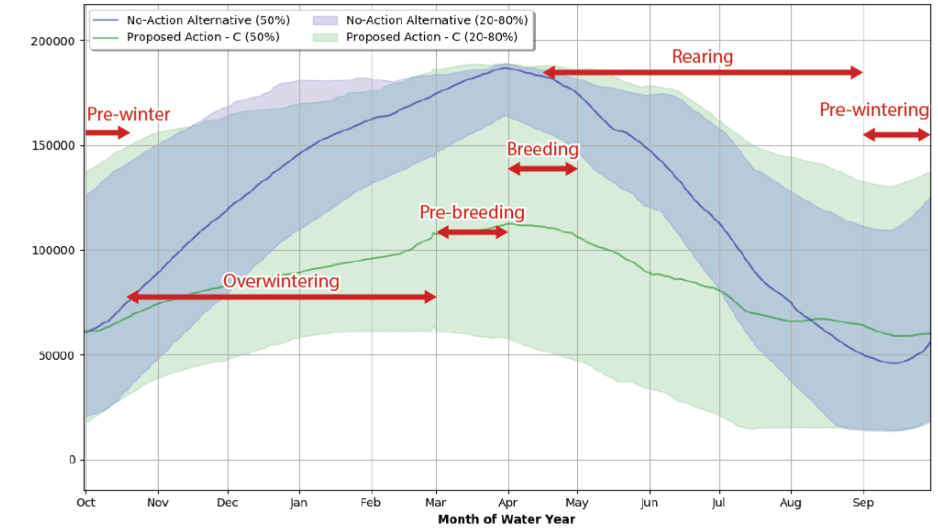
Proposed Action, Years 1–7



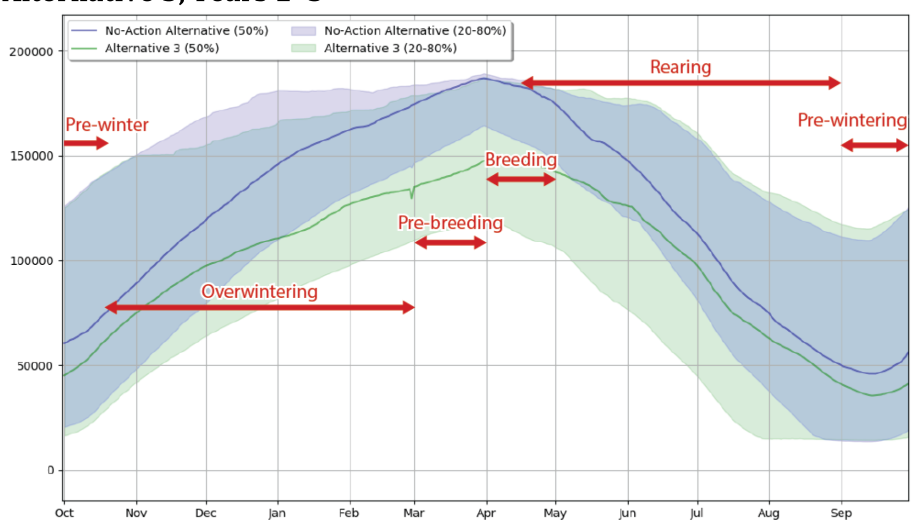
Proposed Action, Years 8–12



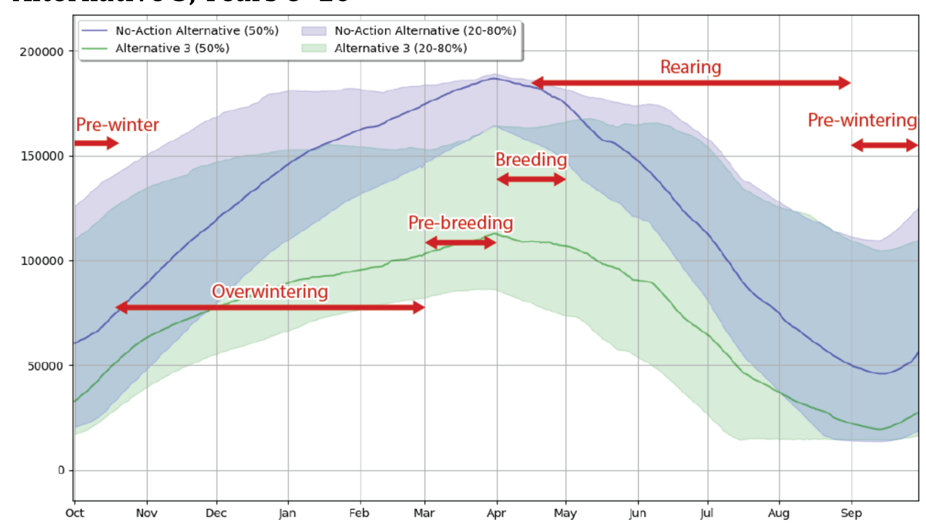
Proposed Action, Years 13–30



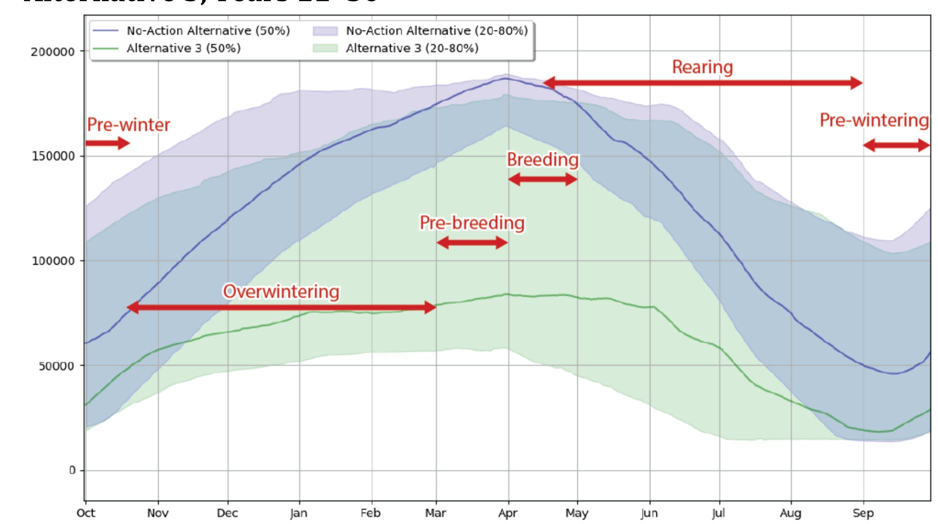
Alternative 3, Years 1–5



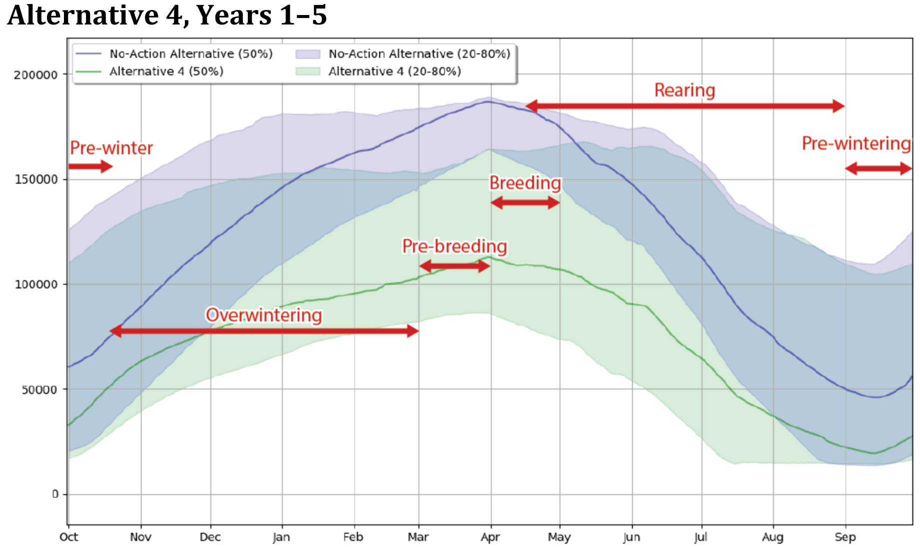
Alternative 3, Years 6–10



Alternative 3, Years 11–30



Alternative 4, Years 1–5



Alternative 4, Years 6–20

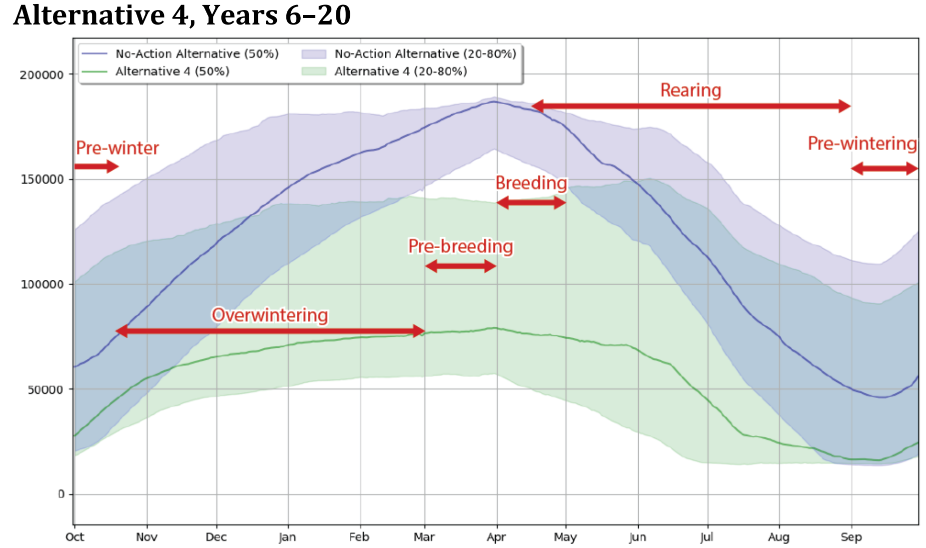


Table 6. Wickiup Reservoir Water Storage Volumes during Key Oregon Spotted Frog Seasons under the Proposed Action, Alternative 3, and Alternative 4 at Full Implementation Compared to the No-Action Alternative

	Dry Years				Median Years				Wet Years			
Wickiup Reservoir	No-Action (ac-ft)	Proposed Action % of No-Action	Alternative 3 % of No-Action	Alternative 4 % of No-Action	No-Action (ac-ft)	Proposed Action % of No-Action	Alternative 3 % of No-Action	Alternative 4 % of No- Action	No-Action (ac-ft)	Proposed Action % of No-Action	Alternative 3 % of No-Action	Alternative 4 % of No-Action
Breeding	156,704.4	33%	33%	32%	182,257.1	61%	46%	42%	185,826.4	101%	95%	76%
Rearing	87,497.62	32%	29%	29%	118,852.3	70%	48%	41%	155,391.3	106%	97%	84%
Pre-winter	17,823	99%	101%	99%	53,941.53	113%	50%	44%	120,197.3	113%	90%	82%
Overwintering	96,733.59	54%	50%	50%	132,569.3	66%	52%	50%	170,978.3	98%	87%	77%
Pre-breeding	155,495.3	38%	37%	36%	181,369.5	60%	45%	43%	185,948.9	101%	94%	75%

Table 7. Wickiup Reservoir Water Elevations during Key Oregon Spotted Frog Seasons under the Proposed Action, Alternative 3, and Alternative 4 at Full Implementation Compared to the No-Action Alternative (feet)

	Dry Years				Median Years				Wet Years			
Wickiup Reservoir	No-Action	Proposed Action difference from No-Action	Alternative 3 difference from No-Action	Alternative 4 difference from No-Action	No-Action	Proposed Action difference from No-Action	Alternative 3 difference from No-Action	Alternative 4 difference from No-Action	No-Action	Proposed Action difference from No-Action	Alternative 3 difference from No-Action	Alternative 4 difference from No-Action
Breeding	4,333.40	21.92	22.37	22.75	4,336.01	8.56	14.13	15.94	4,336.35	-0.19	0.88	4.73
Rearing	4,318.26	19.82	20.96	21.39	4,326.82	5.35	14.67	18.20	4,333.05	-1.09	0.53	3.09
Pre-winter	4,292.67	0.13	-0.14	0.03	4,311.99	-2.90	13.40	15.52	4,328.85	-2.11	1.74	3.62
Overwintering	4,322.81	11.65	12.97	13.30	4,329.94	7.26	12.62	13.21	4,334.86	0.31	2.37	4.38
Pre-breeding	4,333.27	18.93	19.61	19.97	4,335.92	8.66	14.51	15.55	4,336.36	-0.20	0.99	4.83

Effects

- During a normal (median) year, the no-action alternative would maintain a higher volume of water than the proposed action, Alternative 3, and Alternative 4 during all key life history periods except during pre-winter under the fully implemented proposed action.
- During a dry year, the no-action alternative provides more water during all life history periods, except under Alternative 3 during pre-winter where volumes are essentially equivalent.
- During a wet year, the proposed action provides more volume than the no-action alternative during all seasons except overwintering where its volume is equivalent. Alternative 3 provides lower water volumes than the no-action alternative, and Alternative 4 provides even less during all seasons.
- During a normal (median) year, the no-action alternative provides a higher water elevation during all seasons compared to the proposed action, Alternative 3, and Alternative 4 except during pre-winter of the proposed action.
- During a dry year, these differences are amplified such that the no-action alternative provides a higher water elevation in pre-breeding, breeding, rearing, and overwintering than the other alternatives but less during pre-winter under Alternative 3.
- During a wet year, the no-action alternative provides less water during all life history periods except overwintering compared to the proposed action. Alternative 3 and Alternative 4 provide lower water elevations than the no-action alternative across the entire year.
- Differences are amplified for Alternative 4 compared to Alternative 3 and the proposed action.
- From the hydrographs (Figure 4), there is much greater variability of volume and water elevation when Wickiup is operated under any of the alternatives compared to the no-action. This means that wetland vegetation would experience larger year-to-year fluctuations in water availability. Less stability for the wetland plants will result in lower habitat suitability for the Oregon spotted frogs.

Summary Conclusion

Table 9 summarizes the overall results of this comparison of each alternative to the no-action alternative. Under all alternatives, Wickiup Reservoir would be used as a flow regulator to support Oregon spotted frog habitat in the Upper Deschutes River downstream from the dam to varying degrees. This operational objective would be detrimental to Oregon spotted frogs using Wickiup Reservoir during breeding or other life history periods. Oregon spotted frog habitats associated with Wickiup Reservoir would experience adverse habitat conditions under the proposed action and Alternative 3 compared to the no-action alternative, and these conditions would be further exacerbated under Alternative 4.

Reaches Des-12a, Des-12, and Des-11

Reaches Des-12a, Des-12, and Des-11 are the uppermost reaches of the Deschutes River downstream from Wickiup Dam to Benham Falls. The flow in these reaches of the river is most closely associated with measurements collected at the WICO gauge, located just downstream from the Wickiup Reservoir. In the Deschutes Project BiOp (U.S. Fish and Wildlife Service 2017), these three reaches are called Reach 1, Reach 2, and Reach 3; they are the same but referred to by reach name in the Deschutes Basin HCP.

Based on observations made by FWS and presented in the Deschutes Project BiOp (U.S. Fish and Wildlife Service 2017, 2019), flows measured at the WICO gauge that generally improve conditions for Oregon spotted frog use of the available habitat within these three reaches include:

- At 900 cfs, water inundates emergent vegetation at the associated sites which improves suitability of sites for breeding and rearing.
    - During breeding, stability of flow is important as egg masses develop which are vulnerable to displacement during high flows, or desiccation if stranded by low flows.
    - During rearing, tadpoles and metamorphs are mobile, but need cover offered by vegetation, so flows that maintain vegetation inundation (e.g., at least 900 cfs) remain important, although individuals can tolerate higher water levels and more water level fluctuation.
    - Sunriver: at this breeding site, water flows into site through weirs once the WICO gauge flow reaches 1,580 cfs.

Additional flow thresholds and concepts based on the observations described in the Deschutes Project BiOp (U.S. Fish and Wildlife Service 2017, 2019) analyzed here include:

- During the pre-breeding period, as frogs move from overwintering sites to breeding locations 500 and 300 cfs were used to assess the rise in water as the shift in flows occurs from overwintering to the breeding season and to anticipate pre-breeding habitat conditions in early spring.
- Below 700 cfs, water flows towards the river channel and away from the wetlands. This threshold indicates the flow that would improve emergent vegetation conditions if it colonizes downslope in response to changes in inundation patterns.
- During the pre-winter as juveniles and adults move to overwintering locations with flowing water and refugia (e.g., mud banks, vegetation mats), flows in the river decrease as the irrigation season ends and storage begins. Inundation of emergent vegetation at or above 900 cfs remains important, but the magnitude of the decrease in flow and corresponding drop of water level in the river is also important during this period.
- Although frogs do move periodically during overwintering, flow stability protects individuals from exposure and freezing. Flows of at least 300 cfs increase the quality of overwintering habitat within the river channel. Higher flows (e.g., 500 cfs) inundate portions of some sites (e.g., Dead Slough), and provide a shorter distance from overwintering sites along the river's edge and the breeding locations within wetlands.

RiverWare Results

Hydrographs

Figure 5 depicts daily Deschutes River flow hydrographs generated for the WICO gauge location using RiverWare for the no-action alternative, the proposed action, Alternative 3, and Alternative 4. The hydrographs in Figure 5 represent a visual comparison of the river flows expected under the different alternatives at all phases of implementation.

For each alternative, the graphs present the median modeled flow (50%; solid line) and a band capturing the 20% through 80% modeled flows, meaning the flows expected to occur 20% to 80% of the time.

Day-Count Data

To further relate the modeled river flow data for each alternative to the key life history periods for Oregon spotted frogs, the boxplots below (Figure 6 through Figure 14) depict the number of days during each key life history period where the flow at the WICO gauge would be expected to exceed the flow thresholds described earlier in this appendix. In each boxplot, “x” indicates the mean number of days exceeding the threshold counted for that alternative. The box encloses the upper (top of box) and lower (bottom of box) quartiles and the median is indicated by a horizontal line within the box. Whiskers represent the lowest data point within 1.5 interquartile range (IQR) of the lower quartile, and the highest data point within 1.5 IQR of the upper range. Outliers are depicted as dots.

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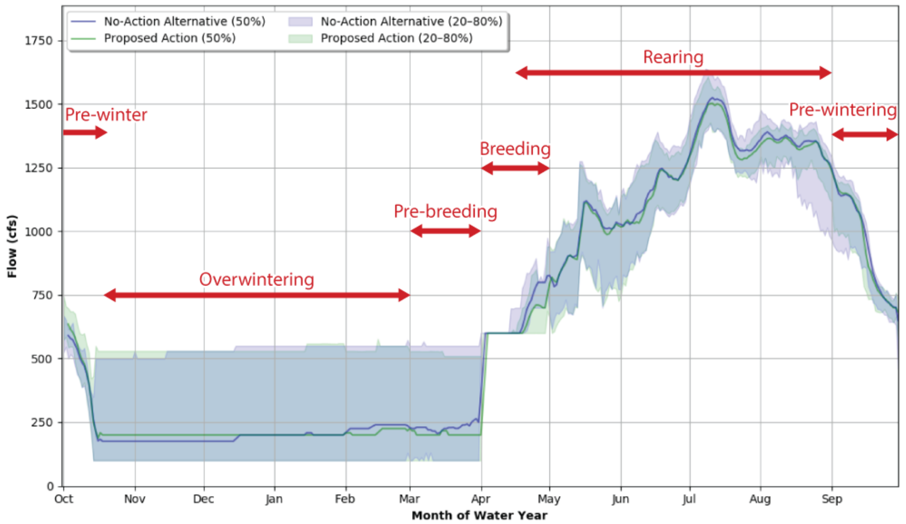
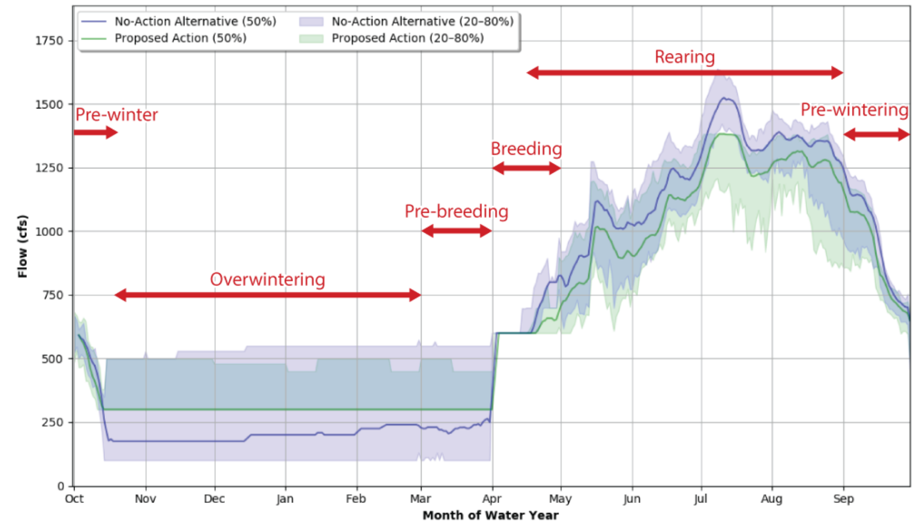
Figure 5. Deschutes River Flow Modeled Using RiverWare at WICO Gauge under Proposed Action, Alternative 3, and Alternative 4 Compared to No-Action Alternative

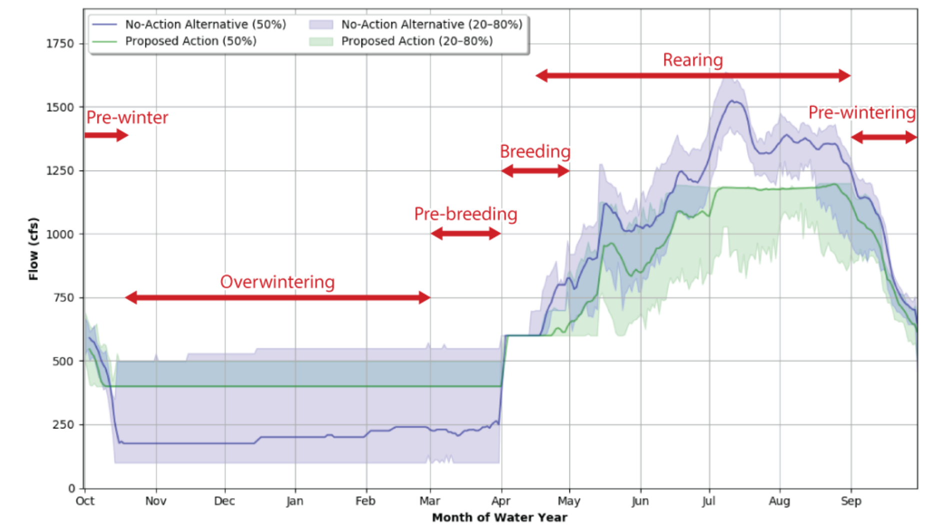
Proposed Action, Years 1–7



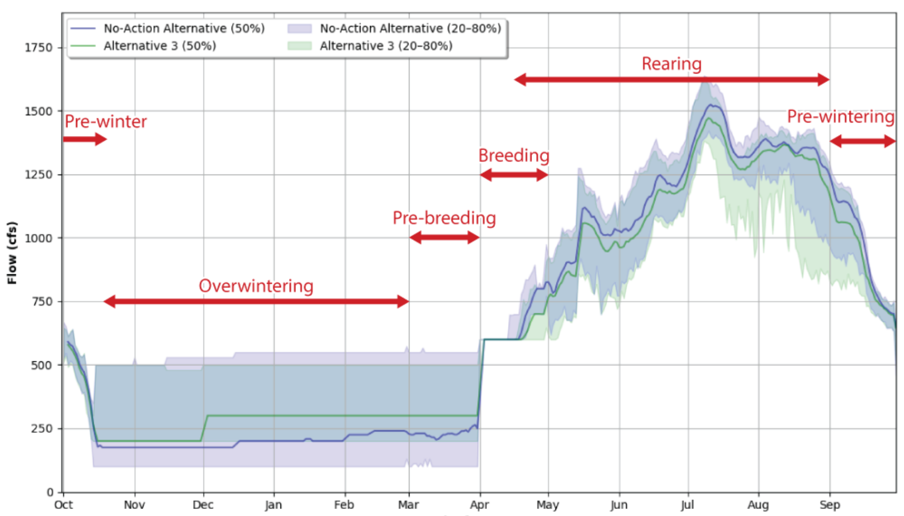
Proposed Action, Years 8–12



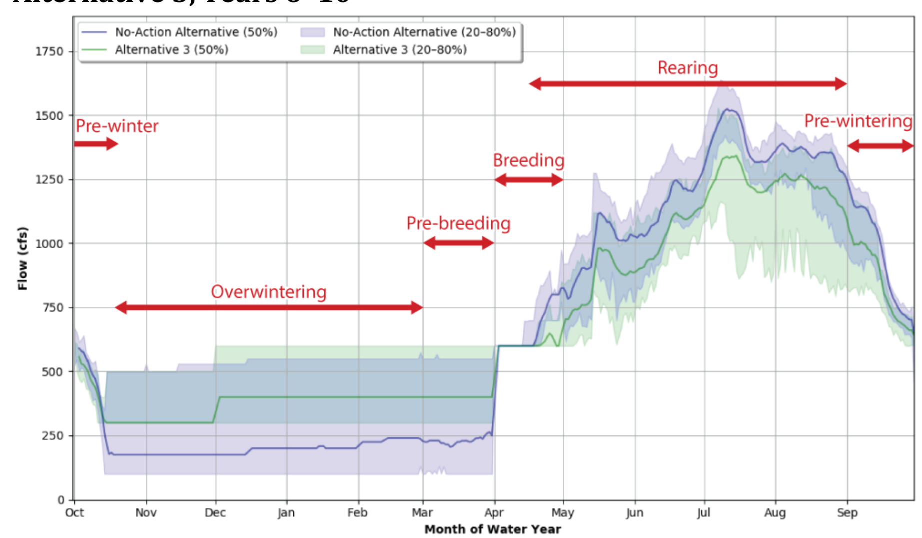
Proposed Action, Years 13–30



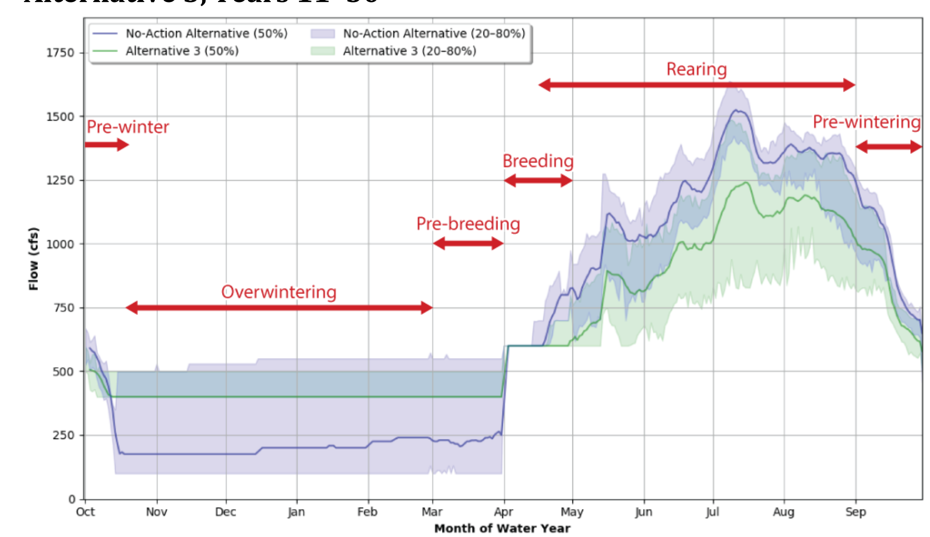
Alternative 3, Years 1–5



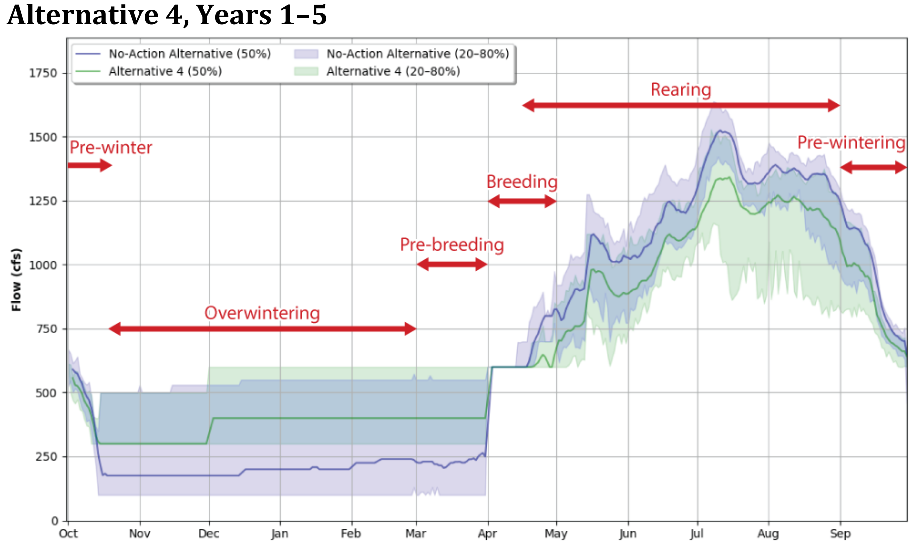
Alternative 3, Years 6–10



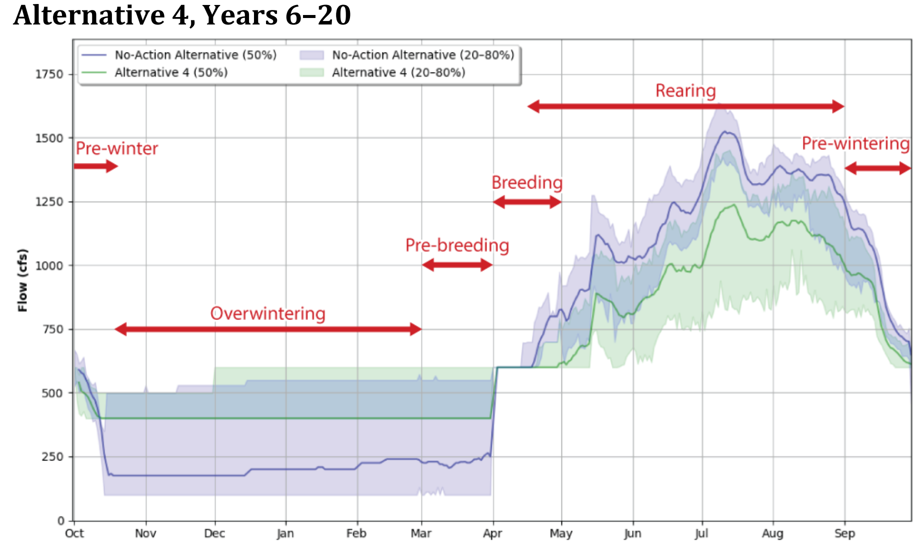
Alternative 3, Years 11–30



Alternative 4, Years 1–5



Alternative 4, Years 6–20



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Pre-breeding (March 1–March 31; 31 days)

The reach-level flow thresholds for the WICO gauge are 300 cfs and 500 cfs.

Figure 6. Boxplot of WICO Day Count for 300 cfs during Pre-breeding

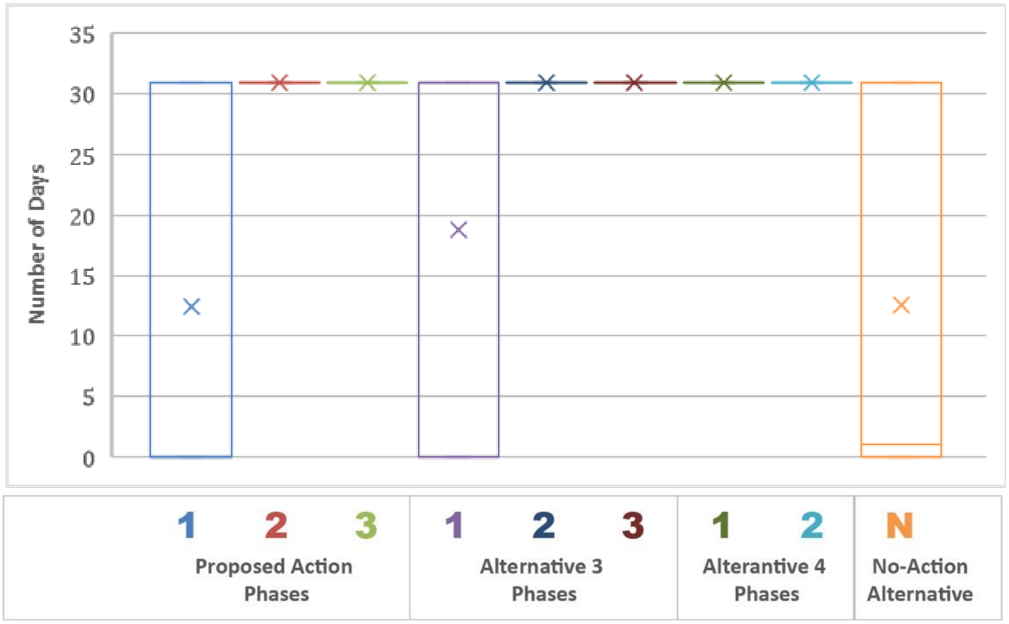
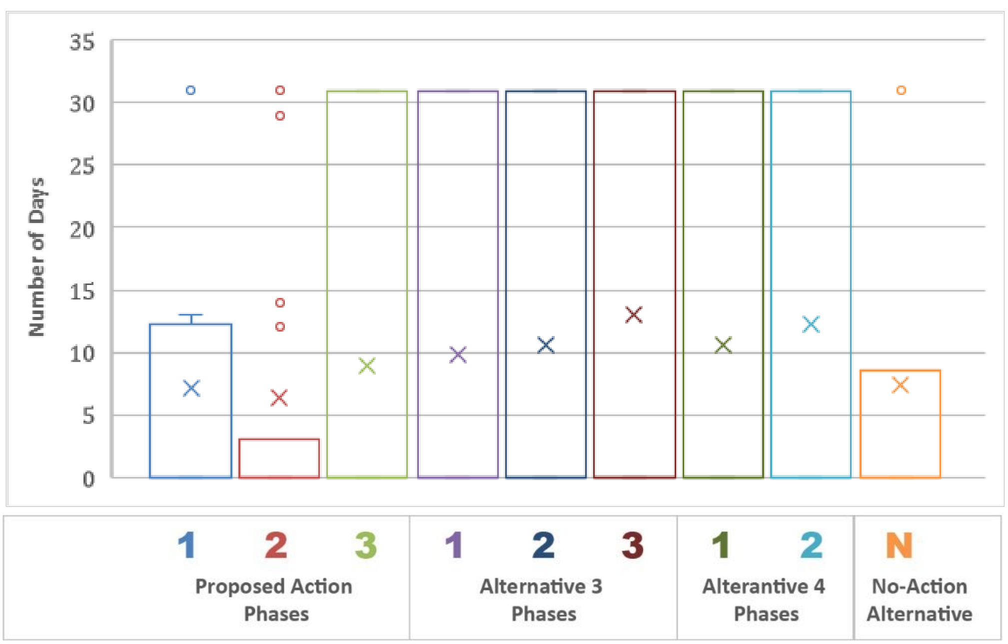


Figure 7. Boxplot of WICO Day Count for 500 cfs during Pre-breeding



Breeding (April 1–April 30; 30 days)

The reach-level flow thresholds for the WICO gauge are 900 cfs and 700 cfs.

Figure 8. Boxplot of WICO Day Count for 900 cfs during Breeding

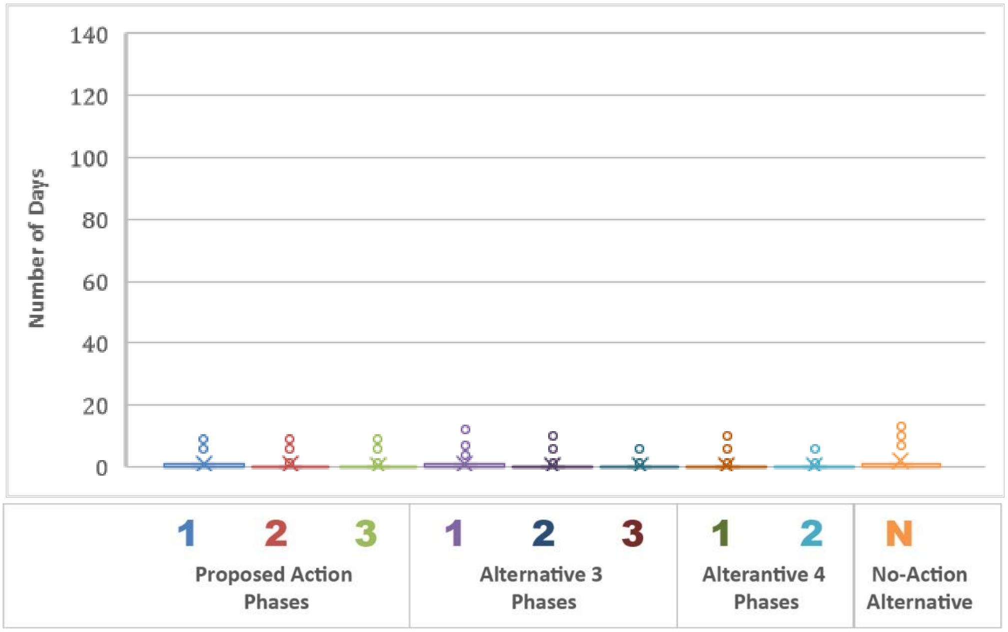
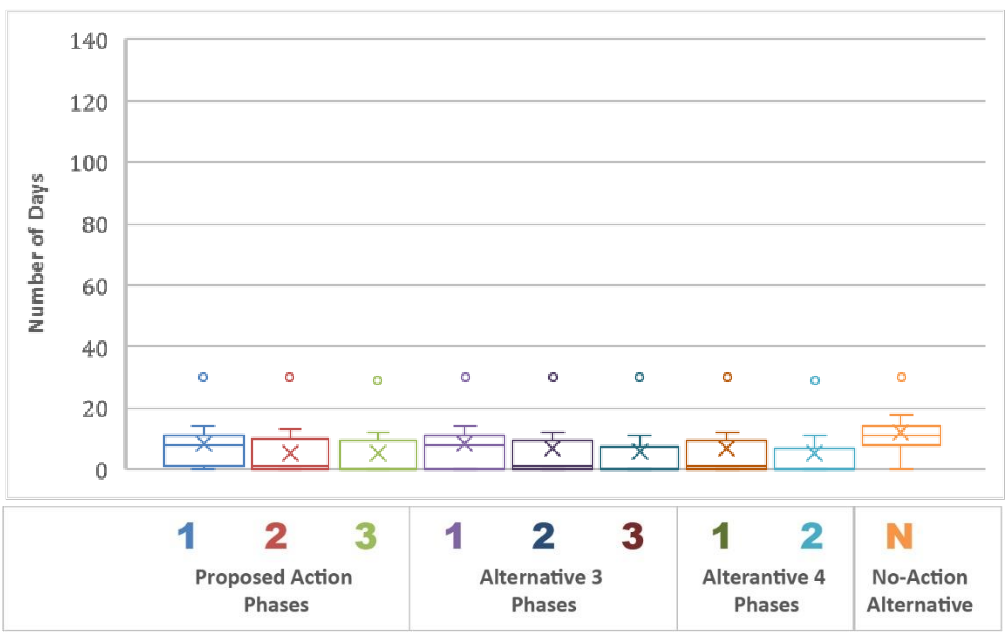


Figure 9. Boxplot of WICO Day Count for 700 cfs during Breeding



Rearing (April 15—August 31; 139 days)

The reach-level flow thresholds for the WICO gauge are 900 cfs and 700 cfs.

Figure 10. Boxplot of WICO Day Count for 900 cfs during Rearing

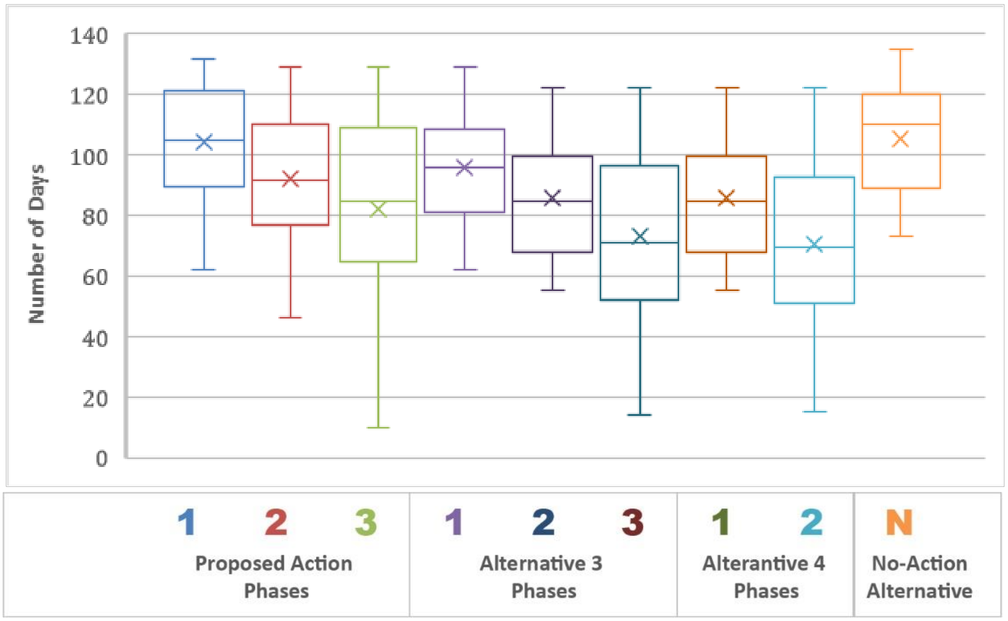
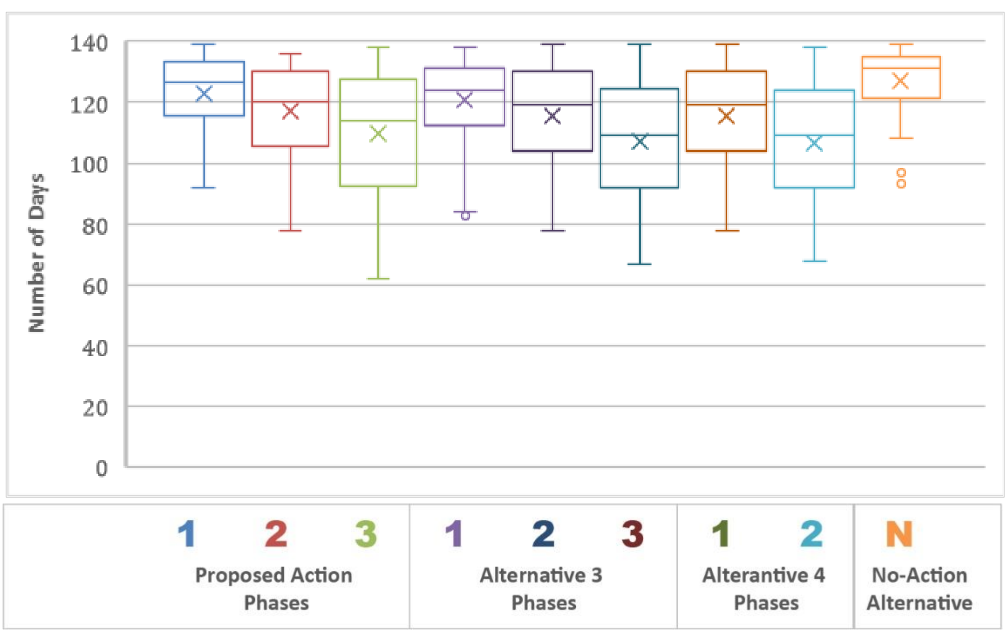


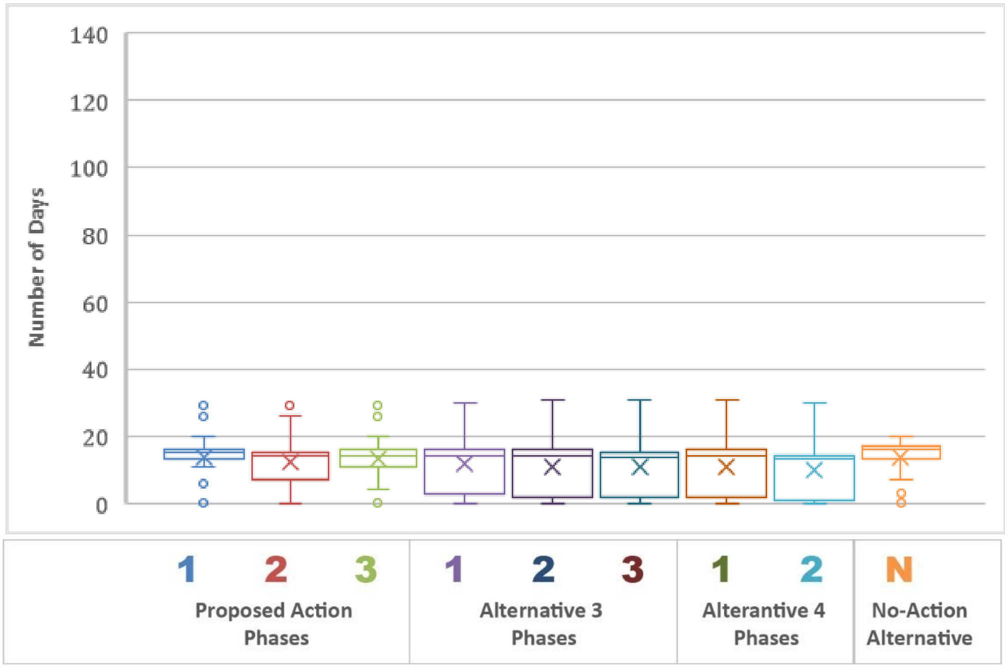
Figure 11. Boxplot of WICO Day Count for 700 cfs during Rearing



Pre-winter (September 1–October 15; 45 days)

The reach-level flow threshold for the WICO gauge is 900 cfs.

Figure 12. Boxplot of WICO Day Count for 900 cfs during Pre-winter



Overwintering (October 16–March 1; ~137 days)

The reach-level flow thresholds for the WICO gauge are 300 cfs and 500 cfs.

Figure 13. Boxplot of WICO Day Count for 300 cfs during Overwintering

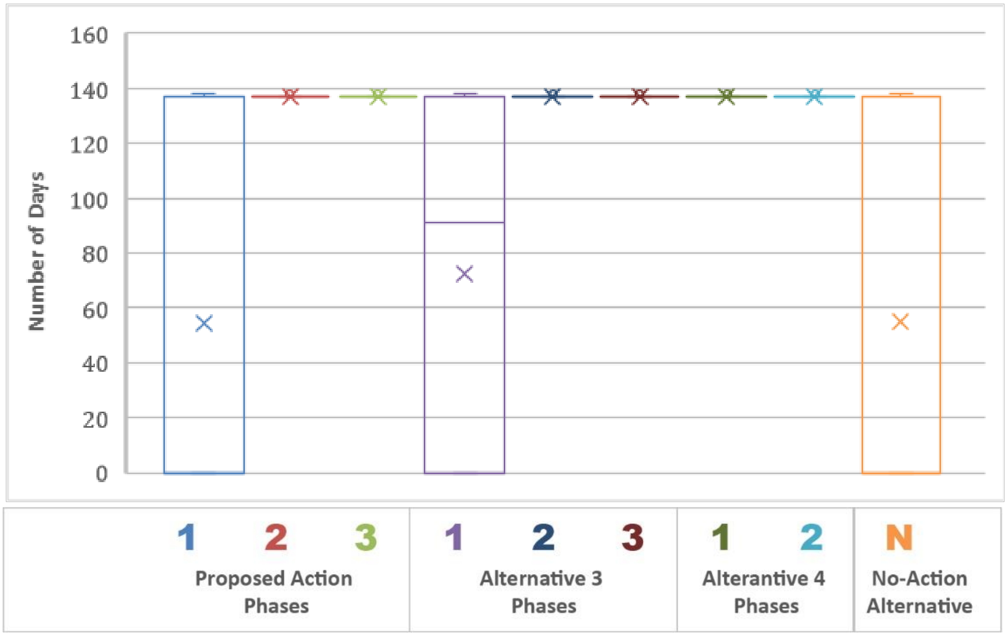
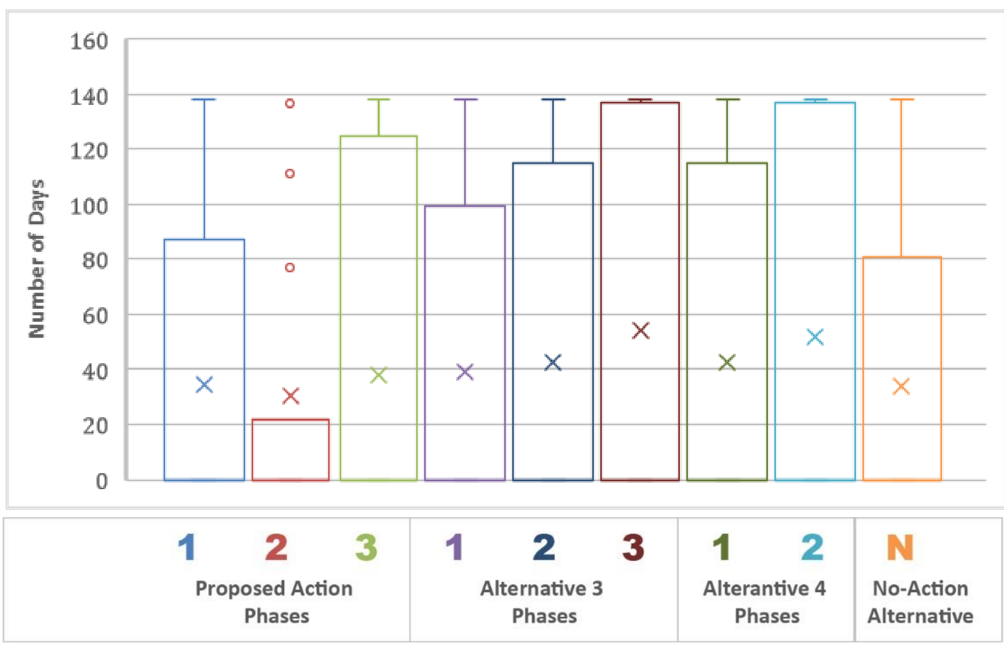


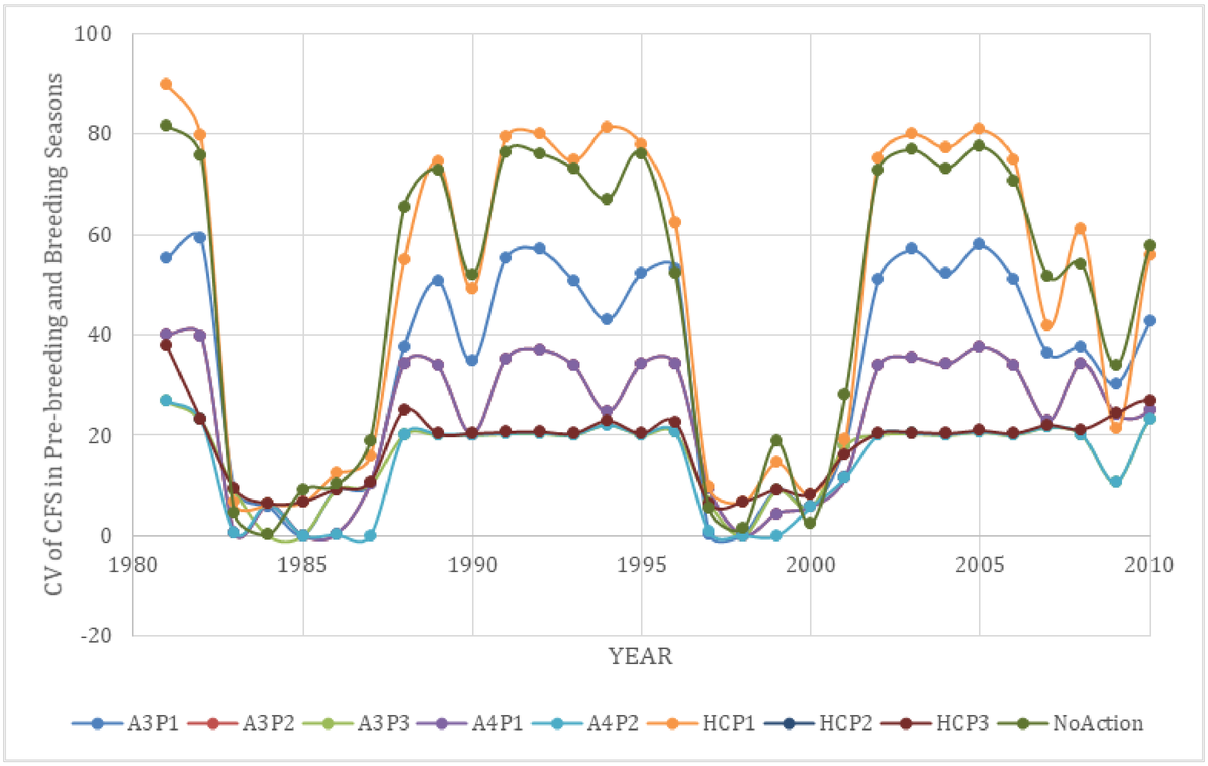
Figure 14. Boxplot of WICO Day Count for 500 cfs during Overwintering



Within-Year Flow Variation

To better understand within-year variation in flow for each alternative, Figure 15 reports the coefficient of variation (CV) during the breeding season. The CV is the standard deviation divided by the average flow and allows us to compare within-year variability among the alternatives. Within-year flow variation is particularly important during the breeding season because the immobile egg masses are the most vulnerable life stage to either desiccation from receding water or displacement and subsequent exposure to deeper water predators.

Figure 15. CV of Within-Year Deschutes River Flow Modeled Using RiverWare at WICO Gauge for Each Alternative during Breeding Season



Effects

Emergent Vegetation

Emergent vegetation would be expected to respond to changes in flow regime by tracking the seasonal inundation patterns and colonizing areas that were historically unavailable because they were too deeply inundated for vegetation to become established during the growing season due to the high summer flows along the Upper Deschutes.

All alternatives differ from the historical flow regime in the Upper Deschutes by prescribing greater minimum flows during the winter and resulting in lower maximum flows during the summer than were observed on average prior to operations prescribed under the Deschutes Project BiOp (U.S. Fish and Wildlife Service 2017, 2019). Historical flow data for WICO (OWRD 2019) collected from

1972 through 2002 (pre-implementation of the no-action alternative) indicate a median flow of 1,455 cfs on June 20, the beginning of the growing season.

Conservation Measure UD-1 provided under the proposed action, Alternative 3, and Alternative 4 could be used to fund efforts to enhance riparian and wetland vegetation.

The RiverWare model outputs indicate:

- Among the alternatives, inundation patterns during the growing season would be based on the highest flows under the no-action alternative, lower flows under the proposed action and Alternative 3, and lowest under Alternative 4 (Figure 5 [hydrographs]). This means that emergent vegetation would be inundated up to the highest topographical or elevation level under the no-action alternative, lower elevations under the proposed action and Alternative 3, and lowest elevation under Alternative 4.

Invasive Species

Reed canarygrass is already well established in the study area. Although its site-specific distribution would be expected to change by tracking water inundation elevation patterns during the growing season, it would be expected to persist throughout the study area under all alternatives. Conservation Measure UD-1 under the proposed action, Alternative 3, and Alternative 4 could be used to fund control measures, particularly where reed canarygrass degrades or has the potential to degrade Oregon spotted frog habitat.

The more stable hydrograph under the proposed action, Alternative 3, and Alternative 4, compared to the no-action alternative, would be more likely to improve conditions for bullfrogs by providing year-round inundation of wetlands.[2] The more stable hydrograph would also be more likely to improve conditions for nonnative fish species such as brown bullhead catfish, brown trout and three-spined sticklebacks known to prey on Oregon spotted frogs. Conservation Measure UD-1 under the proposed action, Alternative 3, and Alternative 4 could be used to fund control measures for bullfrogs which are already widely used successfully in the Deschutes Basin, and they could be used to address nonnative fish species.

Oregon Spotted Frog

In off-channel wetlands, emergent vegetation would track the flow inundation patterns to colonize areas that would become available during the growing season at the lower elevations. The total area covered by emergent vegetation would not necessarily change, but the topographical elevation where wetland vegetation is supported by water would be lower as flows are reduced during the growing season. This effect would be strongest under full implementation of the proposed action when the summertime flow cap is in place, somewhat reduced under Alternative 3 and Alternative 4, and least under the no-action alternative. Along the river channel, vegetation would be expected to colonize areas lower in the channel profile, with the same rank differences between alternatives. Individual Oregon spotted frog sites would respond differently depending on individual site topography, substrate characteristics, and dependence on the river as a water source.

[2] Bullfrogs require permanent wetland habitat to reproduce as tadpoles typically overwinter and metamorphose during their second year.

Pre-breeding (March 1–March 31; 31 days)

- Near the end of the pre-breeding time period, frogs would begin to experience the ramp-up in flows from winter minimums through the beginning of the breeding season. Early deposition of egg masses can happen during this period. Changes in flow can result in egg mass displacement and an associated higher risk of predation, as well as movement of tadpoles to less suitable habitat.
- The modeled hydrographs for flow at the WICO (Figure 5) indicate that the pattern under phase 1 of the proposed action is similar to the no-action alternative, but later implementation phases result in a smaller overall increase in flow during this ramp-up due to the larger baseline overwinter flows. As modeled, Alternative 3 and Alternative 4 more quickly reduce the size of the increase in flow. Through operations management based on monitoring the yearly flow conditions, this effect can also be damped for the proposed action by the release of additional storage volume from Wickiup Reservoir during the spring under Conservation Measure WR-1 (A). Spring flows can be stepped up more gradually. Under the proposed action, Alternative 3, and Alternative 4, the decreased overall flow variation would reduce the likelihood of mortality of developing egg masses through displacement during changes in flow compared to the no-action alternative.

Breeding (April 1–April 30; 30 days)

- Based on day counts derived from the RiverWare model, inundation levels during the breeding season would rarely reach the vegetation inundation threshold observed by the FWS (>900 cfs) under any of the alternatives (Figure 8).
- Days with flows exceeding the 700 cfs threshold result in water flowing towards off-channel sites rather than towards the river. Such days are rare under Alternative 4 and Alternative 3, even more so under the proposed action. The no-action alternative experiences slightly more days where flows exceed the threshold (Figure 9).
- Within-year variation is much larger under the no-action alternative and phase 1 (years 1–7; see Table 2) of the proposed action compared to all other alternatives (Figure 15). This means eggs would be more exposed to variable flows, and the potential for egg mass mortality under the no-action alternative and the early phase of the proposed action, but it would improve under later phases of the proposed action, as well as under Alternative 3 and Alternative 4.
- The proposed action, Alternative 3, and Alternative 4 include Conservation Measure UD-1, which is lacking from the no-action alternative. This measure could be used to enhance breeding habitat.

Rearing (April 15–August 31; 139 days)

During rearing, the no-action alternative would experience approximately 110 days above 900 cfs flow at the WICO gauge, compared with approximately 85 days under the fully implemented proposed action, and approximately 70 under both Alternative 3 and Alternative 4 (Figure 10). Flows above this level inundate wetland vegetation providing cover for developing tadpoles and frogs. This pattern remains the same among the alternatives for 700 cfs (Figure 11).

- The modeled hydrographs (Figure 5) corroborate the day count data. They indicate a higher level of flow and subsequent vegetation inundation is maintained throughout most of the rearing season under the no-action alternative, although all alternatives converge during August.

- During phases 2 and 3 (years 8–30; Table 2) the proposed action includes summer maximum flow caps. During phase 3 of the proposed action the summer cap is 1,200 cfs based on Conservation Measure WR-1 (H). Although the flows would be lower, the summer caps provide a more stable flow environment during the vegetation growing season. Therefore, the effect of fewer days of flow reaching the current threshold for vegetation inundation (900 cfs) could lessen over time as vegetation responds to consistently lower flows. This conclusion would only hold true for sites where the topographic profile would allow inundation of emergent vegetation at less than the 900 cfs threshold, where there is area available to be colonized by emergent vegetation during the growing season at lower flows. For example, lower flows are likely to result in recruitment of emergent vegetation within slough habitats. Therefore, the current threshold of 900 cfs for vegetation inundation is likely to be reduced to a lower volume (e.g., 700 cfs).

Pre-winter (September 1–October 15; 45 days)

- The no-action alternative provides slightly more days of wetland vegetation inundation above 900 cfs compared to phases 2 and 3 of the proposed action and all phases of Alternative 3 and Alternative 4 (Figure 12).[3]
- The hydrographs (Figure 5) demonstrate an important difference among the alternatives during this period. The pre-winter season is concurrent with the operational shift from irrigation (high flows) to storage (lower flows) so flows decrease precipitously until they reach the winter minimum. Under the no-action alternative, frogs would experience a greater amount of change in flow during the pre-winter season than they would under other alternatives; approximately 1,250 cfs to approximately 200 cfs. Under the proposed action, reaches would progressively experience a smaller amount of change as flows decrease at the end of the irrigation season with phase 1 similar to the no-action alternative, but with phases 2 and 3 experiencing smaller changes to reach the winter minimum flow, which steadily increases following Conservation Measures WR-1 (F, G, and H). The amount of change would reach a smaller level faster under Alternative 3 and fastest under Alternative 4. Oregon spotted frogs are known to generally move short distances during the pre-winter season (Pearl et al. 2018) so the less drastic change in water inundation elevation may prevent abrupt stranding of frogs as they migrate to overwintering sites. Alternative 4 would have the most positive impact on Oregon spotted frogs during this period.

Overwintering (October 16–March 1; 137 days)

- Sustained higher winter flows under the proposed action, Alternative 3, and Alternative 4 improve conditions for overwintering Oregon spotted frogs by inundating larger areas of habitat within the river channel and sloughs and maintaining a shorter travel distance between overwintering locations in the river and breeding sites in the adjacent wetlands.
- The fully implemented proposed action, Alternative 3, and Alternative 4 equally outperform the no-action alternative by maintaining more than 300 cfs in the river and associated

[3] See Appendix 3.1-C, *Analysis of RiverWare Model Version 18 Outputs and Implications for Final EIS*, for corrections due to modeling update.

overwintering sites for the duration of the season. The delayed timeframe of the proposed action compared to Alternative 3 means that Alternative 3 would more quickly have a positive effect on Oregon spotted frogs (Figure 13). Under Alternative 4, more sites would experience at least 500 cfs more quickly than under any of the other alternatives which could result in more consistently wetted overwintering sites and shorter distances for frogs to travel between breeding and overwintering locations (Figure 14).

- From the hydrographs (Figure 5), Alternative 4 would maintain more water in the system and do so more quickly over winter than any of the other alternatives, but its overwinter flow would vary more from year to year than either the proposed action or Alternative 3. This type of variation should not have as much effect on individual frogs, but it could affect the overall suitability and availability of overwintering sites.

Summary Conclusion

Table 9 summarizes the overall results of this comparison of the proposed action and Alternatives 3 and 4 to the no-action alternative. Alternative 4 outperforms the other alternatives for all reaches associated with the WICO gauge during all life history periods except rearing. The proposed action provides a more stable rearing period during its later phases of implementation due to a cap limiting maximum summer flows and creating a more stable flow regime than the other alternatives. More consistent flows during the growing season would also support the development of emergent wetland vegetation in areas that were previously inaccessible due to deep water, which would also be expected to improve habitat connectivity in the study area.

Reaches Des-10a and Des-10

Reaches Des-10a and Des-10 are located along the Deschutes River downstream from Benham Falls to Lava Island Falls. The flow in these reaches of the river is most closely associated with measurements collected at the BENO gauge, located at Benham Falls. In the Deschutes Project BiOp (U.S. Fish and Wildlife Service 2017, 2019), these two reaches are called Reach 4 and Reach 5; they are the same but referred to by reach name in the Deschutes Basin HCP.

Oregon spotted frogs occur within two wetland areas within Reach Des-10a: Southwest Slough Camp and the East Slough Camp complex. Both locations consistently support breeding Oregon spotted frogs, and because of this both sites are important to maintaining the species (U.S. Fish and Wildlife Service 2017, 2019). Currently, Oregon spotted frogs have not been observed within Reach Des-10 (U.S. Fish and Wildlife Service 2017, 2019). Critical habitat for Oregon spotted frog is designated within both reaches of the Deschutes River.

Reach-Level Analysis

Habitat flow thresholds and other important criteria for Oregon spotted frog sites associated with flows at the BENO gauge include:

- When BENO measures 1,200 to 1,600 cfs, water inundates emergent vegetation at the associated sites. The site-specific inundating flow varies but the range of 1,200 to 1,600 cfs covers both sites within these reaches (U.S. Fish and Wildlife Service 2017, 2019). When emergent vegetation is inundated it provides suitable habitat for breeding and egg deposition and cover from predation throughout the rearing and pre-winter periods.

- During pre-breeding, frogs move from overwintering locations to breeding sites. The magnitude of the change in flow that happens as flows ramp up during the spring is important for wetland vegetation inundation. Smaller changes in flow protect early-laid egg masses from displacement.
- During breeding, stability of flow is important, as egg masses are vulnerable to displacement during high flows, or desiccation if stranded by low flows.
- During rearing, tadpoles and metamorphs are mobile, but need vegetation cover, and thus need flows that inundate vegetation (e.g., at least 1,200 to 1,600 cfs depending on site). Adults can tolerate more water level fluctuation.

- During the pre-winter as juveniles and adults move to overwintering locations with flowing water and refugia (e.g., mud banks, vegetation mats), flows in the river decrease as the irrigation season ends and storage begins. Inundation of emergent vegetation at or above 1200 to 1,600 cfs remains important, but the amount of flow reduction and corresponding drop of water level in the river is also important during this period because a larger drop in water level can result in a greater travel distance for frogs to reach overwintering sites.
- Although frogs do move periodically during overwintering, flow stability protects individuals from exposure and freezing. Stable flows of 1,200 to 1,300 cfs inundate portions of some sites, and provide a shorter distance from overwintering sites along the river's edge and the breeding locations within wetlands.

RiverWare Results

Hydrographs

Figure 16 depicts daily Deschutes River flow hydrographs generated for the BENO gauge location using RiverWare for the no-action alternative, the proposed action, Alternative 3, and Alternative 4. The hydrographs represent a visual comparison of the river flows expected under the different alternatives at all implementation phases.

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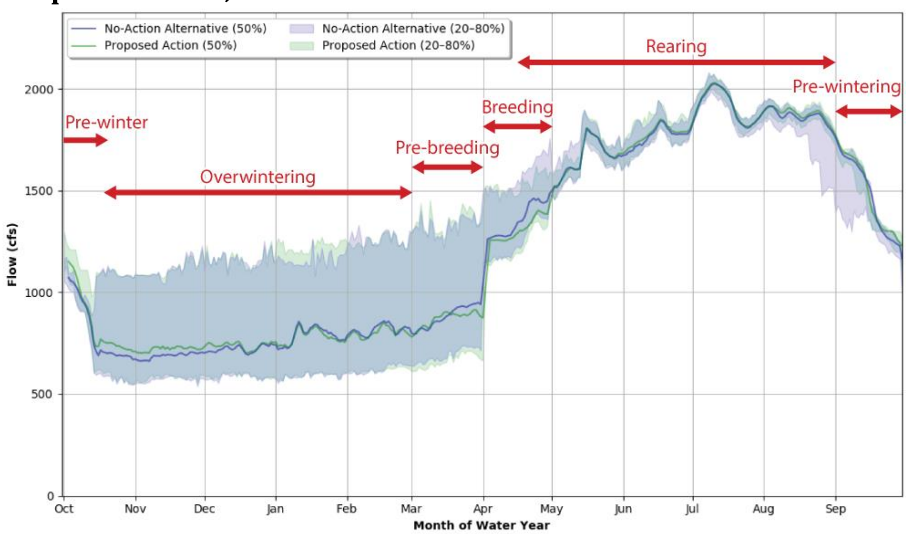
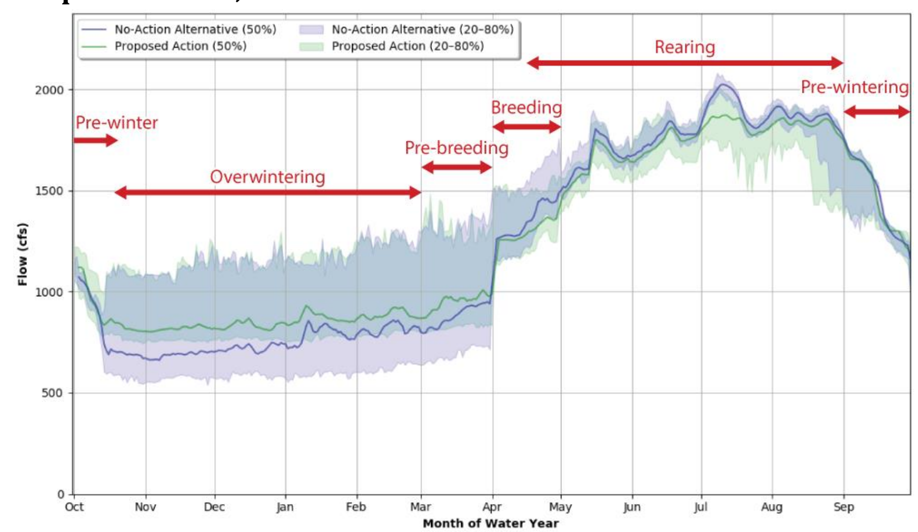
Figure 16. Deschutes River Flow Modeled Using RiverWare at BENO Gauge under Proposed Action, Alternative 3, and Alternative 4 Compared to No-Action Alternative

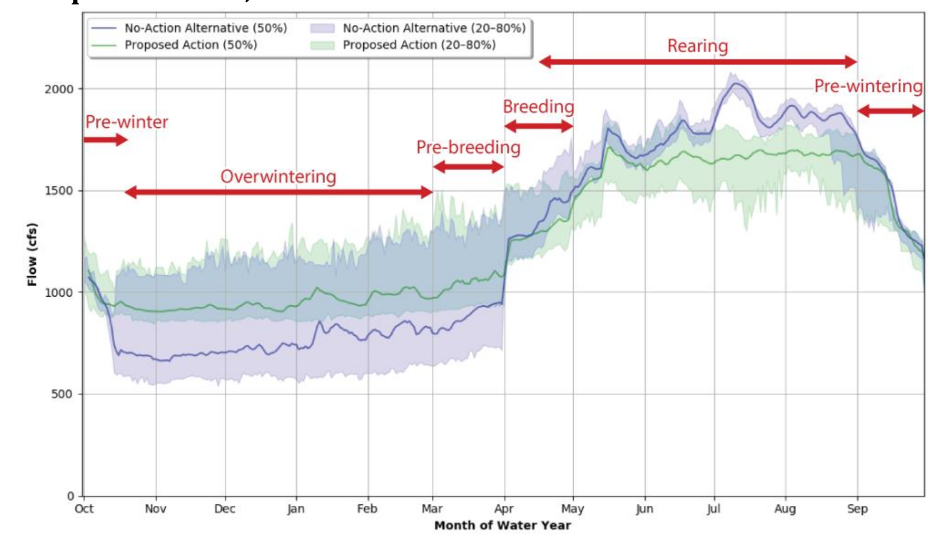
Proposed Action, Years 1–7



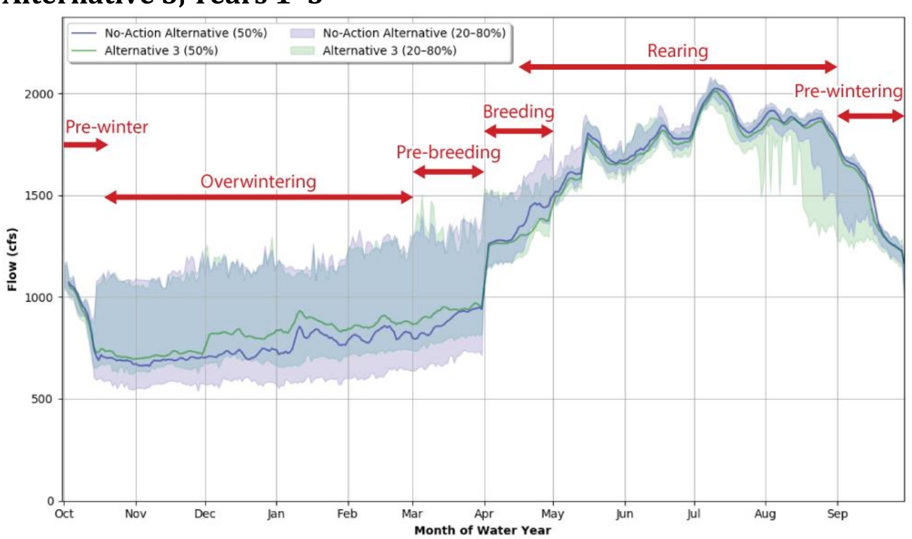
Proposed Action, Years 8–12



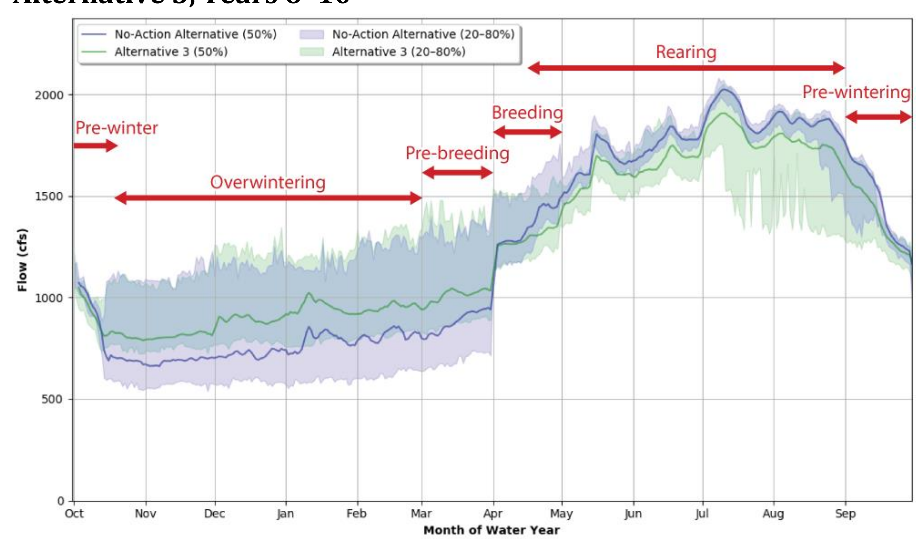
Proposed Action, Years 13–30



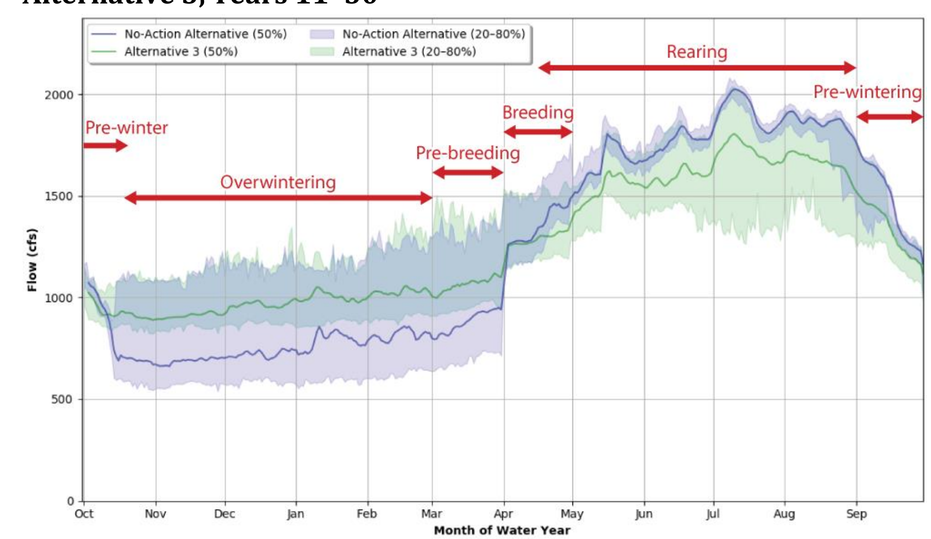
Alternative 3, Years 1–5



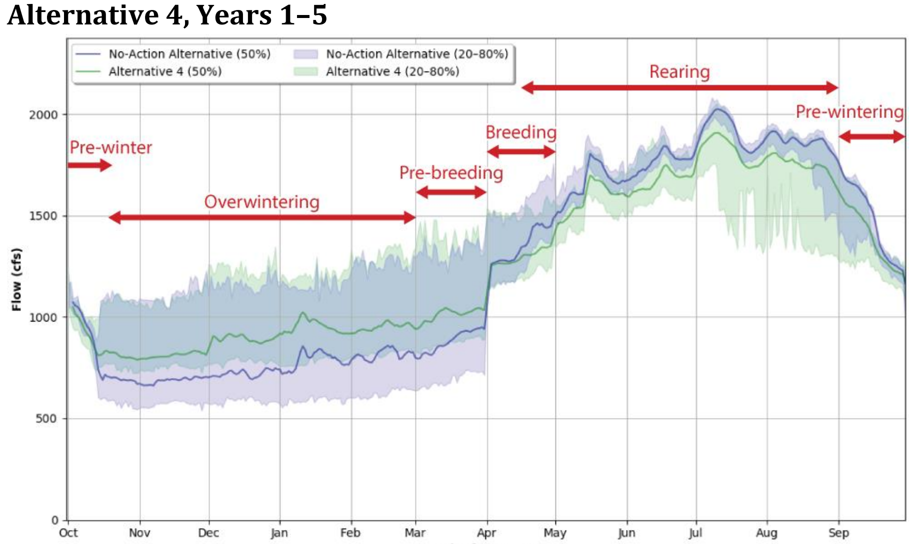
Alternative 3, Years 6–10



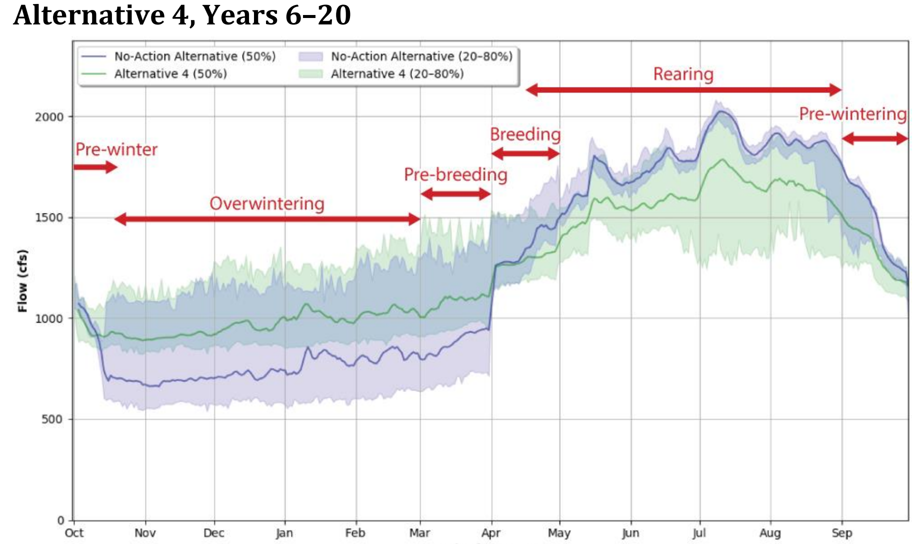
Alternative 3, Years 11–30



Alternative 4, Years 1–5



Alternative 4, Years 6–20



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For each alternative, the graphs present the median modeled flow (50%; solid line) and a band capturing the 20% through 80% modeled flows, meaning the flows expected to occur 20% to 80% of the time.

Day-Count Data

To further relate the modeled river flow data for each alternative to the key life history periods for Oregon spotted frogs, the boxplots below (Figure 17 through 28) depict the number of days during each key life history period where the flow at the BENO gauge would be expected to exceed the flow thresholds described at the beginning of the reach analysis. In each boxplot, "x" indicates the mean number of days exceeding the threshold counted for that alternative. The box encloses the upper (top of box) and lower (bottom of box) quartiles and the median is indicated by a horizontal line within the box. Whiskers represent the lowest data point within 1.5 interquartile range (IQR) of the lower quartile, and the highest data point within 1.5 IQR of the upper range. Outliers are depicted as dots.

Pre-breeding (March 1–March 31; 31 days)

Figure 17. Boxplot of BENO Day Count for 1,200 cfs

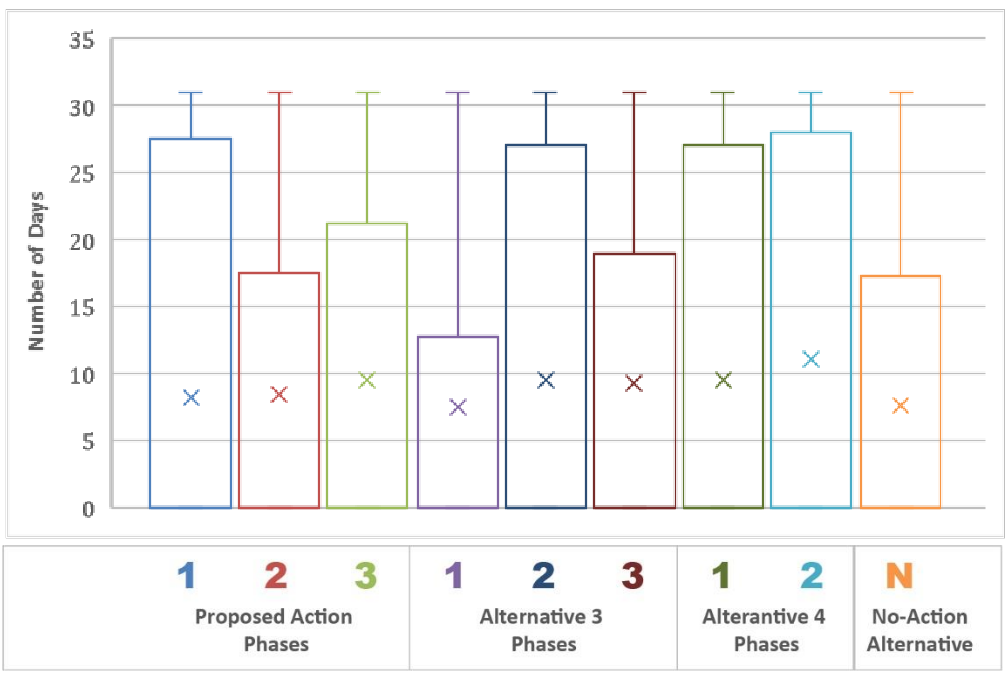
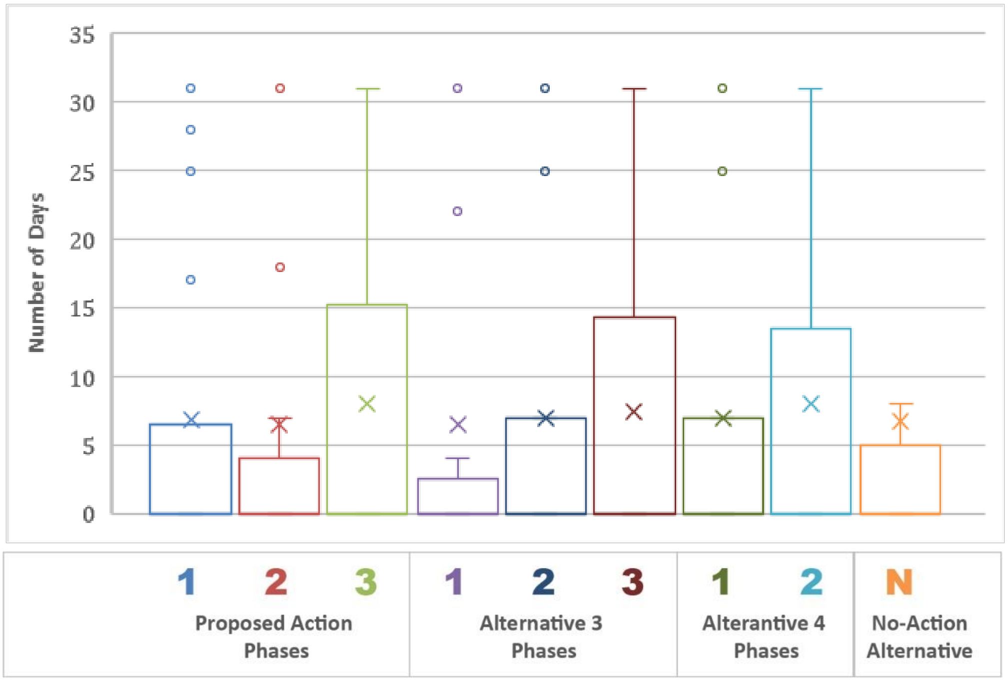


Figure 18. Boxplot of BENO Day Count for 1,300 cfs



Breeding (April 1—April 30; 30 days)

Figure 19. Boxplot of BENO Day Count for 1,200 cfs

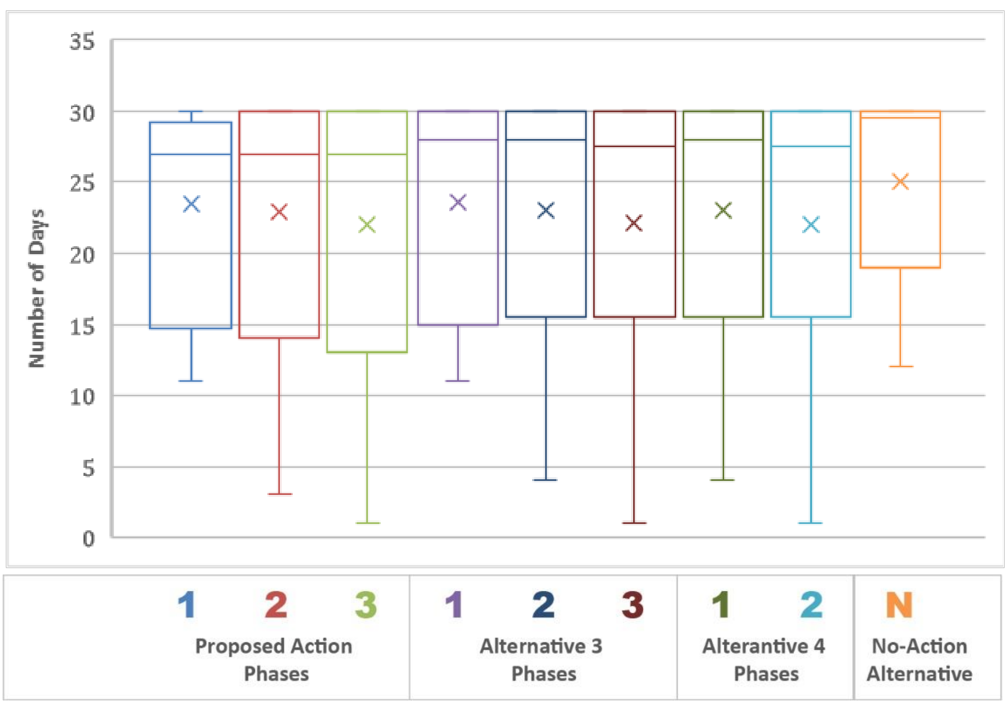


Figure 20. Boxplot of BENO Day Count for 1,300 cfs

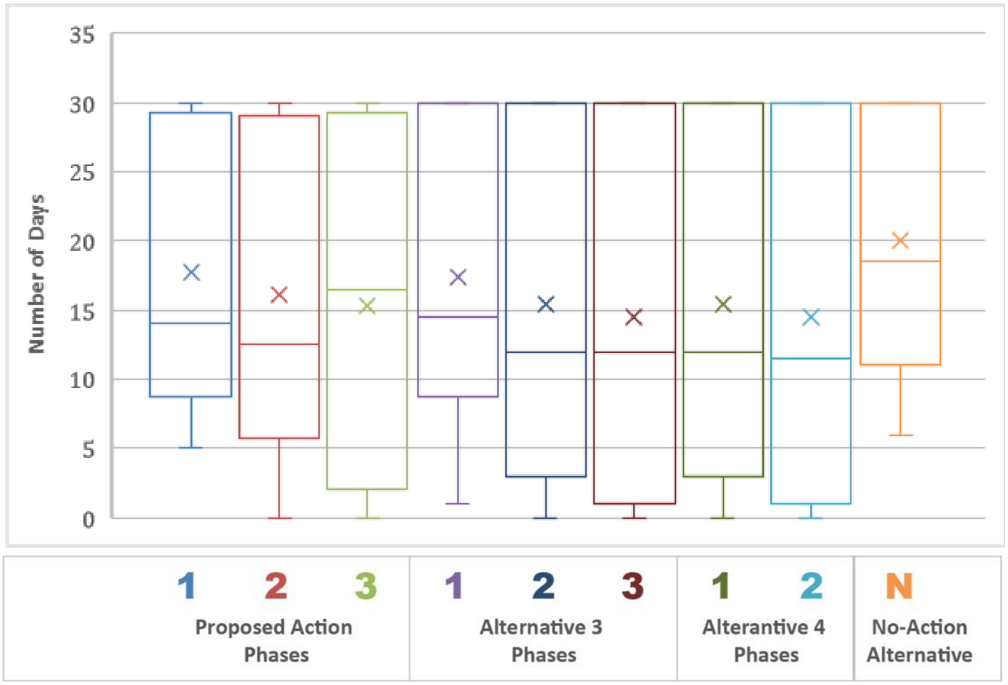
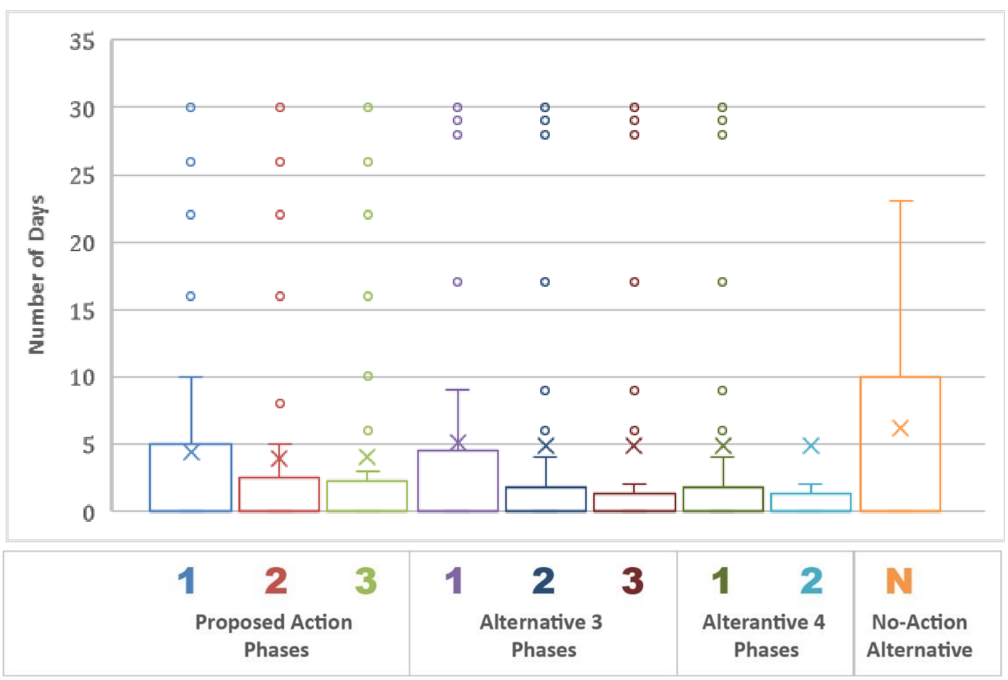


Figure 21. Boxplot of BENO Day Count for 1,600 cfs



Rearing (April 15—August 31; 139 days)

Figure 22. Boxplot of BENO Day Count for 1,200 cfs

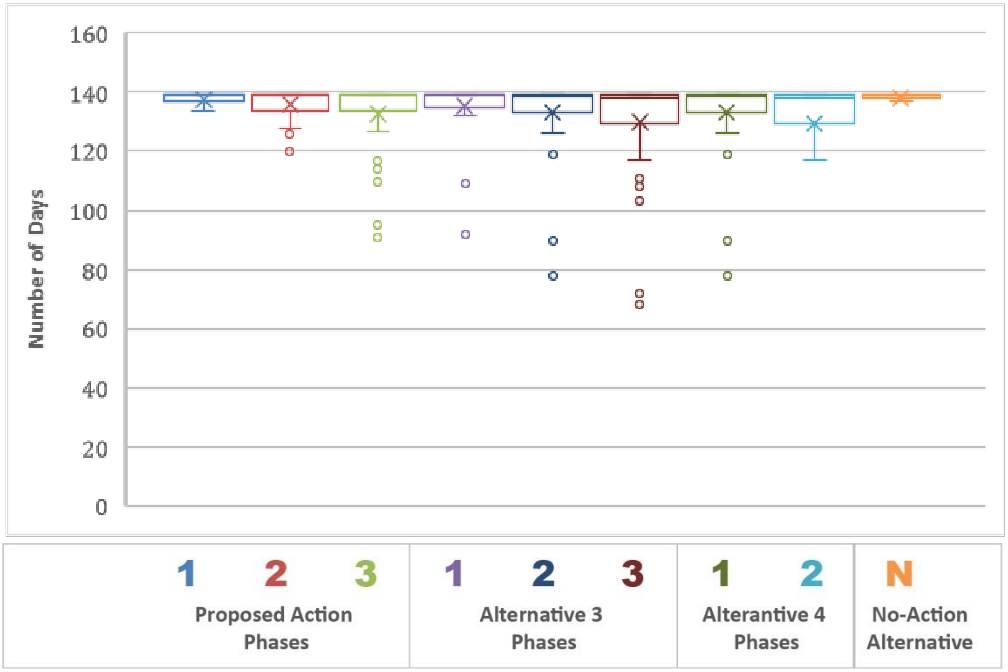


Figure 23. Boxplot of BENO Day Count for 1,300 cfs

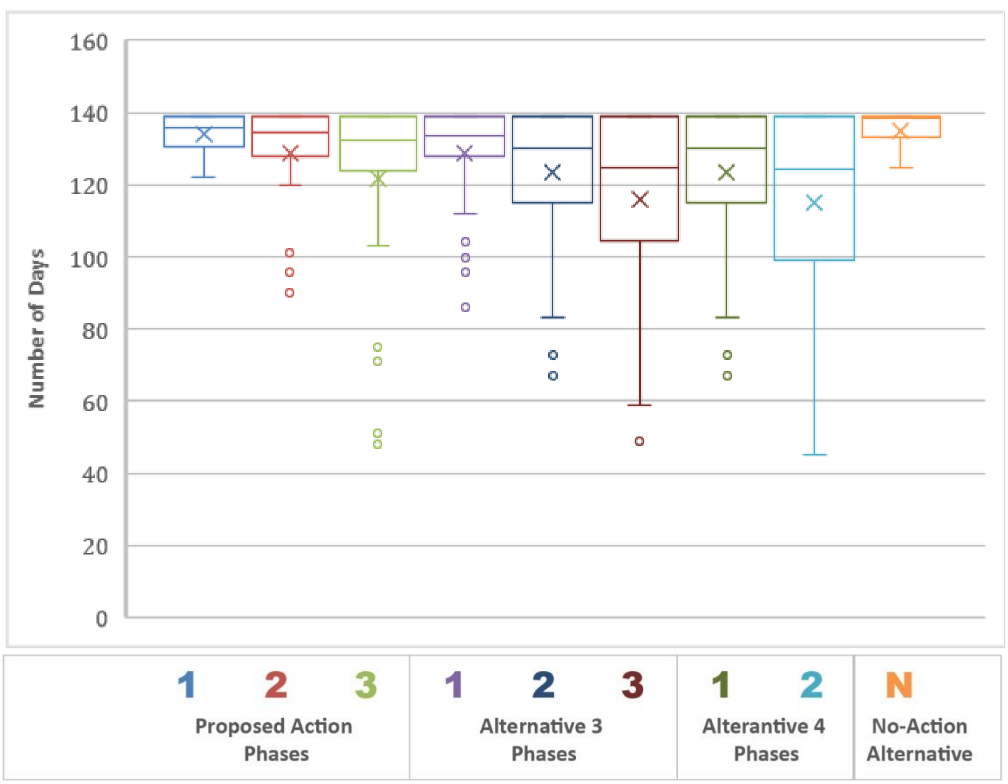
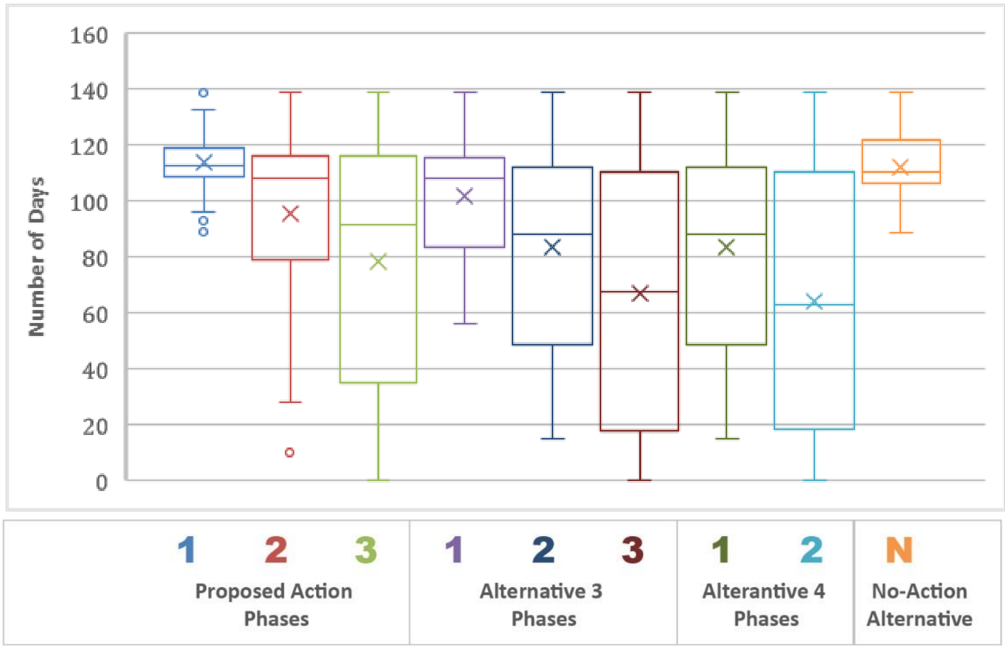


Figure 24. Boxplot of BENO Day Count for 1,600 cfs



Pre-winter (September 1—October 15; 45 days)

Figure 25. Boxplot of BENO Day Count for 1,200 cfs

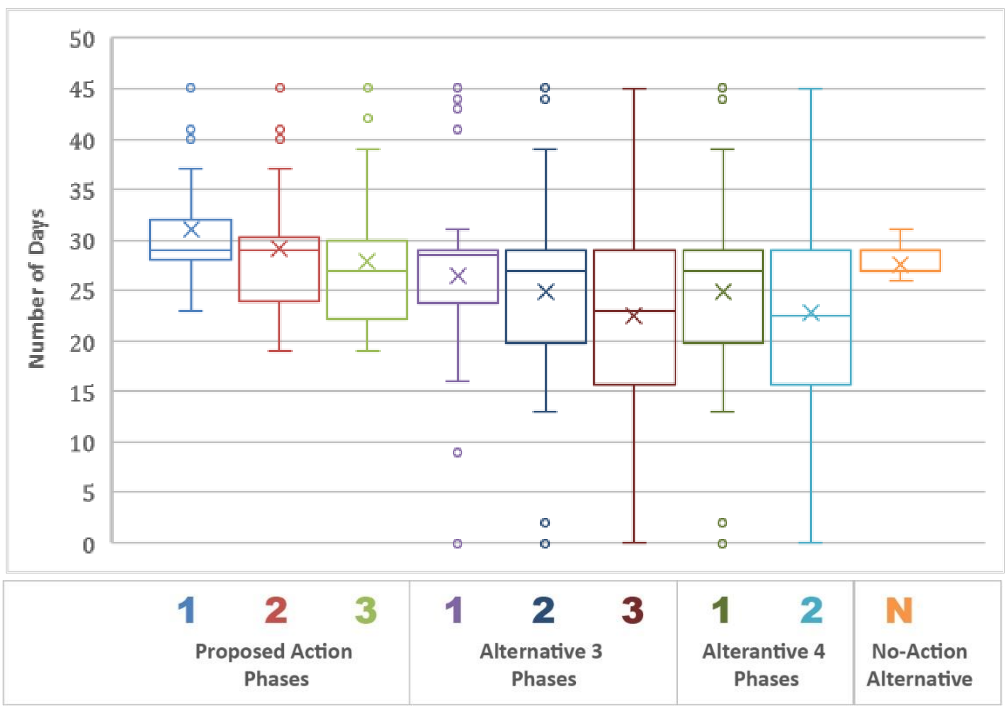
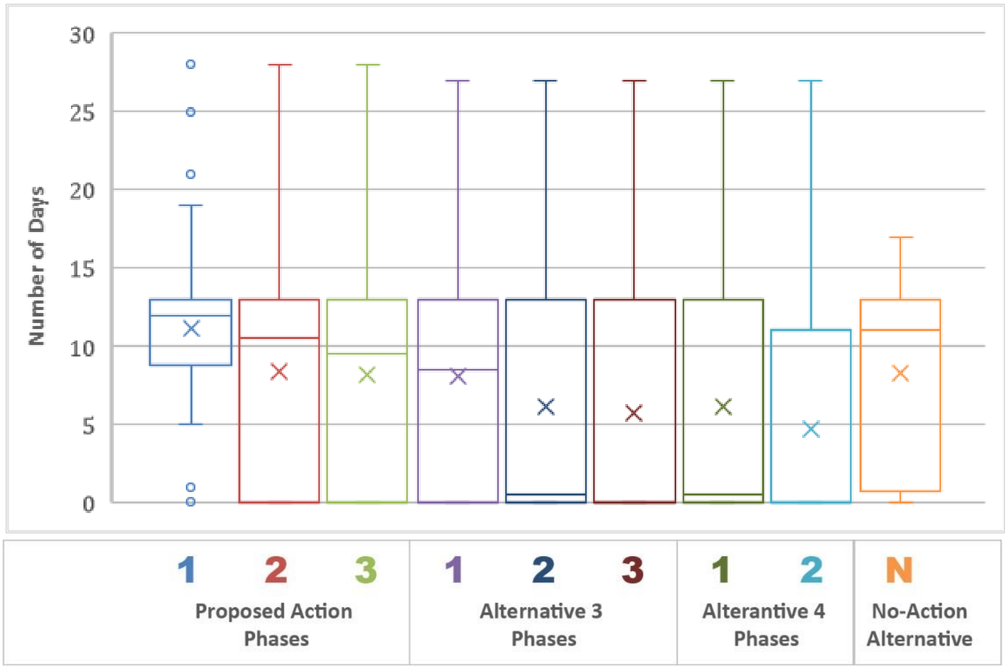


Figure 26. Boxplot of BENO Day Count for 1,600 cfs



Overwintering (October 16—March 1; 137 days)

Figure 27. Boxplot of BENO Day Count for 1,200 cfs

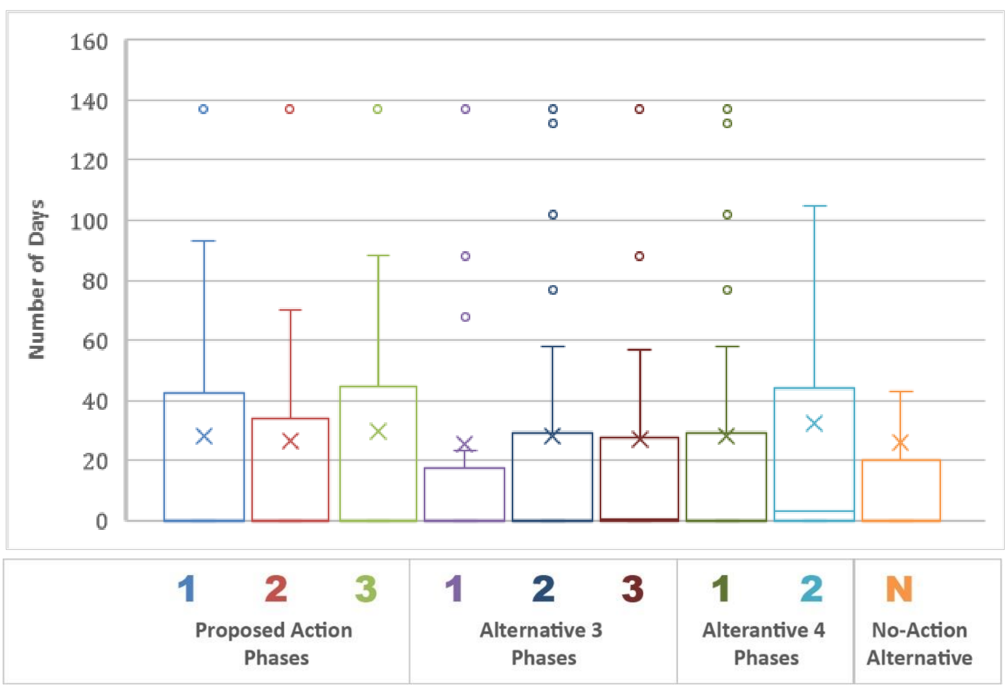
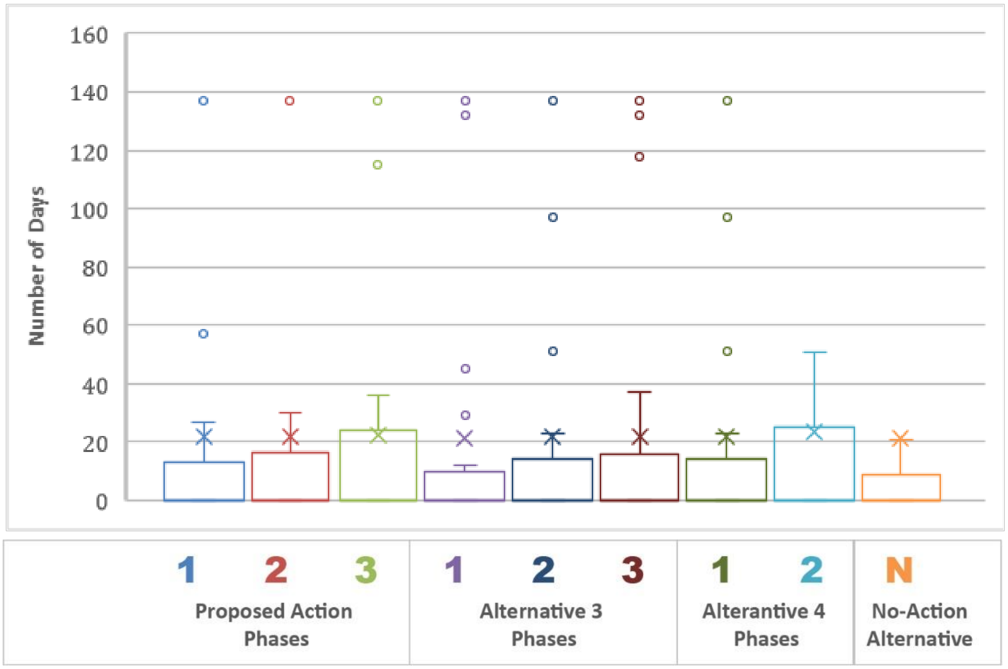


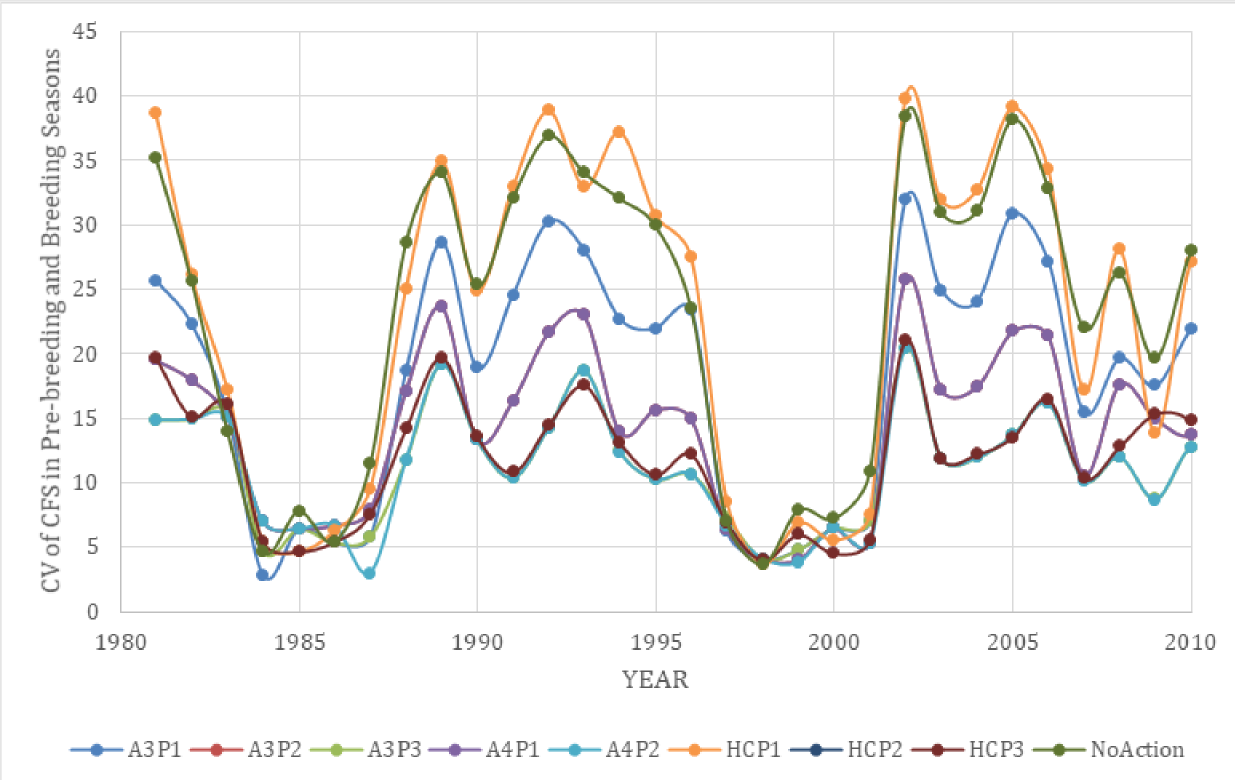
Figure 28. Boxplot of BENO Day Count for 1,300 cfs



Within-Year Flow Variation

To better understand within-year variation in flow for each alternative, Figure 29 reports the CV during the breeding season. The CV is the standard deviation divided by the average flow and allows us to compare within-year variability among the alternatives. Within-year flow variation is particularly important during the breeding season because the immobile egg masses are the most vulnerable life stage to either desiccation from receding water or displacement and subsequent exposure to deeper water predators.

Figure 29. CV of Within-Year Deschutes River Flow Modeled Using RiverWare at BENO Gauge for Each Alternative during Breeding Season



Effects

Emergent Vegetation

Emergent vegetation within wetland sloughs along the Deschutes River would be expected to respond to changes in flow regime and seasonal inundation patterns over time. Emergent vegetation is likely to recolonize areas where water levels were too deep, historically, for vegetation during the growing season due to the high summer flows in the Upper Deschutes River.

All alternatives differ from the historical flow regime in the Upper Deschutes by prescribing greater minimum flows during the winter and resulting in lower maximum flows during the summer than were observed on average prior to operations described under the Deschutes Project BiOp (U.S. Fish and Wildlife Service 2017, 2019).

The RiverWare model outputs indicate:

- Among the alternatives, inundation patterns during the growing season would remain similar during phase 1 of implementation for the proposed action, Alternative 3, and Alternative 4 compared to the no-action alternative (Figure 16 [hydrographs]). As the alternatives progress into the second phases of implementation, Alternative 3 and Alternative 4 experience lower flows and more variation in flow than the proposed action and even more than the no-action alternative. During phase 3, the proposed action has less flow variability but a lower average than Alternative 3 and Alternative 4 because of the summer maximum. This means that emergent vegetation would likely re-establish at a lower topographical or elevation level under the proposed action, but the more stable environment provided by the summer cap during phase 3 would better support its persistence than under the no-action alternative, Alternative 3, or Alternative 4. Higher and more stable winter flows under the proposed action, Alternatives 3 and 4 would also be expected to inundate the root systems of riparian vegetation, further supporting vegetation re-establishment.

Emergent vegetation would track the flow inundation patterns to colonize areas that would become available during the growing season at the lower elevations. The areas that would become available were historically too deeply inundated for vegetation to become established during the growing season. The total area covered by emergent vegetation would not necessarily change, but the topographical elevation where wetland vegetation is supported by water would be at the lowest elevations as flows are reduced during the growing season under full implementation of the proposed action, followed by higher elevations under Alternative 3 and Alternative 4, and the highest elevations under the no-action alternative. Along the river channel, vegetation would be expected to colonize areas lower in the channel profile. Individual Oregon spotted frog sites would respond variably depending on individual site topography, substrate characteristics, and dependence on the river as a water source but connectivity would likely be improved among habitat patches in the study area as a result of the more consistent hydrograph. Conservation Measure UD-1 provided under the proposed action, Alternative 3, and Alternative 4 could be used to fund efforts to enhance riparian and wetland vegetation.

Invasive Species

Reed canarygrass is already well established in the study area. Although its site-specific distribution would be expected to change by tracking water inundation elevation patterns during the growing season, it would be expected to persist throughout the study area under all alternatives. The proposed action, Alternative 3, and Alternative 4 include Conservation Measure UD-1, which could support control of this invasive species.

The earlier phases of the proposed action and all phases of Alternative 3 and Alternative 4 would provide more flow variability than the no-action alternative during the growing season. The more stable hydrograph under the fully implemented proposed action would be more likely to improve conditions for bullfrogs by providing year-round inundation of wetlands.[4] More stability in the hydrograph would also be more likely to improve conditions for nonnative fish species such as brown bullhead catfish, brown trout, and three-spined sticklebacks known to prey on Oregon spotted frogs. However, Conservation Measure UD-1 provided under the proposed action, Alternative 3, and Alternative 4 could be used to fund bullfrog control measures, or to address nonnative fish species.

Oregon Spotted Frog

Pre-breeding (March 1–March 31; 31 days)

- From the day count data derived from the RiverWare model, the proposed action, Alternative 3 and Alternative 4 result in more days of inundation at 1,200 cfs than the no-action alternative progressively through their phases of implementation.

[4] Bullfrogs require permanent wetland habitat to reproduce as tadpoles typically overwinter and metamorphose during their second year.

- Near the end of the pre-breeding period, sites would begin to experience the ramp-up in flows from the winter minimum to the beginning of the breeding season. Phase 1 of the proposed action is similar to the no-action alternative, but later implementation phases of the proposed action experience smaller overall increases in flow during this ramp-up than the no- action alternative. Alternatives 3 and 4 experience smaller increases faster than the proposed action.

Breeding (April 1–April 30; 30 days)

- From the day count data derived from the RiverWare model, during the breeding season, sites experience the most days of wetland vegetation inundation above the flow thresholds of 1,200 to 1,600 cfs under the no-action alternative (Figure 19, Figure 20, and Figure 21). Wetland vegetation inundation provides substrate and cover for egg masses. Although the day counts during breeding are higher under the no-action alternative, these counts are lumped over the entire period and do not reveal important patterns that are evident in the hydrographs described below.
- From the hydrographs (Figure 16), sites within the reach would experience more stable flows that also exceed the 1,300 cfs threshold for wetland inundation across the month of April under all phases of the proposed action, Alternative 3, and Alternative 4, while the no-action alternative results in an increase in flow from approximately April 15 through the end of the month, stable inundation of wetland vegetation (above the 1,300 cfs threshold) would similarly improve habitat conditions for Oregon spotted frogs under the proposed action and Alternatives 3 and 4 compared to the no-action alternative.
- Sites within the reach would also experience the smallest change (increase) in flow compared to the no-action alternative at the onset of the irrigation season around April 1st under all implementation phases of Alternative 4. Alternative 3 and the proposed action would both result in smaller changes in flow at the onset of the irrigation season compared to the no-action alternative (except phase 1 of the proposed action), but not as small as that modeled for the fully implemented Alternative 4. Smaller changes in flow and associated water levels improve conditions for Oregon spotted frogs because there is less chance of stranding or displacing egg masses.
- Within-year variation is much larger under the no-action alternative compared to all other alternatives except for the phase 1 of the proposed action (Figure 29). Within-year variation can increase the risk of egg mass mortality from stranding or displacement.

The no-action alternative would slightly outperform the proposed action and outperform Alternatives 3 and 4 in number of days sites would be inundated above 1,300 cfs; however, this difference in day count is due to a greater change in inundation patterns later in the period.

Rearing (April 15–August 31; 139 days)

- Sites associated with the BENO gauge would experience flows exceeding the 1,300 cfs threshold during the entire rearing period most often under the no-action alternative (Figure 23). During late April the proposed action and Alternatives 3 and 4 have lower flows when compared to the no-action alternative, often less than 1,300 cfs during late April, and this early part of the rearing period accounts for the lower day counts among the three alternatives when compared to the no-action alternative. Conservation Measure WR-1 (E) of the proposed action states that flows at BENO will be no less than 1,300 cfs from July 1 through at least September 15, the latter part of the rearing period, and early part of pre-winter periods assessed here. From the hydrographs, the proposed action meets this threshold even through full implementation while Alternatives 3 and 4 more often drop close to or below 1,300 cfs. Therefore, the proposed action performs as well as the no-action alternative during this portion of rearing, and both outperform Alternatives 3 and 4. Inundated vegetation provides cover for developing tadpoles and juvenile or adult frogs.

- The proposed action and Alternative 3 would both outperform Alternative 4 in number of days expected to exceed the inundation threshold of 1,600 cfs (Figure 34).
- From the hydrographs (Figure 16), beginning in early- or mid-July through August, the proposed action, Alternative 3, and Alternative 4 experience a decrease in flow and more year-to-year variability compared to the no-action alternative. Flows under the proposed action remain above the 1,300 cfs threshold for vegetation inundation and more often approach or drop below this threshold under Alternatives 3 and 4. During phase 3 of the proposed action, the flows are governed by a summer maximum.

The proposed action would perform as well as the no-action alternative and both would outperform Alternative 3 and Alternative 4 during the latter part of the rearing period by maintaining vegetation inundation at or above the 1,300 cfs inundation threshold. Although the no-action alternative presents greater year-to-year stability, the proposed action is likely to be more stable over the course of the entire rearing season.

Pre-winter (September 1–October 15; 45 days)

- The count of days when inundation levels exceed 1,200 cfs, maintaining contact with wetland vegetation at some sites, are similar among the no-action alternative and the proposed action, and earlier phases of Alternative 3 and Alternative 4 (Figure 25). Later phases of Alternative 3 and Alternative 4 result in slightly fewer days of inundation.
- The proposed action includes Conservation Measure WR-1 (E) that states "flow at the BENO gauge (OWRD Gauge 14064500) shall be no less than 1,300 cfs from July 1 through at least September 15". The pre-winter period used to calculate the day counts is longer than this, but from the hydrographs all phases of the proposed action maintain the 1,300 cfs flow through September 15, then flow slowly decreases as frogs move to overwintering locations. A second conservation measure under the proposed action (Conservation Measure WR-1 [J]) limits the speed of the fall ramp-down to result in a more gradual step down of flow at the BENO gauge. Alternatives 3 and 4 do not maintain inundation at 1,300 cfs through September 15, especially during their later phases of implementation, and none of the alternatives besides the proposed action control the fall ramp down. Maintenance of inundation and then a slow ramp down to overwintering flows would facilitate frog movement to overwintering sites during the pre-wintering period most effectively under the proposed action.
- From the hydrographs (Figure 16), flows modeled for Alternatives 3 and 4 experience a similar decrease in flow through the pre-winter season. The no-action alternative experiences a larger decrease as flows are greater at the end of the rearing season and less during the overwintering period for this alternative compared to the others. The proposed action differs from the other alternatives because it holds the flow at or above 1,300 cfs though September 15 (Conservation Measure WR-1 [E]) and controls the speed of the fall ramp-down (Conservation Measure WR-1 [J]). The smaller change in water inundation elevation under the proposed action, Alternative 3,

and Alternative 4 may prevent abrupt stranding of frogs as they migrate to overwintering sites. Alternative 4 most quickly progresses to a more stable hydrograph (less change) through its implementation phases followed by Alternative 3 and then the proposed action. The proposed action controls the speed of the ramp-down in the fall.

- The proposed action, Alternative 3, and Alternative 4 include Conservation Measure UD-1, which is lacking from the no-action alternative.

The proposed action, Alternative 3, and Alternative 4 would perform similarly to the no-action alternative regarding days of inundation but Conservation Measure WR-1 (E) under the proposed action is key to maintaining inundation flows in the reach until at least September 15. The change in inundation level would be less drastic under the proposed action, Alternative 3, and Alternative 4 compared to the no-action alternative. The less drastic change in water inundation elevation may prevent abrupt stranding of frogs as they migrate to overwintering sites. Conservation Measure WR-1 (J) also regulates the speed of the fall ramp-down under the proposed action. Finally, the no-action alternative lacks Conservation Measure UD-1, which would fund activities to restore and maintain habitat to benefit the covered species within the Deschutes River, including Oregon spotted frog. For these reasons, the proposed action would outperform Alternative 3 and Alternative 4, and all would outperform the no-action alternative.

Overwintering (October 16–March 1; 137 days)

- Flows reach the 1,200 cfs threshold rarely under any alternative, but slightly more often under phase 1 of the proposed action, the fully implemented proposed action, and Alternative 4 than under the no-action alternative (Figure 27).[5]
- From the hydrographs (Figure 16), flows under the proposed action, Alternative 3, and Alternative 4 steadily exceed the amount of flow under the no-action alternative throughout the overwintering season except during phase 1 of the proposed action. Higher flows could result in more consistently wetted overwintering sites and shorter distances for frogs to travel from overwintering to breeding locations.

The proposed action, Alternative 3, and Alternative 4 provide higher sustained water levels throughout the overwintering period than the no-action alternative. Alternative 4 reaches full implementation more quickly than the other alternatives.

Summary Conclusion

Table 9 summarizes the overall results of this comparison of each alternative to the no-action alternative. The proposed action, Alternative 3, and Alternative 4 would outperform the no-action alternative during all key life history periods except rearing. The proposed action would outperform other alternatives during the pre-winter period.

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[5] See Appendix 3.1-C, *Analysis of RiverWare Model Version 18 Outputs and Implications for Final EIS*, for corrections due to modeling update.

Reach Des-9

Reach Des-9 does not support any known Oregon spotted frog breeding sites, although there is one site where juveniles have been detected. This reach is located along the river between known breeding sites so Oregon spotted frogs likely disperse through this reach, and there is a possibility Oregon spotted frogs use some of the wetlands associated with the river for breeding.

The flow in this reach does not directly correspond to the nearest gauge, BENO at Benham Falls, and no flow threshold has been identified for this reach because there are little data available for wetlands located within the reach. This assessment relied on a hydrograph produced from internodal data from the RiverWare model (Siphon2COID.Inflow). The hydrograph at this internode can be related back to the flows at the BENO gauge by subtracting from BENO the Arnold Canal diversion flows and approximately 50% of the loss to ground water estimated for the stretch of river extending from BENO to Bend by Gannett et al. (2001). Assuming loss to ground water is consistent from BENO to Bend, reach Des-9 only covers approximately half the distance. These data are caveated because they involve reporting results for a location (internode) that was not designed as a reporting node in the model. They include a degree of uncertainty because the gains and losses in the model have been artificially tied to internodal location rather than spread out along the entire reach. The analysis assumes the Siphon2COID.Inflow data accurately model the flow in the Deschutes River in this reach.

RiverWare Results

Figure 30 depicts daily Deschutes River flow hydrographs generated for the Siphon2COID.Inflow internode location using RiverWare for the no-action alternative, the proposed action, Alternative 3, and Alternative 4. The hydrographs represent a visual comparison of the river flows expected under the different alternatives.

For each alternative, the graphs present the median modeled flow (50%; solid line) and a band capturing the 20% through 80% modeled flows, meaning the flows expected to occur 20% to 80% of the time.

Effects

Emergent Vegetation

Emergent vegetation would be expected to respond to changes in flow regime by tracking the seasonal inundation patterns and colonizing areas that were historically unavailable during the growing season because they were too deeply inundated to become established.

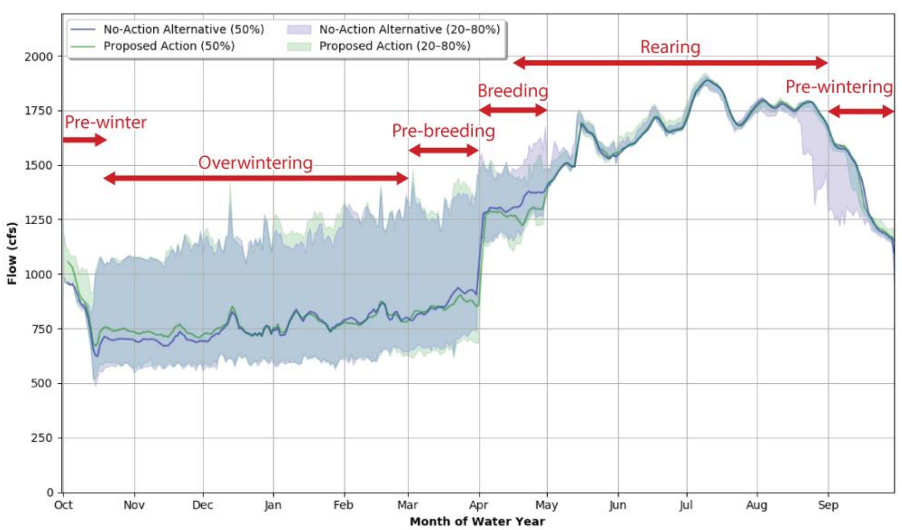
All alternatives differ from the historical flow regime in the Upper Deschutes by prescribing greater minimum flows during the winter and resulting in lower maximum flows during the summer than were observed on average prior to operations prescribed under the Deschutes Project BiOp (U.S. Fish and Wildlife Service 2017, 2019).

The RiverWare model outputs indicate:

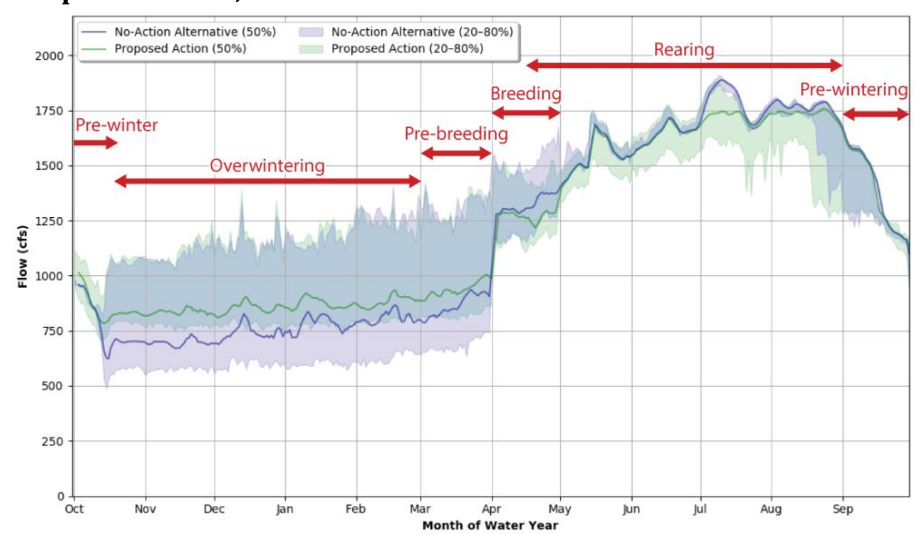
Among the alternatives, inundation patterns during the growing season would be based on the highest flows under the no-action alternative and lower but more stable flows under the proposed action. Phase 1 of the proposed action is similar to the no-action alternative, but as the proposed action progresses through later implementation phases, the summer maximum flows come into play and add stability, especially during phase 3 of implementation. Alternative 3 and Alternative 4 progressively experience reduced flows during the growing season, with Alternative 4 progressing more quickly (Figure 30 [hydrographs]). This means that emergent vegetation would be inundated and supported at the highest topographical or elevation level under the no-action alternative, lower and more stable elevation under the proposed action, and lowest elevations under Alternative 3 and Alternative 4.

Figure 30. Deschutes River Flow Modeled Using RiverWare at the Siphon2COID.Inflow Internode under Proposed Action, Alternative 3, and Alternative 4 Compared to No-Action Alternative

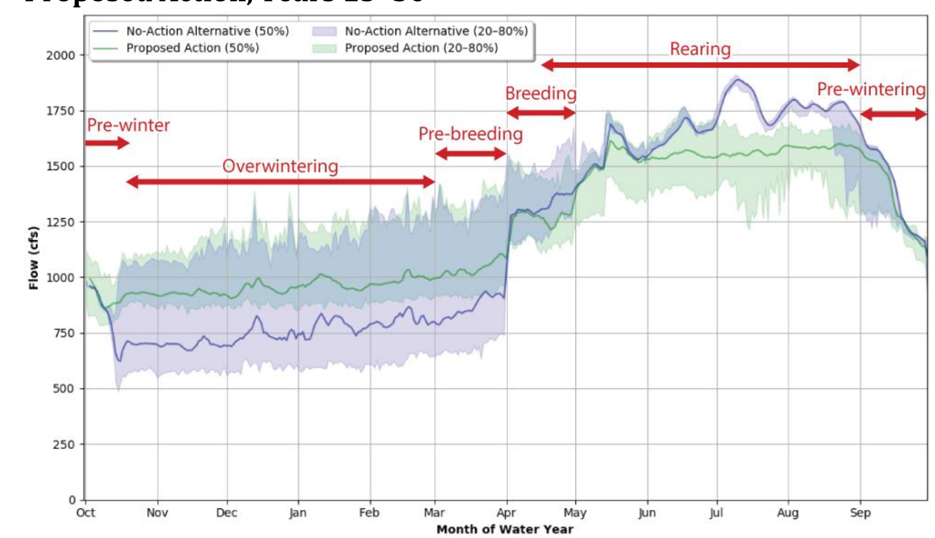
Proposed Action, Years 1–7



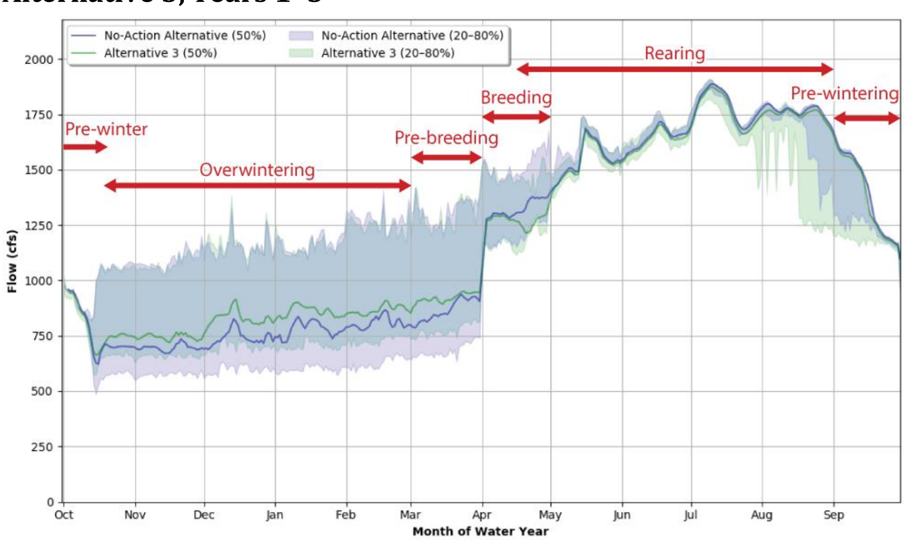
Proposed Action, Years 8–12



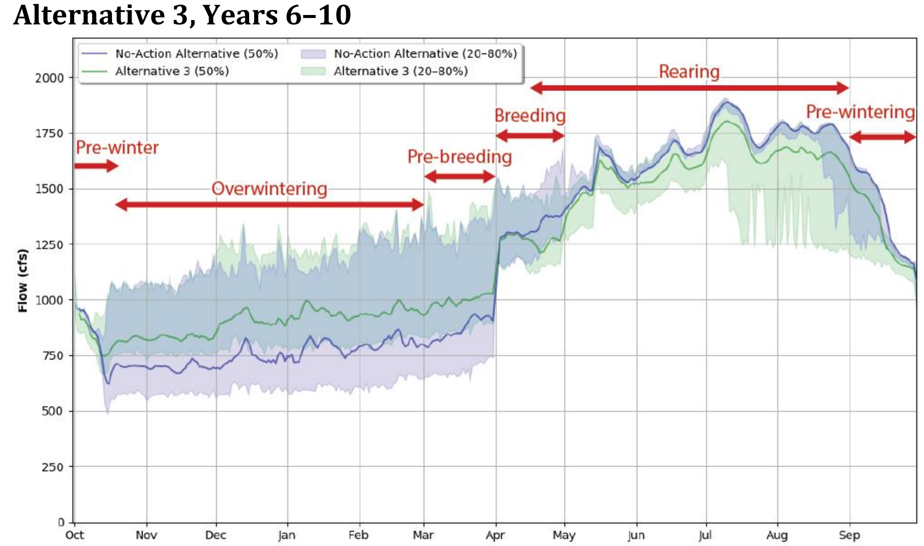
Proposed Action, Years 13–30



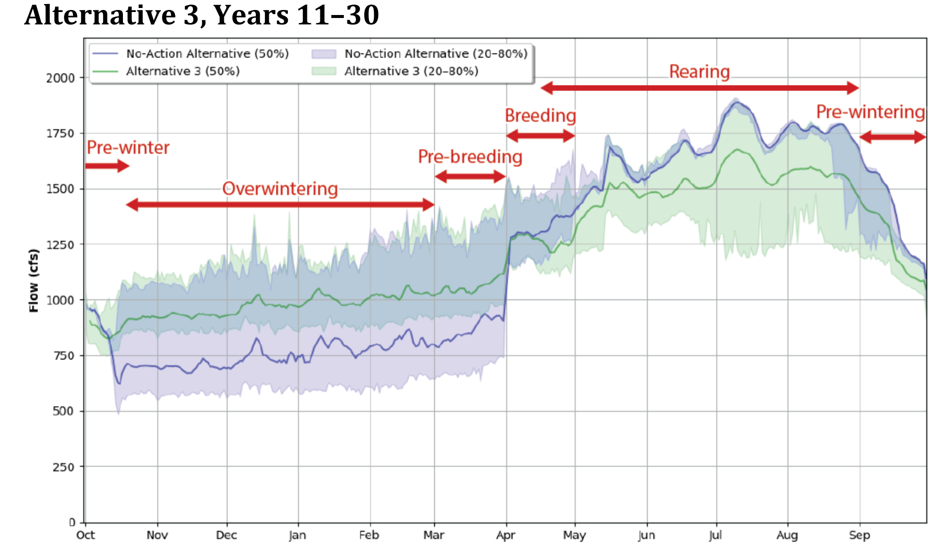
Alternative 3, Years 1–5



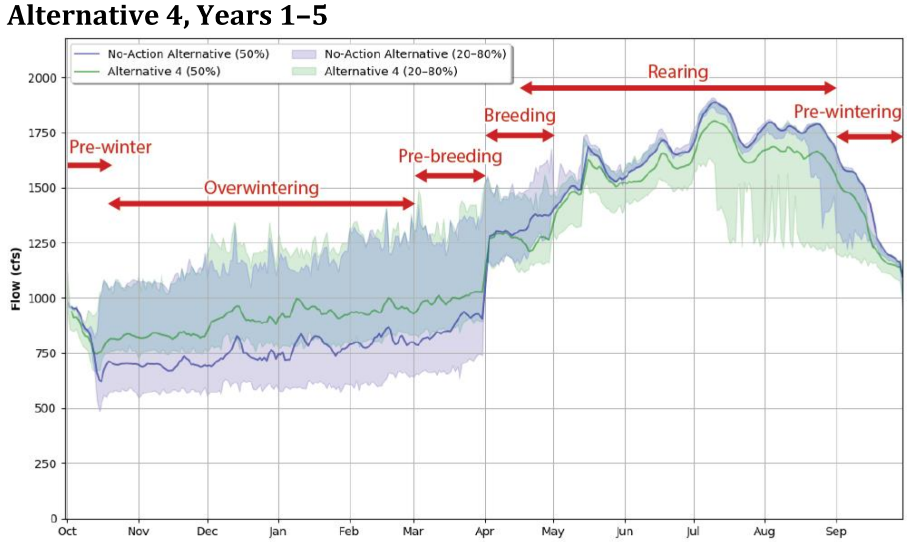
Alternative 3, Years 6–10



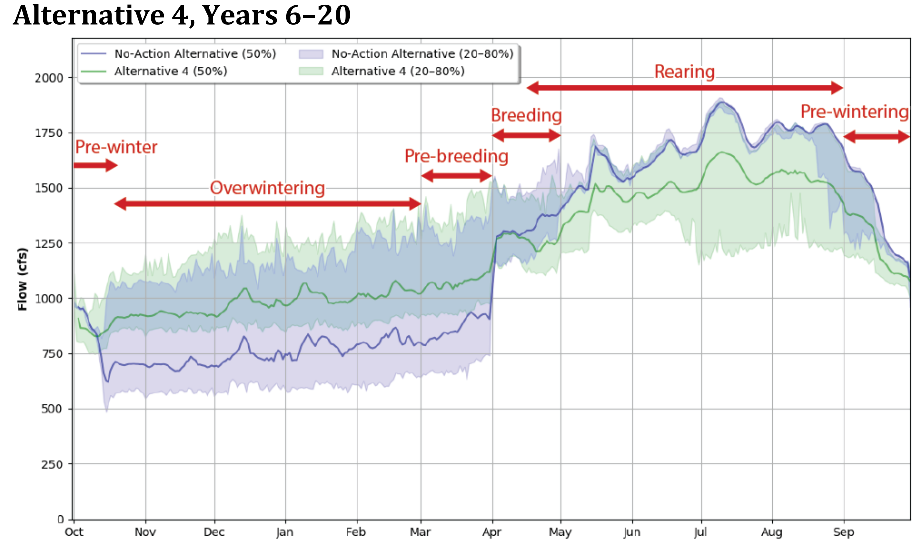
Alternative 3, Years 11–30



Alternative 4, Years 1–5



Alternative 4, Years 6–20



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Emergent vegetation would track the flow inundation patterns to colonize areas that would become available during the growing season at the lower elevations. The areas that would become available were historically too deeply inundated for vegetation to become established during the growing season. The total area covered by emergent vegetation would not necessarily change, but the topographical elevation where wetland vegetation is supported by water would be at lower elevations as flows are reduced during the growing season under full implementation of the proposed action, Alternative 3, and Alternative 4 when compared to the no-action alternative. Alternative 4 would progress most quickly through its implementation phases. Along the river channel, vegetation would be expected to colonize areas lower in the channel profile. Individual Oregon spotted frog sites would respond variably depending on individual site topography, substrate characteristics, and dependence on the river as a water source. Conservation Measure UD-1 provided under the proposed action, Alternative 3, and Alternative 4 could be used to fund efforts to enhance riparian and wetland vegetation.

Invasive Species

Reed canarygrass is already well established in the study area. Although its site-specific distribution would be expected to change by tracking water inundation elevation patterns during the growing season, it would be expected to persist throughout the study area under all alternatives. The proposed action, Alternative 3, and Alternative 4 include Conservation Measure UD-1, which could support control of this invasive species. The more stable hydrograph under the proposed action compared to the no-action alternative would be more likely to improve conditions for bullfrogs by providing year-round inundation of wetlands.[6] More stability in the hydrograph would also be more likely to improve conditions for nonnative fish species such as brown bullhead catfish, brown trout, and three-spined sticklebacks known to prey on Oregon spotted frogs. However, Conservation Measure UD-1 could be used to fund bullfrog control measures or address nonnative fish species.

Oregon Spotted Frog

Pre-breeding (March 1–March 31; 31 days)

Near the end of the pre-breeding period, sites would begin to experience the ramp-up in flows from the winter minimum to the beginning of the breeding season. Phase 1 of the proposed action is similar to the no-action alternative, but later implementation phases of the proposed action experience smaller overall increases in flow during this ramp-up than under the no-action alternative. Alternative 3 and Alternative 4 experience smaller increases faster than the proposed action.

Breeding (April 1–April 30; 30 days)

- From the hydrographs (Figure 30), sites within the reach would experience the largest change (increase) in flow under the no-action alternative as flows ramp up from the winter minimum at the onset of the irrigation season around April 1st. Flows are consistent among all alternatives during the first half of the month of April, and then diverge as flows increase again under the no-action alternative. Relatively stable inundation of wetland vegetation would similarly improve

[6] Bullfrogs require permanent wetland habitat to reproduce as tadpoles typically overwinter and metamorphose during their second year.

habitat conditions for Oregon spotted frogs under the proposed action and Alternatives 3 and 4 compared to the no-action alternative.

The fully implemented Alternative 4 provides the smallest amount of change in water inundation levels at the beginning of the breeding season and would be least likely to dislodge egg masses. The proposed action and Alternative 3 are similar to Alternative 4 at their full implementation, but they take longer to reach this condition, with Alternative 3 progressing faster than the proposed action.

Rearing (April 15–August 31; 139 days)

- From the hydrographs (Figure 30), beginning in early- or mid-July through early August, the proposed action, Alternative 3, and Alternative 4 experience a decrease in flow and more year-to-year variability compared to the no-action alternative. Flows under the proposed action are more likely to maintain higher levels of inundation than Alternatives 3 and 4. During phase 2 and to a greater extent during phase 3 of the proposed action, the flows are governed by a summer maximum that stabilizes them compared to Alternative 3 and Alternative 4.
- Conservation Measure WR-1 (E) of the proposed action regulates a minimum flow at BENO from July 1 through at least September 15, the latter part of the rearing period, and early part of pre-winter periods assessed here. Although flows in this reach do not directly correspond to the BENO gauge, flow regulation as measured at BENO also affects this reach because it is downstream. Although there is not a wetland vegetation inundation threshold identified for this reach, the minimum flow control for the proposed action offered by Conservation Measure WR-1 (E) combined with the greater stability during later phases of the proposed action mean the proposed action would likely perform at least as well as the no-action alternative during this portion of rearing, and both would outperform the Alternatives 3 and 4. Inundated vegetation provides cover for developing tadpoles and juvenile or adult frogs.
- Although the no-action alternative presents greater year-to-year stability, the proposed action is likely to be more stable over the course of the entire rearing season. Therefore, wetland vegetation may respond more effectively under the proposed action to the consistently lower flows by colonizing topographically lower sites along the river.
- Decreased flows could result in drying of wetlands and exposure of juvenile frogs to higher risk of predation if forced to migrate to the river channel.

The no-action alternative would outperform the fully implemented proposed action, Alternative 3, and Alternative 4 in amount of flow available during rearing, but the proposed action provides greater stability at its full implementation.

Pre-winter (September 1–October 15; 45 days)

- The proposed action includes a Conservation Measure WR-1 (E) that states "flow at the BENO gauge (OWRD Gauge 14064500) shall be no less than 1,300 cfs from July 1 through at least September 15." Maintenance of a minimum flow measured at the BENO gauge also affects this reach since it is downstream. Under the proposed action through September 15, flows remain relatively steady compared to the no-action alternative and Alternatives 3 and 4. A second conservation measure under the proposed action (Conservation Measure WR-1 [J]) limits the speed of the fall ramp-down to result in a more gradual step down of flow at the BENO gauge which also affects flow patterns in this reach, evident in the hydrographs (Figure 30). Alternatives 3 and 4 do not maintain a steady flow through September 15, especially during their later phases of implementation, and none of the alternatives besides the proposed action control the speed of the fall ramp-down. Maintenance of inundation and then a slow ramp-down to overwintering flows would facilitate frog movement to overwintering sites during the pre-wintering period most effectively under the proposed action.

- From the hydrographs (Figure 30), flows modeled for the fully implemented proposed action, Alternative 3 and Alternative 4 experience a similar amount of decrease in flow through the pre-winter season. The no-action alternative experiences a larger decrease as flows are greater at the end of the rearing season and less during the overwintering period for this alternative compared to the others. The proposed action controls the speed of the ramp-down in the fall.
- The proposed action, Alternative 3, and Alternative 4 include Conservation Measure UD-1, which is lacking from the no-action alternative.

Conservation Measure WR-1 (E) under the proposed action is key to maintaining inundation flows in the reach until at least September 15. The change in overall inundation level would be less under the proposed action, Alternative 3, and Alternative 4 compared to the no-action alternative. Alternative 3 would reach this pattern more quickly than the proposed action, and Alternative 4 would reach this pattern more quickly than either the proposed action or Alternative 3. The less drastic change in water inundation elevation may prevent abrupt stranding of frogs as they migrate to overwintering sites. Conservation Measure WR-1 (J) also regulates the speed of the fall ramp-down under the proposed action. Finally, the no-action alternative would lack Conservation Measure UD-1, which would fund activities to restore and maintain habitat to benefit the covered species within the Upper Deschutes Basin, including Oregon spotted frog. For these reasons, the fully implemented proposed action would outperform Alternative 3 and Alternative 4, and all would outperform the no-action alternative.

Overwintering (October 16–March 1; 137 days)

- From the hydrographs, flows under the proposed action, Alternative 3, and Alternative 4 steadily exceed the amount of flow under the no-action alternative throughout the overwintering season. The proposed action is similar to the no-action alternative during phase 1 of implementation, and it progresses more slowly to higher winter flows than either Alternative 3 or Alternative 4. Higher flows could result in more consistently wetted overwintering sites and shorter distances for frogs to travel between breeding and overwintering locations.

At full implementation, the proposed action and Alternative 3 provide higher sustained water levels throughout the overwintering period than the no-action alternative. Fully implemented Alternative 4 provides the highest sustained water elevation which could protect overwintering Oregon spotted frogs. Full implementation of Alternative 4 would outperform the other alternatives.

Summary Conclusion

Table 9 summarizes the overall results of this comparison of each alternative to the no-action. The proposed action, Alternative 3, and Alternative 4 would outperform the no-action alternative during all key life history periods except rearing. The proposed action would outperform other alternatives during the pre-winter period.

Reach Des-8a

Reach Des-8a is located along the Deschutes River extending from the Central Oregon Irrigation Diversion (COID) downstream to Colorado Street in downtown Bend, Oregon. In the Deschutes Project BiOp (U.S. Fish and Wildlife Service 2017, 2019), this reach is called Reach 7; it is the same but referred to by reach name in the Deschutes Basin HCP.

There are two known breeding locations in Reach Des-8a: the Old Mill/Casting Pond and the Les Schwab Amphitheater (LSA) Marsh. These two locations are close to each other and individual frogs have been documented moving between the two locations (U.S. Fish and Wildlife Service 2017, 2019). The Old Mill/Casting Pond is not connected to the river while LSA Marsh is a wetland adjacent to and directly connected with the main river channel on the upstream (south) side of the Colorado Bridge and waterpark. Breeding has been sporadically detected at both locations since 2013, although successful use of each site for oviposition appears to be declining (U.S. Fish and Wildlife Service 2017, 2019). LSA Marsh and Old Mill/Casting Pond represent the farthest downstream breeding sites for Oregon spotted frog along the Upper Deschutes River.

The flow in this reach of the river does not directly reflect the flows measured at the BENO gauge, the closest upstream gauge, because water is diverted for irrigation and lost through groundwater seepage between the BENO gauge location at Benham Falls and this reach. This assessment relied on a hydrograph produced from internodal data from the RiverWare model (Siphon2COID.Outflow). The hydrograph at this internode can be related back to the flows at the BENO gauge by subtracting from BENO the Arnold Irrigation District and Central Oregon Irrigation District diversion flows as well as the approximately 7% loss to groundwater estimated for the reach extending from BENO to Bend by Gannett et al. (2001). These data are caveated because they involve reporting results for a location (internode) that was not designed as a reporting node in the model. They include a degree of uncertainty because the gains and losses in the model have been artificially tied to internodal location rather than spread out along the entire reach.

The analysis assumes the Siphon2COID.Outflow data accurately model the flow in the Deschutes River at the Colorado Street Bridge, adjacent to the LSA Marsh. A draft report (Vaughn 2019) reported a similar flow pattern for the Colorado Street Bridge location although the median flows estimated by Vaughn (2019) during winter, which were calculated from measured flows at the BENO gauge adjusted for diversions and losses, appear to be approximately 500 cfs compared to the RiverWare-modeled median around 750 cfs.

Habitat flow thresholds and other important criteria for Oregon spotted frog sites associated with flows in Des-8a at the Colorado Street Bridge (Siphon2COID.Outflow internode) include:

- From Vaughn (2019), the LSA Marsh appears to remain wetted throughout the year, so there is not a vegetation inundation threshold that would capture days of inundation, and associated increased habitat value, during the life history periods. Instead, based on the hydrographs, 1,200 cfs at the Siphon2COID.Outflow internode was selected to compare days of inundation during pre-breeding, breeding and rearing seasons among the alternatives because these values were in the range of those reported by Vaughn (2019) for those timeframes, and pre-breeding, breeding and rearing occurred at the site during the same time frame (O'Reilly pers. comm.).

- For the overwintering period, the analysis used 900 cfs (at the Siphon2COID.Outflow internode) as a comparative flow threshold. Based on the modeled hydrographs, this flow appeared to discriminate among the alternatives and allow us to differentiate among alternatives that consistently provide a higher amount of winter flow and associated water elevation. This increases habitat quality by reducing the travel distance for Oregon spotted frogs moving from overwintering sites to breeding locations within the reach. The analysis also compared alternatives using the 500 cfs flow threshold at the Siphon2COID.Outflow internode because that flow approximates the typical winter flow experienced by one of the sites in the reach, LSA Marsh.

- As in other reaches, the analysis also compared the pattern of flow change during pre-winter and other life history periods to discern patterns or trends that could differentially affect Oregon spotted frog use of the habitat.

RiverWare Results

Hydrographs

Figure 31 depicts daily Deschutes River flow hydrographs generated for the Siphon2COID.Outflow internode (Colorado Street Bridge) location using RiverWare for the no-action alternative, the proposed action, Alternative 3, and Alternative 4. The hydrographs represent a visual comparison of the river flows expected under the different alternatives at all phases of implementation.

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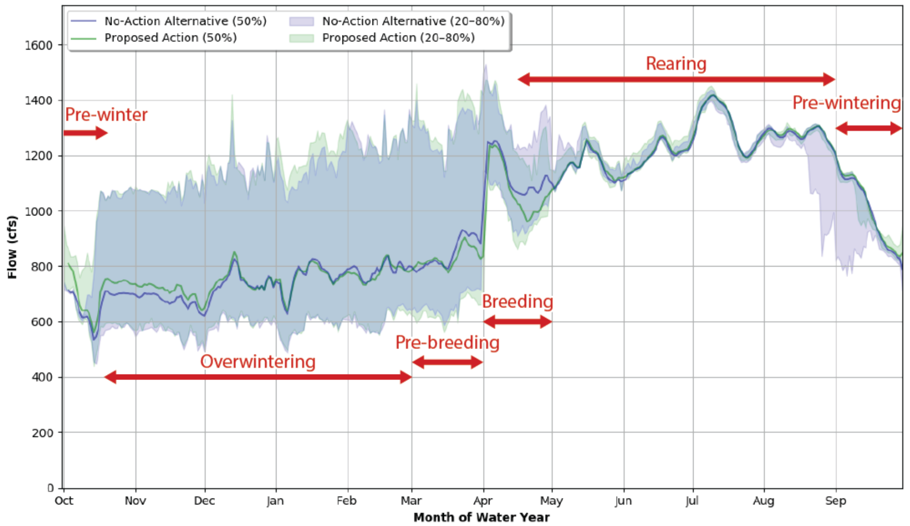
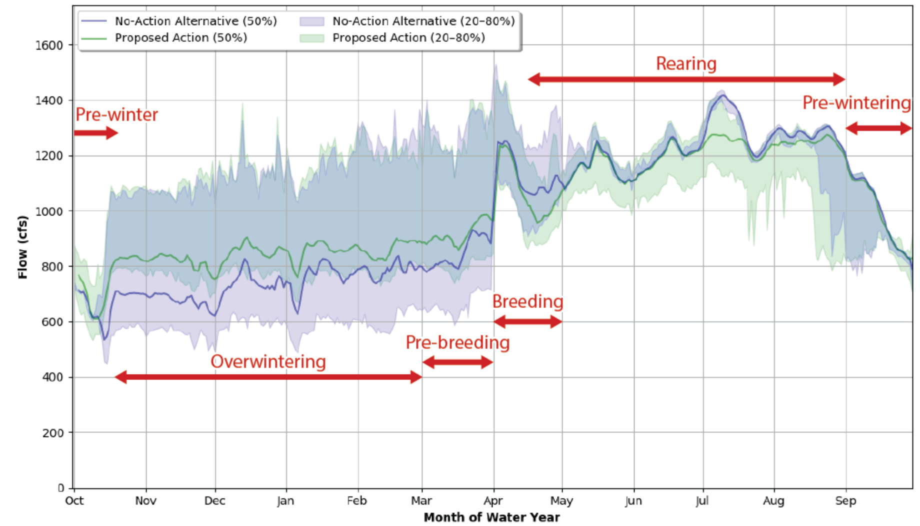
Figure 31. Deschutes River Flow Modeled Using RiverWare at the Siphon2COID.Outflow Internode under Proposed Action, Alternative 3, and Alternative 4 Compared to No-Action Alternative

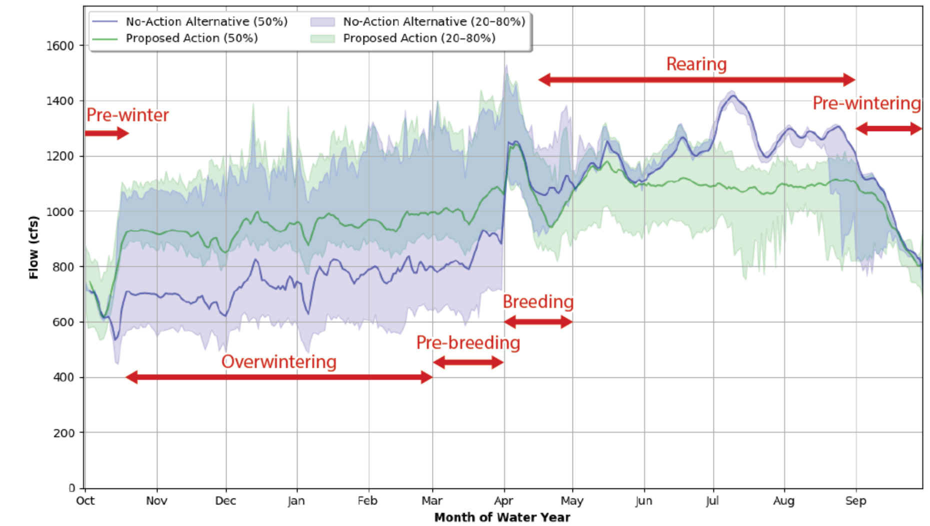
Proposed Action, Years 1–7



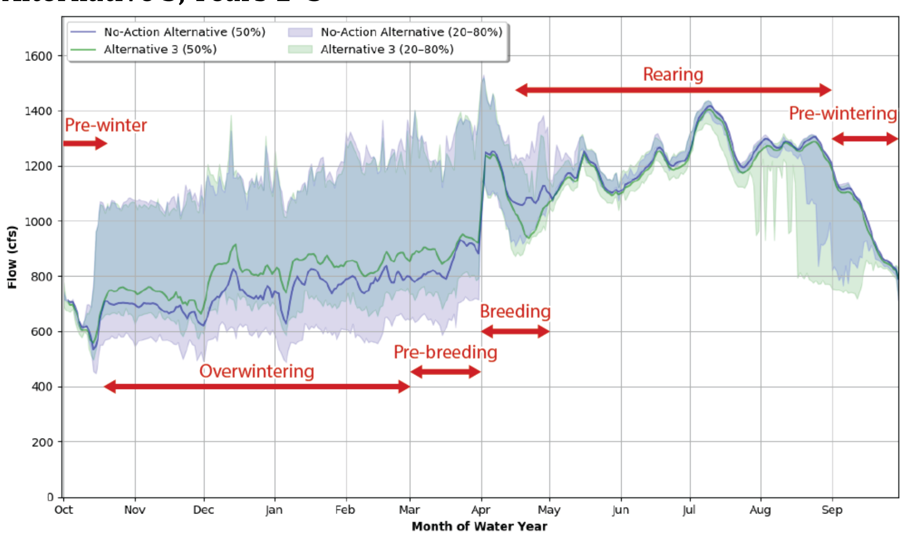
Proposed Action, Years 8–12



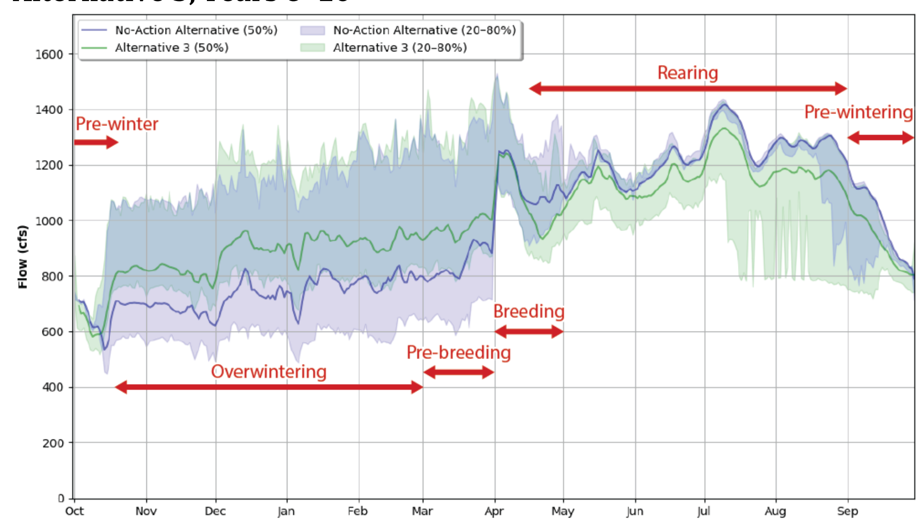
Proposed Action, Years 13–30



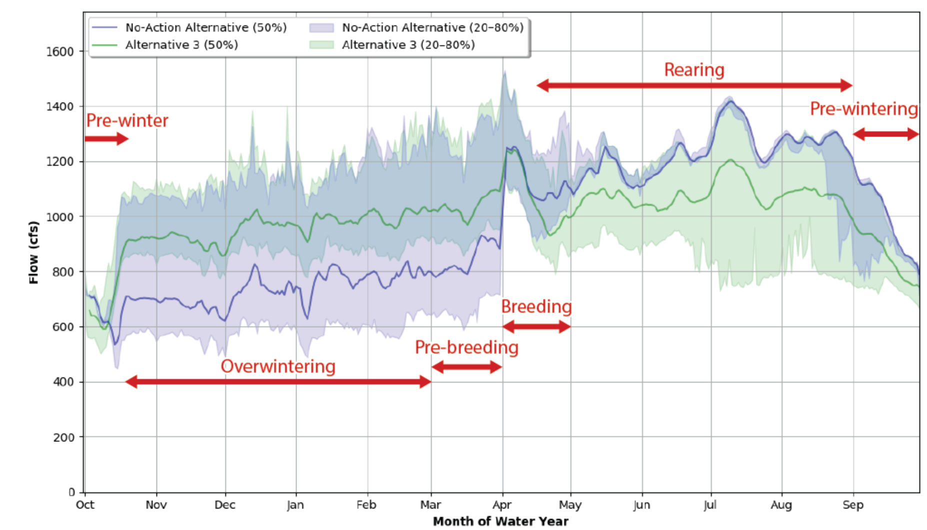
Alternative 3, Years 1–5



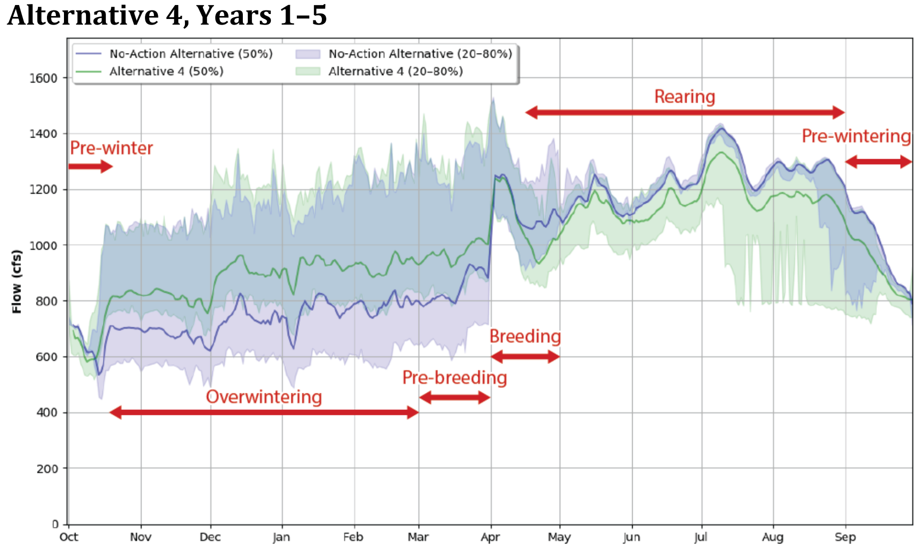
Alternative 3, Years 6–10



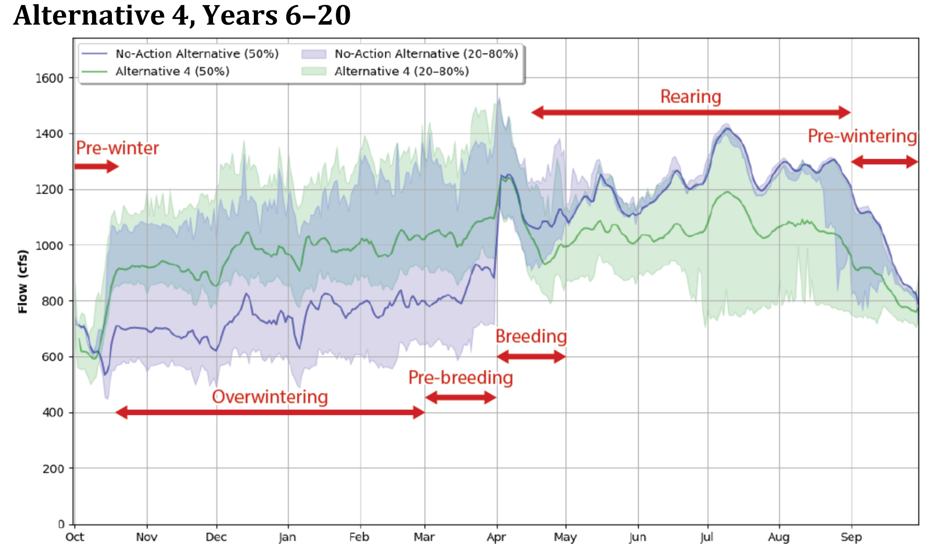
Alternative 3, Years 11–30



Alternative 4, Years 1–5



Alternative 4, Years 6–20



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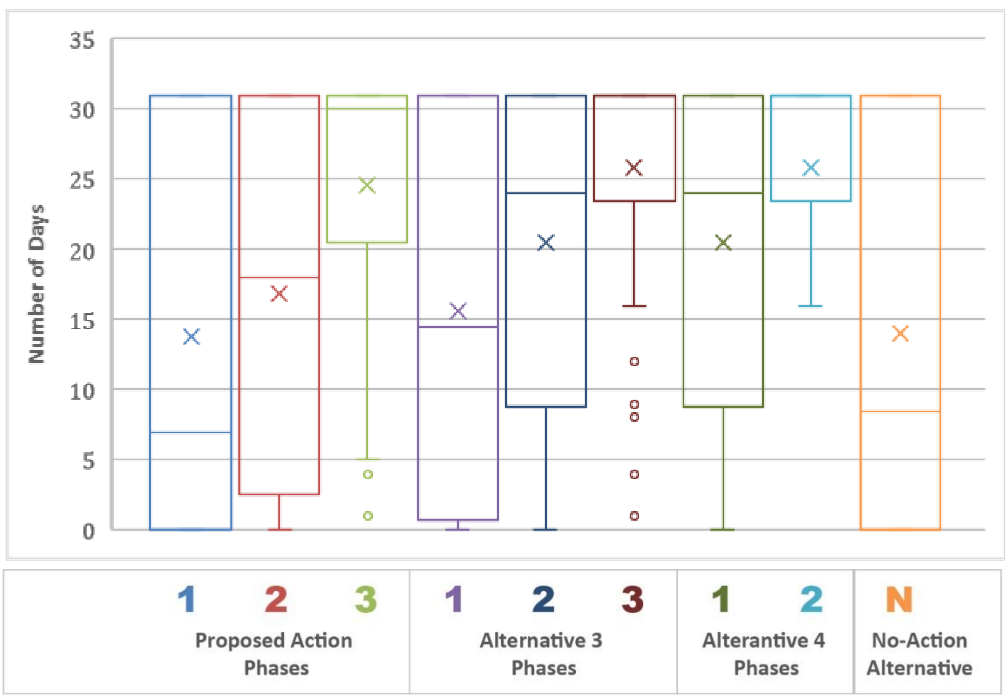
For each alternative, the graphs present the median modeled flow (50%; solid line) and a band capturing the 20% through 80% modeled flows, meaning the flows expected to occur 20% to 80% of the time.

Day-Count Data

To further relate the modeled river flow data for each alternative to the key life history periods for Oregon spotted frogs, the boxplots below (Figure 32 through Figure 37) depict the number of days during each key life history time period where the flow at the Siphon2COID.Outflow RiverWare internode (e.g., Colorado Street Bridge) would be expected to exceed the flow thresholds described earlier in this appendix. In each boxplot, "x" indicates the mean number of days exceeding the threshold counted for that alternative. The box encloses the upper (top of box) and lower (bottom of box) quartiles and the median is indicated by a horizontal line within the box. Whiskers represent the lowest data point within 1.5 interquartile range (IQR) of the lower quartile, and the highest data point within 1.5 IQR of the upper range. Outliers are depicted as dots.

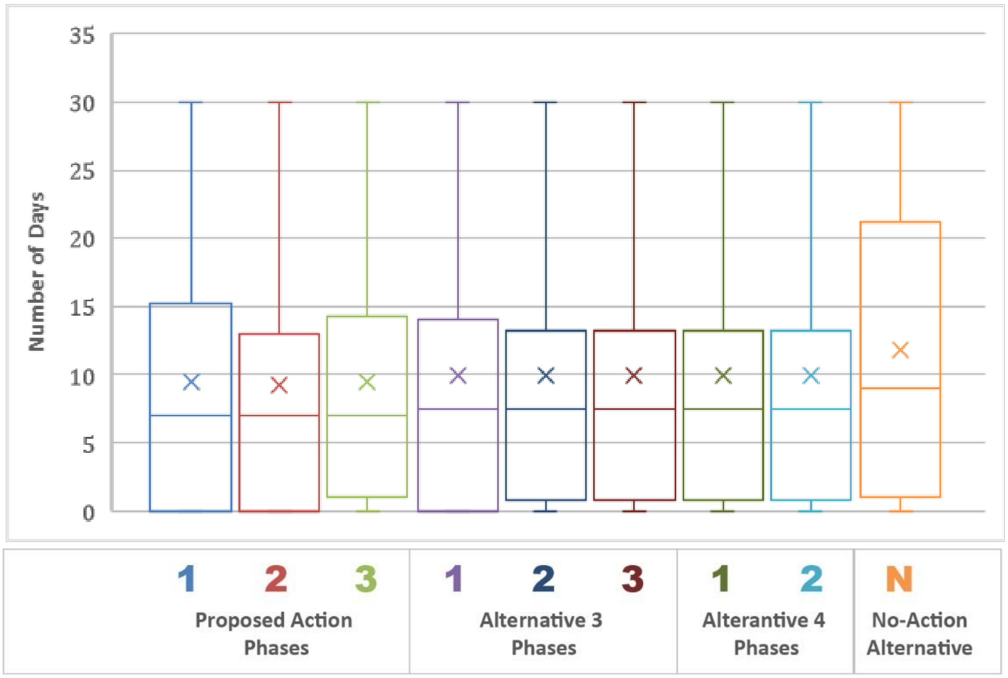
Pre-breeding (March 1–March 31; 31 days)

Figure 32. Boxplot of Siphon2COID.Outflow Day Count for 900 cfs



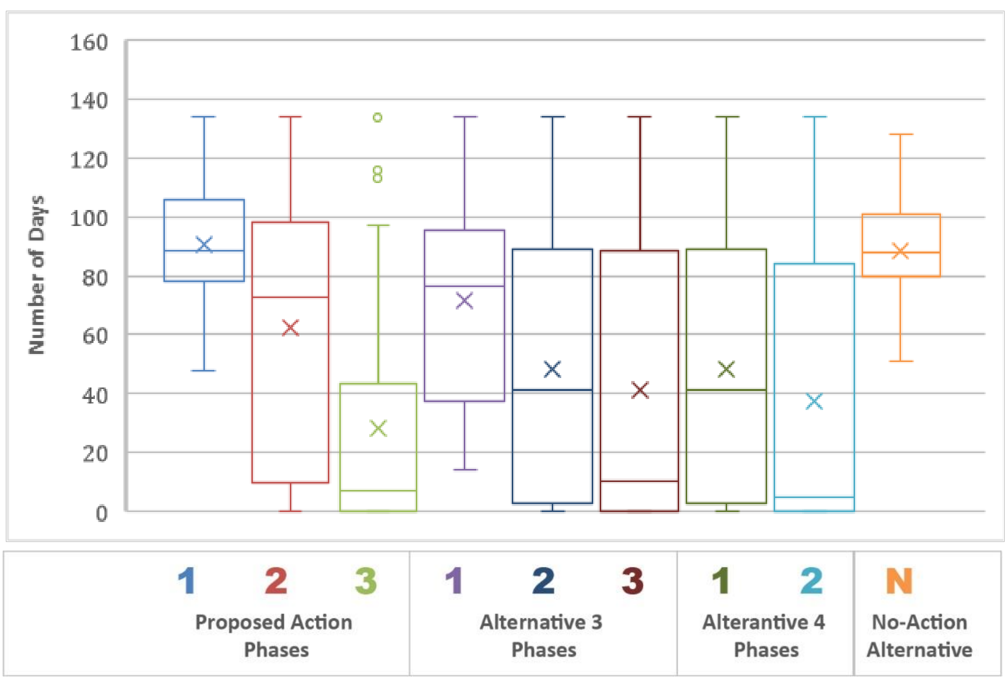
Breeding (April 1–April 30; 30 days)

Figure 33. Boxplot of Siphon2COID.Outflow Day Count for 1,200 cfs



Rearing (April 15–August 31; 139 days)

Figure 34. Boxplot of Siphon2COID.Outflow Day Count for 1,200 cfs during Rearing



Pre-winter (September 1–October 15; 45 days)

Figure 35. Boxplot of Siphon2COID.Outflow Day Count for 900 cfs during Pre-winter

Overwintering (October 16–March 1; 137 days)

Figure 36. Boxplot of Siphon2COID.Outflow Day Count for 500 cfs during Overwintering

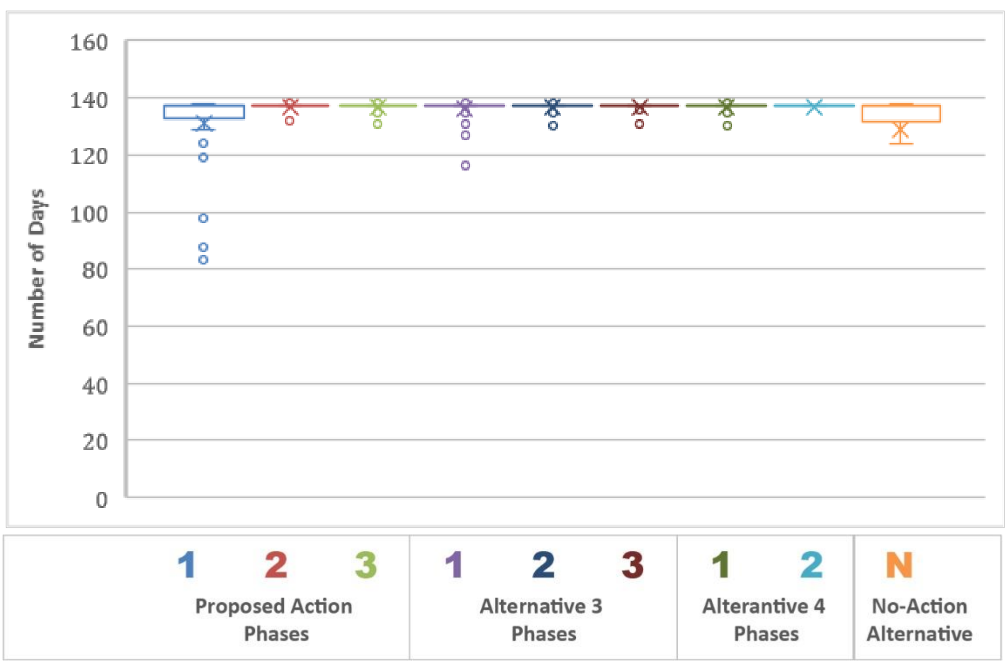
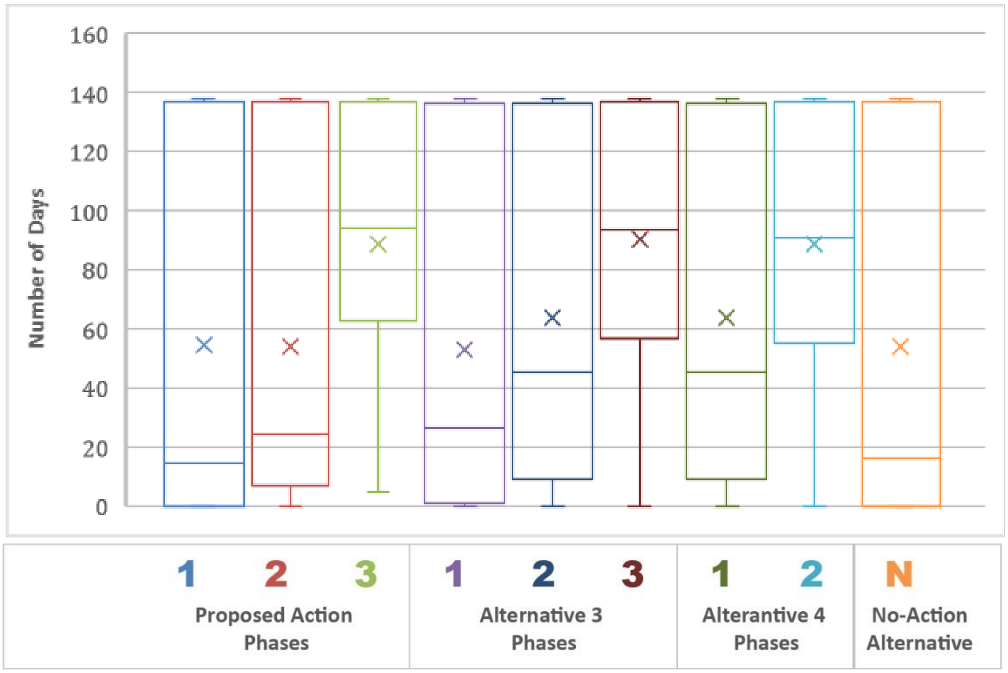


Figure 37. Boxplot of Siphon2COID.Outflow Day Count for 900 cfs during Overwintering



Effects

Emergent Vegetation

All alternatives differ from the historical flow regime in the Upper Deschutes by prescribing greater minimum flows during the winter and resulting in lower maximum flows during the summer than were observed on average prior to operations prescribed under the Deschutes Project BiOp (U.S. Fish and Wildlife Service 2017, 2019). Emergent vegetation would be expected to respond to changes in flow regime by tracking the seasonal inundation patterns and colonizing areas that were historically unavailable because they were too deeply inundated for vegetation to become established during the growing season due to the high summer inundation patterns along the Upper Deschutes.

The RiverWare model outputs indicate:

Among the alternatives, inundation of wetland vegetation during the growing season would be based on the highest median flows under the no-action alternative, lower but more stable flows under the proposed action, and lowest flows under Alternative 3 and Alternative 4 (Figure 31). This means that emergent vegetation would be supported up to the highest topographical or elevation level under the no-action alternative, lower and more stable elevation under the proposed action, and lowest elevations under Alternatives 3 and 4.

Emergent vegetation would track the flow inundation patterns to colonize areas that would become available during the growing season at the lower elevations. The areas that would become available were historically too deeply inundated for vegetation to become established during the growing season. The total area covered by emergent vegetation would not necessarily change, but the topographical elevation where wetland vegetation is supported by water would be at the lowest elevations as flows would be reduced during the growing season under full implementation of the proposed action, Alternative 3, and Alternative 4. Along the river channel, vegetation would be expected to colonize areas lower in the channel profile. Individual Oregon spotted frog sites would respond variably depending on individual site topography, substrate characteristics, and dependence on the river as a water source. Conservation Measure UD-1 provided under the proposed action, Alternative 3, and Alternative 4 could be used to fund efforts to enhance riparian and wetland vegetation.

Invasive Species

Reed canarygrass is already well established in the study area. Although its site-specific distribution would be expected to change by tracking water inundation elevation patterns during the growing season, it would be expected to persist throughout the study area under all alternatives. The proposed action, Alternative 3, and Alternative 4 include Conservation Measure UD-1, which could support control of this invasive species.

The more stable hydrograph under the proposed action, compared to the no-action alternative, would be more likely to improve conditions for bullfrogs by providing year-round inundation of wetlands.[7] More stability in the hydrograph would also be more likely to improve conditions for nonnative fish species such as brown bullhead catfish, brown trout, and three-spined sticklebacks known to prey on Oregon spotted frogs. However, Conservation Measure UD-1 could be used to fund bullfrog control measures or address nonnative fish species.

Oregon Spotted Frog

Pre-breeding (March 1–March 31; 31 days)

- From the day count data derived from the RiverWare model, the later phases of the proposed action, Alternatives 3, and 4 result in more days of inundation at 900 cfs than the no-action alternative.
- From the hydrographs (Figure 31), during the pre-breeding period, sites would begin to experience the ramp-up in flows from the winter minimum to the beginning of the breeding season. Phase 1 of the proposed action is similar to the no-action alternative, but later implementation phases of the proposed action experience smaller overall increases in flow during this ramp-up than under the no-action alternative. Alternatives 3 and 4 experience the reduced ramp-up change in flow faster during their implementation than the proposed action.

Breeding (April 1–April 30; 30 days)

- During the breeding season, sites experience slightly more days of higher flows, above the flow threshold of 1,200 cfs, under the no-action alternative than under any of the implementation phases of the proposed action, Alternative 3, or Alternative 4 (Figure 33). Wetland vegetation inundation provides substrate and cover for egg masses.
- From the hydrographs (Figure 31), sites within the reach would experience the largest change (increase) in flow under the no-action alternative as flows ramp up from the winter minimum at the onset of the irrigation season around April 1. Smaller changes in flow and associated water

[7] Bullfrogs require permanent wetland habitat to reproduce as tadpoles typically overwinter and metamorphose during their second year.

levels improve conditions for Oregon spotted frogs because there is less chance of displacing egg masses. Flows consistently show a decrease for the proposed action, Alternative 3, and Alternative 4 during the month of April when compared to the no-action alternative.

The proposed action, Alternative 3, and Alternative 4 would provide a smaller ramp-up in flow in the spring than the no-action alternative. Alternative 3 would reach this condition more quickly than the proposed action, and Alternative 4 would reach this condition more quickly than either the proposed action or Alternative 3.

Rearing (April 15–August 31; 139 days)

- The no-action alternative consistently provides more days at higher flows (exceeding 1,200 cfs) that inundate vegetation during the rearing period than all other alternatives (Figure 34). Inundated vegetation provides cover for developing tadpoles and juvenile or adult frogs.
- From the hydrographs (Figure 31), beginning in early- or mid-July through early August, the proposed action, Alternative 3, and Alternative 4 experience a decrease in flow and more year-to-year variability compared to the no-action alternative. Although this reach is downstream of two major diversions and it experiences loss to ground water, Conservation Measure WR-1 (E) of the proposed action still appears to influence the pattern of flows during rearing by stabilizing them around 1,100 cfs (median flow) until early September. This pattern becomes more pronounced during phase 3 of the proposed action and flows are much more stabilized compared to the no-action alternative and Alternatives 3 and 4.

Although the no-action alternative presents greater year-to-year stability, the proposed action is likely to be more stable over the course of the entire rearing season. Therefore, wetland vegetation may respond more effectively under the proposed action to the consistently lower flows by colonizing topographically lower sites along the river.

The no-action alternative would outperform the fully implemented proposed action, Alternative 3, and Alternative 4 in amount of flow available during rearing, but the proposed action provides greater stability at its full implementation.

Pre-winter (September 1–October 15; 45 days)

- The count of days when flows exceed 900 cfs are slightly greater under phase 1 of the proposed action when compared to the no-action alternative, Alternative 3, and Alternative 4 (Figure 35).
- From the hydrographs (Figure 31), flows modeled for the proposed action, Alternative 3, and Alternative 4 experience a similar decrease in flow through the pre-winter season, although the decrease is least under Alternative 4. The no-action alternative experiences a larger decrease as flows are greater at the end of the rearing season and less during the overwintering period for this alternative compared to the others. The smaller change in water inundation elevation under the proposed action, Alternative 3, and Alternative 4 could prevent abrupt stranding of frogs as they migrate to overwintering sites.
- The proposed action includes Conservation Measure WR-1 (J), which limits the speed of the fall ramp-down to result in a more gradual step down of flow at the BENO gauge. This pattern is still evident in the hydrographs modeled for this reach. Maintenance of inundation during rearing under Conservation Measure WR-1 (E) and then a slow ramp down to overwintering flows

would facilitate frog movement to overwintering sites during the pre-wintering period most effectively under the proposed action.

- Lower flow conditions late in the rearing season are more common under Alternative 3 and Alternative 4 than under the proposed action, and less common under the no-action alternative.
- The proposed action and Alternatives 3 and 4 include Conservation Measure UD-1, which is lacking from the no-action alternative.

The change in inundation level would be less drastic under the proposed action and Alternative 3 and even less so under Alternative 4 compared to the no-action alternative. The less drastic change in water inundation elevation may prevent abrupt stranding of frogs as they migrate to overwintering sites. The no-action alternative lacks Conservation Measure UD-1, which would fund activities to restore and maintain habitat to benefit the covered species within the Upper Deschutes Basin, including Oregon spotted frog. For these reasons, the proposed action, Alternative 3, and Alternative 4 would outperform the no-action alternative.

Overwintering (October 16–March 1; 137 days)

- Flows reach the 900 cfs threshold more often under the fully implemented proposed action, Alternative 3, and Alternative 4 when compared to the no-action alternative (Figure 37).
- Flows regularly exceed the 500 cfs threshold under all alternatives (Figure 36).
- From the hydrographs (Figure 31), flows under the proposed action, Alternative 3, and Alternative 4 steadily exceed the amount of flow under the no-action alternative throughout the overwintering season. The proposed action is similar to the no-action alternative during phase 1 of implementation, and it progresses more slowly to higher winter flows than either Alternative 3 or Alternative 4. Higher flows could result in more consistently wetted overwintering sites and shorter distances for frogs to travel between breeding and overwintering locations.

At full implementation, the proposed action and Alternative 3 provide higher sustained water levels throughout the overwintering period than the no-action alternative. Fully implemented Alternative 4 provides the highest sustained water elevation, which could protect overwintering Oregon spotted frogs. Full implementation of Alternative 4 would outperform the other alternatives.

Summary Conclusion

Table 9 summarizes the overall results of this comparison of each alternative to the no-action. The proposed action, Alternative 3, and Alternative 4 provide the best conditions for Oregon spotted frogs except during rearing when the no-action alternative provides the most days of inundation, and the proposed action provides more stability.

Reaches CLD-3 through CLD-6: Crescent Creek

Crescent Creek contains five known breeding sites for Oregon spotted frogs. All of these locations are at least 5 miles downstream from Crescent Lake. As explained in the Deschutes Project BiOp (2017), it remains unclear the extent of influence Crescent Lake operations have on Oregon spotted frog habitat in Crescent Creek and along the Little Deschutes River downstream of the Crescent Creek confluence, although there is a notable influence in the fall at the onset of the storage season. This uncertainty is due to large flow inputs from other unregulated sources such as Big Marsh Creek which flows into Crescent Creek, and the Little Deschutes River upstream from its confluence with Crescent Creek. Oregon spotted frog habitat is located along Crescent Creek downstream from Big Marsh Creek and along the Little Deschutes River.

From the Deschutes Project BiOp (2017), there are not clearly determined flow thresholds known to support high quality Oregon spotted frog habitat conditions. The analysis relied on the modeled hydrographs for the comparative assessment of the alternatives. The CREO gauge is located on Crescent Creek just downstream from Crescent Lake.

RiverWare Results

Figure 38 depicts daily flow hydrographs generated for the CREO gauge flows using RiverWare for the no-action alternative and the proposed action, Alternative 3, and Alternative 4. RiverWare results from this gauge do not account for the unregulated sources of water that enter Crescent Creek below this location (e.g., Big Marsh Creek), but they provide a means to relatively compare the alternatives to the no-action alternative. RiverWare results also do not fully account for water management that would occur under Conservation Measure CC-1 of the proposed action. The potential effects of such management are described in the effects section, below.

Pressure Transducer Data

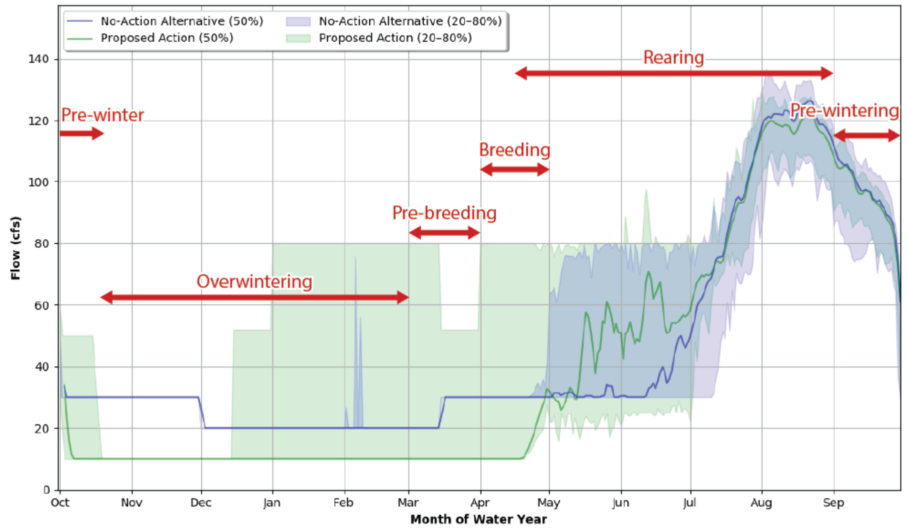
Pressure transducer data collected in Crescent Creek and in the Little Deschutes River near La Pine, OR during 2015 were used to capture the relationship between flow and water surface elevations in this system under operational conditions similar to the no-action alternative (R2 Resource Consultants and Biota Pacific 2016). There was a minimum instream flow of 30 cfs in Crescent Creek from October through January, and irrigation water was released from late June through October.

Water Management

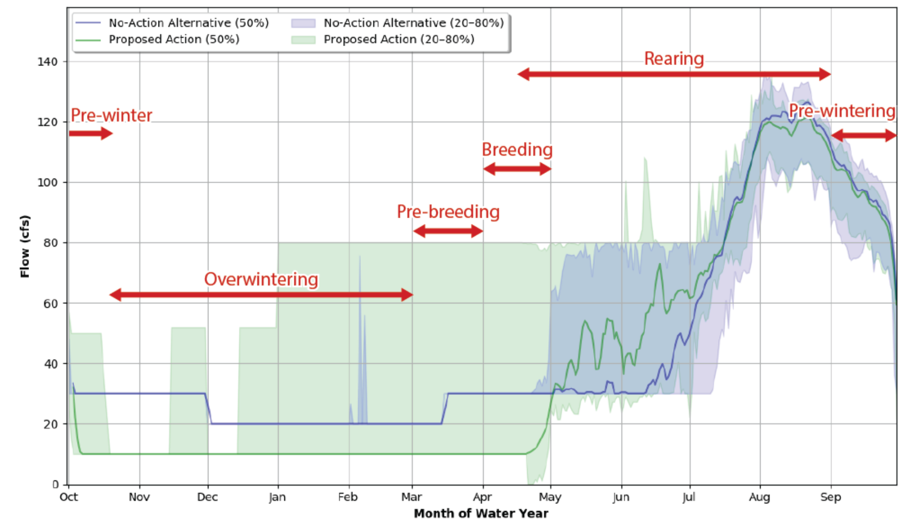
The proposed action includes Conservation Measure CC-1, which sets aside a portion of the water stored in Crescent Lake Reservoir to be used specifically to benefit Oregon spotted frogs. This storage would be used to manage flows in Crescent Creek to maintain or increase winter minimum flow levels, increase instream flow levels in spring, or delay and draw out the ramp-down of irrigation releases in the fall. Conservation Measure CC-1 is analyzed as part of the proposed action. Neither the no-action alternative nor the other action alternatives (Alternative 3 or Alternative 4) include this conservation measure.

Figure 38. Crescent Creek Flow Modeled Using RiverWare at CREO Gauge under Proposed Action, Alternative 3 and Alternative 4 Compared to No-Action Alternative

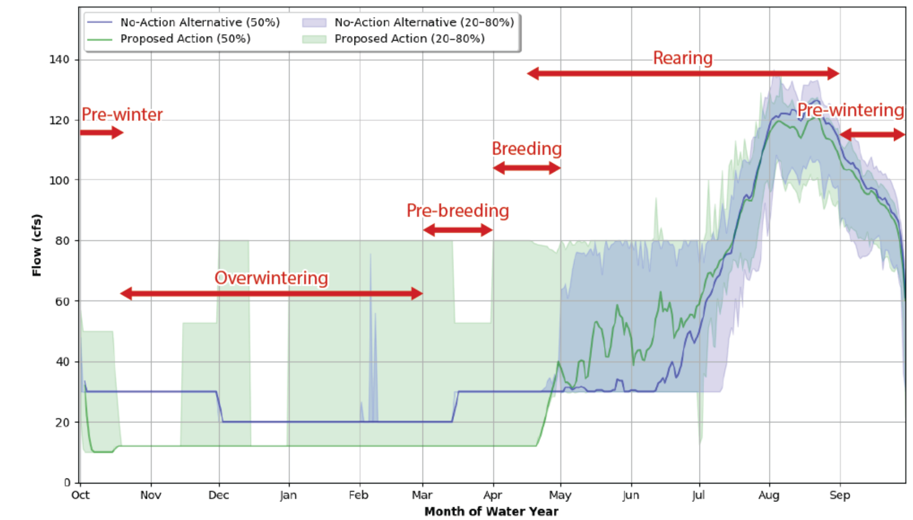
Proposed Action, Years 1–7



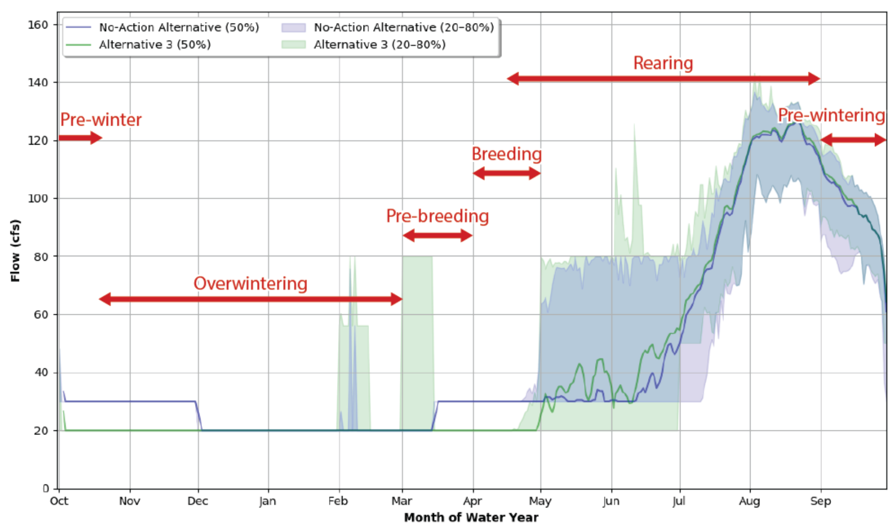
Proposed Action, Years 8–12



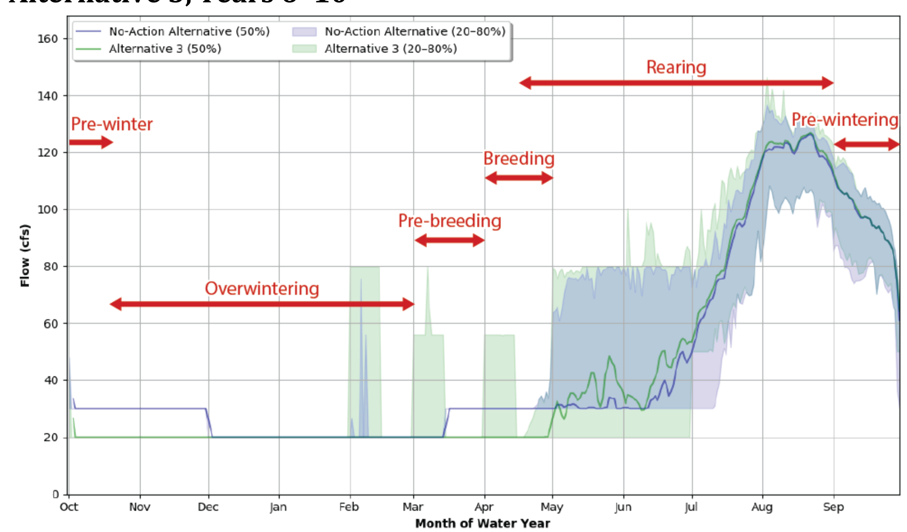
Proposed Action, Years 13–30



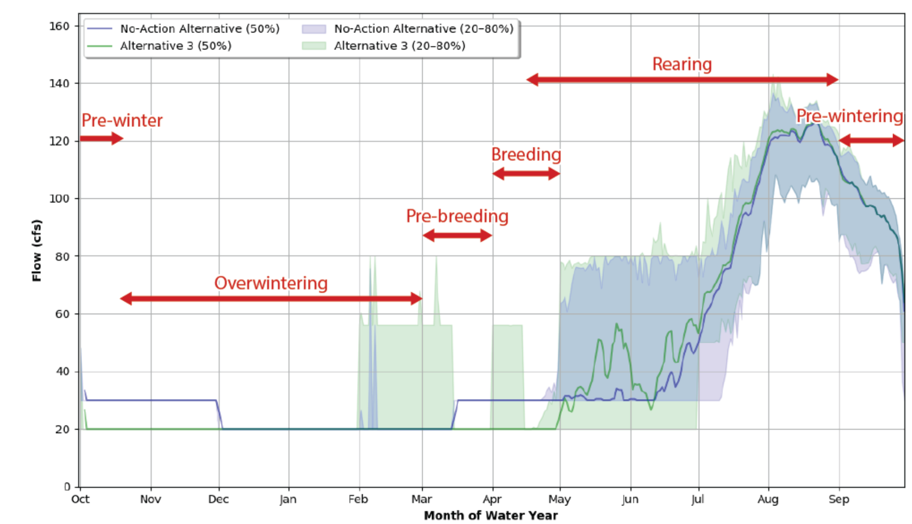
Alternative 3, Years 1–5



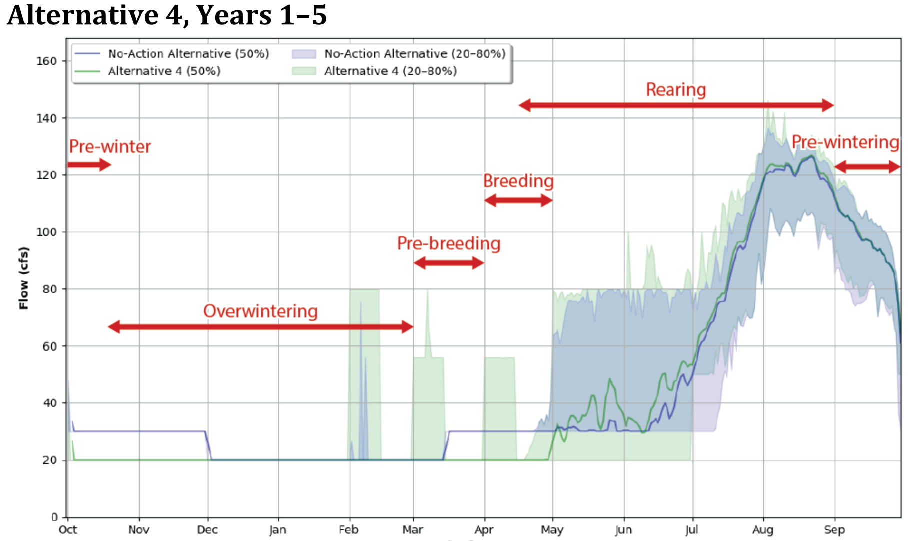
Alternative 3, Years 6–10



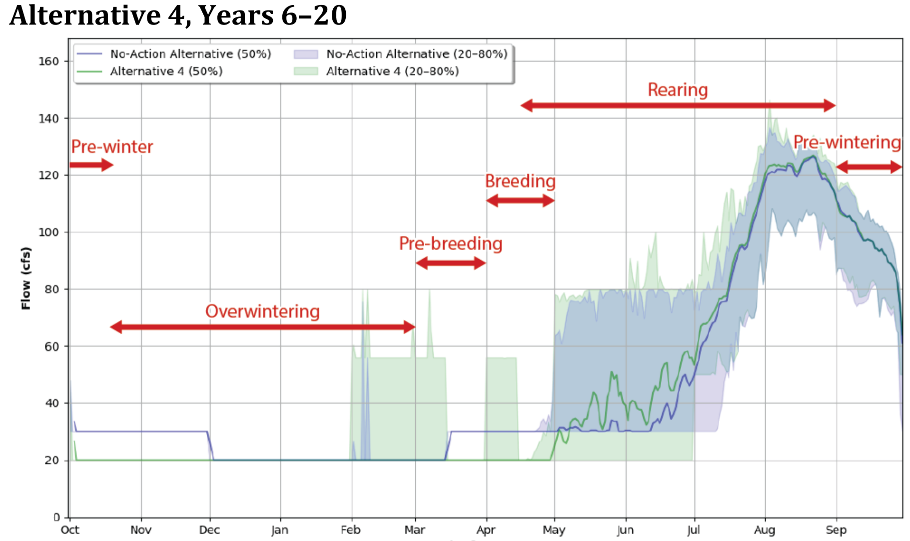
Alternative 3, Years 11–30



Alternative 4, Years 1–5



Alternative 4, Years 6–20



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Effects

Water Management: OSF Storage Account

Under Conservation Measure CC-1, water would be set aside each year from the Crescent Lake Reservoir storage to affect flows in Crescent Creek and the Little Deschutes River downstream from its confluence with Crescent Creek. This "OSF storage" is to be used specifically to benefit Oregon spotted frogs and its volume would increase over the lifetime of the proposed action. Four phases of increasing OSF storage do not precisely track the three phases of overall proposed action implementation, but instead follow the timeline outlined in Conservation Measure CC-1 and shown in Table 8.

Table 8. Storage for Oregon Spotted Frog under Conservation Measure CC-1 of the Proposed Action

	Volume of Crescent Lake Reservoir Storage (acre-feet) to be Available for Oregon Spotted Frog Conservation[a]		
Implementation Phases under Proposed Action	When Total Storage Volume[b] on July 1 is <45,000 acre-feet	When Total Storage Volume[b] on July 1 is 45,000–75,000 acre-feet	When Total Storage Volume[b] on July 1 is >75,000 acre-feet
1–10	5,264	7,264	8,764
11–15	6,464	8,464	9,964
16–20	7,664	9,664	11,164
21–30	8,864	10,864	12,364

[a] Crescent Lake Reservoir storage volumes available for Oregon spotted frog conservation as per this conservation measure shall not exceed the greater of the values stated in this table or the Crescent Creek fish and wildlife storage right in effect at the time.

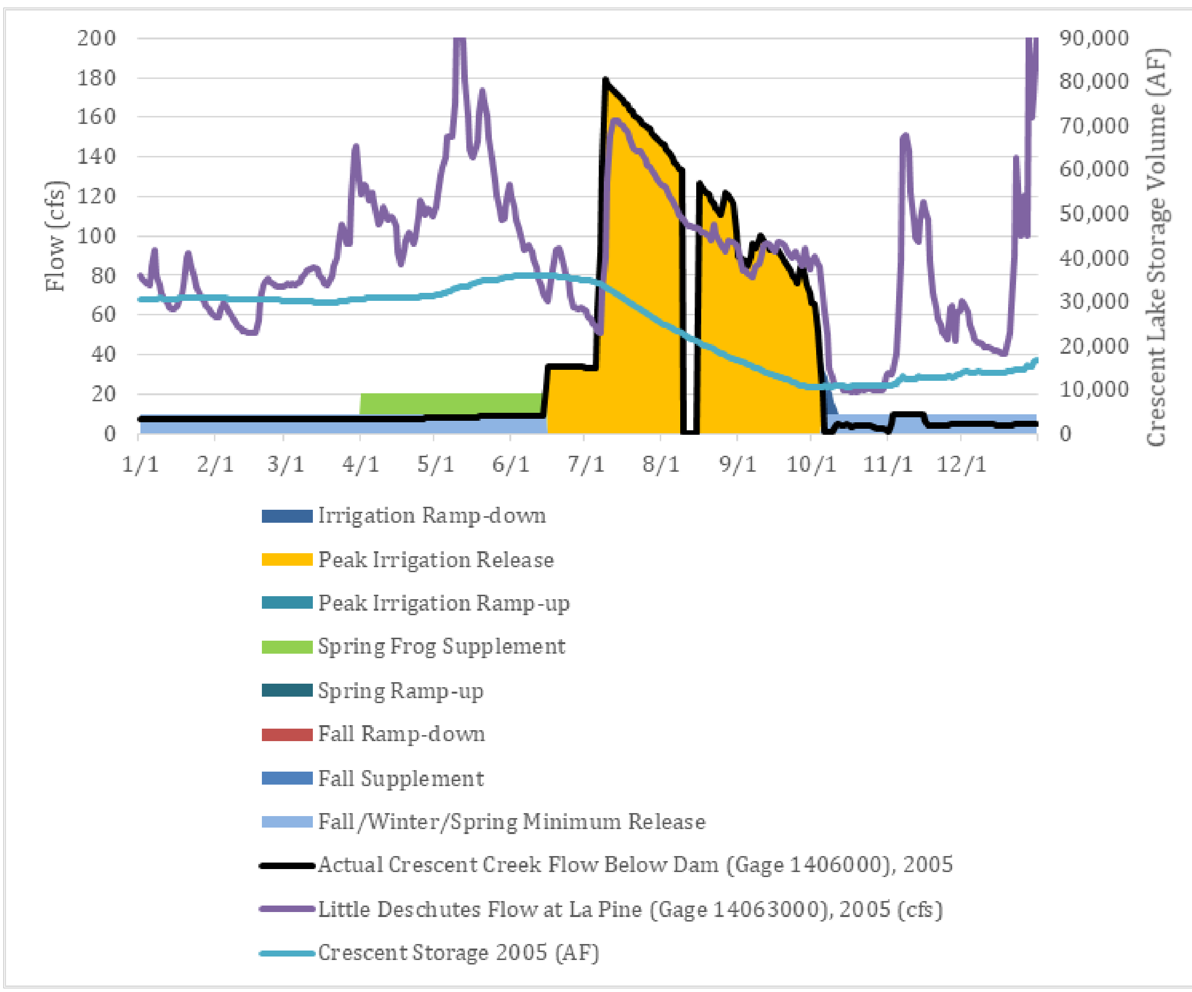
[b] Total storage volume will be measured at Hydromet Station CRE (OWRD Gauge 14059500) as the 3-day average for June 29–July 1 to reduce the effects of wind-induced fluctuations in storage volume readings at the gauge.

Each year, the OSF storage volume available for the following water year would be set depending on the phase of the proposed action and on the storage volume detected in Crescent Lake Reservoir as of July 1. OSF storage would first be used to fulfill the minimum winter flow in Crescent Creek during the overwinter and spring seasons (October 1 through June 30). After fulfilling the minimum winter flow, any remaining OSF storage can be used to manage flows in Crescent Creek to further increase winter flows, increase instream flow levels in spring, or delay and draw out the ramp-down of irrigation releases in the fall. Neither the no-action alternative nor the other alternatives (Alternative 3 or Alternative 4) include this conservation measure.

A tool was developed for this analysis to help visualize how the OSF storage can be used to benefit Oregon spotted frogs. Figure 39 uses the historical flow data from 2005, which was a dry year for Crescent Creek, to depict how the OSF storage releases could be applied under the proposed action to improve conditions for the species under a similar dry-year scenario. The black line tracks the historical Crescent Creek flow measured below the dam in 2005. During 2005, the irrigation season, depicted in gold, began on June 16 and continued through October 4. Note, there are some missing data during the middle of the irrigation season; the brief drop to zero flow is an error. The figure also demonstrates the effect of irrigation water management in Crescent Creek on the Little Deschutes River during a dry year. Historical flow measurements from the LAPO gauge are noticeably influenced by the irrigation releases in a dry year. This pattern is less obvious during wetter years when Crescent Creek accounts for a much smaller percentage of the flow in the Little Deschutes.

In a hypothetical scenario under the proposed action, OSF storage could be allocated as follows. Its primary use would be to hold the winter minimum flows at between 10 and 12 cfs, depending on the phase of implementation. During the first 10 years, the initial phase of implementation for Conservation Measure CC-1 under the proposed action, in a dry year the winter minimum flow would require most of the available OSF storage. In the 2005 historical example the winter minimum flow accounts for 5,038 af of the total 5,264 af available during a dry year. In later years of implementation, or during wetter year scenarios, more water would be added to the OSF storage, ranging from the 5,264 af available during the first 10 years and in a dry year, up to 12,364 af in years 21 through 30 of the permit term during a wet year. This additional OSF storage could be used to step up the spring flow during the breeding or rearing season to inundate wetlands earlier than would otherwise occur (green-colored spring frog supplement in the figure). It could also be used to draw out the ramp-down that normally occurs at the end of the irrigation season, during the frog pre-winter period (dark blue fall supplement on the figure). This would improve conditions for frogs and facilitate movement to overwintering locations. The potential effects of the proposed action's OSF storage water are summarized for each life history period, below.

Figure 39. Performance of OSF Storage Flows in Crescent Creek during a Dry-Year Scenario



Pre-breeding and Breeding Periods (March 1–April 30; 61 days)

- During the last half of March, the no-action alternative provides approximately 10 cfs more flow than Alternative 3, or Alternative 4, and between 18 and 20 cfs more than the proposed action. As modeled using RiverWare, the more gradual step-up in flow under the no-action alternative may aid movement of frogs from overwintering sites to breeding locations compared to the proposed action, Alternative 3, and Alternative 4.
- There is little difference among all alternatives during the breeding season (Figure 38).
- The RiverWare results do not account for spring water management. OSF storage could be applied to increase flows from the overwinter minimum earlier in the season than would otherwise occur at the beginning of the irrigation season (as modeled). Supplemental water in the spring could inundate breeding sites earlier in the season and aid movement of frogs from overwintering locations to breeding sites.

Rearing Period (April 15–August 31; 139 days)

- Based on the hydrographs produced by RiverWare, the proposed action, Alternative 3, and Alternative 4 consistently experience slightly more water in the system throughout the rearing period, especially early in the period, compared to the no-action alternative, therefore, sites closely associated with the creek hydrology would sustain more wetted area over the growing season, and possibly more habitat (Figure 38).
- Under the proposed action, OSF storage could be used to enhance rearing habitat prior to release of irrigation flows from Crescent Dam, which may not occur until as late as July 1 during some years.

Pre-winter (September 1–October 15; 45 days)

- The RiverWare results (hydrographs, Figure 38) indicate a larger pre-winter reduction in flow for the proposed action, and Alternatives 3 and 4 compared to the no-action alternative, with the largest drop in flow occurring under the proposed action.
- The RiverWare results do not account for fall water management. OSF storage could be applied under the proposed action to lengthen the time of the ramp down from irrigation flows to the overwinter minimum flow. The less abrupt change in flows under the proposed action may prevent abrupt stranding of frogs as they migrate to overwintering sites.

Overwintering (October 16–March 1; 137 days)

- The RiverWare results (hydrographs, Figure 38) indicate a reduced minimum outflow of between 10 and 12 cfs under the proposed action and 20 cfs under Alternative 3 and Alternative 4 compared to 30 cfs under the no-action alternative during the early and late overwintering period, and 20 cfs during the middle of the overwintering period. The 30 cfs flow volume was intended under the no-action alternative to benefit Oregon spotted frogs by maintaining more water in the system prior to the arrival of winter rains in the fall.
- RiverWare modeling includes the instream minimum flows but it does not account for other water management that could occur under the proposed action using the OSF storage. Based on

annual conditions, OSF storage could be used to increase minimum winter flows to offset the effects of late or no arrival of fall or winter precipitation.

Emergent Vegetation

Emergent vegetation would be expected to respond to changes in flow regime by tracking the seasonal inundation patterns as they overlap with the growing season.

The RiverWare model outputs indicate the following:

- Among the alternatives, inundation patterns during the early growing season would be based on the highest flows under the proposed action, lower flows under Alternative 3 and Alternative 4, which are roughly equivalent, and lowest under the no-action alternative (Figure 38 [hydrographs]). Inundation levels would be roughly equivalent among all alternatives later in the growing season. Because the inundation patterns vary only slightly among the alternatives during the majority of growing season, the distribution of emergent vegetation would not be expected to change dramatically under any of the alternatives.

Conservation Measure UD-1 provided under the proposed action, Alternative 3, and Alternative 4 could be used to fund efforts to enhance riparian and wetland vegetation.

Invasive Species

Reed canarygrass is already well established in the study area. Although its site-specific distribution would be expected to change by tracking water inundation elevation patterns during the growing season, it would be expected to persist throughout the study area under all alternatives. The proposed action, Alternative 3, and Alternative 4 include Conservation Measure UD-1, which could support control of this invasive species. The less stable hydrograph under the proposed action, Alternative 3, and Alternative 4, compared to the no-action alternative, would be less likely to improve conditions for bullfrogs or for nonnative fish species such as brown bullhead catfish, brown trout, and three-spined sticklebacks known to prey on Oregon spotted frogs.[8] In addition, Conservation Measure UD-1, under the proposed action, Alternative 3, and Alternative 4, could be used to fund bullfrog or nonnative fish species control measures.

Summary Conclusion

Table 9 summarizes the overall results of this comparison of each alternative to the no-action. Based on the RiverWare results, the no-action alternative would outperform all other alternatives during all seasons except rearing; however, the flexible water management made possible by the OSF storage under the proposed action Conservation Measure CC-1 would allow the proposed action to be actively managed to outperform both the no-action alternative and Alternatives 3 and 4. The proposed action, as well as Alternative 3 and Alternative 4, include Conservation Measure UD-1, which could be used to improve habitat conditions throughout the reach.

[8] Bullfrogs require permanent wetland habitat to reproduce as tadpoles typically overwinter and metamorphose during their second year.

Reaches CLD-1 and CLD-2 Little Deschutes River

Oregon spotted frogs are distributed throughout the extent of the Little Deschutes River downstream of its confluence with Crescent Creek (U.S. Fish and Wildlife Service 2017, 2019). There are nine monitored breeding sites within the study area on the Little Deschutes below its confluence with Crescent Creek.

From the Deschutes Project BiOp (2017), there are not clearly determined flow thresholds known to support high quality Oregon spotted frog habitat conditions in the Little Deschutes River. The analysis relied on the modeled hydrographs for the comparative assessment of the alternatives.

RiverWare Results

Hydrographs

Figure 40 depicts daily flow hydrographs generated for the LAPO gauge flows using RiverWare for the no-action alternative and the fully implemented proposed action, Alternative 3, and Alternative 4.

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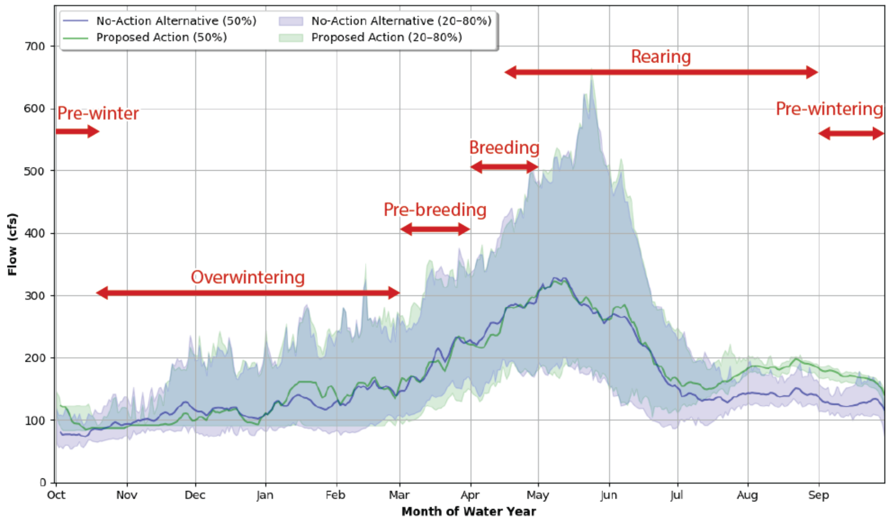
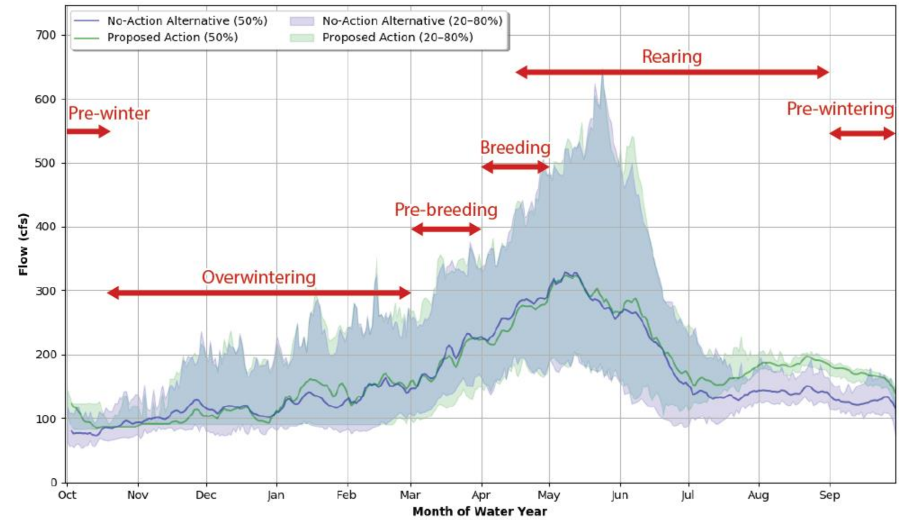
Figure 40. Little Deschutes River Flow Modeled Using RiverWare at LAPO Gauge under Proposed Action, Alternative 3, and Alternative 4 Compared to No-Action Alternative

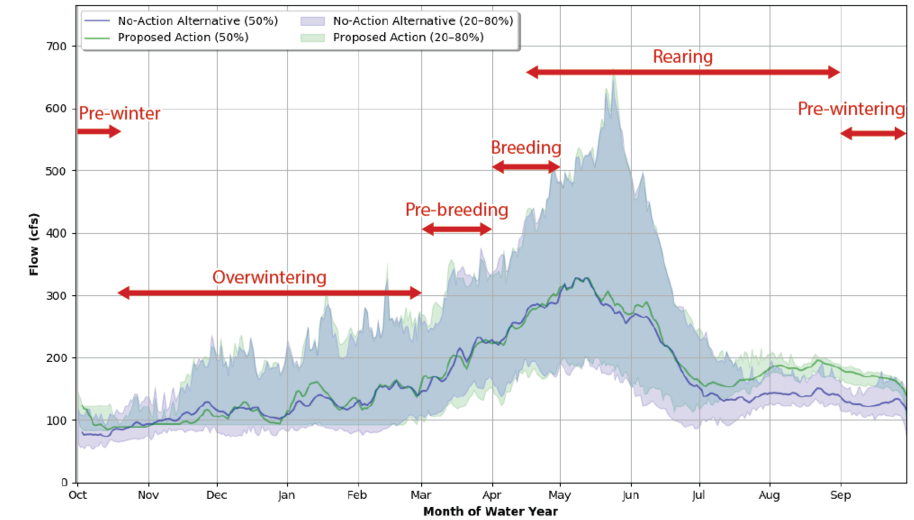
Proposed Action, Years 1–7



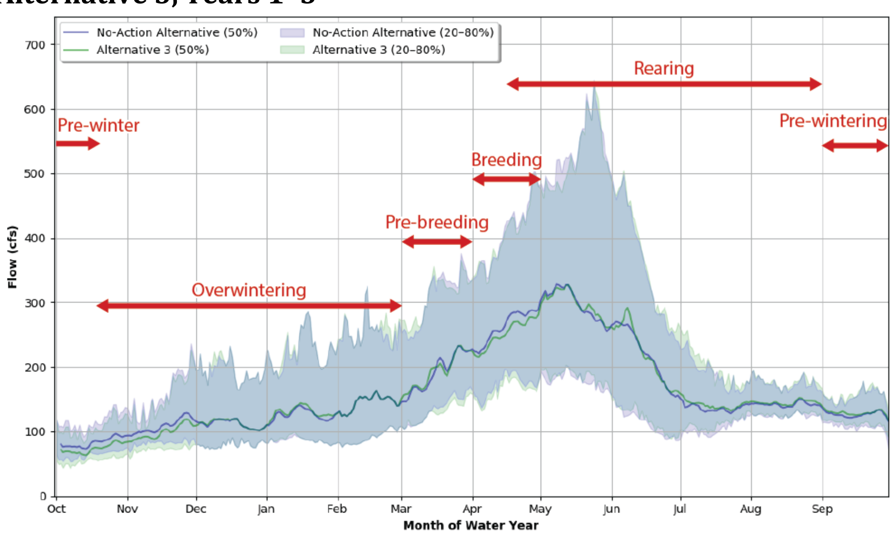
Proposed Action, Years 8–12



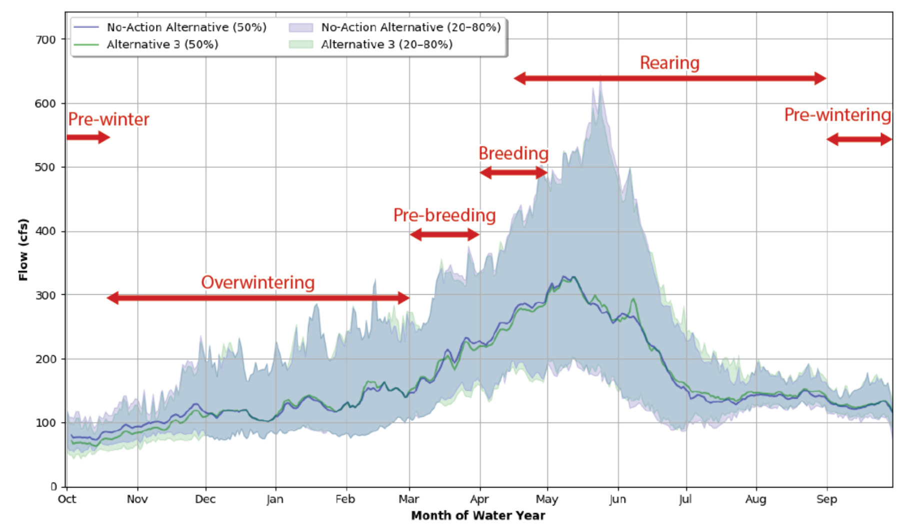
Proposed Action, Years 13–30



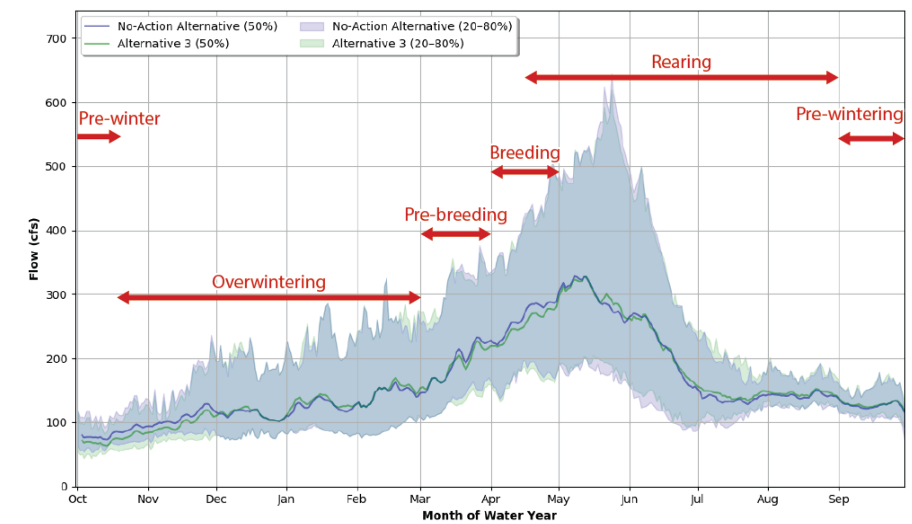
Alternative 3, Years 1–5



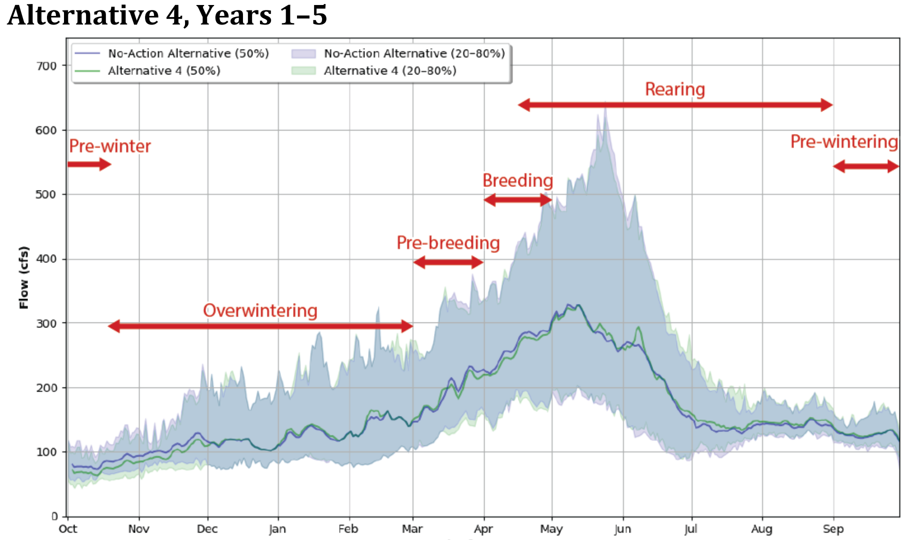
Alternative 3, Years 6–10



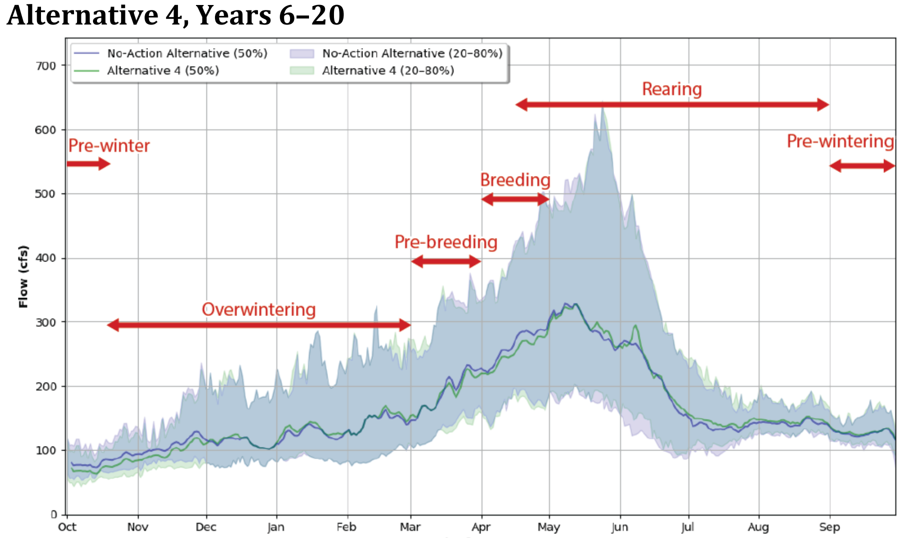
Alternative 3, Years 11–30



Alternative 4, Years 1–5



Alternative 4, Years 6–20



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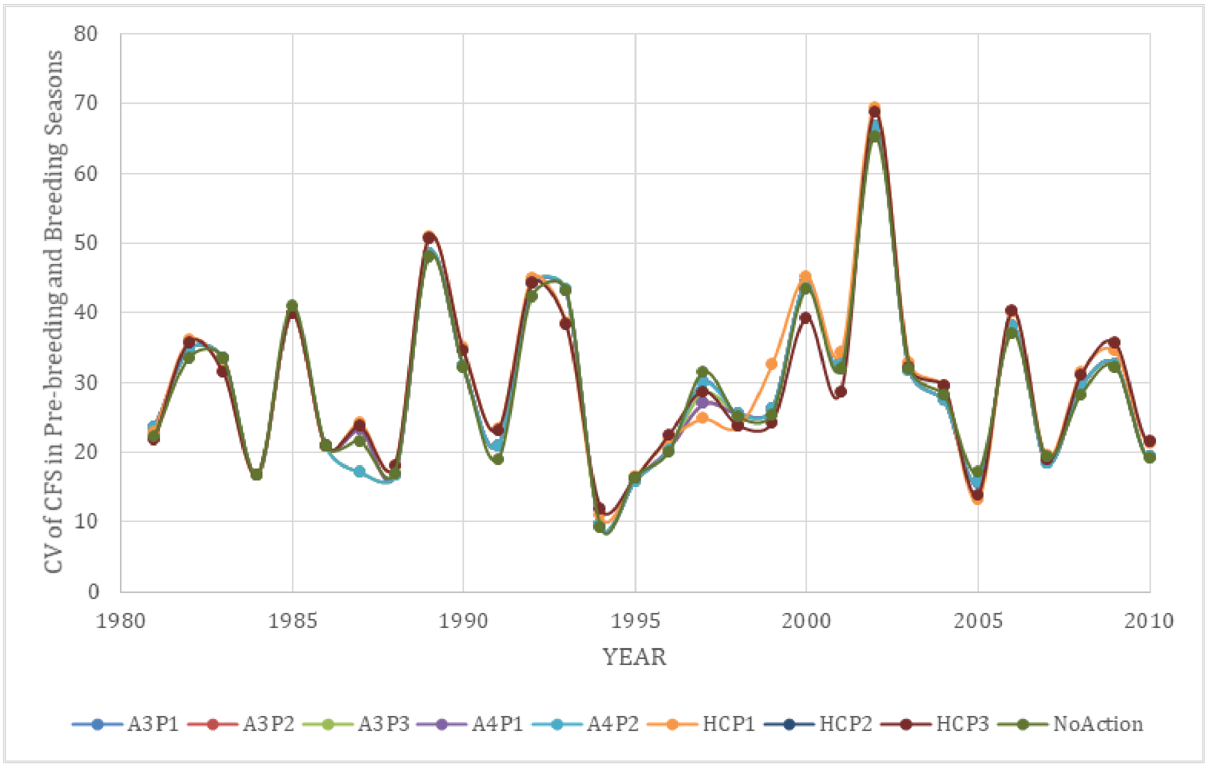
Within-Year Flow Variation

To better understand within-year variation in flow for each alternative, Figure 41 reports the CV during the breeding season. The CV is the standard deviation divided by the average flow and allows us to compare within-year variability among the alternatives. Within-year flow variation is particularly important during the breeding season because the immobile egg masses are the most vulnerable life stage to either desiccation from receding water or displacement and subsequent exposure to deeper water predators.

Figure 41. CV of Within-Year Little Deschutes River Flow Modeled Using RiverWare at LAPO Gauge for Each Alternative during Breeding Season (Proposed Action [HCP] and Alternative 3 [A3] overlap)



Effects

Emergent Vegetation

Emergent vegetation would be expected to respond to changes in flow regime by tracking the seasonal inundation patterns as they overlap with the growing season.

The RiverWare model outputs indicate:

- Inundation patterns during the growing season are similar among the no-action alternative, Alternative 3, and Alternative 4, but flows would remain slightly higher under the proposed action later in the growing season (Figure 40 [hydrographs]). The slight differences in flow among the alternatives would not be expected to result in extensive changes to the distribution of emergent vegetation.[9]

Conservation Measure UD-1 provided under the proposed action, Alternative 3, and Alternative 4 could be used to fund efforts to enhance riparian and wetland vegetation.

Invasive Species

Invasive species such as reed canarygrass, bullfrogs, and nonnative predatory fish would be expected to respond similarly to all of the alternatives because flow regimes do not significantly vary among either any of the alternatives. Conservation Measure UD-1, under the proposed action, Alternative 3, and Alternative 4, could be used to fund control measures for bullfrogs, other nonnative aquatic predators, and reed canarygrass.

Oregon Spotted Frog

Pre-breeding and Breeding Period (March 1–April 30; 61 days)

- There is little difference among all alternatives during the breeding season (Figure 40). Within-year variation is similar among all alternatives (Figure 41), providing equivalent stability in habitat inundation patterns.
- Flows added to the system from the OSF storage volume can influence the Little Deschutes River during low water years. This storage volume under the proposed action could be used to positively affect water inundation patterns at Oregon spotted frog breeding sites that are associated with the Little Deschutes River below the confluence with Crescent Creek.

Rearing Period (April 15–August 31; 139 days)

- There is little difference among the alternatives during the rearing period (Figure 40).
- Under the proposed action, OSF storage could be used to enhance rearing habitat prior to release of irrigation flows from Crescent Dam. The effect would be less pronounced in the Little Deschutes than in Crescent Creek but could be influential during low water years.

Pre-winter (September 1–October 15; 45 days)

- There is little difference among the alternatives during the pre-winter period (Figure 40).
- Flows added to the system from the OSF storage volume under the proposed action could influence the Little Deschutes River during low water years. This means that OSF storage could be used to positively affect water inundation patterns as Oregon spotted frogs move from breeding sites to overwintering locations by reducing the speed of the pre-storage season ramp-down in the fall.

Overwintering (October 16–March 1; 137 days)

- There is little difference among the alternatives during the overwintering period (Figure 40).

[9] See Appendix 3.1-C, *Analysis of RiverWare Model Version 18 Outputs and Implications for Final EIS*, for corrections due to modeling update.

- Flows added to the system from the OSF storage volume under the proposed action could influence the Little Deschutes River during low water years. This means OSF storage could be used to positively affect overwintering habitat conditions by adding to the baseline winter flows.

Summary Conclusion

Table 9 summarizes the overall results of this comparison of each alternative to the no-action alternative. All alternatives perform similarly to each other, as modeled by RiverWare. The proposed action, Alternative 3, and Alternative 4 include Conservation Measure UD-1. In addition, the proposed action has access to the OSF storage volume in Crescent Lake Reservoir.

Summary and Conclusions

This assessment compared the potential effects on Oregon spotted frogs and their habitat of the proposed action, Alternative 3, and Alternative 4 to the no-action alternative.

Table 9 summarizes the reach-specific conclusions, indicating whether each alternative would have a net beneficial effect, and adverse effect, or a mix of beneficial and adverse effects compared to the no-action alternative. Effects are summarized by reach and key life history period.

Based on the assessment, the proposed action appears to offer the most improved conditions for Oregon spotted frogs and their habitat among the alternatives. This is primarily due to water management strategies that can be applied under the proposed action, as well as inclusion of Conservation Measure UD-1.

Table 9. Effects of Hydrological Changes on Oregon Spotted Frog by Key Life History Period under the Proposed Action, Alternative 3, and Alternative 4 at Full Implementation Compared to the No-Action Alternative

	Proposed Action					Alternative 3					Alternative 4				
Reach	**PB**	**B**	**R**	**P**	**O**	**PB**	**B**	**R**	**P**	**O**	**PB**	**B**	**R**	**P**	**O**
CLD-1 and CLD-2 (Little Deschutes River)	BE	BE	NE	BE	BE	AE	NE	NE	NE	NE	AE	NE	NE	NE	NE
CLD-3 through CLD-6 (Crescent Creek)	BE	BE	BE	NE	NE	AE	BE	BE	AE	AE	AE	NE	BE	AE	AE
Des-8a (Central Oregon Diversion to Colorado Street)	BE	BE	BE	BE	BE	BE	BE	AE	BE	BE	BE	BE+	AE+	BE	BE+
Des-9 (Lava Island Falls to Central Oregon Diversion)	BE	BE	NE	BE+	BE	BE	BE	AE	BE	BE	BE	BE+	AE+	BE	BE+
Des-10 (Dillon Falls to Lava Island Falls)	BE	BE	NE	BE+	BE	BE+	BE	AE	BE	BE+	BE+	BE+	AE+	BE	BE+
Des-10a (Benham Falls to Dillon Falls)	BE	BE	NE	BE+	BE	BE+	BE	AE	BE	BE+	BE+	BE+	AE+	BE	BE+
Des-11 (Little Deschutes to Benham Falls)	BE+	BE	BE	BE	BE	BE	BE	AE	BE	BE+	BE+	BE	AE+	BE+	BE+
Des-12 (Fall River to Little Deschutes)	BE+	BE	BE	BE	BE	BE	BE	AE	BE	BE+	BE+	BE	AE+	BE+	BE+
Des-12a (Wickiup Dam to Fall River)	BE+	BE	BE	BE	BE	BE	BE	AE	BE	BE+	BE+	BE	AE+	BE+	BE+
Des-13 (Wickiup Reservoir)	AE	AE	AE	AE	AE	AE	AE	AE	AE	AE	AE+	AE+	AE+	AE+	AE+
Des-14 (Deschutes River between reservoirs)	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Des-15 (Crane Prairie Reservoir)	BE	BE	BE	BE	BE	BE	BE	BE	BE	BE	BE	BE	BE	BE	BE

PB= Pre-breeding; B=Breeding; R=Rearing; P=Pre-winter; O=Overwintering; BE = beneficial effect; AE = adverse effect; NE = no effect; "+" indicates increased level of effect.

References Cited

Printed References

Blouin, Michael S., I. C. Phillipsen, and K. J. Monsen. 2010. Population structure and conservation genetics of the Oregon spotted frog, *Rana pretiosa*. *Conservation Genetics* 11:2179–2194.

Cook, F. R. 1984. *Introduction to Canadian amphibians and reptiles*. National Museums of Canada, Ottawa. 200 pp.

Cushman, K. A., and C. A. Pearl. 2007. A conservation assessment for the Oregon spotted frog (*Rana pretiosa*). U.S. Department of Agriculture Forest Service Region 6, U.S. Department of Interior Bureau of Land Management Oregon and Washington. 46 pp.

Deschutes Basin Board of Control and City of Prineville. 2020. *Final Deschutes Basin Habitat Conservation Plan. Submittal to U.S. Fish and Wildlife Service and National Marine Fisheries Service in Support of Application for Endangered Species Act Section 10 Incidental Take Permits*. Deschutes Basin Board of Control, Madras, OR.

Detweiler, A. J. 2016. *Central Oregon climate and how it relates to gardening. Oregon State University Extension Service*. Available: https://extension.oregonstate.edu/gardening/techniques/central-oregon-climate-how-it-relates-gardening.

Engler, J., and D. C. Friesz. *1998 Draft 1998 Oregon spotted frog breeding surveys, Conboy Lake National Refuge, Klickitat County, Washington*. Unpublished Report. 5 pp.

Gannett, M. W., Lite, K. E., Jr., Morgan, D. S., and Collins, C. A., 2001. *Ground-water hydrology of the upper Deschutes Basin, Oregon: U.S. Geological Survey Water-Resources Investigations Report 00–4162*. 78 p.

Hallock, L., and S. Pearson. 2001. Telemetry study of fall and winter Oregon spotted frog (*Rana pretiosa*) movement and habitat use at Trout Lake, Klickitat County, Washington. Unpublished report to Washington State Department of Transportation and Washington Department of Natural Resources Natural Areas Program. 20 pp.

Hayes, M. P. 1994. The spotted frog (*Rana pretiosa*) in western Oregon. Part I. Background. Part II. Current status. Oregon Department of Fish and Wildlife Technical Report 94-1-01. Unpublished Report.

Hayes, M. P. 1997. Status of the Oregon spotted (*Rana pretiosa* sensu stricto) in the Deschutes basin and selected other systems in the Oregon and northeastern California with a rangewide synopsis of the species' status. Final report prepared for The Nature Conservancy under contract to the U.S. Fish and Wildlife Service, Portland, Oregon. Unpublished Report. 57 pp.

Hayes, M. P., J. D. Engler, S. Van Leuven, D. C. Friesz, T. Quinn, and D. J. Pierce. 2001. Overwintering of the Oregon spotted frog (*Rana pretiosa*) at Conboy Lake National Wildlife Refuge, Klickitat County, Washington, 2000–2001. Final Report to Washington Department of Transportation. June 2001. 86 pp.

Kapust, H. Q. W., K. R. McAllister, and M. P. Hayes. 2012. Oregon spotted frog (*Rana pretiosa*) response to enhancement of oviposition habitat degraded by invasive reed canarygrass (*Phalaris arundinacea*). Herpetological Conservation and Biology 7:358–366.

Leonard, W. P., H. A. Brown, L. L. C. Jones, K. R. McAllister, and R. M. Storm. 1993. *Amphibians of Washington and Oregon*. Seattle Audubon Society, Seattle, Washington. 169 pp.

Licht, L. E. 1971. Breeding habits and embryonic thermal requirements of the frogs *Rana aurora* and *Rana pretiosa* in the Pacific Northwest. Ecology 52: 116–124.

Licht, L. E. 1974. Survival of embryos, tadpoles, and adults of the frogs *Rana aurora* and *Rana pretiosa* sympatric in southwestern British Columbia. Canadian Journal of Zoology 52: 613–627.

McAllister, K. R. and W. P. Leonard. 1997. *Washington State status report for the Oregon spotted frog*. Washington Department of Fish and Wildlife, Olympia. 38 pp.

Nussbaum, R. A, E. D. Brodie, Jr., and R. M. Storm. 1983. *Amphibians and reptiles of the Pacific Northwest*. University of Idaho Press, Moscow.

Oregon Water Resources Department (OWRD). 2019. Near Real Time Hydrographics Data. Accessed at https://apps.wrd.state.or.us/apps/sw/hydro_near_real_time/.

Pearl, C. A., B. McCreary, J. C. Rowe, and M. J. Adams. 2018. Late-season movement and habitat use by Oregon spotted frog (*Rana pretiosa*). Copeia 106: 539–549.

R2 Resource Consultants and Biota Pacific Environmental Sciences. 2016. *Crescent Creek and Little Deschutes River Hydrology Study*. November 2016.

Tattersall, G. J. and G. R. Ultsch. 2008. Physiological ecology of aquatic overwintering in ranid frogs. Biological Reviews 83:119–140.

U.S. Department of Interior Bureau of Reclamation, Arnold Irrigation District, Central Oregon Irrigation District, Lone Pine Irrigation District, North Unit Irrigation District, Tumalo Irrigation District. 2019. *2018 Annual Report. Monitoring Conducted in Compliance with the Incidental Take Statement Issued for the Approval of Contract Changes to the 1938 Inter-District Agreement for the Operation of Crane Prairie and Wickiup Dams and Implementation of Review of Operations and Maintenance and Safety Evaluation of Existing Dams Programs at Crane Prairie and Wickiup Dams.*

U.S. Fish and Wildlife Service. 2017. Biological Opinion: Approval of Contract Changes to the 1938 Inter-District Agreement for Operation of Crane Prairie and Wickiup Dams and Implementation of Review of Operations and Maintenance and Safety Evaluation of Existing Dams Programs at Crane Prairie and Wickiup Dames, Deschutes County, Oregon. September 29. Bend Field Office, Bend, OR.

U.S. Fish and Wildlife Service. 2019. *Reinitiation of Formal Consultation on Bureau of Reclamation Approval of Contract Changes to the 1938 Inter-District Agreement for the Operation of Crane Prairie and Wickiup Dams, and Implementation of the Review of Operations and Maintenance (ROM) and Safety Evaluation of Existing Dams (SEED) Programs at Crane Prairie and Wickiup Dams, Deschutes Project, Oregon (2017–2019)*. July 26. Bend Field Office, Bend, OR.

Vaughn, M. 2019. *Hydrology of Deschutes River Reach 7*. Draft Report. Biota Pacific Environmental Sciences, Inc., April 4, 2019.

Watson, J. W., K. R. McAllister, D. J. Pierce, and A. Alvarado. 1998. Movements, habitat selection, and population characteristics of a remnant population of Oregon spotted frogs (*Rana pretiosa*). Annual Progress Report. Washington Department of Fish and Wildlife, Olympia, Washington. 19 pp.

Watson, J. W., K. R. McAllister, and D. J. Pierce. 2003. Home ranges, movements, and habitat selection of Oregon spotted frogs (*Rana pretiosa*). Journal of Herpetology 37: 292–300.

Zagona, E.A., T.J. Fulp, R. Shane, T.M. Magee, H.M. Goranflo. 2001. RiverWare: A Generalized Tool for Complex Reservoir System Modeling. *Journal of the American Water Resources Association* 37(4), 913–929.

Personal Communications

O'Reilly, Jennifer. Fish and Wildlife Biologist. Bend Field Office. Bend, OR. April 4, 2019—Phone conversation with Wendy Wente, MB&G regarding oviposition at LSA Marsh during 2018.

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Appendix 3.4-C

Fish and Mollusks Technical Supplement

Appendix 3.4-C
Fish and Mollusks Technical Supplement

Introduction

This appendix provides the technical supplement to the EIS for fish and mollusks, excluding Oregon spotted frog (presented in Appendix 3.4-B, *Oregon Spotted Frog Technical Supplement*). It describes the environmental setting, analysis methods, and environmental consequences for covered and non-covered fish and mollusks in the study area. It also includes summaries used to evaluate effects on fish and mollusks that would result from the proposed action and Alternatives 3 and 4 (action alternatives).

Study Area

The study area for fish and mollusks consists of waters where fish and mollusks could be affected under the proposed action and action alternatives. The proposed action and action alternatives would affect the hydrology and water quality of certain streams and reservoirs in the Deschutes Basin. These changes may, in turn, affect the survival and ability of fish and mollusks to complete their life cycle.

The study area for fish and mollusks is illustrated in Figure 1. Table 1 lists the 15 water bodies included in the study area for fish and mollusks.

The descriptions of affected environment and environmental consequences are organized into five geographic areas across the study area:

- Crescent Creek/Little Deschutes
- Upper Deschutes
- Middle Deschutes
- Crooked River
- Lower Deschutes including Trout Creek and Mud Springs Creek

Figure 1. Fish and Mollusks Study Area

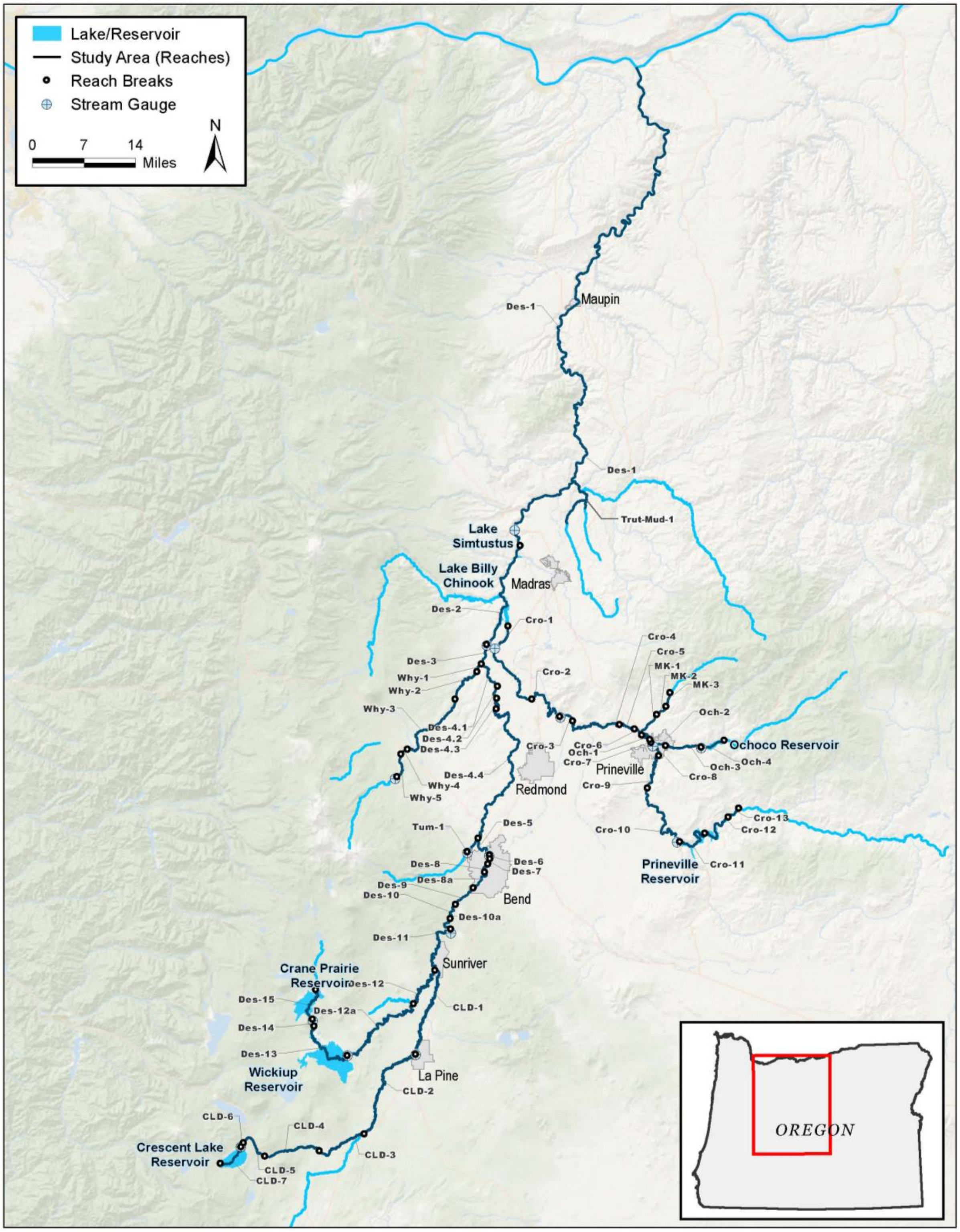


Table 1. Study Area Waterbodies

Geographic Area	Waterbody	Description
Crescent Creek/Little Deschutes	Crescent Lake Reservoir	A large natural body of water that has been increased with an outlet dam to provide irrigation water. In 1922, a small earth and wooden dam was built across the outlet to store water for irrigation via Crescent Creek, Little Deschutes and Deschutes Rivers. In 1956 a 40 foot-high earth and concrete structure was built to raise the reservoir volume. Water volume and elevation often varies dramatically over the year with lowest volumes at the end of the irrigation season in October. Crescent Lake Reservoir has very little riparian or wetland vegetation, some is present in three large embayments (the inflow stream and two slack water areas), these locations have mixed wetland and riparian vegetation.
	Crescent Creek	Tributary to Little Deschutes River; downstream of Crescent Lake Reservoir to the Little Deschutes River. Big Marsh Creek enters downstream of Crescent Lake Reservoir, adding at times significant additional streamflow to Crescent Creek (R2 and Biota Pacific 2016)
	Little Deschutes River	Tributary to Upper Deschutes River; Crescent Creek enters the Little Deschutes at RM 57. Streamflows are largely unregulated as inflows from other sources overwhelm any regulation at Crescent Lake Reservoir.
Upper Deschutes	Crane Prairie Reservoir	A relatively shallow reservoir originally dammed to store irrigation water managed by the Central Oregon Irrigation District. Crane Prairie Reservoir has locally extensive riparian/wetland vegetation on its margins and at its head. The upper limit of potential project effects on the Deschutes River.
	Wickiup Reservoir	A relatively shallow reservoir created to store irrigation water managed by the North Unit Irrigation District. Reservoir volume and elevation often varies dramatically over the year, with the lowest volumes being at the end of the irrigation season in October. The reservoir has little riparian/wetland vegetation but has provided significant sport fishing of several species.
	Upper Deschutes River	The Deschutes River between Crane Prairie and Wickiup Reservoirs, and the Deschutes River from Wickiup Reservoir to city of Bend. Streamflows are strongly influenced by water management at Wickiup Dam. Several tributaries and springs flow into the Deschutes below Wickiup.

Geographic Area	Waterbody	Description
Middle Deschutes	Middle Deschutes River	Deschutes River from Bend to Lake Billy Chinook. The upper section is heavily influenced by irrigation diversions. Groundwater inflows are significant in the lower portion of this section of river.
	Tumalo Creek	A westside tributary that flows into the Middle Deschutes River. Enters Deschutes River upstream of significant groundwater inflow, thus outflow from Tumalo Creek can have an effect on water quality in the Deschutes River during the summer. The Tumalo Diversion, is the upper limit of potential project effects.
	Whychus Creek	A westside tributary that flows into the Middle Deschutes River. Whychus Creek enters downstream of adult salmon and trout migration barriers on the Deschutes River.
	Lake Billy Chinook and Lake Simtustus	Round Butte and Pelton Dam Reservoirs, including the reregulating dam (RM 100).
Lower Deschutes	Lower Deschutes River	Deschutes River from Re-regulating Dam (RM 100) to Columbia River
	Mud Springs and Trout Creek	An eastside tributary that flows into the Lower Deschutes River. Trout Creek enters downstream of Pelton-Round Butte Complex. Steelhead have access to most of Trout Creek and its tributary, Mud Springs Creek. Includes North Unit ID 58-11 and 61-111 irrigation returns.
Crooked River	Prineville Reservoir	A high desert reservoir with large wetland and benches or bars with shrub and herb riparian and wetland vegetation at the upper end and no riparian vegetation at the lower end.
	Crooked River	Bowman Dam (RM 70.5) to Lake Billy Chinook. The upper section (RM 70.5 to 55.9) is in a canyon and supports an important sport fishery on redband trout. Downstream the river flows through broad valley with extensive agriculture. The lower section beginning at about RM 34 is within a canyon and beginning at about RM 7.3 (Osborne Canyon) receives significant groundwater inflow providing high-quality salmonid habitat in the Lower Crooked River
	Ochoco Reservoir and Creek	Tributary to Crooked River at RM 43.9; Ochoco Reservoir is the upper extent of projected effects.
	McKay Creek	Tributary to Crooked River at RM 43.0.

Fish and Mollusks

Table 2 lists the species in the study area that are evaluated in the EIS. Fish and mollusks included are those covered by the Deschutes Basin Habitat Conservation Plan (Deschutes Basin HCP), special-status species, and species that are of cultural and recreational interest. This appendix does not address Oregon spotted frog.

Table 3 lists the geographic extent within the study area by species.

Table 2. Fish and Mollusks Evaluated in the EIS

Taxonomic Group	Species Common Name	Species Scientific Name	Status	Origin
Species covered in the Deschutes Basin Habitat Conservation Plan				
Fish	Bull trout	*Salvelinus confluentus*	FT (FWS) SS	Indigenous
Fish	Steelhead trout	*Oncorhynchus mykiss*	FT (NMFS) SC	Indigenous, anadromous form
Fish	Sockeye salmon	*Oncorhynchus nerka*	NA	Indigenous, anadromous form
Non-covered species evaluated in the EIS				
Fish	Spring Chinook salmon	*Oncorhynchus tshawytscha*	SS	Indigenous
Fish	Redband trout	*Oncorhynchus mykiss*	NA	Indigenous, non-anadromous form
Fish	Kokanee Salmon	*Oncorhynchus nerka*	NA	Indigenous, non-anadromous form
Fish	Summer - fall Chinook salmon	*Oncorhynchus tshawytscha*	SS	Indigenous
Fish	Mountain whitefish	*Prosopium williamsoni*	NA	Indigenous
Non-native Trout	Brook Trout	*Salvelinus fontinalis*	NA	Introduced
Non-native Trout	Brown trout	*Salmo trutta*	NA	Introduced
Native Non-game Fish	Pacific lamprey	*Entosphenus tridentatus*	SS	Indigenous
Native Non-game Fish	Bridgelip sucker	*Catostomus columbianus*	NA	Indigenous
Native Non-game Fish	Largescale sucker	*Catostomus macrocheilus*	NA	Indigenous
Native Non-game Fish	Chiselmouth	*Acrocheilus alutaceus*	NA	Indigenous
Native Non-game Fish	Northern pikeminnow	*Ptychocheilus oregonensis*	NA	Indigenous
Native Non-game Fish	Dace species	*Rhinichthys* (spp.)	NA	Indigenous
Native Non-game Fish	Sculpin species	Family Cottidae	NA	Indigenous
Mollusks	Crater lake tightcoil	*Pristiloma crateris*	NA	Indigenous
Mollusks	Evening field slug	*Deroceras hesperium*	NA	Indigenous
Mollusks	Floater species mussels	*Anodonta* (spp.)	NA	Indigenous
Mollusks	Western pearlshell mussel	*Margaritifera falcata*	NA	Indigenous
Mollusks	Western ridged mussel	*Gonidea angulata*	NA	Indigenous

FT = Federally listed as threatened; SC = Candidate for listing as threatened or endangered on the Oregon state Threatened and Endangered Species List (Oregon Department of Fish and Wildlife 2016); SS = A species listed as an Oregon Sensitive Species (Oregon Department of Fish and Wildlife 2016); NMFS = National Marine Fisheries Service; NA = Not applicable

Table 3. Geographic Extent of Fish and Mollusks in the Study Area

Species Common Name	Crescent Lake Reservoir	Crescent Creek	Little Deschutes	Crane Prairie Reservoir	Wickiup Reservoir	Upper Deschutes	Middle Deschutes	Tumalo Creek	Whychus Creek	Lake Billy Chinook/Lake Simtustus	Crooked River	Prineville Reservoir	Ochoco Creek	McKay Creek	Lower Deschutes
Bull trout							X		X	X	X		X	X	X
Steelhead trout							X		X	X	X		X	X	X
Spring Chinook salmon							X		X	X	X		X		X
Sockeye salmon									X	X	X				X
Redband trout	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Kokanee Salmon	X			X	X				X	X					
Summer/Fall Chinook Salmon															X
Mountain whitefish	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pacific lamprey															X
Largescale sucker	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Bridgelip sucker	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Chiselmouth	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dace species	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Northern pikeminnow										X	X	X			X
Sculpin species	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Brook Trout	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Brown trout	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Crater lake tightcoil	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Evening field slug	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Floater species mussels											X				
Western pearlshell mussel		X	X			X	X	X	X		X		X	X	X
Western ridged mussel							X		X	X	X	X			

*These species exist in perennially wet forested areas or riparian areas potentially throughout the basin.

HCP Covered Fish Species

This section describes extent and life history for the three covered fish species in the Deschutes Basin HCP. Additional information about these species is in Deschutes Basin HCP, Chapter 5, *Covered Species*.

Bull Trout

Bull trout (*Salvelinus confluentus*) were federally listed as threatened on June 10, 1998 (FR 63; 31647), and critical habitat was designated in the study area in September 2005 (70 FR 185; 56212) and revised on September 30, 2010 (U.S. Fish and Wildlife Service 2010, FR 75(200) 63898). The Deschutes Basin is considered a population stronghold for the species. Within the study area there are four known locations with bull trout: Lower Deschutes River, Lake Billy Chinook, Deschutes River above Lake Billy Chinook upstream to Big Falls, the lower Crooked River upstream to Opal Springs Dam and with upstream with passage at Opal Springs Dam the Crooked River upstream of Osborne Canyon to Bowman Dam, and lower Whychus Creek.

The predominant life history type in the study area is a migratory, adfluvial form, where a large body of water (e.g., reservoir) is used by subadults and adults to increase feeding opportunities and accelerate growth. Adfluvial bull trout in the study area use Lake Billy Chinook where they forage for prey in shallow areas of the reservoir. Bull trout occupy deep areas of the reservoir where water temperatures are cool (7–12 degrees Celsius [°C] [45–54 degrees Fahrenheit [°F]) and move to the surface when surface water temperatures drop to or below 12 °C (54 °F). At other times of the year, these fish may move upstream to forage in the lowermost portions of the Crooked River where water temperatures are cool from substantial groundwater inflow and the middle and upper Crooked River during the winter, Deschutes River, or Whychus Creek.

Bull trout require cold water temperatures, complex stream habitat, connectivity between spawning and rearing areas, and downstream foraging, migration, and overwintering habitats (U.S. Fish and Wildlife Service 2015a). Water temperature is typically the primary limiting habitat characteristic, with temperatures above 15 °C (59 °F) limiting bull trout distribution (Batt 1996; McCullough et al. 2001). Such temperatures are only found in the uppermost reaches of headwater streams during summer months, or in spring fed systems like the Metolius River.

Steelhead Trout

Middle Columbia River (MCR) steelhead (*Oncorhynchus mykiss*) Distinct Population Segment (DPS) were listed as threatened by NMFS in March 1999 (FR 64:4517) and reaffirmed in January 2006. Final critical habitat designation was published in September 2005, with an effective date of January 2006 (FR 70:52360). Steelhead critical habitat downstream of the Pelton-Round Butte Complex is included in this listing. Efforts are currently underway to reintroduce steelhead upstream of the complex and steelhead in the Deschutes Basin upstream of the complex is designated an experimental population under the Endangered Species Act (ESA) and is subject to different protections under ESA.

Steelhead were historically present upstream of the Pelton-Round Butte Complex to Big Falls (river mile [RM] 132) on the Deschutes River, in the Crooked River and tributaries, and throughout Whychus Creek. Multiple fish passage barriers blocked steelhead migration to the upper basin. Migration barriers in the Crooked River Watershed are in Ochoco Creek (RM 10) and at Bowman

Dam (RM 70.5) on the Crooked River. Fish passage facilities were added at Opal Springs Dam (RM 7.2) on the Crooked River in November 2019 providing volitional upstream passage. The Deschutes Reintroduction and Conservation Plan (Oregon Department of Fish and Wildlife and Confederated Tribes of Warm Springs 2008) is underway to re-establish steelhead production within the Crooked River Basin up to Ochoco and Bowman dams and in Whychus Creek. Reintroduction efforts are a combination of hatchery stock from the Round Butte Hatchery and adults that originated from natural spawning upstream of the Pelton-Round Butte Complex.

Deschutes River steelhead are the summer-run variety. Adult steelhead enter freshwater during the summer and migrate up the Deschutes River from June through October. Deschutes River steelhead spawn from the middle of March to the end of May (Zimmerman and Reeves 2000). Major limiting factors for the three summer steelhead populations in the Deschutes Basin are degraded floodplain and channel structure, degraded riparian communities, water quality (temperature, chemical contaminants and nutrients), altered hydrology, altered sediment routing, blocked and impaired fish passage, and limited spawning habitat. Land use has been identified as having the most key concerns of any threat category affecting MCR summer steelhead populations (Interior Columbia Technical Recovery Team 2008). Specific threats related to land use include agriculture, grazing, forestry and road maintenance activities that result in impaired upstream and downstream movement of juvenile and adult steelhead, impaired physical habitat quality, impaired water quality due to elevated water temperatures and agricultural chemicals, and reduced water quantity and/or modified hydrologic processes. For the Crooked River, operation of irrigation systems is included as a land use activity that negatively affects summer steelhead by altering seasonal hydrographs and increasing summer water temperatures.

Sockeye Salmon

Anadromous sockeye salmon (*O. nerka*) were historically present in tributaries to the Deschutes Basin upstream of the Pelton-Round Butte Complex. This species was extirpated by tributary passage problems and the construction of Round Butte Dam. Efforts are currently underway to reestablish anadromous sockeye salmon upstream of Pelton-Round Butte in the Metolius River, a tributary not in the study area (Oregon Department of Fish and Wildlife and Confederated Tribes of Warm Springs 2008). Within the study area, sockeye salmon use Lake Billy Chinook for adult migration and juvenile rearing in spring and may also spawn the fall in lower portions of the Crooked River, Whychus Creek, and the Deschutes River upstream of Lake Billy Chinook. Eggs remain in the gravel through the winter.

Sockeye salmon spawn in rivers and streams and in some cases lake beaches. Spawning sockeye typically seek out tributaries to lakes and reservoirs with suitable riffles or areas with smooth flow (Groot and Margolis 1991). Successful sockeye production and survival are dependent on sufficient instream temperature (Bell 1986) and flows for migration, spawning, egg incubation, and juvenile outmigration. In addition, sockeye salmon survival is dependent on stream conditions with minimal siltation, stable stream banks, and overhanging vegetation (Hartman et al. 1962).

Upon emergence from spawning beds sockeye fry migrate to nearby lakes and reservoirs and spend 1 to 2 years before migrating to sea. Sockeye adults return in mid-summer and may hold for short periods in Lake Billy Chinook before continuing to migrate to spawning areas.

Non-Covered Fish and Mollusks

This section describes extent and life history for species not covered in the Deschutes Basin HCP. These species are included in the EIS because of their special status, cultural and recreational significance, and ecological significance.

Spring Chinook Salmon

Deschutes spring Chinook (*O. tshawytscha*) are part of the mid-Columbia spring Chinook Evolutionarily Significant Unit (ESU). This ESU is not listed under ESA.

Spring Chinook salmon are present in the Deschutes River and its tributaries downstream of the Pelton-Round Butte Complex. Historically, they were present upstream of the Complex up to Big Falls on the Deschutes River, which was a natural barrier to migration and spawned in the Deschutes, Crooked, and Metolius Rivers and in lower Whychus Creek (Fies et al. 1996a, 1996b). By 1968 they were extirpated from these areas with construction of the Pelton Round Butte Project completed in 1964.

Reintroduction of spring Chinook salmon above the Pelton-Round Butte Complex is currently underway. The Deschutes Reintroduction and Conservation Plan (Oregon Department of Fish and Wildlife and Confederated Tribes of Warm Springs 2008) is underway to re-establish Spring Chinook production within the Crooked River Basin up to Ochoco and Bowman dams and in Whychus Creek. Reintroduction efforts are a combination of hatchery stock from the Round Butte Hatchery and adults that originated from natural spawning upstream of the Pelton-Round Butte Complex.

Spring Chinook adults enter freshwater during the spring (April through June) and tend to migrate relatively far upstream before they spawn in late summer and early fall. Spring Chinook may also hold through the summer in cooler portions of rivers and streams in deepwater pools before making a final migration to upstream spawning areas. Cool summer water temperatures are critical for adult holding through the summer. In the Crooked River, adult spring Chinook may hold through in the lower river where groundwater inflow maintains cooler temperatures through the summer. These adults may then make a second migration in the fall higher into the Crooked River when water temperatures are cooler and thermal barriers to migration are no longer present. Adult spring Chinook spawn from August to October in accessible areas of the Deschutes River, Whychus Creek, and the Crooked River. Eggs remain in the gravel until spring. Juvenile rearing occurs all months of the year.

Under existing conditions, over 75% of the available habitat in the Upper Deschutes Basin is in river reaches that are inaccessible to fish (Spateholts et al. 2008). Habitat conditions for Chinook salmon in the Lower Deschutes River are not likely to be constrained by flow and temperature conditions due to the relatively stable environment created by controlled water releases. Spawning and rearing habitat for mid-Columbia spring Chinook has been affected by agriculture (water withdrawals, livestock grazing, and agricultural effluents) throughout the range of the ESU, and migration corridors have been affected substantially by hydroelectric development (Myers et al. 1998). The most notable threat to the persistence of the spring Chinook in the Deschutes Basin is the presence of passage barriers that restrict access to historical habitat areas. Water temperatures and degraded habitat are significant stressors affecting spring Chinook. The presumed presence of the fish parasite *Ceratomyxa shasta* in the mainstem Deschutes River below Steelhead Falls (RM 127) and the mainstem Crooked River below the Lone Pine Bridge (RM 24.6) is also a threat to the successful reintroduction underway of spring Chinook salmon in the Upper Deschutes Basin (Oregon Department of Fish and Wildlife and Confederated Tribes of Warm Springs 2008).

Redband Trout

Redband trout (*O. mykiss*) are present in all streams, rivers, and reservoirs of the study area, including downstream of the Pelton-Round Butte Complex. Primary redband trout production areas above Lake Billy Chinook include the mainstem Deschutes River, Tumalo Creek, Whychus Creek, the Metolius River, and the Deschutes River above Crane Prairie Reservoir, Crooked River below Bowman Dam and tributaries to the Crooked River. They appear to be reproductively isolated from steelhead when sympatric.

Redband trout are present in the rivers throughout the study area year-round. They spawn in the spring and early summer; spawning timing varies across the Deschutes River Basin, with peak spawning occurring from January through May in the Upper Deschutes (and March through May in the Lower Deschutes (Zimmerman and Reeves 2000). Redband trout fry may emerge from the gravel from June through August, depending on spawn timing and water temperatures during egg incubation.

Redband trout are often called “desert trout” because they show a greater tolerance for high water temperatures, low dissolved oxygen levels, and extremes in streamflows that frequently occur in desert climates. Instream flow modifications and changes in water quality have the potential to affect redband trout in the study area.

Kokanee Salmon

Kokanee salmon are not listed on the state or federal sensitive species lists. They are a biologically significant species in Lake Billy Chinook, Wickiup Reservoir and Crane Prairie Reservoir, and support a substantial sport harvest in these locations. There historically has been a significant sport harvest of kokanee salmon in Wickiup Reservoir and until recently Wickiup Reservoir kokanee were abundant and sport harvest had very liberal (25 fish) daily catch limits for kokanee.

Kokanee are a non-anadromous (remain in freshwater) life history form of sockeye. They are smaller in size compared with sockeye and reach sexual maturity at 3 years of age. Similar to sockeye, adult kokanee spawn in the fall and die after spawning. Kokanee from Lake Billy Chinook migrate upstream each fall to spawn in the first 2 miles of Whychus Creek (Fies et al. 1996a) and within the tributaries of the Metolius River (Schulz and Thiesfeld 1996). A few fish also spawn in the Crooked River below Opal Springs, the Deschutes River, and other small tributaries (Stuart et al. 1996).

Kokanee eggs hatch in the Metolius River Basin from early December through early February, with emergence occurring from January through April. Most fry migrate downstream to a lake in late March and early April, where they rear for 4 years, at which point they return to their stream and spawn. Successful kokanee production and survival are dependent on sufficient instream temperature (Bell 1986) and flows for migration, spawning, egg incubation, and juvenile outmigration.

Kokanee populations currently exist in the reservoirs of Lake Billy Chinook, Wickiup, Crescent Lake Reservoir, and Crane Prairie. Most kokanee in the Deschutes Basin are associated with Lake Billy Chinook and the Metolius River.)

In the Upper Deschutes kokanee in Wickiup Reservoir migrate and spawn in the short segment of the Deschutes River below Crane Prairie Dam. Due to an unscreened outlet of the reservoir, kokanee are often found immediately downstream in the Deschutes River and as far as Bend, as evidenced by the Central Oregon Irrigation District (ID) fish trap (Fies et al. 1996b). Kokanee in Crane Prairie Reservoir migrate and spawn in the headwaters of the Deschutes River above Crane Prairie.

Summer/Fall Chinook Salmon

The Deschutes River Summer/Fall-run Chinook ESU includes naturally spawning populations of summer/fall Chinook salmon from the Deschutes River downstream of the Pelton-Round Butte Complex. Nehlsen (1995) concluded this life history form occurred in portions of the basin upstream of the Pelton-Round Butte Complex based on historic accounts of Chinook observations at the Pelton Dam trap.

Non-Native Trout Species (Brook and Brown Trout)

Brook *S. fontinalis* and brown trout *Salmo trutta* were introduced into the Deschutes Basin in the early 1900s. Brook trout are now widely distributed thought the Deschutes Basin upstream of the Pelton-Round Butte Complex. Brown trout are found in the Deschutes River mainstem downstream of Crane Prairie Dam, in Wickiup Reservoir, East Lake, Crescent Lake Reservoir, Spring River, Tumalo Creek, and the Fall River. They are also present in the Little Deschutes River Basin, where they occur high in the system above Highway 58 (U.S. Fish and Wildlife Service 2002). These non-native fish compete with native fish, like redband and bull trout, for resources.

Brook trout prefer clear, cool, well-oxygenated streams and lakes. As temperatures rise, they migrate to deeper waters in lakes or reservoirs (Oregon Department of Fish and Wildlife 2018). Brown trout are more tolerant of warm water temperatures that occur downstream of the city of Bend in the summer and low water conditions below Wickiup in the winter. Young brown trout can be found in open riffle waters. As they mature, they prefer deeply undercut banks, log or brush jams, and areas under overhanging stream brush. Both species spawn in the fall and fry would emerge from the gravel from February through March.

Native Non-Game Fish Species

Native non-trout species and non-game species in the study area include, mountain whitefish (*Prosopium williamsoni*), Pacific lamprey (*Entosphenus tridentatus*), Bridgelip sucker (*Catostomus columbianus*), largescale sucker *(C. macrocheilus*), chiselmouth (*Acrocheilus alutaceus*), northern pikeminnow (*Ptychocheilus oregonensis*), and multiple species of dace (*Rhinichthys*) and sculpin (family Cottidae). Except for Pacific lamprey, which is anadromous, these fish have the potential to occur in all life stages in the rivers and reservoirs throughout the study area.

Mountain Whitefish

Mountain whitefish (*Prosopium williamsoni*) are large native game fish found in lakes, reservoirs, and streams with large pools, preferring clear, cold water. Within the study area, mountain whitefish can be found in the Deschutes River mainstream from the headwaters to Lake Billy Chinook, the Crooked River, and in Crane Prairie and Wickiup Reservoirs.

Mountain whitefish spawn November through early December, with eggs hatching 5 months later at temperatures above 35°F. They reach sexual maturity at 3 to 4 years and live up to 8 years.

Mountain whitefish feed on aquatic and terrestrial insects and occasional other fish (NatureServe 2018).

Pacific Lamprey

Pacific lamprey (*Entosphenus tridentatus*) is a federal Species of Concern and is an Oregon sensitive species in the Deschutes Basin. Their historical range has been greatly reduced as they no longer occur above impassable barriers in the West and their numbers have declined thought the Columbia River Basin. Current distribution within the study area is limited to the Deschutes River downstream of the Pelton-Round Butte Complex.

Pacific lamprey are anadromous. They spawn in gravel nests in stream riffles, like salmon, with eggs hatching in approximately 19 days. After hatching the larva drift downstream and bury themselves in low velocity habitats where they live as filter feeders for the next 3 to 7 years. Larva then transform to juveniles and begin to move downstream between late fall and spring where they mature into adults and enter the ocean. Adults live in the ocean for 1 to 3 years before returning to streams between February and June to spawn between March and July of the following year.

Bridgelip Sucker

Bridgelip sucker (*Catostomus columbianus*) is a sucker with an overall range as far north as the Fraser River in British Columbia and as far south as the Snake River in Nevada; the taxonomy of this species is somewhat unclear (NatureServe 2018). In the Deschutes Basin, the bridgelip sucker has been found from Steelhead Falls downstream to Lake Billy Chinook, and has also been found in Whychus Creek and Indian Ford Creek (Deschutes National Forest 2018). Bridgelip Sucker are also found in the Crooked River, Ochoco Creek, and McKay Creek.

This species is considered secure by NatureServe (Global Status: G5/ National Status: N5), and has an IUCN rating of least concern. In Oregon, its rating is S4 (apparently secure) (NatureServe 2018).

Bridgelip suckers range from 5 inches at maturity to as long as 17 inches. Bridgelip suckers are thought to spawn in late spring and are broadcast spawners. It is a non-migrant, and feeds by scraping algae from rocks in addition to likely supplementing its diet with insect larvae or other aquatic invertebrates.

The preferred habitat of bridgelip suckers is small or medium swift rivers with cold water and gravelly bottoms. They can also be found in rivers with more moderate flow and sandy or silty bottoms, as well as reservoirs, indicating they have a wide range of adaptability to aquatic environments.

No major threats are known to this species, and there is little known about its biology.

Largescale Sucker

The overall range of the largescale sucker includes many areas of western North America, as far north as the Peace River drainage in British Columbia and the Smokey River drainage in Alberta, to as far south as the Snake River drainage in Nevada. In the Deschutes Basin, the largescale sucker resides in the mainstem Deschutes from Steelhead Falls to Lake Billy Chinook, Crooked River, McKay Creek and Ochoco Creek.

The largescale sucker is ranked as secure globally and nationally by NatureServe (G5/N5), and is ranked S4 in Oregon (apparently secure). IUCN categorizes the largescale sucker as of least concern (NatureServe 2018).

Largescale suckers can reach 2 feet in length, can reach up to 7 pounds in weight, and can live longer than 8 years. Becoming reproductively mature by 4 or 5 years of age, largescale suckers spawn in the spring with females depositing as many as 20,000 eggs that hatch in approximately 2 weeks. Fry remain in the gravel or on the sand surface for a few weeks, and as they grow move toward deeper water and toward the bottom. Adults generally live at depths of a few feet, but can be found at depths as great as 80 feet. Largescale suckers primarily eat small invertebrates and insect larvae, and eat larger food items as they grow. Food items can also include mollusks, fish eggs, detritus, diatoms, and algae. Largescale suckers may consume trout eggs, and may also compete with trout species for food.

Largescale suckers are non-migrants, and primarily inhabit medium to large rivers near the stream bottom in pools and runs, and also can be found in lakes near stream mouths, shorelines with aquatic vegetation, or backwaters.

Chiselmouth

The chiselmouth (*Acrocheilus alutaceus*) is a cyprinid with a spotty distribution in British Columbia, Washington, Oregon, Idaho and Nevada (NatureServe 2018). In the Deschutes Basin, it is found in the mainstem from Big Falls to Lake Billy Chinook, and also in the lower reaches of Whychus Creek and Paulina Lake (Deschutes National Forest 2018).

The chiselmouth is considered nationally and globally secure with NatureServe ratings of G5 and N5, and an IUCN rating of Least Concern, though it has a rating of S4 (apparently secure) in Oregon.

In a study of a population in British Columbia, it was found that spawning generally occurred in mid-summer. Individuals are thought to become mature at 3 or 4 years of age, reaching a maximum age of about 6 years (NatureServe 2018). Chiselmouth can reach a length of about 20 centimeters. Chiselmouth are local migrants; there is evidence that lake populations migrate to tributaries to spawn. While young chiselmouth primarily feed on insects and invertebrates, adults primarily feed on diatoms that they scrape from rocks or other substrate (NatureServe 2018).

Chiselmouth prefer warmer areas of small to medium rivers in moderately fast to fast water. They have been found in pools and runs over sand or gravel substrate, and in margins of lakes. Juvenile chiselmouth rear in calmer areas of water (NatureServe 2018).

While no major threats are known to this species, it could be threatened by habitat loss in relation to impoundments. There is little known about this species (NatureServe 2018).

Northern Pikeminnow

Northern pikeminnow (*Ptychocheilus oregonensis*) are large fish with a large overall range that includes drainages as far north as the Nass River in British Columbia to as far south as the Columbia River drainage of northern Nevada (NatureServe 2018). In the Deschutes Basin, northern Pikeminnow can be found in Lake Billy Chinook as well as Lake Simtustus and the Prineville Reservoir (Deschutes National Forest 2018).

Northern pikeminnow are considered secure at a global and national level by NatureServe (G5 ranking) and are considered apparently secure in Oregon with a S4 ranking. IUCN ranks northern pikeminnow as of least concern (NatureServe 2018).

Northern pikeminnow become sexually mature at 3 to 4 years of age, and gather in large numbers up to 8,000 fish in lakes or streams to broadcast spawn in summer months. Adhesive eggs sink to gravel where they only incubate for about a week before hatching. These fish are long-lived with a lifespan of up to 15 to 20 years. Northern pikeminnow feeds on other fish, insects and other invertebrates, and plankton. While they generally are lake species, young fish move to inshore waters during the summer and spawners may also move to nearby streams (Deschutes National Forest 2018; NatureServe 2018).

Dace Species

Multiple species of dace (*Rhinichthys*) are indigenous to Central Oregon. In the Deschutes Basin, they are present the Crooked River, in lower Whychus Creek and in the Deschutes River downstream of Steelhead Falls (Deschutes National Forest 2018).

Dace require water that is above 50 °C and are generally 4 to 6 inches in length. They spawn in the spring in shallow, gravely areas. Instead of constructing a nest, males selectively guard territories and females select which males to spawn near. Dace maintain positions near the stream bottom of even, fast-flowing streams; they have wedge shaped heads and reduced air bladders that aid them in staying in this habitat. Dace primarily consume insect larvae (Deschutes National Forest 2018).

Sculpin species

Multiple species of sculpin (family Cottidae) can be found in the mainstem Deschutes and tributaries downstream of Wickiup Reservoir (Deschutes National Forest 2018).

Reaching a length of 6 to 7 inches, sculpin spawn in the spring. They primarily feed on aquatic insect larvae and can be piscivorous (i.e., prey on other fish species) and are often prey items themselves of piscivorous fish. They prefer streams with cobble, boulder, or flat rock bottoms (Deschutes National Forest 2018).

Freshwater Mollusks

This species group includes the Crater Lake tightcoil snail, evening field slug, and several species of freshwater mussels present in the study area.

Crater Lake Tightcoil

The Crater Lake tightcoil (*Pristiloma crateris*) is an air-breathing, non-migrant terrestrial snail that is associated with aquatic habitats, primarily wet meadows or riparian areas along small streams (Blackburn 2017). It is known to occur along streams within the study area. The most records of this species in Oregon occur in the Deschutes National Forest (Blackburn 2017), with other documentations in the Fremont-Winema forest, Mt. Hood, Willamette, Umatilla, and Umpqua National Forests.

The Crater Lake tightcoil is ranked as imperiled at the global, national, and state levels by NatureServe (G2, N2, and S2). It was petitioned for federal listing as endangered in 2011 but the petition was considered unwarranted (Blackburn 2017). One of the most important habitat features for Crater Lake tightcoil is that its riparian habitat has perennially moist soil. Thus, decreases in the water table or riparian and wetlands areas inundated can impact its survival. One survey for this species discovered that snails were not found in grazed areas in meadows, while they were found in nearby ungrazed areas (Blackburn 2017), suggesting grazing may pose a threat to population persistence. Any actions that cause soil compaction could be detrimental to this species, as could actions that alter groundwater levels or affect canopy cover. Water diversions or impoundments, construction and heavy equipment use, logging and recreation are all potential threats (Blackburn 2017). Because of their patchy distribution, 1-year life cycle, and limitations on reproduction due to seasonal events at higher elevations, this species may be vulnerable to stochastic disturbances (Blackburn 2017).

Evening Field Slug

The evening field slug (*Deroceras hesperium*) is a terrestrial mollusk associated with moist habitats specifically in areas where soil is consistently saturated. It is patchily distributed throughout Oregon, with records on both sides of the Oregon Cascades. It has been found in and surrounding Portland, Oregon, as far east as Hood River; in Klamath River (Jackson County); and in the Elliot State Forest, and it is believed to occur in patches throughout the Cascade and Klamath Basin. Most current records are on the eastern slopes of the Cascades; this species' historical range also extends into western Washington and Vancouver Island, B.C. though it may be extirpated in these areas (Burke and Duncan 2005; NatureServe 2018).

The evening field slug is rated N2 at a national level and S2 for the state of Oregon, which is considered imperiled (NatureServe 2018). This species is most threatened due to habitat loss and especially loss of moisture. Draining of their habitat or conversion of habitat from wet meadows to agricultural uses, urban uses, or forest management would all be detrimental. Hydrological alterations that reduce inundation of wetlands are a threat to this species, and activities that lower the water table would be harmful (Burke and Duncan 2005).

Freshwater Mussels

Three species of native freshwater mussels reside in the Deschutes River Basin: the California floater (*Anodonta californiensis*, treated the same as the winged floater *Anodonta nuttalliana* in the same clade), the western pearlshell (*Margaritifera falcata*), and the western ridged mussel (*Gonidea angulata*, also known as the Rocky Mountain ridged mussel). All three species are recognized as Species of Greatest Conservation Need within the state of Oregon and are protected under scientific take permits by the State of Oregon (Blevins et al. 2018).

Overall, freshwater mussel adults are benthic organisms that live in a number of freshwater environments. Mussels are fairly immobile as adults, and depending on the species may exist singly; in sparsely concentrated groups; or in large, concentrated groups known as mussel beds. Mussels filter water with their gills both for oxygen and for food (Blevins et al. 2018).

California Floater and Winged Floater Mussels

The California floater can be difficult to identify (along with other floater mussels) due to its lack of obvious shell characteristics; genetic studies are currently being developed to aid in distinguishing between the species. Currently, the winged floater (*Anodonta nuttalliana*) is treated along with the California floater as one clade (*Anodonta* clade 1) for conservation purposes (Blevins et al. 2018).

Floater species overlap in range and often co-occur (Blevins et al. 2018). Floaters are usually found at low elevations in floodplain ponds, reservoirs and lakes, and rivers or creeks with muddy or sandy substrate where burrowing is possible (Blevins et al. 2018). In the Deschutes Basin, the California Floater has observed records in the Crooked River near Smith Rock State Park, including confirmed recent sightings (Xerces and CTUIR 2018).

The California floater is currently ranked as vulnerable (G3/N3) at a global and national level due to its patchy distribution and decreased range. The California floater is ranked S2 (imperiled) at the state level for Oregon (NatureServe 2018). IUCN ranks *A. nuttalliana* as vulnerable due to a decrease in watershed area size and extent of occurrence (Blevins et al. 2016c).

Western Pearlshell Mussel

The western pearlshell is the longest-lived of these three mussel species; some individuals have been found to live up to 100 years or more (Blevins et al. 2018). The habitat of western pearlshell is usually in perennial rivers and streams, and at a variety of elevations from sea level to approximately 8,000 feet. Areas in river that have low velocity, shear stress, and gradient, plus a variety of sediment types, are generally preferred (Blevins et al. 2018). In the Deschutes Basin, the western pearlshell has been found in the mainstem Deschutes as far downstream as the Lower Deschutes downstream of the White River and as far upstream as near Bend. It has also been found in the Little Deschutes River, the lower Crooked River, and Ochoco Creek (Xerces and CTUIR 2018).

While the western pearlshell is in decline, both in overall distribution and number of specific sites and individuals, it is still ranked as secure by NatureServe at the global and national levels due to its widespread distribution with hundreds of occurrences (NatureServe 2018). However, IUCN ranks the western pearlshell as near threatened due to its decreasing population trend (Blevins et al. 2016a). At a state level in Oregon it is ranked as vulnerable by NatureServe (S3).

Western Ridged Mussel

The monospecific western ridged mussel is a long-lived freshwater mussel (up to 30 years or more). They prefer well-oxygenated environments generally in stable areas with boulders, sand, silt, or cobble substrate. In the Deschutes Basin, the western ridged mussel has been found in the mainstem Deschutes just upstream of Whychus Creek and in many portions of the Crooked River upstream to near Swartz Canyon. The most recent records are all in the Crooked River, especially near Smith Rock State Park (Xerces and CTUIR 2018).

NatureServe ranks the western ridged mussel as G3 globally and N3 nationally (vulnerable) due to decline in range and in number of sites and individuals; it is ranked S2S3 at a state level for Oregon (imperiled/vulnerable). IUCN ranks the western ridged mussel as vulnerable due to a decreasing population trend and decline in number of mature individuals (Blevins et al. 2016b). The western ridged mussel is more pollution- and disturbance-tolerant than many western freshwater mussels, though it is still sensitive (NatureServe 2018).

Methods

The description of the affected environment relied on best available information in existing publications describing conditions in the study area and the biology and ecology of habitats and species potentially occurring in the study area.

The analysis of effects on fish and mollusks relied on evaluation of predicted hydrologic data for specific reaches and representative sites with detailed information on seasonal patterns of channel inundation at known flow. Alternatives were evaluated using a combination of flow summaries. These summaries included annual hydrologic data and monthly median flows. Additional information used were results of results of habitat and water temperature modeling in support of the Deschutes Basin HCP.

RiverWare

RiverWare model simulations for the EIS alternatives were generated for a 38-year period using water years to October 1, 1980, to September 30, 2018. Appendix 3.2-A, *Water Resources Technical Supplement*, provides an overview of the RiverWare model, description of inputs to the simulation, and information on how RiverWare was used to generate daily streamflow across the study area for each alternative, and analysis years.

Effects were evaluated by comparing modeled outputs for the proposed action, Alternative 3, and Alternative 4 to outputs for the no-action alternative.

Reach-level analysis of effects was based on modeled results for RiverWare nodes, which are locations with a USGS or OWRD gauge. For reaches without nodes or locations of particular interest (e.g., Crooked River streamflow below the North Unit ID pump), internode locations in RiverWare were used to evaluate reach level effects. RiverWare modeled output for internode locations are based on the nearest upstream node and assumptions for gains and losses associated with diversions, surface- and groundwater exchange, and tributary inputs. The internode outputs are a less reliable predictor of streamflow; however, they provide a valuable understanding of conditions at these ungauged locations.

The effects analysis considered the following types of RiverWare outputs.

- Annual hydrographs of daily streamflow combined across all 38 years with median, 20% and 80% daily flows.
- Median monthly streamflows by water year with summaries of change in median flow relative to the No-action alternative and frequency of increase and decrease in monthly median flow across the simulation years
- Occasionally daily streamflows within timeframes relevant to fish and mollusks that are shorter than a month
- Annual and monthly reservoir elevations

Each output type is described in the sections below using examples.

Annual Hydrograph

The annual hydrograph provides an overall assessment of differences in daily streamflow across all 38 analysis years. The median, 20% and 80% streamflows are calculated for each day of the year and plotted. The annual hydrograph provides a generalized picture of how median flows vary between alternatives and the range of variability in daily streamflow. The 20% and 80% range was used in these plots to exclude the extreme range of daily streamflow produced by RiverWare and provide a more reasonable projection of potential variation in streamflow across the analysis years.

Figure 2 shows the annual hydrograph for the Crescent Lake Reservoir outlet (CREO). In this example winter flows are stable across years based on a release schedule from Crescent Lake Reservoir. The median, 20% and 80% daily flows do not vary among years. In contrast, spring and summer daily flows are much more variable by day and among years. Overall, there is little difference under the proposed action across the implementation phases over the course of the 30-year permit term at this node. The proposed action median flows from October to mid-April are approximately 40 to 60%lower than the no-action and proposed action median streamflows from May to July are approximately 100% higher than the no-action. In other months the proposed action median streamflows tend to be similar to the no-action alternative. The proposed action streamflows are more variable across years from May to July compared to the no-action, and in some years are less than the no-action alternative.

Figure 3 shows the annual hydrograph at the LAPO node in the Little Deschutes River. This node includes outflow from Crescent Lake Reservoir (CREO), contribution of tributary inflow, groundwater, and inflow from the Little Deschutes River. In this example winter streamflows are more variable across years from differences in Little Deschutes River streamflow and spring daily streamflows are much more variable. Overall, there is little difference across the proposed action phases over the 30-year permit term at this node. In addition, there are very minor differences (<10%) in daily median streamflow between the no-action, proposed action most of the year. Streamflows are higher from July to about mid-October under the proposed action. Differences in streamflow at the Crescent Lake Reservoir outlet during winter months are masked by inflows from unregulated tributaries and the Little Deschutes River. There is no evidence that the proposed action streamflows are more variable across years compared to the no-action.

Figure 2. Example Annual Hydrograph for Crescent Lake Reservoir Outlet (CREO node) under the Proposed Action Years 1–7 (top left), 8–12 (top right); 13–30 (bottom) compared to the No-Action Alternative

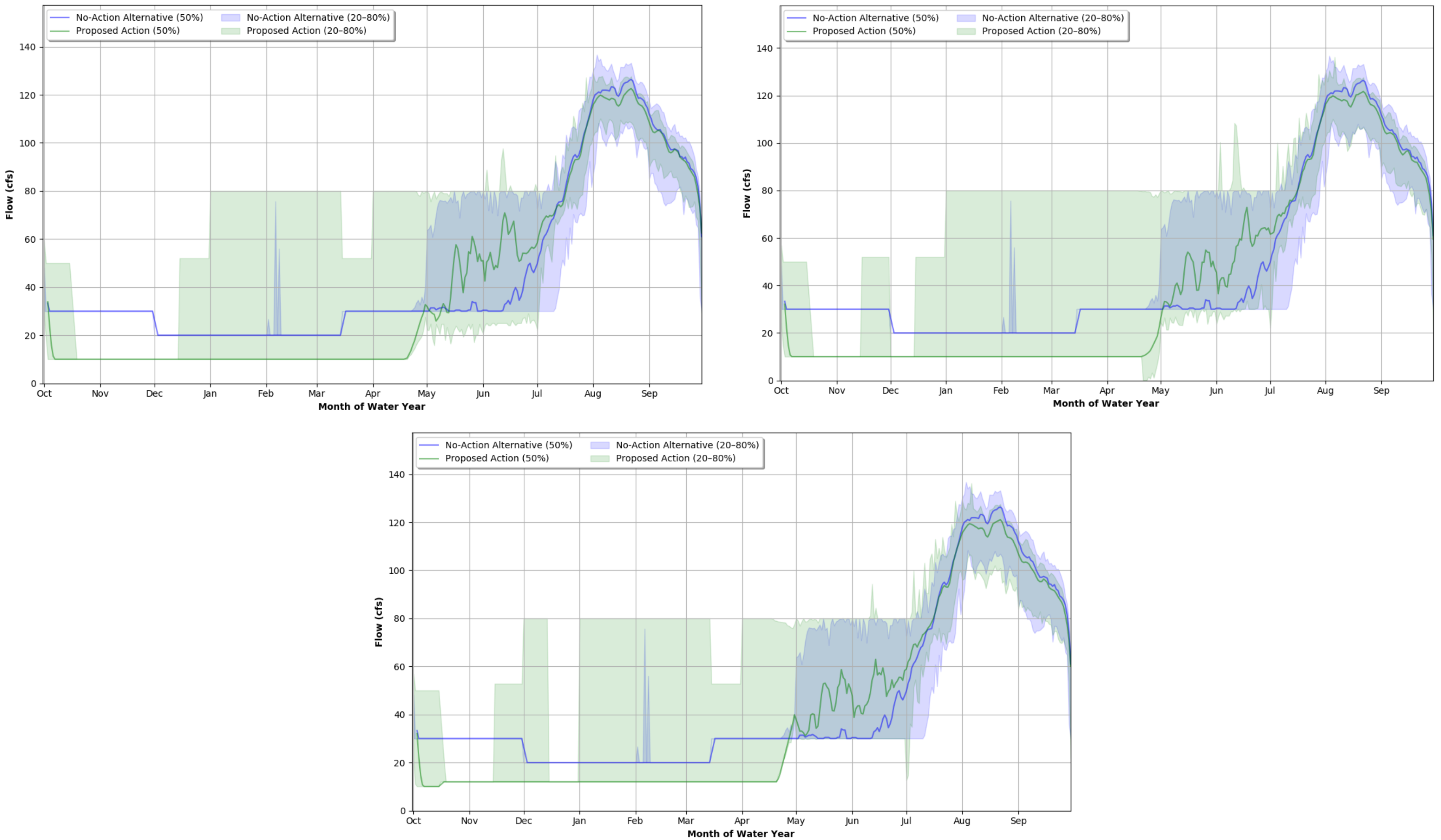
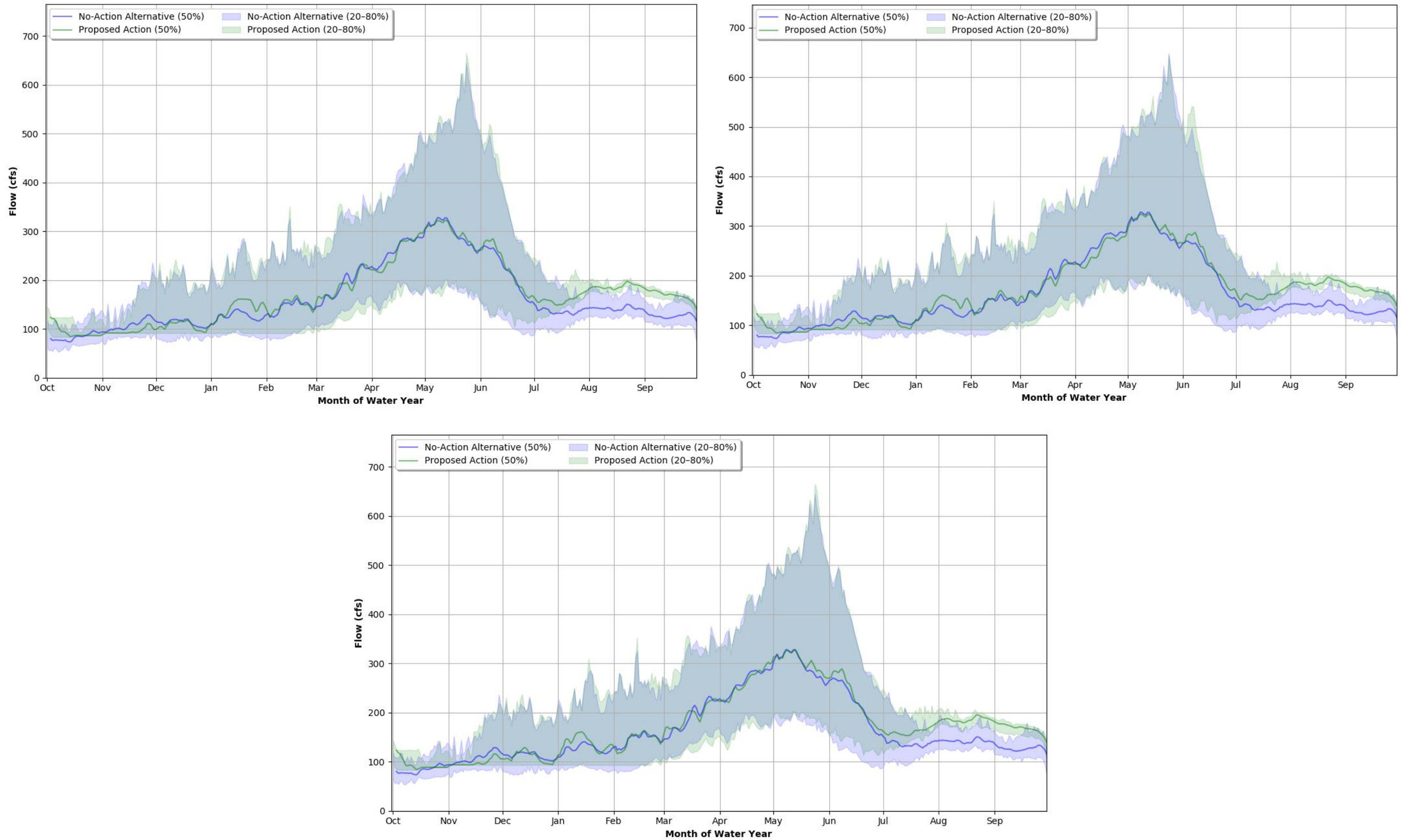


Figure 3. Example Annual Hydrograph for Little Deschutes River (LAPO node) under the Proposed Action Years 1–7 (top left), 8–12 (top right), and 13–30 (bottom) compared to the No-Action Alternative



Monthly Median Streamflows

A more detailed analysis of differences and species impacts was made by comparing monthly median streamflows among water years. These summaries provided an understanding of streamflow variability across the RiverWare simulation years and how the alternatives differ by water year. Monthly median streamflows were used to summarize streamflow in a month versus average because 50% of the time streamflow will fall above the median value and 50% of the time it will fall below the median value. Monthly averages tend to over-represent low or high outliers in a skewed data series.

Table 4 and Table 5 present summaries of differences in median streamflow by month at the CREO and LAPO nodes. These summaries are the percentage difference in median streamflow calculated as:

$$\%Diff \ = \frac{(PA\ Month\ Median\ Flow - NA\ Month\ Median\ Flow)}{NA\ Month\ Median\ Flow} * 100$$

Median monthly streamflow was calculated for each year of the RiverWare simulation. In the tables the median difference is the median for all years. The tables also include the range in differences in median streamflow by month across the RiverWare modeled years. Years with median streamflow that was higher or lower under the alternative relative to the no-action alternative were summarized separately.

For example, at the CREO node (Figure 2) in the majority of years (26 of 38 years) median streamflow was lower in January, an average decrease of 41% across years. In contrast, median streamflows under the proposed action were higher and lower in June depending on the year. Monthly median streamflows were lower (average 36%) in 12 years and higher (average 87%) in 12 years.

The same pattern of higher and lower median streamflows is observed at the LAPO node (Figure 3). However, the differences in median streamflow between the no-action alternative and proposed action are not as great during the winter because of the influence of the Little Deschutes River inflow. Streamflows were higher in the majority of years from July to October under the proposed action by an average of 42 to 60% depending on the month.

The percentage difference between the no-action alternative, the proposed action, Alternative 3, and Alternative 4 changes at different nodes depend on the no-action median streamflow. For example, the percentage change between the no-action and proposed action at Bowman Dam on the Crooked River may be less than 100% and between 200 and 300% downstream at the CAPO node for the same month. The proposed action streamflow may not change between the two locations, but the greater percentage difference at CAPO is because the no-action alternative streamflow at CAPO is lower relative to the no-action streamflow at Bowman Dam.

The frequency of change in streamflow was evaluated by month across the RiverWare modeled analysis years. A "majority of years" is more than 50% of the years in the analysis period. The term "most years" designates 75% of the years in the analysis period fall in a certain category, and the term "few years" designates less than 25% of the years in the analysis period. These categories were used to categorize the frequency of years with different streamflow conditions.

The assessment also considered the magnitude of change in streamflow relative to habitat conditions. Median streamflow and the 20 to 80% range of daily streamflows in a month and water year were summarized and put into bar charts to better understand the potential for effects related to differences under an alternative. Figure 4 is an example water year (2005) at the Crescent Lake Reservoir outlet (CREO). Median streamflow from November to May are lower under the proposed action compared to the no-action alternative in years 1 through 7and higher from June to October. In contrast, median streamflow under the proposed action in years 13 through 30 are the same as years 1 through 7 in most months and lower in August and September.

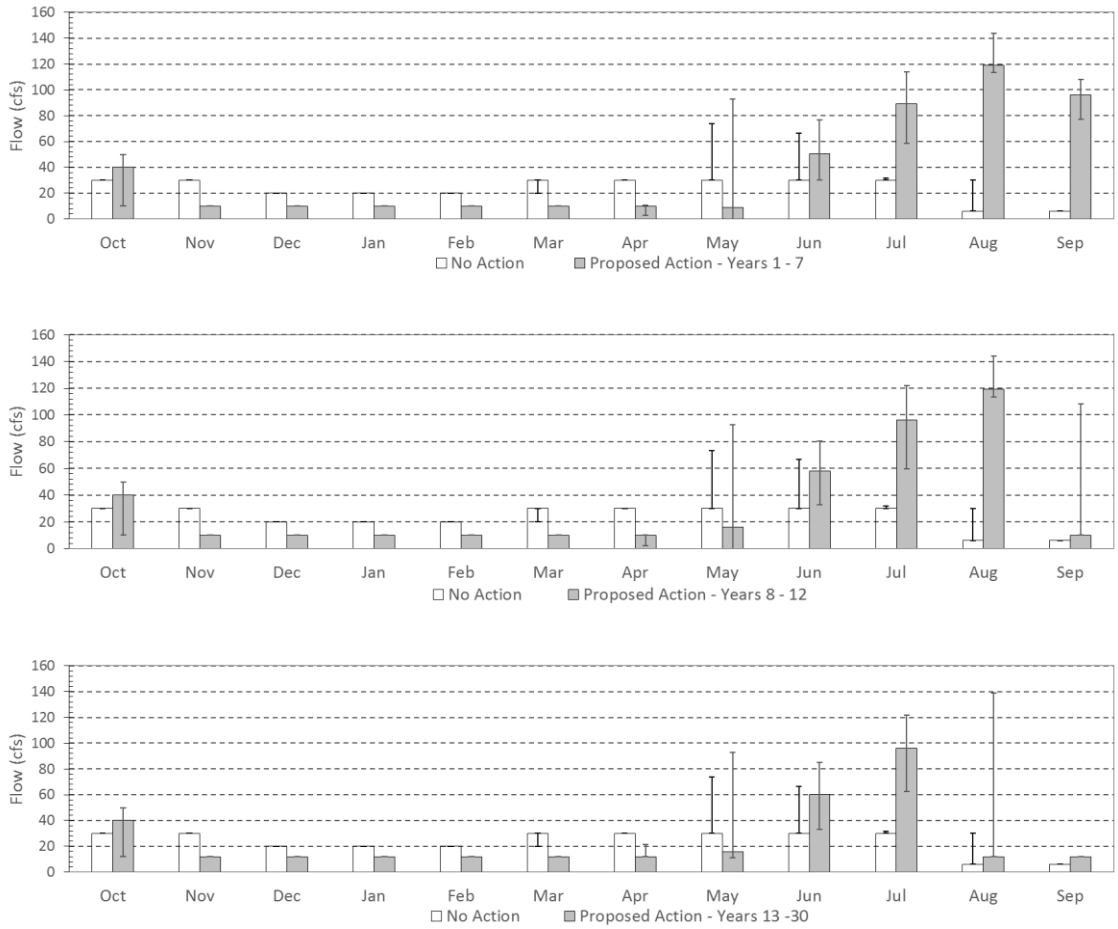
Table 4. Monthly Median Streamflows for Crescent Lake Reservoir Outlet (CREO node) in Example Analysis Year under the Proposed Action (Years 13–30) Compared to the No-Action Alternative

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Average diff. median flow (%)	-12%	-26%	-2%	30%	1%	-28%	-17%	21%	16%	19%	15%	16%
Range diff. in monthly median flow (%)	-60 to 207%	-85 to 167%	-85 to 300%	-85 to 950%	-85 to 300%	-60 to 167%	-78 to 167%	-63 to 167%	-81 to 167%	-60 to 220%	-60 to 623%	-60 to 241%
# Years no diff. in median flow	1	4	3	5	6	5	4	15	14	14	21	11
# Years increase in median flow	14	5	5	6	6	4	9	10	12	12	4	6
Range increase in monthly median flow (%)	15 to 207%	100 to 167%	100 to 300%	100 to 950%	100 to 300%	167%	5 to 167%	13 to 167%	5 to 167%	8 to 220%	10 to 623%	25 to 241%
Median increase flow (%)	33%	167%	300%	300%	130%	167%	82%	159%	79%	28%	62%	138%
# Years decrease in median flow	23	29	30	27	26	29	25	13	12	12	13	21
Range decrease in monthly median flow (%)	-60 to -60%	-85 to -60%	-85 to -40%	-85 to -40%	-85 to -8%	-60 to -40%	-78 to -60%	-63 to -6%	-81 to -7%	-60 to -6%	-60 to -5%	-60 to -5%
Median decrease flow (%)	-60%	-60%	-40%	-40%	-40%	-60%	-60%	-15%	-35%	-7%	-6%	-6%

Table 5. Summary Monthly Median Streamflows for Little Deschutes River (LAPO node) under the Proposed Action (Years 13–30) Compared to No-Action Alternative

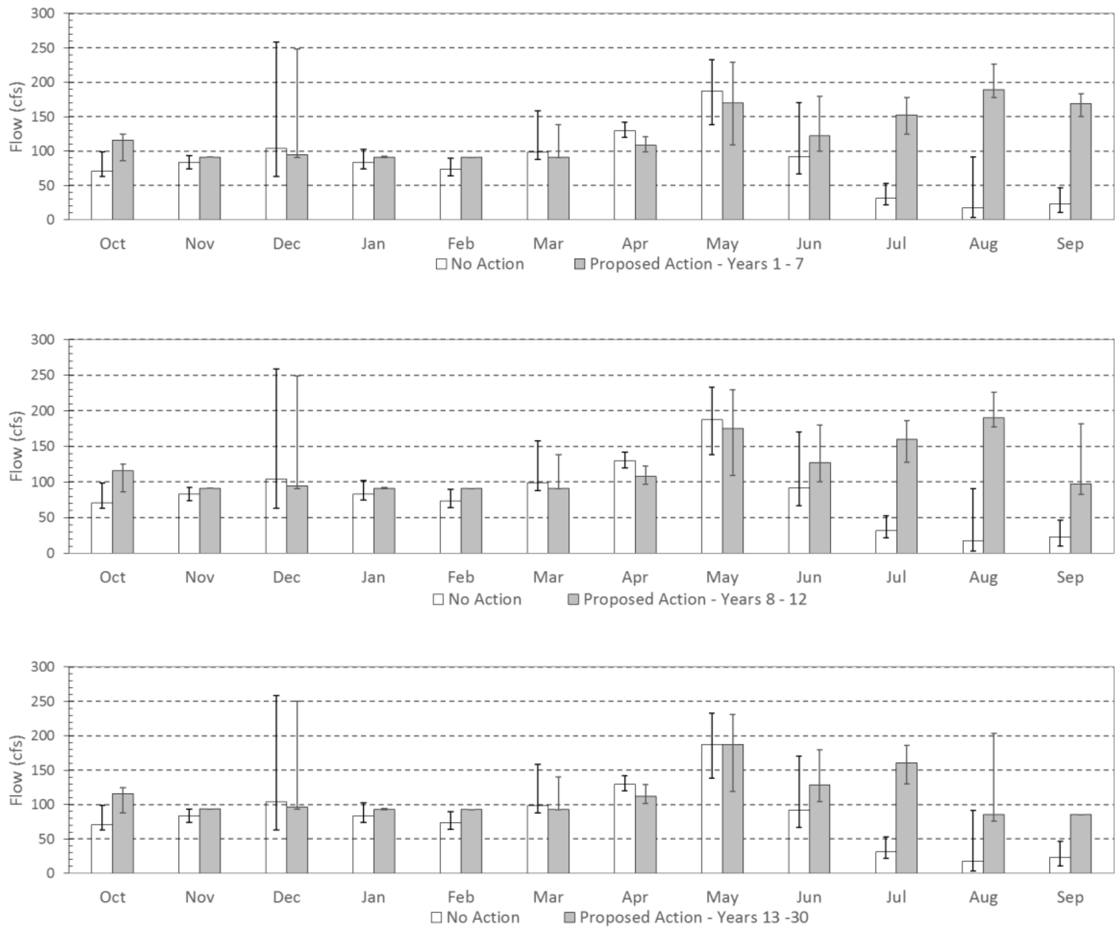
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Average diff. median flow (%)	28%	1%	9%	12%	10%	-1%	-2%	3%	10%	37%	35%	47%
Range diff. in monthly median flow (%)	-18 to 148%	-42 to 50%	-51 to 91%	-53 to 131%	-18 to 242%	-14 to 42%	-14 to 23%	-53 to 42%	-79 to 128%	-51 to 407%	-27 to 380%	-4 to 262%
# Years no diff. in median flow	5	7	12	12	18	9	16	25	16	8	8	6
# Years increase in median flow	27	13	14	16	12	9	6	11	18	25	29	32
Range increase in monthly median flow (%)	5 to 148%	5 to 50%	11 to 91%	5 to 131%	7 to 242%	6 to 42%	8 to 23%	7 to 42%	6 to 128%	5 to 407%	5 to 380%	5 to 262%
Median increase flow (%)	39%	21%	29%	19%	18%	12%	12%	10%	16%	26%	29%	32%
# Years decrease in median flow	6	18	12	10	8	20	16	2	4	5	1	0
Range decrease in monthly median flow (%)	-18 to -6%	-42 to -6%	-51 to -5%	-53 to -5%	-18 to -5%	-14 to -5%	-14 to -5%	-53 to -7%	-79 to -14%	-51 to -7%	-27 to -27%	NA
Median decrease flow (%)	-15%	-14%	-7%	-7%	-6%	-8%	-8%	-30%	-17%	-8%	-27%	NA

Figure 4. Monthly Median Streamflows at Crescent Lake Reservoir Outlet (CREO) in Water Year 2005: No-Action Alternative vs. Proposed Action, Years 1–7 (top), Years 8 – 12 (middle) and 13–30 (bottom). Vertical lines indicate the 20 to 80% range of streamflows in the month.



Further downstream in the Little Deschutes River (LAPO) the differences in monthly median streamflows in the winter are much less for the water year represented by 2005 (Figure 5). There remains an increase in median streamflow from June through October under the proposed action in years 1 through 7 and years 13 through 30. The increase in September streamflows was not substantial in years 13 through 30.

Figure 5. Monthly Median Streamflows in the Little Deschutes River (LAPO node) in Water Year 2005: No-Action Alternative vs. Proposed Action, Years 1–7 (top), Years 8–12 (middle) and Years 13–30 (bottom). Vertical lines indicate the 20 to 80% range of streamflows in the month.



Daily Streamflow Patterns

Modeled daily streamflows show extreme variation in some months and water years. The substantial variability in daily streamflows reported from RiverWare occurs more often when reservoir storage is low during the irrigation season. This is because of limitations in the RiverWare model logic and its simplification of a complex set of interactions between water delivery, and reservoir volume and inflow. The analysis of daily predictions assumes actual water management would smooth daily water management to provide a more predictable daily irrigation delivery and ignores most of the daily variability coming from RiverWare. Because of this limitation of RiverWare logic and extreme variability in the daily results in some cases, the effects analysis examined variability using a 7-day running average.

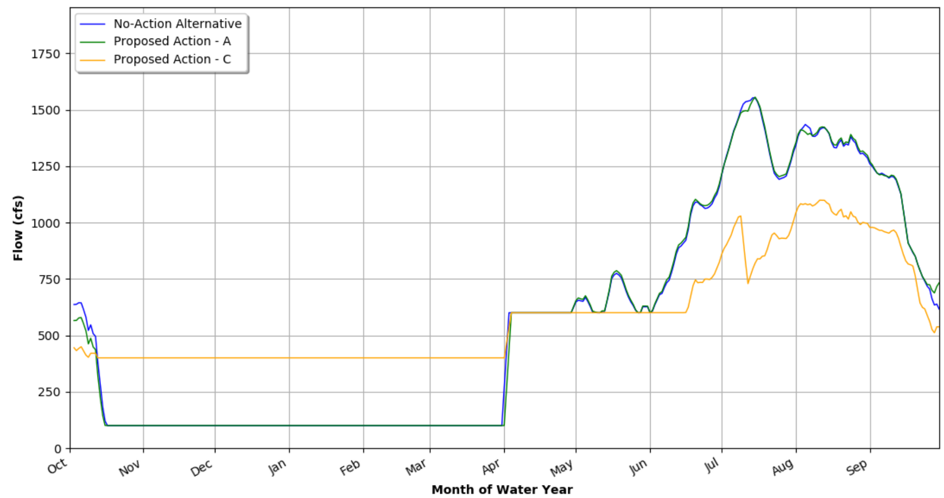
There are years and periods in the RiverWare time series simulation when the proposed action and action alternatives result in substantially lower streamflows during the irrigation period (April through October) compared to the no-action alternative (Figure 6). Although RiverWare results include in some years substantial flow regulation from Wickiup Reservoir (WICO node) under the no-action alternative and proposed action in years 1 through 7, regulation was more common in later years of the permit term under the proposed action and action alternatives when winter releases from Wickiup Reservoir are higher and storage during the irrigation season is insufficient to supply irrigation water through the entire summer.

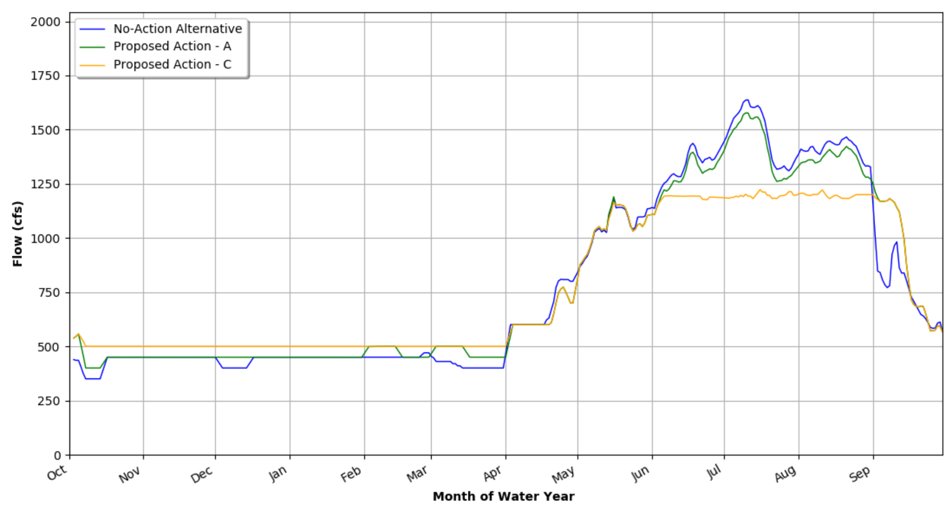
Potential effects on fish and mollusks were based on two metrics: 1) identification of magnitude of variability in streamflows relative to the no-action alternative, and 2) timing of the variability with respect to species life stage. Magnitude of variability was evaluated using coefficient of variation (CV) of the 7-day smoothed daily streamflow (the standard deviation of daily streamflow divided by average streamflow over the month), the daily rate of decline in streamflow in the month, and the number of days streamflow declined in the month.

Differences in streamflow ramping at the end of the irrigation season were considered in the effects analysis for species. Figure 7 shows end of irrigation season ramping extracted from the daily time series at the outlet of Wickiup Reservoir (WICO node). In this case, the daily streamflows are the time series daily median streamflow. The decline in streamflow in October at the end of the irrigation season is less under the proposed action in years 13 through 30 than under the no-action alternative. This is likely a beneficial effect on some fish and mollusks.

Another example of differences in daily streamflow patterns is in the Crooked River and the predicted shifts in timing of water released to supply the North Unit ID pumps. The analysis considered the effect of these shifts in timing on water temperatures in the Crooked River during the summer. This effect is discussed in more detail in the next section under water quality.

Figure 6. Example of Daily Predicted Streamflow for Three Water Years for the outlet of Wickiup Reservoir (WICO node) under the No-Action Alternative and Proposed Action Years 1–7 (A) and Years 13–30 (C) in Normal (top), Wet (middle), and Dry (bottom) Water Years





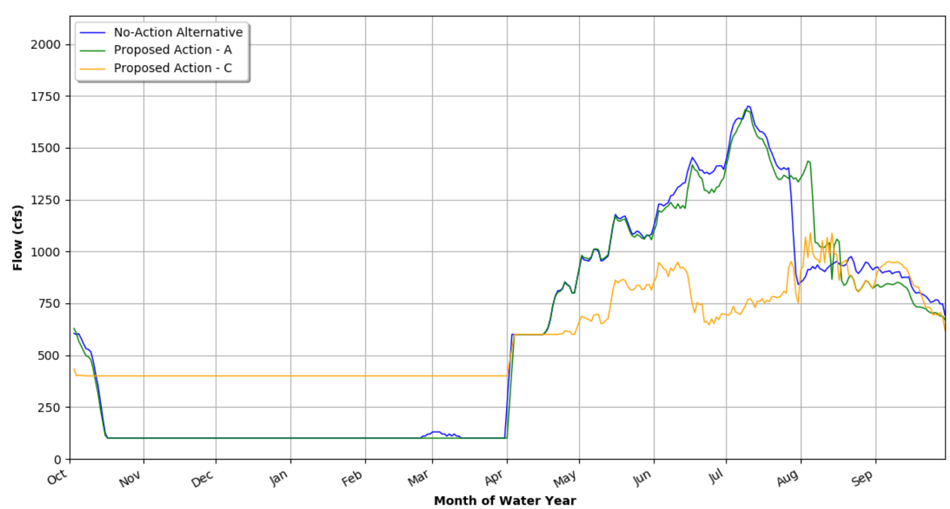
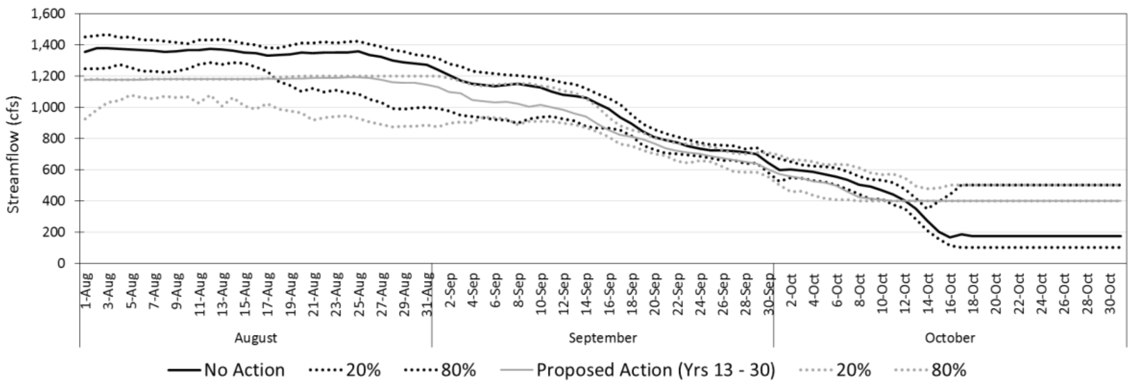


Figure 7. Example Daily Predicted Streamflow for Wickiup Reservoir Outlet (WICO node) under the No-Action Alternative and Proposed Action (Years 13–30)



Analysis of Storage Reservoirs

Analysis of storage reservoirs considered RiverWare modeled reservoir elevations across the model years.

An example of RiverWare predicted elevations used to evaluate effects of alternatives on fish and mollusks is shown in Figure 8 for Crane Prairie Reservoir and Wickiup Reservoir. In this example elevations in Crane Prairie are higher from October through April, lower from about mid-May through September, are more variable from year to year, and do not differ by permit term. In contrast, Wickiup Reservoir elevations are unchanged early in the permit term, lower under the proposed action later in the permit term from about mid-October through July, higher in August and September, and more variable from year to year.

Figure 8. Modeled Elevations in Crane Prairie and Wickiup Reservoirs under the Proposed Action Years 1–7 (top left), 8–12 (top right), and 13–30 (bottom) compared to the No-Action Alternative

Crane Prairie

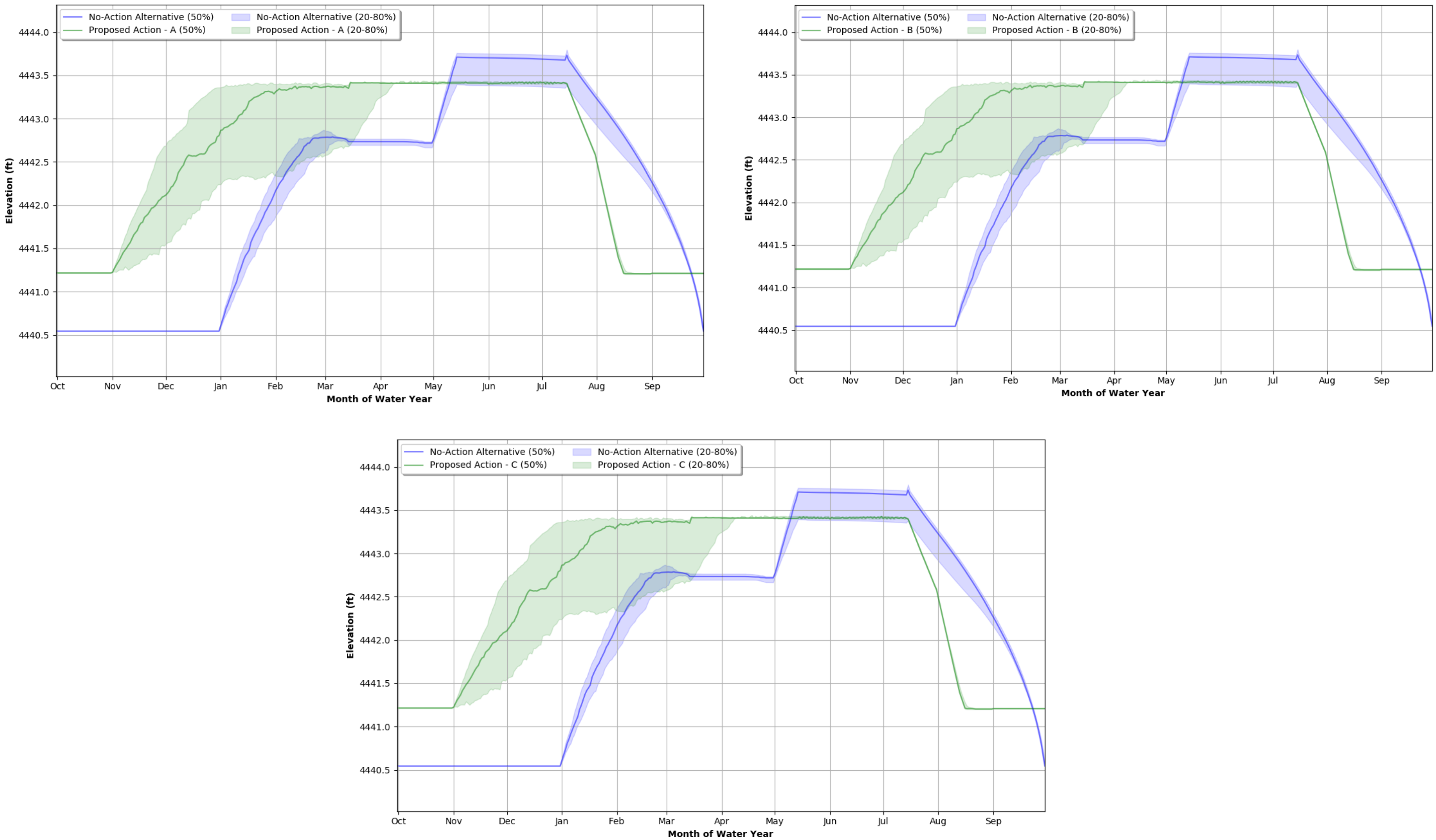
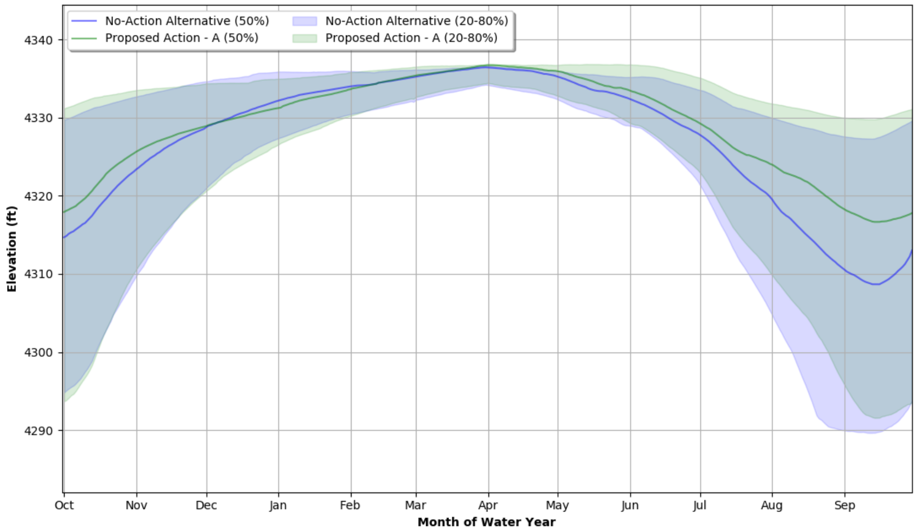
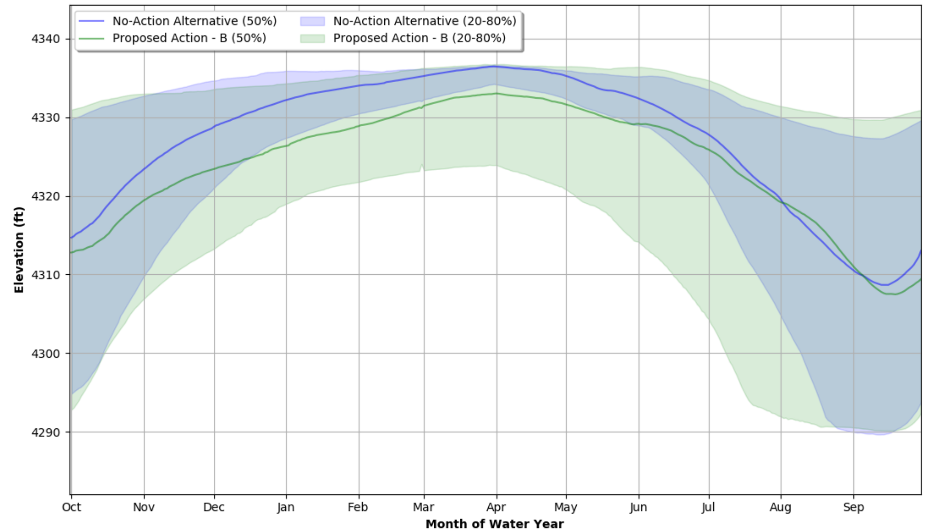
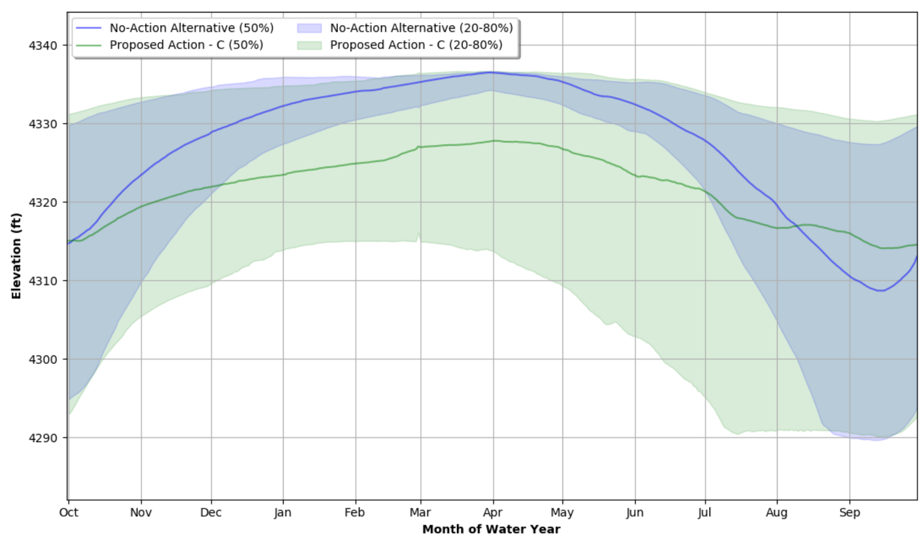


Figure 8 Continued

Wickiup







Water Quality

Changes in seasonal streamflows under the alternatives have the potential to alter a variety of water quality variables. Alternatives that increase streamflow typically provide beneficial responses to water quality affecting fish and mollusks; conversely, reductions in streamflow are more typically associated with water quality changes that adversely affect fish and mollusks habitats. Reductions in streamflow during the summer are generally more likely to degrade water quality with increased water temperatures and pH, and greater extremes in dissolved oxygen.

Most of the assessment of effects on water quality were qualitative because quantitative models were not available or unnecessary. The following describes quantitative modeling in the Upper Deschutes River and in the Crooked River.

The analysis of effect of irrigation returns on water quality and species habitats was qualitative. While pesticides are known to occur within return flows that enter the Crooked River (Oregon Water Quality Pesticide Management Team 2018), the proposed action and action alternatives would not create additional pesticide sources, pathways or otherwise alter the occurrence of pesticides in the Crooked River. As described in the Deschutes Basin HCP, Chapter 3, *Scope of the DBHCP,* flow and diversion rate changes on the Crooked River are not expected to have noticeable changes in return flows at locations on the Crooked River. Similarly, irrigation return flows to Trout Creek are not expected to have a noticeable change.

Upper Deschutes Water Quality Model—Wickiup Reservoir to Tumalo Creek

A quantitative analysis of water quality parameters was completed for the Upper Deschutes River from Wickiup Reservoir to Tumalo Creek using a numerical model (QUAL2Kw). Development and application of the QUAL2Kw model is described in detail in the water quality analysis (Appendix 3.3, *Water Quality Technical Supplement*). The model was developed to utilize input data from the RiverWare simulations, along with local climate data and water quality data provided by the U.S. Bureau of Reclamation, Oregon Department of Environmental Quality, and the City of Bend. The more significant factor potentially affecting water quality parameters in the Upper Deschutes River is the drawdown of Wickiup Reservoir to an elevation of 4,290 feet (approximately 7,600 acre-feet) for long durations during the summer under the proposed action and action alternatives. Predicted changes in water quality from the QUAL2Kw model were used to evaluate effects of alternatives on fish and mollusks from Wickiup Reservoir to Tumalo Creek.

Crooked River Water Temperature Model

The effects analysis for the Crooked River was based on water temperature modeling developed by Portland State University (PSU) (Berger et al. 2019), described below. The analysis of effects in this appendix was based on analysis independent of any conclusions of effects made by the authors of the water temperature study.

The water temperature model developed by PSU covers the Crooked River from the City of Prineville to the gaging station at Smith Rock (Station ID: OWRD 14087300, Crooked River near Terrebonne, OR). This lower river model was linked to a previously developed model of Prineville Reservoir and the Crooked River from Prineville Reservoir downstream to the City of Prineville (Berger et al. 2019; Berger and Wells 2017). The linked models were calibrated based on 2016 conditions, and water temperature predictions were made using predictions of streamflow from the

2019 version of RiverWare for the each of the alternatives. The linked models covered 14.0 miles in Prineville Reservoir, 23.3 miles from Bowman Dam to the City of Prineville, and 20.3 miles from the City of Prineville to the gauge at Smith Rock. Water temperature predictions were made for 3 years in the RiverWare analysis period; 2005 was identified as an average (normal) water year, 1993 was chosen as a representative wet water year, and 2001 was chosen as a representative dry water year. Year type was based on Prineville Reservoir volume in April at the start of the irrigation season.

The water temperature model reported predictions of daily minimum, maximum, and average water temperatures for 49 segments in Prineville Reservoir, 75 segments from Bowman Dam to the City of Prineville, and 76 segments from the City of Prineville to the gaging station at Smith Rock (Berger et al. 2019).

Predicted water temperatures were based on the 2019 RiverWare model. The wet, dry, and normal water year types modeled streamflow at CAPO are shown in Figure 9 for the no-action alternative, proposed action, and action alternatives at the last phase of the permit term when differences were greatest between the proposed action, action alternatives, and the no-action alternative.

The timing of wet year streamflows under the proposed action and action alternatives generally do not differ from the no-action alternative (Figure 9). Streamflows are slightly lower at times during the summer under the proposed action and action alternatives. There is no discernable difference among the proposed action and action alternatives.

The timing of dry year streamflows under the proposed action and action alternatives generally follow a pattern of higher streamflows during the winter, then low flows beginning April 15 and finally higher flows in late summer when North Unit ID began to use its 10,000 acre-feet (af) of storage in Prineville Reservoir (Figure 9). The timing of normal year streamflows under the proposed action and action alternatives changed the most out of the three water year types modeled. The timing of this use shifted earlier in the last phase of the permit term under the proposed action and action alternatives. North Unit ID began to use its 10,000 af of storage in Prineville Reservoir mid-July to mid-August when water temperatures are the warmest in the river under the no-action alternative. The timing of this use was earlier by one to two months under the proposed action and action alternatives, when river water temperatures were cooler.

The temperature model demonstrated an effect of shift in timing of streamflows on 7-day average of daily maximum (7DADM) in the Crooked River. The shift in timing to May in a normal water year extended the period of warm water in the Crooked River at the CAPO gauge by several weeks (Figure 10). The consequence of this shift was that water temperatures were cooler in late spring and early summer and warmed rapidly when streamflows were lower in July and August under the proposed action and action alternatives. The consequence of the shift in streamflow timing was a more protracted period of warm temperatures in late summer and a less suitable environment for temperature-sensitive fish species.

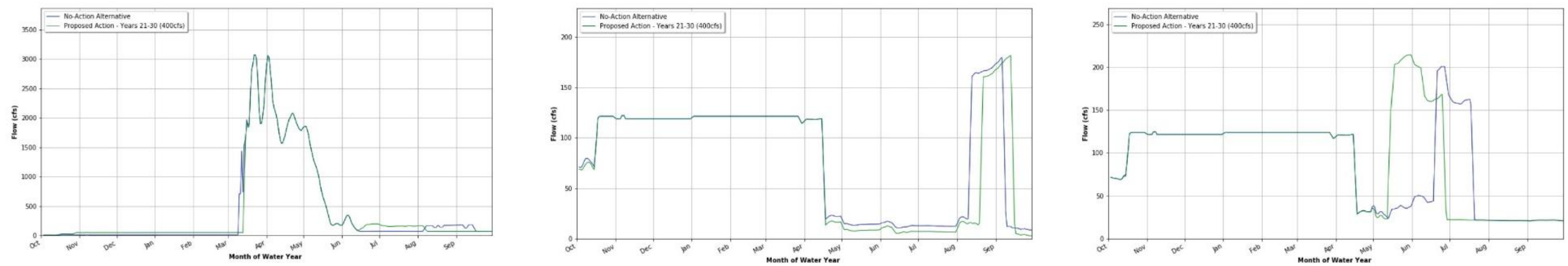
Maximum 7DADM at the CAPO gauge (RM 46.7) under the no-action alternative varied from 22.3 °C (wet year) to 24.5 °C (normal year) (Figure 10). Maximum temperatures were predicted to be slightly cooler under the proposed action in a wet year (21.5 °C), about the same in a dry year (24.0 °C) and slightly warmer in a normal year (24.8 °C). Alternatives 3 was slightly warmer in a wet year (22.7 °C) and warmer in a dry and normal year, 24.1 and 24.8 °C, respectively. Predicted maximum 7DADM temperatures under Alternative 4 were the warmest (24.5 °C, 24.1 °C, and 25.2 °C, for a wet, dry and normal year, respectively).

Water management in a wet year resulted in approximately a 1.0 °C cooler temperature in June, 1.4 °C cooler temperature in July, and a 1.0 to 2.8 °C warmer temperature in August under the proposed action and action alternatives (Figure 10). Water management in a dry year resulted in no difference in June and July under the proposed action and Alternative 3, and under Alternative 4 no difference in June and approximately a 2.3 °C cooler temperature in July. In a dry year August temperatures were predicted to be warmer by 0.5 to 1.9 °C.

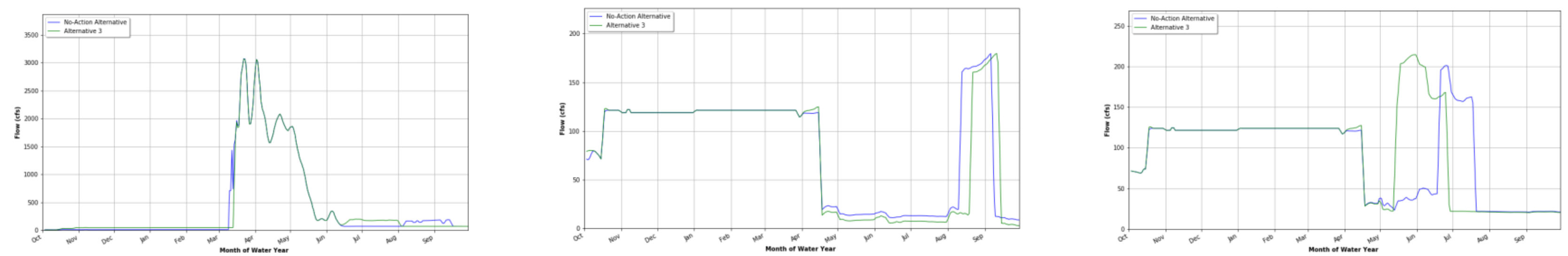
Figure 9. Annual Hydrograph based on the 2019 RiverWare model for the Crooked River near Highway 126 (CAPO node) for Wet (left), Dry (center) and Normal (right) Water Years and the Proposed Action (top), Alternative 3 (middle) and Alternative 4 (bottom) at the end of the Permit Term Compared to the No-Action Alternative

Wet | **Dry** | **Normal**

No-Action Alternative and Proposed Action



No-Action Alternative and Alternative 3



No-Action Alternative and Alternative 4

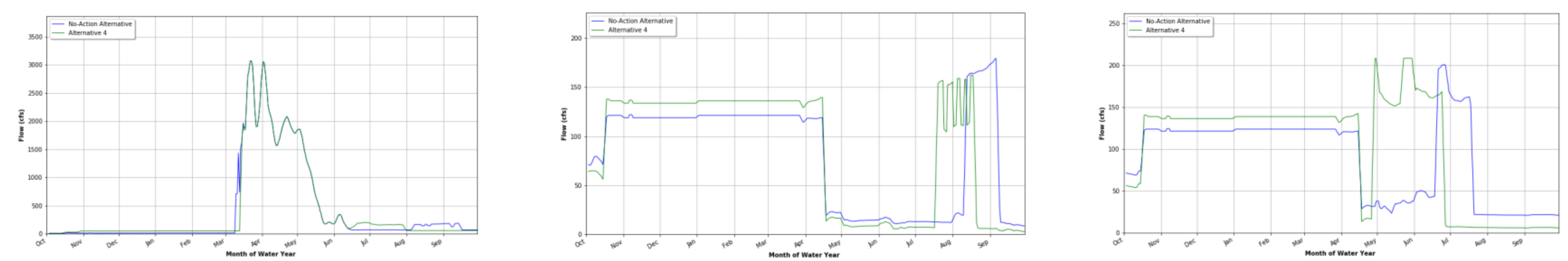
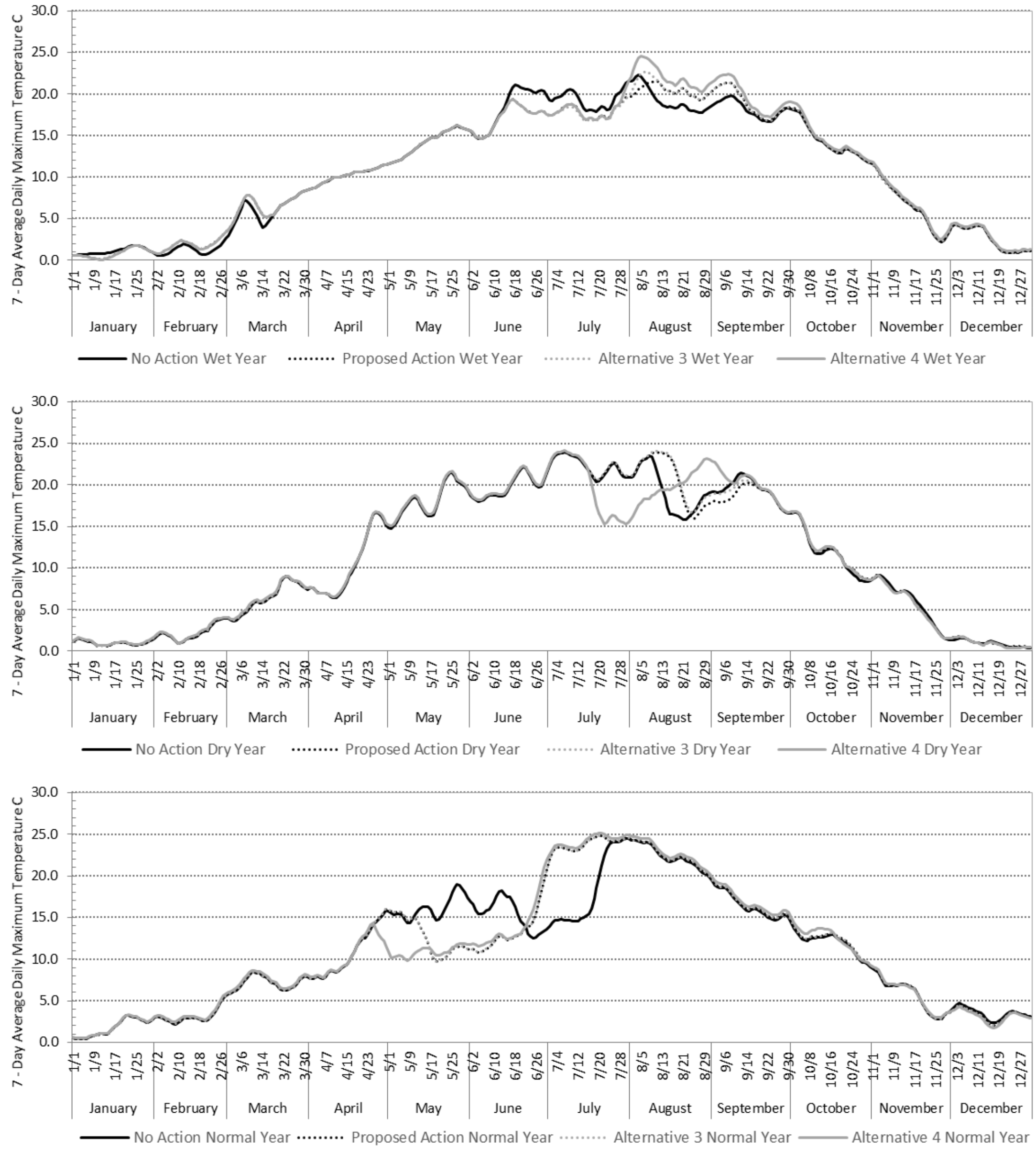
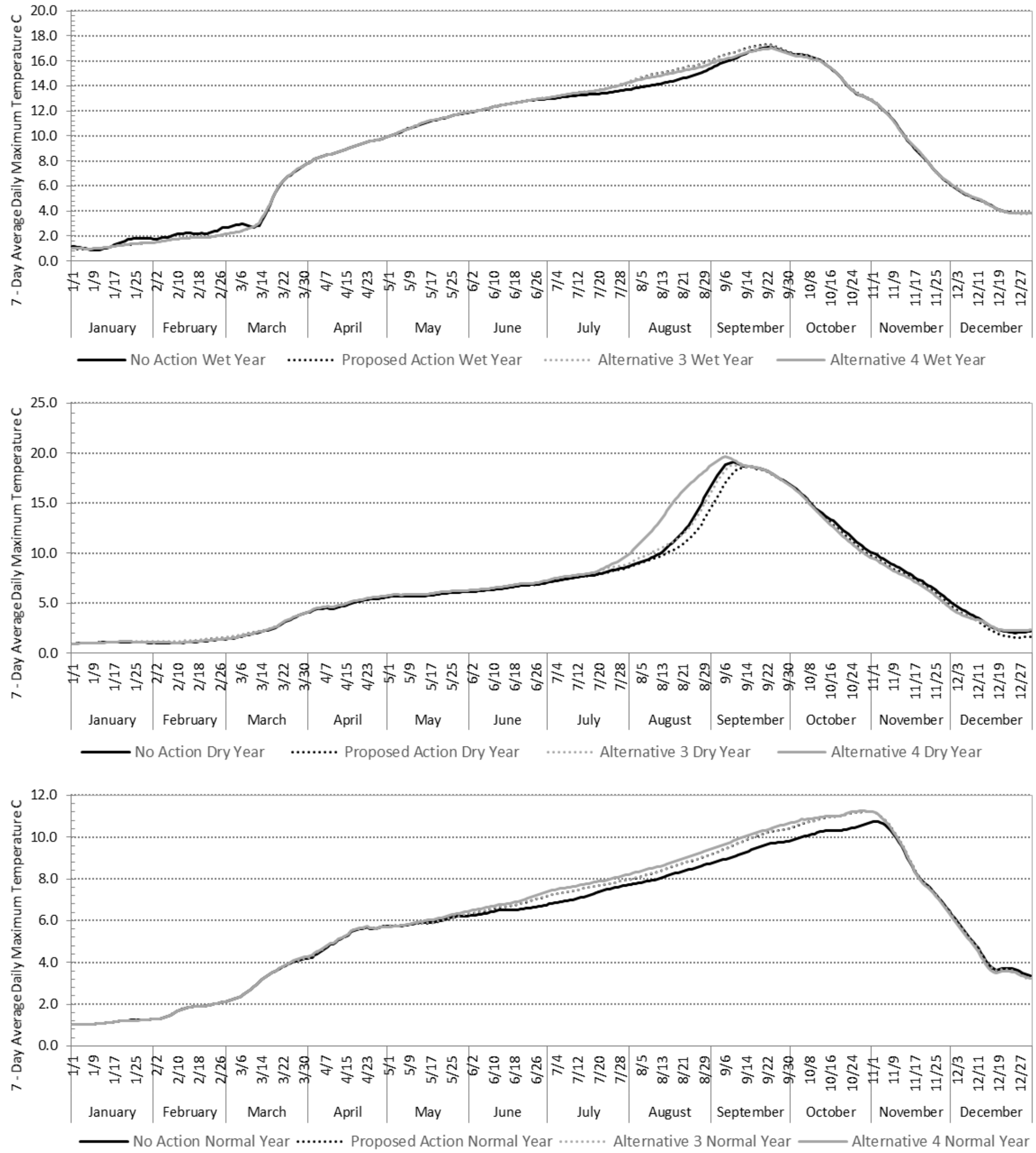


Figure 10. Annual Water Temperature Predictions (7-Day Average Daily Maximum) for the Crooked River (CAPO node) based on the 2019 RiverWare Model for a Wet (top), Dry (middle), and Normal (bottom) Year under the No-Action Alternative, Proposed Action, Alternative 3, and Alternative 4



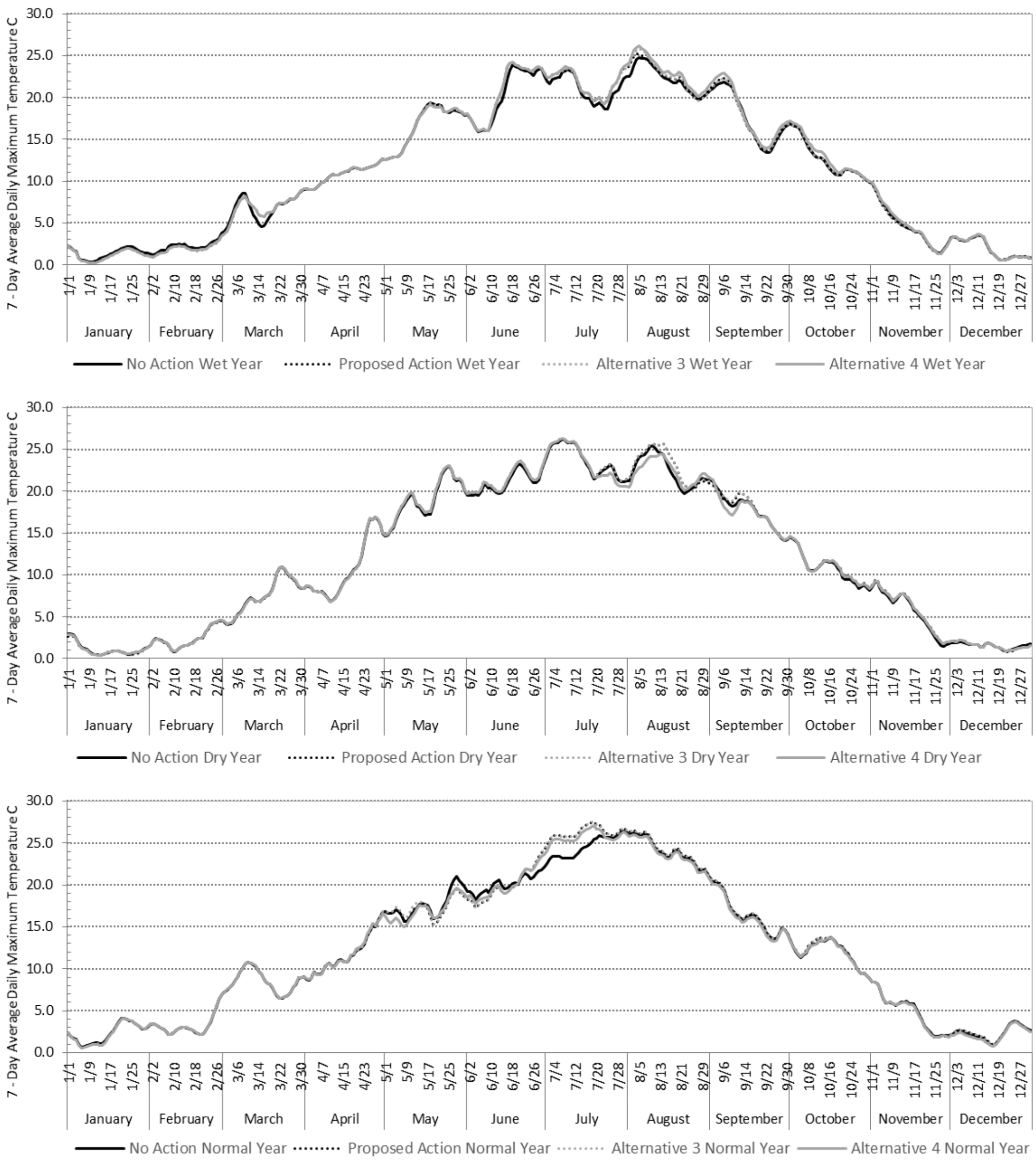
As discussed in Berger et al. (2019), outflow water temperatures in the wet year type were warmer than in the dry and normal year types because the reservoir did not fill until March. Outflow temperatures in June were approximately 13 °C compared to 6 °C in the dry and normal year types in the first segment below Bowman Dam (Figure 11). The warmer outflow temperatures affected conditions for species life stages in that year type.

Figure 11. Annual Water Temperature Predictions (7-Day Average Daily Maximum) for the Crooked River (PRVO node) based on the 2019 RiverWare Model for a Wet (top), Dry (middle), and Normal (bottom) Year under the No-Action Alternative, Proposed Action, Alternative 3, and Alternative 4



Effects of water management on water temperatures were less at the North Unit ID pumps at RM 22.4 compared to at the CAPO gauge at RM 46.7 (Figure 12). Maximum 7DADM at the pumps under the no-action alternative varied from 24.7 °C (wet year) to 26.5 °C (normal year). Maximum 7DADM temperatures were predicted to be slightly warmer under proposed action and action alternatives (25.2 to 27.5 °C under proposed action, 25.9 to 27.5 °C under Alternative 3, and 26.1 to 27.0 °C under Alternative 4). Effects of water management resulted in generally slightly warmer (~0.5 °C) maximum 7DADM water temperatures at North Unit ID pumps in June, July and August in the wet and dry year types. Normal year maximum water temperatures were approximately 1.7 °C warmer in July under the proposed action and Alternative 3, and 1.2 °C warmer under Alternative 4.

Figure 12. Annual Water Temperature Predictions (7-Day Average Daily Maximum) for the Crooked River (North Unit ID pump) based on the 2019 RiverWare Model for a Wet (top), Dry (middle), and Normal (bottom) Year under the No-Action Alternative, Proposed Action, Alternative 3, and Alternative 4



The 7DADM water temperatures was used to evaluate water temperature effects on fish species in the Crooked River. The predicted 7DADM temperature was calculated for a representative temperature model segment in Crooked River reaches 2 through 10 and was compared to species and life stage-specific temperature thresholds described in R2 and Biota Pacific (2013). Species and life stage temperature thresholds were reported for preference, avoidance, stress/disease, delay, and lethality (Table 6).

Table 6. Species Temperature Thresholds from R2 and Pacific Biota (2013)

Species	Life Stage	Categories	Criteria	Period
Spring Chinook	Adult Migration & Prespawn Holding	Preference	≤19.4	March – August
		Avoidance	>19.4 & ≤ 21	
		Delay	>21 & ≤ 25	
		Lethal	>25	
	Spawning	Preference	≤ 14	August – September
		Suboptimal	>14 & ≤16	
		Delay	>16 & ≤19	
		Lethal	>19	
	Egg Incubation	Preference	≤12.8	August – February
		Suboptimal	>12.8 & ≤14.4	
		Stress/Disease	>14.4 & ≤15.6	
		Lethal	>15.6	
	Summer Juvenile Rearing	Preference	≤15.6	June – September
		Suboptimal	>15.6 & ≤19.1	
		Stress/Disease	>19.1 & ≤22	
		Lethal	> 22	
	Juvenile Outmigration	Preference	≤15.6	February - May
		Suboptimal	> 15.6 & ≤19.1	
		Stress/Disease	> 19.1 & ≤22	
		Lethal	> 22	
Steelhead/ Redband Trout	Adult Migration & Prespawn Holding	Preference	≤12.8	October - March
		Suboptimal	>12.8 & ≤14.4	
		Avoidance	>14.4 & ≤21	
		Delay	>21 & ≤23.9	
		Lethal	>23.9	
	Spawning	Preference	≤12	March - May
		Suboptimal	>12 & ≤21	
		Lethal	>21	
	Egg Incubation	Preference	≤11.1	March - June
		Suboptimal	>11.1 & ≤15	
		Stress/Disease	>15	
	Summer Juvenile Rearing	Preference	≤14	June – September
		Suboptimal	>14 & ≤19	
		Avoidance	>19 & ≤22	
		Stress/Disease	>22 & ≤24	
		Lethal	>24	
	Juvenile Outmigration	Preference	≤13.6	April - June
		Delay	>13.6	

Species	Life Stage	Categories	Criteria	Period
Bull Trout	Adult & Subadult Migration	Preference	≤15	October - June
		Avoidance	>15 & ≤16	
		Delay	>16 & ≤23	
		Lethal	>23	
	Spawning	Preference	≤9	August – October
		Suboptimal	>9 & ≤11	
		Avoidance	>11	
	Egg Incubation	Preference	≤6	August – March
		Stress/Disease	>6	
	Juvenile and Subadult Rearing	Preference	≤15	January - December
		Suboptimal	>15 & ≤16	
		Stress/Disease	>16 & ≤23	
		Lethal	>23	
	Subadult and Adult Feeding/Migration /Overwinter (FMO)	Preference	≤15	January - December
		Avoidance	>15 & ≤16	
		Stress/Disease	>16 & ≤23	
		Lethal	>23	

The species-life stage effect analysis was based the number of days the 7DADM temperature was within the appropriate threshold ranges by reach for the no-action alternative, proposed action and action alternatives. This approach quantified shifts in timing and duration of warm and cool temperature events related to streamflow and critical temperature thresholds relative to the no-action alternative. The analysis compared temperature effects between the no-action alternative and the last stage of the permit term for the proposed action and action alternatives.

The RiverWare model was updated in 2019/2020 for the final EIS. The update included several revisions summarized in Table 7. These updates affected predicted water storage in Wickiup Reservoir, North Unit ID deliveries from the Upper Deschutes River, and North Unit ID diversions at the Crooked River pumps. The update affected predicted streamflows in the Crooked River and patterns of magnitude and timing (Figure 13).

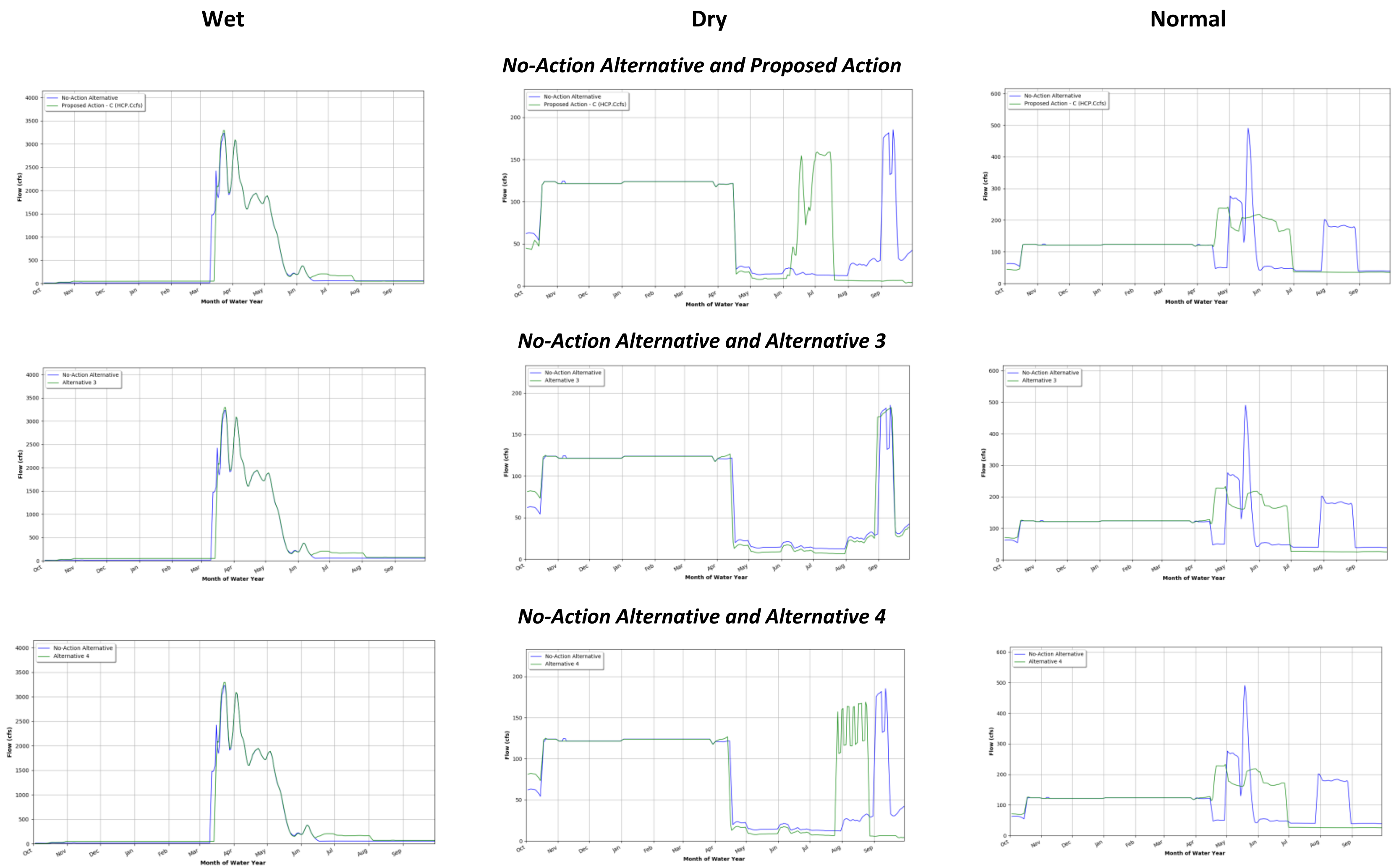
Table 7. RiverWare Update

RiverWare Component	Update to RiverWare	Effects on Hydrologic Conditions
Wickiup Reservoir	RiverWare irrigation demand is based on a normal water year and did not realistically reflects how the districts operate, i.e., reducing allocations in dry years.	The model logic was modified to better reflect how water managers would reduce allocations in a dry to extend irrigation deliveries over more of the irrigation season. This had the effect in the Crooked River of increasing North Unit ID reliance pump operations.
Upper Deschutes Conservation Measure WR-1	A 1,200 cfs maximum release from Wickiup Reservoir was added to WR-1	Adding the upper limit reduced water available for the North Unit ID diversion and increased diversions from the Crooked River under the proposed action. This measure was not included in Alternatives 3 and 4.

For example results from the 2019 RiverWare model were as follows: the release of water from Prineville Reservoir as predicted in the normal year (2005) under the no-action alternative occurred in late July through mid-August compared to a release in mid-May through the end of June under the proposed action in the last stage of the permit term (Figure 9). Results from the 2020 RiverWare model in a normal year follow a similar pattern. The release of water from Prineville Reservoir as predicted in the normal year (2005) under the no-action alternative occurred in May and August compared to a release in mid-April through the end of June under the proposed action in the last stage of the permit term (Figure 13). Streamflows under Alternatives 3 and 4 were similar to the proposed action in the normal year. Predicted streamflows at the CAPO gauge in a wet year were similar between the 2019 and 2020 RiverWare models. Predicted streamflows from the 2019 RiverWare model in a dry year were slightly earlier in the year under the proposed action and action alternatives. Results from the 2020 RiverWare model were different, but followed the same pattern of earlier release for the North Unit ID pump diversion.

The purpose of the temperature modeling was to evaluate effects of water management scenarios on water temperatures in the Crooked River. The 2019 RiverWare model results were used for temperature predictions because they described a range of streamflow scenarios and associated effects on water temperature. The range of streamflow scenarios modeled for water temperatures reflected the range of predicted streamflows from the 2020 RiverWare model. Furthermore, as described in Appendix 3.2-A one potentially significant difference between modeled water supply operations from RiverWare and real-time operational decisions made by water managers is the capability of managers to change operational decisions based on changing conditions. The timing of stored water releases for downstream irrigation diversions is necessarily simplified in the RiverWare model to follow a set of defined assumptions that can affect the timing of reservoir releases and streamflows in the Crooked River and Deschutes River. So, even though the 2020 RiverWare model was modified to better reflect some elements of water management, actual water management may differ. The 2019 RiverWare results were deemed suitable to evaluate effects of water management on water temperatures and fish species habitats in the Crooked River.

Figure 13. Annual Hydrograph based on the 2020 RiverWare model for the Crooked River near Highway 126 (CAPO node) for Wet (left), Dry (center) and Normal (right) Water Years and the Proposed Action (top), Alternative 3 (middle) and Alternative 4 (bottom) at the end of the Permit Term Compared to the No-Action Alternative



Crooked River Steelhead and Chinook Habitat Models

The effects analysis for the Crooked River was also based on results of the steelhead trout and Chinook salmon juvenile habitat capacity models developed by Mount Hood Environmental described below. The analysis of species effects is this appendix were based on results from this study independent of conclusions of effects made by the authors of the study.

These models are an extension of previous modeling by Mount Hood Environmental (Courter et al. 2014). Updates were made to the steelhead model to include winter habitat predictions and data on juvenile steelhead densities and habitat use from snorkel surveys in August and December 2018 (Mount Hood Environmental 2019a, 2019b).

The steelhead model produces an estimate of capacity in number of fish supported by the environment. The Chinook model is a numeric estimate of the amount of suitable rearing habitat area (square miles) for juvenile Chinook salmon.

The models include habitat unit types from Oregon Department of Fish and Wildlife (ODFW) habitat surveys, stream unit width and depths for a range of predicted streamflows, and maximum weekly average water temperatures (MWAT) observed during the 2018 summer snorkel surveys.

Both models were used to evaluate change in capacity (steelhead) and suitable habitat (Chinook) under the proposed action and action alternatives. Streamflows were taken from the 2019 RiverWare model results in both habitat models. MWAT values for the proposed action and each alternative and reach were based on water temperature predictions provided by PSU for the 3 years in the RiverWare analysis period based on the 2019 RiverWare model (Berger et al. 2019).

Estimates of winter steelhead capacity were highly influenced by summer water temperatures. An additional analysis was completed that held the water temperature parameter constant to evaluate effects of streamflow on capacity independent of water temperatures.

Affected Environment

Each geographic area is presented upstream to downstream and includes tributaries and reservoirs.

- Crescent Creek/Little Deschutes
  - Crescent Lake Reservoir
  - Crescent Creek
  - Little Deschutes River downstream of confluence with Crescent Creek to Deschutes River
- Upper Deschutes
  - Crane Prairie Reservoir
  - Deschutes River between Crane Prairie and Wickiup Reservoirs
  - Wickiup Reservoir
  - Deschutes River downstream of Wickiup Dam to the DEBO gauge in the city of Bend

- Middle Deschutes
  - Deschutes River from the DEBO gauge in the city of Bend downstream to Lake Billy Chinook
  - Tumalo Creek
  - Whychus Creek
  - Lake Billy Chinook and Lake Simtustus
- Lower Deschutes
  - Deschutes River downstream of Pelton-Round Butte Complex to confluence with the Columbia River
  - Trout Creek
- Crooked River
  - Prineville Reservoir
  - Crooked River downstream of Bowman Dam (RM 70.5) to confluence with the Deschutes River
  - Ochoco Reservoir
  - Ochoco Creek
  - McKay Creek

For the purposes of the fish and mollusks effects analysis, the large and environmentally diverse study area and geographic areas described in Table 1 were further subdivided into 47 reaches shown and labeled in Figures 14 through 18 and listed in Table 8. The demarcation of river reaches was performed according to the following principles.

- Reaches identified by FWS (2017)
- Reaches identified by Courter et al. (2014)
- Reach breaks located at dams and major diversions
- Each reservoir containing one or more reaches
- Reaches selected to have relatively uniform topography, channel conditions, hydrological gain or loss characteristics, and riparian and wetland vegetation

RiverWare model locations (nodes) representative of streamflow by reach are reported in Table 7.

Table 8. Study Area Reaches by Geographic Area

Geographic Area	Feature	Reach	RiverWare Output Node	Description
Crescent Creek/Little Deschutes	Crescent Lake Reservoir	CLD-7	Crescent Lake Reservoir Elevation and Volume	Crescent Lake is a reservoir that has no riparian or wetland vegetation except in three large embayments (the inflow stream and two slack water areas) that support mixed wetland and riparian vegetation.
	Crescent Creek	CLD-6	CREO	A pool-riffle channel flowing through a mostly unforested riverine wetland wetland/riparian vegetation corridor with a total width of 99–164 feet, flanked by ponderosa pine-dominated upland forest.
		CLD-5	CREO	Upper end of the reach the channel is constricted by road and railroad crossing; downstream a low-gradient meandering channel within a mostly unforested riverine wetland corridor with a total width of 164–328 feet, flanked by ponderosa pine-dominated upland forest.
	Little Deschutes River	CLD-4	Walker Canal Internode	Reach begins at Crescent Creek/Little Deschutes River confluence; moderately meandering underfit channel with glide morphology in an unforested wetland/riparian vegetation corridor with a total width of 164–328 feet.
		CLD-3	Walker Canal Internode	Same as CLD-1 and 2.
		CLD-2	LAPO	Same as CLD-1, but upstream of the LAPO gauge.
		CLD-1	LAPO	Reach begins at LAPO gauge; low-gradient underfit channel with glide morphology in an unforested wetland/riparian vegetation corridor with a total width of 328–984 feet.
Upper Deschutes	Crane Prairie Reservoir	Des-15	Crescent Lake Reservoir Elevation and Volume	Locally extensive riparian/wetland vegetation on its margins and at its head. This is the upper limit of potential project effects on the Deschutes River.
	Deschutes River	Des-14	CREO	Deschutes River between Crane Prairie and Wickiup Reservoirs; pool-riffle reach with narrow bands of riparian vegetation, mostly located on point bars.

Geographic Area	Feature	Reach	RiverWare Output Node	Description
	Wickiup Reservoir	Des-13	Wickiup Reservoir Elevation and Volume	About 30% of Wickiup Reservoir has riparian/wetland vegetation, and it develops some localized herbaceous vegetation during drawdown. Uppermost Des-13 is less often inundated and has substantial areas of both herb and shrub wetland and riparian vegetation. Year-to-year water level variations are very large and the riparian/wetland vegetation is persistent despite this variability.
	Deschutes River	Des-12a	WICO	Wickiup Reservoir to Fall River. Lower part of the reach is similar to Des-12. Above the State Park, the river transitions to much less sinuosity with a relatively narrow riparian zone. Wetlands generally occur on the inside of meander bends.
		Des-12	WICO + Fall River inflow	Fall River to Little Deschutes River. The river is highly sinuous overall, with a fairly high frequency of cutoff meanders. There is more development with riverfront homes. Wetlands typically occur in meander scars and oxbows.
		Des-11	WICO + Fall River inflow +Spring River inflow+LAPO	Little Deschutes River to Benham Falls (BENO node) Similar in river characteristics to Des-10a. Wetlands are more sparse than between Dillon and Benham and in some sections the valley walls extend down to the river’s edge.
		Des-10a	BENO	Benham Falls (BENO node) to Dillon Falls. Similar to Des-10, but some extensive wetland complexes flank the river or its former cut-off meanders; these include a mix of aquatic, wetland and riparian vegetation, mostly in herbs and shrubs but locally in hardwood and mixed forest. The wetland complexes are distinctly influenced by groundwater, surface water, and/or pluvial inputs depending on the site. This reach includes the Slough Camp complex and Ryan Ranch, two very large and notable wetlands.

Geographic Area	Feature	Reach	RiverWare Output Node	Description
		Des-10	Arnold Canal inflow internode	Dillon Falls to Lava Island Falls (Arnold Canal diversion). River is low gradient, glide morphology due to ancient damming by a lava flow at Lava Island Falls and the Arnold Canal diversion. Some extensive wetland complexes flank the river or its former cut-off meanders; these include a mix of aquatic, wetland, and riparian vegetation, mostly in herbs and shrubs but locally in hardwood and mixed forest.
		Des-9	Central Oregon ID inflow internode	Lava Island Falls (Arnold Canal diversion) to Central Oregon ID diversion. Wetlands are present in this reach, but the river is more confined in some locations and there are stretches of fast water, including Big Eddy rapids and other swift water sections.
		Des-8a	Central Oregon ID outflow internode	Central Oregon ID Diversion to Colorado Street Bridge. River is confined variously by lava flows, development, and topography, with limited but locally important riparian or aquatic vegetation. River channel has a mixed pool-riffle, step-pool and glide morphology with occasional cascades. Reach Des-8a is designated for consistency with the U.S. Fish and Wildlife Service (2017, 2019) analysis, which placed a reach break at the Colorado Avenue bridge.
		Des-8	Central Oregon ID outflow internode	Colorado Street Bridge to Bend Feeder Canal diversion in Bend.
		Des-7	North Unit inflow internode	Bend Feeder Canal diversion in Bend to North Unit irrigation diversion. River is confined variously by lava flows, development, and topography, with limited but locally important riparian or aquatic vegetation. River channel has a mixed pool-riffle, step-pool and glide morphology with occasional cascades.
		Des-6	DEBO	North Unit irrigation diversion to DEBO node. Same characteristics as Des-7.

Geographic Area	Feature	Reach	RiverWare Output Node	Description
Middle Deschutes	Deschutes River	Des-5	DEBO	DEBO node downstream of Bend to Tumalo Creek. Same characteristics as Des-3.
		Des-4.4	DEBO + TUMO	Tumalo Creek to Big Falls (upper extent historical anadromous species). Same characteristics as Des-3.
		Des-4.3	DEBO + TUMO	Big Falls (upper extent historical anadromous species) to RM 130 (reach break delineated for covered species modeling). Same characteristics as Des-3.
		Des-4.2	DEBO + TUMO	RM 130 (reach break delineated for covered species modeling) to Steelhead Falls. Same characteristics as Des-3.
		Des-4.1	DEBO + TUMO	Steelhead Falls to Whychus Creek. Same characteristics as Des-3.
		Des-3	CULO	Whychus Creek to Lake Billy Chinook. River has pool-riffle and step-pool morphology, and is confined within a canyon that experiences active groundwater inflow at or above the river surface elevation for most of its length.
	Lake Billy Chinook/ Simtustus, & Re-Regulating	Des-2	NA	Lake Billy Chinook, Lake Simtustus, and Re-regulating reservoirs
	Tumalo Creek	TC-1	TUMO	Tumalo Feed Canal diversion to Deschutes River. Tumalo Diversion is the upper limit of proposed action and action alternatives effects.
	Whychus Creek	Why-5		Three Sisters ID diversion to upstream of Sisters. Consistent with reach W-4 of Courter et al. (2014). Channel is confined, pool-riffle, flowing within conifer (ponderosa pine mostly) forest with an average riparian vegetation width of 20 feet along each streambank. The upper limit is the upstream limit of potential project effects.
		Why-4	Whychus blw Three Sisters ID	Reach within the town of Sisters (consistent with W-3 reach in Courter et al. 2014). Reach with intensive suburban development with negligible riparian and no wetland vegetation.

Geographic Area	Feature	Reach	RiverWare Output Node	Description
		Why-3	Whychus at Sisters	Sisters to beginning confined section of creek (upper portion of W-2 reach in Courter et al. 2014). Creek is unconfined or moderately confined with a riparian vegetation width of 66–164 feet along each streambank. There is evidence of domestic pasturage, local evidence of groundwater inflow, and local areas of wetlands, irrigated agriculture, and exurban development. The floodplain includes oxbows and other alluvial features.
		Why-2	Whychus at Sisters	Top of confined section of creek to Alder Springs (lower portion of W-2 reach in Courter et al. 2014).
		Why-1	Whychus at Sisters	Alder Springs to Deschutes River (consistent with W-1 reach in Courter et al. 2014). Creek has pool-riffle and step-pool morphology, and is confined within a canyon that experiences active groundwater inflow at or above the river surface elevation for most of its length, and which is the primary hydrology source for riparian and wetland vegetation found in this reach.
Crooked River	Prineville Reservoir	Cro-13	Prineville Elevation and Volume	The headwaters of Prineville Reservoir, includes a large wetland and benches or bars with shrub and herb riparian and wetland vegetation. This is the upper limit of potential project effects on the Crooked River.
		Cro-12	Prineville Elevation and Volume	Upper Prineville Reservoir, where seasonally exposed areas have some riparian or wetland vegetation.
		Cro-11	Prineville Elevation and Volume	Lower Prineville Reservoir, which has no riparian or wetland vegetation.
	Upper Crooked River	Cro-10	PRVO	Bowman Dam (RM 70.5) to OID Crooked River diversion (RM 55.9); consistent with reach C-5 in Courter et al. 2014. River is mostly in an open canyon with riparian vegetation about 33 feet wide on each bank, locally wider (on point bars). There are some small areas of agriculture (hayfields) adjacent to the river.

Geographic Area	Feature	Reach	RiverWare Output Node	Description
		Cro-9	PRVO	OID Crooked River Diversion (RM 55.9) to Peoples Canal diversion (RM 49.4); consistent with reach C-4 in Courter et al. 2014. Moderately confined, flanked almost continuously by irrigated agriculture. The river with its riparian zone is mostly 115 feet wide but in places is several times wider between the cultivated fields.
		Cro-8	PRVO	Peoples Canal diversion (RM 49.4) to near Highway 126 in Prineville (CAPO Gauge location) (RM 46.7). The river is flanked by intensive development; there is negligible riparian or wetland vegetation.
	Middle Crooked River	Cro-7	CAPO	Near Highway 126 in Prineville, CAPO gauge (RM 46.7) to Ochoco Creek (RM 43.90. Unconfined reach, flanked almost continuously by irrigated agriculture. The river with its riparian zone is mostly 115 feet wide, but wider in places between the cultivated fields.
		Cro-6	CAPO	Ochoco Creek (RM 43.9) to Central Canal diversion (RM 41.5). McKay Creek enters this reach at RM 43.0. Same characteristics as Cro-7.
		Cro-5	CAPO	Central Canal diversion (RM 41.5) to Low Line Canal diversion (RM 34.8). Lytle Creek enters this reach at RM 38.1. Same characteristics as Cro-7.
		Cro-4	CAPO	Low Line Canal diversion (RM 34.8) to Lone Pine Bridge (RM 24.6). Same characteristics as Cro-7.
		Cro-3	CAPO	Lone Pine Bridge (RM 24.6) to North Unit Irrigation pump diversion (RM 22.4). Moderately confined, flanked almost continuously by irrigated agriculture. The river with its riparian zone is mostly 115 feet wide but in places is several times wider between the cultivated fields.
	Crooked River Below NUID Diversion	Cro-2.2	North Unit ID Crooked Divert.Outflow internode	North Unit ID pump diversion (RM 22.4) to CSRO node near Smith Rock (RM 19.9); this internode approximates streamflow below the North Unit ID pump to Osborne Canyon. Partly in a deep canyon, but has a 33- to 99-foot-wide riparian zone on each bank of the river in places.

Geographic Area	Feature	Reach	RiverWare Output Node	Description
		Cro-2.1	North Unit ID Crooked Divert.Outflow internode	CSRO node near Smith Rock (RM 19.9) to Highway 97 (RM 12.4); reach affected by North Unit ID pumps. Same characteristics as Cro-2.2.
		Cro-1.3	North Unit ID Crooked Divert.Outflow internode	Highway 97 (RM 12.4) to Osborne Canyon (RM 7.3); reach affected by North Unit ID pumps. Same characteristics as Cro-2.2.
	Crooked River Below Opal Springs	Cro-1.2	Opal	Osborne Canyon (RM 7.3) to Opal Springs Dam (RM 0.8), start of gaining reach. Same characteristics as Cro-1.1.
		Cro-1.1	Opal	Opal Springs Dam (RM 0.8) to Lake Billy Chinook (RM 0); significant gaining reach. River is tightly confined in deep canyon with no wetlands and almost no riparian vegetation.
	Ochoco Reservoir	Och-4	Ochoco Elevation and Volume	Ochoco Reservoir, shoreline has negligible riparian or wetland vegetation.
	Ochoco Creek	Och-3	OchMin	Ochoco Reservoir to Route 380 Bridge; reach O-1 in Courter et al. (2014). Generally same as Och-1, but somewhat more heterogeneous with some desert upland and some residential areas and parks, and aquatic/riparian corridor width 65–100 feet.
		Och-2	OchMin	Route 380 Bridge to Prineville; reach O-1 in Courter et al. (2014). Creek is in developed city of Prineville, has riparian trees, but is essentially all developed as parks or residential. No wetlands.
		Och-1	OchMin	Prineville city/urban landscape to Crooked River; reach O-1 in Courter et al. (2014). Creek is unconfined, flanked almost continuously by irrigated agriculture. Combined width of aquatic and riparian vegetation averages 115 feet.
	McKay Creek	Mck-3	No data	Jones Dam to Reynolds Siphon; consistent with reach MK-3 in Courter et al. (2014). Similar to Mck-2 with a somewhat steeper channel that is seasonally dry.
		Mck-2	No data	Dry Creek to Reynolds Siphon; consistent with reach MK-2 in Courter et al. (2014). Similar to Mck-1, with some areas of predominately shrub or tree vegetation.

Geographic Area	Feature	Reach	RiverWare Output Node	Description
		Mck-1	No data	Reynolds Siphon to Crooked River; consistent with reach MK-1 in Courter et al. (2014). Unconfined low-gradient stream through cultivated fields. The riparian corridor width varies from 15–328 feet depending on how much land is left uncultivated along the stream. Vegetation is mostly herbs with some shrubs.
Lower Deschutes	Deschutes River	Des-1	MADRAS	Re-regulating Dam at RM 100 to Columbia River. There is negligible groundwater inflow or outflow. Several eastside tributary inputs and Warm Springs River on westside. There are very few wetlands, and riparian vegetation extends in a narrow band 0–197 feet wide, with an average total width (both river banks combined) of 61 feet.
	Trout Creek	Trout	No data	Eastside tributary with steelhead access, includes Mud Creek. Streamflow augmented by irrigation returns.

Figure 14. Fish and Mollusks Study Area Reaches—Upper Deschutes and Crescent Creek/Little Deschutes

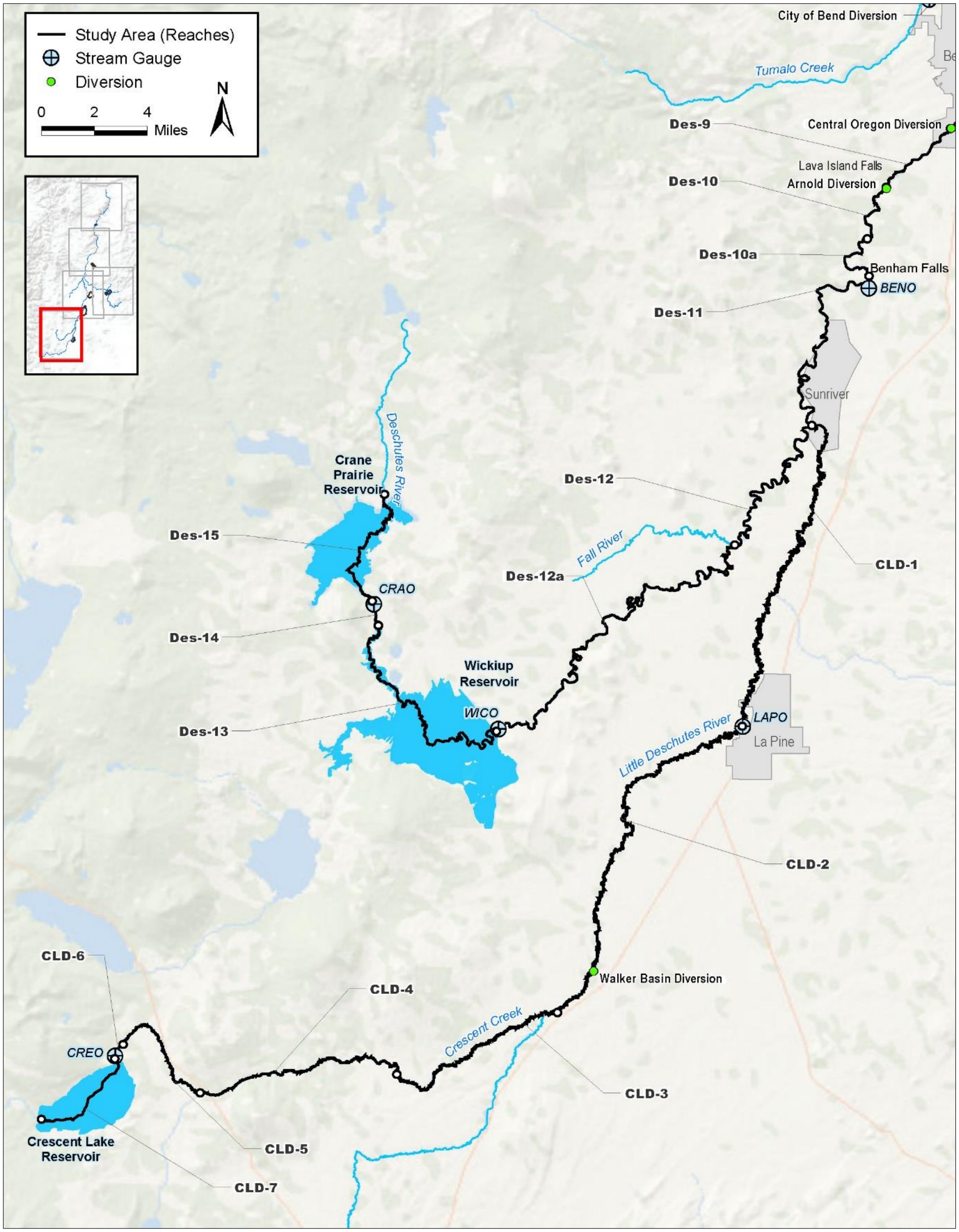


Figure 15. Fish and Mollusks Study Area Reaches—Middle Deschutes and Lower Crooked River

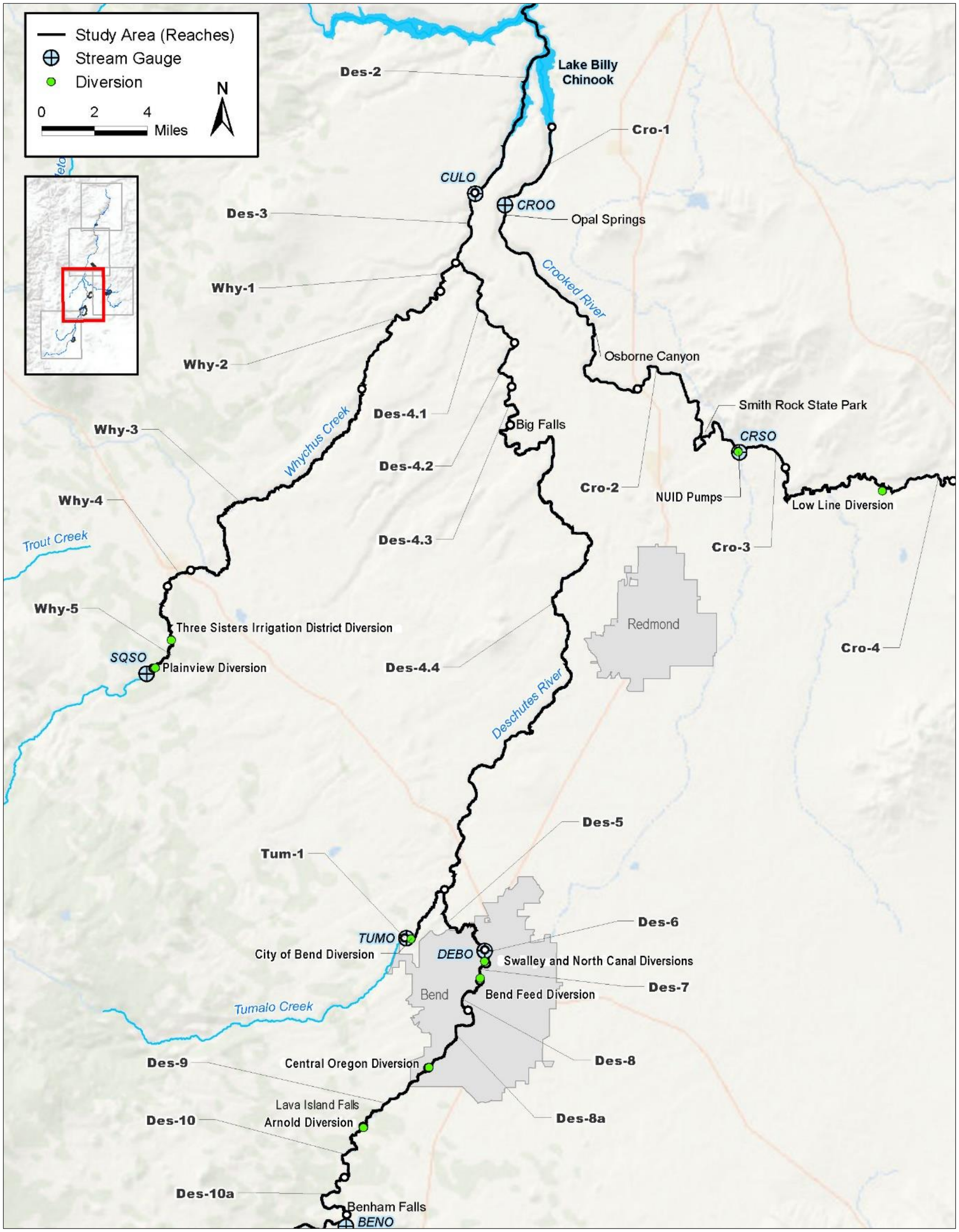


Figure 16. Fish and Mollusks Study Area Reaches—Upper Crooked River

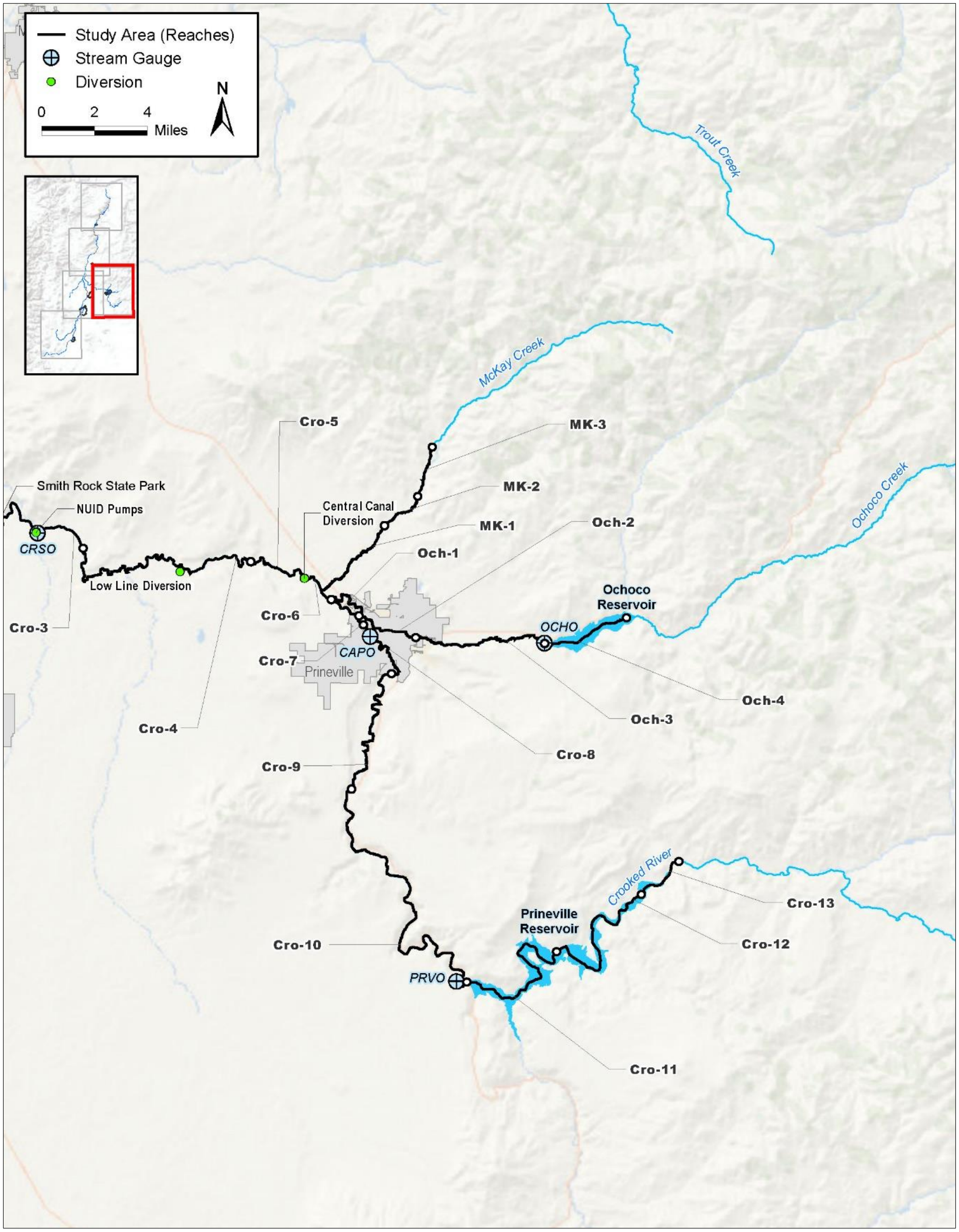


Figure 17. Fish and Mollusks Study Area Reaches—Lake Billy Chinook, Lake Simtustus, and Lower Deschutes

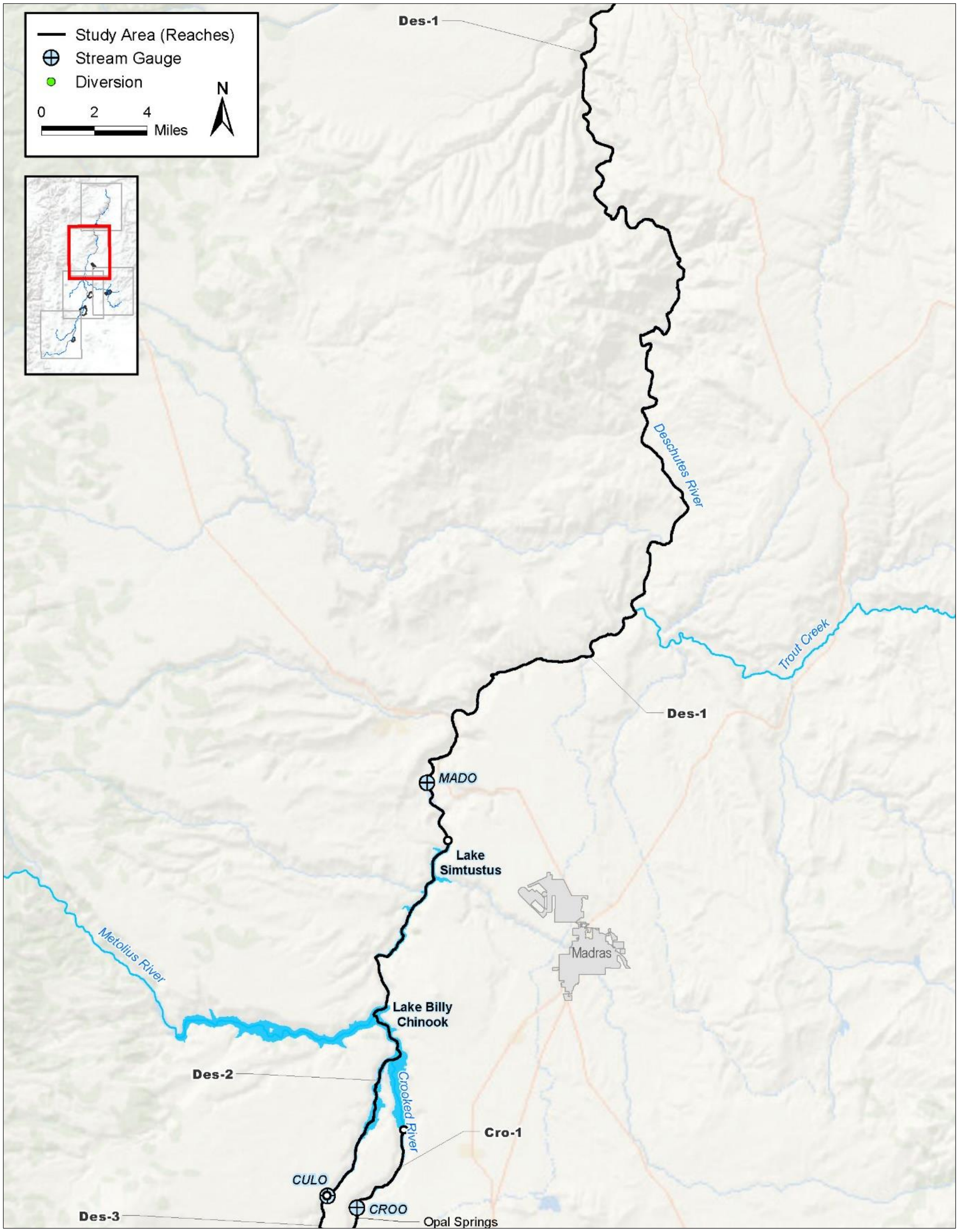
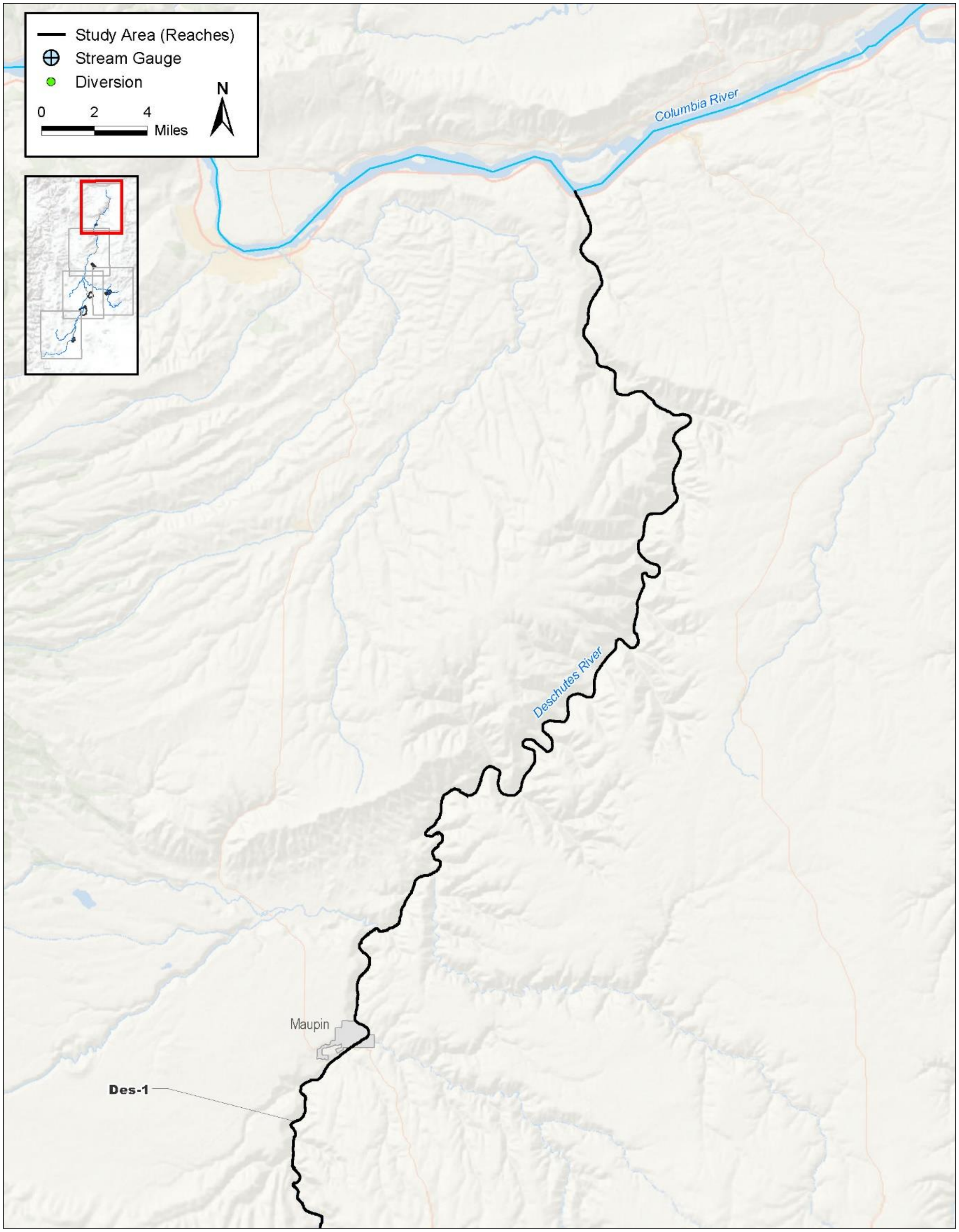


Figure 18. Fish and Mollusks Study Area Reaches—Lower Deschutes



Environmental Consequences

Species impacts are evaluated by geographic area listed in Table 1 across the study area.

Effects Determination Thresholds

Effects of the proposed action and action alternatives on fish and other aquatic resources would be considered adverse if they would result in any of the following conditions.

- Cause a decline in fish or mollusk population productivity, abundance, or diversity that may result in a substantial effect, either directly or through habitat modifications, on recovery, persistence, or reintroduction of the species population.
- Cause direct mortality of any fish or mollusks identified as a candidate, sensitive, or special-status species in local or regional plans, policies, or regulations of by ODFW, FWS, or the National Marine Fisheries Service (NMFS).
- Substantially reduce the habitat or windows for life stage expression in geographies for any fish or mollusks identified as a candidate, sensitive, or special-status species in local or regional plans, policies, or regulations of ODFW, FWS, or NMFS, including essential fish habitat (EFH) under the Magnuson-Stevens Act in the Lower Deschutes (EFH does not extend above the Pelton-Round Butte Complex Re-regulating dam).
- Permanently reduce the acreage or alter the value of any sensitive aquatic natural community identified in local or regional plans, policies, or regulations or by ODFW or FWS.
- Interfere substantially with the movement of any native resident or migratory fish species.

Alternative 1: No Action

Continuation of current water management operations under the no-action alternative, described in Chapter 2, *Proposed Action and Alternatives*, would result in no changes in streamflows for fish and mollusk habitat compared to existing conditions. Continuation of existing operations under the no-action alternative would result in slightly less seasonal and year-to-year flow variation in the Deschutes River upstream of Bend, relative to the past hydrology that established the existing environmental conditions. These conditions include summer flows so high that riparian vegetation is inundated and winter flows so low that riparian vegetation is generally dewatered and is vulnerable to seasonal drying and freezing. It is possible that over the analysis period, in some locations along the Deschutes River upstream of Bend, the continued implementation of reduced flow variation under the no-action alternative would allow a small improvement in the extent and functional value of riparian and wetland vegetation benefiting fish habitat. Extreme low winter streamflows have, under past water management, exposed bank vegetation to subfreezing temperatures and drought stress that can contribute to vegetation dieback and exposed streambanks. Slightly and intermittently reducing these extreme events could increase bank vegetation, which would contribute to reduced bank erosion, decreased water turbidity, and river channel sedimentation during high irrigation season flows. However, data are not adequate to identify those locations or to quantify the magnitude of the habitat quality improvement. Similarly, continued implementation of existing water management rules and agreed minimum streamflow requirements on the Crooked River (i.e., Crooked River Act, Deschutes River Conservancy/North

Unit Water Supply Program on the Crooked River) as described in Chapter 2, would improve habitat for fish and mollusks in the Crooked River.

Other variables, such as climate change, habitat restoration and fish enhancement projects for reintroduction above the Pelton-Round Butte project, and water conservation projects that increase streamflows, would affect fish and mollusks over the analysis period. Additional details are presented in Appendix 3.4-C, *Fish and Mollusks Technical Supplement.*

Implementation of the existing plans for water conservation projects assumed under the no-action alternative, as described in Chapter 2, would increase streamflows below irrigation diversions in the Deschutes River, Tumalo Creek, and Whychus Creek.[1] Benefits to fish and mollusk habitat would be higher summer streamflows and potentially cooler water temperatures with higher streamflows. Habitat restoration projects, listed in Appendix 2-B, *No-Action and Cumulative Scenarios*, would result in overall, but unquantifiable, improvements to fish and mollusk habitats in the study area over the analysis period. Fish enhancement projects to support reintroduction of steelhead trout, sockeye salmon, and spring Chinook salmon above the Pelton-Round Butte Complex and restore fish passage[2] to the Crooked River at Opal Springs Dam would result in additional improvements to fish habitats, access to blocked habitat, and benefits to fish species.

However, projected effects of climate change, described in Section 3.2, *Water Resources*, could result in adverse effects on the distribution and quality of fish habitat available in the study area. Changes in precipitation patterns and precipitation type (e.g., a shift from snowpack to rain) due to climate change could affect fish habitats, which would affect the abundance, productivity, and distribution of these fish and mollusk species.

Although the continuation of existing restoration and protection strategies under the no-action alternative could result in the improvements to fish and mollusk habitat, climate change could result in adverse effects on the covered species that would negatively affect the distribution and quality of habitat available in the study area. The resulting outcome (adverse, not adverse, beneficial, or no effect) and magnitude of this combination of effects on fish and mollusks cannot currently be forecast reliably. However, not addressing water management and effects on streamflows in a comprehensive manner likely would have an adverse effect on the ability to manage for future changes in climate.

Effect Conclusion: A continuation of existing water management operations may be beneficial to fish habitat in the Deschutes River upstream of Bend, and plans for habitat restoration, fish enhancement, and water conservation projects in the study area under the no-action alternative would result in unquantifiable improvements to fish and mollusk habitat. Continued water management operations on the Crooked River would have no effect compared to existing conditions, but fish access and habitat restoration projects could be beneficial to fish species. However, the effect of climate change assumed over the analysis period has the potential to adversely affect the distribution and quality of the covered fish species habitat that is available in the study area. Therefore, effects under the no-action alternative are expected to be adverse because of the

[1] Three Sisters ID has completed piping of their canals; therefore, the addition of 3.0 cfs to Whychus Creek (included under Conservation Measure WC-1) is accounted for in the RiverWare model for the no-action alternative, as well as the proposed action and Alternatives 3 and 4.

[2] The fish passage structure at Opal Springs Dam in the Crooked River was completed in 2019 and is providing access to this river for all fish species, supporting the reintroduction of steelhead and Chinook in this area, and recolonization by bull trout in the Crooked River.

anticipated effects of climate change to reduce habitat quality and quantity for coldwater fish species such as trout and salmon. Effects would likely be greatest in the Crooked River because of relatively less influence of groundwater inflow to portions of the river.

Alternative 2: Proposed Action

Modeled changes in streamflows, reservoir volumes and elevations, and water quality conditions under the proposed action compared to the no-action alternative are described below in the *Modeled Environmental Conditions* section followed by descriptions of how these changes would affect individual species in the *Species Impacts* section.

Modeled Environmental Conditions

This section describes important changes in reservoir storage and elevation, seasonal river and creek streamflows, and relevant water quality information in the study area by geographic area and subarea under the proposed action. Effects are evaluated based on changes in modeled results for the proposed action compared to the no-action alternative.

Conservation measures relevant to fish and mollusk habitats are described at the beginning of each geographic area summary. Conservation measures are described to better understand differences between the no-action alternative and proposed action.

Crescent Creek/Little Deschutes

The proposed action includes a Conservation Measure CC-1 that sets aside a portion of the water stored in Crescent Lake Reservoir to be used specifically to benefit Oregon spotted frogs. This OSF storage would be used to manage streamflows in Crescent Creek to maintain or increase winter minimum flow levels, increase instream flow levels in spring or delay and draw out the ramp down of irrigation releases in the fall. Conservation Measure CC-1 is analyzed as part of the proposed action. The conservation measure is not part of the no-action alternative or Alternatives 3 or 4.

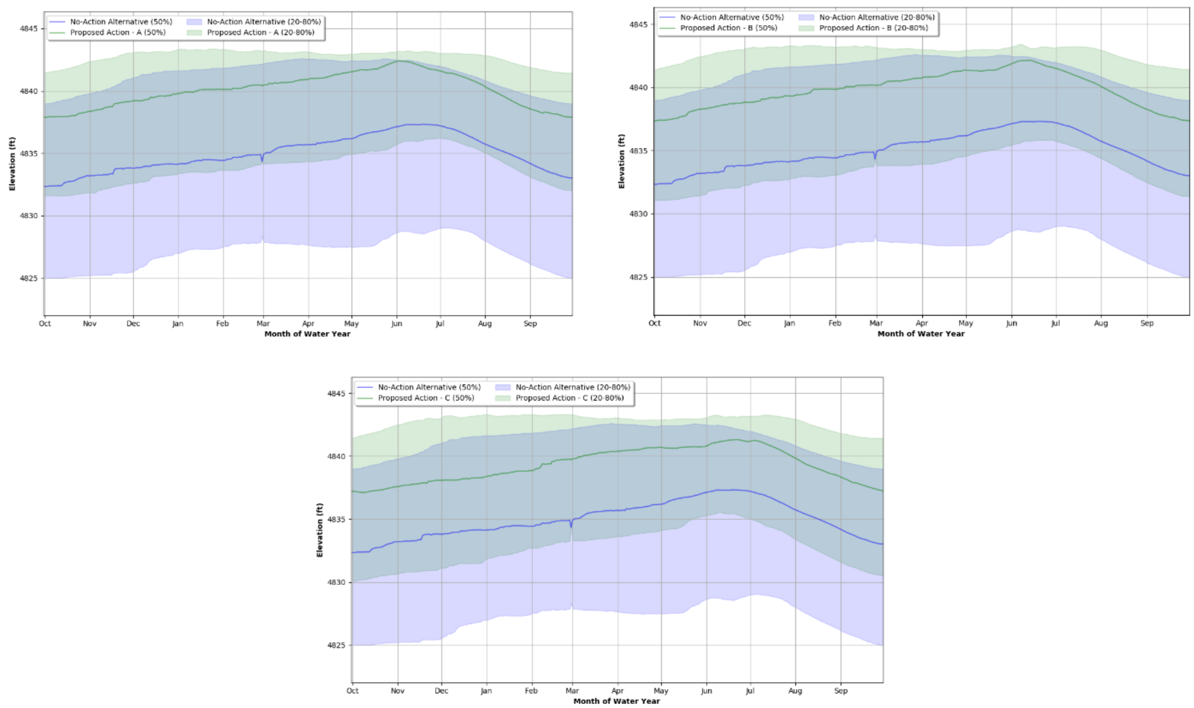
RiverWare results do not fully account for water management under Conservation Measure CC-1 in Crescent Creek and Little Deschutes River downstream of Crescent Creek. This storage could be used to manage for higher streamflows at critical periods for Oregon spotted frog life stages. A full description of how streamflows would be managed is included in Appendix 3.4-B.

Crescent Lake Reservoir

RiverWare based modeled results for the Crescent Lake Reservoir node (CRE), illustrated in Figure 19, the following would occur:

- Median reservoir elevations would be substantially higher in all months.
- Reservoir elevations would not differ over the permit term.

Figure 19. Modeled Elevations for Crescent Lake Reservoir (CRE node) under the Proposed Action Years 1–7 (top left), 8–12 (top right), and 13–30 (bottom) Compared to the No-Action Alternative



Crescent Creek

Conservation Measure CC-1 OSF storage could be used to manage for higher streamflows at critical periods for Oregon spotted frog life stages. A full description of how streamflows will be managed is included in Appendix 3.4-B.

This "OSF storage" is to be used specifically to benefit Oregon spotted frogs and its volume will increase over the lifetime of the proposed action. Four phases of increasing OSF storage do not precisely track the three phases of overall proposed action implementation, but instead follow the timeline outlined in Conservation Measure CC-1.

Each year, the OSF storage volume available for the following water year will be set depending on the phase of the proposed action and on the storage volume detected in Crescent Lake Reservoir as of July 1. OSF storage will first be used to fulfill the minimum winter flow in Crescent Creek during the overwinter and spring seasons (October 1 through June 30). After fulfilling the minimum winter flow, any remaining OSF storage can be used to manage flows in Crescent Creek to further increase winter flows, increase instream flow levels in spring, or delay and draw out the ramp down of irrigation releases in the fall. Neither the no-action alternative nor the other action alternatives (Alternatives 3 or 4) include this conservation measure.

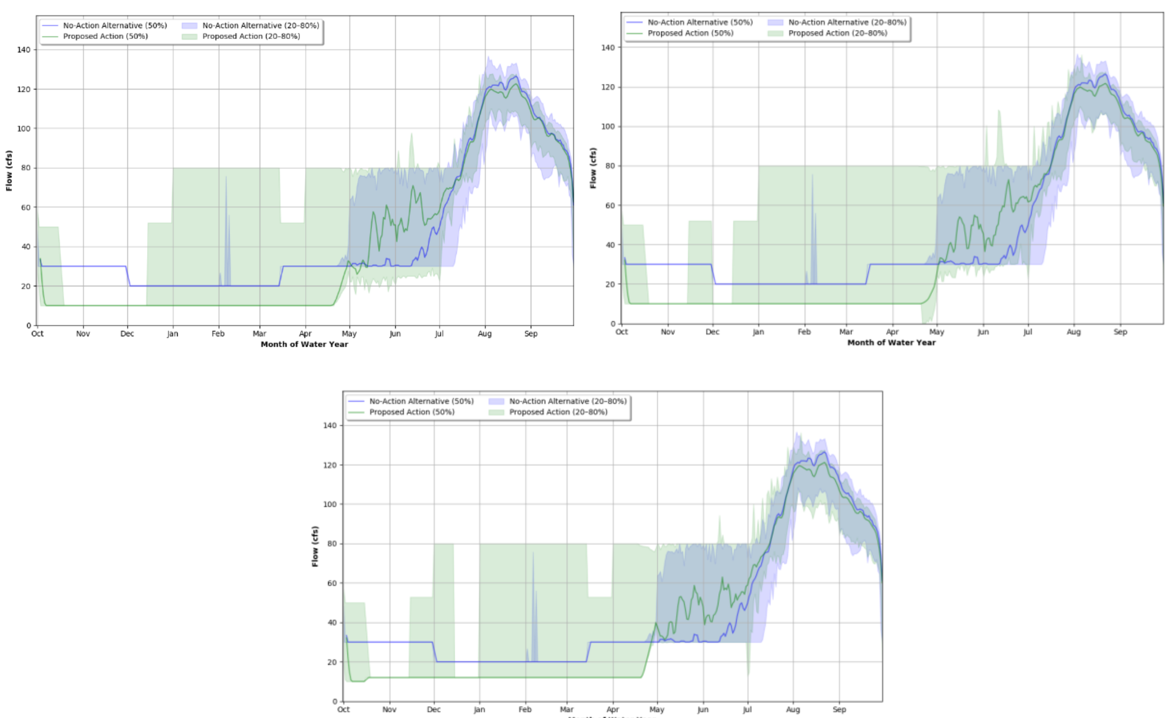
Water management under Conservation Measure CC-1 would likely provide beneficial effects on fish and mollusk habitats by providing higher streamflows during the winter and moderating ramp down at the end of the irrigation season.

Conservation Measure CC-2 (Crescent Dam Ramping Rates) sets the rate of increase in the streamflow below Crescent Dam (as measured at OWRD Gauge 14060000) to no more than 30 (±2) cfs per 24-hour period or the decrease in streamflow to no more than 20 (±2) cfs per 48-hour period, except under emergency conditions. This measure would protect aquatic species from ramping rates that may strand individuals in backwater areas or force them out of preferred habitats.

RiverWare based modeled results for the Crescent Creek node (CREO), illustrated in Figure 20, the following would occur:

- Median winter streamflows would be lower in nearly all years by 40 to 60% depending on month.
- May and June streamflows would be higher in about half the years by 80 to 160%
- There would be minor differences in streamflows over the permit term.

Figure 20. Modeled Streamflows Crescent Creek at Crescent Lake Reservoir (CREO node) under the Proposed Action Years 1–7 (top left), 8–12 (top right), and 13–30 (bottom) compared to the No-Action Alternative



Little Deschutes River

RiverWare based modeled results for the Little Deschutes River node (LAPO), illustrated in Figure 21, the following would occur:

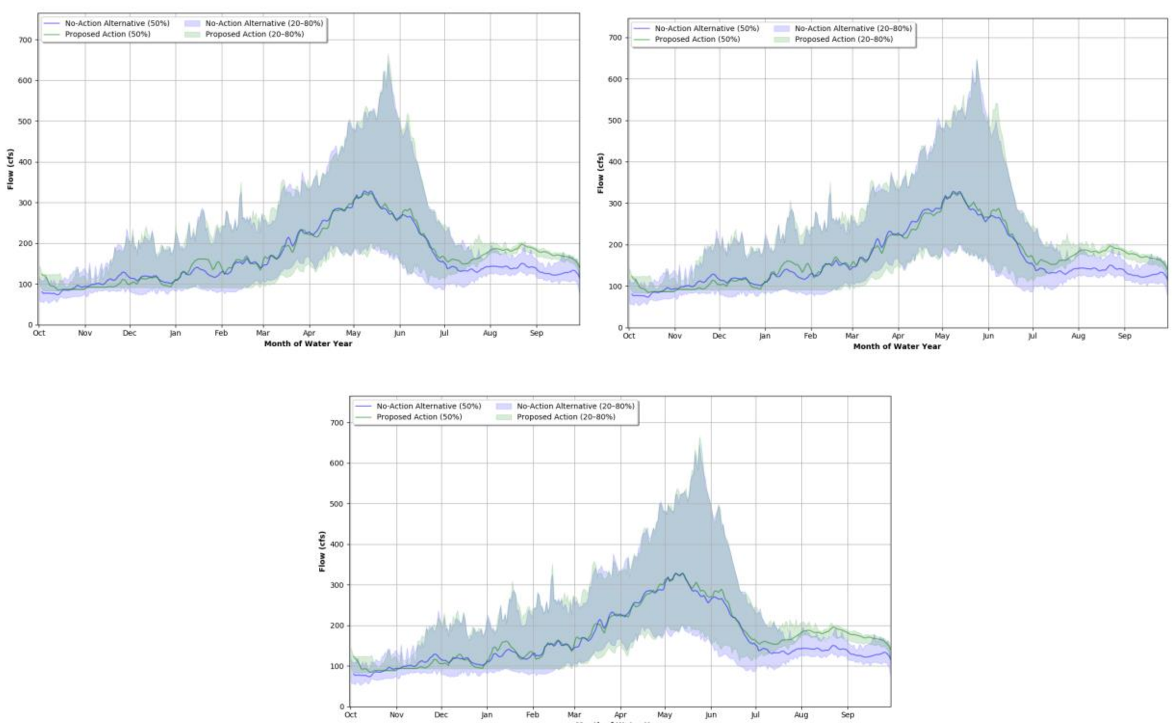
- November to May streamflows are slightly higher in some years.
- Flows are higher under the proposed action from about mid-July to middle of September in the majority of years

Streamflows added to the system from the OSF storage volume can influence the Little Deschutes during low water years. This OSF storage could be used to positively affect streamflows in the Little Deschutes below the confluence with Crescent Creek during the spring for Oregon spotted frog breeding.

Streamflows added to the system from the OSF storage volume can influence the Little Deschutes during low water years. This OSF storage could be used to positively affect streamflows in the Little Deschutes below the confluence with Crescent Creek during the fall as Oregon spotted frogs move from breeding sites to overwintering locations by reducing the rate of pre-storage season ramp down at the start of storage season.

Streamflows added to the system from the OSF storage volume under the proposed action can influence the Little Deschutes during low water years. This OSF storage could be used to positively affect overwintering habitat conditions for fish by adding to winter streamflows.

Figure 21. Modeled Streamflows Little Deschutes River (LAPO node) under the Proposed Action Years 1–7 (top left), 8–12 (top right), and 13–30 (bottom) Compared to the No-Action Alternative



Upper Deschutes

The proposed action includes Conservation Measure CP–1. This measure affects seasonal reservoir management. Conservation Measure WR–1 describes how Wickiup Reservoir will be operated according to a seasonal schedule to provide Oregon spotted frog conservation. This includes higher winter flows, spring flow regulation, and in years 13 to 30 a maximum summer flow of 1,200 cfs to protect and restore wetland and riparian habitats.

The proposed action includes Conservation Measure UD-1. The fund would be used to improve or enhance habitat in the Upper Deschutes Basin for Oregon spotted frog and other aquatic species.

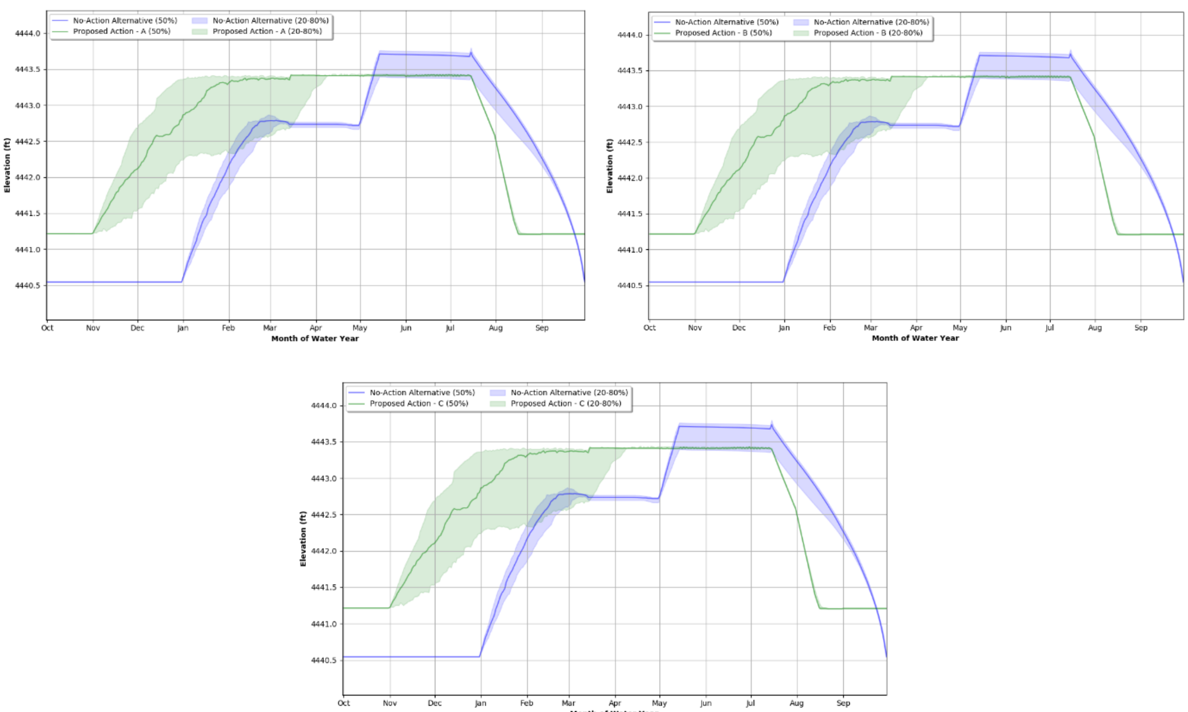
The effects of Conservation Measure UD-1 are not quantifiable; however, the assessment of environmental consequences considers it qualitatively because the measure could be used to support habitat restoration actions designed to respond to trends of either decreasing Oregon spotted frog habitat loss or degradation, or Oregon spotted frog declining populations during the permit period. Habitat restoration actions for Oregon spotted frog would likely improve aquatic habitats for fish and mollusks species.

Crane Prairie Reservoir

Based on modeled results for the Crane Prairie Reservoir node (CRA), illustrated in Figure 22, elevations would change as follows:

- Median elevations would be higher from October through April and lower from May to approximately the end of September.
- Elevations and volumes would not differ over the permit term.
- Minimum and maximum elevations would be more variable from year to year beginning in November to March and less variable from May to the end of September.

Figure 22. Modeled Elevations for Crane Prairie Reservoir (CRA node) under the Proposed Action Years 1–7 (top left), 8–12 (top right), and 13–30 (bottom) Compared to the No-Action Alternative



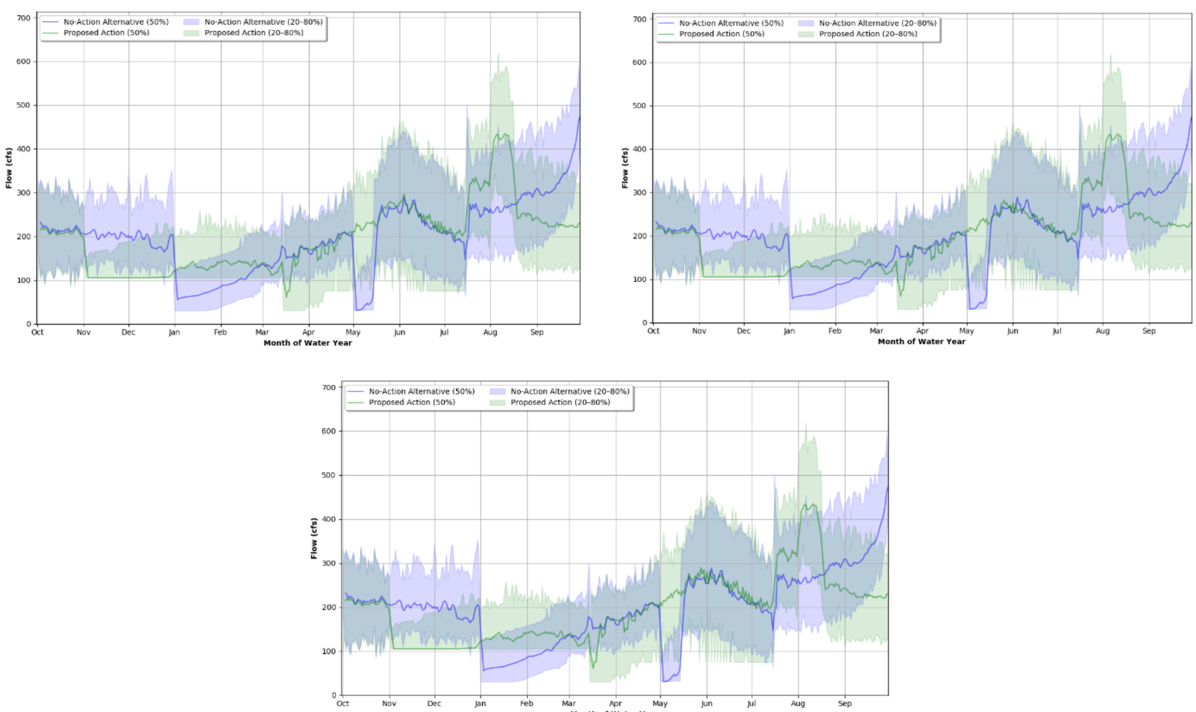
Upper Deschutes River between Crane Prairie and Wickiup Reservoirs

Based on modeled results for the Crane Prairie Reservoir Outlet (CRAO), streamflows in the Upper Deschutes River between Crane Prairie Reservoir and Wickiup Reservoir would be less variable over the year (Figure 23) compared to the no-action alternative. Furthermore, differences in monthly median streamflow would vary over the year. The pattern of high and low monthly differences would be consistent over the permit term.

The following changes would occur at the CRAO node through the permit term.

- In most years, streamflows would decrease in November and December by 40 and 30%, respectively.
- In most years, streamflows would be higher in January and February by 90 and 66%, respectively.
- In March of most years, streamflows would decrease by 20%. In April, streamflows would not change in about half the years and would decrease by 50% in the other half of the years.
- In May of most years, streamflows would be higher by 20% and June streamflows would vary across years: in the majority of years they would not change; in a quarter of the years they would decrease by 35%; and a quarter of the years they would increase by about 10%.
- In July and August in nearly all years, streamflows would increase by about 25%. In September in all years, streamflows would decrease by 32%.
- Steep decreases in streamflow in January and May would be eliminated, reducing variability in these months. However, there would be more variability in daily streamflows in August.

Figure 23. Modeled Streamflows Upper Deschutes River at Crane Prairie Outlet (CRAO node) under the Proposed Action Years 1–7 (top left), 8–12 (top right), and 13–30 (bottom) compared to the No-Action Alternative

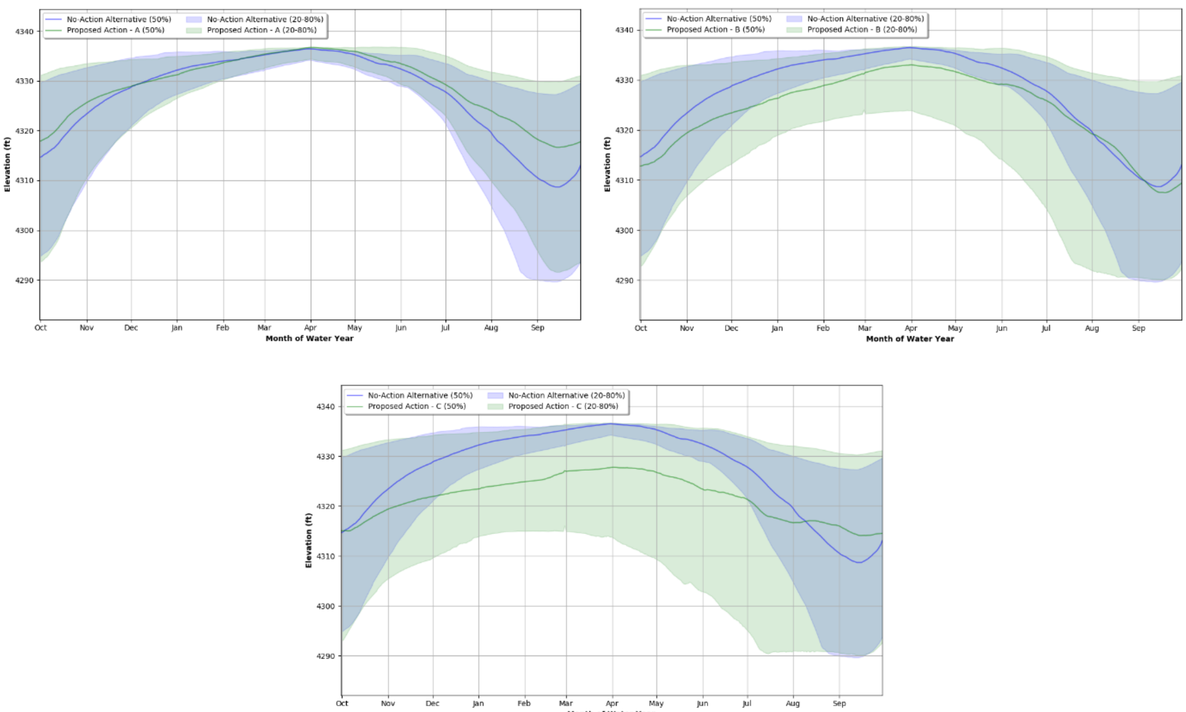


Wickiup Reservoir

Based on modeled results for Wickiup Reservoir node (WIC), illustrated in Figure 24, reservoir elevations would change as follows:

- Median elevations would be higher in October and November and June through September early in the permit term (years 1–7).
- Differences in elevations would increase over the permit term with difference greatest in years 13 through 30 of the permit term with elevations substantially lower from October through July.
- Minimum and maximum reservoir elevations would be much more variable from year to year in all months toward the end of the permit term.

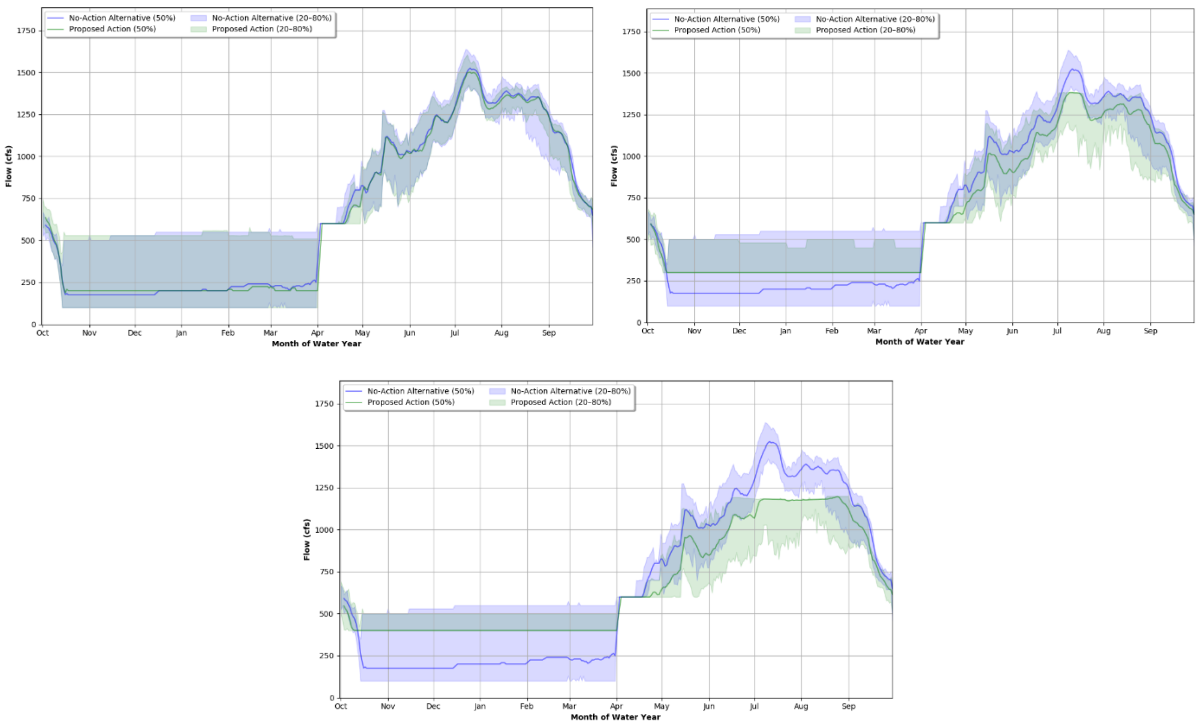
Figure 24. Modeled Elevations for Wickiup Reservoir (WIC node) under the Proposed Action Years 1–7 (top left), 8–12 (top right), and 13–30 (bottom) compared to the No-Action Alternative



Upper Deschutes River downstream of Wickiup Dam

Based on modeled results for the Wickiup Reservoir Outlet (WICO) and Benham Falls (BENO) nodes, streamflows in the Upper Deschutes River downstream of Wickiup Dam would be less variable over the year. At WICO, the general pattern across the year and permit term is increasing streamflows from mid-October through March consistent with Conservation Measure WR-1, and decreasing streamflows from May through September. There is a tendency for more variable streamflows from May through September through the permit term (Figure 25).

Figure 25. Modeled Streamflows for Wickiup Reservoir Outflow (WICO) under the Proposed Action Years 1–7 (top left), 8–12 (top right), and 13–30 (bottom) compared to the No-Action Alternative



The following changes would occur at the Wickiup Reservoir outlet node through the permit term.

- In about a quarter of the years, streamflows would increase from October through March by about 20% early in the permit term. Through the permit term, streamflows would increase in majority of the years by 200 to 300%. Daily median streamflows at the end of the permit term would be 400 to 500 cfs consistent with WR-1.
- Streamflows in April would generally not change in nearly all years. This pattern would be consistent through the permit term.
- Streamflows in May would decrease by approximately 20% in over half the years by years 13 through 30 of the permit term.
- In April, May, and June streamflows would ramp up in years Wickiup storage was sufficient to supply water through the irrigation season. Streamflows would ramp up to a maximum of 1,400 cfs in years 8 through 12 of the permit term and 1,200 cfs in years 13 to 30 of the permit term.
- In years of low storage on April 1, streamflows from Wickiup would be adjusted downward to extend deliveries later into the summer. The result of this is spring streamflows would tend to be less variable in years of low storage. This pattern would be more prevalent toward the end of the permit term. By years 13 through 30 of the permit term, streamflows in about half the years would decline by approximately 20% and stay below 1,000 cfs at WICO through the summer.

- Streamflows from June through September would be lower toward the end of the permit term. Toward the end of the permit term, streamflows would decrease from June through September by approximately20% in nearly all years. Median daily streamflows toward the end of the permit term would vary from 750 cfs early in the summer and a maximum of 1,200 cfs in July and August.

The following changes would occur at the Benham Falls node (BENO) through the permit term.

- Surface and groundwater inflow upstream of this location would reduce the effects of water management upstream of this location at WICO. Toward the end of the permit term, streamflows in the majority of the years would increase from October through March by approximately 40%.
- Streamflows in April would be relatively unchanged under the proposed action.
- Streamflows in May would decrease in a little over half the years by approximately 10%.
- Streamflows would decrease in the majority of years from June through September by approximately 10%.

Between Benham Falls and the city of Bend, a similar pattern would occur.

Middle Deschutes

The proposed action includes Conservation Measure DR-1. This measure affects winter flow management and provides a coordinated effort from November 1 to March 31 to manage diversions to maintain a 1-day average flow of more than 250 cfs (±25 cfs) at Hydromet Station DEBO (OWRD Gauge 14070500).

The proposed action includes Conservation Measure WC–1. This measure defines streamflows passed at the Three Sisters ID diversion. This measure formalizes agreements included in the no-action alternative RiverWare model. Other conservation measures in Whychus Creek include Conservation Measure WC–2 to provide funds for temporary leasing water in dry years to meet instream flows; Conservation Measure WC–3 to formalize measures to maintain fish screens and fish passage at diversions; and Conservation Measures WC–4, WC–5, WC–6, and WC–7.

The effect of Whychus conservation measures are not quantifiable; however, the assessment of environmental consequences considers it qualitatively because the measures could be used to support habitat restoration actions, protect instream flows, and maintain fish passage. Several of these measures are included in the no-action alternative.

Middle Deschutes River

Based on modeled results for the city of Bend (DEBO) node and the Culver City internode (CULOGauge.Outflow), winter streamflows would be higher.

- Increasing minimum winter streamflows (Conservation Measures WR-1 and DR-1) through the permit term would increase streamflows from October through March by approximately 30 to 90%, depending on month, by the end of the permit term.
- Streamflows in April would decline by 20% in the majority of years at the end of the permit term.
- Streamflows in May would increase by approximately 35% in about a quarter of the years, decrease by 10% in a quarter of the years, and be unchanged in about half the years.

- Streamflows from June to August would not change in the majority of years.
- Streamflows in September would increase by approximately 30% in the majority of years.

The following changes would occur at the Culver City internode through the permit term.

- Surface and groundwater inflows upstream of this location would reduce the effects of water management and changes in streamflow upstream of this location at DEDO.
- Higher minimum winter streamflows in the Upper Deschutes River (WR-1) would increase streamflows from October through March in the Middle Deschutes River by 20 to 30%, on average in the majority of years, by the end of the permit term.
- Streamflows in April through September would not change in the majority of years.

Tumalo and Whychus Creeks

Based on RiverWare modeled results, streamflows in Tumalo and Whychus Creeks would be unchanged. Streamflow agreements and water conservation projects assumed under the no-action alternative would continue in Whychus Creek.

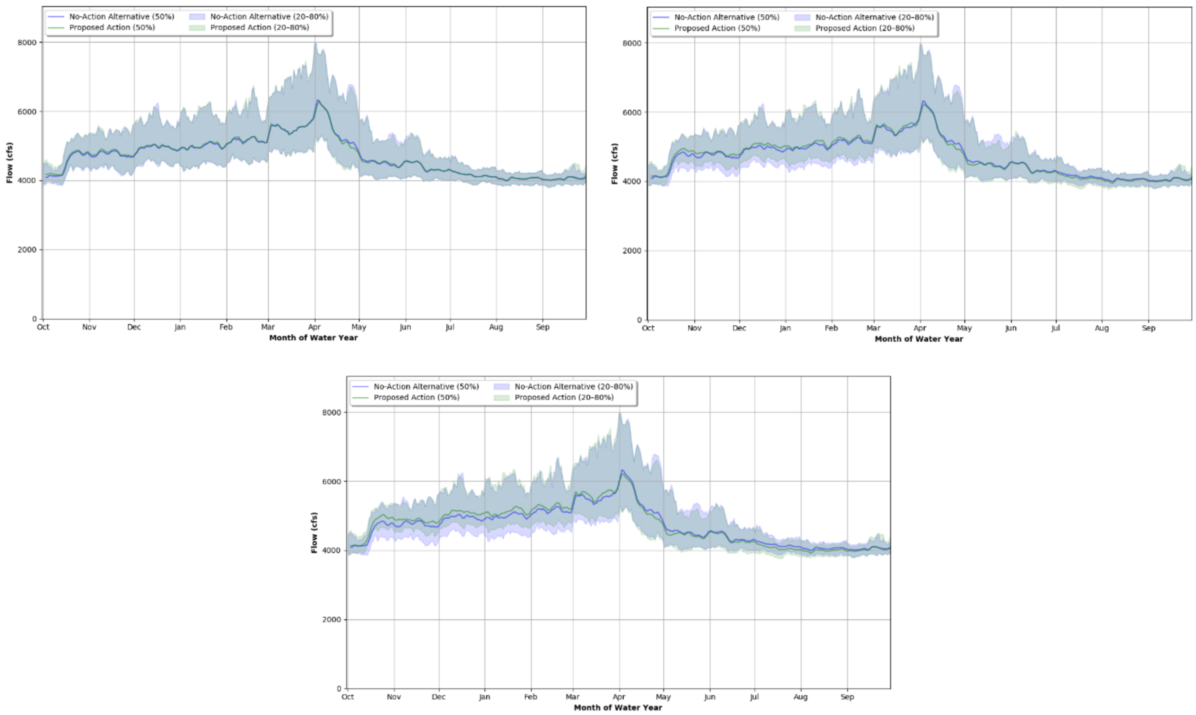
Several of the conservation measures in Whychus Creek would protect or improve streamflows and provide funds to improve or enhance habitat in Whychus Creek for fish.

Lower Deschutes

Based on modeled results for the Madras node (MADO), illustrated in Figure 26, median winter (October to March) streamflows would increase very slightly in years 13 through 30.

RiverWare model results are not available for Trout Creek. There is a potential irrigation returns to Trout Creek could be lower under the proposed action based on reductions in North Unit ID diversions in a normal and dry year types (Appendix 3.2-A). However, differences in irrigation returns are not expected to effect water quality in Trout Creek.

Figure 26. Modeled Streamflows for the Lower Deschutes River near Madras (MADO) under the Proposed Action for Years 1–7 (top-left), 8–12 (top-right), and 13–30 (bottom) and No-Action Alternative



Crooked River

The proposed action includes Conservation Measure CR-1: Crooked River Flow Downstream of Bowman Dam. This measure sets minimum daily average streamflows of 50 cfs at OWRD Gauge 14080500 below Bowman Dam (Hydromet Station PRVO) outside the active irrigation season. This measure protects against extreme low winter streamflows documented in past years in the Crooked River (Porter and Hodgson (2016).

Conservation Measure CR-2: Ochoco Creek Flow sets contribution to the streamflow in Ochoco Creek of 3 to 5 cfs. Conservation Measure CR-3: McKay Creek Flow sets minimum streamflows in McKay Creek.

Conservation Measure CR-4: Crooked River Conservation Fund contributes a total of $8,000 annually for habitat actions for covered species or temporary instream water leasing.

Other conservation measures addressed in the analysis of species effects were Conservation Measure CR-5 that addresses screening of diversion structures. CR-5 formalizes agreement to maintain fish screens and funds to support maintenance of screens. Conservation Measure CR-6 says North Unit ID will only divert water at the Crooked River pumps diversion when the minimum daily average streamflow of 51 cfs to 181 cfs, depending on month and water year type, can be maintained, as measured at OWRD Gauge 14087300 at Smith Rock (RM 19.9) or a new gauge location established by OWRD that adequately describes streamflow downstream of the pump location.

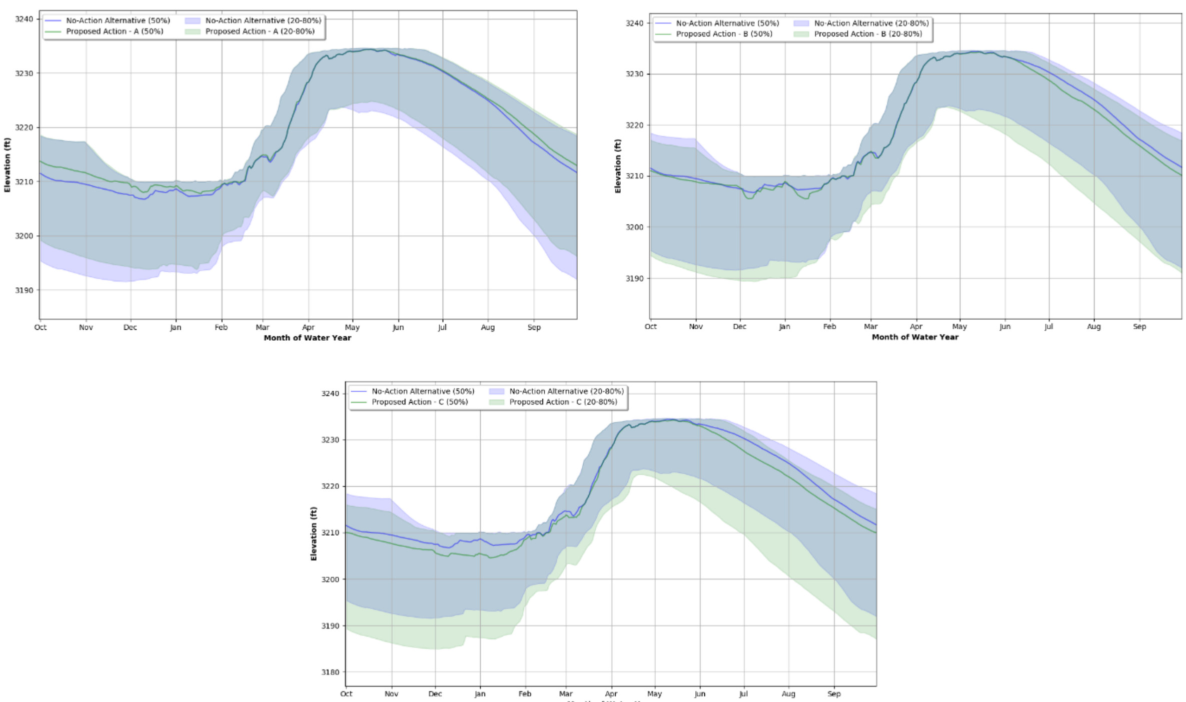
Conservation Measure CR-7: Crooked River Downstream Fish Migration Pulse Flows protects streamflows that are part of downstream fish migration pulse flows. Pulse streamflows were not included in the RiverWare model but were considered in the effects analysis.

Prineville Reservoir

Based on modeled results for Prineville Reservoir node (PRV), illustrated in Figure 27, elevations would change as follows.

- Median elevations would be slightly higher from October to January and August and September early in the permit term.
- Differences in median elevations would tend to be greater toward the end of the permit term (years 13–30) with slightly lower elevations from October to February and June through September.
- Year to year variability would tend to occur in the low range of reservoir elevations.

Figure 27. Modeled Elevations for Prineville Reservoir (PRVO node) under the Proposed Action Years 1–7 (top left), 8–12 (top right), and 13–30 (bottom) compared to the No-Action Alternative



Crooked River

Modeled environmental conditions in the Crooked River are described below based on median monthly streamflows from the 2020 RiverWare model. As described in Methods, median values were used to describe differences in streamflows to better characterize typical conditions. Water temperatures predictions are based on the 2019 RiverWare model as described in Methods section.

Median Monthly Streamflow

Differences in median monthly streamflow are summarized below for the following locations (nodes): Prineville Outlet (PRVO), near Highway 126 (CAPO), below the North Unit ID pumps (NUID), and below Opal Springs Dam (OPAL).

Prineville Outlet (PRVO):

- October through March: Generally there was no change in winter streamflows in the majority of years. There were a few years streamflows went below 50 cfs during the winter (1993 for example) under the no-action alternative. In those years Conservation Measure CR-1 resulted in winter flows of 50 cfs during the winter under the proposed action.
- April and May: No change in median streamflows in most years.
- June: An increase in monthly median streamflows of approximately 40% in half of the analysis years. There were very few years that monthly median streamflow decreased in June under the proposed action.
- July and August streamflows were shaped by North Unit ID use of its 10k af of rental storage in Prineville Reservoir:
  - In July median streamflows are higher under the proposed action in the majority of years by approximately 40%. In July proposed action monthly median streamflows are 50 to 100 cfs higher in 22 of the analysis years (58%of the 38 analysis years).
  - In August median streamflows are higher under the proposed action in about one quarter of the years by 30% and lower in one quarter of the years by 40%. In August proposed action monthly median streamflows are 50 to 100 cfs higher in 10 of the analysis years (26% of the 38 analysis years).
  - During the warmest months (July and August) month median streamflows are lower under the proposed action in 3 years in July and 10 years in August.
- September: Monthly median streamflows are lower in September by on average approximately 20% in 8 of the 38 analysis years. Generally September median streamflows were unchanged under the proposed action at this node.

CAPO node near Highway 126 and the City of Prineville (CAPO) showing change in monthly median streamflows at the end of the permit term are summarized in Table 9.

- Generally the pattern of monthly streamflows was the same at CAPO as reported at PRVO. The exception was August and September median streamflows. In both months median streamflows are lower under the proposed action in 24 of the analysis years by 14% in August and 13% in September. The difference in streamflows is small in most years with a median across the years of decreased streamflows of 14%.
- July and August:
  - In July proposed action median streamflows are 50 to 100 cfs higher in 23 of the analysis years (58%of the 38 analysis years).
  - In August proposed action median streamflows are 50 to 100 cfs higher in 11 of the analysis years (29% of the 38 analysis years).

    - However in August proposed action median streamflows were lower in 24 the analysis years (63%) by 14%.

- September: In contrast to no change in streamflows released from Prineville (PRVO), median streamflows are lower in September by 13% in 36 of the 38 analysis years at CAPO.

Below the North Unit ID pumps (NUID.outflow):

- October through March: In most years, there was no change in monthly median streamflows; in about 10% of years there was an increase in median streamflows of 25% to 50%; and in about 5% of years, a decrease in median streamflows of approximately 10%.
- April: No change in median streamflows in the majority of years and a decrease of 9% in about 35% of the years.
- May through September: Average decrease across all months of 10% to 45% in nearly all years, corresponding to increased reliance by North Unit ID on Crooked River.

Below Opal Springs Dam (OPAL):

- No discernable differences in streamflows.

Water Temperature Modeling

Differences between the no-action alternative and proposed action has the potential to influence water temperatures during the summer months. The annual hydrograph for the three representative water year types (wet, normal and dry) was modeled based on the 2019 RiverWare model. Shifts in streamflow timing are most pronounced under the dry and normal water year types.

The shift in predicted 7DADM water temperatures at the Crooked River CAPO and North Unit ID pump diversion is presented in Methods. The updated 2020 RiverWare model suggest a highly variable pattern of differences in streamflows between the no-action alternative and proposed action similar to results from the 2019 model (Figure 28).

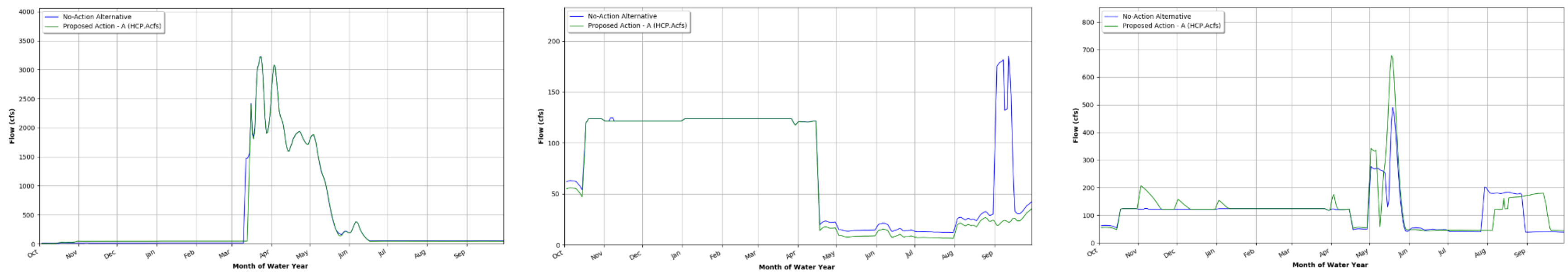
An analysis of how streamflows may affect species survival was based on the predicted 7DADM results and compared to species preferences, sublethal, stress/disease, and lethal temperature thresholds summarized from a literature review (R2 and Pacific Biota 2013). Species thresholds are reported in Table 6 in Methods section. The threshold analysis is discussed in the *Species Impacts* sections by species.

Table 9. Summary Monthly Median Streamflows for the Crooked River near Highway 126 (CAPO node) under Proposed Action (Years 13–30) compared to the No-Action Alternative

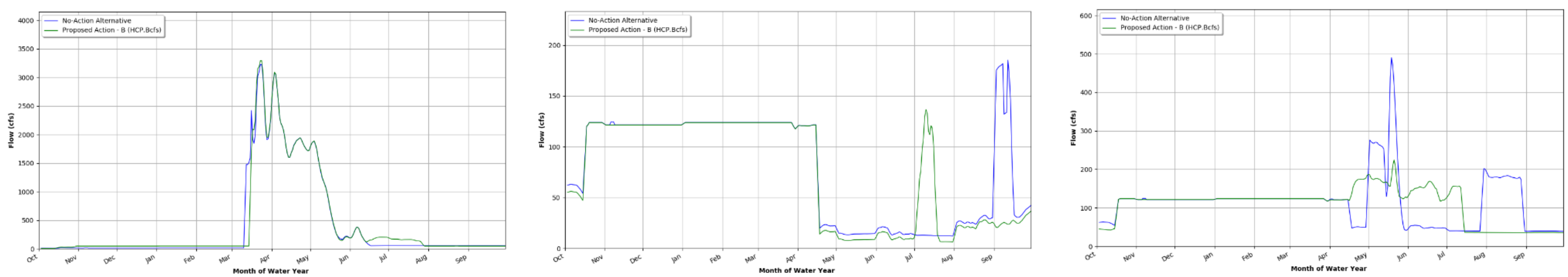
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Average diff. median flow (%)	12%	8%	17%	12%	13%	8%	1%	77%	117%	134%	10%	-25%
Range diff. in monthly median flow (%)	-34 to 387%	-80 to 405%	-76 to 405%	-77 to 319%	-55 to 319%	-19 to 319%	-66 to 66%	-80 to 972%	-78 to 904%	-85 to 835%	-94 to 269%	-89 to 0%
# Years no diff. in median flow	29	18	26	28	28	27	24	14	3	1	3	2
# Years increase in median flow	3	4	4	3	3	2	5	10	19	23	11	0
Range increase in monthly median flow (%)	75 to 387%	16 to 405%	12 to 405%	69 to 319%	69 to 319%	69 to 319%	7 to 66%	6 to 972%	38 to 904%	8 to 835%	39 to 269%	NA
Median increase flow (%)	119%	202%	202%	268%	268%	194%	33%	76%	237%	190%	109%	NA
# Years decrease in median flow	6	16	8	7	7	9	9	14	16	14	24	36
Range decrease in monthly median flow (%)	-34 to -9%	-80 to -6%	-76 to -6%	-77 to -6%	-55 to -8%	-19 to -7%	-66 to -6%	-80 to -7%	-78 to -5%	-85 to -10%	-94 to -11%	-89 to -8%
Median decrease flow (%)	-14%	-30%	-10%	-15%	-15%	-10%	-8%	-19%	-13%	-13%	-14%	-13%

Figure 28. Annual Hydrograph for Crooked River (CAPO node) based on the 2020 RiverWare Model for Wet, Dry, and Normal Water Years (left to right columns) under the No-Action Alternative and Proposed Action in Years 1–7 (top), 8–12 (middle), and 13–30 (bottom)

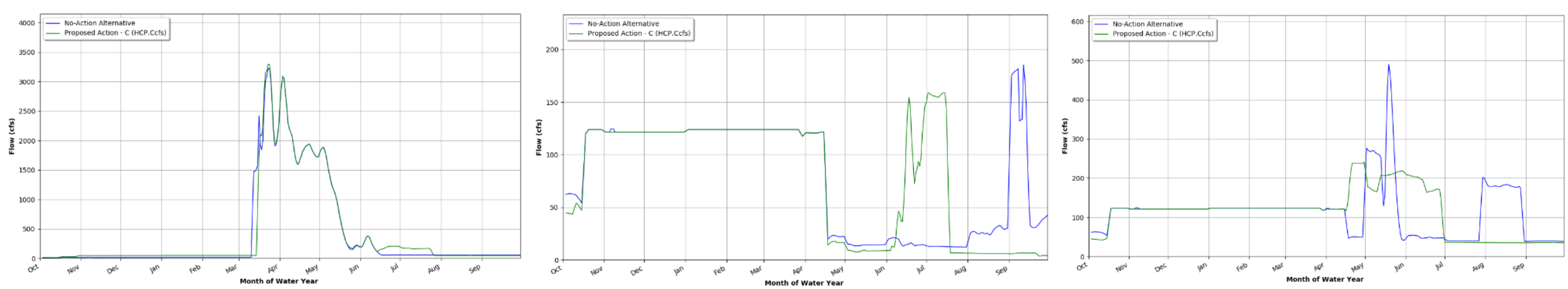
Years 1–7



Years 8–12



Years 13–30



Ochoco Reservoir

Based on modeled results for the Ochoco Reservoir node (OCH), there would be no change in reservoir elevation or volume.

Ochoco and McKay Creeks

The proposed action would have small increases in streamflow in Ochoco Creek, from slightly higher seasonal minimum and maximum median streamflows under Conservation Measure CR-2, and in McKay Creek, from higher minimum streamflows during the active irrigation season under Conservation Measure CR-3.

Species Impacts

Species impacts in this section are discussed by geographic area and include only those geographic areas where each species occurs or has the potential to occur. Species impacts are compared to the no-action alternative. This means impacts of water management on streamflow, for example low or highly variable streamflows under the no-action alternative, were not evaluated as an adverse effect.

BIO-4: Affect Bull Trout Habitat

Based on RiverWare modeled results, streamflows in Whychus Creek would be unchanged.[3] Streamflow agreements and water conservation projects assumed under the no-action alternative would continue in Whychus Creek and would provide protection of existing conditions for bull trout over the permit term.

The proposed action would have beneficial effects on bull trout habitat in Whychus Creek from Conservation Measures WC-2, WC-4, WC-5, and WC-7. Several of the conservation measures in Whychus Creek would protect or improve streamflows and provide funds to improve or enhance habitat in the Whychus Creek. Improved fish passage and fish screens at Plainview Dam under Conservation Measure WC-7 would make accessible 11.5 miles of Whychus Creek to bull trout and protect juvenile bull trout from entrainment at the diversion.

The proposed action would have no effect on bull trout habitat the Lower Deschutes River, Lake Billy Chinook, or Lake Simtustus because changes in streamflows and reservoir volumes and elevations would either not change or changes would be minor over the permit term compared to the no-action alternative.

The proposed action would have small beneficial effects on bull trout habitat in Ochoco Creek outside the irrigation season, from slightly higher seasonal minimum and maximum median streamflows (CR-2) and no effect in McKay Creek from higher minimum streamflows during the active irrigation season (CR-3). Effects in the remaining reaches relevant to the species are described.

Middle Deschutes

Increased fall and winter streamflows under Conservation Measures DR-1 and WR-1 would result in median streamflows in the Middle Deschutes River increasing by approximately 20% from October

[3] Conservation Measure WC-1, the addition of 3 cfs to the existing 31.18 cfs to instream flows by Three Sisters ID just downstream of the diversion, is assumed under the no-action alternative, as is the minimum instream flow of 20 cfs when Three Sisters ID is diverting.

to March. This would have a beneficial effect on the quantity and connectivity of bull trout habitat for foraging subadults and adults (increasing wetted channel area and adding more depth to pool habitat) over the permit term in the portion of the reach accessible to the species.

Crooked River

The Crooked River is critical habitat for bull trout from Lake Billy Chinook to Highway 97 (12.4 miles). Bull trout presence in the Crooked River is seasonally limited because of water temperatures during summer rearing and fall spawning. Daily maximum temperatures in the Crooked River during the fall spawning period exceed the upper limits of temperature preference for spawning (9.0 °C) in all reaches (Figure 28) and exceed the preference threshold for egg incubation during much of the egg incubation period (Figure 29). Bull trout moving upstream from Lake Billy Chinook have been observed and captured at Opal Springs Dam RM 0.8 (FWS unpublished observations 2016–2019), and foraging subadult bull trout are observed to migrate upstream Opal Springs Dam following construction of fish passage facilities in November 2019. Preliminary fish counts at Opal Springs Dam as of August 1, 2020, reported 238 bull trout have moved upstream through the fish ladder, ranging in length from 190 millimeters (mm) to 390 mm with an average length of 247 mm (Lickwar pers. comm. [a]). The extent of distribution of these fish is unknown; they may occupy habitats throughout the river up to Bowman Dam during the winter when temperatures are favorable. They may occupy habitats throughout the river up to Bowman Dam during the winter when temperatures are favorable. Summer daily maximum temperatures exceed the temperature thresholds for subadult bull trout under the no-action alternative, with the exception of the reach downstream of Bowman Dam (Cro-10). Daily maximum water temperatures in this reach are within the preference threshold during much of the year and are dependent on water release from Bowman Dam. In addition, although the water temperature model did not extend to reaches Cro-1.2 and 1.1 from Osborne Canyon at RM 7.3 downstream to the Crooked River confluence with Lake Billy Chinook, this section of the river is also within preference thresholds for bull trout due to spring inflows (Torgerson et al. 2007).

The analysis of potential effects of temperatures included all reaches of the Crooked River based on the assumption that subadults may move higher into the river during the winter and water management may result in bull trout encountering additional days with adverse temperatures in other times of the year.

Water Temperature Results

Streamflows under the proposed action would be expected to affect bull trout habitat with potential distribution up to Bowman Dam with completion of a fish passage structure at Opal Springs Diversion Dam in November of 2019. Preliminary fish counts at Opal Springs Dam as of August 1, 2020, reported 238 bull trout have moved upstream through the fish ladder, ranging in length from 190 to 390 mm with an average length of 247 mm (Lickwar pers. comm. [a]). The extent of distribution of these fish is unknown; they may occupy habitats throughout the river up to Bowman Dam during the winter when temperatures are favorable.

Figures 29 and 30 summarize temperature thresholds predicted temperatures for bull trout spawning and egg incubation, respectively. Results support conclusions that current condition water temperatures are too warm for bull trout spawning in the Crooked River upstream of Smith Rock (modeled portion of the Crooked River or in any other accessible area of the Crooked River or its tributaries).

Figure 31 summarizes temperature thresholds and predicted temperatures for juvenile and subadult rearing in all months. These temperatures support the potential use of the Crooked River by foraging bull trout during the winter in all modeled reaches and in the summer in the reach immediately downstream of Bowman Dam (Reach Cro-10; RMs 70.5 to 55.9) and reported temperatures favorable to bull trout in the reach from Osborne Canyon to Lake Billy Chinook (Reaches Cro-1.2 and 1.1; RMs 7.3 to 0) (Torgerson et al. 2007).

Under the no-action alternative, water temperatures during the summer exceed the preference threshold for nearly 2 months in the normal water year and longer in the wet and dry years in reach downstream of Bowman Dam (differences among years because of differences in streamflows and meteorological conditions during the summer). However, temperature heterogeneity created by inflow of cooler subsurface flow may allow bull trout to avoid the warmest temperatures during this period in this reach. Bull trout that do not emigrate prior to summer from the approximately 40 miles of the Crooked River encompassed by reaches Cro-9 to Cro-2 would experience potentially lethal temperatures of 23 °C and higher under the no-action alternative.

At the end of the permit term under the proposed action, water temperatures for the dry and normal water years are predicted to exceed the stress/disease threshold by an additional 12 and 19 days, respectively. Under water management in the normal year at the end of the permit term, 70 days above the preference threshold would occur compared to 49 days under the no-action alternative. In wet and dry water years the number of preference days would not change.

Figure 29. Predicted Percentage Days within Water Temperature Thresholds for Spawning Bull Trout for a Wet (top), Dry (middle), and Normal (bottom) Year under the Proposed Action Years 13 to 30 compared to the No-Action Alternative

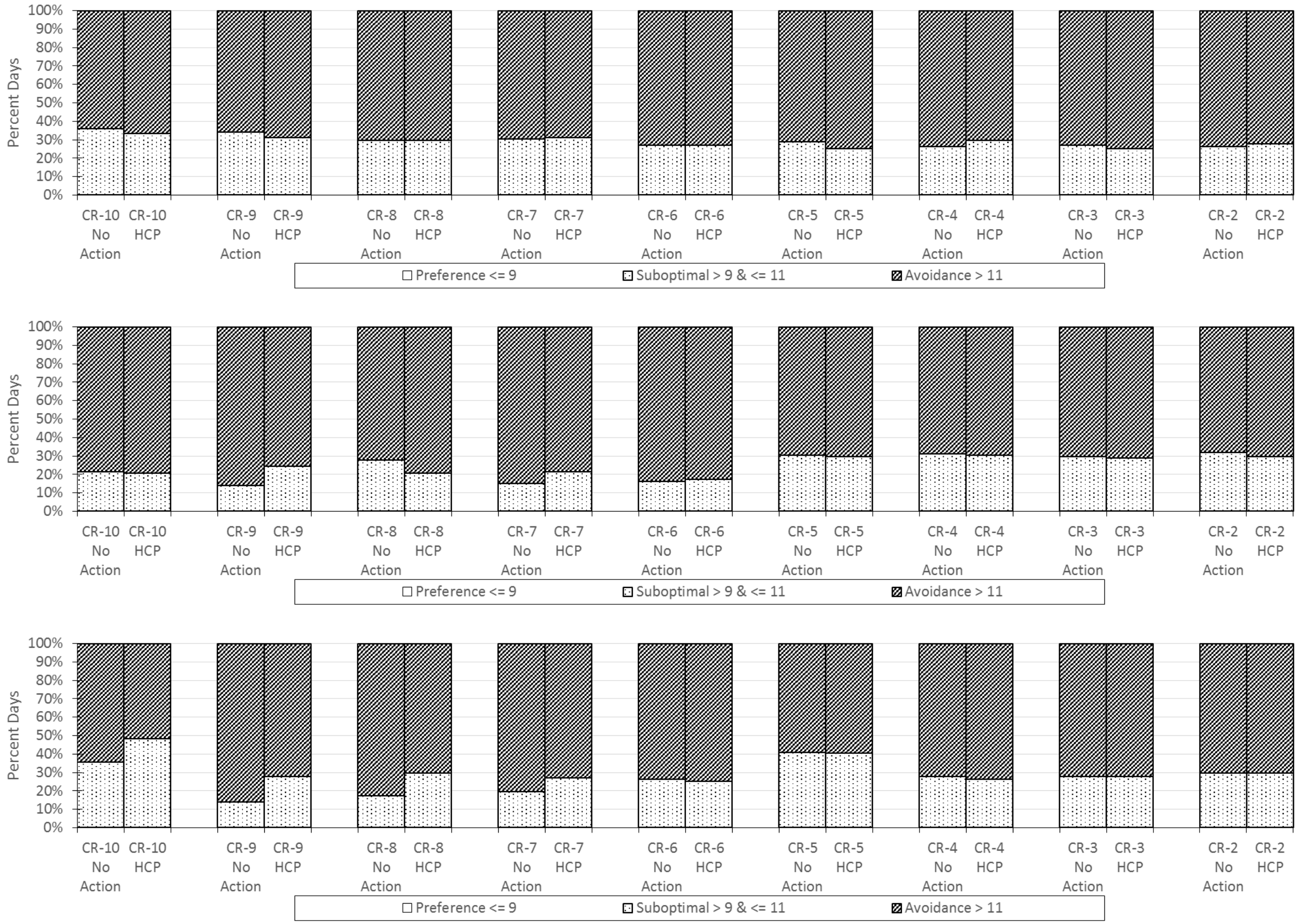


Figure 30. Predicted Percentage Days within Water Temperature Thresholds for Bull Trout Egg Incubation for a Wet (top), Dry (middle), and Normal (bottom) Year under the Proposed Action compared to the No-Action Alternative

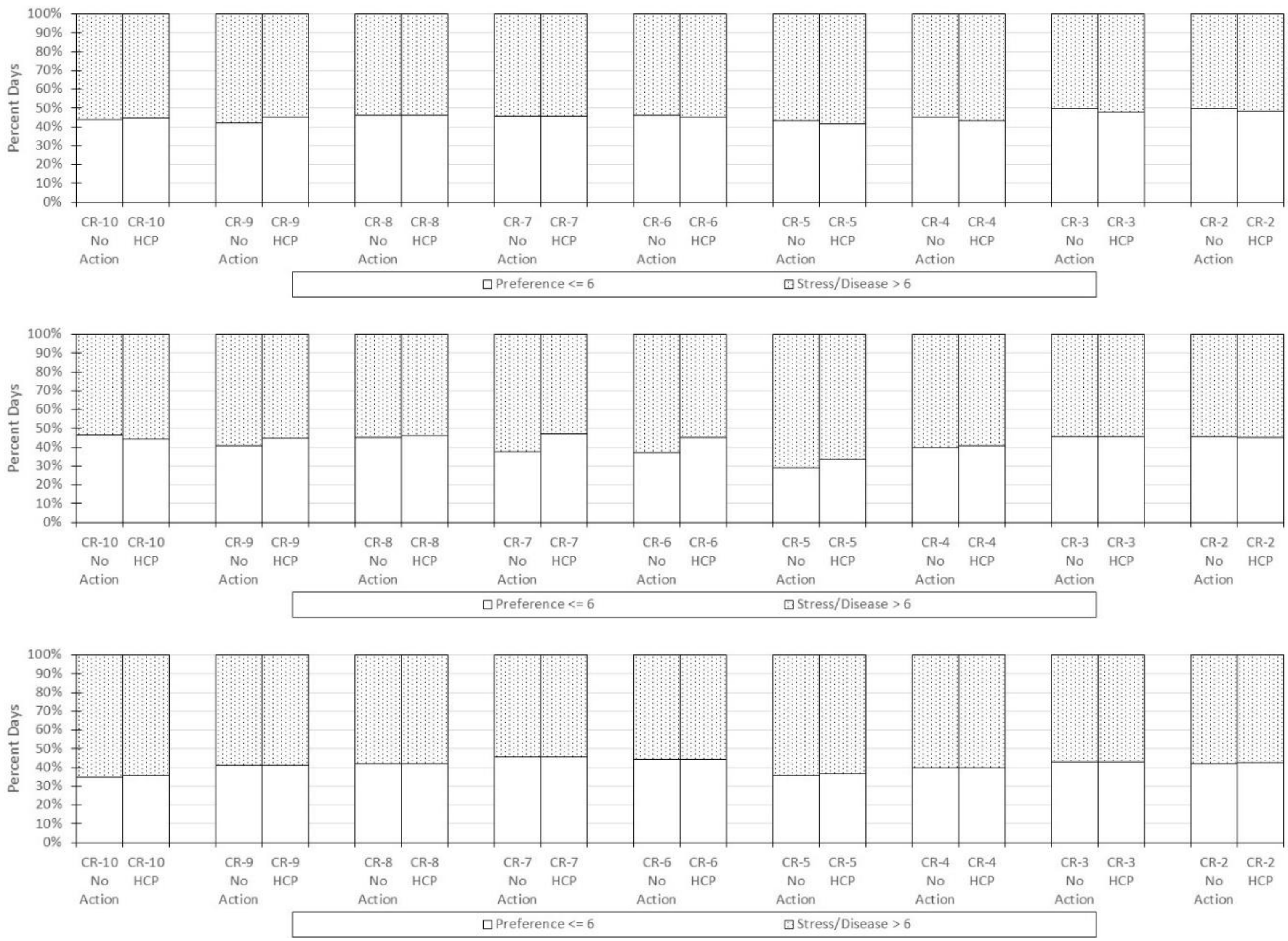
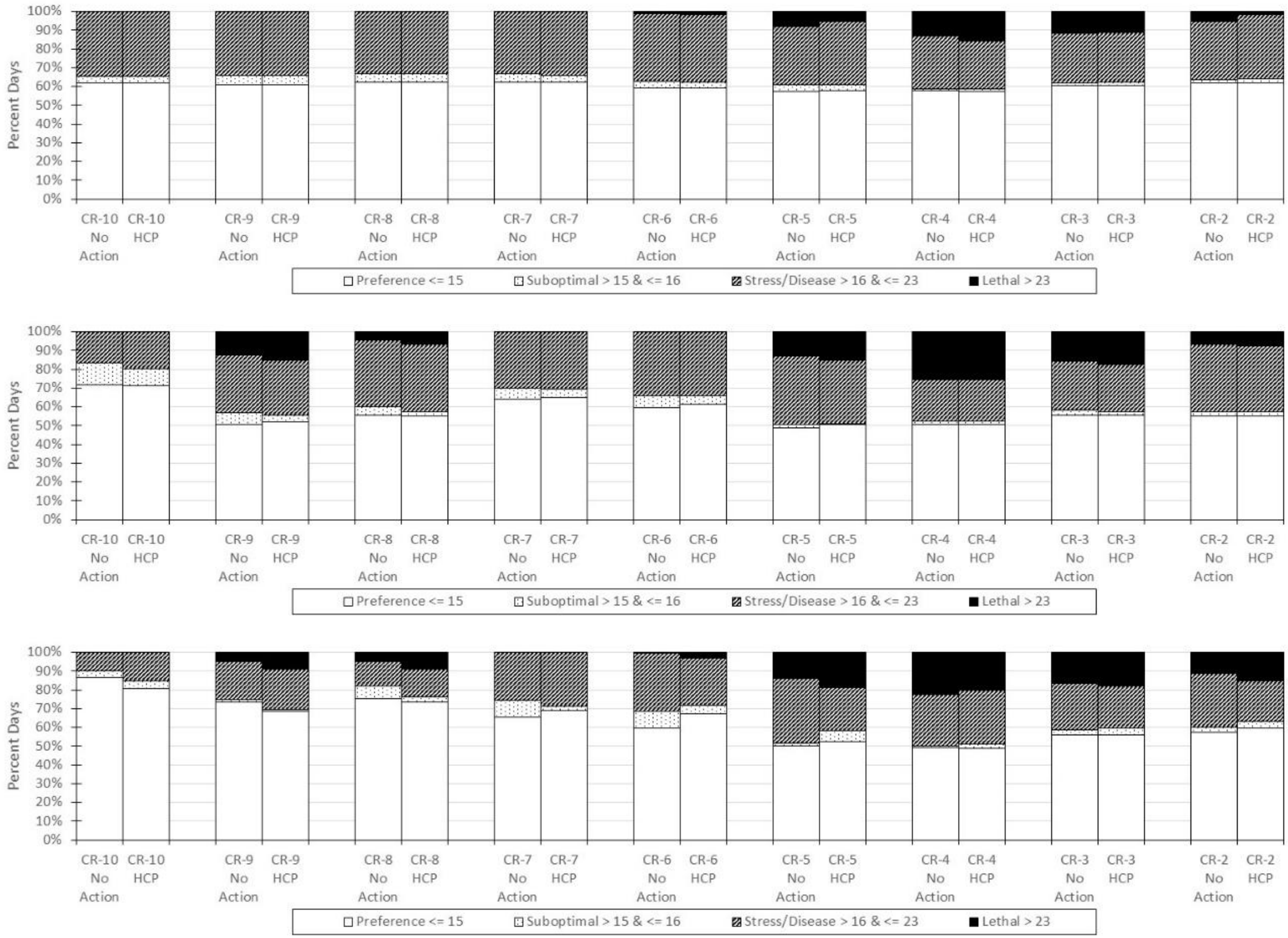


Figure 31. Predicted Percentage Days within Water Temperature Thresholds for Juvenile/Subadult Bull Trout Rearing for Wet (top), Dry (middle), and Normal (bottom) Year under the Proposed Action compared to the No-Action Alternative



Summary Crooked River

Bull trout would be exposed to a range of water management effects under the proposed action, including differences in streamflow across the year affecting the amount of habitat available and water management affecting water temperatures during critical life stages.

The analysis assumes potential bull trout occupancy in multiple reaches during the winter. Bull trout may attempt to rear through the summer in the upper reach or those that fail to emigrate in the spring would encounter warmer temperatures in reaches Cro-9 through Cro-2 under the proposed action.

Modeled water temperatures in the wet water year shows no effect on bull trout juvenile and subadult habitat over the permit term. However, water management in dry and normal water years indicate a potential for adverse effect on bull trout that may attempt to rear through the summer in the reach immediately downstream of Bowman Dam (Cro-10) with shifts in timing of streamflows. The number of preference days declines from 313 days under the no-action alternative to 292 days under the proposed action by the end of the permit term, and the number of stress/disease days increases from 36 to 55 days.

Under Conservation Measure CR-4, funds would be available to support Crooked River habitat restoration measures and may benefit bull trout habitat. Conservation Measure CR-5 would provide funds for screening to National Oceanic and Atmospheric Administration (NOAA) fish screen standards of Ochoco ID patron diversions, and maintenance and operation of fish screens on all Ochoco ID-controlled diversions. This would likely have a minor benefit on bull trout habitat because bull trout may only be present in the river at the beginning of the irrigation season.

Conservation Measure CR-6 would ensure minimum streamflows are maintained when the North Unit ID pumps are operating, which would have a beneficial effect on bull trout habitat by reducing streamflow variations downstream of the North Unit ID pumps to Osborne Canyon.

Conservation Measure CR-1 would supplement storage season streamflows to ensure the 50 cfs minimum flows on the Crooked River during storage season (as prescribed under the Crooked River Act) are met. These additional winter streamflows would benefit bull trout habitat.

In the Crooked River, Conservation Measures CR-4, CR-5, and CR-6 may result in small beneficial effects on bull trout habitat. Water management under the proposed action at full implementation (years 13–30) compared to the no-action alternative would result in no effect on bull trout habitat conditions in wet water years and potentially no effect or possibly beneficial effects in dry and normal water years.

Habitat quantity and quality during bull trout critical life stages could decline in dry and normal water years depending on annual water management practices. Water supply modeling assumes irrigation season diversions from the Crooked River would increase as water supply availability from the Upper Deschutes River declines. The frequency of this outcome would depend on specific, annual water supply management decisions and water supply availability that are not captured fully by modeling results.

While pesticides and nutrients are known to occur within return flows that enter the Crooked River (Oregon Water Quality Pesticide Management Team 2018; Noone 2020), the proposed action would not create additional pesticide sources, nutrient sources, or pathways. Nor would the proposed action otherwise alter the occurrence of pesticides or nutrients in the Crooked River affecting bull trout habitat. As described in the Deschutes Basin HCP Chapter 3, *Scope of the DBHCP*, flow and diversion rate changes on the Crooked River are not expected to have noticeable changes in return flows at locations on the Crooked River. In addition, the proposed action would have no effect on discharges from the City of Prineville's wastewater treatment facility and associated contribution of water pollutants.

BIO-5: Affect Bull Trout Migratory Life Stages

Based on RiverWare modeled results, streamflows in Whychus Creek[4] would be unchanged. Streamflow agreements and water conservation projects assumed under the no-action alternative would continue in Whychus Creek and would provide protection of existing conditions for bull trout over the permit term.

Several of the conservation measures in Whychus Creek would protect or improve streamflows and provide funds to improve or enhance habitat in the Whychus Creek that may benefit bull trout. The proposed action would have beneficial effects on bull trout migratory life stages in Whychus Creek by providing unimpeded upstream passage to additional habitat and fish screens at the diversion (Conservation Measure WC-7).

The proposed action would have no effect on bull trout migratory life stages in the Lower Deschutes River, Lake Billy Chinook, or Lake Simtustus because streamflows and reservoir volumes and elevations would either not change or changes would be minor compared to the no-action alternative over the permit term. The proposed action would have small beneficial effects on bull trout migratory life stages in Ochoco Creek outside the irrigation season, from slightly higher seasonal minimum and maximum median streamflows and no effect in McKay Creek from higher minimum streamflows during the active irrigation season. Effects in the remaining reaches relevant to the species are described.

Middle Deschutes

Increased median streamflows by 30 to 80% in the Middle Deschutes from October to March (Conservation Measures DR-1 and WR-1) would have a beneficial effect on bull trout migratory life stages over the permit term in the portion of the reach accessible to the species. Higher winter streamflows would likely improve access of foraging bull trout moving upstream into the Middle Deschutes River from Lake Billy Chinook.

Crooked River

The proposed action would have no effect on bull trout migratory life stages in Crooked River because migration windows for entering and moving upstream in the fall and for subadults to leave the Crooked River in the spring before temperatures exceed preference thresholds would not be affected (Figures 32 and 33).

[4] Conservation Measure WC-1, the addition of 3 cfs to the existing 31.18 cfs to instream flows by Three Sisters ID just downstream of the diversion, is assumed under the no-action alternative, as is the minimum instream flow of 20 cfs when TSID is diverting.

Figure 32. Predicted Percentage Days within Water Temperature Thresholds for Bull Trout Fall/Winter Migratory Stages for Wet (top), Dry (middle), and Normal (bottom) Years under the Proposed Action compared to the No-Action Alternative

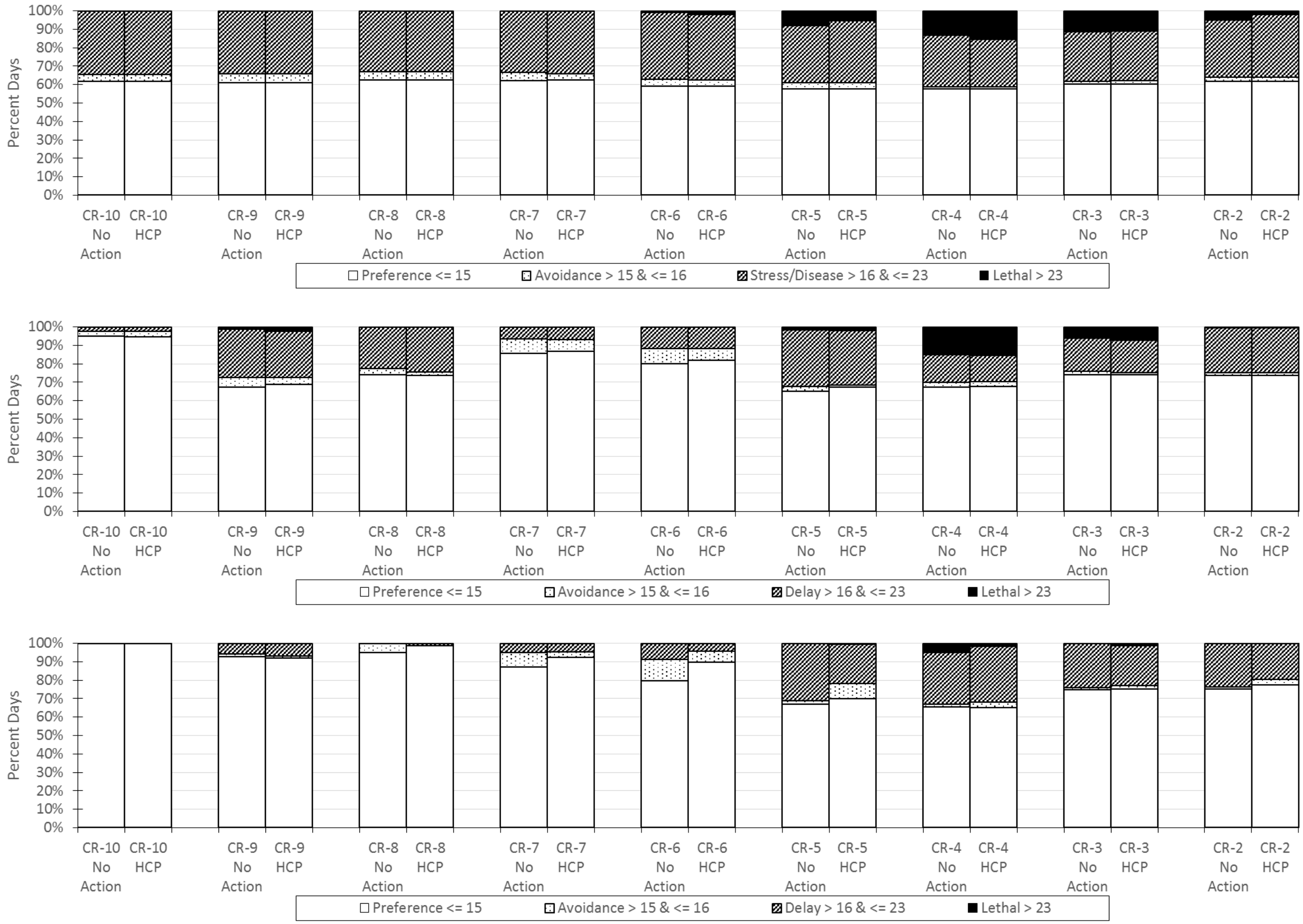
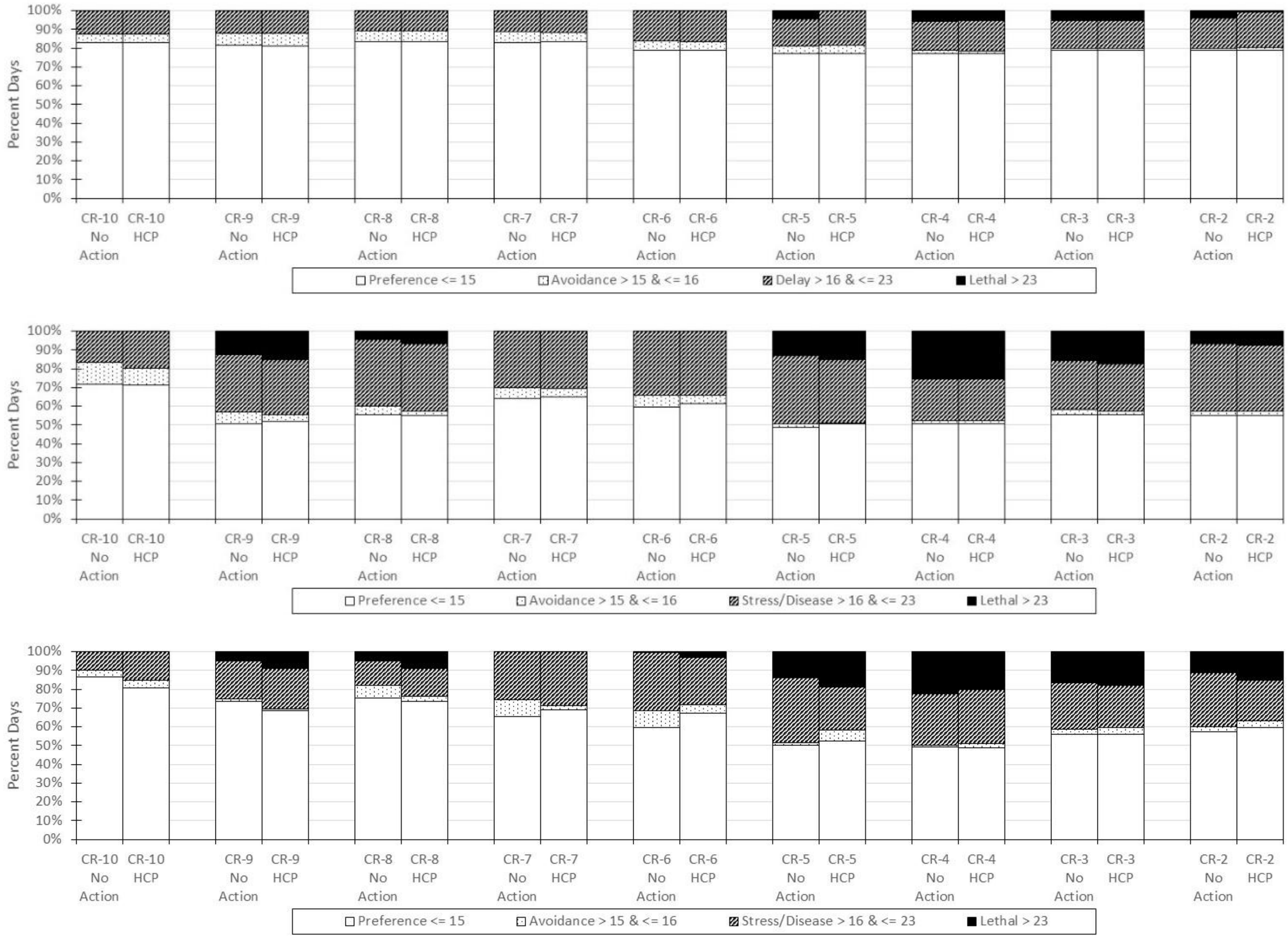


Figure 33. Predicted Percentage Days within Water Temperature Thresholds for Bull Trout Foraging, Migration, and Overwinter (FMO) Stages (Annual) for Wet (top), Dry (middle), and Normal (bottom) Years under the Proposed Action compared to the No-Action Alternative



BIO-6: Affect Steelhead Trout Habitat

Based on RiverWare modeled results, streamflows in Whychus Creek[5] would be unchanged. Streamflow agreements and water conservation projects assumed under the no-action alternative would continue in Whychus Creek and would provide protection of existing conditions for steelhead trout over the permit term.

The proposed action would have beneficial effects on steelhead trout habitat in Whychus Creek from Conservation Measures WC-2, WC-4, WC-5, and WC-7. Several of the conservation measures in Whychus Creek would protect or improve streamflows and provide funds to improve or enhance habitat in the Whychus Creek. Improved fish passage and fish screens at Plainview Dam under Conservation Measure WC-7 would make accessible 11.5 miles of Whychus Creek to steelhead trout and protect juvenile steelhead trout from entrainment at the diversion.

The proposed action would have no effect on steelhead trout habitat in the Lower Deschutes River, Lake Billy Chinook, or Lake Simtustus because changes in streamflows and reservoir volumes and elevations would either not change or changes would be minor over the permit term compared to the no-action alternative. The proposed action would have small beneficial effects on steelhead trout habitat in Ochoco Creek, from slightly higher seasonal minimum and maximum median streamflows under Conservation Measure CR-2, and in McKay Creek, from higher minimum streamflows during the active irrigation season under Conservation Measure CR-3. Effects in the remaining reaches relevant to the species are described.

Middle Deschutes

Increased median streamflows by 20% in the Middle Deschutes River from October to March (Conservation Measure DR-1 and WR-1) would have a beneficial effect on the quantity and connectivity of steelhead trout rearing and adult holding habitat over the permit term. Higher winter streamflows would increase wetted channel area and add more depth to pool habitat used by steelhead trout.

Overall the proposed action would have a beneficial effect on steelhead trout habitat.

Crooked River

Conservation Measures CR-4, CR-5, and CR-6 may result in small beneficial effects on steelhead trout habitat. Under Conservation Measure CR-4, funds would be available to support Crooked River habitat restoration measures and may benefit steelhead trout habitat. Conservation Measure CR-5 would provide funds for screening to National Oceanic and Atmospheric Administration (NOAA) fish screen standards of Ochoco ID patron diversions, and maintenance and operation of fish screens on all Ochoco ID-controlled diversions.

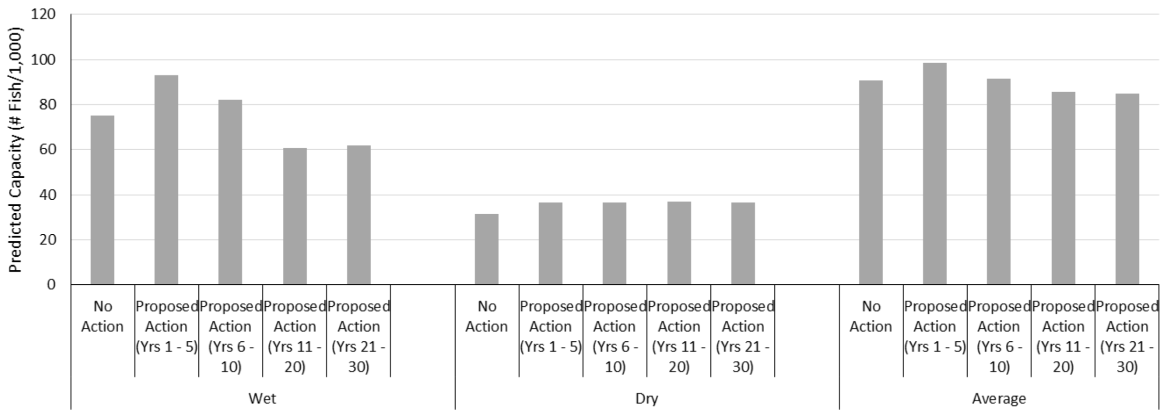
Conservation Measure CR-6 would ensure minimum streamflows are maintained when the North Unit ID pumps are operating, which would have a beneficial effect on steelhead trout habitat by reducing intra-daily streamflow variations downstream of the North Unit ID pumps to Osborne Canyon and maintaining minimum streamflows in this reach.

[5] Conservation Measure WC-1, the addition of 3 cfs to the existing 31.18 cfs to instream flows by Three Sisters ID just downstream of the diversion, is assumed under the no-action alternative, as is the minimum instream flow of 20 cfs when TSID is diverting.

Habitat Model Results

Results of modeling for summer juvenile rearing based on the 2019 RiverWare model show no effect or a decline in capacity under the proposed action (Figure 34). Temperature effects are largely influencing these results with slightly warmer temperatures in the wet and normal water year type toward the end of the permit term, resulting in a decline in juvenile capacity across all reaches.

Figure 34. Juvenile Steelhead Summer Capacity Estimates for the Mainstem Crooked River under the No-Action Alternative and Proposed Action Years 1–7, 8–12, and 13–30



Results of modeling winter juvenile rearing capacity are inconclusive. The decline in capacity under the proposed action in wet and normal water years modeled is from effects of summer water temperatures on the predicted abundance of steelhead in the winter (Figure 35). However, these results may not reflect winter conditions for juvenile rearing with the increased minimum streamflow rule. The results presented in Figure 36 represent effects of summer maximum water temperatures and winter streamflows (Mount Hood Environmental 2019). It is unclear if the winter minimum streamflow rule under the proposed action would affect summer water temperatures in the Crooked River. Figure 36 presents model results assuming a fixed summer maximum temperature (22˚C) in the no-action alternative and proposed action across the entire permit term. This analysis is included to focus effects of managing for higher streamflows during the storage season on juvenile capacity. In this analysis, steelhead winter capacity increases slightly under the proposed action in the dry water year with a slight increase in winter streamflows in that year type. Winter streamflows and juvenile capacity did not change under the proposed action in a wet and normal water year type because under the no-action alternative, streamflows exceeded the minimum rule.

Figure 35. Juvenile Steelhead Winter Capacity Estimates for the Mainstem Crooked River under the No-Action Alternative and Proposed Action Years 1–7, 8–12, and 13–30

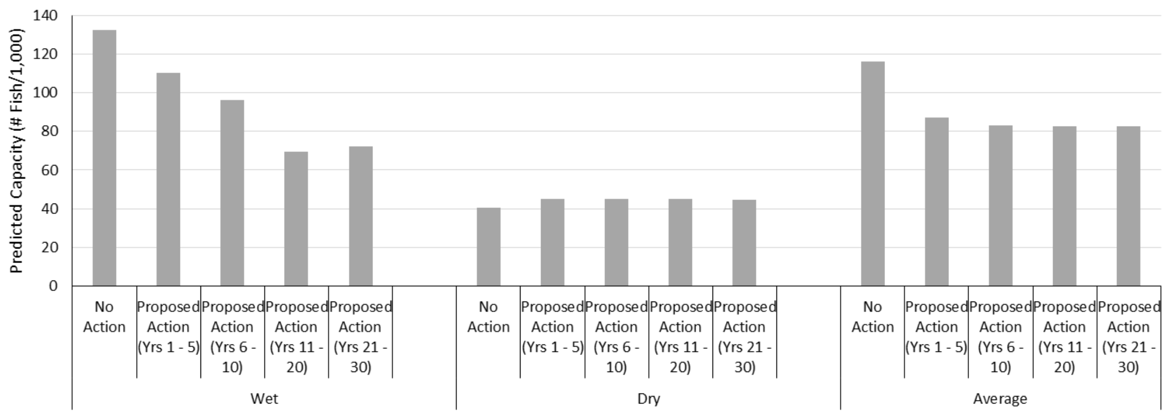
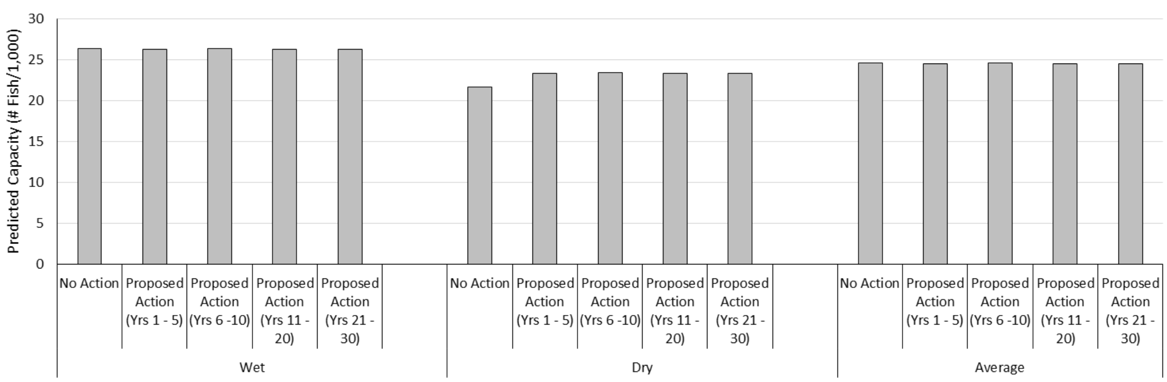


Figure 36. Juvenile Steelhead Winter Capacity Estimates for the Mainstem Crooked River with Fixed Summer Maximum Temperatures (22˚C) under the No-Action Alternative and Proposed Action



Water Temperature Results

Figures 37 through 39 summarize temperature thresholds and predicted temperatures for steelhead trout spawning, egg incubation and juvenile rearing.

Steelhead fry may emerge from the gravel into late June to early July and survival of eggs prior to emergence can be affected by rapidly warming conditions toward the end of the incubation period. Water temperatures during egg incubation are not being affected by water management under the proposed action (Figure 38). The number of days in the preferred category tended to not change or actually increased over the permit term for the year types.

Analysis of temperature thresholds for juvenile steelhead rearing show an effect of the shift in timing of release of water for the North Unit ID pumps to May on temperatures (Figure 39). The number of days in the avoidance category increase in the wet water year in the reach immediately downstream of Bowman Dam from 33 days under the no-action alternative to 59 days under the proposed action by the end of the permit term. In addition, there were more warm days in the normal water year toward the end of the permit term. The number of suboptimal days increased from 77 days to 109 days in the reach immediately downstream of Bowman Dam (Cro-10). The number of days in the stress/disease category increased from 34 days to 48 days in reach CR-9, downstream of the canyon reach and from 27 days to 52 days in reach CR–8, upstream of Prineville.

Effects of water management on water temperature in lower reaches (Cro-7 through Cro-2) tended to be more variable as temperatures were warmer under the no-action alternative and effects of water management from Bowman Dam have less of an influence on water temperatures (Berger et al. 2019). Berger et al. (2019) summarized this effect this way:

> Scenario simulations showed that the temperature impact of Bowman Dam releases were very sensitive to travel time. The longer the travel time and further the distance from the dam, the less effect dam releases had on downstream river temperatures. At longer travel times, water temperatures became more of a function of meteorological conditions instead of dam release temperatures. This was illustrated by the No Action scenario predicting cooler downstream temperatures later in the summer relative to the other scenarios for 1993 and 2005 due to higher Bowman Dam releases.

Overall there was a tendency for more days in the stress/disease and lethal categories under the proposed action.

Figure 37. Predicted Percentage Days within Water Temperature Thresholds for Spawning Steelhead Trout for a Wet (top), Dry (middle) and Normal (bottom) Year under the Proposed Action Compared to the No-Action Alternative

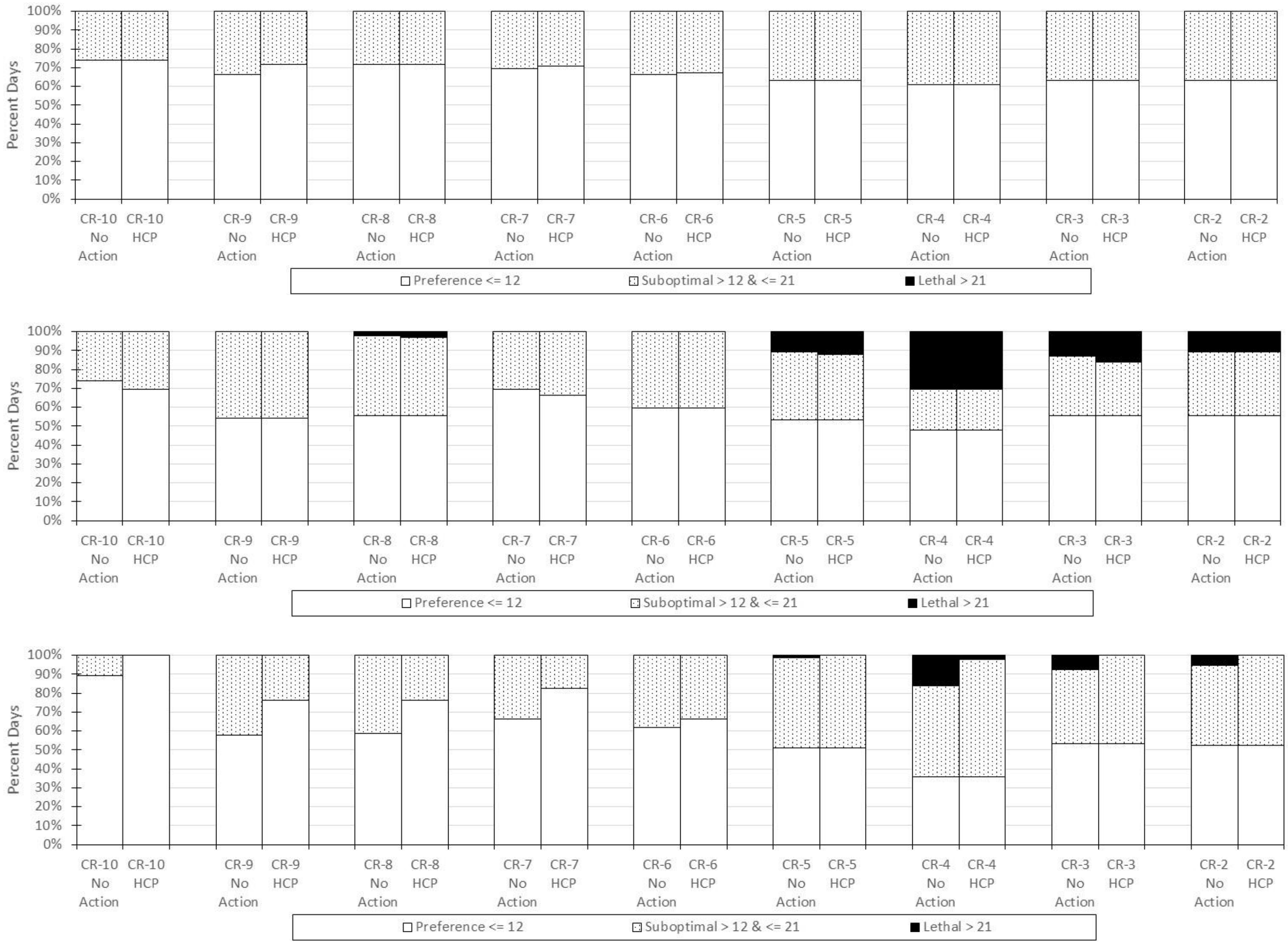


Figure 38. Predicted Percentage Days within Water Temperature Thresholds for Steelhead Trout Egg Incubation for a Wet (top), Dry (middle) and Normal (bottom) Year under the Proposed Action Compared to the No-Action Alternative

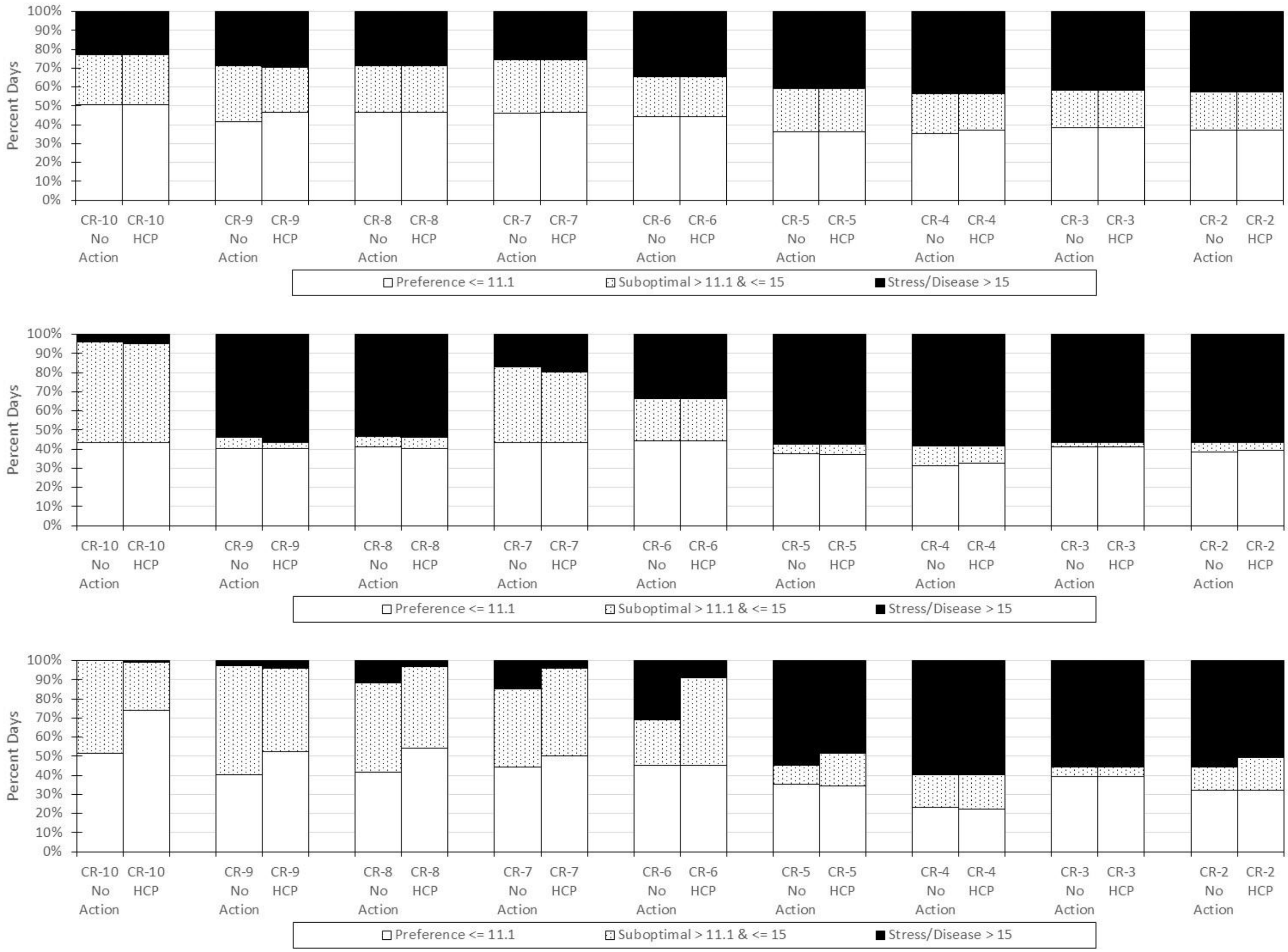
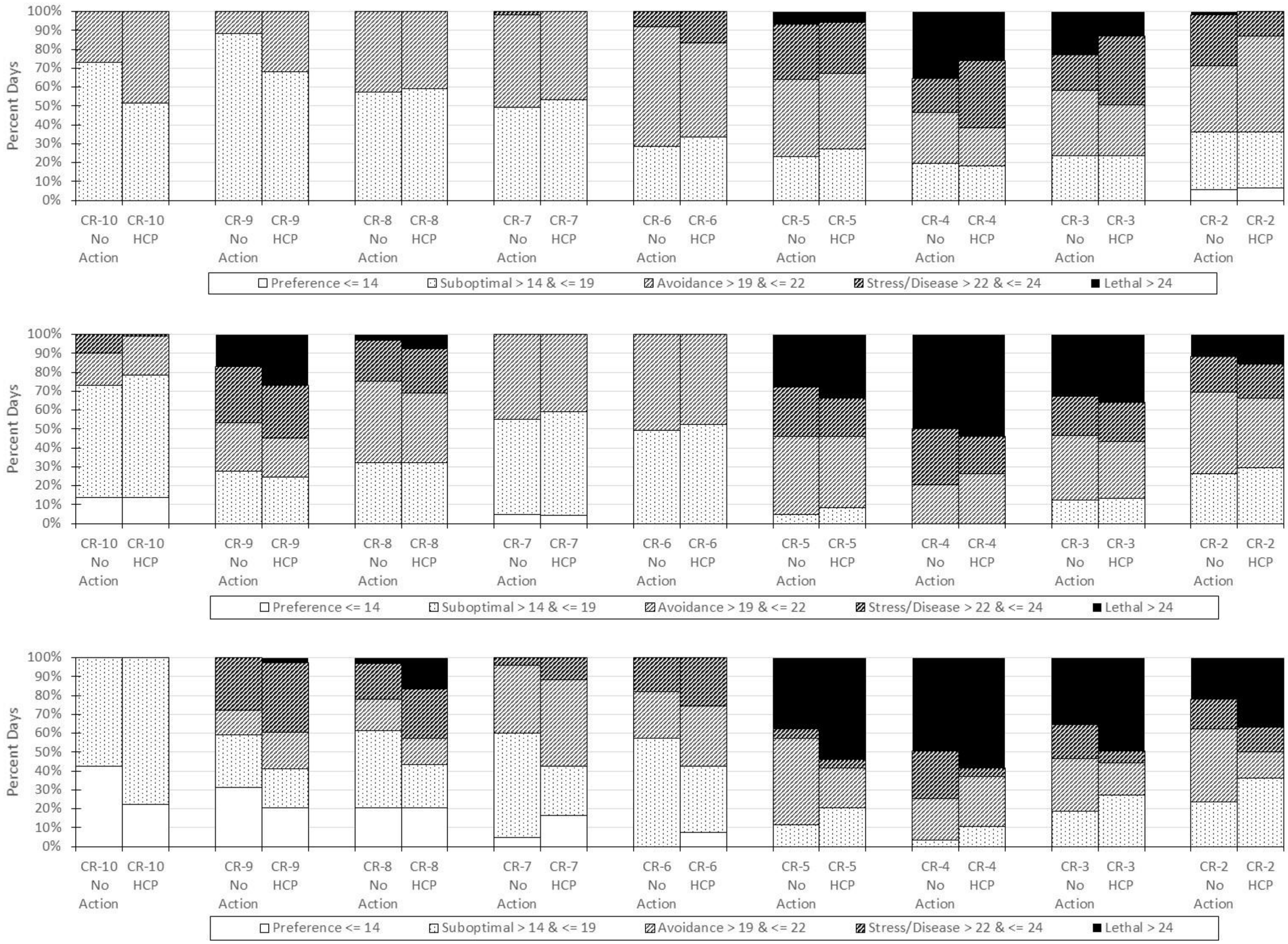


Figure 39. Predicted Percentage Days within Water Temperature Thresholds for Steelhead Trout Juvenile Rearing for a Wet (top), Dry (middle), and Normal (bottom) Year under the Proposed Action Compared to the No-Action Alternative



Summary Crooked River

Steelhead trout would be exposed to a range of water management effects under the proposed action, including differences in streamflow across the year affecting the amount of habitat available (Conservation Measures CR-1) and effects of water management on water temperatures during critical life stages (Conservation Measure WR-1).

Habitat model results suggest an adverse effect on summer rearing and inconclusive effects on winter rearing, although protected winter streamflows that would avoid years like reported by Porter and Hodgson (2016) would be a beneficial effect and would increase habitat capacity independent of summer water temperatures.

Decreased streamflows downstream of the North Unit ID pumps to Osborne Canyon (Reaches Cro-2 through 1.3; RMs 22.4 to 7.3) from May through September would have an adverse effect on steelhead trout habitat in a little over half of the years over the permit term. This is due to increased North Unit ID reliance on the Crooked River to compensate for decreased Upper Deschutes water supply under Conservation Measure WR-1.

Modeled water temperatures and thresholds for juvenile steelhead trout rearing habitat suggest the potential for an adverse effect of water management on water temperatures and juvenile habitat in a normal water year type toward the end of the permit term.

As described for bull trout (Impact BIO-4), the proposed action would not create additional pesticide or nutrient sources, pathways or otherwise alter the occurrence of pesticides or nutrients in the Crooked River affecting steelhead trout habitat.

BIO-7: Affect Steelhead Trout Migratory Life Stages

Based on RiverWare modeled results, streamflows in Whychus Creek[6] would be unchanged. Streamflow agreements and water conservation projects assumed under the no-action alternative would continue in Whychus Creek and would provide protection of existing conditions for bull trout over the permit term.

Several of the conservation measures in Whychus Creek would protect or improve streamflows and provide funds to improve or enhance habitat in the Whychus Creek that may benefit steelhead trout. The proposed action would have beneficial effects on steelhead trout migratory life stages in Whychus Creek by providing unimpeded upstream passage to additional habitat and fish screens at the diversion (Conservation Measure WC-7).

The proposed action would have small beneficial effects on steelhead trout migratory life stages in Ochoco, and McKay Creeks for the reasons described for bull trout (Impact BIO-5). Likewise, the proposed action would have no effect on steelhead trout migratory life stages in the Lower Deschutes because the increase in winter streamflows over the permit term would be minor.

[6] Conservation Measure WC-1, the addition of 3 cfs to the existing 31.18 cfs to instream flows by Three Sisters ID just downstream of the diversion, is assumed under the no-action alternative, as is the minimum instream flow of 20 cfs when Three Sisters ID is diverting.

Middle Deschutes

The proposed action would have no effect on steelhead trout migratory life stages during the irrigation period because streamflows in this reach during this period would be unchanged over the permit term.

Small to moderate increases in winter streamflows, under the proposed action, would have no effect on steelhead trout migratory life stages in the portion of the reach accessible to the species over the permit term.

Crooked River

Conservation Measure CR-7 protects streamflows that are part of downstream fish migration pulse flows. Pulse streamflows are not included in the RiverWare model but were considered beneficial to migrating steelhead in the effects analysis.

Water Temperature Results

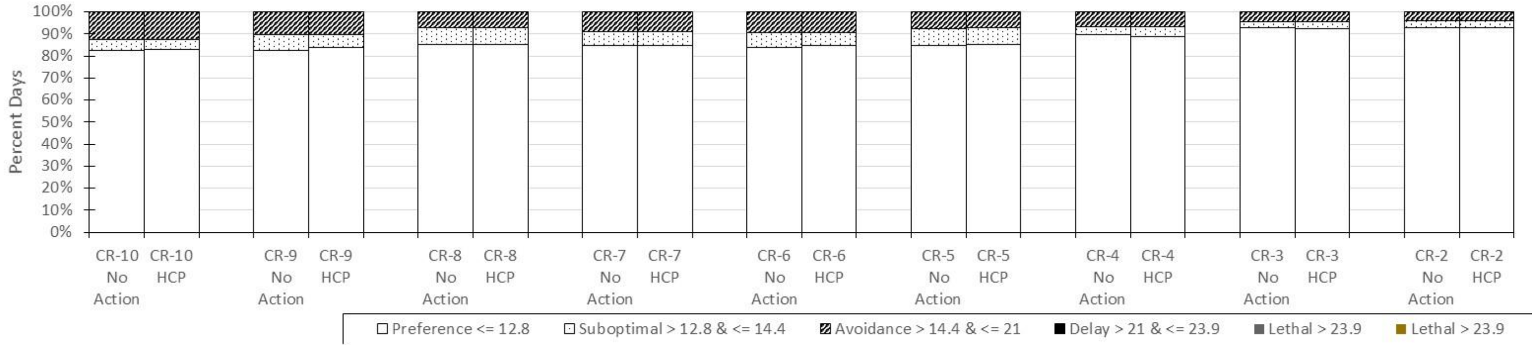
Figures 40 and 41 summarize temperature thresholds and predicted temperatures for steelhead trout adult migration and juvenile smolt outmigration.

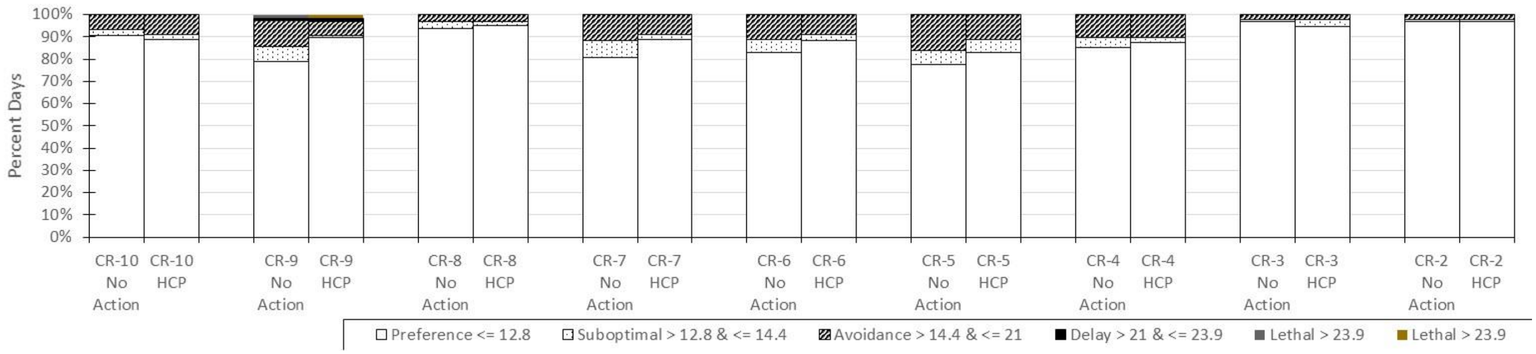
There was no evidence that the proposed action streamflows were affecting water temperatures during steelhead trout migratory life stages across the permit term compared to the no-action alternative for all three water year types. Results show slightly more days that water temperatures were in the preferred category for migratory life stages under the proposed action, suggesting a beneficial effect.

Conservation Measure CR-6 to keep flows downstream of the North Unit ID pumps at or above 50 cfs at all times when the pumps are operating will protect streamflows in this reach and will help prevent extremely low streamflows and facilitate downstream migration. However, streamflows are reduced in the reach downstream of the North Unit ID pumps toward the end of the permit term with increased dependence on the pump diversion for North Unit ID deliveries.

Overall, there would be no effect on migratory life stages of steelhead trout in this reach.

Figure 40. Predicted Percentage Days within Water Temperature Thresholds for Steelhead Trout Adult Migrants for a Wet (top), Dry (middle), and Normal (bottom) Year under the Proposed Action Compared to the No-Action Alternative





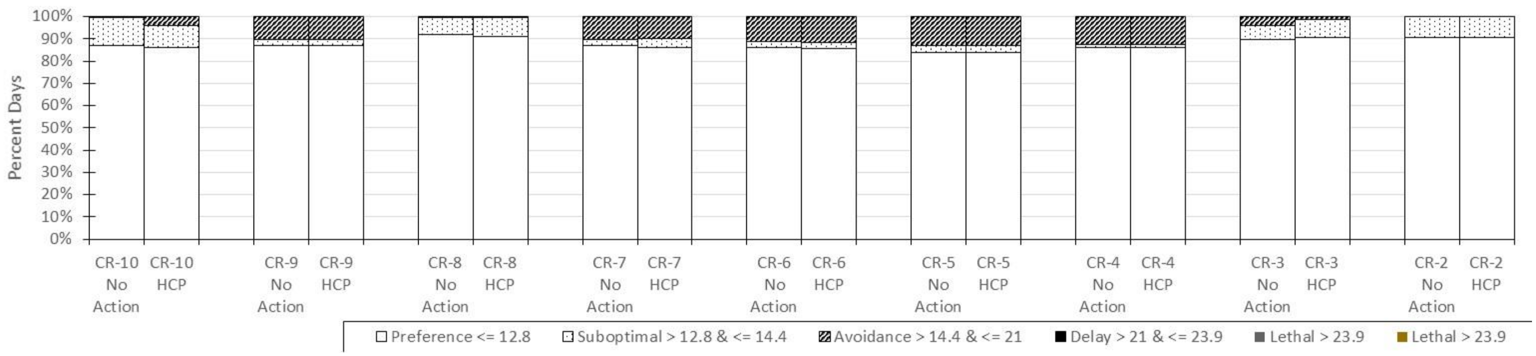
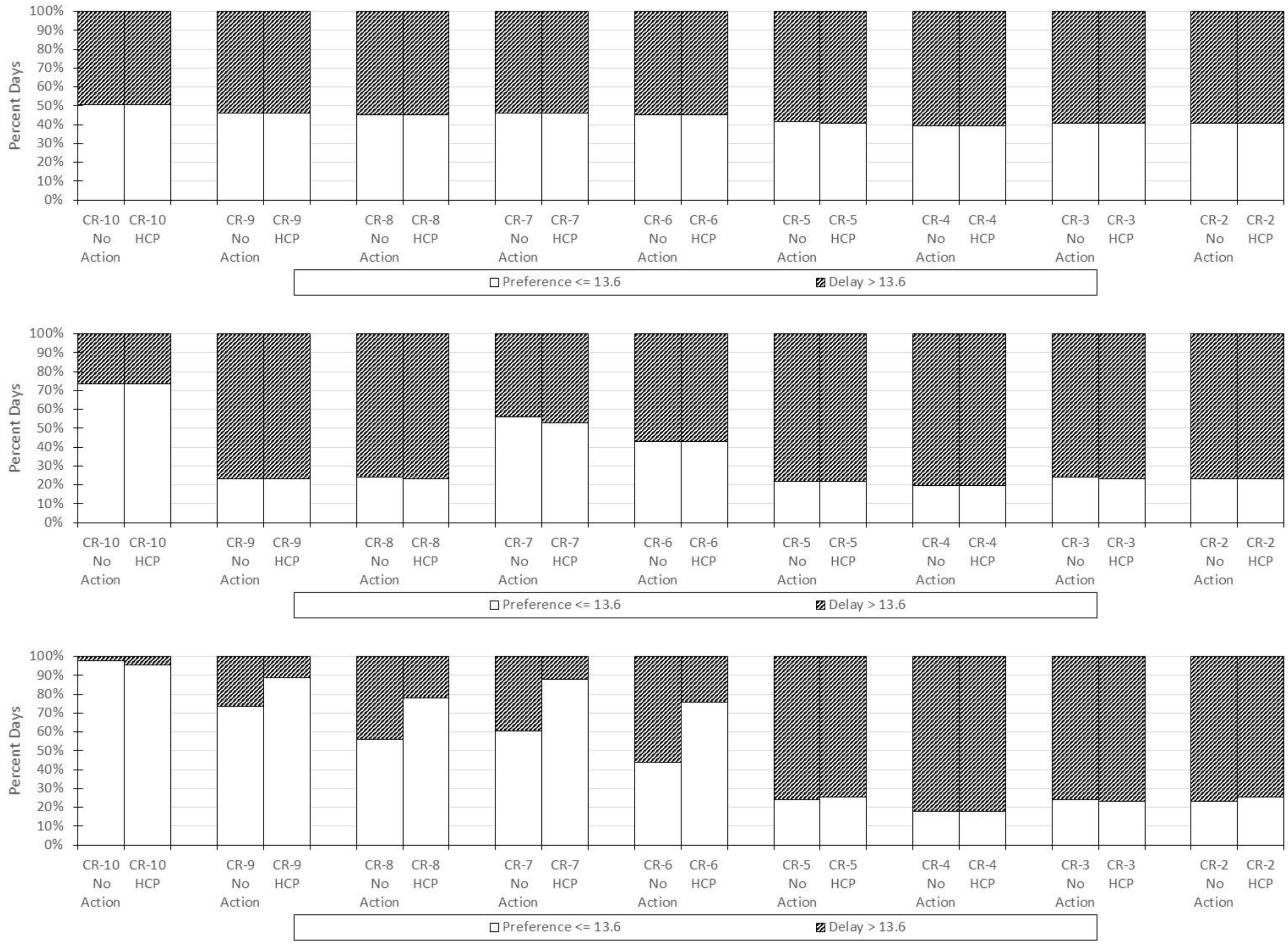


Figure 41. Predicted Percentage Days within Water Temperature Thresholds for Steelhead Trout Smolt Migrants for a Wet (top), Dry (middle), and Normal (bottom) Year under the Proposed Action Compared to the No-Action Alternative



Summary Crooked River

In the Crooked River, conservation measures would result in beneficial effects on steelhead trout habitat. Not all of these are quantifiable. Conservation Measures CR-7 protects pulse flows for migration below the North Unit ID pumps. Pulse flows is a management option considered by the resource agencies to improve migration survival.

Modeled water temperatures and thresholds for steelhead trout migration life stages show no adverse effect of water management on water temperatures and migration habitat.

The updated RiverWare model included operational changes in the Upper Deschutes River, which affected North Unit ID deliveries and timing of North Unit ID the pump diversion on the Crooked River. The North Unit ID pump diversion may occur from May to September depending on the year.

BIO-8: Affect Spring Chinook Salmon Habitat

Based on RiverWare modeled results, streamflows in Whychus Creek[7] would be unchanged. Streamflow agreements and water conservation projects assumed under the no-action alternative would continue in Whychus Creek and would provide protection of existing conditions for spring Chinook over the permit term.

Several of the conservation measures in Whychus Creek would protect or improve streamflows and provide funds to improve or enhance habitat in the Whychus Creek that would benefit spring Chinook.

The proposed action would have no effect on spring Chinook salmon habitat in the Lower Deschutes River, Lake Billy Chinook, or Lake Simtustus because changes in streamflows and reservoir volumes and elevations would either not change or changes would be minor over the permit term compared to the no-action alternative. The proposed action would have small beneficial effects on spring Chinook salmon habitat in Ochoco Creek, from slightly higher seasonal minimum and maximum median streamflows under Conservation Measure CR-2. Effects in the remaining reaches relevant to the species are described.

Middle Deschutes

The proposed action would have no effect on spring Chinook salmon habitat during the irrigation period because streamflows in the Middle Deschutes would be unchanged over the permit term. Small to moderate increases in winter streamflows, under the proposed action, would have no effect on spring Chinook salmon habitat in the portion of the reach accessible to the species over the permit term.

Crooked River

In the Crooked River, Conservation Measures CR-4, CR-5, and CR-6 may result in small beneficial effects on spring Chinook habitat. Under Conservation Measure CR-4, funds would be available to support Crooked River habitat restoration measures and may benefit spring Chinook habitat. Conservation Measure CR-5 would provide funds for screening to National Oceanic and Atmospheric

[7] Conservation Measure WC-1, the addition of 3 cfs to the existing 31.18 cfs to instream flows by Three Sisters ID just downstream of the diversion, is assumed under the no-action alternative, as is the minimum instream flow of 20 cfs when Three Sisters ID is diverting.

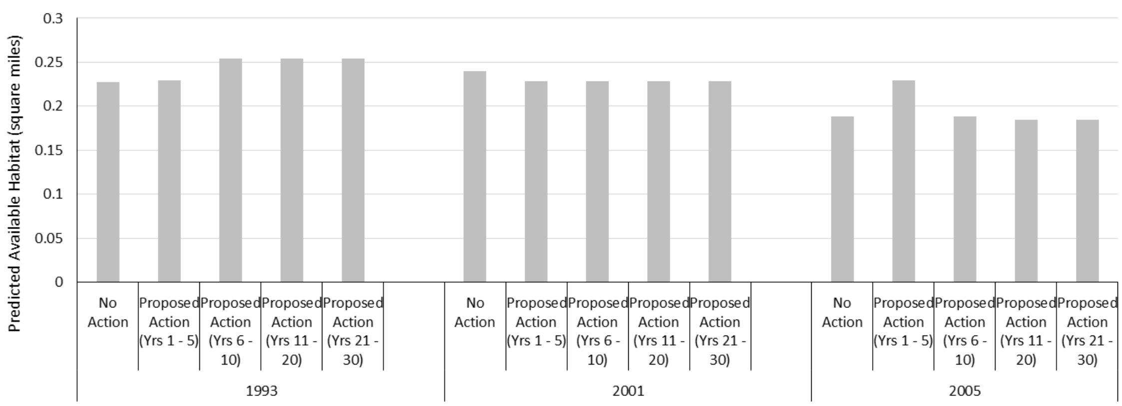
Administration (NOAA) fish screen standards of Ochoco ID patron diversions, and maintenance and operation of fish screens on all Ochoco ID-controlled diversions.

Conservation Measure CR-6 would ensure minimum streamflows are maintained when the North Unit ID pumps are operating, which would have a beneficial effect on spring Chinook salmon habitat by reducing intra-daily streamflow variations downstream of the North Unit ID pumps to Osborne Canyon and maintaining minimum streamflows in this reach.

Habitat Model Results

Results of modeling available summer habitat for Chinook juvenile rearing indicate no trend toward adverse or beneficial effects. Effects of streamflows on available habitat do not suggest any particular trend between the no-action alternative and the proposed action (Figure 42).

Figure 42. Estimate of Juvenile Chinook Summer Habitat Availability for the Mainstem Crooked River under the No-Action Alternative and Proposed Action



Water Temperature Results

Figures 43 through 45 summarize temperature thresholds and predicted temperatures for spring Chinook spawning, egg incubation and juvenile rearing.

Modeled water temperatures from Bowman Dam to Smith Rock in August and September during spring Chinook salmon spawning are higher than the preference threshold of 14.0 °C under the no-action alternative and the proposed action. Daily maximum water temperatures do not drop below the avoidance threshold of 16.0 °C until mid-September.

Analysis of temperature thresholds for spring Chinook salmon egg incubation does not suggest an effect of water management operations on water temperatures under modeled streamflows (Figure 44). The shift in timing of release from Prineville from August to May and June does not change temperatures in August at the beginning of incubation to suggest a shift in habitat suitability. Modeled water temperatures from Bowman Dam to Smith Rock exceed the preference threshold of 12.8°C for spring Chinook salmon egg incubation under the no-action alternative. Water temperatures cool rapidly in late September and early October.

Analysis of temperature thresholds based for spring Chinook salmon rearing suggests an adverse effect of water management operations on water temperatures under modeled streamflows (Figure 45). The shift in timing of release from Prineville from July and August to May and June is increasing the number of days with warmer temperatures. The number of days in the stress/disease category in the wet water year in the reach immediately downstream of Bowman Dam increased from 28 days under the no-action alternative to 58 days under the proposed action by the end of the permit term. There were more warm days in the normal water year toward the end of the permit term. The number of sub-optimal days increased from 41 days to 62 days in the reach immediately downstream of Bowman Dam (Cro-10). The number of days in the optimal category decreased from 47 days to 26 days in reach CR-9, downstream of the canyon reach and from 53 days to 31 days in reach CR–8, upstream of Prineville. Effects of water management on water temperature in lower reaches (Cro-7 through Cro-2) tended to be more variable as temperatures were warmer under the no-action alternative and effects of water management from Bowman Dam have less of an influence on water temperatures (Berger et al. 2019). Overall there was a tendency for more days in the stress/disease and lethal categories under the proposed action.

Water temperatures thresholds were not available for adult spring Chinook holding through the summer in the Crooked River. However, the additional number of warm days under the proposed action toward the end of the permit term indicate a worsening of habitat conditions for spring Chinook adults holding through the summer. The number of days in each category for juvenile Chinook report in Figure 45 indicate conditions would be more stressful for spring Chinook adults in the upper Crooked River reaches where temperatures are fairly cool through the summer under the no-action alternative.

Summary Crooked River

Spring Chinook would be exposed to a range of water management effects under the proposed action, including differences in streamflow across the year affecting the amount of habitat available and effects of water management on water temperatures during critical life stages (indirect effects of Conservation Measure WR-1).

Results of modeling available summer habitat for Chinook juvenile rearing indicate no trend toward adverse or beneficial effects.

RiverWare model results show decreased streamflows downstream of the North Unit ID pumps to Osborne Canyon (Reaches Cro-2 through 1.3; RMs 22.4 to 7.3) from May through September. Conservation Measure CR-6 sets minimum flows below the North Unit ID pumps of 51 cfs to 181 cfs depending on month and water year type. The complexities of CR-6 and determination of water year type were not included in the RiverWare model and thus RiverWare is possibly over-estimating the effects of pumping in this section of the Crooked River. Conservation Measure CR-6 would provide an unquantifiable level of protection of spring Chinook salmon habitat in this reach. In summary, there is likely an effect of Conservation Measure WR-1 in this portion of the Crooked River, but likely not adverse based on available information.

Modeled water temperatures and thresholds for juvenile spring Chinook habitat suggest an adverse effect of water management on water temperatures and juvenile habitat in a normal water year type toward the end of the permit term.

Water released from Prineville Reservoir for the North Unit ID pump diversion may occur in June, July, or August depending on the year. Late June, July, and August releases may be beneficial to juvenile spring Chinook rearing through the summer in the Crooked River by reducing temperatures during the warmest periods.

Figure 43. Predicted Percentage Days within Water Temperature Thresholds for Spawning Spring Chinook for a Wet (top), Dry (middle), and Normal (bottom) Year under the Proposed Action Years 13–30 Compared to the No-Action Alternative

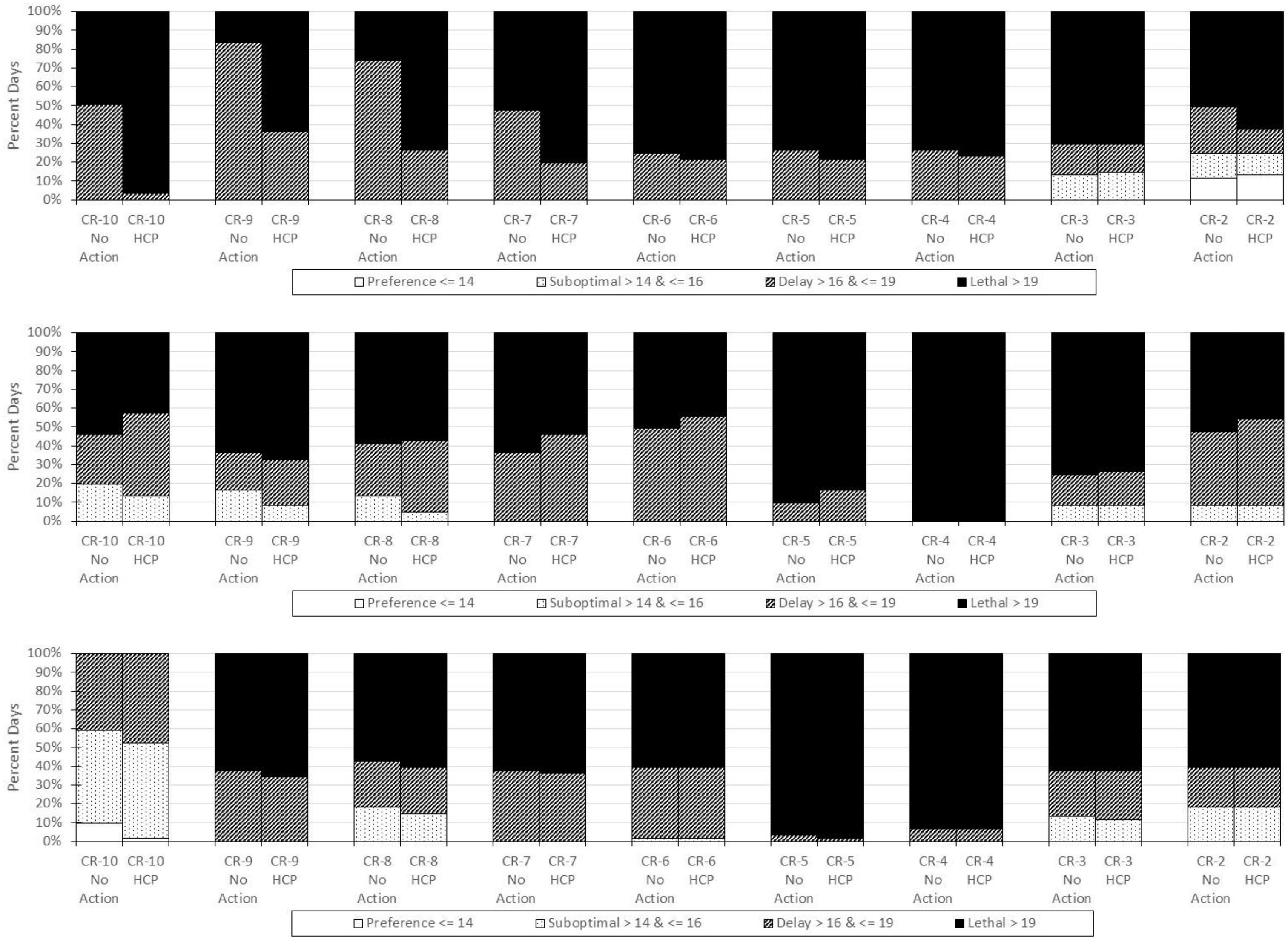


Figure 44. Predicted Percentage Days within Water Temperature Thresholds for Spring Chinook Egg Incubation for a Wet (top), Dry (middle), and Normal (bottom) Year under the Proposed Action Years 13–30 Compared to the No-Action Alternative

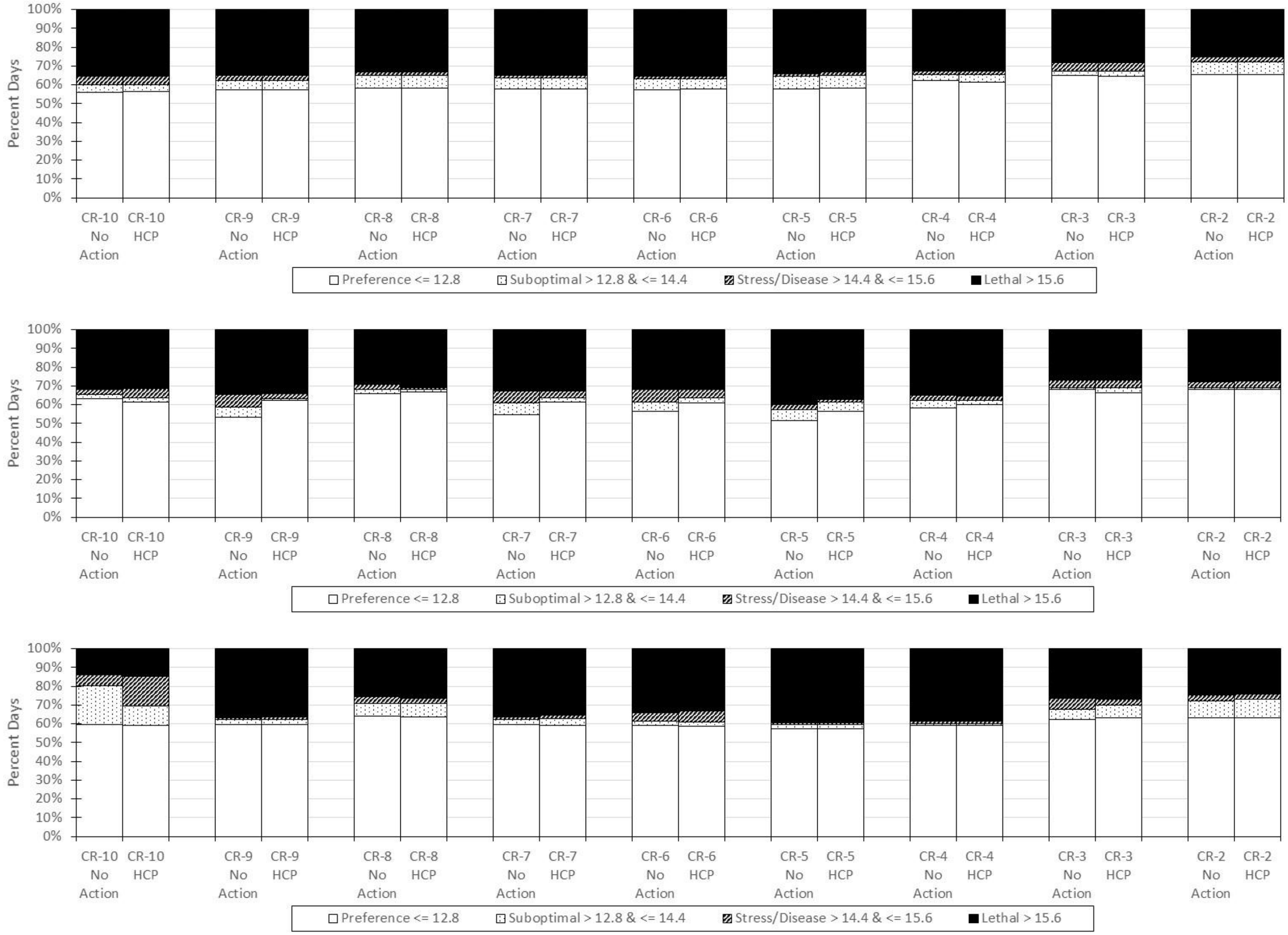
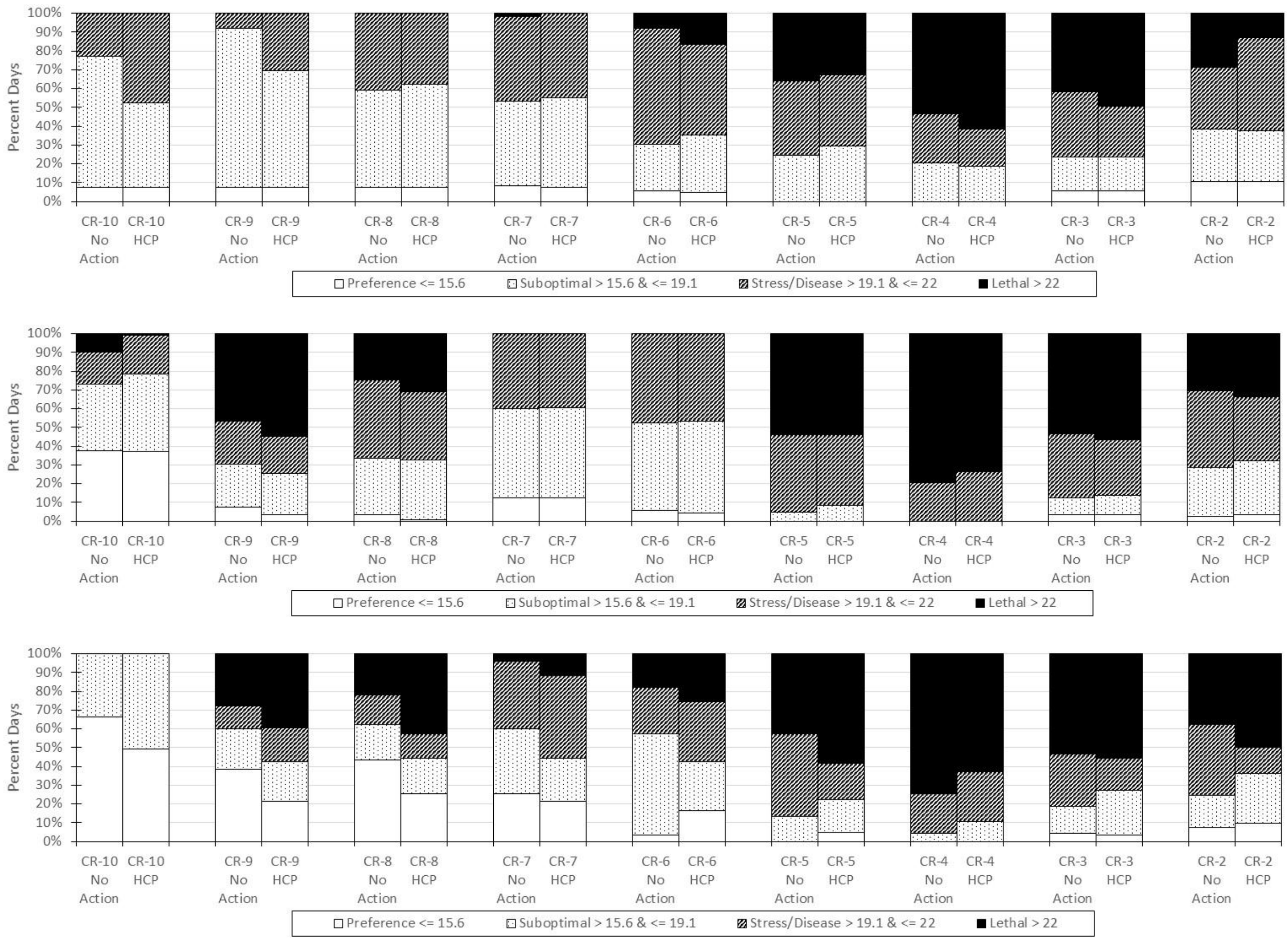


Figure 45. Predicted Percentage Days within Water Temperature Thresholds for Juvenile Spring Chinook Rearing June through September for a Wet (top), Dry (middle), and Normal (bottom) Year under the Proposed Action Years 13–30 Compared to the No-Action Alternative



BIO-9: Affect Spring Chinook Salmon Migratory Life Stages

The proposed action would have no effect on spring Chinook salmon habitat in Whychus Creek because streamflows would be unchanged in this creek over the permit term. Likewise, the proposed action would have no effect on spring Chinook salmon migratory life stages in the Lower Deschutes because the increase in winter streamflows over the permit term would be minor.

Middle Deschutes

The proposed action would have no effect on spring Chinook salmon migratory life stages during the irrigation period because streamflows in the Middle Deschutes would be unchanged over the permit term.

The proposed action would have no effect on spring Chinook salmon migratory life stages during the irrigation period because streamflows in the Middle Deschutes would be unchanged over the permit term. Small to moderate increases in winter streamflows would have no effect on spring Chinook salmon migratory life stages in the portion of the reach accessible to the species over the permit term because they are outside of the migratory period for adult spring Chinook and smolts.

Crooked River

Average depth of riffles in the Crooked River suggest low streamflows may impede adult migration under the no-action alternative (Draft Deschutes Basin HCP, Chapter 8, Section 8.3.3). Water supply modeling assumes irrigation season diversions from the Crooked River would increase as water supply availability on the Deschutes River declines. The frequency of this outcome would depend on specific, annual water supply management decisions and water supply availability that are not captured fully by modeling results. This effect on Chinook salmon adult migration habitat may be beneficial by increasing riffle depths when adult Chinook are migrating with higher streamflows between Bowman Dam and the North Unit ID diversion at RM 22.4. However, adult migration may be adversely affected downstream of the North Unit ID diversion to approximately Osborne Canyon (RM 7.3) because of lower streamflows when early season irrigation diversions occur and riffle depths are reduced compared to the no-action alternative.

Conservation Measure CR-7 protects streamflows that are part of downstream fish migration pulse flows. Pulse streamflows are not included in the RiverWare model but were considered beneficial to migrating spring Chinook in the effects analysis.

Water Temperature Results

Figures 46 and 47 summarize temperature thresholds and predicted temperatures for spring Chinook adult migration and smolt outmigration.

Analysis of temperature thresholds for spring Chinook salmon adult migration suggests fewer warm days during the adult spring migration under the proposed action because of the earlier release of water at Bowman Dam for the North Unit ID pump diversion. The number of avoidance, delay and lethal days tended to decrease over the permit term (Figure 46).

Radio tracking data collected in 2013 of migrating adult spring Chinook salmon found evidence that adult spring Chinook may be migrating during the summer. One adult entering the Crooked River in mid-June was later recovered at the mouth of Ochoco Creek in late August, suggesting adults may move upstream in the Crooked River in July and August (Hill et al. 2014). Another spring Chinook adult was observed moving upstream in the Crooked River during summer 2020 (Lickwar pers. comm. [b]). Furthermore, radio tracking of adults in other locations upstream of the Pelton-Round Butte Complex indicate movement of adults in July and August (Lickwar pers. comm. [c]). These results suggest that spring Chinook salmon may attempt to migrate upstream later in the year and that migration habitat could be affected by elevated river temperatures during the summer. Because of this potential effect on migration habitat during July and August, water temperatures may effect adult spring Chinook salmon migration habitat and could be potentially adverse based on water management.

The 2020 RiverWare model included operational changes in the Upper Deschutes which affected North Unit ID deliveries and timing of North Unit ID the pump diversion on the Crooked River. North Unit ID pump diversion may occur in June, July, or August depending on the year. Late June, July, and August releases may be beneficial to upstream migrating adults.

Water temperatures did not differ during the spring smolt migration (Figure 47).

Summary Crooked River

The proposed action would have no effect on migrating spring Chinook salmon adults attempting to move upstream in the spring or out-migrating smolts because of water temperature effects on these life stages would be likely be minor.

Modeled water temperatures and thresholds for spring Chinook migration habitat suggest no effect of water management on water temperatures and spring Chinook migration life stages toward the end the permit term.

RiverWare model results show decreased streamflows downstream of the North Unit ID pumps to Osborne Canyon (Reaches Cro-2 through 1.3; RMs 22.4 to 7.3) from May through September when juvenile and adult Chinook are migrating. Conservation Measure CR-6 sets minimum flows below the North Unit ID pumps when operating of 51 cfs to 181 cfs depending on month and water year type. The complexities of CR-6 and determination of water year type were not included in the RiverWare model and thus RiverWare is possibly over-estimating the effects of pumping in this section of the Crooked River. Conservation Measure CR-6 would provide an unquantifiable level of protection of spring Chinook salmon habitat in this reach. In summary, there is likely an effect of WR-1 in this portion of the Crooked River, but likely not adverse based on available information.

Protection of pulse spring streamflows below the North Unit ID pump diversion (Conservation Measure CR-7) will have a beneficial effect to move juvenile and adult Chinook through the Crooked River depending on when the water was released.

As described for bull trout (Impact BIO-4), the proposed action would not create additional pesticide or nutrient sources, pathways or otherwise alter the occurrence of pesticides or nutrients in the Crooked River affecting spring Chinook habitat.

Figure 46. Predicted Percentage Days within Water Temperature Thresholds for Migrating Adult Spring Chinook March through June for a Wet (top), Dry (middle), and Normal (bottom) Year under the Proposed Compared to the No-Action Alternative

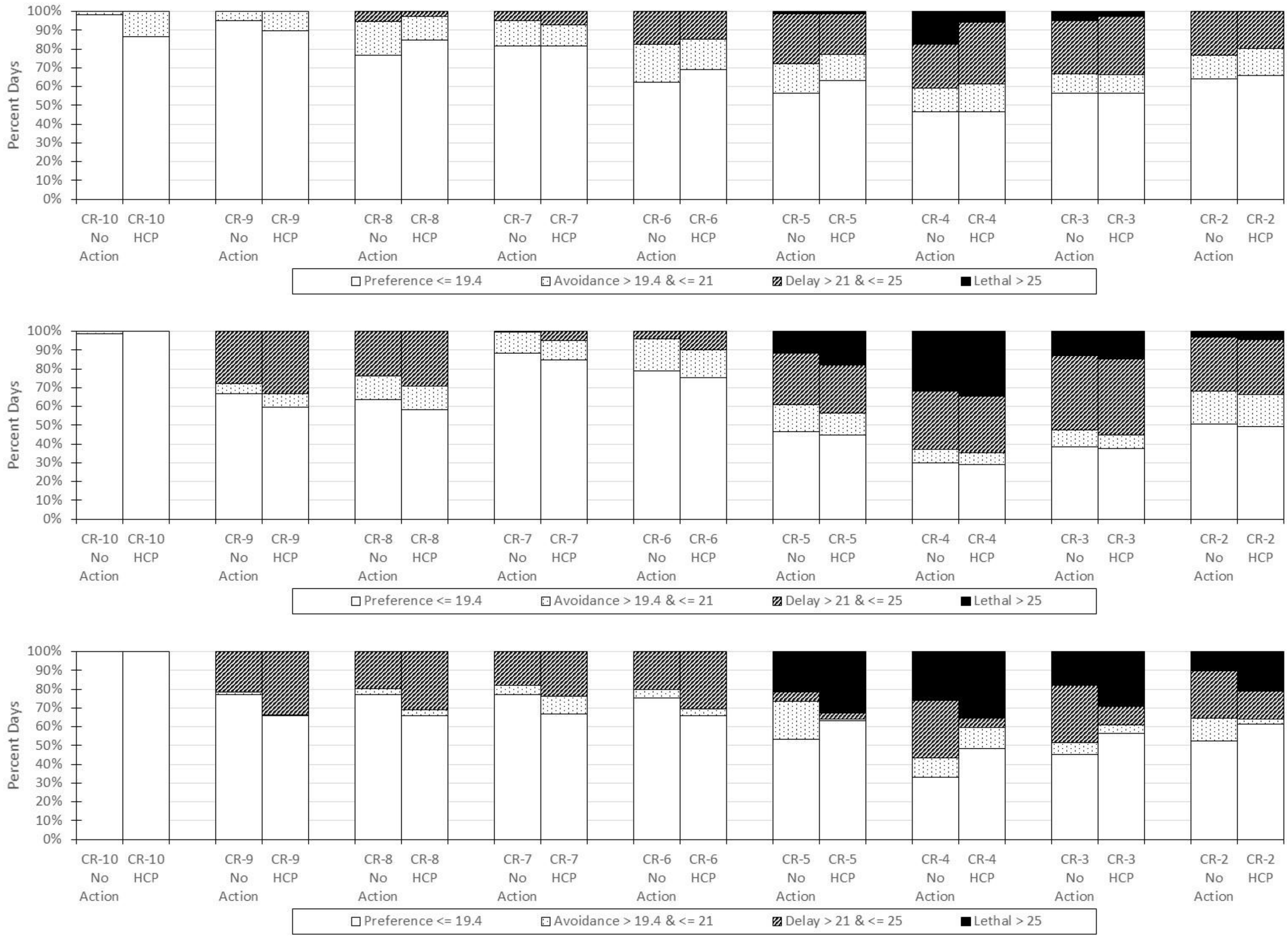
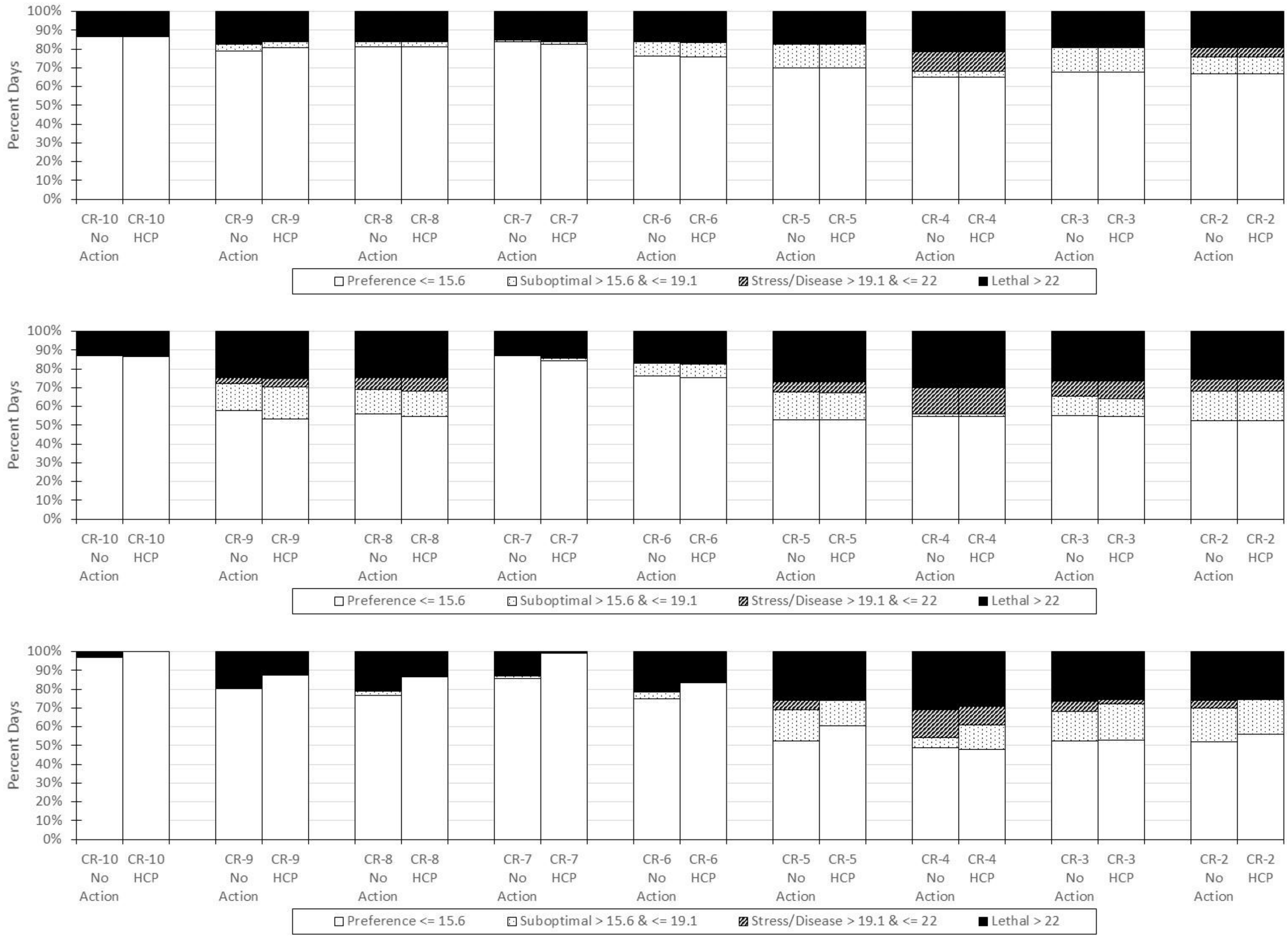


Figure 47. Predicted Percentage Days within Water Temperature Thresholds for Migrating Smolt Spring Chinook for a Wet (top), Dry (middle), and Normal (bottom) Year under the Proposed Action Compared to the No-Action Alternative



BIO-10: Affect Sockeye Salmon Habitat

The proposed action would have no effect on sockeye salmon habitat in Whychus Creek because streamflows would be unchanged in this creek over the permit term. Differences in reservoir volume and elevations in Lake Billy Chinook and Lake Simtustus would be minor under the proposed action and would have no effect on sockeye salmon habitat. Likewise, the proposed action would have no effect on sockeye salmon habitat in the Lower Deschutes because the increase in winter streamflows over the permit term would be minor.

Middle Deschutes

The proposed action would have no effect on sockeye salmon habitat during the irrigation period because streamflows in the Middle Deschutes would be unchanged over the permit term.

Relatively small increases in winter streamflows, under the proposed action, would have no effect on sockeye salmon habitat in the portion of the reach accessible to the species over the permit term.

Crooked River

Adult sockeye salmon may enter the Crooked River in the fall to spawn in the lower section of the river, downstream of Opal Springs hydroelectric project. Eggs would remain in the gravel through the winter. Newly emerged fry would migrate to Lake Billy Chinook in the spring for juvenile rearing. The limited use by sockeye suggests any effects of water management on sockeye salmon habitat would be limited to availability of spawning and egg incubation habitat in the lower river, downstream of Opal Springs hydroelectric project.

Under the proposed action, modeled streamflows in the Crooked River at the Opal node in the lower river (Reaches Cro-1.2 and Cro-1.1; RMs 7.3 to 0) are relatively unchanged compared to the no-action alternative for the entire permit term. The changes in flow from upstream water management are too small in the context of the high volume groundwater inflow upstream of the Opal node to result in effects on the species in this reach. Therefore, there would be no effect on habitat for sockeye salmon in the portion of the Crooked River used by sockeye salmon for spawning.

BIO-11: Affect Sockeye Salmon Migratory Life Stages

The proposed action would have no effect on sockeye salmon migratory life stages in Whychus Creek because streamflows would be unchanged in this creek over the permit term. Likewise, the proposed action would have no effect on sockeye salmon migratory life stages in the Lower Deschutes because the increase in winter streamflows over the permit term would be minor.

Middle Deschutes

The proposed action would have no effect on sockeye salmon migratory life stages during the irrigation period because streamflows in the Middle Deschutes would be unchanged over the permit term.

Relatively small increases in winter streamflows, under the proposed action, would have no effect on sockeye salmon migratory life stages in the portion of the reach accessible to the species over the permit term.

Crooked River

Adult sockeye salmon may enter the Crooked River in the fall to spawn in the lower section of the river, downstream of the Opal Springs hydroelectric project. The limited use by sockeye salmon suggests any effects of water management on sockeye salmon migration habitat would be limited to the lower river, downstream of the Opal Springs hydroelectric project. Under the proposed action, RiverWare modeled streamflows in the Crooked River at the Opal node in the lower river are unchanged or change slightly (less than 2%) compared to the no-action alternative for the entire permit term. The changes in flow are too small to result in migration effects on sockeye salmon when considered in context with the high volume of groundwater inflow upstream of the Opal node. Therefore, there would be no effect on adult or juvenile migration life stages for this species in the portion of the Crooked River likely used by sockeye salmon for spawning and egg incubation.

BIO-12: Affect Redband Trout Habitat

The proposed action would have no effect on redband trout habitat in Whychus and Tumalo Creeks and the Lower Deschutes because streamflows would be unchanged over the permit term. Likewise, differences in reservoir volume and elevations in Lake Billy Chinook, Lake Simtustus, and Prineville Reservoir would be minor under the proposed action and would have no effect on redband trout habitat. The proposed action would have small beneficial effects on steelhead trout habitat in Ochoco Creek, from slightly higher seasonal minimum and maximum median streamflows under Conservation Measure CR-2, and in McKay Creek, from higher minimum streamflows during the active irrigation season under Conservation Measure CR-3.

Ramping rates (change in streamflow over a period of hours or days) would prevent the more adverse impacts on redband trout that would otherwise result from unregulated hourly or daily variation in streamflows. However, negative effects on redband trout could still occur from longer periods of variation in streamflow during less mobile life stages. These effects could occur during streamflow ramp up at the beginning of the irrigation season in response to increased irrigation demand, as well as during ramp down at the end of the irrigation season and when reservoir storage may be at critically low levels and regulation of reservoir release is necessary under Conservation Measure WR-1.

Effects in the remaining reaches relevant to the species are described below.

Crescent Lake Reservoir

Under the proposed action, reservoir elevations would not change during most of the year. Slightly higher reservoir elevations in the spring may provide a minor improvement in access to spawning tributaries during this period. However, the increase in reservoir elevation in the spring would be minor and would likely have no discernable effect on redband trout connectivity to tributary spawning habitat. Therefore, the proposed action would have no effect on redband trout habitat in Crescent Lake Reservoir.

Crescent Creek

Under the proposed action, streamflows would be lower in the fall and early spring and may adversely affect winter habitat. Streamflows would be slightly higher during the summer, which may affect emergent bank vegetation and corresponding habitat structure important to juvenile redband trout. However, the differences would be minor and would likely have no discernable effect on stream margin vegetation related to redband trout habitat. Streamflows would be more variable during the summer, but likely to not enough to suggest an adverse effect when compared to variability in streamflows under the no-action alternative.

Ramping rates (change in streamflow over a period of hours or days), made mandatory under the proposed action (Conservation Measure CC-2), would prevent the more adverse effects on redband trout habitat that would otherwise result from unregulated daily variation in streamflows.

Conservation Measure CC-1 that sets aside a portion of the water stored in Crescent Lake Reservoir to be used specifically to benefit Oregon spotted frogs would also benefit redband trout. This OSF storage will be used to manage streamflows in Crescent Creek to maintain or increase winter minimum flow levels, increase instream flow levels in spring or delay and draw out the ramp down of irrigation releases in the fall. Conservation Measure CC-1 is analyzed as part of the proposed action. The conservation measure is not part of the no-action alternative or Alternatives 3 or 4.

Little Deschutes River

There would be beneficial changes in streamflows in the Little Deschutes with higher summer streamflows under the proposed action. Therefore, the proposed action would have a beneficial effect on redband trout habitat in the Little Deschutes River.[8]

Crane Prairie Reservoir

Reservoir elevations and volume would be less variable over the year, and would be higher throughout most of the year. The rate of fill in the fall would be more gradual and may allow juvenile and subadult redband trout to adjust to rising reservoir elevations at the start of the storage season. Therefore, the proposed action would have a beneficial effect on redband trout habitat in Crane Prairie Reservoir because less variable and higher reservoir volumes indicate improved reservoir ecology for redband trout prey items and improved migratory habitat for redband trout to move to and from Crane Prairie Reservoir.

Upper Deschutes between Crane Prairie and Wickiup Reservoirs

Although streamflows in the Upper Deschutes River downstream of Crane Prairie Reservoir would be more variable at times during the year, overall water management would maintain minimum streamflows during the winter and spring, during redband trout spawning and egg incubation, and streamflows would be less variable and higher in most years. Therefore, the proposed action would have a beneficial effect on redband trout habitat in the Upper Deschutes River between Crane Prairie and Wickiup Reservoirs.

Wickiup Reservoir

The variability in reservoir volume and elevation over the year and greater variability in years 13 to 30 of the permit term would adversely affect reservoir rearing habitat for juvenile and subadult redband trout, may adversely affect redband trout access to spawning tributaries in the spring, and would adversely affect the lake food web (Murphy et al. 2019). Furthermore, the drawdown may result in the greater competition with and predation by other nonnative trout species and entrainment of juvenile redband trout into the unscreened reservoir outlet resulting in the displacement of redband trout to the Deschutes River. Therefore, the proposed action would have an adverse effect on redband trout habitat in Wickiup Reservoir.

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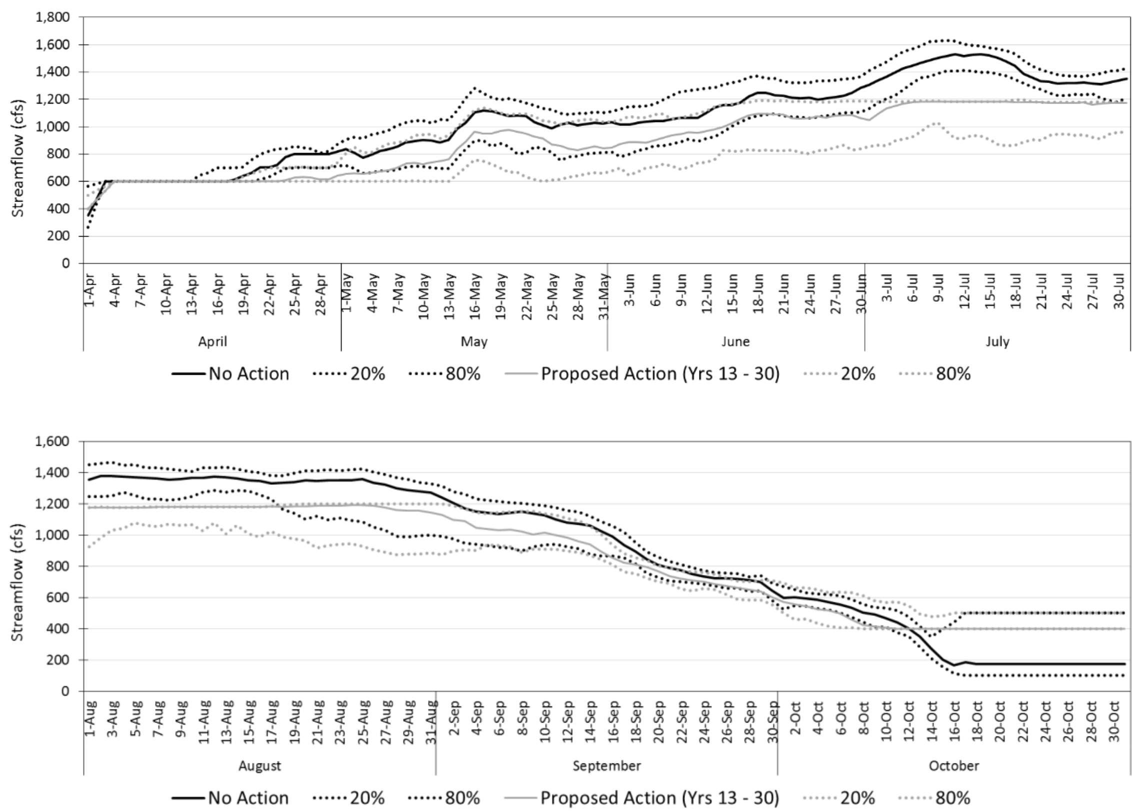
[8] See Appendix 3.1-C, *Analysis of RiverWare Model Version 18 Outputs and Implications for Final EIS*, for corrections due to modeling update.

Upper Deschutes between Wickiup Reservoir and City of Bend

There would be several beneficial effects of the proposed action. Higher winter streamflows over the permit term would benefit redband trout habitat (Starcevich and Bailey 2015). Reduced summer streamflows would be expected to result in emergent vegetation recruitment into the river channel, thereby improving habitat complexity for redband trout (River Design Group and HDR 2017). The proposed action would also decrease the fall transition in streamflows at the end of the irrigation season, further benefiting redband trout by reducing the risk of stranding of trout in side channels (Starcevich and Bailey 2015). The range of streamflows in the fall indicate a decreased reduction in streamflows during the transition at the end of the irrigation season (Figure 48).

Figure 48. Streamflow Ramping in the Upper Deschutes Downstream of Wickiup Reservoir (WICO node) during Beginning of Irrigation Season (Top) and End of Irrigation Season (Bottom) under the No-Action Alternative and Proposed Action (Years 13–30)



The updated 2020 RiverWare model more accurately describes early season diversions when storage is unable to meet irrigation demand. Spring streamflows increase under the proposed action, but not as sharply as under the no-action alternative (Figure 48). Refinements to the 2020 RiverWare model manage release avoid a sharp increase in streamflows followed by a sharp decline in streamflows when storage is unable to meet demand. This combined with a 1,200 cfs maximum flow under the proposed action (Conservation Measure WR–1) in years 13 through 30 of the permit term have a beneficial effect on redband habitat.

An adverse effect on redband trout habitat in the Upper Deschutes River would be the displacement of nonnative brown trout and nonnative brown bullhead catfish (*Ictalurus nebulosus*) into the Upper Deschutes River following extreme drawdown of Wickiup Reservoir during the irrigation season.

Brown trout compete with native redband trout in the Upper Deschutes River (Starcevich and Bailey 2015). Brown bullhead catfish will eat a variety of aquatic invertebrates, freshwater mussels, frogs, snails, and insects. They will also eat other fish, fish eggs, and plants.

In summary, several components of the proposed action would be beneficial to redband trout habitat:

- Increased winter streamflows
- Lower summer streamflows and a 1,200 cfs maximum flow in years 13 through 30 of the permit term would improve wetland and riparian vegetation over the permit term and restore river complexity for redband trout
- Managed spring streamflows when storage is unable to meet demand would avoid adverse impacts of fluctuating streamflows during this critical period
- A decrease in the fall transition in streamflows at the end of the irrigation season

Overall, based on the several beneficial effects the proposed action would have beneficial effect on redband trout habitat in the Upper Deschutes River between Wickiup Reservoir and the city of Bend.

Middle Deschutes

Increased median streamflows in the Middle Deschutes River from October to March (Conservation Measure DR-1 and WR-1) in the portion immediately downstream of Bend would have a beneficial effect on the quantity and connectivity of redband trout habitat over the permit term. This beneficial effect would be in the portion of the river upstream of significant groundwater influences. Higher winter streamflows would increase wetted channel area and add more depth to pool habitat used by redband trout.

There are concerns specific to the rapid down ramping of streamflows in April below the diversions in the city of Bend and the negative effect on survival of resident redband trout in that reach (Hodgson pers. comm.). Down ramping at the start of the irrigation season is not predicted to change under the proposed action based on RiverWare model results at the DEBO node. The ramp down of streamflows follows a typical pattern starting in early April and ending by the second week of April. Any adverse effect of down ramping during this period on redband trout habitat would be the same under the proposed action.

Overall, the proposed action would have a beneficial effect on redband trout habitat in the Middle Deschutes River between the city of Bend and Lake Billy Chinook.

Lake Billy Chinook

The proposed action would have no effect on redband trout habitat in Lake Billy Chinook because the minor changes to inflow to the reservoir would not change redband trout habitat over the permit term.

Prineville Reservoir

The proposed action would have no effect on redband trout habitat in Prineville Reservoir because the minor changes to reservoir elevation and volume would not change redband habitat over the permit term.

Crooked River

In the Crooked River, abundant populations of redband trout exist in the Cro-10 reach immediately downstream of Bowman Dam due to a consistent supply of cool water from Bowman Dam and in the lower Crooked River reaches Cro-1.2 and 1.1 upstream of Lake Billy Chinook due to a consistent input of cool groundwater.

Conservation Measures CR-4, CR-5, and CR-6 may result in small beneficial effects on redband trout habitat. Under Conservation Measure CR-4, funds would be available to support Crooked River habitat restoration measures and may benefit trout habitat. Conservation Measure CR-5 would provide funds for screening to NOAA fish screen standards of Ochoco ID patron diversions, and maintenance and operation of fish screens on all Ochoco ID-controlled diversions.

Conservation Measure CR-6 would ensure minimum streamflows are maintained when the North Unit ID pumps are operating, which would have a beneficial effect on trout habitat by reducing intra-daily streamflow variations downstream of the North Unit ID pumps to Osborne Canyon and maintaining minimum streamflows in this reach.

Redband trout would be exposed to a range of streamflow and related water temperature effects under the proposed action similar to effects evaluated for juvenile steelhead. These effects include differences in streamflow across the year, which would affect the amount of habitat available, and water management for irrigation delivery, which would affect water temperatures during critical life stages.

There would be a beneficial effect of higher minimum winter streamflows under the proposed action (Conservation Measure CR-1), consistent with study findings by Porter and Hodgson (2016). They concluded low streamflows during the winter were a factor negatively effecting redband trout habitat in the Crooked River. The habitat model developed for juvenile steelhead rearing for the Deschutes Basin HCP analysis supports their findings. Higher winter streamflows would increase habitat capacity for juvenile steelhead. The same conclusion is applicable to juvenile redband trout.

Under the proposed action, during the irrigation season, streamflows and redband trout habitat in the Crooked River downstream of the North Unit ID pumps to Osborne Canyon (Reaches Cro-2 through 1.3; RMs 22.4 to 7.3) may be adversely affected from May through September due to increased North Unit ID reliance on the Crooked River. Conservation Measure CR-6 will provide some protection, but with greater reliance on Crooked River for North Unit ID deliveries streamflows downstream of the North Unit ID pumps are predicted to be lower.

Water management and associated water temperatures indicate a potential for an adverse effect on redband trout habitat because of an increase in number of days of warm water temperatures due to changes in timing of release of water from Prineville Reservoir as discussed for steelhead trout (Impact BIO-6).

As described for bull trout (Impact BIO-4), the proposed action would not create additional pesticide or nutrient sources, pathways or otherwise alter the occurrence of pesticides or nutrients in the Crooked River affecting redband trout habitat.

BIO-13: Affect Nonnative Resident Trout Habitat

The proposed action would have beneficial effects on nonnative trout habitat in Whychus, Ochoco, and McKay Creeks because streamflows would increase in these creeks over the permit term or conservation measures. Differences in reservoir volume and elevations in Crescent Lake Reservoir, Crane Prairie Reservoir, Prineville Reservoir, Ochoco Reservoir, Lake Billy Chinook, and Lake Simtustus under the proposed action would be minor and would have no effect on nonnative trout habitat. Differences in streamflows in Crescent Creek and Lower Deschutes River under the proposed action would be minor and would have no effect on nonnative trout habitat. There would be beneficial effects in the Little Deschutes River with higher summer streamflows under the proposed action.[9]

Upper Deschutes River between Crane Prairie and Wickiup Reservoirs

Although streamflows in the Upper Deschutes River downstream of Crane Prairie Reservoir would be more variable at times during the year, overall water management would maintain minimum streamflows during the winter for juvenile and subadult rearing, and streamflows would be less variable and higher in most years. Therefore, the proposed action would have a beneficial effect on nonnative resident trout habitat in the upper Deschutes River between Crane Prairie and Wickiup Reservoirs.

Wickiup Reservoir

The extreme variation in reservoir elevation and volume under the proposed action would have an adverse effect on nonnative trout in the reservoir. In addition, trout would be entrained in the dam outlet and swept downstream during extreme drawdown of the reservoir. Therefore, the proposed action would have an adverse effect on nonnative resident trout habitat in Wickiup Reservoir.

Upper Deschutes River Wickiup Reservoir and Bend

Increased winter flows would provide additional habitat for nonnative brook and brown trout. Both species are fall spawners and spawning and egg incubation would occur during times of the year when streamflow variation is less under the proposed action. Therefore, the proposed action would have a beneficial effect on nonnative resident trout habitat in the Upper Deschutes River between Wickiup Reservoir and Bend.

Middle Deschutes

The proposed action would have a beneficial effect on nonnative resident trout habitat in the Middle Deschutes River between Bend and Lake Billy Chinook because increased winter streamflows would provide additional habitat for nonnative brook and brown trout.

Crooked River

The proposed action would have an adverse effect on nonnative resident trout habitat in the Crooked River because of effects of streamflows on summer temperatures discussed previously for salmon, steelhead, and redband trout. Increased periods of warm temperatures discussed for Chinook, steelhead and redband trout would also adversely affect habitat for nonnative trout.

BIO-14: Affect Summer/Fall Chinook Salmon Habitat

Summer/fall Chinook salmon distribution is limited to the Lower Deschutes, downstream of the Pelton-Round Butte Complex.

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[9] See Appendix 3.1-C, *Analysis of RiverWare Model Version 18 Outputs and Implications for Final EIS*, for corrections due to modeling update.

The proposed action would have no effect on summer/fall Chinook salmon habitat in the Lower Deschutes because the increase in winter streamflows over the permit term would be minor.

BIO-15: Affect Kokanee Salmon Habitat and Migratory Life Stages

The proposed action would have no effect on kokanee salmon habitat and migratory life stages in Crescent Lake Reservoir or Whychus Creek because lake conditions and streamflows, respectively, would not change over the permit term. Differences in reservoir volume and elevations in Lake Billy Chinook and Lake Simtustus would be minor under the proposed action and would have no effect on kokanee salmon habitat.

Crane Prairie Reservoir

Higher reservoir elevations and volumes in fall and winter months indicate improved conditions in the reservoir for kokanee salmon and possibly better access to tributary and, if present, lake beach spawning habitats in the fall. The greater variability in reservoir elevation and volume across the analysis period suggests negative effects in some years. However, the lower reservoir elevations in spring and summer would not be enough to suggest an impact on lake habitat used by rearing kokanee. Therefore, the proposed action would have no effect overall on kokanee salmon habitat and migratory life stages in Crane Prairie Reservoir because of the counter-seasonal differences of improved and possibly less suitable conditions over the year.

Wickiup Reservoir

The predicted extreme variation in reservoir elevation and volume over the permit term would adversely affect kokanee habitat in the reservoir. Effects would be less extreme in years 1–5 of the permit term. Near the end of the permit term (years 13–30), extremely low reservoir elevations in low water years would have an adverse effect on kokanee habitat in the reservoir.

The extreme variation in reservoir volume over the year likely would cause additional effects on the population by entrainment at the dam outlet and downstream displacement of kokanee salmon into the Deschutes River.

Therefore, the proposed action would have an adverse effect overall on kokanee salmon habitat and migratory life stages in Wickiup Reservoir because of extremely low reservoir elevations and volumes in most years and extreme seasonal differences.

BIO-16: Affect Native Non-Trout and Non-Game Fish Habitat

The proposed action would have no effect on habitat for native non-trout and non-game species—including as mountain whitefish (*Prosopium williamsoni*), bridgelip sucker (*Catostomus columbianus*), largescale sucker *(C. macrocheilus*), chiselmouth (*Acrocheilus alutaceus*), and northern pikeminnow (*Ptychocheilus oregonensis*)—in Whychus Creek, the Lower Deschutes River, Lake Billy Chinook, or Lake Simtustus because changes in streamflows and reservoir volumes and elevations would either not change or changes would be minor over the permit term compared to the no-action alternative.

The proposed action would have small beneficial effects on species present in Ochoco and McKay Creeks from increased flows.

Water management in Wickiup Reservoir would likely have adverse effects on habitat for these species (except for Pacific lamprey, which is not present in the reservoir) due to the extreme variation in reservoir elevation and volume.

On the Upper Deschutes River downstream of Wickiup Reservoir, increased fall and winter flows would provide additional habitat for native non-game species present in this reach. Mountain whitefish are fall spawners and spawning and egg incubation would occur during times of the year when streamflow variation is less variable under the proposed action resulting in a beneficial effect for this species when combined with increased winter streamflows under the proposed action. Other native non-game species spawn in spring and summer and are broadcast spawners; i.e., do not build a nest. These species would benefit from higher winter streamflows under the proposed action, but may be adversely affected by greater variability in streamflows in the spring and summer under the proposed action. Overall, effects in this reach on native non-trout and non-game species habitats would be not adverse because of the beneficial effect during winter to all species and uncertain conclusion of adverse effect during spring and summer on a subset of species.

There would be beneficial effects in the Little Deschutes River with higher summer streamflows.[10]

On the Middle Deschutes River the proposed action would have a beneficial effect on native non-trout and non-game species habitat because increased winter flows would provide additional habitat for these species.

In the Crooked River, water management could have adverse effects on habitat of cold water preference cyprinid species because of effects of water management on water temperature discussed for other species. Several native species are adapted to the cooler temperatures typical in most areas in the study area. The effect of water management resulting in more warm days under the proposed action toward the end of the permit term would adversely affect these species.

BIO-17: Affect Freshwater Mollusk Habitat

There would be no effect on freshwater mollusk habitat in Whychus, Ochoco, and McKay Creeks under the proposed action because streamflows would not change over the permit term. Likewise, there would be no effect on freshwater mollusk habitat in the Lower Deschutes under the proposed action because increases in winter streamflows at the Madras gauge would be minor. Effects in the remaining reaches where species occur or have the potential to occur are described below.

Crescent Lake Reservoir

Crater Lake Tightcoil and Evening Field Slug. Overall, there would be no adverse effect on Crater Lake tightcoil and evening field slug habitat in the Crescent Lake Reservoir under the proposed action because reservoir elevations, while lower between August and October than under the no-action alternative, would be generally higher the rest of the year.

Crescent Creek

Crater Lake Tightcoil. Increased summer streamflows would provide additional moist habitat for this species. Flow differences during winter months would have little no effect on this species

[10] See Appendix 3.1-C, *Analysis of RiverWare Model Version 18 Outputs and Implications for Final EIS*, for corrections due to modeling update.

because tightcoil often aestivate under the ground during the winter. Overall, there would be a beneficial effect on Crater Lake tightcoil habitat in Crescent Creek under the proposed action.

Evening Field Slug. Unlike snails, slugs generally remain active during cooler months as long as temperatures are slightly above freezing. Therefore, while the reduced fall streamflows under the proposed action could lessen habitat for the field slug in the fall, increased summer streamflows would provide additional moist habitat and be beneficial for the species. Overall, there would be no adverse effect on evening field slug in Crescent Creek under the proposed action.

Western Pearlshell Mussels. Reductions in streamflows during fall and spring could interfere with juvenile development and adult maturation resulting in an adverse effect; however, increased summer streamflows could be beneficial for maturing western pearlshell mussels and for their glochidia traveling on host fish.

Extreme water level reductions at the end of September and beginning of October could cause stranding of newly settled juveniles, which need to be inundated to survive and do not have a good mechanism for avoiding rapid reductions in water level. In addition, streamflows in October and November would be lower in some years than under the no-action alternative (<25 cfs versus 30 cfs, respectively). This could cause additional mussel stranding or reduced water quality. Streamflows would be as low as approximately 20 cfs in some years in late April through May, a critical period for adult pearlshell maturation. In June, increased streamflows could provide additional habitat and better streamflow conditions during the time period of larval pearlshell attachment and maturation on host fish.

Overall effects would not be adverse, comprising both adverse and beneficial effects across seasons.

Little Deschutes River

Crater Lake Tightcoil and Evening Field Slug. There would be a beneficial effect on Crater Lake tightcoil and evening field slug habitat in the Little Deschutes River under the proposed action because streamflows would increase across an annual cycle, resulting in additional or improved habitat (perennially moist areas) for the species during the summer months.[11]

Western Pearlshell Mussels. There would be no effect on western pearlshell mussel habitat in the Little Deschutes River under the proposed action because May and June, the critical period of reproduction and juvenile establishment for the species, are the months that experience minimal change in median streamflow.

Upper Deschutes

Crater Lake Tightcoil. In the far Upper Deschutes (CRAO gauge), streamflow would change variably throughout the year but not in a way that would cause less inundation on average. Similarly, lower in the Upper Deschutes (WICO and BENO gauges), average median streamflows generally increase from October through March and decrease from May through September. Though streamflows decrease on average in the summer months, overall the streamflow levels are still relatively high and are higher than fall and winter streamflows. Overall, fall and winter streamflows would provide more inundation for the tightcoil.

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[11] See Appendix 3.1-C, *Analysis of RiverWare Model Version 18 Outputs and Implications for Final EIS*, for corrections due to modeling update.

There would be no adverse effect on Crater Lake tightcoil habitat on the Upper Deschutes under the proposed action because though there would be summer streamflow decreases overall, with additional summer streamflow decreases over the course of the permit term, these decreases would not significantly alter habitat for the species.

Evening Field Slug. Increased base streamflow during fall and winter months in most of the Upper Deschutes would provide additional habitat for the evening field slug during this time, and while summer months experience significantly lowered flows, the flow levels are still relatively high. There would be no adverse effect on evening field slug habitat in the Upper Deschutes under the proposed action because though there would be summer streamflow decreases overall, with additional summer streamflow decreases over the course of the permit term, these decreases would not significantly alter habitat for the species.

Western Pearlshell Mussels. Flows would decrease (WICO and BENO gauges) in May and June, the critical period of reproduction and juvenile establishment, flows would still be high and not significantly affect establishment success. Further upstream at the CRAO node, flows increase on average in May and decrease only slightly in June on average. Therefore, there would be no adverse effect on Western pearlshell mussel habitat in the Upper Deschutes under the proposed action.

Crane Prairie Reservoir

Crater Lake Tightcoil. There would be no adverse effect on Crater Lake tightcoil in Crane Prairie Reservoir under the proposed action because changes in reservoir elevations would be small and not affect habitat used by this species.

Evening Field Slug. There would be no adverse effect on evening field slug in Crane Prairie Reservoir under the proposed action because differences in reservoir elevation and volume are minor.

Wickiup Reservoir

Crater Lake Tightcoil. Riparian conditions in Wickiup Reservoir are poor and suggest that Crater Lake tightcoil is not present; however, increased variation in reservoir elevations would have an adverse effect on the species if present.

Evening Field Slug. There would be an adverse effect on evening field slug in Wickiup Reservoir under the proposed action. Riparian conditions in Wickiup Reservoir are mostly poor and suggest that Crater Lake tightcoil is not present or located in a few isolated locations. Increased variation in reservoir elevations would adversely affect the species if present.

Middle Deschutes

Crater Lake Tightcoil and Evening Field Slug. There would be a beneficial effect on Crater Lake tightcoil habitat in the Middle Deschutes under the proposed action because there would be significant increases in streamflows October through March and no other significant flow changes during other times of the year.

Western Pearlshell Mussels. Overall, May and June, the critical period for reproduction and juvenile establishment, would experience the largest average decreases in median flows among months in the reaches immediately downstream of the DEBO gauge. Therefore, there would be an adverse effect on Western pearlshell mussel habitat in the Middle Deschutes downstream of the DEBO gauge under the proposed action.

Western Ridged Mussels. There would be potential beneficial effects from higher streamflows during some times of the year; however, average streamflows would decline during the first part of the reproductive period for this species.

Western ridged mussels are present in this reach, up to Big Falls. The most critical time period for population success is during reproduction and juvenile settlement, from June through August. While flows would decrease on average in June, by July and August when mussels would be settling, the changes would be very minimal on average, and increased winter flows would be beneficial for host fish.

Overall, there would be no adverse effect on western ridges mussel habitat in the Middle Deschutes under the proposed action.

Crooked River

Crater Lake Tightcoil. In the Upper and Middle Crooked River, decreased flows in some summer months in some years could cause drying of potential habitat for Crater Lake tightcoil. In the reach downstream of the North Unit ID pumps, there would be even more of a decrease in median monthly flow in summer months, which could negatively affect tightcoil habitat. Additionally, while increased median monthly flows in winter months could provide increased moist habitat for tightcoil, any severe or sudden increases in flows in winter months could inundate overwintering tightcoil.

There would be an adverse effect on Crater Lake tightcoil habitat in the Crooked River under the proposed action because of an increased frequency of lowered flows in summer months.

Evening Field Slug. There would be an adverse effect on evening field slug habitat in the Crooked River under the proposed action because of an increased frequency of decreased median monthly flows in summer months through the majority of the Crooked River, which could cause drying of potential habitat for this species.

Floater Species Mussels. There would be an adverse effect on floater species mussel habitat in the Crooked River under the proposed action because of more frequent decreased median monthly flows during May through August, the critical period of reproduction and juvenile establishment for this species.

Western Pearlshell Mussels. There would be no adverse effect on western pearlshell mussel habitat in the Crooked River because flows would change variably through May and June, the critical period of reproduction and juvenile establishment, with some flows and years experiencing significant increase in flows.

Western Ridged Mussels. There would be an adverse effect on western ridged mussel habitat in the Crooked River under the proposed action because there would be a higher frequency of years with decreasing median monthly flows during June through August, the critical period of reproduction and juvenile establishment for this species.

Alternative 3: Enhanced Variable Streamflows

Modeled changes in streamflows, reservoir volumes and elevations, and water quality conditions under Alternative 3 compared to the no-action alternative are described below in the *Modeled Environmental Conditions* section followed by descriptions of how these changes would affect individual species in the *Species Impacts* section.

Modeled Environmental Conditions

This section describes important changes in reservoir storage and elevation, seasonal river and creek streamflows, and relevant water quality information in the study area by geographic area and subarea under Alternative 3. Effects are evaluated based on changes in modeled results for Alternative 3 compared to the no-action alternative.

Changes in streamflows and reservoir elevations and variability would be the same type as described for the proposed action for all reaches except for Crescent Creek, the Little Deschutes, the Crooked River, and the Upper and Middle Deschutes River.

Crescent Creek/Little Deschutes

Alternative 3 does not include Conservation Measure CC-1 that sets aside a portion of the water stored in Crescent Lake Reservoir to be used specifically to benefit Oregon spotted frogs. Other measures included in the proposed action are included under Alternative 3.

Generally changes in streamflow are the same as described for the proposed action except summer streamflows in Crescent Creek (CRAO) are higher in more years under Alternative 3 than the proposed action and summer streamflows under Alternative 3 are similar to the no-action alternative.

Upper Deschutes

Under Alternative 3, as under the proposed action, summer flows would diminish and winter flows would increase compared to the no-action alternative. Alternative 3 would alter the timing of those changes, such that winter minimum flow targets would be achieved earlier in the permit term and would end at a higher level compared to the proposed action. Although Alternative 3 targets a higher minimum flow (500 cfs) in above-normal and wet years, the model used the same assumption for release of flows in excess of the minimum for the proposed action in above-normal and wet years.[12] Therefore, modeled flow values presented for the proposed action and Alternative 3 at these flows (400 cfs and 400–500 cfs, respectively) are the same.

Upper Deschutes

Under Alternative 3, as under the proposed action, summer flows would diminish and winter flows would increase compared to the no-action alternative. Alternative 3 would alter the timing of those changes, such that winter minimum flow targets would be achieved earlier in the permit term.

Accordingly, modeled environmental conditions under Alternative 3 follow the same trend over the permit term as described for the proposed action. The differences described below are more extreme differences in median reservoir elevations and streamflows. Alternative 3 does not include a limit to maximum streamflow added to Conservation Measure WR-1 for the proposed action. This affects Wickiup Reservoir elevations and volume compared to the proposed action and irrigation season streamflows below Wickiup Reservoir. Wickiup Reservoir

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[12] Although the proposed action does not include the commitment to target the higher flow, typical operations practice is to release more water during above-normal and wet years. The RiverWare model required an assumption for how flows in excess of the minimum would be managed. The same equation for managing flows was applied to the proposed action and Alternative 3 to maintain comparative model outputs.

Alternative 3 reservoir elevations would be lower than the no-action alternative in all months of the year and would be much lower than described for the proposed action over the permit term. Reservoir elevations would be similar to Alternative 4 toward the end of the permit term.

Upper Deschutes River downstream of Wickiup Dam

Under Alternative 3, as under the proposed action, summer flows would diminish and winter flows would increase compared to the no-action alternative. Alternative 3 would alter the timing of those changes, such that winter minimum flow targets would be achieved earlier in the permit term and would end at a higher level compared to the proposed action and Alternative 3.

Based on modeled results for the Wickiup Reservoir Outlet (WICO) and Benham Falls (BENO) nodes and internodes between Benham Falls and the city of Bend, streamflows in the Upper Deschutes River downstream of Wickiup Dam would be less variable over the year because regulation of streamflows would happen earlier and in more years.

Alternative 3 does not include a limit to maximum streamflow added to WR-1 for the proposed action. Summer maximum streamflows under Alternative 3 may exceed 1,400 cfs occasionally. However, median streamflows are approximately 1,200 cfs in years 11 through 30 of the permit term.

Crooked River

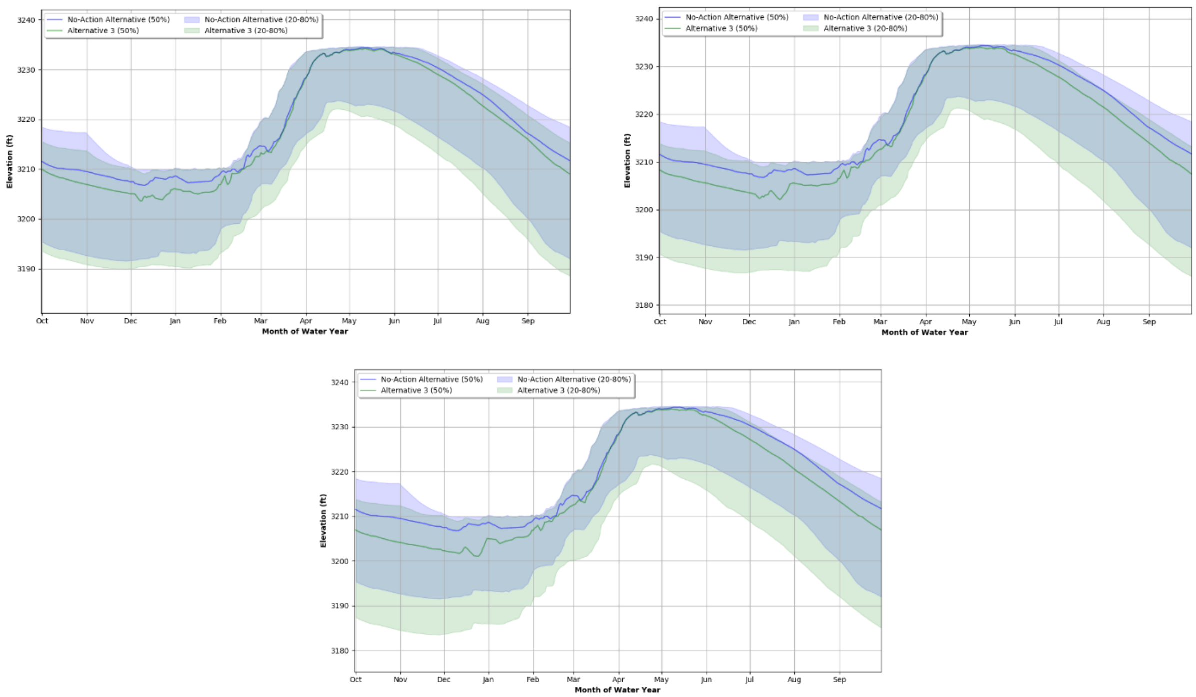
Generally Alternative 3 is the same as the proposed action, but provides for instream protection of the uncontracted (fish and wildlife) storage releases from Bowman Dam to Lake Billy Chinook. This conditions is not fully reflected in the RiverWare results, but is assumed to provide additional benefits to fish in the Crooked River during the irrigation season when these releases may occur.

Prineville Reservoir

Model predictions comparing Prineville Reservoir elevations under the no-action alternative and Alternative 3 are shown in Figure 49.

- Median elevations are lower from July to January under Alternative 3. Differences in elevation are greatest in October and November.
- Median elevations are unchanged from February to June.
- Elevations do not differ over the permit term.
- There is a tendency toward more variation from year to year in the low and high range of elevations.

Figure 49. Modeled Elevations for Prineville Reservoir (PRV) under Alternative 3 Years 1–5 (top left), 6–10 (top right), 11–30 (bottom) Compared to the No-Action Alternative



Crooked River

Modeled environmental conditions in the Crooked River are described below based on median monthly streamflows from the 2020 RiverWare model and modeled water temperatures.

Median Monthly Streamflow

Differences in median monthly streamflow are summarized below for the following locations (nodes): Prineville Outlet (PRVO), near Highway 126 (CAPO), below the North Unit ID pumps (NUID), and below Opal Springs Dam (OPAL).

Prineville Outlet (PRVO):

- October through March: Generally there was no change in winter streamflows in the majority of years. There were a few years streamflows went below 50 cfs during the winter (1993 for example) under the no-action alternative. In those years Conservation Measure CR-1 resulted in winter flows of 50 cfs during the winter.
- April: No change in median streamflows in most years. A 15% increase in monthly median streamflows in 10 of the analysis years
- May: No change in median streamflows in the majority of years. A 17% increase in monthly median streamflows in 17 of the analysis years.
- June: An increase in monthly median streamflows of approximately 25% in a most years. There were very few years that monthly median streamflow decreased by 7% in June under Alternative 3.

- July and August:
    - During the warmest months (July and August) month median streamflows are higher under Alternative 3. In July and August monthly median streamflows are 50 to 100 cfs higher in 23 of the analysis years (58%of the 38 analysis years).
    - During the warmest months (July and August) month median streamflows are lower under Alternative 3 in just August – 11 of the years by 20%.
- September: Monthly median streamflows were higher in September by approximately 10% in 22 of the 38 analysis years and lower in 10 years by 15%.

CAPO node near Highway 126 and the City of Prineville (CAPO) showing change in monthly median streamflows at the end of the permit term are summarized in Table 10.

- Generally the pattern of monthly streamflows was the same at CAPO as reported at PRVO.
- July and August:
    - In July median streamflows are 50 to 100 cfs higher in 26 of the analysis years.
    - In August median streamflows are 50 to 100 cfs higher in 23 of the analysis years.
    - However in August median streamflows were lower in 15 the analysis years by 62%.
- September: Median streamflows at CAPO were higher in September by approximately 40% in 22 of the 38 analysis years and lower in 16 years by 40%.

Below the North Unit ID pumps (NUID.outflow):

- October through March: In most years, there was no change in monthly median streamflows; in about 10% of years there was an average increase in median streamflows of 40%; and in about 5% of years, an average decrease in median streamflows of approximately 20%.
- April: No change in median streamflows.
- May through September: Average decrease across all months of 20 to 40% in the majority of the years.

Below Opal Springs Dam (OPAL):

- No discernable differences in streamflows.

Water Temperature Modeling

Differences between the no-action alternative and Alternative 3 has the potential to influence water temperatures during the summer months. Shifts in streamflow timing are most pronounced under the dry and normal water year types.

The shift in timing of water released from Prineville Reservoir affects timing and duration of warm water temperatures in the Crooked River (Berger et al. 2019). Water temperature predictions and overall observations of effects of streamflow on water temperatures from the 2019 analysis was used to infer effects and compared to results from the 2020 RiverWare model.

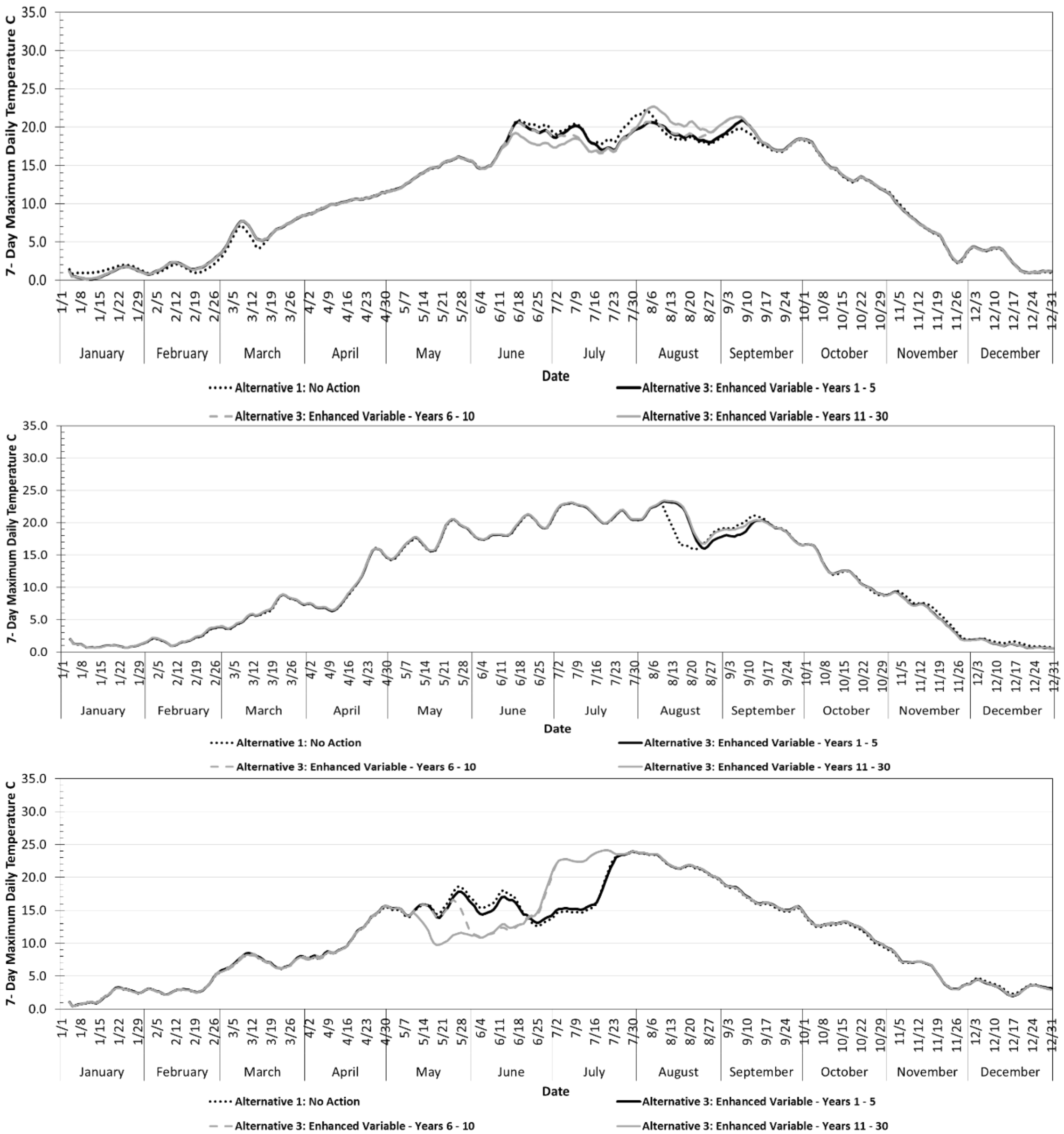
The shift in predicted 7DADM water temperatures at the Crooked River CAPO node from the 2019 analysis is shown in Figure 50. Under Alternative 3, water temperatures are cooler in early summer and warm rapidly when streamflows are lower in July. The maximum summer 7DADM water temperature was not affected by the shift in timing at Bowman Dam. The maximum for the summer season is approximately the same between the no-action alternative and Alternative 3 for each of the analysis years. However, the consequence of the shift in streamflow timing is a longer period of warm temperatures in the normal water year type example. The number of warm days during the summer increased substantially in the normal water year type indicating a potentially less suitable environment for temperature sensitive salmonids.

An analysis of how streamflows may affect species survival was based on the predicted 7DADM results and compared to species preferences, sublethal, stress/disease, and lethal temperature thresholds summarized from a literature review (R2 and Pacific Biota 2013). Species thresholds are reported in Table 6 in Methods section. The threshold analysis is discussed in the *Species Impacts* section by alternative.

Table 10. Summary Monthly Median Streamflows for the Crooked River near Highway 126 (CAPO node) under Alternative 3 (Years 11–30) compared to the No-Action Alternative

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Average diff. median flow (%)	4%	1%	14%	10%	17%	8%	3%	110%	126%	52%	27%	11%
Range diff. in monthly median flow (%)	-29% to 119%	-73% to 405%	-74% to 405%	-76% to 319%	-62% to 319%	-24% to 319%	-75% to 73%	-64% to 973%	-80% to 905%	-85% to 331%	-94% to 473%	-89% to 103%
# Years no diff. in median flow	26	15	22	24	25	25	19	12	3	2	0	0
# Years increase in median flow	4	3	3	4	4	3	11	19	28	26	23	22
Range increase in monthly median flow (%)	6% to 119%	75% to 405%	75% to 405%	6% to 319%	69% to 319%	60% to 319%	6% to 73%	6% to 973%	31% to 905%	13% to 331%	27% to 473%	22% to 103%
Median increase flow (%)	69%	329%	329%	168%	247%	69%	28%	80%	129%	36%	63%	39%
# Years decrease in median flow	8	20	13	10	9	10	8	7	7	10	15	16
Range decrease in monthly median flow (%)	-29% to -6%	-73% to -8%	-74% to -5%	-76% to -6%	-62% to -8%	-24% to -6%	-75% to -7%	-64% to -7%	-80% to -19%	-85% to -12%	-94% to -8%	-89% to -5%
Median decrease flow (%)	-15%	-45%	-14%	-15%	-19%	-14%	-23%	-38%	-57%	-45%	-62%	-39%

Figure 50. Annual Water Temperature Predictions for the Crooked River (CAPO node) for a Wet (top), Dry (middle) and Normal (bottom) Water Year under the No-Action Alternative and Alternative 3



Species Impacts

This section describes effects on fish and mollusks under Alternative 3 compared to the no-action alternative. Where effects are the same as for the proposed action, the description of effects under the proposed action are referenced for brevity.

Changes in streamflows and reservoir elevations and variability would be the same or nearly the same type as described for the proposed action for all of the reaches except for the Crooked River between the North Unit ID pumps and Osborne Canyon due to instream protection of uncontracted (fish and wildlife) storage releases from Prineville Reservoir. In addition, because implementation of increased releases from Wickiup Reservoir would occur earlier under Alternative 3 than the proposed action, related effects would occur earlier as well, as noted in the effects discussion.

BIO-4: Affect Bull Trout Habitat

Effects on bull trout habitat under Alternative 3 would be the same type as described for the proposed action in the Middle and Lower Deschutes River, Lake Billy Chinook and Lake Simtustus, and Whychus, Ochoco and McKay Creeks. Effects on bull trout habitat in the Crooked River are described below.

In addition, effects in the Middle Deschutes River and Crooked River would occur earlier in the permit term and, therefore, be of longer duration under Alternative 3 than the proposed action

Crooked River

Adverse effects in the Crooked River reach between the North Unit ID pumps and Osborne Canyon related to early season irrigation diversions in dry and normal water year types at full implementation would be of slightly lesser magnitude due to instream protection of uncontracted (fish and wildlife) releases under this alternative (Conservation Measure CR-1).

Water Temperature Results

Streamflows under the Alternative 3 would be expected to affect bull trout habitat with potential distribution up to Bowman Dam with fish passage structure at Opal Springs Diversion Dam.

Figures 51 and 52 summarize temperature thresholds predicted temperatures for bull trout spawning and egg incubation, respectively. Results support conclusions that current condition water temperatures are too warm for bull trout spawning in the Crooked River upstream of Smith Rock (modeled portion of the Crooked River or in any other accessible area of the Crooked River or its tributaries).

Figure 53 summarizes temperature thresholds and predicted temperatures for juvenile and subadult rearing. At the end of the permit term under Alternative 3 water temperatures for the dry and normal water years are predicted to exceed the stress/disease threshold by an additional 23 and 19 days, respectively in the reach immediately downstream of Bowman Dam (Cro-10). Seventy days above the preference threshold would occur in under water management in the normal water year at the end of the permit term compared to 49 days under the no-action alternative in Cro-10. In Cro-9, 114 days would occur above the preference threshold in the normal year under Alternative 3 compared to 96 days under the no-action alternative. In Cro-8, 96 days would occur above the preference threshold in the normal year under the Alternative 3 compared to 90 days under the no-action alternative, but more days exceeding the preference threshold would exceed the lethal threshold under Alternative 3.

Effects of water management on water temperature in lower reaches (Cro-7 through Cro-2) tended to be more variable as temperatures were warmer under the no-action alternative and effects of water management from Bowman Dam have less of an influence on water temperatures (Berger et al. 2019). Overall there was a tendency for more days in the stress/disease and lethal categories under Alternative 3.

Water management and associated water temperatures in the wet water year shows no effect on bull trout juvenile and subadult habitat over the permit term. However, water management in dry and normal water years indicate a potential for adverse effects on bull trout that may attempt to rear through the summer, such as in the reach downstream of Bowman Dam (Cro-10).

BIO-5: Affect Bull Trout Migratory Life Stages

Effects on bull trout migratory life stages under Alternative 3 would be the same type as described for the proposed action in the Middle and Lower Deschutes River, Lake Billy Chinook and Lake Simtustus, and Whychus, Ochoco and McKay Creeks. Effects in the Crooked River are described below.

Crooked River

RiverWare modeled streamflows and predicted water temperatures in the Crooked River based on the 2019 RiverWare model do not suggest an effect on migratory life stages. Migration windows for entering and moving upstream in the fall and for subadults to leave the Crooked River in the spring before temperatures exceed preference thresholds are not impacted (Figures 54 and 55).

Figure 51. Predicted Percentage Days within Water Temperature Water Temperature Thresholds for Spawning Bull Trout for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 3 Years 11–30 Compared to the No-Action Alternative

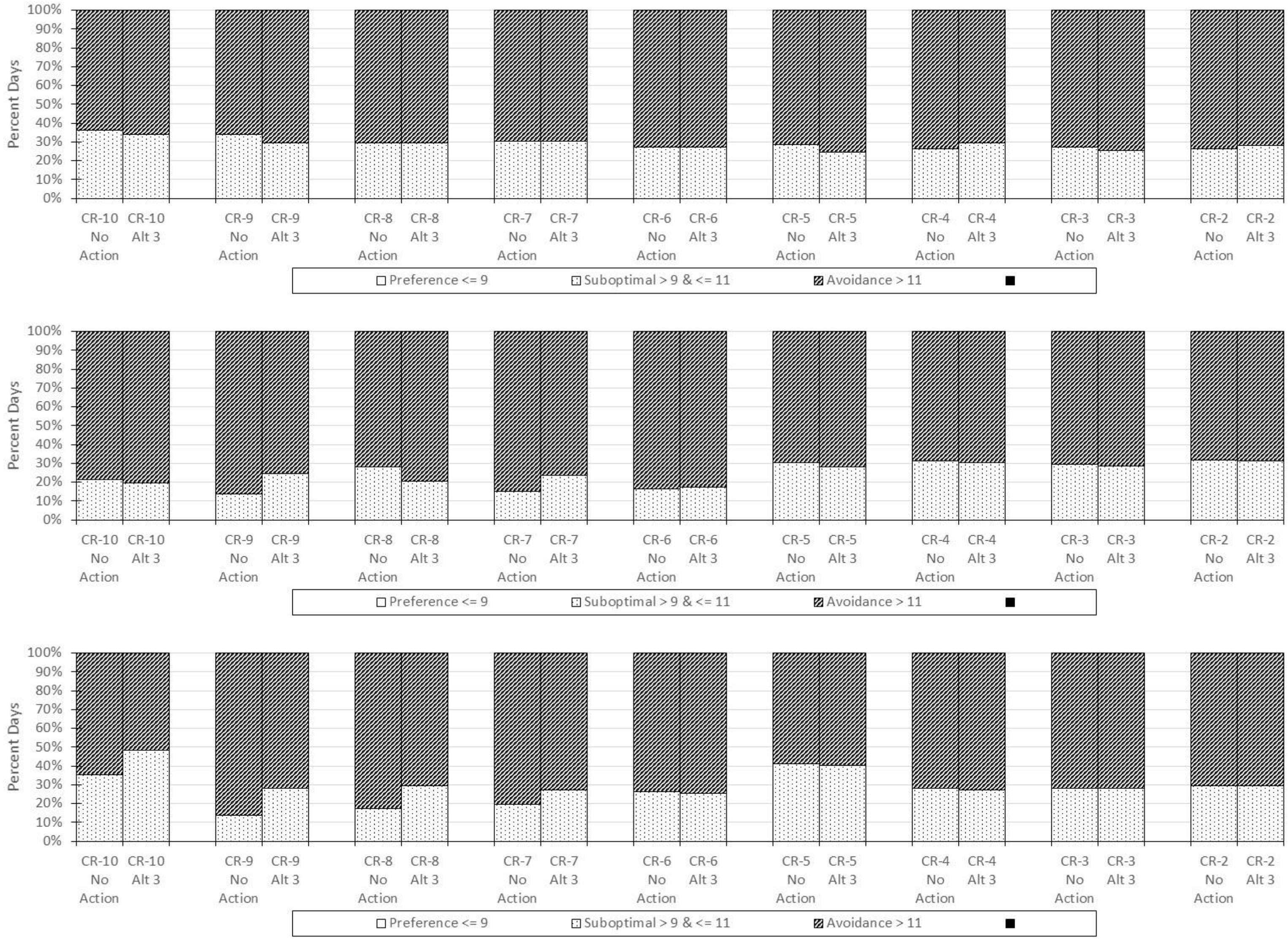


Figure 52. Predicted Percentage Days within Water Temperature Water Temperature Thresholds for Bull Trout Egg Incubation for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 3 Years 11–30 Compared to the No-Action Alternative

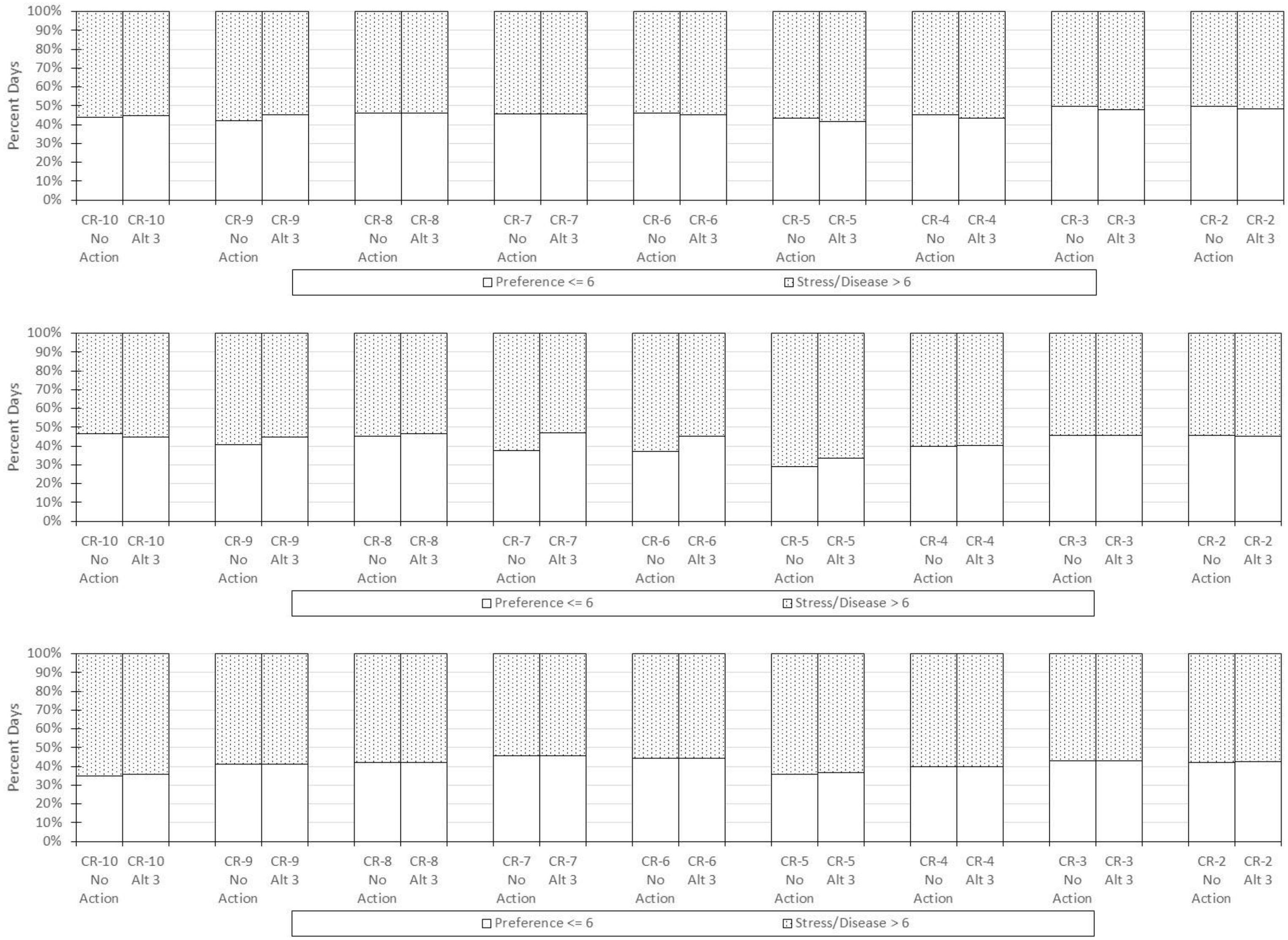


Figure 53. Predicted Percentage Days within Water Temperature Thresholds for Juvenile and Subadult Bull Trout Rearing for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 3 Years 11–30 Compared to the No-Action Alternative

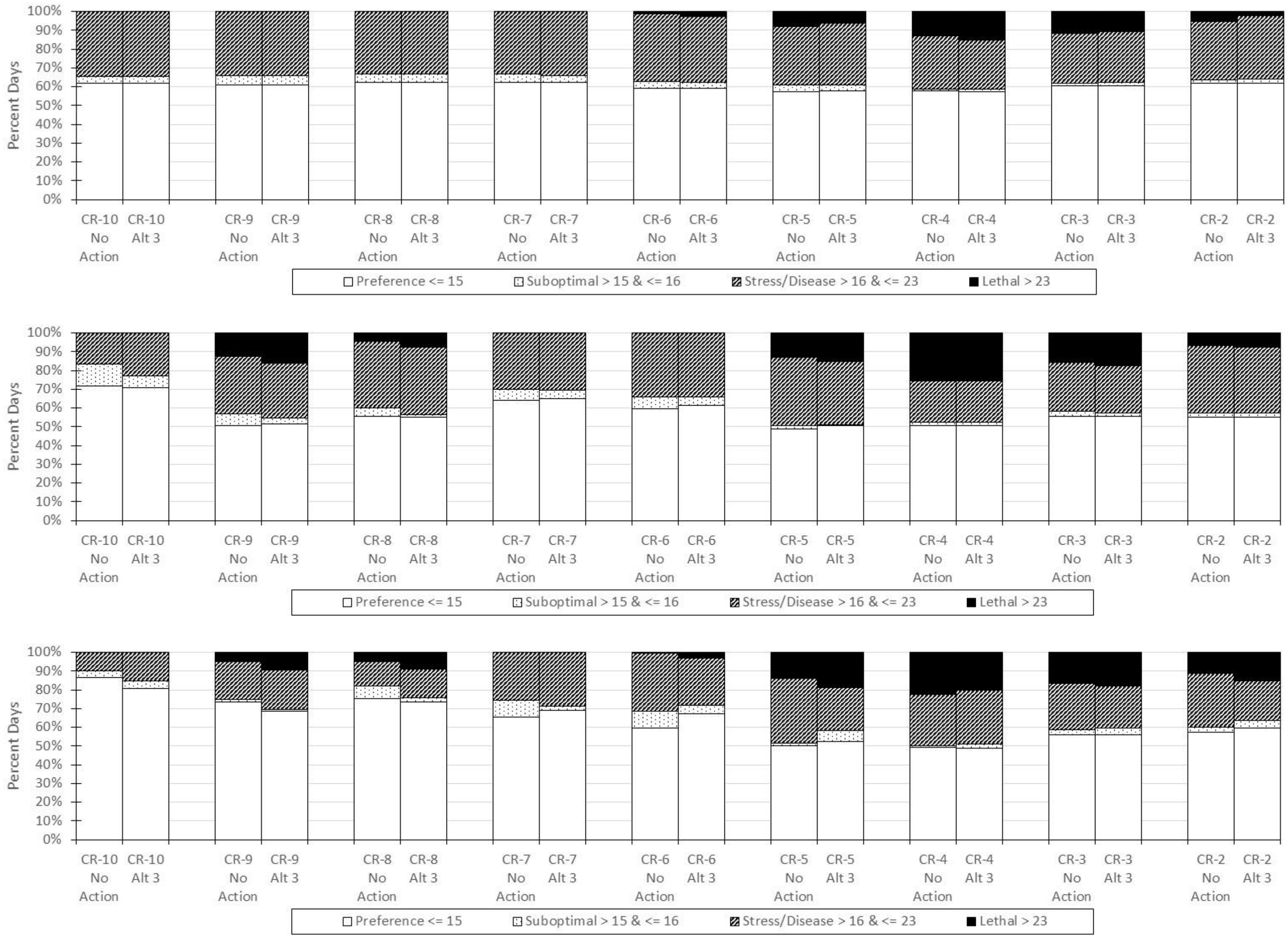


Figure 54. Predicted Percentage Days within Water Temperature Thresholds for Bull Trout Fall/Winter Migratory Stages for Wet (top), Dry (middle), and Normal (bottom) Years under the Alternative 3 Years 11–30 Compared to the No-Action Alternative

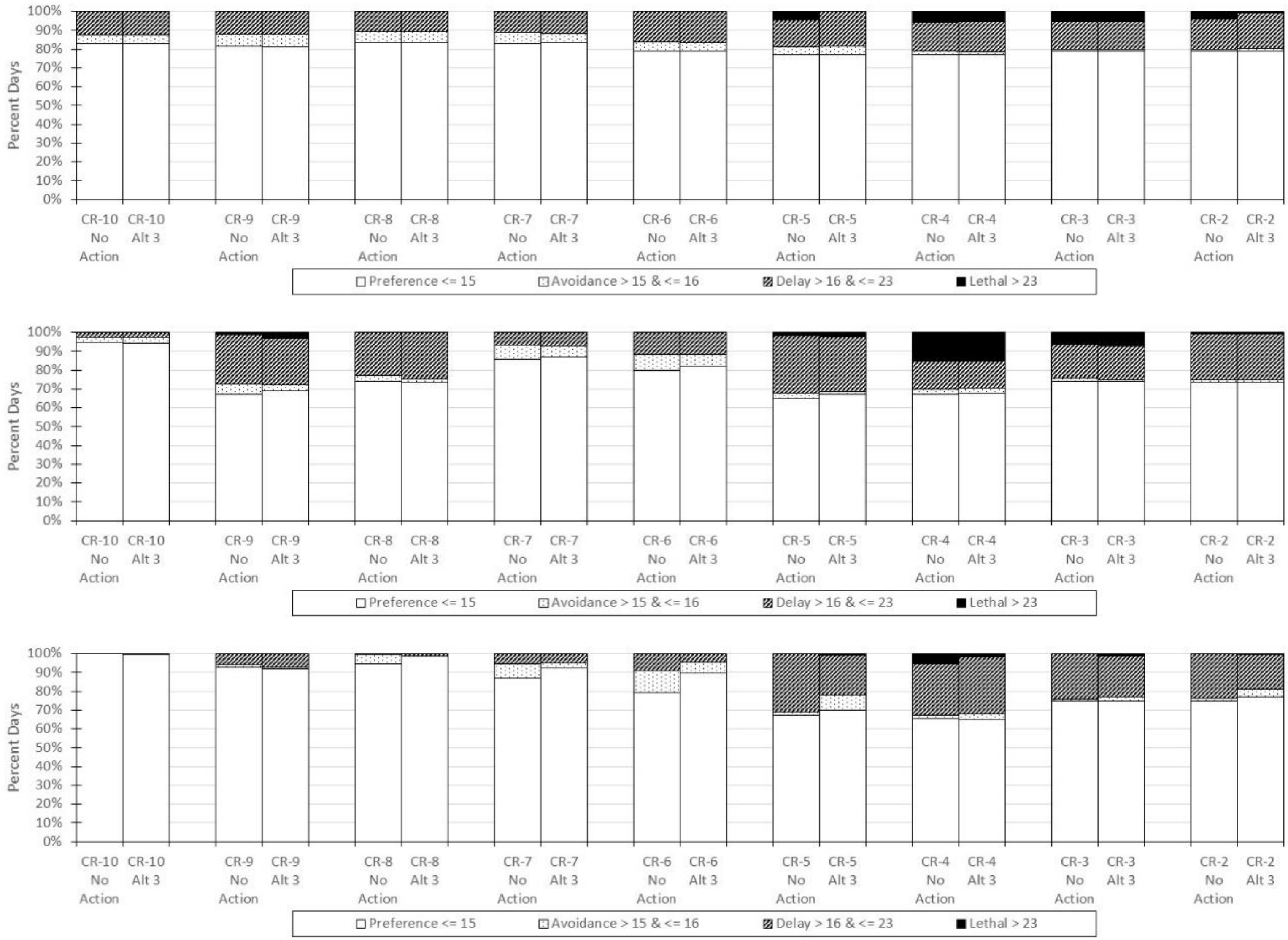
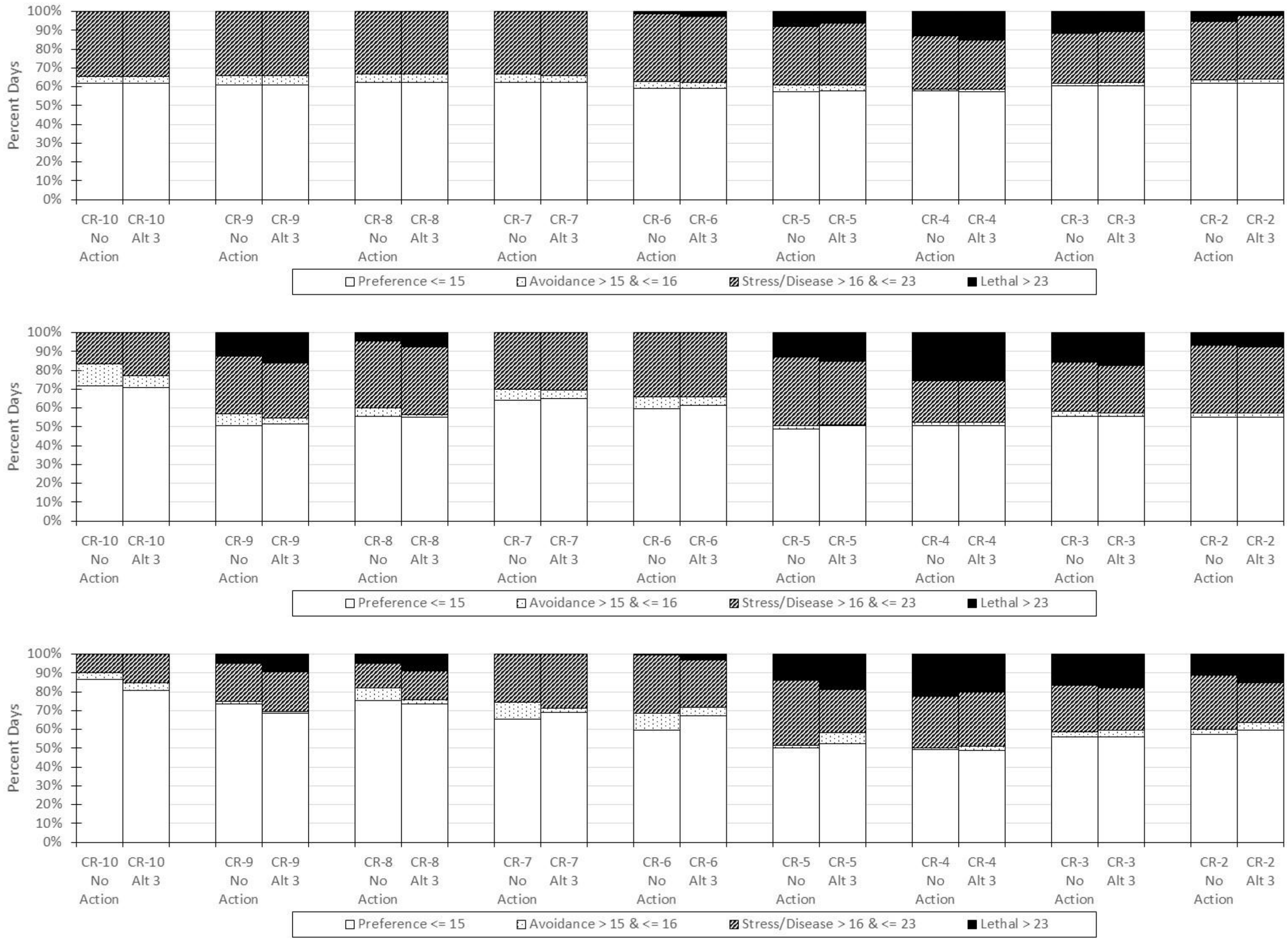


Figure 55. Predicted Percentage Days within Water Temperature Thresholds for Bull Trout Foraging, Migration, and Overwinter (FMO) Stages (Annual) for Wet (top), Dry (middle), and Normal (bottom) Years under Alternative 3 Compared to the No-Action Alternative



BIO-6: Affect Steelhead Trout Habitat

Effects on steelhead trout habitat under Alternative 3 compared to the no-action alternative would be the same type as described for the proposed action for all reaches, except in the Crooked River reach between the North Unit ID pumps and Osborne Canyon. In addition, effects in the Middle Deschutes River and Crooked River would occur earlier in the permit term and, therefore, be of longer duration under Alternative 3 than the proposed action.

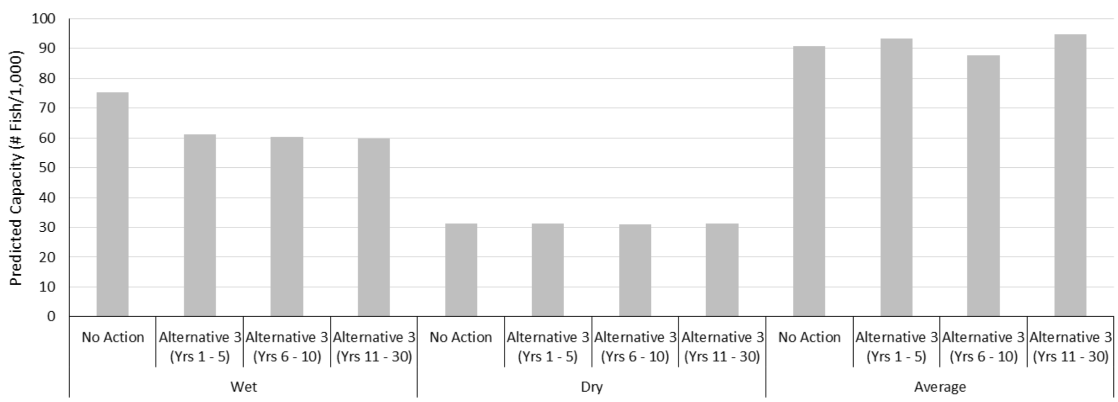
Crooked River

Adverse effects in the Crooked River reach between the North Unit ID pumps and Osborne Canyon related to early season irrigation diversions in dry and normal water year types at full implementation would be of slightly lesser magnitude due to instream protection of uncontracted (fish and wildlife) releases under this alternative (Conservation Measure CR-1).

Habitat Model Results

Results of modeling for summer juvenile rearing show no effect or a decline in capacity under Alternative 3 (Figure 56). Temperature effects are largely influencing these results.

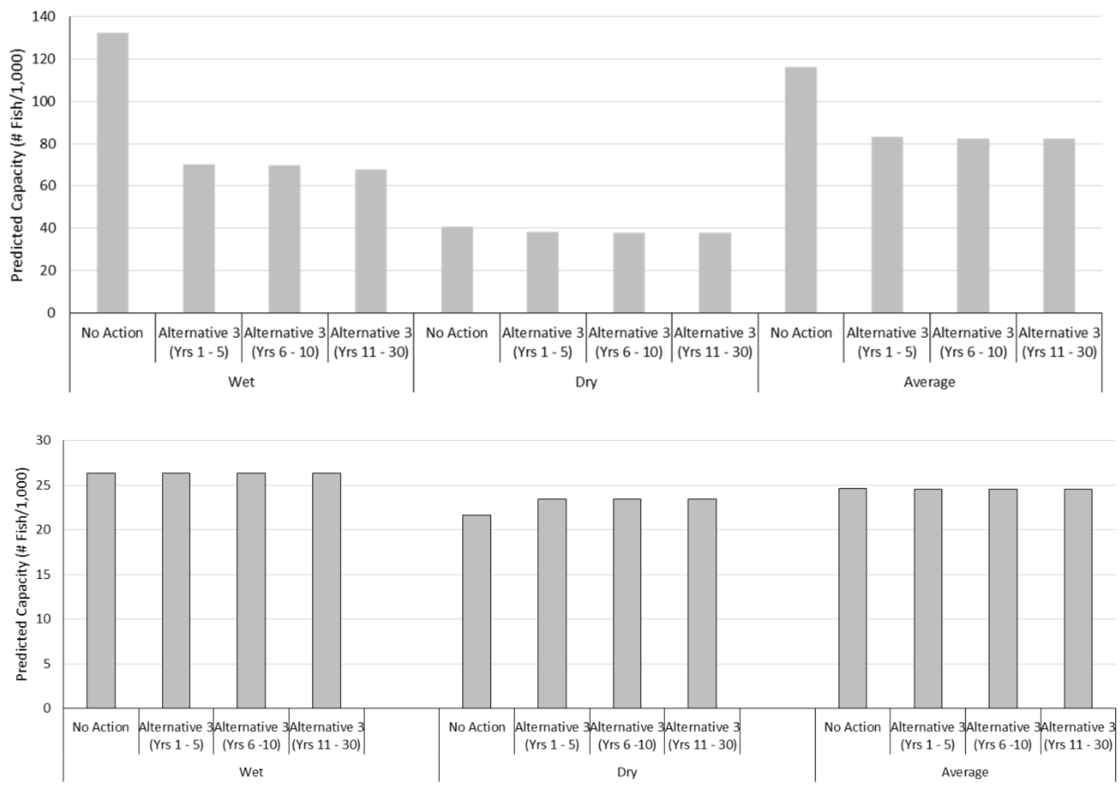
Figure 56. Juvenile Steelhead Summer Capacity Estimates for the Mainstem Crooked River under the No-Action Alternative and Alternative 3



Results of modeling winter juvenile rearing capacity are inconclusive. The decline in capacity under Alternative 3 in wet and normal years modeled is from effects of summer water temperatures on the predicted abundance of steelhead in the winter (Figure 57). However, these results may not reflect winter conditions for juvenile rearing with the increased minimum streamflow rule (Conservation Measure CR-1). The results presented in Figure 57 represent effects of summer maximum water temperatures and winter streamflows (Mount Hood Environmental 2019). It is unclear if the winter minimum streamflow rule under Alternative 3 would affect summer water temperatures in the Crooked River. Figure 57 also presents model results assuming a fixed summer maximum temperature (22 °C) in the no-action alternative and Alternative 3 across the entire permit term. This analysis is included to focus effects of managing for higher streamflows during the storage season on juvenile capacity. In this analysis steelhead winter capacity increases slightly under the proposed action in the dry year type with a slight increase in winter flows. Winter flows did not change under Alternative 3 in a wet and normal water year type because under the no-action alternative streamflows exceeded the minimum rule.

It is likely the minimum winter streamflow rule (Conservation Measure CR-1) and summer water temperatures are independent and increased winter streamflows under Alternative 3 would be expected to improve winter habitat conditions for juvenile steelhead.

Figure 57. Juvenile Steelhead Winter Capacity Estimates for the Mainstem Crooked River with Predicted Summer Temperatures (top) and with Fixed Summer Maximum Temperatures (22˚C, bottom) under the No-Action Alternative and Alternative 3



Water Temperature Results

Figures 58 through 60 summarize temperature thresholds and predicted temperatures for steelhead trout spawning, egg incubation and juvenile rearing.

Water temperatures during egg incubation would not be affected by water management under Alternative 3 (Figure 59). The number of days in the preferred category tended to not change or actually increased over the permit term for the year types.

Analysis of temperature thresholds for juvenile steelhead rearing show an effect of the shift in timing of release of water for the North Unit ID pumps to May on temperatures (Figure 60). The number of days in the avoidance category in the wet water year in the reach immediately downstream of Bowman Dam increased from 33 days under the no-action alternative to 61 days under Alternative 3 by the end of the permit term. In addition, there were more warm days in the normal water year toward the end of the permit term. The number of suboptimal days increased from 77 days to 109 days in the reach immediately downstream of Bowman Dam (Cro-10). The number of days in the stress/disease category increased in reaches Cro-9 and Cro-8. Effects of water management on water temperature in lower reaches (Cro-7 through Cro-2) tended to be more variable as temperatures were warmer under the no-action alternative and effects of water management from Bowman Dam have less of an influence on water temperatures (Berger et al. 2019). Overall there was a tendency for more days in the stress/disease and lethal categories under the proposed action.

Summary Crooked River

Habitat model results are inconclusive (Figures 56 and 57). Results suggest an adverse effect on winter capacity (Figure 57 top), but that may not reflect winter streamflows.

Irrigation season effects in reaches of the Crooked River described for the proposed action at full implementation would also occur under Alternative 3. These effects would increase, though only slightly, in the reach between the North Unit ID pumps and Osborne Canyon, despite instream protection of uncontracted (fish and wildlife) storage releases in this reach. This is due to further increased reliance of North Unit ID pumps on the Crooked River to compensate for further decreased Upper Deschutes water supply under Conservation Measure WR-1.

Figure 58. Predicted Percentage Days within Water Temperature Thresholds for Spawning Steelhead Trout for a Wet (top), Dry (bottom), and Normal (bottom) Year under Alternative 3 in Years 11–30 compared to the No-Action Alternative

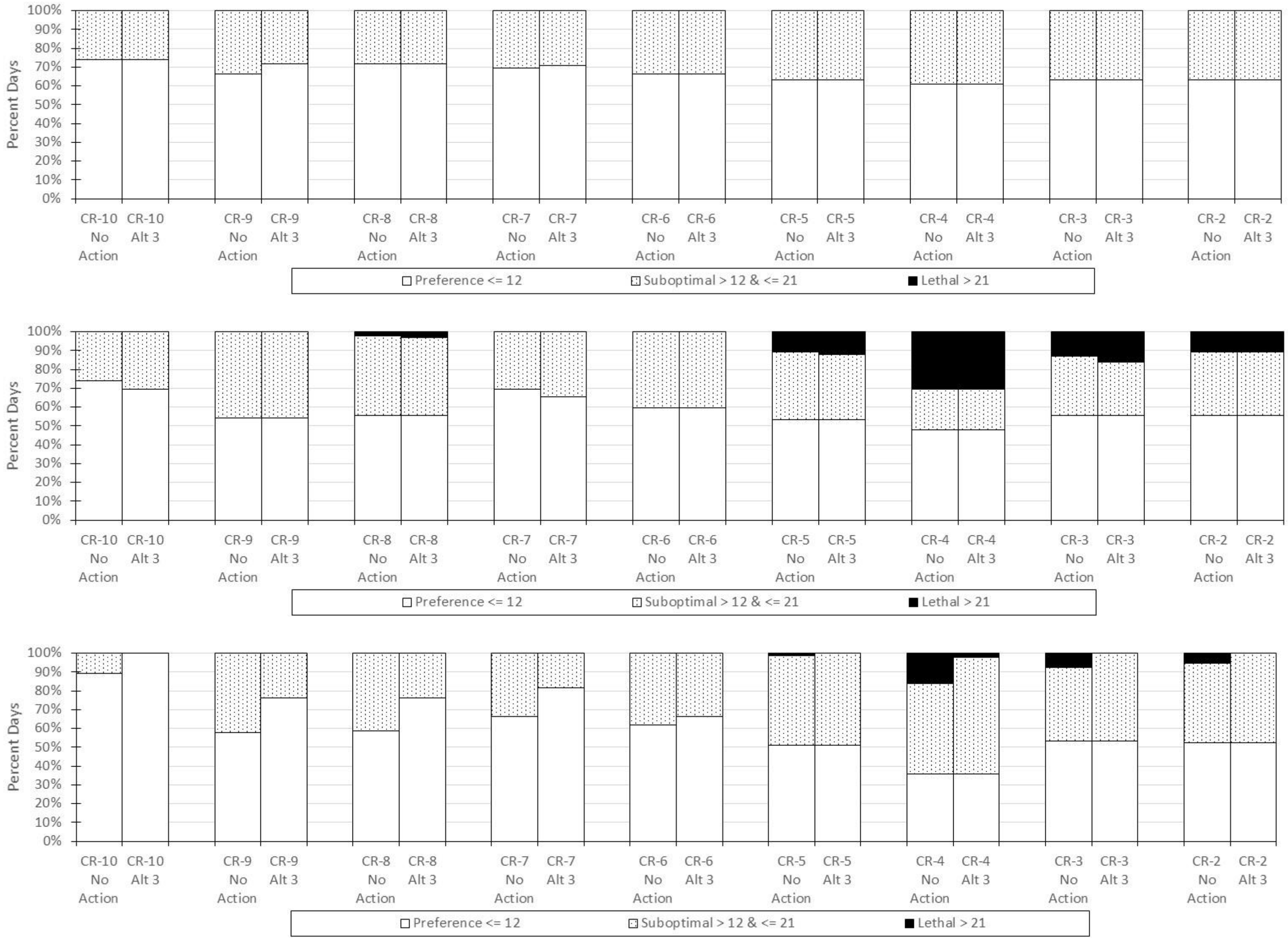


Figure 59. Predicted Percentage Days within Water Temperature Thresholds for Steelhead Trout Egg Incubation for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 3 Years 11–30 Compared to the No-Action Alternative

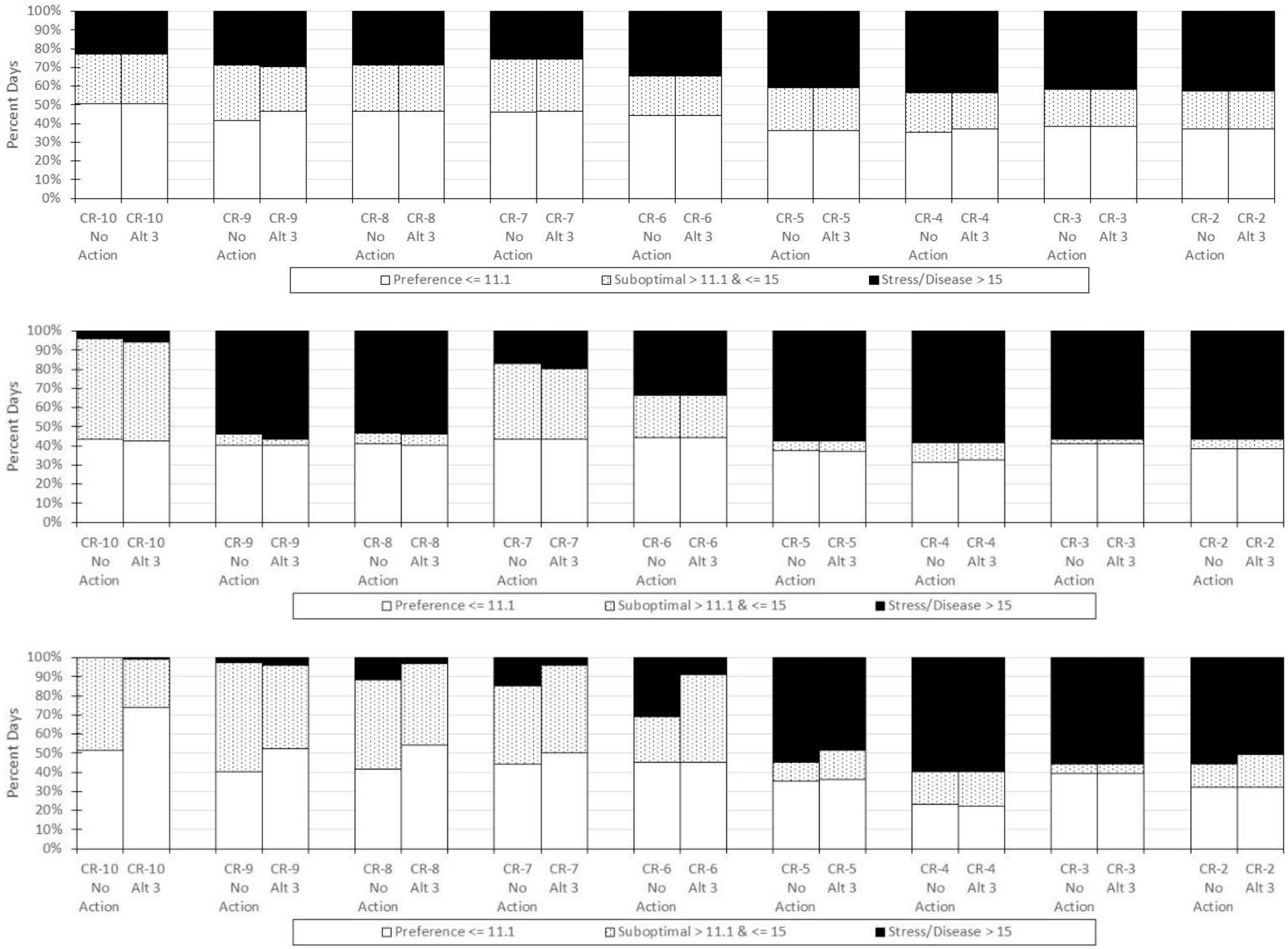
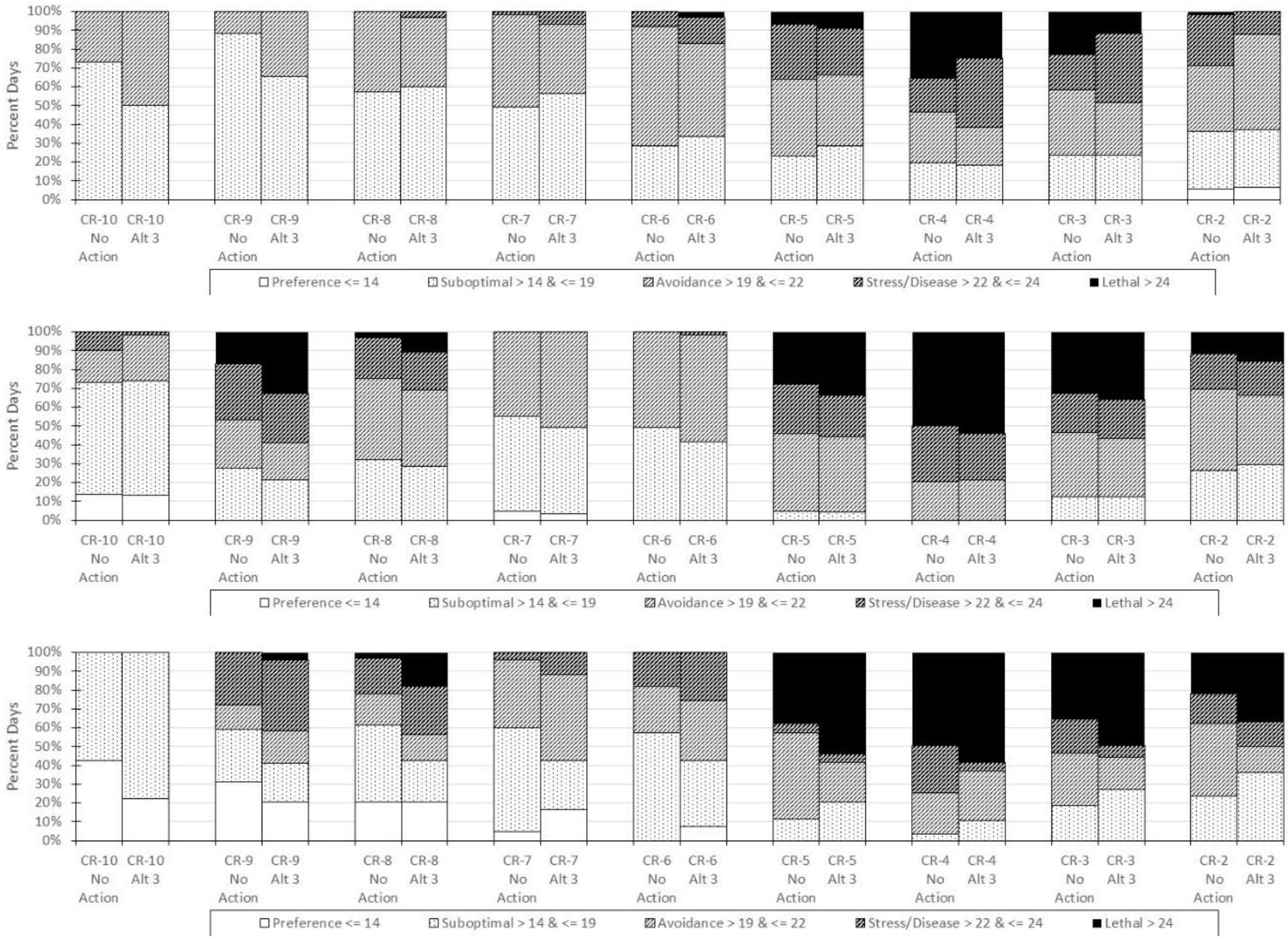


Figure 60. Predicted Percentage Days within Water Temperature Thresholds for Juvenile Steelhead Trout Rearing for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 3 Years 11–30 Compared to the No-Action Alternative



BIO-7: Affect Steelhead Trout Migratory Life Stages

Effects on steelhead migratory life stages under Alternative 3 would be the same type as described for the proposed action in the Middle and Lower Deschutes River, Lake Billy Chinook and Lake Simtustus, and Whychus, Ochoco and McKay Creeks. Effects in the Crooked River are described below.

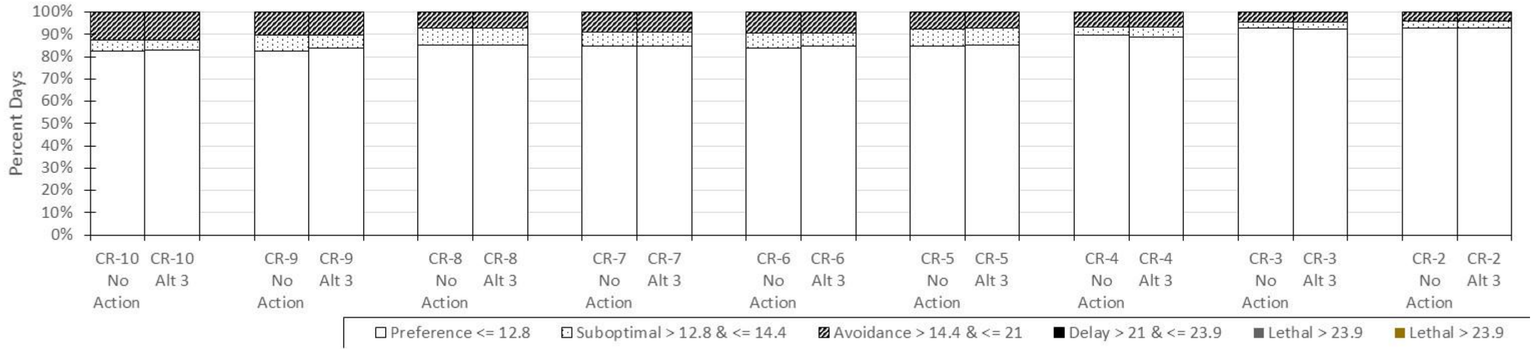
Crooked River

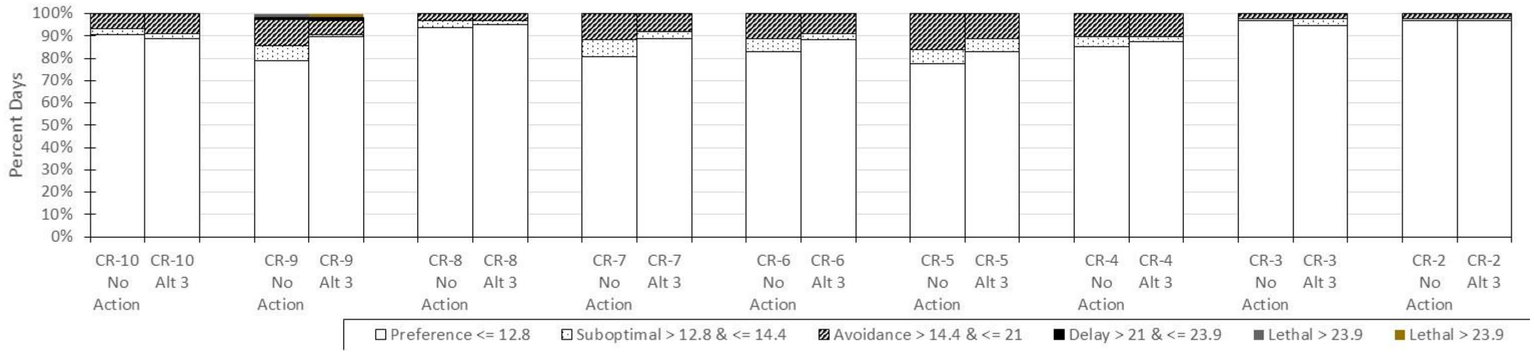
Effects on steelhead migratory life stages under Alternative 3 would be the same type as described for the proposed action. There would be no effect on steelhead trout migratory life stages in the Crooked River under Alternative 3 because streamflows would not affect water temperatures across the permit term compared to the no-action alternative (Figures 61 and 62).

In the Crooked River, Conservation Measures CR-1, CR-2, CR-3, CR-4, CR-5, CR-6, and CR-7 would result in beneficial effects on steelhead trout migratory habitat. Not all of these are quantifiable. CR-7 protects pulse flows for migration below the North Unit ID pumps. Pulse flows is a management option considered by the resource agencies to improve migration survival.

Modeled water temperatures and thresholds for steelhead trout migration life stages show no adverse effect of water management on water temperatures and migration habitat.

Figure 61. Predicted Percentage Days within Water Temperature Thresholds for Adult Migrant Steelhead Trout for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 3 Years 11–30 Compared to the No-Action Alternative





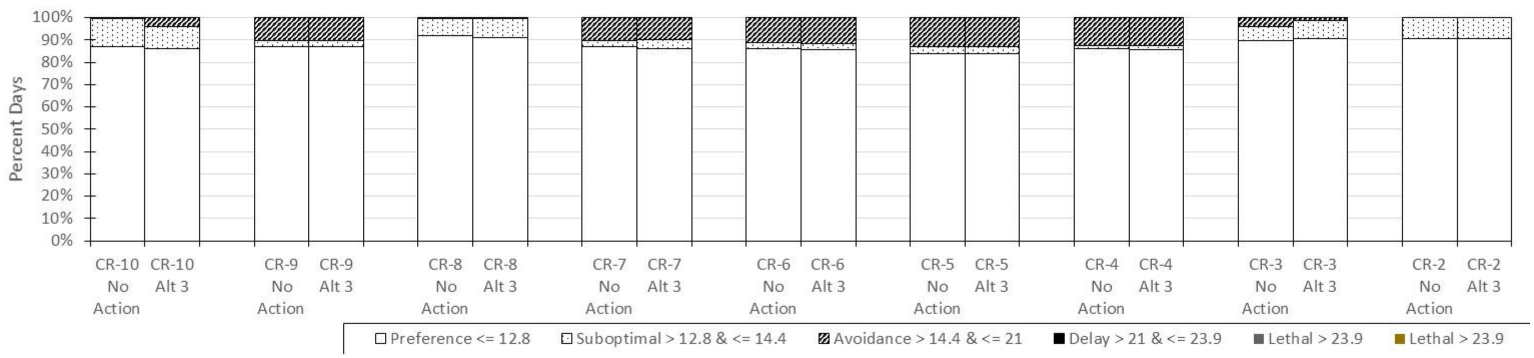
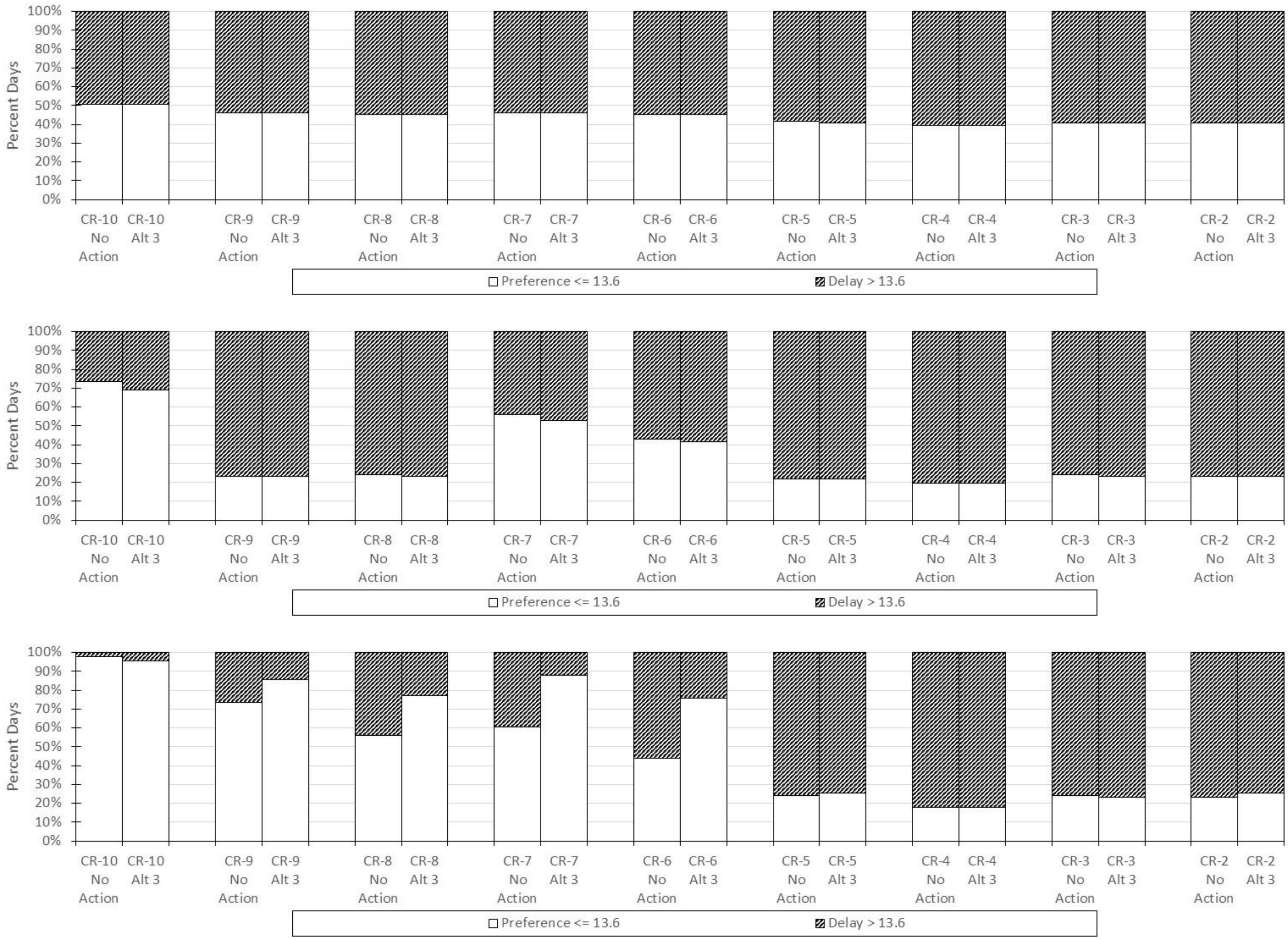


Figure 62. Predicted Percentage Days within Water Temperature Thresholds for Steelhead Trout Smolts for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 3 Years 11–30 Compared to the No-Action Alternative



BIO-8: Affect Spring Chinook Salmon Habitat

Effects on spring Chinook salmon habitat under Alternative 3 would be the same type as described for the proposed action in the Middle and Lower Deschutes River, Lake Billy Chinook and Lake Simtustus, and Whychus, and Ochoco Creeks. Effects in the Crooked River are described below.

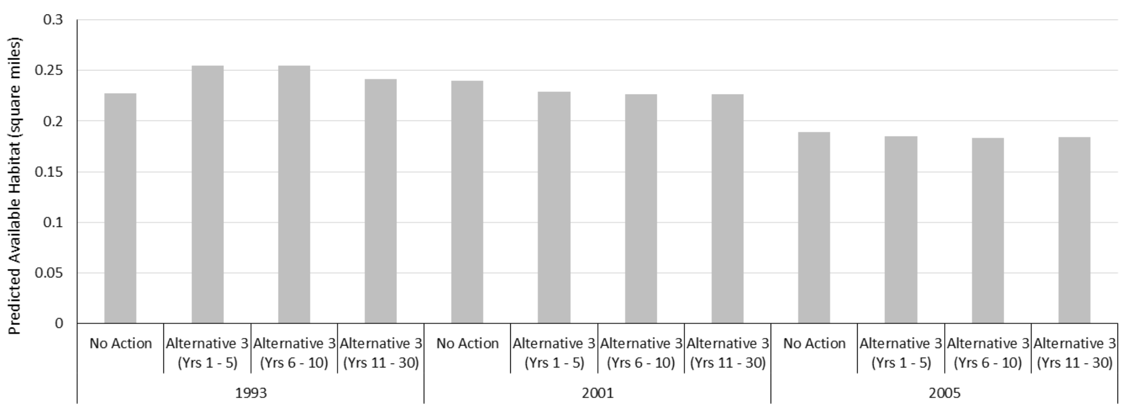
Crooked River

In the Crooked River reach between the North Unit ID pumps and Osborne Canyon adverse effects would be of slightly lesser magnitude than described for the proposed action due to instream protection of uncontracted (fish and wildlife) releases under this alternative (Conservation Measure CR-1).

Habitat Model Results

Results of modeling available summer habitat for Chinook juvenile rearing are inconclusive. Effects of streamflows on available habitat are not suggesting any particular trend between the no-action alternative and Alternative 3 (Figure 63).

Figure 63. Estimate of Juvenile Chinook Summer Habitat Availability for the Mainstem Crooked River under the No-Action Alternative and Alternative 3



Water Temperature Results

Figures 64 through 66 summarize temperature thresholds and predicted temperatures for spring Chinook spawning, egg incubation, and juvenile rearing.

Similar to the proposed action, analysis of temperature thresholds for spring Chinook life stages indicate an effect of timing of release of water from Bowman Dam on water temperatures. Analysis of temperature thresholds for spring Chinook salmon spawning suggests an adverse effect on water management operations on water temperatures under modeled streamflows (Figure 64). The shift in timing of release from Prineville from August to May and June is the basis for the adverse conditions under the proposed action.

The greatest effect is spring Chinook juvenile rearing (Figure 66). The number of days in the stress/disease category in the wet water year in the reach immediately downstream of Bowman Dam increased from 28 days under the no-action alternative to 61 days under Alternative 4 by the end of the permit term. There were more warm days in the normal water year toward the end of the permit term. The number of stress/disease days increased from 41 days to 67 days in the reach immediately downstream of Bowman Dam (Cro-10). The number of days in the optimal category decreased from 47 days to 24 days in reach CR-9, downstream of the canyon reach and from 53 days to 25 days in reach Cro–8, upstream of Prineville. In Cro-9 the number of days in the lethal category increased from 34 days to 68 days and in Cro-8 the number of days in the lethal category increased from 27 days to 57 days.

Effects of water management on water temperature in lower reaches (Cro-7 through Cro-2) tended to be more variable as temperatures were warmer under the no-action alternative and effects of water management from Bowman Dam have less of an influence on water temperatures (Berger et al. 2019). Overall there was a tendency for more days in the stress/disease and lethal categories under the proposed action.

Water temperatures thresholds were not explicitly evaluated for adult spring Chinook holding through the summer in the Crooked River. However, similar to the proposed action, the additional number of warm days toward the end of the permit term indicate a worsening of habitat conditions for spring Chinook adults holding through the summer.

Summary Crooked River

Habitat model results are inconclusive, results suggest no trend toward better or worsening amount of available habitat. However, these results do not reflect variation in summer streamflows and cumulative effects of summer water temperatures.

Similar to the proposed action, there could be an adverse effect toward the end of the permit term based on the wet, dry, and normal year type water temperature simulations.

Under the 2020 RiverWare model water released from Prineville Reservoir for the North Unit ID pump diversion may occur in June, July, or August depending on the year. Late June, July, and August releases may be beneficial to juvenile spring Chinook rearing through the summer in the Crooked River by reducing temperatures during the warmest periods.

Figure 64. Predicted Percentage Days within Water Temperature Thresholds for Spawning Spring Chinook for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 3 Years 11–30 Compared to the No-Action Alternative

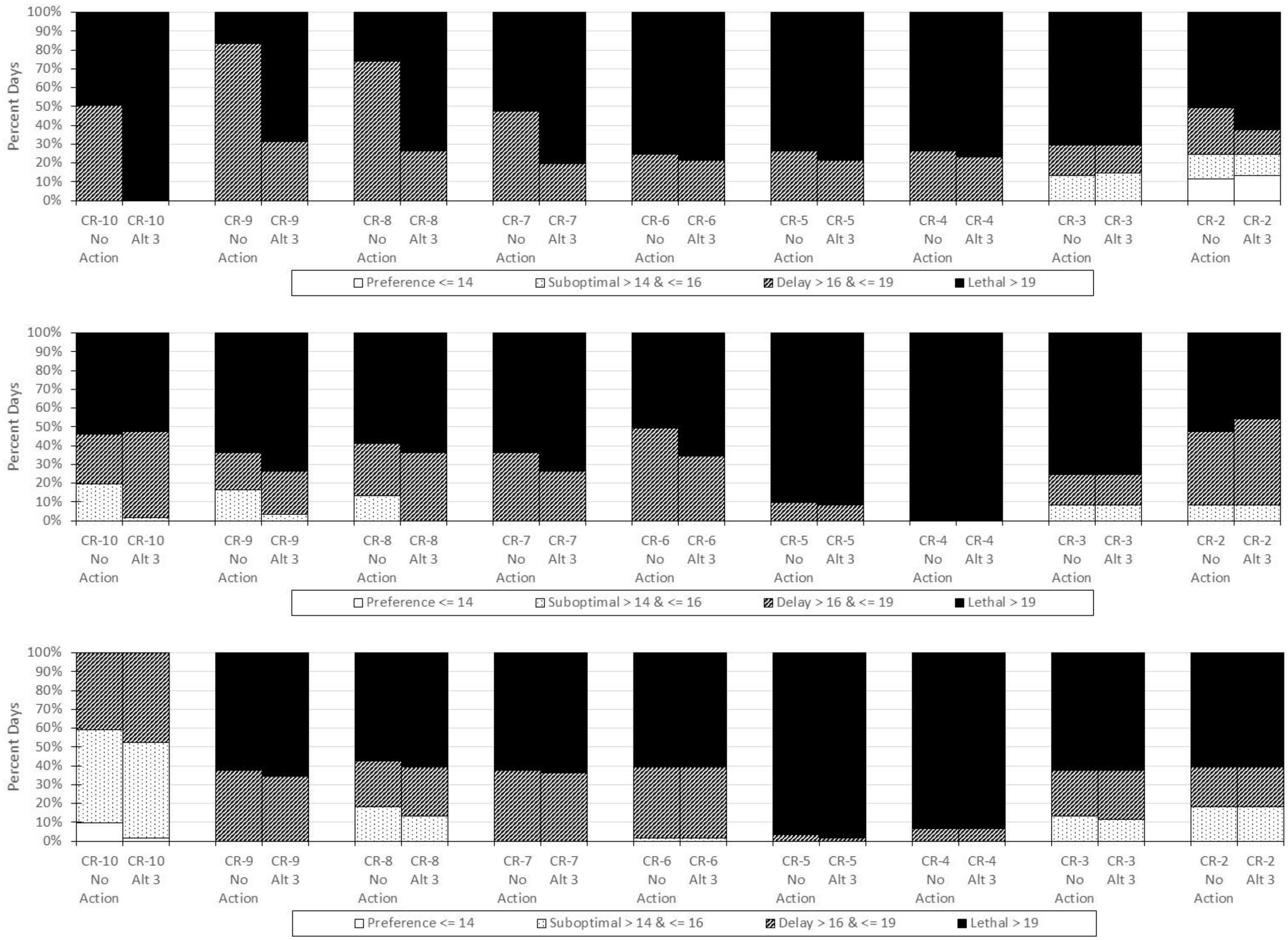


Figure 65. Predicted Percentage Days within Water Temperature Thresholds for Spring Chinook Egg Incubation for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 3 Years 11–30 Compared to the No-Action Alternative

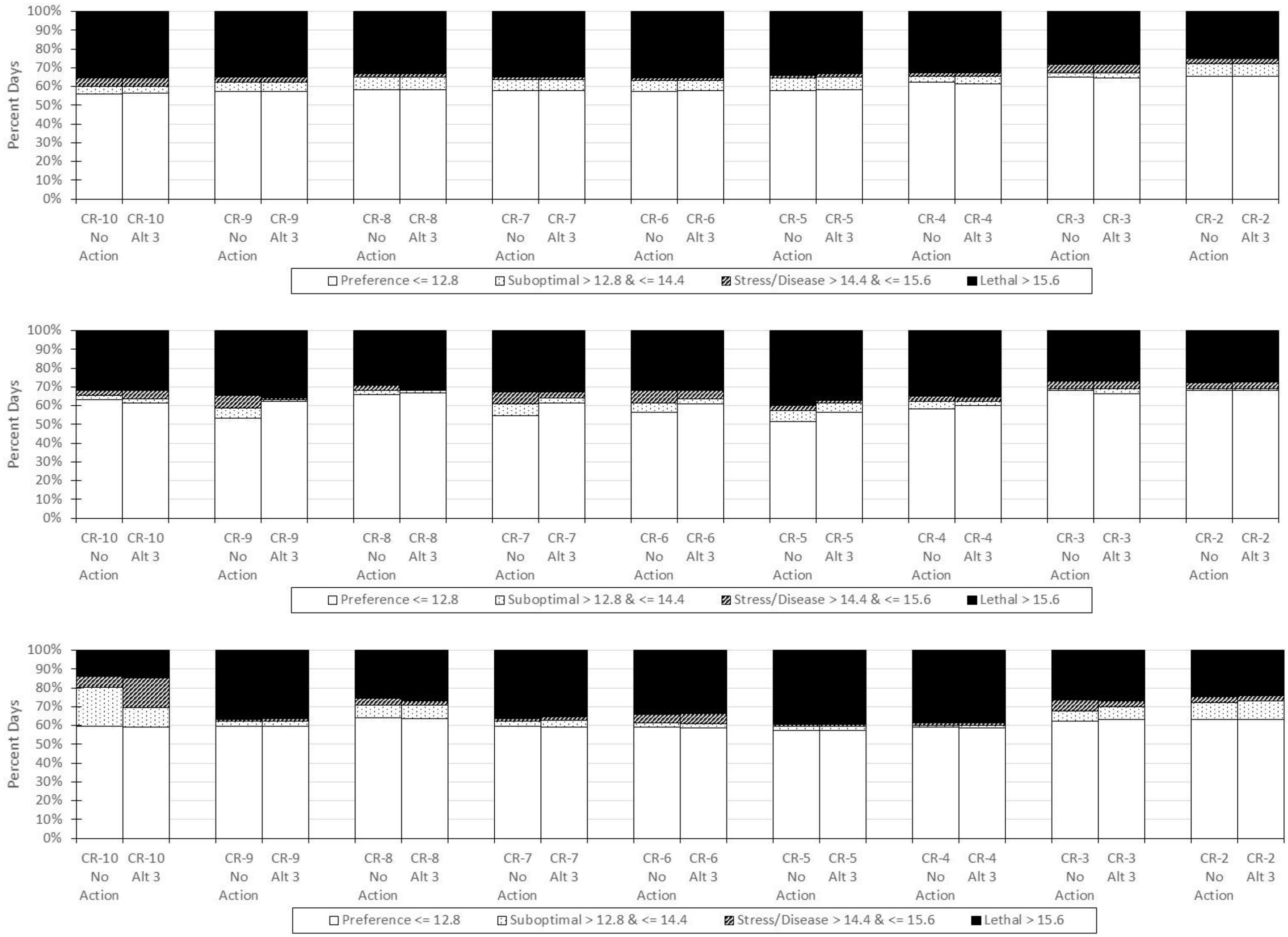
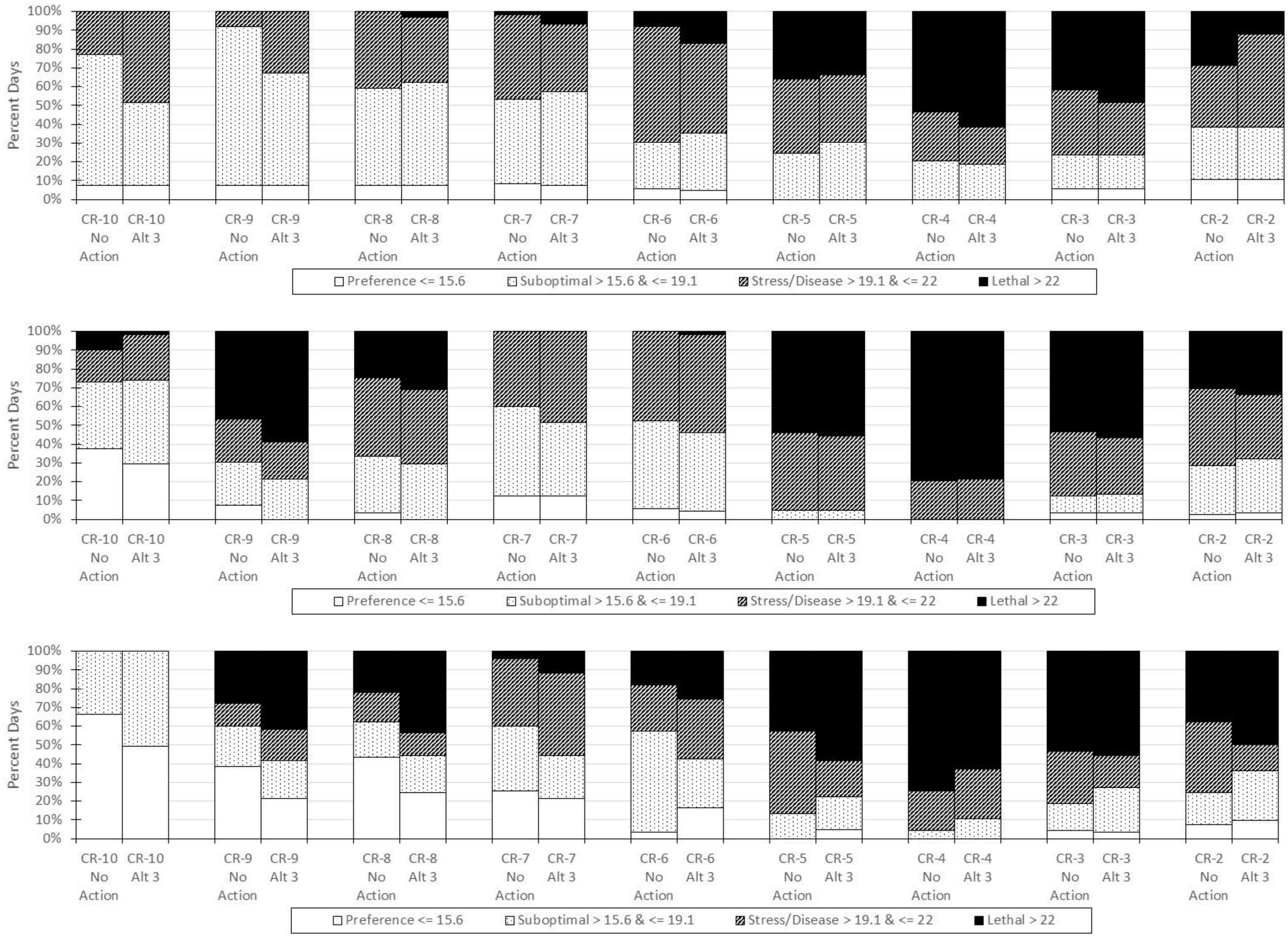


Figure 66. Predicted Percentage Days within Water Temperature Thresholds for Juvenile Spring Chinook Rearing (June–September) for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 3 Years 11–30 Compared to the No-Action Alternative



BIO-9: Affect Spring Chinook Salmon Migratory Life Stages

Effects on spring Chinook salmon migratory life stages under Alternative 3 would be the same type as described for the proposed action in the Middle and Lower Deschutes River, Lake Billy Chinook and Lake Simtustus, and Whychus, and Ochoco Creeks. Effects in the Crooked River are described below.

Crooked River

Effects in the Crooked River would occur earlier in the permit term and, therefore, have a longer duration under Alternative 3 than under the proposed action.

Water Temperature

The results of adult migration temperature thresholds are described in Figure 67. Smolt migration thresholds are described in Figure 68.

Similar to the proposed action, Alternative 3 would have no effect on migrating spring Chinook salmon adults attempting to move upstream in the spring or downstream migrating smolts because of water temperature effects on these life stages would be minor. However, the effect of water temperature on adult spring Chinook salmon migration habitat in July and August would be potentially adverse because the potential for migration effects exist but are not conclusive based on the available data.

Under the 2020 RiverWare model water released from Prineville Reservoir for the North Unit ID pump diversion may occur in June, July, or August depending on the year. Late June, July, and August releases may be beneficial to migrating adult spring Chinook rearing in the Crooked River by reducing temperatures during the warmest periods.

Figure 67. Predicted Percentage Days within Water Temperature Thresholds for Migrating Adult Spring Chinook (March–June) for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 3 Years 11–30 Compared to the No-Action Alternative

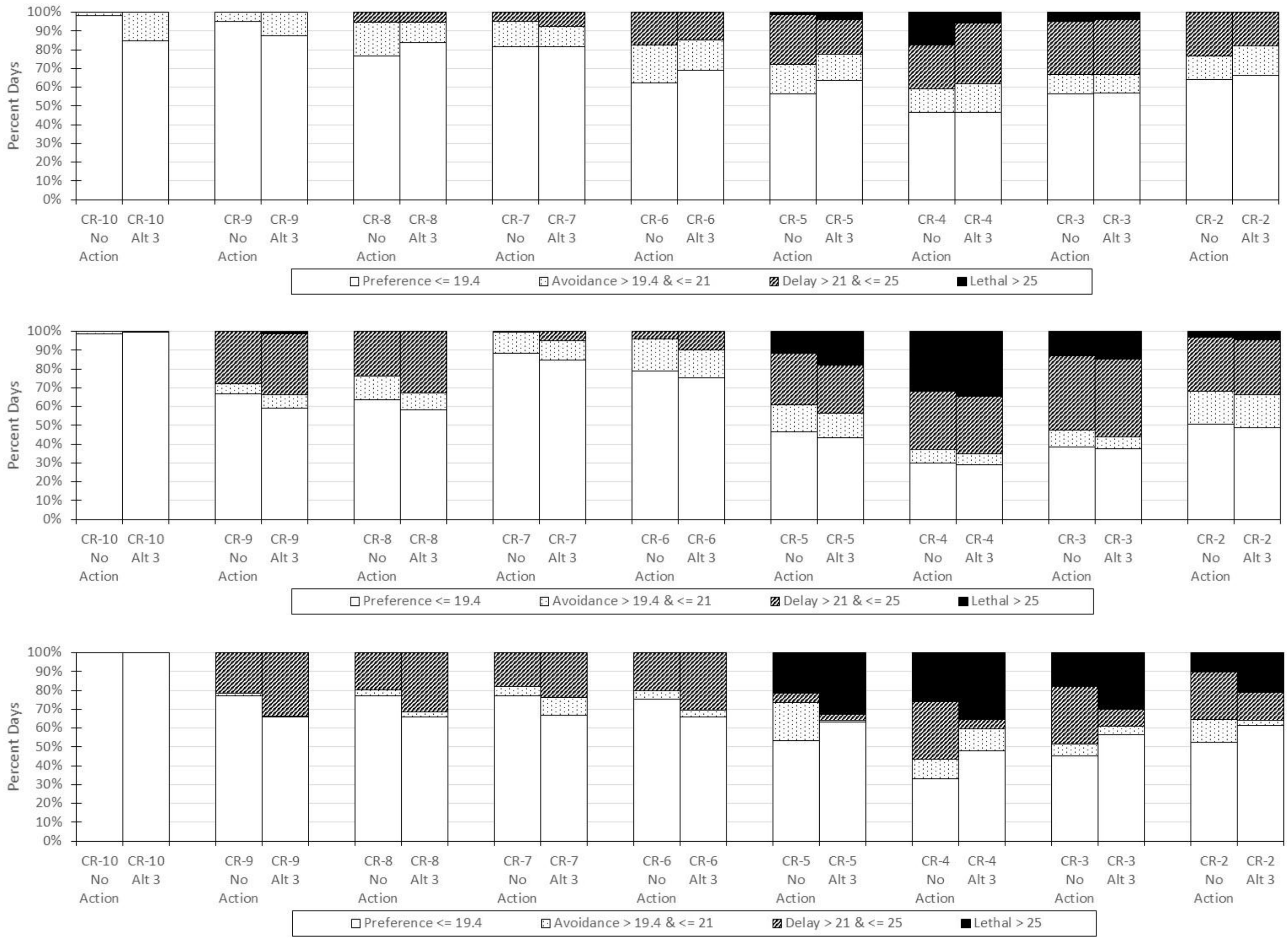
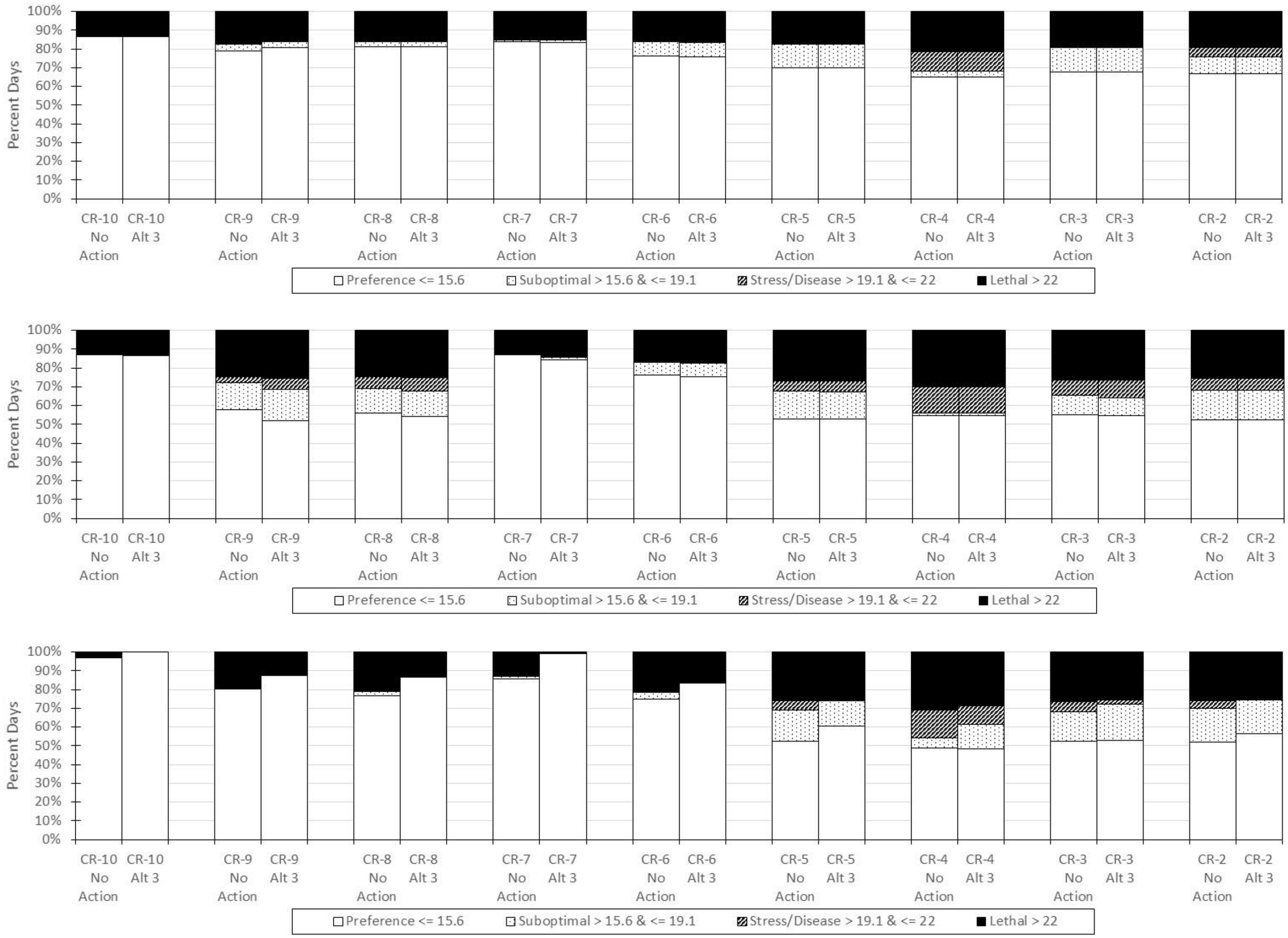


Figure 68. Predicted Percentage Days within Water Temperature Thresholds for Migrating Smolt Spring Chinook for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 3 Years 11–30 Compared to the No-Action Alternative



BIO-10: Affect Sockeye Salmon Habitat

Effects on sockeye salmon habitat under Alternative 3 would be the same type as described for the proposed action in the Middle and Lower Deschutes River, Lake Billy Chinook and Lake Simtustus, and Whychus Creek. Effects in the Crooked River are described below.

Crooked River

Adult sockeye may enter the Crooked River in the fall to spawn in the lower section of the river. Eggs would remain in the gravel through the winter. Newly emerged fry would migration to Lake Billy Chinook in the spring for juvenile rearing. The limited use by sockeye suggests any effects of streamflows on sockeye habitat would be limited to availability of spawning areas and egg incubation habitat in the lower river downstream of Osborne Canyon.

Under Alternative 3 predicted streamflows in the Crooked River at the Opal gauge are unchanged or change slightly compared to the no-action alternative for the entire permit term. Groundwater inflow upstream of the Opal gauge mostly negates any impact of water management observed in reaches higher in the Crooked River.

There would be no adverse effect on habitat for this species in the portion of the Crooked River likely used by sockeye for spawning.

BIO-11: Affect Sockeye Salmon Migratory Life Stages

Effects on sockeye salmon migratory life stages under Alternative 3 would be the same type as described for the proposed action in the Middle and Lower Deschutes River, Lake Billy Chinook and Lake Simtustus, and Whychus Creek. Effects in the Crooked River are described below.

Crooked River

Adult sockeye may enter the Crooked River in the fall to spawn in the lower section of the river. The limited use by sockeye suggests any effects of streamflows on sockeye migration would be limited to access to spawning areas in the lower river, downstream of Osborne Canyon.

Under Alternative 3 predicted streamflows in the Crooked River at the Opal gauge are mostly unchanged compared to the no-action alternative for the entire permit term. Groundwater inflow upstream of the Opal gauge negates any impact of water management observed in reaches higher in the Crooked River.

There would be no adverse effect on habitat for this species in the portion of the Crooked River likely used by sockeye for spawning.

BIO-12: Affect Redband Trout Habitat

Effects on redband trout under Alternative 3 compared to the no-action alternative would be the same type as described for the proposed action for all reaches, except Wickiup Reservoir, the Upper Deschutes River, the Little Deschutes River, and the Crooked River between North Unit ID pumps and Osborne Canyon.

Under Alternative 3 streamflows in the Little Deschutes River would be unchanged compared to the no-action alternative, and beneficial effects described for the proposed action would not occur.

Wickiup Reservoir elevations vary more under Alternative 3 compared to the proposed action resulting in a greater adverse effect on trout habitat in the reservoir. In the Upper Deschutes River between Wickiup Reservoir and Bend, beneficial effects would occur earlier. In the Crooked River between North Unit ID pumps and Osborne Canyon adverse effects would be of slightly lesser magnitude due to instream protection of uncontracted (fish and wildlife) releases under this alternative in Conservation Measure CR-1.

Effects in Wickiup Reservoir, the Upper and Middle Deschutes River, and the Crooked River would occur earlier in the permit term and therefore be of longer duration under Alternative 3 than the proposed action.

Crooked River

There would be a beneficial effect of higher minimum winter streamflows under Alternative 3 compared to the no-action alternative, consistent with study findings by Porter and Hodgson (2016) and habitat modeling by Mount Hood Environmental (2019). Porter and Hodgson concluded low flows during the winter were a factor negatively effecting redband trout habitat the Crooked River. The habitat model developed Mount Hood Environmental (2019) for steelhead for the Deschutes Basin HCP analysis supports their findings. Habitat modeling showed higher winter streamflows would increase habitat capacity for juvenile steelhead. The same conclusion is applicable to juvenile redband trout.

Water temperatures in the Upper Crooked River reach (Cro-10) are less affected by water management compared to downstream reaches, which experience more warming with change in streamflow. This finding suggests habitat would not change as much in this key reach as downstream. However, warming of water temperatures in downstream reaches could impact redband trout movement in the Crooked River and their ability to occupy habitats elsewhere in the Crooked River.

Under the 2020 RiverWare model water released from Prineville Reservoir for the North Unit ID pump diversion may occur in June, July, or August depending on the year. Late June, July, and August releases may be beneficial to redband trout through the summer in the Crooked River by reducing temperatures during the warmest periods.

BIO-13: Affect Nonnative Resident Trout Habitat

Effects on nonnative resident trout under Alternative 3 compared to the no-action alternative would be the same type as described for the proposed action in all reaches, except in the Little Deschutes River where streamflows would be unchanged under Alternative 3 compared to the no-action alternative, the Upper Deschutes River where beneficial effects would be slightly greater, and the Crooked River between North Unit ID pumps and Osborne Canyon where adverse effects would be slightly less, as described for BIO-12 redband trout. Effects in Wickiup Reservoir and the Upper and Middle Deschutes River and Crooked River would occur earlier in the permit term and, therefore, be of longer duration under Alternative 3 than under the proposed action. Overall, effects on nonnative resident trout habitat under Alternative 3 would be not adverse compared to the no-action alternative for the reasons described for the proposed action.

BIO-14: Affect Summer/Fall Chinook Salmon Habitat

Summer/Fall Chinook salmon distribution is limited to the Lower Deschutes, downstream of the Pelton-Round Butte Complex. Effects would be the same type as described for the proposed action.

BIO-15: Affect Kokanee Salmon Habitat and Migratory Life Stages

Effects on kokanee salmon habitat and migratory life stages under Alternative 3 compared to the no-action alternative would be the same type as described for the proposed action. Effects in Wickiup Reservoir would occur earlier in the permit term and, therefore, be of longer duration under Alternative 3 than under the proposed action. Overall, effects on kokanee salmon habitat and migratory life stages under Alternative 3 would be adverse compared to the no-action alternative for the reasons described for the proposed action.

BIO-16: Affect Native Non-Trout and Non-Game Fish Habitat

Effects on non-game native fish habitat under Alternative 3 compared to the no-action alternative would be the same type as described for the proposed action except for the Little Deschutes River as described for BIO-12 redband trout. Effects in Wickiup Reservoir, Upper and Middle Deschutes River, and Crooked River would occur earlier in the permit term and, therefore, be of longer duration under Alternative 3 than under the proposed action. Overall, effects on non-game native fish habitat under Alternative 3 would be not adverse compared to the no-action alternative for the reasons described for the proposed action.

BIO-17: Affect Freshwater Mollusk Habitat

Effects on freshwater mollusk habitat under Alternative 3 would be the same type as described for the proposed action except for in the Crooked River, which is described below.

Crooked River

Crater Lake Tightcoil and Evening Field Slug

There would be no adverse effect on Crater Lake tightcoil and evening field slug in the Crooked River under Alternative 3 because flows would increase in the fall and winter months in most years and would decrease or increase in the spring and summer months in different years, depending on reach.

Floater Species Mussels

There would be an adverse effect on floater species mussels in the Crooked River under Alternative 3 because there would be an average decrease in flows during the critical period of reproduction and juvenile establishment for this species (May through August) in the reach of the river where the mussels are primarily found. There would be an average decrease in flows in July in the reaches measured by the CAPO gauge and in May through July in reaches measured by the North Unit ID gauge.

Western Pearlshell Mussels

There would be a beneficial effect on western pearlshell mussels in the Crooked River under Alternative 3 because flows would increase in many reaches during May and June, the critical period of reproduction and juvenile establishment for the species.

Western Ridged Mussels

There would be no adverse effect on western ridged mussels in the Crooked River under Alternative 3 because though flow would increase, on average, during the initial reproductive period in many reaches, overall, there would be small decreases in flows during the latter part of their reproductive period (especially July) in many reaches.

Alternative 4: Enhanced and Accelerated Variable Streamflows

Modeled changes in streamflows, reservoir volumes and elevations, and water quality conditions under Alternative 4 compared to the no-action alternative are described below in the Modeled Environmental Conditions section followed by descriptions of how these changes would affect individual species in the Species Impacts section.

Modeled Environmental Conditions

This section describes important changes in reservoir storage and elevation, seasonal river and creek streamflows, and relevant water quality information in the study area by geographic area and subarea under Alternative 4. Effects are evaluated based on changes in modeled results for Alternative 4 compared to the no-action alternative.

Changes in streamflows and reservoir elevations and variability would be the same type as described for the proposed action for all reaches except for Crescent Creek, the Little Deschutes, the Crooked River and the Upper and Middle Deschutes River.

Crescent Creek/Little Deschutes

Alternative 4 does not include Conservation Measure CC-1 that sets aside a portion of the water stored in Crescent Lake Reservoir to be used specifically to benefit Oregon spotted frogs. Other measures included in the proposed action are included under Alternative 4.

Generally changes in streamflow are the same as described for the proposed action except summer streamflows in Crescent Creek (CRAO) are higher in more years under Alternative 4 compared to the proposed action and no-action alternative. The Little Deschutes River streamflows are unchanged compared to the no-action alternative.

Upper Deschutes

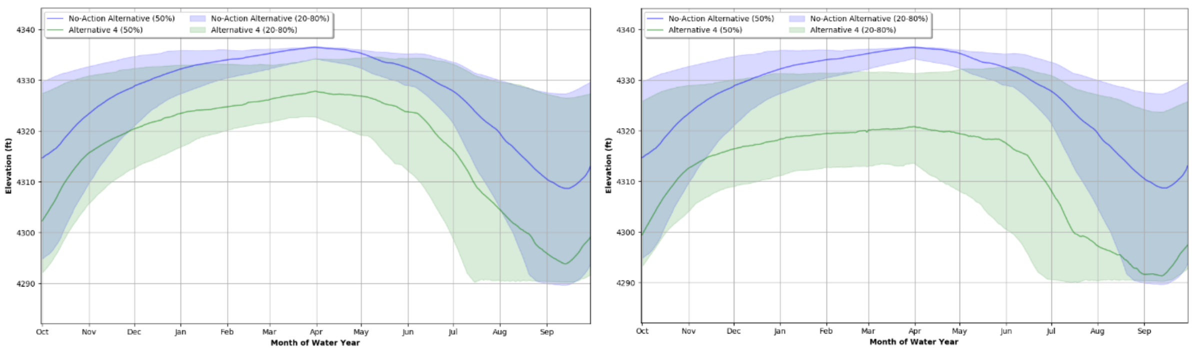
Under Alternative 4, as under the proposed action and Alternative 3, summer flows would diminish and winter flows would increase compared to the no-action alternative. Alternative 4 would alter the timing of those changes, such that winter minimum flow targets would be achieved earlier in the permit term and would end at a higher level compared to the proposed action and Alternative 3.

Accordingly, modeled environmental conditions under Alternative 4 follow the same trend over the permit term as described for the proposed action and Alternative 3. The differences described below are more extreme differences in median reservoir elevations and streamflows.

Wickiup Reservoir

Alternative 4 reservoir elevations would be lower than the no-action alternative in all months of the year and would be much lower than described for the proposed action over the permit term (Figure 69).

Figure 69. Modeled Elevations for Wickiup Reservoir (WIC) under Alternative 4 Years 1–5 (left) and 6–20 (right) Compared to the No-Action Alternative



Upper Deschutes River downstream of Wickiup Dam

Under Alternative 4, as under the proposed action and Alternative 3, summer flows would diminish and winter flows would increase compared to the no-action alternative. Alternative 4 would alter the timing of those changes, such that winter minimum flow targets would be achieved earlier in the permit term and would end at a higher level compared to the proposed action and Alternative 3.

Based on modeled results for the Wickiup Reservoir Outlet (WICO) and Benham Falls (BENO) nodes and internodes between Benham Falls and the city of Bend, streamflows in the Upper Deschutes River downstream of Wickiup Dam would be less variable over the year because regulation of streamflows would happen earlier and in more years.

Alternative 4 does not include a limit to maximum streamflow added to WR-1 for the proposed action. Summer maximum streamflows under Alternative 4 may exceed 1,400 cfs occasionally. However, median streamflows are approximately 1,200 cfs in years 6 through 20 of the permit term.

Middle Deschutes

Middle Deschutes River

Modeled results for the city of Bend (DEDO) node and the Culver City internode (CULOGauge.Outflow), winter streamflows would be higher.

- In years 1 through 5 of the permit term median monthly streamflows at DEBO would be higher in all analysis years during the winter storage season from October through March by on average 40% in October and 20% from November through March.
- In years 6 through 20 median monthly streamflows at DEBO during the winter storage season would be 50% higher in October and 30% higher from October through March.
- Median streamflows at DEBO during the transition period to irrigation season in April would be unchanged through the permit term in all analysis years through the permit term.
- Median monthly streamflows at DEBO from July through September at DEBO would not change in the majority of years through the permit term. Differences would be evenly split between lower or higher by 10% on average.

At the Culver City internode surface and groundwater inflows upstream of this location would reduce the effects of water management and changes in streamflow upstream of this location at

DEBO. Increasing minimum winter streamflows would increase streamflows from October through March by approximately 15%, on average, by the end of the permit term.

Crooked River

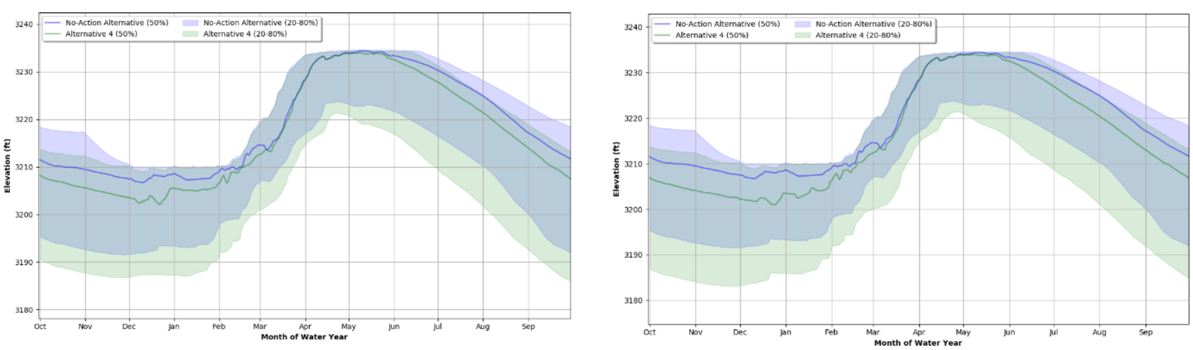
Generally Alternative 4 is the same as the proposed action, but increases storage season minimum flows to 80 cfs (with Ochoco ID responsible for up to 50 cfs), and provides for instream protection of the uncontracted (fish and wildlife) releases from Bowman Dam to Lake Billy Chinook. These conditions are not fully reflected in the RiverWare results, but are assumed to provide additional benefits to fish in the Crooked River during the storage season months (mid-October to April) and during the irrigation season when fish and wildlife flows may occur.

Prineville Reservoir

Based on modeled results for Prineville Reservoir node (PRV), illustrated in Figure 40, elevations would be similar to the proposed action. Changes are described below in comparison to the no-action alternative.

- Median elevations would be lower from July through January with differences greatest in October and November. Median elevations would be unchanged from February to June.
- Differences in median elevations would not differ over the permit term.
- Year to year variability would tend to occur in the low and high range of elevations.

Figure 70. Modeled Elevations for Prineville Reservoir (PRVO) under Alternative 4 Years 1–5 (left) and 6–20 (right) Compared to the No-Action Alternative



Crooked River

Modeled environmental conditions in the Crooked River are described below based on median monthly streamflows and modeled water temperatures.

Median Monthly Streamflow

Differences in median monthly streamflow are summarized below for the following locations (nodes): Prineville Outlet (PRVO), near Highway 126 (CAPO), below the North Unit ID pumps (NUID), and below Opal Springs Dam (OPAL).

Prineville Outlet (PRVO):

- October through March: Generally there was no change in winter streamflows in the majority of years. There were a few years streamflows went below 50 cfs during the winter (1993 for example) under the no-action alternative. In those years Conservation Measure CR-1 with the 80 cfs limit would attempt to achieve winter flows of 80 cfs during the winter.

- April and May: No change in median streamflows in most years. A 14% 30% increase in monthly median streamflows in 10 and 17 of the analysis years.
- June: An increase in monthly median streamflows of approximately 30% in the majority of analysis years. There were very few years that monthly median streamflow decreased in June under Alternative 4.
- July and August:
    - During the warmest months (July and August) month median streamflows are higher under Alternative 4. In July monthly median streamflows are 50 to 100 cfs higher in 21 of the analysis years. In August monthly median streamflows are 50 to 100 cfs higher in 24 of the analysis years.
    - During the warmest months (July and August) month median streamflows are lower under the Alternative 4 in both months – 7 of the years in July and 12 of the years in August.
- September: Monthly median streamflows were higher in September by 10% in 22 of the 38 analysis years and lower by 13% in 12 of the analysis years.

CAPO node near Highway 126 and the City of Prineville (CAPO) showing change in monthly median streamflows at the end of the permit term are summarized in Table 11.

- Generally the pattern of monthly streamflows was the same at CAPO as reported at PRVO.
- July and August:
    - In July median streamflows are 50 to 100 cfs higher in 24 of the analysis years of the 38 analysis years.
    - In August median streamflows are 50 to 100 cfs higher in 24 of the analysis years of the 38 analysis years.
    - However in August median streamflows were lower in 14 the analysis years by 65%.
- September: Median streamflows at CAPO were higher in September by 36% in 22 of the 38 analysis years. Median streamflows at CAPO were lower in September by 44% in 16 of the 38 analysis years

Below the North Unit ID pumps (NUID.outflow):

- October through March: In most years, there was no change in monthly median streamflows; in about 10% of years there was an average increase in median streamflows of 40%; and in about 5% of years, an average decrease in median streamflows of approximately 20%.
- April: No change in median streamflows.
- May through September: Average decrease across all months of 20 to 40% in the majority of the years.

Below Opal Springs Dam (OPAL):

- No discernable differences in streamflows.

Water Temperature Modeling

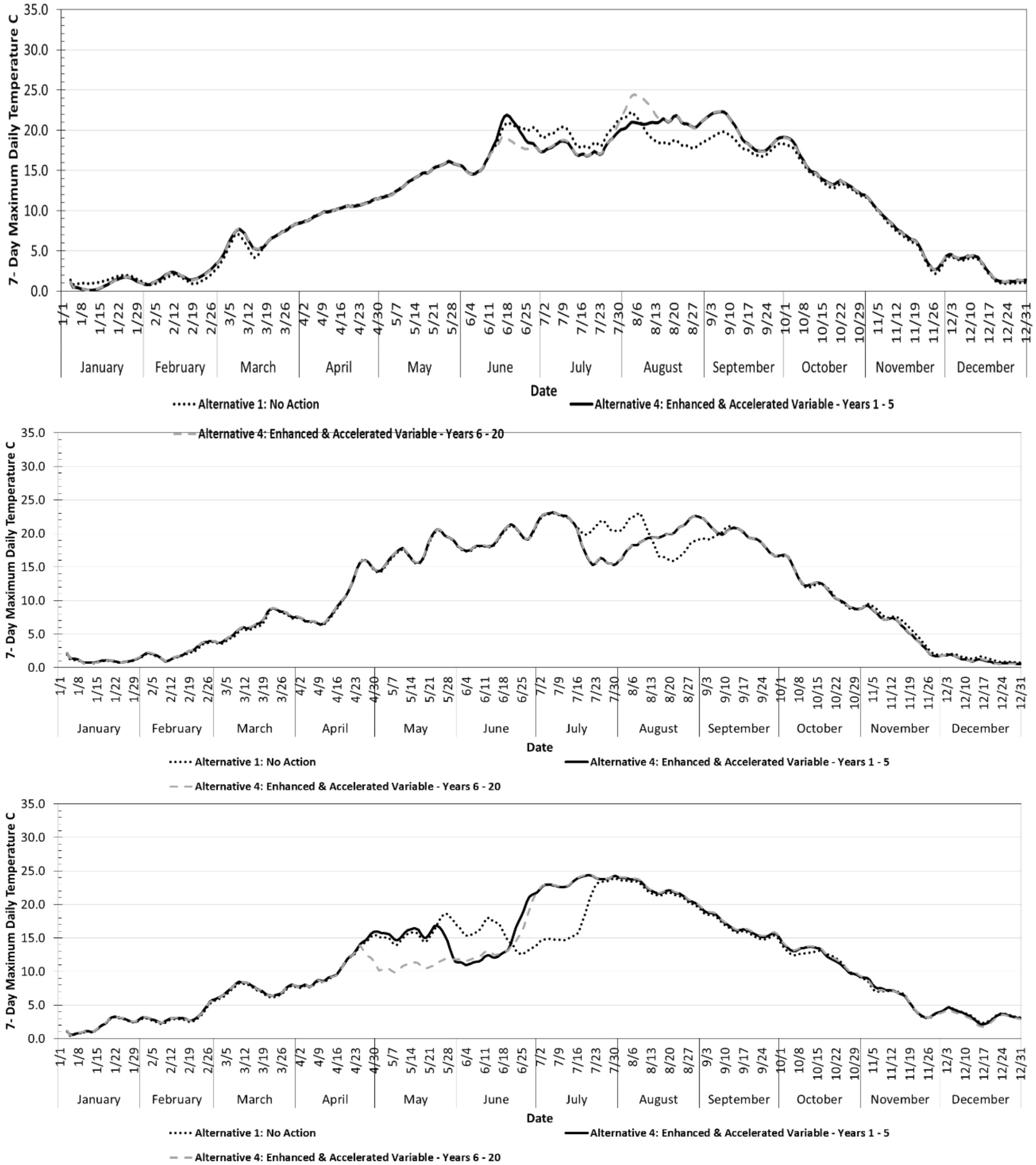
The shift in predicted 7DADM water temperatures at the Crooked River CAPO node from the 2019 analysis is shown in Figure 71. Under Alternative 4, water temperatures are cooler in early summer and warm rapidly when streamflows are lower in July. The maximum summer 7DADM water temperature was not affected by the shift in timing at Bowman Dam. The maximum for the summer season is approximately the same between the no-action alternative and Alternative 4 for each of the analysis years. However, the consequence of the shift in streamflow timing is a longer period of warm temperatures in the normal water year type example. The number of warm days during the summer increased substantially in the normal water year type indicating a potentially less suitable environment for temperature sensitive salmonids.

An analysis of how streamflows may affect species survival was based on the predicted 7DADM results and compared to species preferences, sublethal, stress/disease, and lethal temperature thresholds summarized from a literature review (R2 and Pacific Biota 2013). Species thresholds are reported in Table 6 in Methods section. The threshold analysis is discussed in the *Species Impacts* section by alternative.

Table 11. Summary Monthly Median Flows for the Crooked River near Highway 126 (CAPO node) under the No-Action Alternative and Alternative 4 (Years 6–20)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Average diff. median flow (%)	4%	1%	13%	10%	16%	8%	3%	129%	115%	40%	42%	8%
Range diff. in monthly median flow (%)	-29 to 119%	-73 to 405%	-74 to 405%	-76 to 319%	-62 to 319%	-24 to 319%	-75 to 73%	-64 to 974%	-80 to 906%	-85 to 314%	-94 to 513%	-89 to 103%
# Years no diff. in median flow	26	15	22	24	25	25	19	12	3	2	0	0
# Years increase in median flow	4	3	3	4	4	3	11	19	26	24	24	22
Range increase in monthly median flow (%)	6 to 119%	75 to 405%	75 to 405%	6 to 319%	69 to 319%	60 to 319%	6 to 73%	6 to 974%	30 to 906%	13 to 314%	27 to 513%	22 to 103%
Median increase median flow (%)	69%	329%	329%	168%	247%	69%	27%	84%	126%	36%	66%	36%
# Years decrease in median flow	8	20	13	10	9	10	8	7	9	12	14	16
Range decrease in monthly median flow (%)	-29 to -12%	-73 to -11%	-74 to -5%	-76 to -6%	-62 to -13%	-24 to -6%	-75 to -7%	-64 to -7%	-80 to -22%	-85 to -12%	-94 to -8%	-89 to -8%
Median decrease flow (%)	-17%	-45%	-17%	-16%	-19%	-16%	-23%	-38%	-56%	-44%	-65%	-44%

Figure 71. Annual Water Temperature Predictions for the Crooked River near Highway 126 (CAPO node) for a Wet (top), Dry (middle), and Normal (bottom) Year under the No-Action Alternative and Alternative 4 (Years 1–5 and 6–20)



Species Impacts

This section describes effects on fish and mollusks under Alternative 4 compared to the no-action alternative. Where effects are the same as for the proposed action, the description of effects under the proposed action are referenced for brevity.

Changes in streamflows and reservoir elevations and variability would be the same or nearly the same type as described for the proposed action for all of the reaches except for Wickiup Reservoir, the Crooked River, and the Upper and Middle Deschutes River.

Under Alternative 4, as under the proposed action and Alternative 3, summer streamflows would diminish and winter streamflows would increase compared to the no-action alternative in the Upper Deschutes River between Wickiup Reservoir and Bend. Alternative 4 would alter the timing of those changes, such that winter minimum streamflow targets would be achieved earlier in the permit term and would end at a higher level compared to the proposed action and Alternative 3.

Under Alternative 4, seasonal differences in Wickiup Reservoir elevation and volume would be more extreme compared to the proposed action and Alternative 3, which would affect water use on Crooked River. Higher minimum releases on the Crooked River during storage season would result in decreases in irrigation season flows even in the reaches downstream of North Unit pump with instream protection of uncontracted (fish and wildlife) storage releases from Prineville Reservoir.

In addition, because implementation of increased releases from Wickiup Reservoir would occur earlier under Alternative 4 than the proposed action or Alternative 3, related effects would occur earlier as well, as noted in the effects discussion. Due to the shorter (20-year) permit term, the duration of full implementation would be 15 years (between the proposed action and Alternative 3).

BIO-4: Affect Bull Trout Habitat

Changes in streamflows and variability would be the same or nearly the same type as described for the proposed action for all reaches except for the Middle Deschutes River and Crooked River, which are described below.

Middle Deschutes

Increased storage season streamflows and associated beneficial effects on bull trout habitat in the Middle Deschutes River would be the same type as described for the proposed action but of greater magnitude at full implementation. The flow increases in the Middle Deschutes are due to increased releases from Wickiup Reservoir in above-normal and wet years under this alternative (Conservation Measure WR-1).

The increase in winter streamflows for foraging subadult and adult bull trout would have a beneficial effect over the permit term in the portion of the reach accessible to the species.

Crooked River

In the Crooked River minimum winter streamflows would increase to 80 cfs under Conservation Measure CR-1. However, adverse irrigation season effects in reaches of the Crooked River described below would also occur and would be of slightly greater magnitude due to further increased storage season releases from Prineville Reservoir to meet the 80 cfs minimum storage season flows under Conservation Measure CR-1. Furthermore, these effects would increase, though only slightly, in the reach between the North Unit ID pumps and Osborne Canyon, despite instream protection of uncontracted (fish and wildlife) storage releases in this reach (Conservation Measure CR-6). This is due to further increased reliance of North Unit ID pumps on the Crooked River to compensate for further decreased Upper Deschutes water supply under Conservation Measure WR-1.

Water Temperature Results

Streamflows under Alternative 4 would be expected to affect bull trout habitat should their distribution expand up to Bowman Dam with the completion of a fish passage structure at Opal Springs Diversion Dam.

Figures 72 and 73 summarize temperature thresholds predicted temperatures for bull trout spawning and egg incubation, respectively. Results support conclusions that current condition water temperatures are too warm for bull trout spawning in the Crooked River upstream of Smith Rock (modeled portion of the Crooked River or in any other accessible area of the Crooked River or its tributaries).

Figure 74 summarizes temperature thresholds and predicted temperatures for juvenile and subadult rearing. These temperatures support the potential use of the Crooked River by foraging bull trout during the winter in all reaches and in the summer in the reach downstream of Bowman Dam (Reach Cro-10; RMs 70.5 to 55.9) and in the reach from Osborne Canyon to Lake Billy Chinook (Reaches Cro-1.2 and 1.1; RMs 7.3 to 0) (Torgerson et al. 2007).

At the end of the permit term under Alternative 4 water temperatures in Reach Cro-10 for the normal water year are predicted to exceed the stress/disease threshold by an additional 25 days. Predicted water temperatures for the dry water year are predicted to exceed the lethal threshold by an additional 16 days. Seventy-seven days above the preference threshold would occur under water management in the normal water year at the end of the permit term compared to 49 days under the no-action alternative.

Summary Crooked River

Bull trout would be exposed to a range of water management effects under the proposed action, including differences in streamflow across the year affecting the amount of habitat available and water management affecting water temperatures during critical life stages.

BIO-5: Affect Bull Trout Migratory Life Stages

Changes in streamflows and reservoir elevations and variability would be the same or nearly the same type as described for the proposed action for all reaches except for the Middle Deschutes River and Crooked River, which are described below.

Middle Deschutes

Under Alternative 4 streamflows in the Deschutes River at the CULO gauge are predicted to increase slightly during the winter (mid-October to the end of March) in years 1 through 6 and moderately in years 6 through 20, but of greater magnitude at full implementation. The flow increases in the Middle Deschutes are due to increased releases from Wickiup Reservoir in above-normal and wet years under this alternative (Conservation Measure WR-1).

The increase in winter streamflows over the permit term would have a beneficial effect on the migratory life stage of bull trout in the portion of the reach accessible to this species.

Crooked River

RiverWare modeled streamflows and predicted water temperatures in the Crooked River do not suggest an effect on migratory life stages. Migration windows for entering and moving upstream in the fall and for subadults to leave the Crooked River in the spring before temperatures exceed preference thresholds would not be affected by the alternative. There would be no effect on migratory life stages of this species (Figures 75 and 76).

Figure 72. Predicted Percentage Days within Water Temperature Thresholds for Spawning Bull Trout for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 4 Years 6–20 Compared to the No-Action Alternative

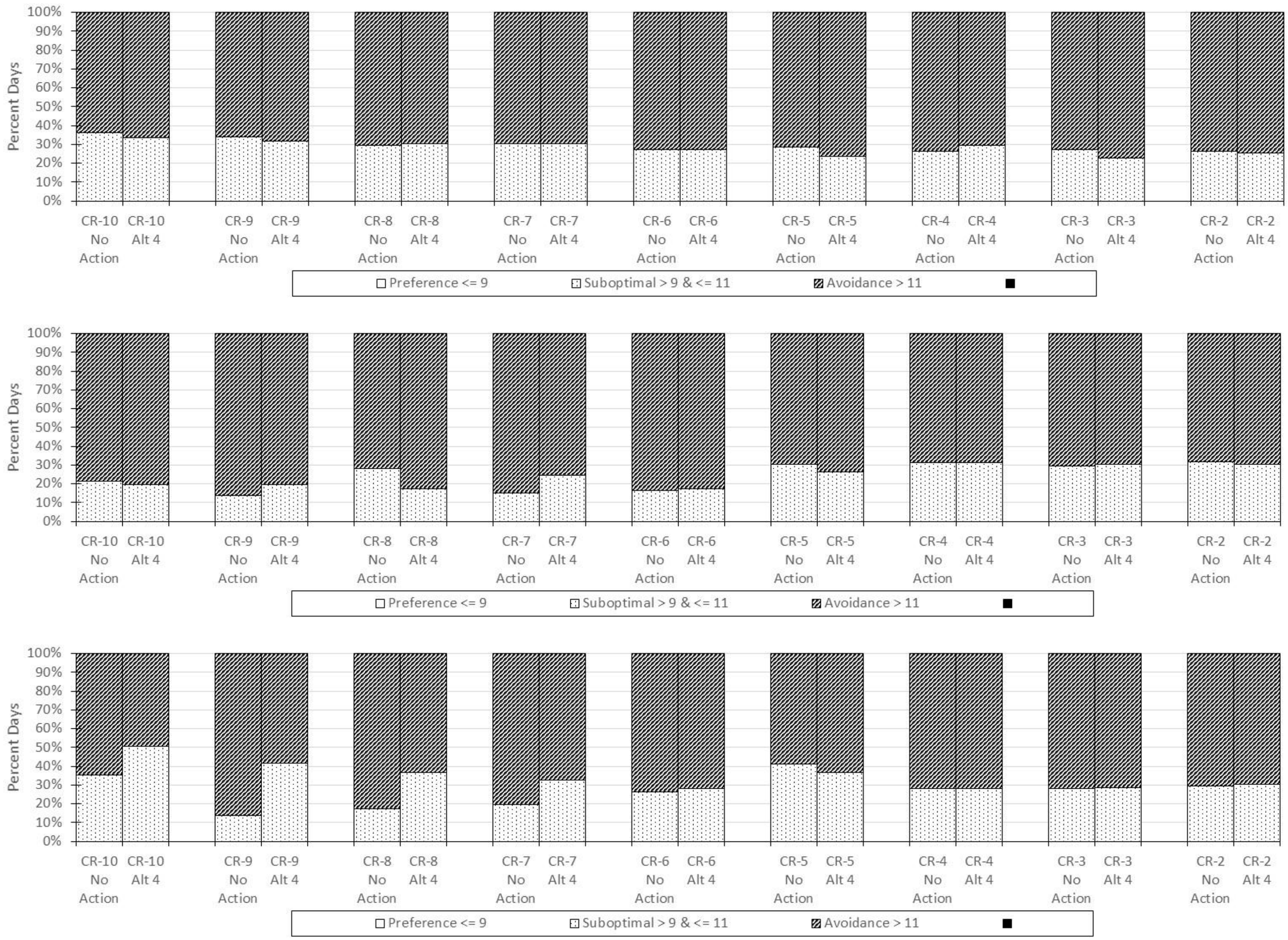


Figure 73. Predicted Percentage Days within Water Temperature Thresholds for Bull Trout Egg Incubation for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 4 Years 6–20 Compared to the No-Action Alternative

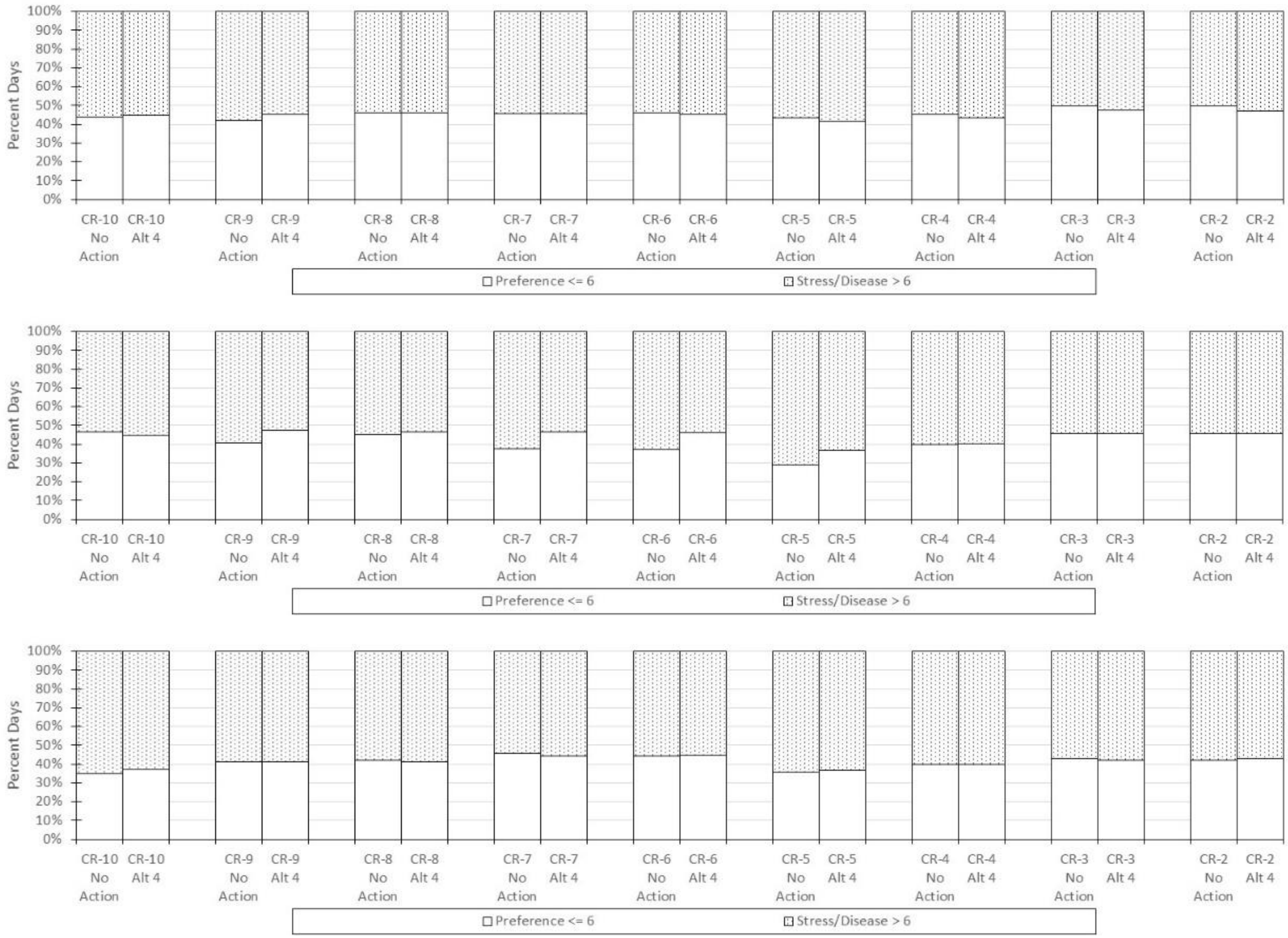


Figure 74. Predicted Percentage Days within Water Temperature Thresholds for Juvenile and Subadult Bull Trout Rearing for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 4 Years 6–20 Compared to the No-Action Alternative

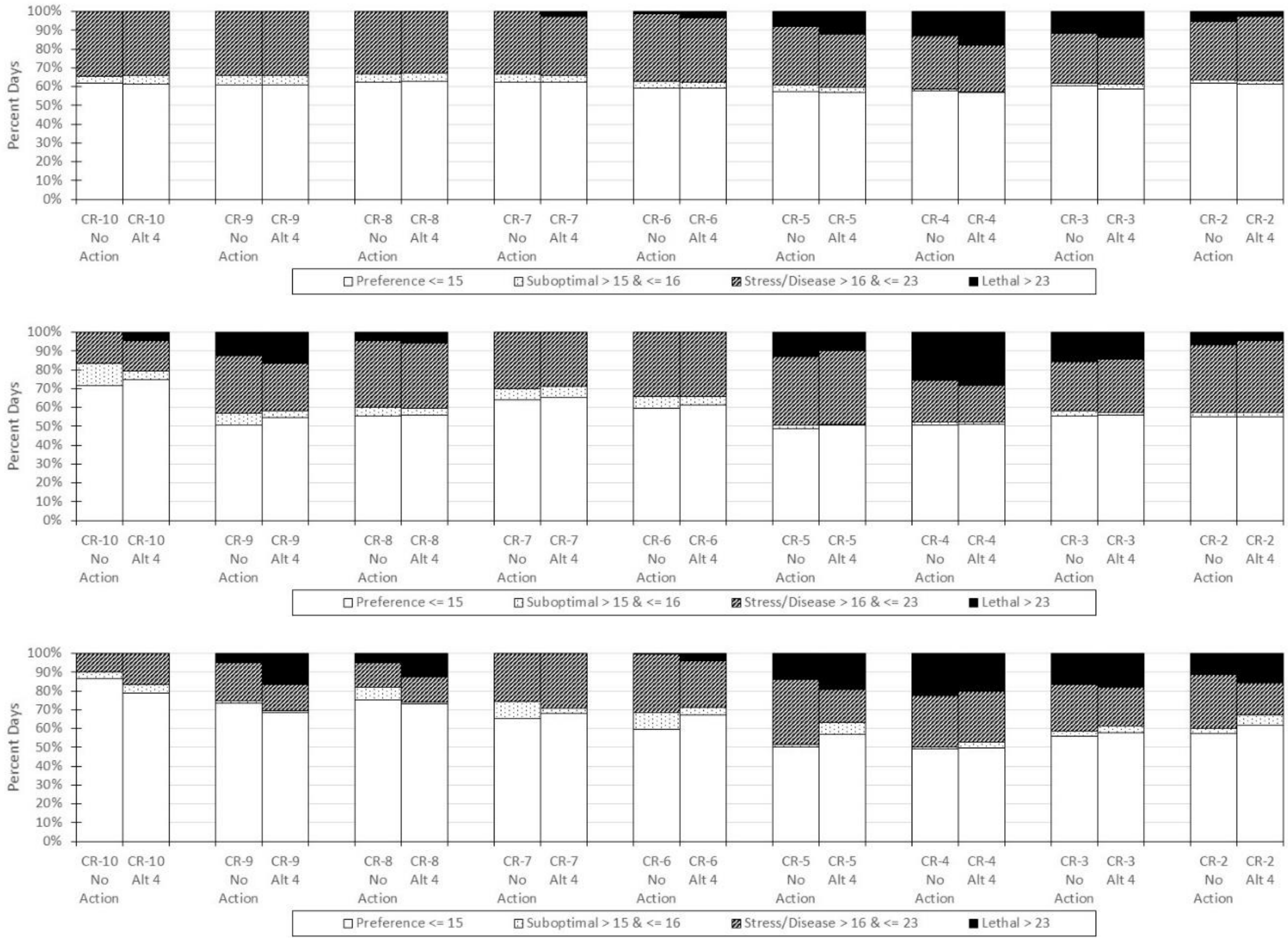


Figure 75. Predicted Percentage Days within Water Temperature Thresholds for Bull Trout Fall/Winter Migratory Stages for Wet (top), Dry (middle), and Normal (bottom) Years under the Alternative 4 Compared to the No-Action Alternative

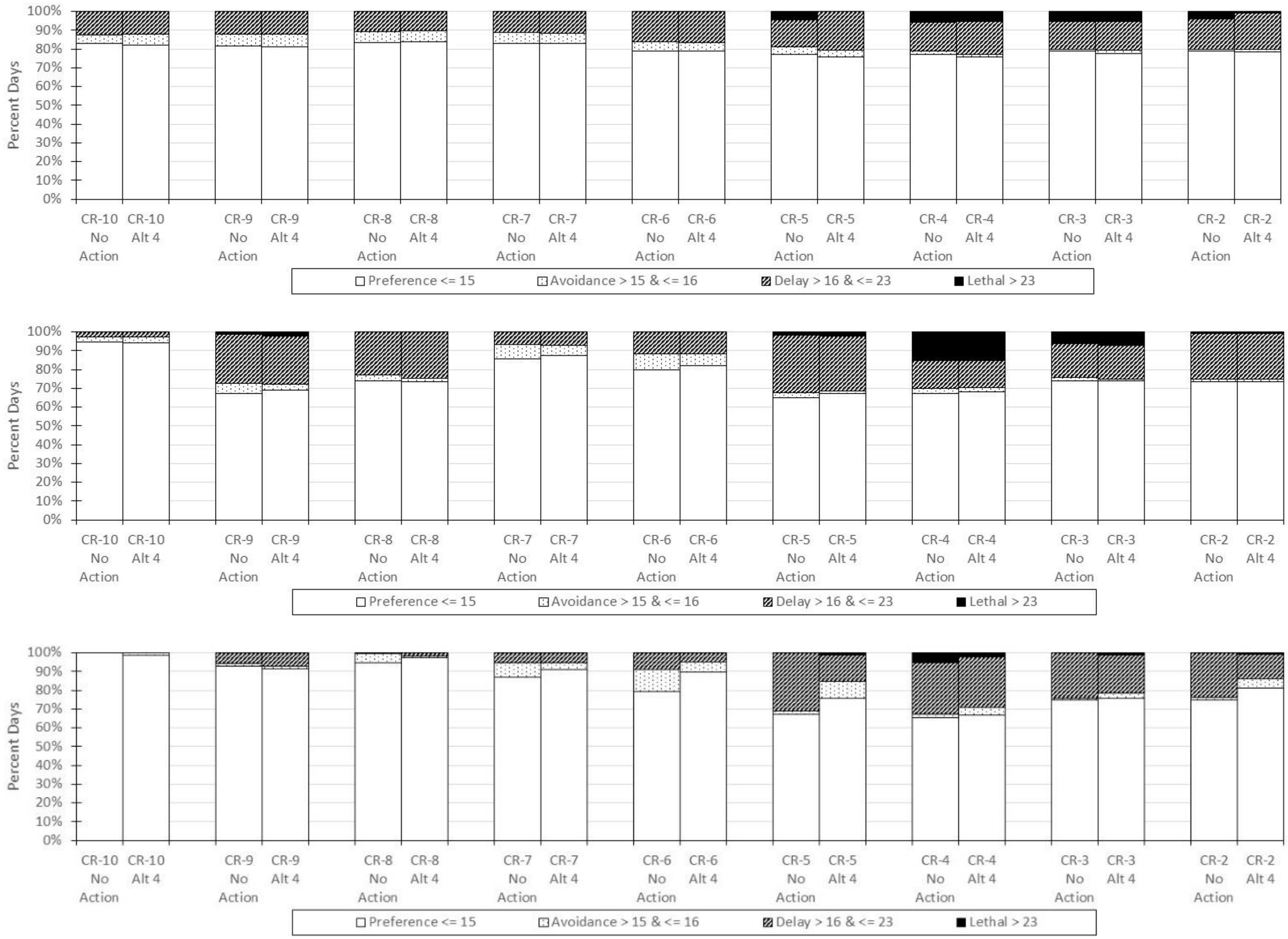
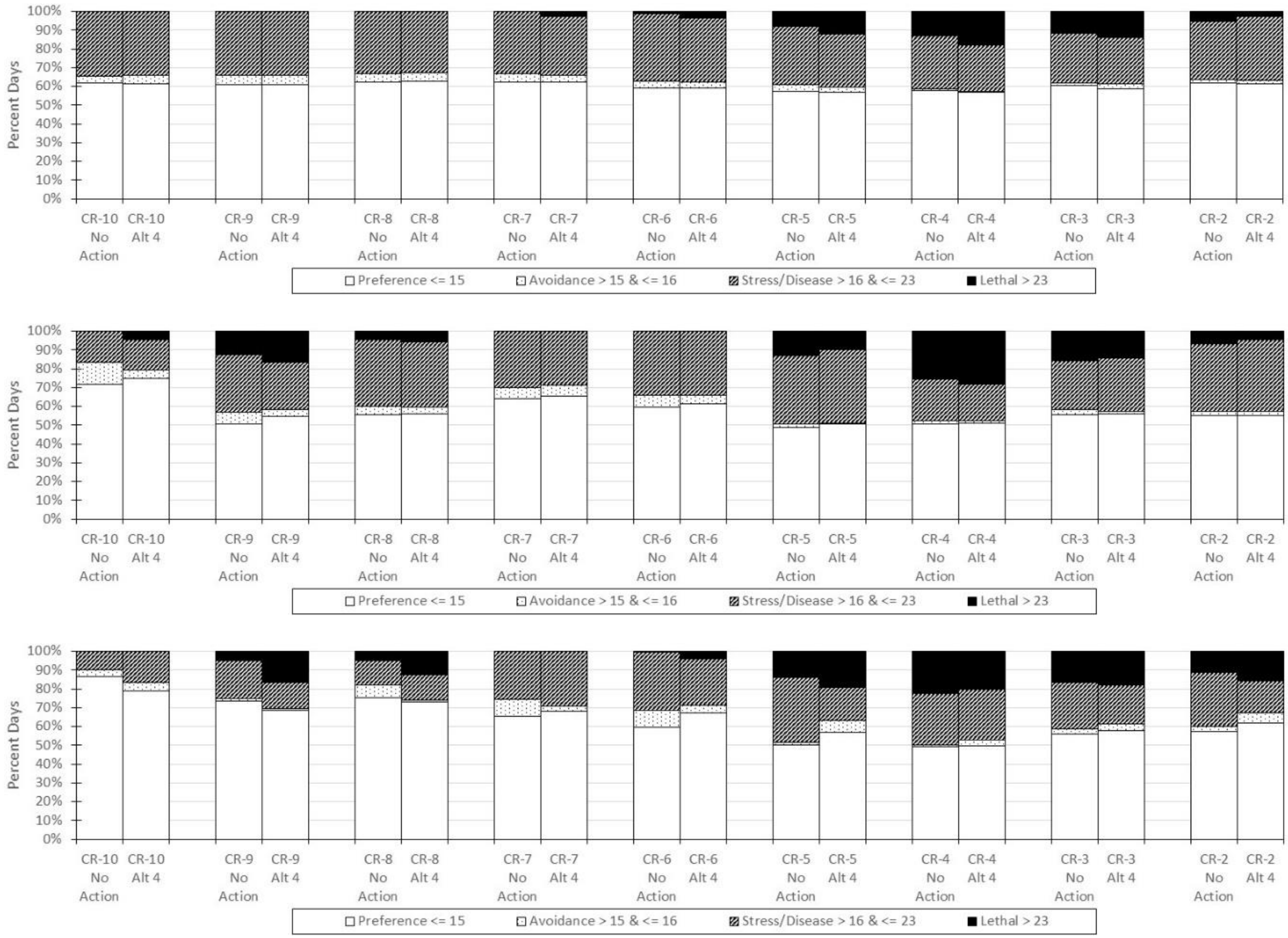


Figure 76. Predicted Percentage Days within Water Temperature Thresholds for Bull Trout Foraging, Migration, and Overwinter (FMO) Stages (Annual) for Wet (top), Dry (middle), and Normal (bottom) Years under Alternative 4 Compared to the No-Action Alternative



BIO-6: Affect Steelhead Trout Habitat

Changes in streamflows and reservoir elevations and variability would be the same or nearly the same as described for the proposed action for all reaches except for the Middle Deschutes River and Crooked River, which are described below.

Middle Deschutes

Under Alternative 4 streamflows in the Deschutes River at the CULO gauge are predicted to increase slightly during the winter (mid-October to the end of March) in years 1 through 5 and moderately in years 6 through 20 of the permit term, but of greater magnitude at full implementation. The flow increases in the Middle Deschutes are due to increased releases from Wickiup Reservoir in above-normal and wet years under this alternative (Conservation Measure WR-1). These changes in streamflow would benefit habitat for holding and spawning adult steelhead and rearing juvenile steelhead during the winter.

Streamflows decline beginning approximately mid-April with the start of irrigation diversions. During this period steelhead eggs are still in the gravel. However, predicted streamflows during this period and in the fall with the end of irrigation under Alternative 4 are no different than under the no-action alternative. There would be no effect relative to the no-action alternative during these periods.

Because of the small to moderate increase in winter streamflows over the permit term, there would be a beneficial effect on habitat for steelhead trout in the portion of this reach accessible to the species. Adult steelhead holding in the Deschutes River and rearing juvenile steelhead would benefit from the moderate increase in streamflow in the winter.

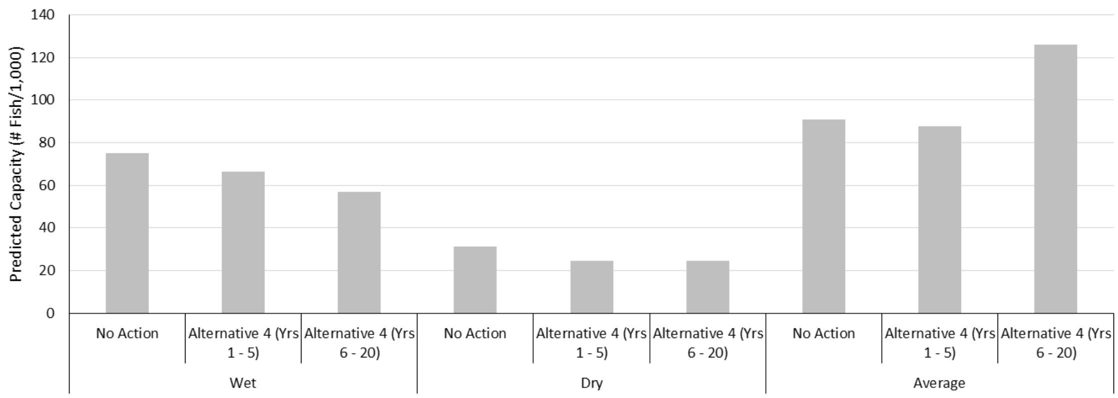
Crooked River

In the Crooked River minimum winter streamflows would increase to 80 cfs under Conservation Measure CR-1. However, adverse irrigation season effects in reaches of the Crooked River described below would also occur and would be of slightly greater magnitude due to further increased storage season releases from Prineville Reservoir to meet the 80 cfs minimum storage season flows under Conservation Measure CR-1. Furthermore, these effects would increase, though only slightly, in the reach between the North Unit ID pumps and Osborne Canyon, despite instream protection of uncontracted (fish and wildlife) storage releases in this reach (Conservation Measure CR-6). This is due to further increased reliance of North Unit ID pumps on the Crooked River to compensate for further decreased Upper Deschutes water supply under Conservation Measure WR-1.

Habitat Model Results

Results of modeling for summer juvenile rearing are inconclusive. Result show a decline or an improvement in capacity under Alternative 4 depending on water year type (Figure 77). Water temperature effects are largely influencing these results.

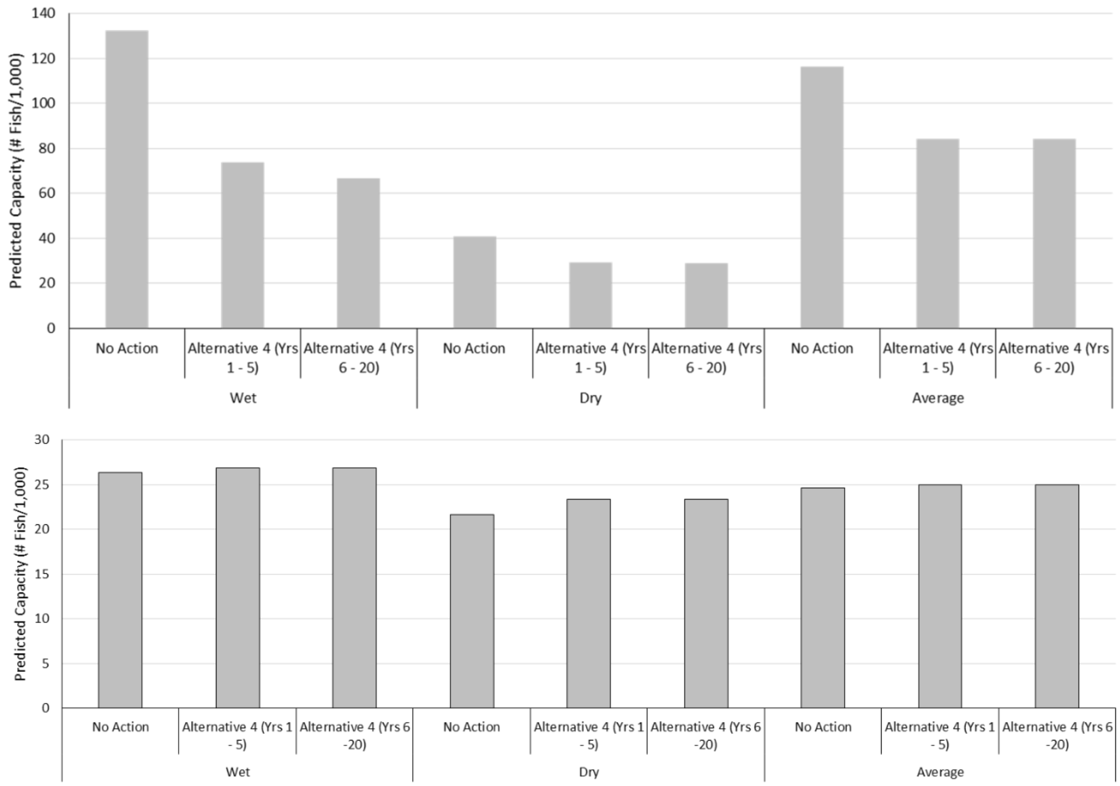
Figure 77. Juvenile Steelhead Summer Capacity Estimates for the Mainstem Crooked River under the No-Action Alternative and Alternative 4



Results of modeling winter juvenile rearing capacity are inconclusive. The decline in capacity under Alternative 4 shown in Figure 78 (top figure) is from effects of summer water temperatures affecting abundance of steelhead in the winter. However, these results may not reflect winter conditions for juvenile rearing with increased minimum streamflows. The results presented in Figure 78 represent effects of summer maximum water temperatures and winter streamflows on winter capacity (Mount Hood Environmental 2019). It is unclear if higher winter minimum streamflows (Conservation Measure CR-1) would affect summer water temperatures in the Crooked River. Therefore, Figure 78 also presents model results assuming a fixed summer maximum temperature (22 °C) under the no-action alternative and Alternative 4 across the entire permit term. In this analysis steelhead winter capacity increases slightly under Alternative 4 in the dry year type with an increase in winter streamflows consistent with Conservation Measure CR-1.

It is likely higher minimum winter streamflows (Conservation Measure CR-1) and summer water temperatures are independent and higher minimum winter streamflows under Alternative 4 would improve winter habitat conditions for juvenile steelhead.

Figure 78. Juvenile Steelhead Winter Capacity Estimates for the Mainstem Crooked River under the No-Action Alternative and Alternative 4 (top variable summer water temperatures and bottom fixed summer water temperatures)



Water Temperature Results

Figures 79 through 81 summarize temperature thresholds and predicted temperatures for steelhead trout spawning, egg incubation, and juvenile rearing.

Water temperatures during spawning and egg incubation would not be affected by water management under Alternative 4 (Figures 79 and 80). The number of days in the preferred category tended to not change or increased over the permit term for the year types.

Analysis of temperature thresholds for juvenile steelhead rearing suggest an effect of water management on temperatures (Figure 81). The number of days in the avoidance category in the wet water year in the reach immediately downstream of Bowman Dam increased from 33 days under the no-action alternative to 63 days under Alternative 4 by the end of the permit term. In addition, there were more warm days in the normal water year toward the end of the permit term. The number of suboptimal days increased from 77 days to 105 days in the reach immediately downstream of Bowman Dam (Reaches Cro-10; RMs 70.5 to 55.9). The number of days in the stress/disease category increased in Reaches Cro-9 and Cro-8 (RMs 55.9 to 46.7).

Release of water in June, July, and August in the 2020 RiverWare model may provide additional cool water relief for steelhead trout present through the summer in the Crooked River.

Summary Crooked River

Habitat model results are inconclusive (Figures 77 and 78). Results suggest an adverse effect on winter capacity (Figure 78 top), but that may not reflect winter streamflows because of effects of summer temperatures included in the model.

Irrigation season effects in reaches of the Crooked River described for the proposed action at full implementation would also occur under Alternative 4. These effects would increase, though only slightly, in the reach between the North Unit ID pumps and Osborne Canyon, despite instream protection of uncontracted (fish and wildlife) storage releases in this reach. This is due to further increased reliance of North Unit ID pumps on the Crooked River to compensate for further decreased Upper Deschutes water supply under Conservation Measure WR-1.

Higher winter streamflows under Alternative 4 would provide additional benefits to juvenile and adult steelhead in the Crooked River.

Figure 79. Predicted Percentage Days within Water Temperature Thresholds for Spawning Steelhead Trout for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 4 Years 6–20 Compared to the No-Action Alternative

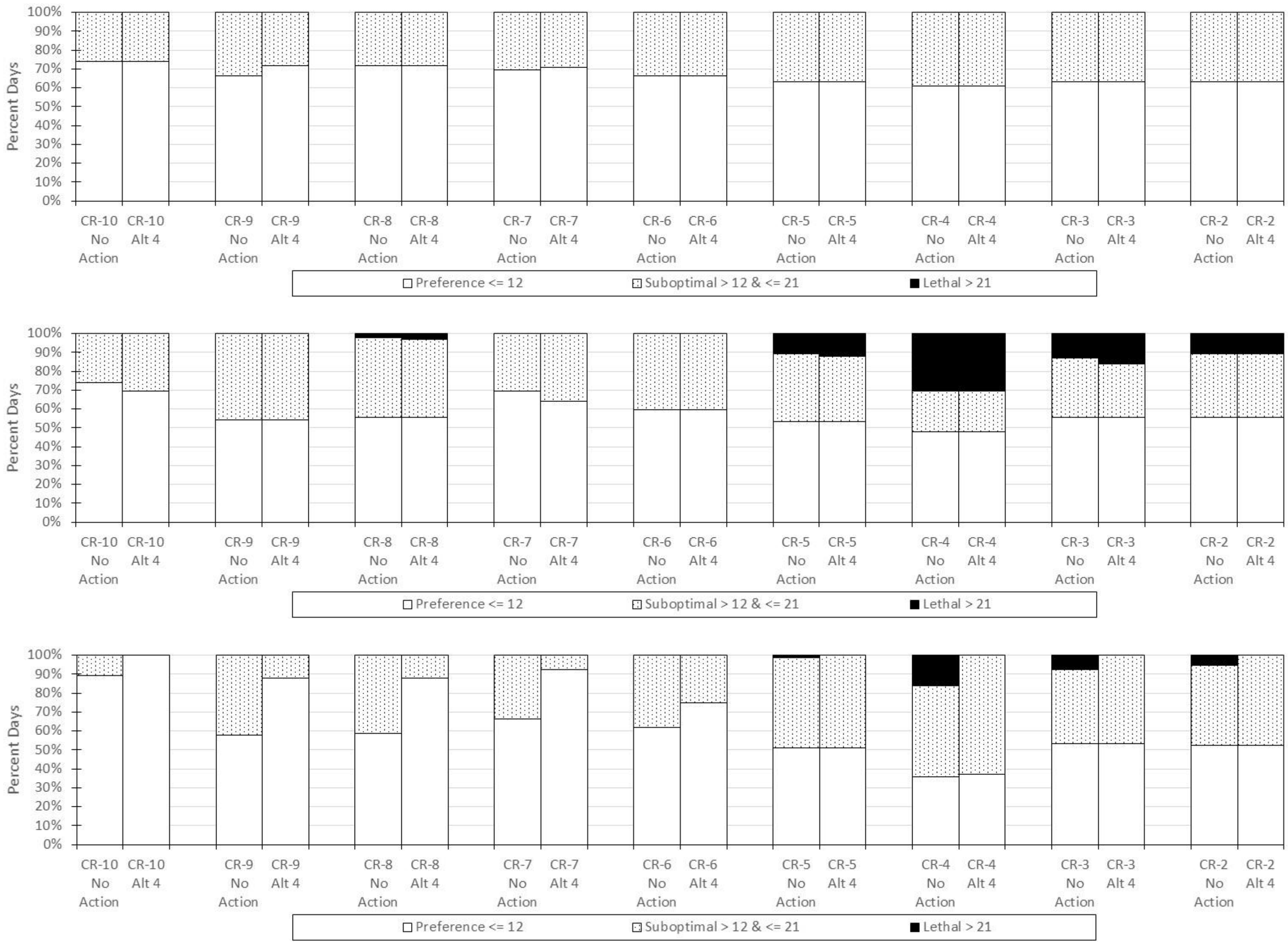


Figure 80. Predicted Percentage Days within Water Temperature Thresholds for Steelhead Trout Egg Incubation for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 4 Years 6–20 Compared to the No-Action Alternative

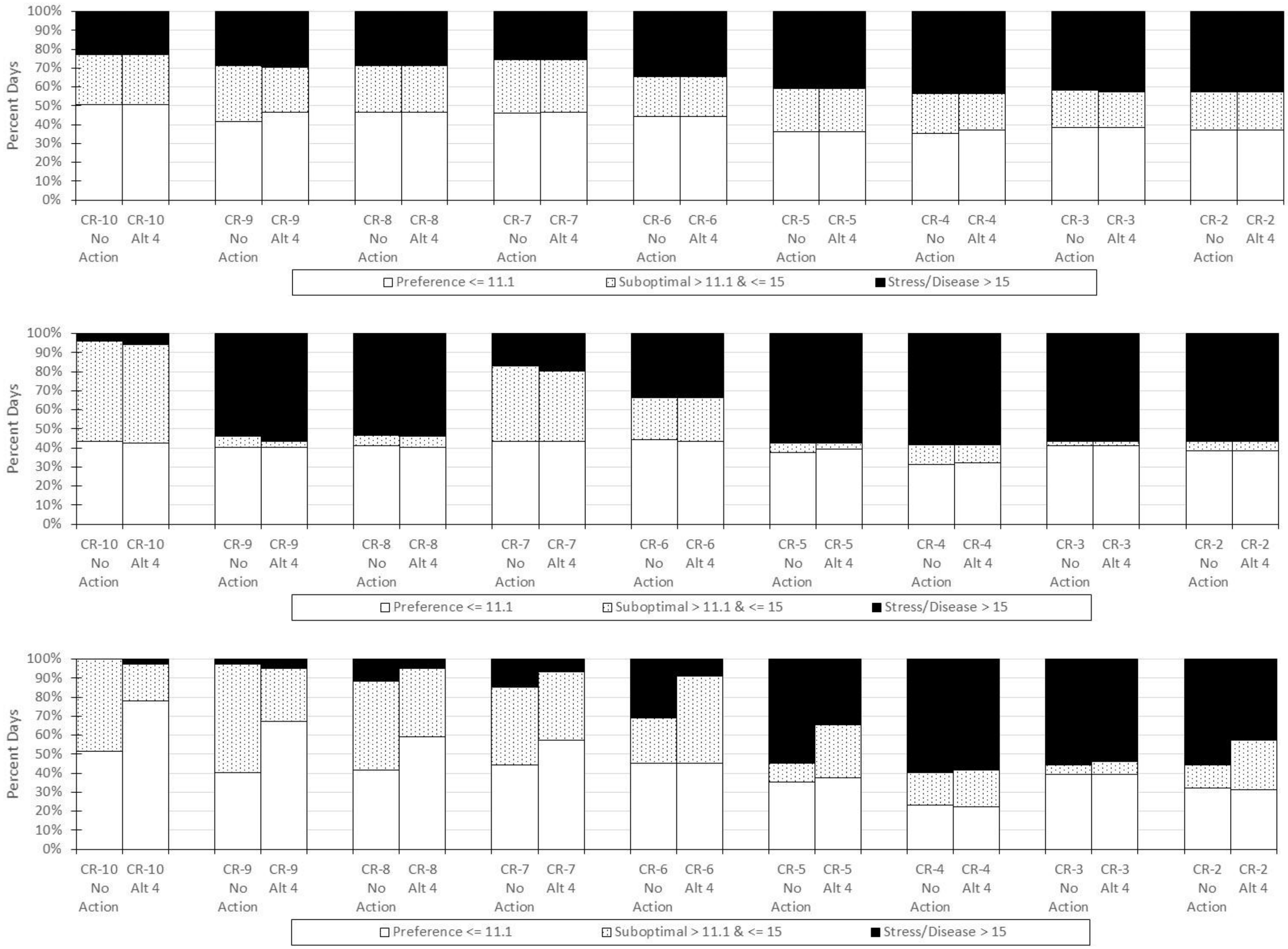
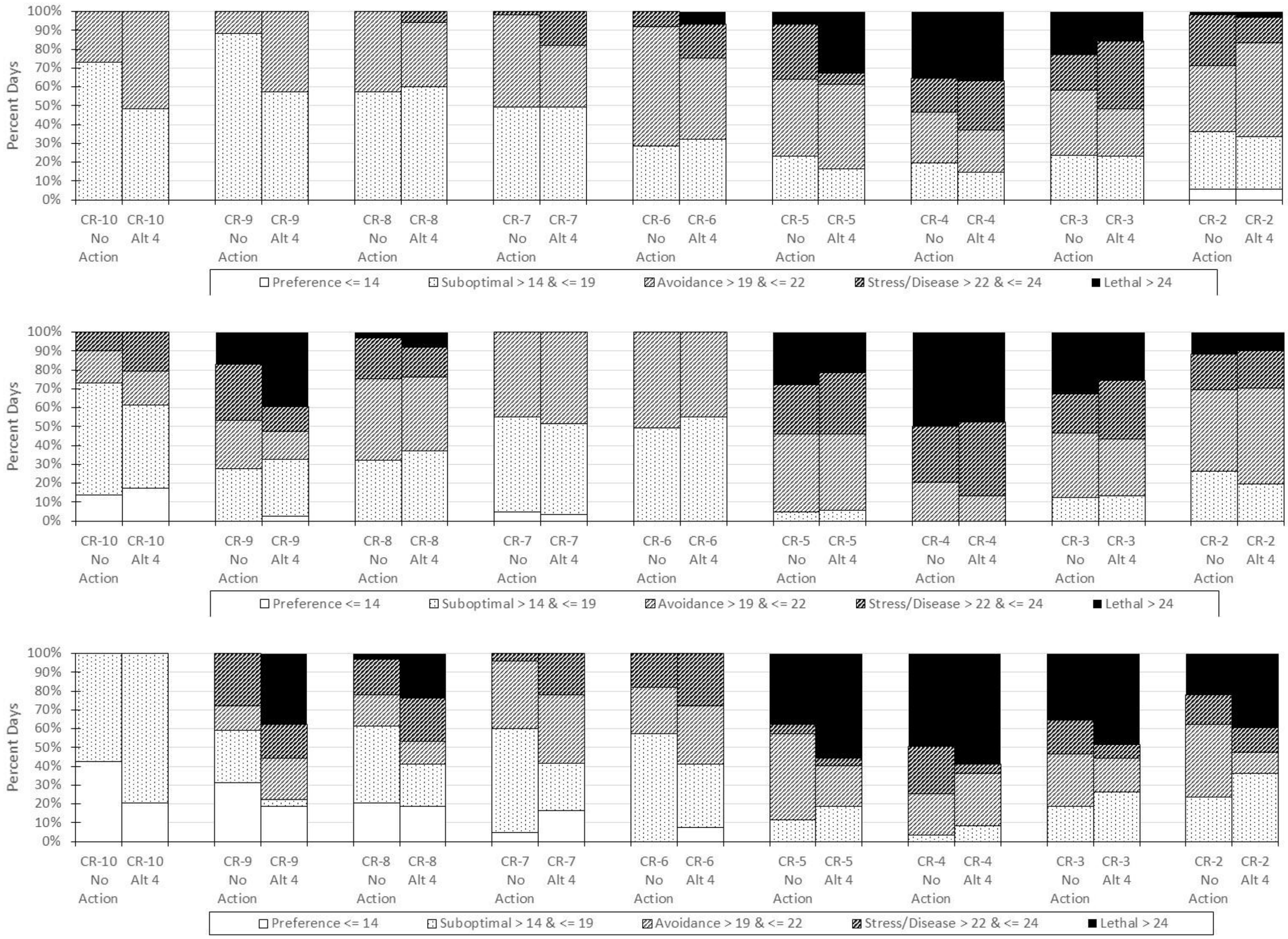


Figure 81. Predicted Percentage Days within Water Temperature Thresholds for Juvenile Steelhead Trout Rearing for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 4 Years 6–20 Compared to the No-Action Alternative



BIO-7: Affect Steelhead Trout Migratory Life Stages

Changes in streamflows and reservoir elevations and variability would be the same or nearly the same type as described for the proposed action for all reaches except for the Middle Deschutes River and Crooked River, which are described below.

Middle Deschutes

Under Alternative 4 streamflows in the Deschutes River at the CULO gauge are predicted to increase slightly during the winter (mid-October to the end of March) in years 1 through 5 and moderately in years 6 through 20 of the permit term, but of greater magnitude at full implementation. The flow increases in the Middle Deschutes are due to increased releases from Wickiup Reservoir in above-normal and wet years under this alternative (Conservation Measure WR-1).

Streamflows decline beginning approximately mid-April with the start of irrigation diversions when smolts would be migrating to sea. However, predicted streamflows during this period under Alternative 4 are no different than under the no-action alternative. While there would be a small to moderate increase in winter streamflows over the permit term, they would be insufficient to suggest a beneficial effect. Thus, there would be no effect relative to the no-action alternative during this period.

Crooked River

In the Crooked River minimum winter streamflows would increase to 80 cfs under Conservation Measure CR-1.

The analysis considered the effects of water management on adult migration and temperature thresholds (Figure 82), smolt migration and temperature thresholds (Figure 83), and any evidence that streamflows may impair adult or juvenile migration.

Effects on steelhead migratory life stages under Alternative 4 would be the same type as described for the proposed action. There would be no effect on steelhead trout migratory life stages in the Crooked River under Alternative 4 because streamflows would not affect water temperatures across the permit term compared to the no-action alternative (Figures 82 and 83).

Summary Crooked River

In the Crooked River, Conservation Measures CR-1, CR-2, CR-3, CR-4, CR-5, CR-6, and CR-7 would result in beneficial effects on steelhead trout habitat. Not all of these are quantifiable. CR-7 protects pulse flows for migration below the North Unit ID pumps. Pulse flows is a management option considered by the resource agencies to improve migration survival.

Modeled water temperatures and thresholds for steelhead trout migration life stages show no adverse effect of water management on water temperatures and migration habitat.

Under the 2020 RiverWare model water released from Prineville Reservoir for the North Unit ID pump diversion may occur in June, July, or August depending on the year. Late June, July, and August releases may be beneficial to juvenile and adult steelhead migration.

Figure 82. Predicted Percentage Days within Water Temperature Thresholds for Adult Migrant Steelhead Trout for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 4 Years 6–20 Compared to the No-Action Alternative

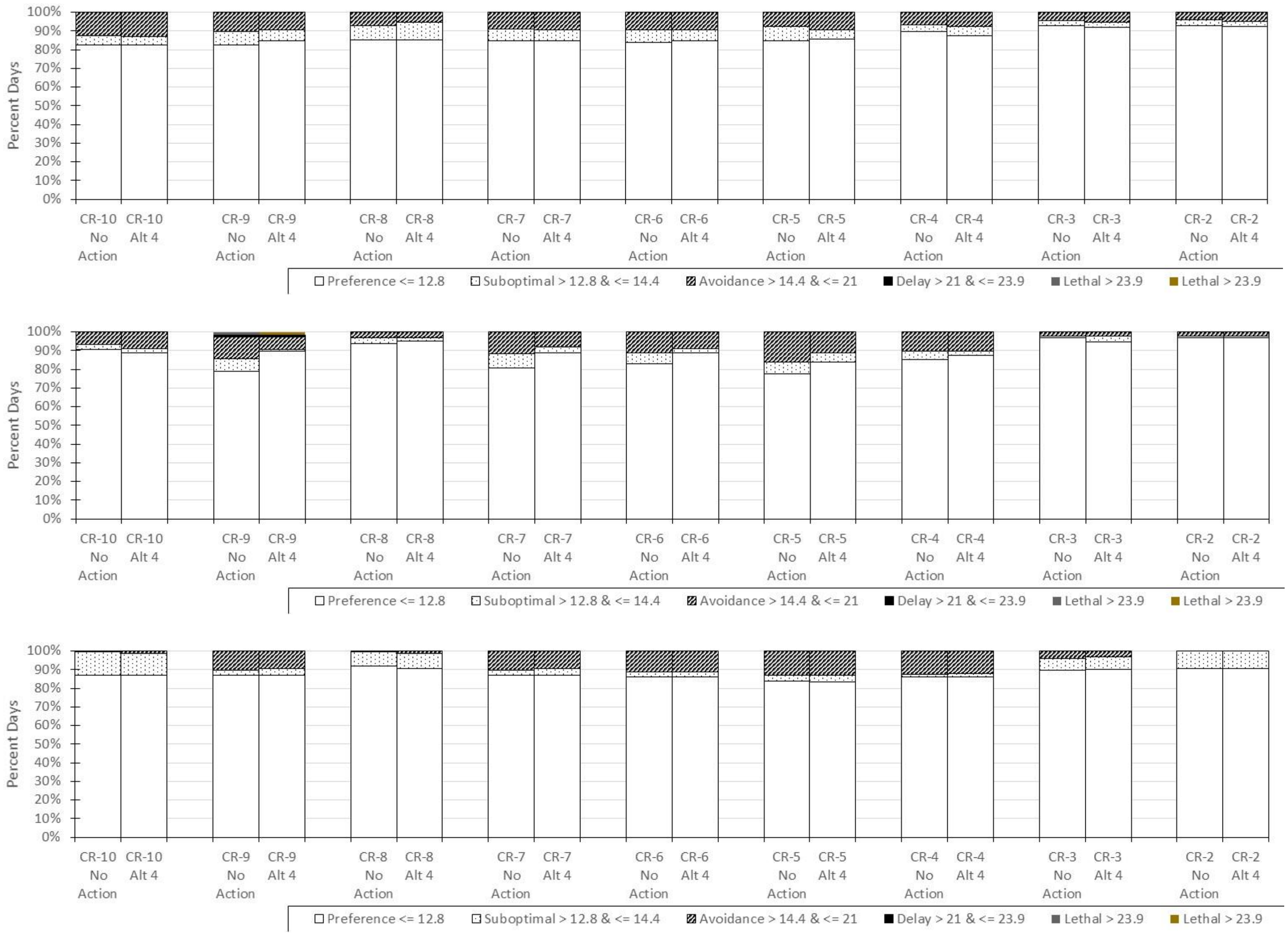
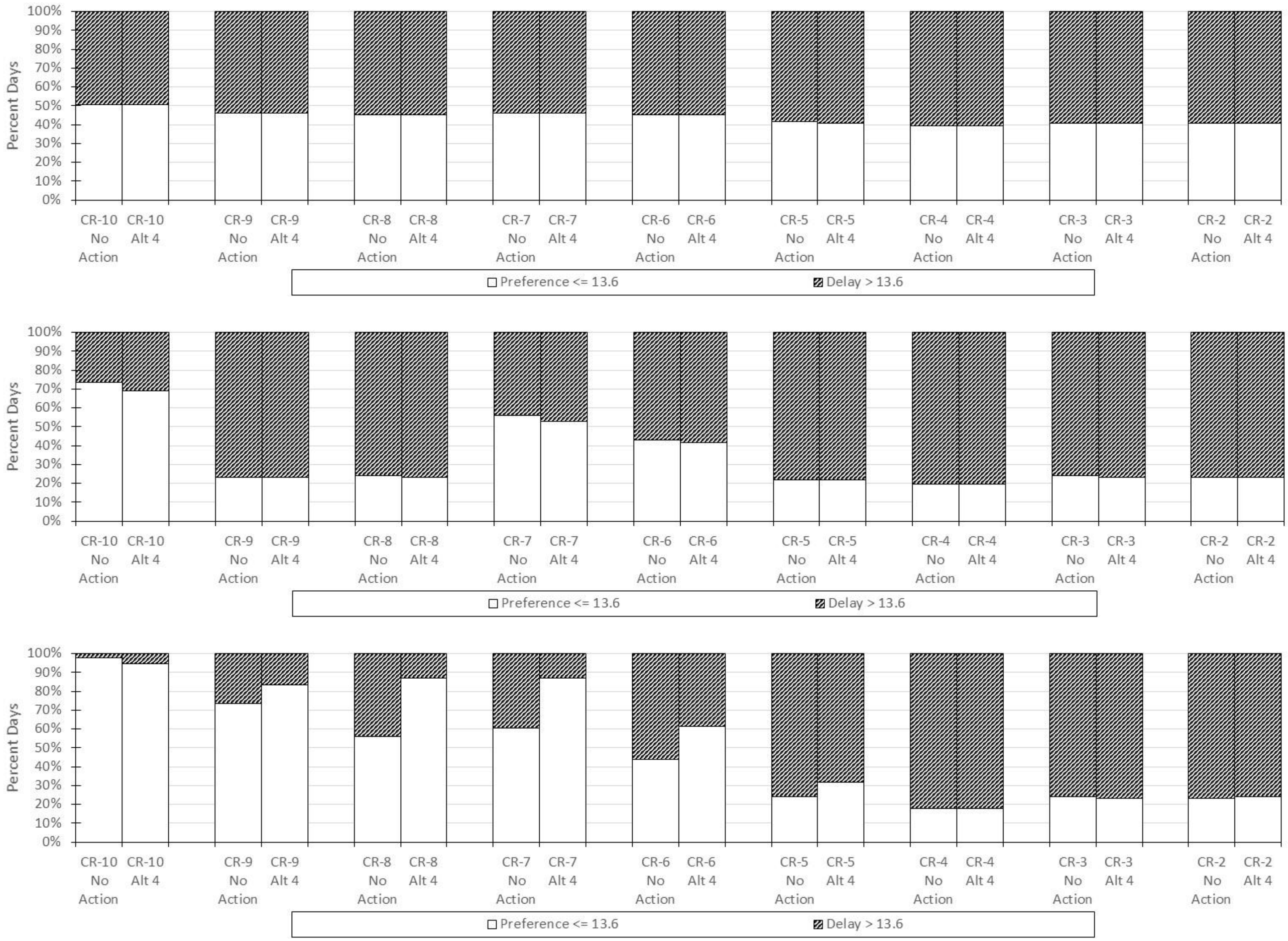


Figure 83. Predicted Percentage Days within Water Temperature Thresholds based on 2019 RiverWare Model for Steelhead Trout Smolts for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 4 Years 6–20 Compared to the No-Action Alternative



BIO-8: Affect Spring Chinook Salmon Habitat

Changes in streamflows and reservoir elevations and variability would be the same or nearly the same type as described for the proposed action for all reaches except for the Middle Deschutes River and Crooked River, which are described below.

Middle Deschutes

Under Alternative 4 streamflows in the Deschutes River at the CULO gauge are predicted to increase slightly during the winter (mid-October to the end of March) in years 1 through 5 and moderately in years 6 through 20, but of greater magnitude at full implementation. The flow increases in the Middle Deschutes are due to increased releases from Wickiup Reservoir in above-normal and wet years under this alternative (Conservation Measure WR-1).

Streamflows decline beginning approximately mid-April with the start of irrigation diversions. During this period Chinook eggs may still be in the gravel, but likely spring Chinook fry that recently emerged from the gravel are free swimming and are present along shallow bank or pools in the Middle Deschutes River. However, predicted streamflows during this period and in the fall with the end of irrigation under the Alternative 4 are no different than the no-action alternative. Thus, there would be no effect relative to the no-action alternative during this period.

There would be no effect on spring Chinook in the accessible portion of the Deschutes River. The relatively small to moderate increases in winter streamflows over the permit term likely are not enough to suggest a beneficial effect for this species.

Crooked River

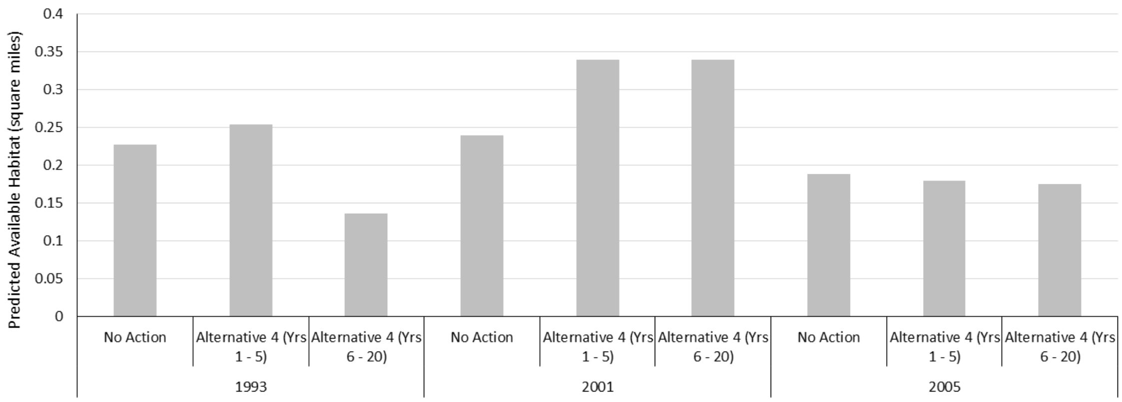
In the Crooked River minimum winter streamflows would increase to 80 cfs under Conservation Measure CR-1.

In the Crooked River reach between the North Unit ID pumps and Osborne Canyon adverse effects would be of slightly lesser magnitude than described for the proposed action due to instream protection of uncontracted (fish and wildlife) releases under this alternative (Conservation Measure CR-1).

Habitat Model Results

Results of modeling available summer habitat for Chinook juvenile rearing are inconclusive. Effects of water management on available habitat and water temperatures are not suggesting any particular trend between the no-action alternative and Alternative 4 (Figure 84).

Figure 84. Estimate of Juvenile Chinook Summer Habitat Availability for the Mainstem Crooked River under the No-Action Alternative and Alternative 4



Water Temperature Results

Figures 85 through 87 summarize temperature thresholds and predicted temperatures for spring Chinook spawning, egg incubation and juvenile rearing.

Similar to the proposed action, analysis of temperature thresholds for spring Chinook life stages indicate an effect of timing of release of water from Bowman Dam on water temperatures. Analysis of temperature thresholds for spring Chinook salmon spawning suggests an adverse effect on water management operations on water temperatures under modeled streamflows (Figure 85).

The greatest effect is spring Chinook juvenile rearing (Figure 87). The number of days in the stress/disease category in the wet water year in the reach immediately downstream of Bowman Dam increased from 28 days under the no-action alternative to 61 days under Alternative 4 by the end of the permit term. There were more warm days in the normal water year toward the end of the permit term. The number of stress/disease days increased from 41 days to 67 days in the reach immediately downstream of Bowman Dam (Cro-10). The number of days in the optimal category decreased from 47 days to 24 days in reach CR-9, downstream of the canyon reach and from 53 days to 25 days in reach CR–8, upstream of Prineville. In Cro-9 the number of days in the lethal category increased from 34 days to 68 days and in Cro-8 the number of days in the lethal category increased from 27 days to 57 days.

Effects of water management on water temperature in lower reaches (Cro-7 through Cro-2) tended to be more variable as temperatures were warmer under the no-action alternative and effects of water management from Bowman Dam have less of an influence on water temperatures (Berger et al. 2019). Overall there was a tendency for more days in the stress/disease and lethal categories under the proposed action.

Water temperatures thresholds were not explicitly evaluated for adult spring Chinook holding through the summer in the Crooked River. However, similar to the proposed action, the additional number of warm days toward the end of the permit term indicate a worsening of habitat conditions for spring Chinook adults holding through the summer.

Summary Crooked River

Habitat model results are inconclusive, results suggest no trend toward better or worsening amount of available habitat. However, these results do not reflect variation in summer streamflows and cumulative effects of summer water temperatures.

Similar to the proposed action, there could be an adverse effect toward the end of the permit term based on the wet, dry, and normal year type water temperature simulations.

Under the 2020 RiverWare model water released from Prineville Reservoir for the North Unit ID pump diversion may occur in June, July, or August depending on the year. Late June, July, and August releases may be beneficial to juvenile spring Chinook rearing through the summer in the Crooked River by reducing temperatures during the warmest periods.

Figure 85. Predicted Percentage Days within Water Temperature Thresholds for Spawning Spring Chinook for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 4 Years 6–20 Compared to the No-Action Alternative

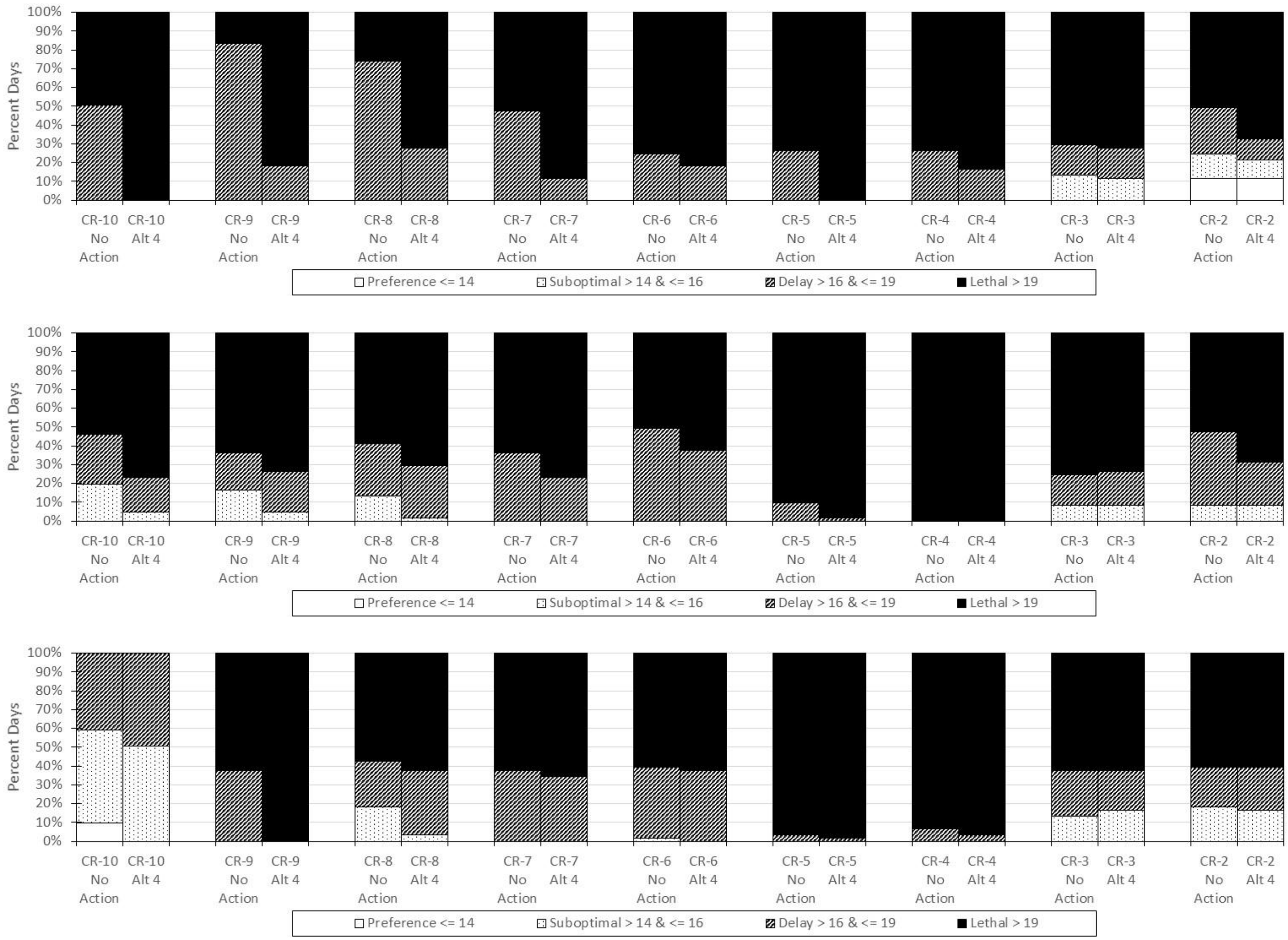


Figure 86. Predicted Percentage Days within Water Temperature Thresholds for Spring Chinook Egg Incubation for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 4 Years 6–20 Compared to the No-Action Alternative

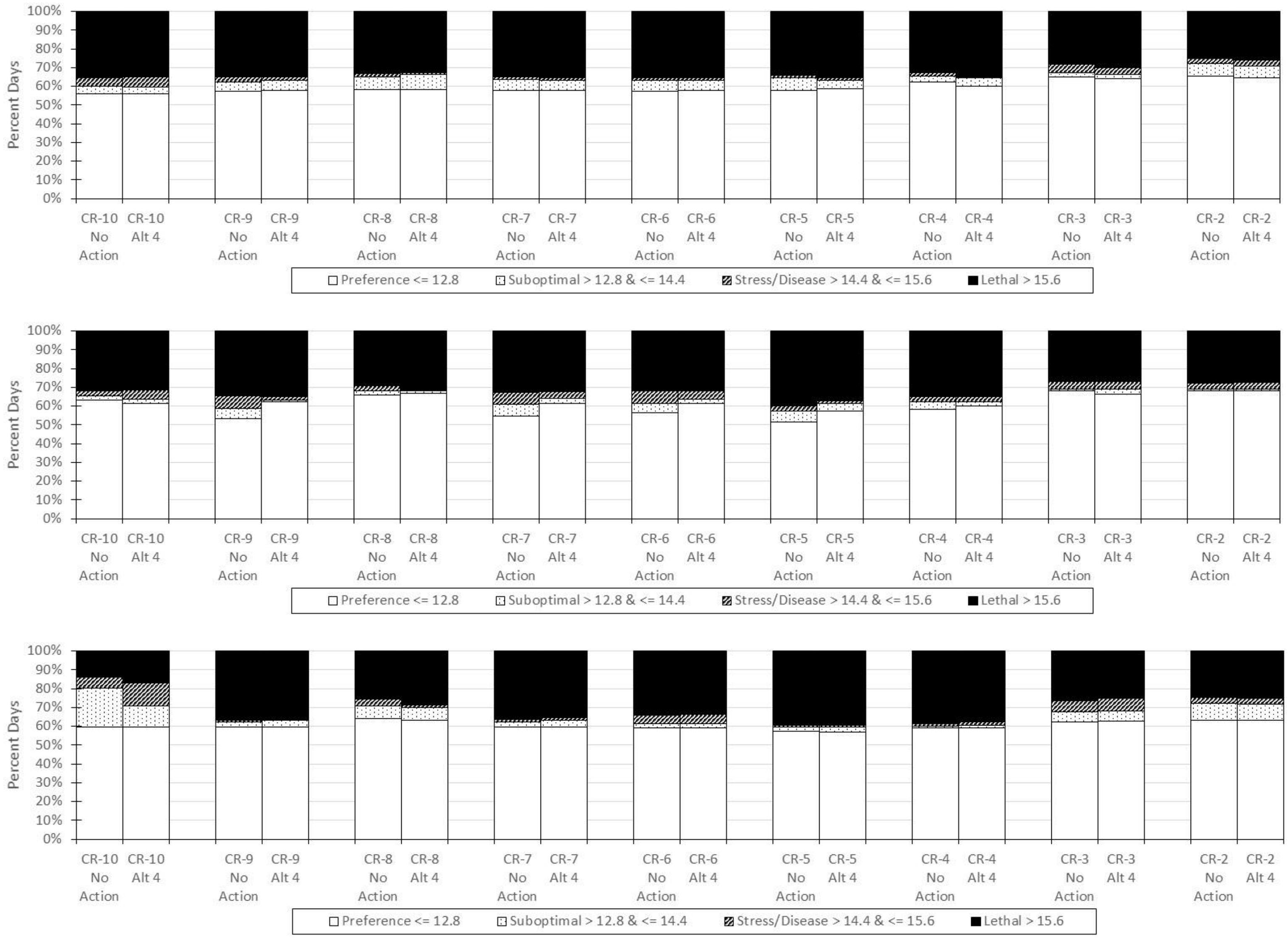
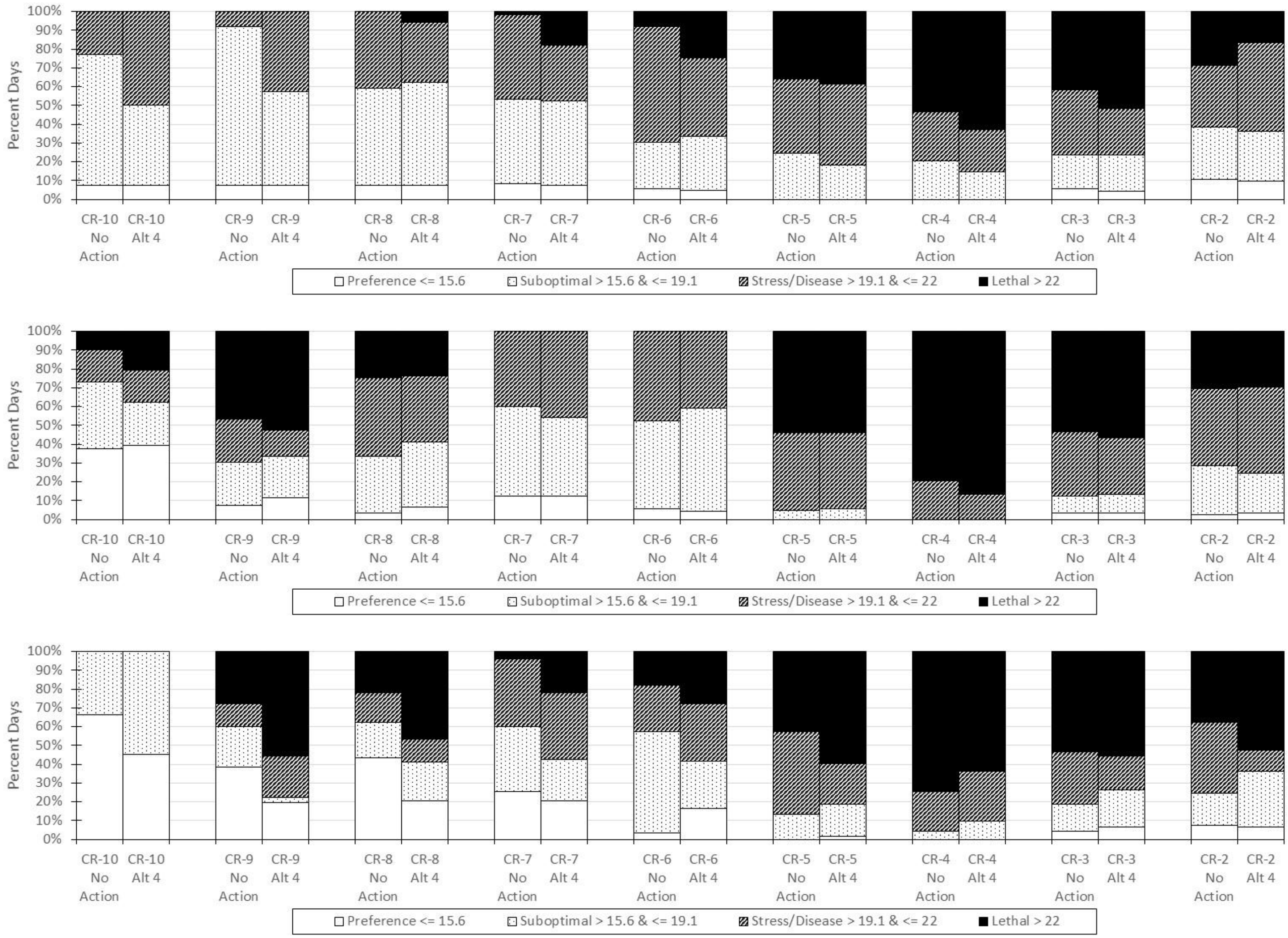


Figure 87. Predicted Percentage Days within Water Temperature Thresholds for Juvenile Spring Chinook Rearing (June–September) for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 4 Years 6–20 Compared to the No-Action Alternative



BIO-9: Affect Spring Chinook Salmon Migratory Life Stages

Changes in streamflows and reservoir elevations and variability would be the same or nearly the same type as described for the proposed action for all reaches except for the Middle Deschutes River and Crooked River, which are described below.

Middle Deschutes

There would be no effect on migrating spring Chinook in the accessible portion of the Deschutes River. The relatively small to moderate increase in winter streamflows over the permit term were likely not enough to suggest a beneficial effect for this species.

Crooked River

Water Temperature

The results of adult migration temperature thresholds are shown in Figure 88. Smolt migration thresholds are shown in Figure 89.

Similar to the proposed action, Alternative 4 would have no effect on migrating spring Chinook salmon adults attempting to move upstream in the spring or downstream migrating smolts because of water temperature effects on these life stages would be minor. However, the effect of water temperature on adult spring Chinook salmon migration habitat in July and August would be potentially adverse because the potential for migration effects exist but are not conclusive based on the available data.

Under the 2020 RiverWare model water released from Prineville Reservoir for the North Unit ID pump diversion may occur in June, July, or August depending on the year. Late June, July, and August releases may be beneficial to migrating adult spring Chinook rearing in the Crooked River by reducing temperatures during the warmest periods.

Figure 88. Predicted Percentage Days within Water Temperature Thresholds for Migrating Adult Spring Chinook (March–June) for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 4 Years 6–20 Compared to the No-Action Alternative

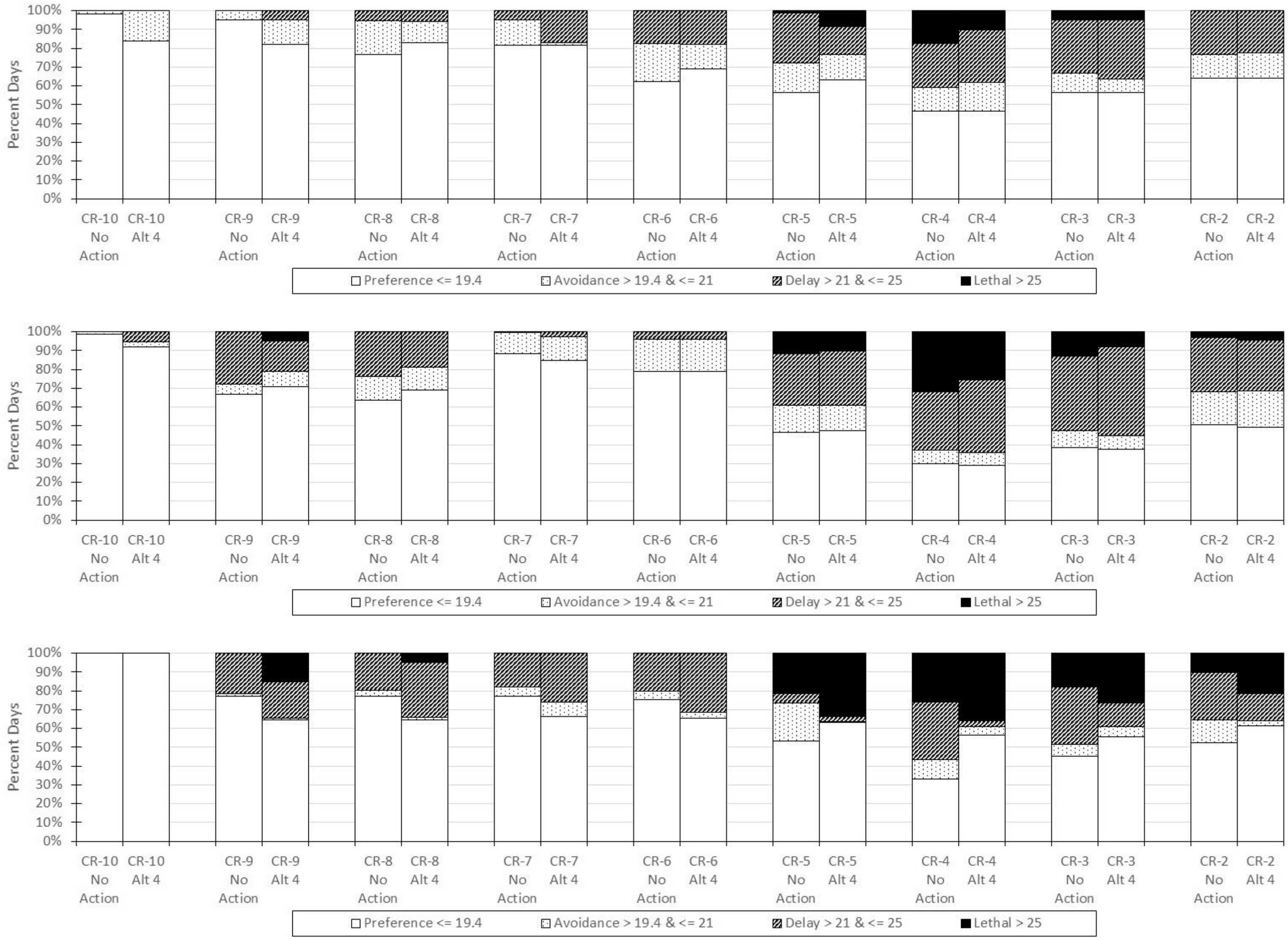
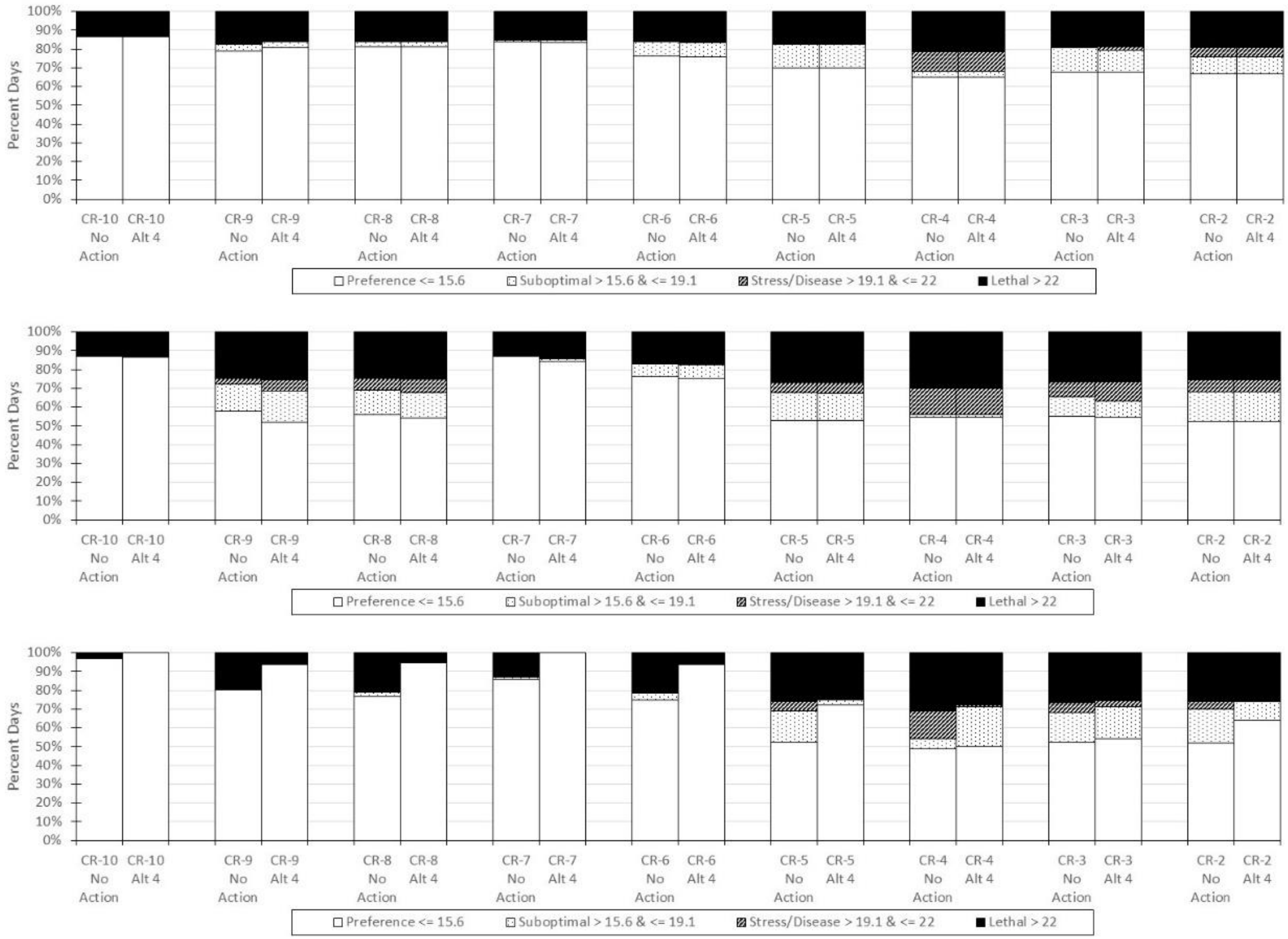


Figure 89. Predicted Percentage Days within Water Temperature Thresholds for Migrating Smolt Spring Chinook for a Wet (top), Dry (middle), and Normal (bottom) Year under Alternative 4 Years 6–20 Compared to the No-Action Alternative



BIO-10: Affect Sockeye Salmon Habitat

Changes in streamflows and reservoir elevations and variability would be the same or nearly the same type as described for the proposed action for all reaches except for the Middle Deschutes River and Crooked River, which are described below.

Middle Deschutes

Under Alternative 4 streamflows in the Deschutes River at the CULO gauge are predicted to increase slightly during the winter (mid-October to the end of March) in years 1 through 6 and moderately in years 6 through 20.

Streamflows decline beginning approximately mid-April with the start of irrigation diversions, about the time sockeye fry would be emerging from the gravel to migrate to Lake Billy Chinook. However, predicted streamflows under Alternative 4 are no different than the no-action alternative during this period and in the fall at the end of irrigation when sockeye adults may be attempting to spawn. There would be no effect relative to the no-action alternative.

Because of the relatively small increase in winter flows over the permit term and patterns of use by sockeye, there would be no adverse effect on habitat for sockeye salmon in the reach accessible to this species.

Crooked River

Adult sockeye salmon may enter the Crooked River in the fall to spawn in the lower section of the river, downstream of Opal Springs hydroelectric project. Eggs would remain in the gravel through the winter. Newly emerged fry would migrate to Lake Billy Chinook in the spring for juvenile rearing. The limited use by sockeye suggests any effects of water management on sockeye salmon habitat would be limited to availability of spawning and egg incubation habitat in the lower river, downstream of Opal Springs hydroelectric project.

Under the Alternative 4, modeled streamflows in the Crooked River at the Opal node in the lower river (Reaches Cro-1.2 and Cro-1.1; RMs 7.3 to 0) are relatively unchanged compared to the no-action alternative for the entire permit term. The changes in flow from upstream water management are too small in the context of the high volume groundwater inflow upstream of the Opal node to result in effects on the species in this reach. Therefore, there would be no effect on habitat for sockeye salmon in the portion of the Crooked River used by sockeye salmon for spawning.

BIO-11: Affect Sockeye Salmon Migratory Life Stages

Changes in streamflows and reservoir elevations and variability would be the same or nearly the same type as described for the proposed action for all reaches except for the Middle Deschutes River and Crooked River, which are described below.

Middle Deschutes

Under Alternative 4 streamflows in the Deschutes River at the CULO gauge are predicted to increase slightly during the winter (mid-October to the end of March) in years 1 through 6 and moderately in years 6 through 20.

Streamflows decline beginning approximately mid-April with the start of irrigation diversions, about the time sockeye fry would be emerging from the gravel to migrate to Lake Billy Chinook. However, predicted streamflows under Alternative 4 are no different than the no-action alternative during this period and in the fall at the end of irrigation when sockeye adults may be attempting to enter the Deschutes River to spawn. Thus, there would be no effect relative to the no-action alternative.

Because of the relatively small increase in winter flows over the permit term and patterns of use by sockeye salmon, there would be no effect on migratory life stages for this species in the portion of the reach accessible to the species.

Crooked River

Adult sockeye salmon may enter the Crooked River in the fall to spawn in the lower section of the river, downstream of the Opal Springs hydroelectric project. The limited use by sockeye salmon suggests any effects of water management on sockeye salmon migration habitat would be limited to the lower river, downstream of the Opal Springs hydroelectric project. Under Alternative 4, RiverWare modeled streamflows in the Crooked River at the Opal node in the lower river are unchanged or change slightly (less than 2%) compared to the no-action alternative for the entire permit term. The changes in flow are too small to result in migration effects on sockeye salmon when considered in context with the high volume of groundwater inflow upstream of the Opal node. Therefore, there would be no effect on adult or juvenile migration life stages for this species in the portion of the Crooked River likely used by sockeye salmon for spawning and egg incubation.

BIO-12: Affect Redband Trout Habitat

Changes in streamflows and reservoir elevations and variability and therefore effects on redband trout habitat under Alternative 4 compared to the no-action alternative would be the same or nearly the same type as described for the proposed action and Alternative 3 for all reaches except for Wickiup Reservoir, the Upper and Middle Deschutes River, the Little Deschutes River, and the Crooked River.

Wickiup Reservoir

Adverse effects in Wickiup Reservoir would also be the same type as described for Alternative 3 but of greater magnitude because variability in reservoir volume and elevation over the year would be of greater magnitude and occur earlier.

Upper Deschutes River

In the Upper Deschutes River, increased winter streamflows and decreased summer streamflows and associated benefits for redband trout would be the same type as described for the proposed action and Alternative 3, but of greater magnitude at full implementation due to increased releases from Wickiup Reservoir in above-normal and wet years under this alternative (Conservation Measure WR-1).

Little Deschutes River

Under Alternative 4 streamflows would be the same as described for Alternative 3, unchanged from the no-action alternative and there would be no effect on redband trout habitat.

Crooked River

There would be a beneficial effect of higher minimum winter streamflows under Alternative 4, consistent with study findings by Porter and Hodgson (2016). The habitat model developed for steelhead for the Deschutes Basin HCP analysis supports their findings. Higher winter streamflows would increase habitat capacity for juvenile steelhead. The same conclusion is applicable to juvenile redband trout.

Water temperatures in the Upper Crooked River reach (Cro-10) are less affected by water management compared to downstream reaches, which experience more warming with change in streamflow. This finding suggests habitat would not change as much in this key reach as downstream. However, warming of water temperatures in downstream reaches could impact redband trout movement in the Crooked River and their ability to occupy habitats elsewhere in the Crooked River.

Under the 2020 RiverWare model water released from Prineville Reservoir for the North Unit ID pump diversion may occur in June, July, or August depending on the year. Late June, July, and August releases may be beneficial to redband trout through the summer in the Crooked River by reducing temperatures during the warmest periods.

BIO-13: Affect Nonnative Resident Trout Habitat

Effects on nonnative resident trout under Alternative 4 would be the same type as described for the proposed action in all geographic areas except the Crooked River, which would experience the same effects as described for redband trout under Alternative 4.

BIO-14: Affect Summer/Fall Chinook Salmon Habitat

Summer/Fall Chinook salmon distribution is limited to the Lower Deschutes, downstream of the Pelton-Round Butte Complex. Under the Alternative 4 streamflows in the Lower Deschutes River at the Madras gauge are predicted to increase slightly during the winter. The increase in streamflows are considered minor. There would be no effect on habitat used by this species in the Lower Deschutes River.

BIO-15: Affect Kokanee Salmon Habitat

Effects on kokanee salmon habitat and migratory life stages under Alternative 4 would be the same type as described for the proposed action except Wickiup Reservoir.

Wickiup Reservoir

The predicted more extreme variation in reservoir elevations and lower volumes over the permit term will adversely affect kokanee habitat in the reservoir to a greater extent compared to the proposed action and Alternative 3. Effects will be extreme over the entire permit term.

The extreme variation in reservoir volume over the year likely will cause additional effects on the population by entrainment at the dam outlet and downstream displacement of kokanee salmon into the Deschutes River.

There would be an adverse effect overall because of extremely low reservoir elevations and volumes in most years and extreme seasonal differences.

BIO-16: Affect Native Non-Trout and Non-Game Fish Habitat

Effects on native non-trout and non-game fish habitat under Alternative 4 compared to the no-action alternative would be the same type as described for the proposed action in all reaches except the Little Deschutes River, the Upper Deschutes River, Wickiup Reservoir, and the Crooked River. There would be no effect on native non-trout habitat in the Little Deschutes River for the reasons described for redband trout (BIO-12). Beneficial and potential adverse effects on the Upper Deschutes River would be of greater magnitude and with implementation of habitat restoration activities funded through Conservation Measure UD-1 under Alternative 4 could offset potential adverse effects and increase beneficial effects. Adverse effects in Wickiup Reservoir would be the same type as described for the proposed action and Alternative 3, but of greater magnitude because within-year variability in reservoir volume and elevation would be greater. Adverse effects in the Crooked River would also be the same type as described for the proposed action but of slightly greater magnitude because of slightly warmer temperatures in the summer. The duration of these adverse effects would be between the proposed action and Alternative 3.

BIO-17: Affect Freshwater Mollusk Habitat

Effects on freshwater mollusk habitat would be the same type as described for the proposed action for all reaches except for the Little Deschutes River and Crooked River, which is described below. In the Little Deschutes River there would be no change in streamflows under Alternative 4. In the Deschutes River, there would be a higher magnitude of increased fall and winter flows and decreased irrigation season flows compared to the proposed action; however, the overall effects on species habitat would be the same type as described under the proposed action.

Crooked River

Crater Lake Tightcoil and Evening Field Slug

The most important habitat element for Crater Lake tightcoil and evening field slug is perennially inundated soil. Under Alternative 4, flows increase in fall/ winter months in most years, but decrease especially in middle and upper reaches in late summer in many years. This could dry out the necessary perennially inundated habitat. Therefore, overall effects on would be adverse.

Floater Species Mussels

Floater species mussels have primarily been found in the lower Crooked River, with habitat just above the Northern Irrigation Unit Pump Diversion and further downstream. May through August is the critical period of reproduction and juvenile establishment for these mussels. While flows increase in May and June on average in the reaches measured by the CAPO gauge, they decrease significantly in July through September. Flows in reaches measured by the North Unit ID gauge decrease in median flows on average during this time period. Therefore, overall effects on would be adverse.

Floater species mussels are not known to be present in Ochoco and McKay Creeks. However, flows in Ochoco and McKay creeks would be unchanged; therefore, there would be no effect on this species if present.

Western Pearlshell Mussels

Western pearlshell mussels have records and suitable habitat throughout the Crooked River, and the critical period of reproduction and juvenile establishment is during May and June. Because flows under alternative 4 increase for many reaches as compared to no-action flows during this time period, there would be a beneficial effect for Western pearlshell mussels.

Western Ridged Mussels

Western ridged mussels have records and suitable habitat throughout the Crooked River, and the critical period of reproduction and juvenile establishment is June through August. Because of the increases in flow during the initial reproductive period on average in many reaches, but overall decreases in flows as compared to No-action during the latter part of their reproductive period (especially in August) in many reaches, there would be no adverse effect on Western ridged mussels.

Summary and Conclusions

This assessment compared the potential effects on fish and mollusk and their habitat of the proposed action, Alternative 3, and Alternative 4 to the no-action alternative.

Table 12 summarizes specific conclusions, indicating whether each alternative would have a beneficial effect, and adverse effect, or a mix of beneficial and adverse effects compared to the no-action alternative. Effects are summarized by species and geographic area.

Table 13 shows the overall direction for each species or species group. An overall “not adverse” finding acknowledges there are adverse effects in some portions of the study area, but when considering the mixture of effects, an overall adverse effect was not warranted.

Table 12. Fish and Mollusks Effects Summary for Proposed Action, Alternative 3, and Alternative 4

Affected Species or Habitat Type	Crescent Lake Reservoir	Crescent Creek	Little Deschutes	Crane Prairie Reservoir	Wickiup Reservoir	Upper Deschutes	Middle Deschutes	Tumalo Creek	Whychus Creek	Lake Billy Chinook/ Lake Simtustus	Crooked River	Prineville Reservoir	Ochoco Creek	McKay Creek	Lower Deschutes
BIO-4: Bull Trout Habitat							BE		BE	NE	AE		BE	BE	NE
BIO-5: Bull Trout Migratory Life Stages							BE		BE	NE	NE		BE	BE	NE
BIO-6: Steelhead Trout Habitat							BE		BE	NE	AE		BE	BE	NE
BIO-7: Steelhead Trout Migratory Life Stages							NE		BE	NE	NE		BE	BE	NE
BIO-8: Spring Chinook Salmon Habitat							NE		BE	NE	AE		BE	BE	NE
BIO-9: Spring Chinook Salmon Migratory Life Stages							NE		NE	NE	NA		BE	BE	NE
BIO-10: Sockeye Salmon Habitat							NE		NE	NE	NE				NE
BIO-11: Sockeye Migratory Life Stages							NE		NE	NE	NE				NE
BIO-12: Redband Trout Habitat	BE/ NE	NA/ NE	BE/ NE	BE	AE	NA/ BE	BE	NE	BE	NE	AE	NE	BE		NE
BIO-13: Nonnative Resident Trout Habitat			BE/ NE		AE	BE	BE		BE		AE		BE	BE	NE
BIO-14 Summer/Fall Chinook Salmon Habitat															NE
BIO-15: Kokanee Salmon Habitat and Migratory Life Stages	NE			BE	AE		NE		NE	NE	NE				
BIO-16: Native Non-Trout and Non-Game Species Fish Habitat	NE	NE	BE/ NE	BE	AE	BE	BE	NE	NE	NE	AE	NE	BE	BE	NE
BIO-17: Freshwater Mollusk Habitat	V	V	V/NE	BE	AE	V	V	NE	NE		V		NE	NE	NE

BE – Beneficial Effect; NE – No Effect; NA – Not Adverse; AE – Adverse Effect; V – Variable
PS; Blank – species not present
Proposed Action/Alts 3 and 4

Table 13. Fish and Mollusks Overall Effects Summary for Proposed Action, Alternative 3, and Alternative 4

Affected Species or Habitat Type	Proposed Action	Alternative 3	Alternative 4
BIO-4: Affect Bull Trout Habitat	NA	NA	NA
BIO-5: Affect Bull Trout Migratory Life Stages	BE	BE	BE
BIO-6: Affect Steelhead Trout Habitat	NA	NA	NA
BIO-7: Affect Steelhead Trout Migratory Life Stages	NE	NE	NE
BIO-8: Affect Spring Chinook Salmon Habitat	NA	NA	NA
BIO-9: Affect Spring Chinook Salmon Migratory Life Stages	NA	NA	NA
BIO-10: Affect Sockeye Salmon Habitat	NE	NE	NE
BIO-11: Affect Sockeye Salmon Migratory Life Stages	NE	NE	NE
BIO-12: Affect Redband Trout Habitat	BE	NA	NA
BIO-13: Affect Nonnative Resident Trout Habitat	NA	NA	NA
BIO-14: Affect Summer/Fall Chinook Salmon Habitat	NE	NE	NE
BIO-15: Affect Kokanee Salmon Habitat and Migratory Life Stages	NA	NA	NA
BIO-16: Affect Native Non-Trout and Non-Game Species Fish Habitat	NA	NA	NA
BIO-17: Affect Freshwater Mollusk Habitat	V	V	V

BE – Beneficial Effect; NE – No Effect; NA – Not Adverse; AE – Adverse Effect; V - Variable

References Cited

Printed References

Batt, P.E. 1996. Governor Phillip E. Batt's State of Idaho Bull Trout Conservation Plan. Boise, Idaho. 20 pp.

Bell, M. C. 1986. Fisheries handbook of engineering requirements and biological criteria. Fish passage development and evaluation program. US Army Corps of Engineers, North Pacific Division. 290 pp.

Berger, C. and Wells, S. 2017. Technical Memorandum, Prineville Reservoir and Crooked River Temperature Model: Development, Calibration, and Scenarios. Department of Civil and Environmental Engineering, Portland State University. Portland, Oregon.

Berger, C., A. Cervarich, and S. Wells. 2019. Technical Memorandum Prineville Reservoir and Crooked River Temperature Model Development, Calibration, and Scenarios. Department of Civil and Environmental Engineering, Portland State University. Portland, Oregon. June 2019. 182 pp.

Blackburn, M. 2017. Species Fact Sheet: Pristiloma crateris. Final draft- version 1. Prepared by the Xerces Society for Invertebrate Conservation for the Inter-agency Special Status/ Sensitive Species Program.

Blevins, E., S. Jepsen, J. Brim Box, and D. Nez. 2016a. Margaritifera falcata (errata version published in 2017). The IUCN Red List of Threatened Species 2016: e.T91109639A114128748. http://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T91109639A91109660.en. Downloaded on 6 December 2018.

Blevins, E., S. Jepsen, J. BrimBox, and D. Nez. 2016b. Gonidea angulata (errata version published in 2017). The IUCN Red List of Threatened Species 2016: e.T17307A114146359. http://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T173073A62905403.en. Downloaded on December 10, 2018.

Blevins, E., Jepsen, S., Brim Box, J. & Nez, D. 2016c. Anodonta oregonensis (errata version published in 2017). The IUCN Red List of Threatened Species 2016: e.T189487A114131600. http://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T189487A69491650.en. Downloaded on 6 December 2018.

Blevins, E., L. McMullen, S. Jepsen, M. Blackburn, A. Code, and S.H. Black. 2018. Conserving the Gems of our Waters: Best Management Practices for Protecting Native Freshwater Mussels during Aquatic and Riparian Restoration, Construction, and Land Management Projects and Activities. The Xerces Society for Invertebrate Conservation, Portland, OR. 108 pp.

Burke, T.E. and N. Duncan. 2005 (original version 1998). Conservation Assessment for Deroceras hesperium, evening fieldslug. USDA Forest Service Region 6 and USDI Bureau of Land Management, Oregon and Washington. 16 pp.

Courter, I., K. Ceder, M. Vaughn, R. Campbell, F. Carpenter and G Engelgau. 2014. DBHCP Study 11 – Phase 2: Evaluation of steelhead trout and Chinook salmon summer rearing habitat, spawning habitat, and fish passage in the Upper Deschutes Basin. Report to the Deschutes Basin Board of Control and the City of Prineville, Oregon. September 26.

Deschutes National Forest. 2018. *Non-game fish species*. USDA Forest Service. Available: https://www.fs.usda.gov/detail/deschutes/recreation/fishing/?cid=stelprdb5278352. Accessed: 22 October 2018.

Fies, T., B. Lewis, M. Manion, and S. Marx. 1996a. Metolius River Subbasin Fish Management Plan. Oregon Department of Fish and Wildlife, Portland, Oregon. December 1996.

Fies, T., J. Fortune, B. Lewis, M. Manion, and S. Marx. 1996b. Upper Deschutes River Subbasin Fish Management Plan. Oregon Department of Fish and Wildlife, Portland, Oregon. October 1996.

Groot, C. and L. Margolis. *Pacific Salmon: Life Histories*. 1991. UBC Press, British Columbia, Canada. 576 pp. Halofsky, J. E., D. L. Peterson, and J. J. Ho. 2018. Climate Change Vulnerability and Adaptation in South Central Oregon. Portland, OR: USDA Forest Service General Technical Report PNW-GTR-XXXX. http://adaptationpartners.org/scoap/docs/SCOAP_GTR_Final.pdf

Hartman, W. L., C. W. Strickland, and D. T. Hoopes. 1962. Survival and behavior of sockeye salmon fry migrating into Brooks Lake, Alaska. *Transactions of the American Fisheries Society* 91(2): 133-141.

Interior Columbia Technical Recovery Team (ICTRT). 2008. *Current Status Reviews: Interior Columbia Basin Salmon and Steelhead ESUs. Volume III: Middle Columbia River Steelhead Distinct Population Segment (DPS)*. Draft, May 9.

Lichatowich, J.A. 1998. A conceptual foundation for the management of native salmonids in the Deschutes River basin. Portland General Electric Company. Portland, Oregon.

McCullough, D., S. Spalding, D. Sturdevant, M. Hicks. 2001. Issue Paper 5. Summary of technical literature examining the physiological effects of temperature on salmonids. Prepared as part of U.S. EPA Region 10 Temperature Water Quality Criteria Guidance Development Project. EPA-910-D-01-005.

Mount Hood Environmental. 2019a. Technical Memorandum: Juvenile Chinook (Onchorhychus tshawytscha) Rearing Habitat Area in the Crooked River, Oregon. DRAFT May 16, 2019. 14 pp.

Mount Hood Environmental. 2019b. Technical Memorandum: Juvenile Oncorhynchus mykiss Rearing Capacity in the Crooked River, Oregon: Model Results, Oregon. DRAFT May 16, 2019. 14 pp.

Murphy C.A., Arismendi I., Taylor G.A, Johnson S.L. 2019. Evidence for lasting alterations to aquatic food webs with short-duration reservoir draining. PLoS ONE 14(2): e0211870. https://doi.org/10.1371/journal.pone.0211870.

NatureServe. 2018. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available: http://explorer.natureserve.org. Accessed: 22 October 2018.

Nehlsen, W. 1995. Historical salmon and steelhead runs of the upper Deschutes River and their environments. Report to Portland General Electric Company, Portland, Oregon.

Oregon Department of Fish and Wildlife and Confederated Tribes of the Warm Springs. 2008. Reintroduction and Conservation Plan for Anadromous Fish in the Upper Deschutes River Sub-basin, Oregon. Edition 1: Spring Chinook and Summer Steelhead. October 2008. 84 pp.

Oregon Department of Fish and Wildlife. 2016. Sensitive Species List. Available: https://www.dfw.state.or.us/wildlife/diversity/species/docs/2016_Sensitive_Species_List.pdf. Accessed: November 1, 2018.

Porter, T. and B. Hodgson. 2016. Effects of a modified flow regime on the fish populations of the Crooked River below Bowman Dam. Oregon Department of Fish and Wildlife, Bend Oregon. 32 pp.

R2 Resource Consultants and Biota Pacific Environmental Sciences (R2 and Biota Pacific). 2013. *Deschutes Basin Habitat Conservation Plan Study Report; Study 2: Potential effects of covered activities on surface water temperature – Phase 1: releases, return plow, and discharges*. Prepared for the Deschutes Basin Board of Control and the City of Prineville, Oregon. March 2013. 54 pp.

R2 Resource Consultants and Biota Pacific Environmental Sciences (R2 and Biota Pacific). 2016. Crescent Creek and Little Deschutes River Hydrology Study. Prepared for the Deschutes Basin Board of Control and the City of Prineville, Oregon. November 2016. 54 pp.

River Design Group and HDR. 2017. Oregon Spotted Frog and Deschutes Redband Trout Habitat Modeling and Riparian Analysis at Two Sites on the Upper Deschutes River. Prepared for the Deschutes Basin Board of Control on behalf of the Basin Study Work Group. July 2017. 53 pp + appendices.

Schulz, E. E., and S. L. Thiesfeld. 1996. Kokanee spawning survey in the Metolius Basin - 1995. Portland General Electric Company, Portland, Oregon. [as cited in Lichatowich 1998].

Spateholts, B., M. Hill, and C. Quesada. 2008. Pelton Round Butte Project (FERC 2030) Native Fish Monitoring Plan License Article 421: 2007 Annual Report and 2008 Work Plan. Portland General Electric Company. Portland, Oregon.

Starcevich, S. and B. Bailey. 2015. 2015 Deschutes River Fisheries Monitoring Report: Assessing Redband Trout status in the middle and upper Deschutes River basin using young-of-the-year occupancy surveys in lateral habitats. Technical Report. Native Fish Investigations Program, Oregon Department of Fish and Wildlife. June 2017. 52 pp.

Stuart, A., S. Thiesfeld, T. Nelson, and T. Shrader. 1996. Crooked River subbasin fish management plan. Oregon Department of Fish and Wildlife, Portland, Oregon.

Torgersen, C.E., Hockman-Wert, D.P., Bateman, D.S., and Gresswell, R.E., 2007, Longitudinal patterns of fish assemblages, aquatic habitat, and water temperature in the Lower Crooked River, Oregon: U.S. Geological Survey Open-File Report 2007-1125, 36 p.

U.S. Fish and Wildlife Service (FWS). 2002. Chapter 7, Deschutes Recovery Unit, Oregon in US Fish and Wildlife Service. Bull Trout (Salvelinus confluentus) Draft Recovery Plan. Portland, Oregon. 62 pp.

U.S. Fish and Wildlife Service. 2017. *Biological Opinion: Approval of Contract Changes to the 1938 Inter-District Agreement for Operation of Crane Prairie and Wickiup Dams and Implementation of Review of Operations and Maintenance and Safety Evaluation of Existing Dams Programs at Crane Prairie and Wickiup Dams, Deschutes County, Oregon*. September 29. Bend Field Office, Bend, OR.

Xerces Society for Invertebrate Conservation (Xerces) and the Confederated Tribes of the Umatilla Indian Reservation Mussel Project (CTUIR). 2018. Western Freshwater Mussel Database.

Available at http://www.xerces.org/western-freshwater-mussels/. List of contributors available at: http://xerces.org/western-freshwater-mussel-database-contributors/.

Zimmerman, C. E., and G. H. Reeves. 2000. Population structure of sympatric anadromous and nonanadromous *Oncorhynchus mykiss*: evidence from spawning surveys and otolith microchemistry. *Canadian Journal of Fisheries and Aquatic Sciences* 57:2152–2162.

Personal Communications

Hodgson, Brett. Fisheries Biologist. Oregon Department of Fish and Wildlife. Bend, OR. June 8, 2018—Phone conversation with G. Blair regarding resident trout distribution and stressors in the Deschutes River and water management.

Lickwar, Peter. Biologist. U.S. Fish and Wildlife Service. Bend, OR. July 10, 2019—Email containing Pelton, Crooked, Whychus, and Metolius spring Chinook Movement in 2013.

Appendix 3.5-A
Agricultural Uses and Agricultural Economics Technical Supplement

Appendix 3.5-A
Agricultural Uses and Agricultural Economics Technical Supplement

Introduction

This appendix describes how Deschutes Basin irrigation districts and other irrigators affected by the proposed action and action alternatives (Alternatives 3 and 4) may respond to changes in the water supply available for irrigation diversion, and also how these responses may change the value of agricultural production and the economic contribution of agricultural production. This appendix identifies and quantifies how agricultural water management and application to crops may change under each alternative, with the primary purpose of identifying and quantifying the potential effects on agricultural land use and cropping pattern. Two primary types of responses to reductions in agricultural water diversions are described and analyzed:

- **Increased agricultural water use efficiency.** Agricultural water use efficiency as used in this analysis is the proportion of irrigation water that is diverted (or pumped from groundwater) used productively by the crop and not lost to seepage (e.g., infiltration into the ground) or evaporation. For example, if for every 100 acre-feet (af) of water diverted, 60 af is water used by the crop (through crop evapotranspiration [ET])[1] and 40 af is lost to seepage or evaporation, then the agricultural water use efficiency is 60%.[2] Agricultural water use efficiency may be increased through financial investments in district infrastructure (such as piping district canals) and on-farm infrastructure (such as converting to more efficient sprinkler and drip irrigation technologies). Increasing water use efficiency reduces the amount of diversion water required to produce a given level of crop output. Investing in water use efficiency requires upfront capital investment but reduces the effect on agricultural crop production of a reduction in water available for irrigation diversions.
- **Reduced use of water by crops.** Farmers may respond to water supply shortages by applying less water to their farmland. This may be accomplished through various mechanisms: a) farmers may maintain their crop mixture and acreage and apply less water than the crops need (deficit irrigating), which reduces yield; b) farmers may shift some or all of their acreage to less water-intensive crops (changing crop mix); c) farmers may reduce the number of acres they irrigate (potentially using these acres for dry pasture/grazing); and/or d) farmers may reduce the number of acres they farm in a given year (fallowing some acres).

Based on the estimated reduced use of water by crops, and the associated acres of reduced irrigation, the analysis then estimates the potential change in the value of agricultural production and the associated change in the economic contribution of agriculture (in terms of jobs and income supported).

There are eight sections to this appendix. The first provides an overview of methods, assumptions, and data sources. The second describes acreage and crop water use under existing conditions. The

[1] Evapotranspiration is the sum of the evaporation (E) from soil and plant surfaces and transpiration (T) which is vaporization that occurs inside of the plant leaves.

[2] Agricultural water use efficiency can be measured as the ratio of water used by the crop to water withdrawn (as used here), or it may be measured as the ratio of agricultural yield to water withdrawn.

third describes the water available for diversion and identifies the districts that are affected by the proposed action and alternatives. The fourth outlines the estimated agricultural water use efficiency and conservation investments through time for each district. The fifth estimates water supply available for crop consumptive use for each district through time (after accounting for diversion volumes under each alternative and efficiency improvements). The sixth estimates on-farm responses to changes in water supplies and projects impacts on cropping pattern, acreage, and yields. The seventh estimates the change in agricultural production value and associated economic contribution. The eighth provides references cited in the previous sections.

Methods, Key Assumptions, and Data Sources

This section describes methods/key assumptions/data sources used to estimate the responses to changes in irrigation water supplies (methods/assumptions/data sources used to estimate the economic changes resulting from these responses is included in the seventh section addressing economics). There is significant annual variability in hydrology in both the Crooked River and Upper Deschutes Subbasins. Dry years result in much lower flows (and hence reduced water supplies available for diversion) than wet years. Consistent with other resource analyses, this analysis focuses on three water year types: wet (80th percentile water available for diversions), median (50th percentile water available for diversions), and dry water years (20th percentile water available for diversions).[3] It is important to note that 20% of water years are drier than the dry water year analyzed in this analysis. The impacts of the alternatives on irrigation water supplies (and therefore agriculture) would be more severe for extreme dry water years than the impacts estimated for the dry year presented in this analysis.

The study area for the socioeconomic analysis is Deschutes, Jefferson, and Crook Counties. For the agricultural land use and agricultural economics analysis, the focus is the agricultural land area that receives irrigation water from the Deschutes and Crooked River Basins (including Whychus Creek, Tumalo Creek, and Crescent Creek) in these counties. This includes the Deschutes Basin Board of Control (DBBC) permit applicant districts (referred to collectively as the DBBC districts), as well as other lands (referred to herein as Other Irrigated Lands) receiving irrigation water through the following non-DBBC diversions: Walker Irrigation District (ID), People's Canal, Low Line Canal, Crooked River Central Canal, Rice Baldwin Canal, and the small private canal above Feed Canal.

Within the study area, the agricultural analysis focused on the districts that are projected to experience a change in water supply availability (i.e., amount of water available for diversion) under the proposed action and action alternatives. For these districts, the analysis evaluated water supply availability relative to crop water demand for periods within the irrigation season. This is because the effect on water supplies is more acute in the high demand irrigation months of June, July, and August. For example, for a given water year with a 15% annual water supply reduction under an alternative, the average effect on water supplies in June and July may be a 35% reduction. Because of this variation in water supplies within a water year type, this analysis separately analyzed acreage impacts in May, June/July, and August/September. (Irrigation water supplies in April and October were not separately analyzed as water availability was much higher in these months relative to crop demand compared to the other months.) The three irrigation subseason periods of

[3] For example, in dry year, which is equivalent to the 20th percentile of streamflow, streamflow conditions would be as dry or drier in 2 out of 10 years; in wet years (80th percentile) streamflow conditions would be as dry or drier in 8 out of 10 years and, therefore, as wet or wetter in 2 out of 10 years.

May, June/July, and August/September were selected because these roughly correspond to the irrigation months determining each hay cutting, assuming three cuttings of hay (with cuttings occurring, roughly, in early June, late July/early August, and late September/early October).

To estimate impacts on acreage, this analysis took a six-step approach (*key data sources are provided in italics*):

1. Estimated current crop water demand for irrigation water for each district based on crop mix and annual water use by crop. (See *Existing Conditions: Crop Acreage and Crop Water Demand*.)
    a. *District crop acreage and cropping pattern: Publications including basin publications, district reports, and modernization plan documents; interviews with district managers and Oregon State University extension agent; North Unit Crop Acreage report for 2013–2018.*
    b. *Crop water use: Bureau of Reclamation AgriMET Cooperative Agricultural Weather Network evapotranspiration data for the Madras station (MRSO), the Bend station (BEWO), and the Powell Butte station (POBO).*
2. Identified the DBBC districts and Other Irrigated Lands that are projected to face a change in the availability of diversion (i.e., supplies differ in one or more of the proposed action and action alternatives compared to the no-action alternative). Analyze only those DBBC districts/Other Irrigated Lands that are projected to face a change in diversion water availability in these years (hereafter, referred to as 'potentially affected districts'). Identify but do not quantitatively evaluate the impacts on districts that may face a change in the water availability of diversion water in extremely dry years. (See *Water Available for Diversion under the Proposed Action and Alternatives.)*
    a. *Water available for irrigation diversion: RiverWare model provided the estimated amount of water available for irrigation diversion for each district primary diversion canal for each alternative and wintertime flow level.*
3. Estimated the agricultural water use efficiency in the Deschutes Basin over time for affected DBBC districts and Other Irrigated Lands, taking into account the potential range of district conveyance and on-farm efficiency improvements that may occur in the future. This is done for each affected district for each year over the 30-year analysis period. Develop a high conservation scenario (with the highest likely feasible district and on-farm conservation improvements) and a low conservation scenario (with the lowest likely feasible district and on-farm conservation improvement). (See *Agricultural Water Use Efficiency*.) A range is necessary as there is significant uncertainty regarding the timing and magnitude of future conservation projects. Many district efficiency projects are currently going through the process of obtaining permits and approval for funding; the level of available funding will determine the magnitude and rate of district water conservation. There is also uncertainty regarding the level of on-farm efficiency improvements that may be adopted as these projects are completed at the discretion of the landowner/producer
    a. *DBBC district and on-farm conservation: district modernization planning and permitting documents, district agricultural water management and conservation plans, district on-farm efficiency studies, interviews with district managers, interviews with irrigation equipment supplies and Oregon State University extension, Deschutes Basin studies and planning documents with information on agricultural water management and resource planning in the basin.*
4. Estimated crop water supply (after taking into account canal and on-farm efficiencies) available to meet crop water demand (ET) by applying agricultural water use efficiencies to the water available for diversion (with diversions estimated by the RiverWare model for a historical dry and median water year), and identified reductions in crop water supply by alternative and

conservation scenario. This was done for each district for each irrigation subseason (May, June/July, and August/September) in each year over the analysis period. (See *Water Available for Crops (Accounting for Efficiency).*)

5. Estimated how farmers would respond to any shortages in meeting crop water requirements in terms of changes to cropping pattern, acreage, and yields. This was done for each district in each irrigation subseason in each year over the analysis period for both the low and the high conservation scenarios. (See *Farm Response to Crop Water Shortages*.)
    a. *Information on responses to shortages: Interviews with district managers, North Unit ID board member, and Oregon State University Extension; publications from Oregon State University Extension; North Unit Crop Acreage reports from 2008 to 2018 that show how crop acreage and mix has fluctuated over time in North Unit ID; economic literature on on-farm response to water shortages.*

To reflect the uncertainty in the type, timing, and magnitude of responses by agricultural water users (both in increasing efficiency and in responding to shortages), this analysis used ranges to estimate the effect of the alternatives on agricultural land use and agricultural production.

Key Assumptions

Following is a description of the key analysis assumptions.

1. There are no alternative water supplies available to farmers. Additional groundwater development in the Deschutes Basin must be mitigated (through such mechanisms as leases, transfers, conserved water projects, etc.) and there are no other unallocated surface water sources.
2. With the exception of Lone Pine ID and Swalley ID, all water conserved from piping of district canals (conveyance efficiency improvements) is dedicated to instream flow, as most public grant funding for piping requires dedication to instream flow for the portion of the project funded by the grant. The conserved water amount (reduced seepage) equals the increased instream flow, as well as the district's reduced diversion requirement to meet the same level of patron demand. (i.e., if 100 af per year [af/y] is conserved from piping, then 100 af/y are put back in-stream and the district can divert 100 af/y less to satisfy the same level of patron demand). In the case of Lone Pine ID and Swalley, in accordance with their existing plans for district piping, Lone Pine ID is expecting to retain for its own use 25% of the water conserved through piping (Smith pers. comm.).[4] Arnold ID's existing plan also indicates that the District may also retain for its own use 25% of water conserved through piping, but this is not incorporated into the analysis as it will depend future funding arrangements that are as yet not determined.
3. All conserved water from Central Oregon ID would result in increased instream flows. However, it is expected that all summertime water conserved from Central Oregon ID canal piping and on-farm efficiency improvements is made available to North Unit ID, and in turn, North Unit ID would make available its Wickiup stored water for winter releases. This type of water management arrangement has not yet been implemented in Oregon and will likely require close coordination with the Oregon Water Resources Department and other state agencies to implement. The analysis takes this hurdle into account as the low conservation scenario assumes that Central Oregon ID piping proceeds at a slower pace and is entirely funded by Central Oregon ID and North Unit ID.

[4] Subsequent to this analysis, based on its funding arrangements, Lone Pine ID increased the proportion of conserved water that it expects to retain 40%.

4. Apart from Central Oregon ID making conserved water available to North Unit ID, shortages are managed within each district, with no water supply sharing across districts. In other words, each district was separately analyzed and water sharing was not directly modeled across districts as could occur if a basin-wide water market develops. Currently, there are legal barriers to trading water between districts. These barriers may be removed and a basin-wide water market may develop in the future that would enable growers to buy and sell water between districts. The effect of a potential market on water supplies and agricultural production was not evaluated for two reasons: the timing and certainty of water market development are not known, and acreage affected by water shortages is assumed to be grain and forage crops (hay, alfalfa, pasture) in all districts (which limits the difference in value of water across all districts and reduces the economic effect of a water market – or said differently, by assuming grain and forage crops are only affected by the changes in water supply, the analysis has a similar outcome as would result from a water market).
5. The range of feasible conservation investments would be similar across all alternatives. While more district piping and on-farm conservation are likely with greater reduction in water supplies, it is reasonable to assume that some level of conservation would occur in all alternatives. Currently, the DBBC districts are developing modernization plans and going through an environmental review process as part of their pursuit of funding for piping projects. Similarly, on-farm efficiency is increasing in many districts.
6. The proposed action would not result in increased water availability to crops compared to existing median water year conditions. If fully implemented, water conservation from district conveyance and on-farm efficiency projects could result in more water available to agriculture under the proposed action and alternatives than available under existing conditions. Such additional water could result in increased yields or increased irrigated acreage. However, since this is not an effect of the proposed action and action alternatives but rather an outcome that would similarly affect all future conditions, the analysis did not consider this potential effect. Furthermore, whether conservation efforts could result in more water being made available to agriculture in the future than under current conditions is uncertain, as districts and growers (and funding agencies) would likely be most incentivized to invest in conservation that would reduce water supply shortfalls rather than increase water supply beyond existing median water year conditions. As such, the analysis capped the total water supply available to the crop (after accounting for conveyance and irrigation efficiencies) in median and dry water year types in all future years to the existing median water supply (the no-action alternative).
7. Because of low growing season rainfall, crop water requirements are met through irrigation, with no crop water requirement met through precipitation. Data from the Bureau of Reclamation AgriMet Station in Madras indicates that total rainfall from May through September averaged less than 3 inches between 2010 and 2018, with some years receiving as little as 1.75 inches during this timeframe (Bureau of Reclamation 2019).
8. When water supply is available, the future crop mix and acreage would remain similar to the current cropping pattern. In particular, the analysis assumed that forage crops would remain the predominant crop in the study area, consistent with decades of agriculture in the region. Because the market and economic potential for large-scale transition to other crops, as well as farmer preference for growing forage to support their own livestock,[5] is speculative, this analysis estimated the effects of changes in water availability assuming the current cropping pattern. To the extent that other relatively lower water-use crops replace forage crops on a wide-scale basis, the effects would likely be overestimated because of the lower water requirement of these crops.

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[5] Forage crops contribute to the area's cattle and dairy production, and are also used to feed horses and other animals raised on many hobby farms in the area.

9. In responding to water supply reductions, farmers would strive to minimize negative effects on farm profits and would reduce water supplies to hay/pasture/grains before reducing water supplies to higher-valued crops such as carrot seed, grass seed, mint, and vegetables. As such, fallowing/deficit irrigating would primarily affect hay/pasture/grain crops. Hay/pasture is the predominant crop in all districts, representing 81% of acreage in all districts excluding North Unit ID (the most crop diversified district), and representing 51% of acreage in North Unit ID (but an estimated 83% of water use in North Unit ID. This is expected to be a reasonable assumption as farms with high value specialty crops also typically have lower valued crops (so at least some on-farm movement of water from lower value to high value crops is possible), or would conceivably be able to purchase water from predominantly hay/pasture/grain crop farmers (resulting in idling of hay/pasture/grain crops). Also, the feasibility of a basin-wide water transaction program is currently being explored in the Deschutes Basin (Central Oregon Irrigation District, 2017), which if developed would facilitate transfers of water to high value crops. To the extent that this does not happen, this analysis may underestimate the impact on agricultural production value and associated economic impact, particularly in NUID.
10. Irrigation water supply in April/May[6] determines the amount of yield in the first cutting of hay, while irrigation water supply in June/July determines the amount of yield in the second cutting of hay, and irrigation water supply in August/September determines the amount of yield in the third cutting of hay (with cuttings occurring, roughly, in early June, late July/early August, and late September/early October).

Existing Conditions: Crop Acreage and Crop Water Demand

This section provides the crop acreage and crop water use data used to estimate total crop water demand by district. **Table 1** presents data on the existing average cropping pattern and irrigated acreage by district. Cropping patterns are based on published documents and interviews with district managers. In total, this analysis estimates 141,000 acres of irrigated lands in the study area. This roughly corresponds to the estimate from the 2012 Census of Agriculture that there were 136,975 acres of irrigated acreage in the three-county area (U.S. Department of Agriculture 2012). Crop mix is fairly similar across irrigation districts, with irrigated lands predominantly planted in forage crops (alfalfa, hay, pasture). North Unit ID is distinct in having much greater crop diversification, including such high value crops as carrot seed, mint, grass seed, and vegetables. Several other districts also have limited acreage of these high value crops. Excluding North Unit ID, approximately 80% of irrigated acreage in DBBC districts is estimated to be in hay or pasture, while approximately 56% of irrigated acreage in North Unit ID is in hay or pasture.

Under existing conditions, it is important to note that irrigation water supply fluctuates based on water year type, with dry water years resulting in lower acreage and/or yields in many districts. The reduction in water supply in dry water years under existing conditions is higher than it has been historically due to the 2016 Settlement Agreement. Under this agreement, the Districts agreed to increased releases of storage water to enhance wintertime flows for the Oregon Spotted Frog.

[6]As April irrigation supply was high across all districts and water year types, only May and not the average of April and May was analyzed to estimate the relative impact of crop water supply changes on acreage/yield for the first cutting of hay.

Existing conditions for Tumalo ID in particular are lower than historical conditions. As part of the Settlement Agreement, Tumalo ID increased its minimum release into Crescent Creek from 6 cfs to 20 to 30 cfs. Under existing conditions, the Districts that face reduced irrigation water supplies and associated reduced acreage/deficit irrigation (due both to historical hydrology and the changes to water management associated with the Settlement Agreement) include Central Oregon ID North Unit ID, Lone, Pine ID, Three Sisters ID, and Ochoco ID (**Table 2**). RiverWare shows a shortage to Central Oregon ID under existing conditions. However, this shortage is a very small relative to total diversions, and is also projected by district management to be met through improved operational flexibility resulting from planned conveyance efficiency projects (Horrell pers. comm. [a]). North Unit ID under existing conditions faces the greatest impacts in dry water years, and it is most affected by the proposed action and action alternatives. In other words, for North Unit ID, water supply reductions resulting from the proposed action and action alternatives in dry water years would exacerbate an existing dry water year shortage.

As shown in **Table 2**, under existing conditions, up to approximately 8,100 acres of irrigated acreage may be impacted (deficit irrigated or fallowed), or approximately 6% of median water year acreage. The analysis of potential dry year impacts under existing conditions follows the same methodologies and assumptions for acreage impacts as for the alternatives (as laid out in *Methods, Key Assumptions, and Data Sources*). These impacts represent the maximum acreage that may be impacted. For example, under Existing Conditions in a dry year, the analysis estimates that 6,600 acres of grain and forage crops in North Unit ID is affected. This is not because all of these acres are fallowed, but rather that in a dry water year, irrigation of these acres is cut off during the season and the farms lose forage production for the remainder of the season.

Table 1. Existing Conditions Average Irrigated Acreage by DBBC District, Crop Type

Crop Type	DBBC Districts: Arnold	Central Oregon	Lone Pine	North Unit	Ochoco	Swalley	Three Sisters	Tumalo	Total, DBBC Districts	Other Irrigated Lands[a]	Total
Other Hay/Pasture	2,700	20,600	700	15,300	8,000	2,700	3,600	4,000	57,600	2,000	59,500
Alfalfa	800	16,900	500	14,100	4,600	0	2,100	1,000	40,000	1,200	41,200
Grains	0	800	400	5,700	1,800	0	1,200	0	9,900	200	10,100
Carrot and Other Seed	0	0	0	6,700	400	0	200	0	7,400	0	7,400
Peppermint/Other Herbs	0	0	500	1,000	200	0	0	0	1,700	0	1,700
Grass Seed/Sod/Nursery	0	400	0	8,500	300	0	0	0	9,300	0	9,300
Other Crops	0	2,900	200	900	0	100	500	1,000	5,700	200	5,900
Urban	500	400	0	0	3,400[b]	1,200	0	0	5,600	300	5,800
Irrigated Acres	4,000	42,100	2,400	52,200	18,700	4,000	7,600	6,000	137,000	4,000	141,000

Sources: Gerdes pers. comm.; Farmers Conservation Alliance 2018a; Central Oregon Irrigation District 2012; Horrell pers. comm. [a]; Farmers Conservation Alliance 2018c; Farmers Conservation Alliance 2018b; Rieck pers. comm., Britton and Horrell pers. comm.; Bohl pers. comm., Ochoco Irrigation District 2012; Thalacker pers. comm.; Rieck pers. comm.; Farmers Conservation Alliance 2018c.

[a] Includes estimated acreage for Walker ID, People's Canal, Low Line Canal, Crooked River Central Canal, Rice Baldwin Canal, and the small private canal above Feed Canal. Acreage estimate based on median year diversion of approximately 28,300 af/y, average crop consumptive water requirement of 3 af/y/acre, and assumed canal efficiency of 60% and on-farm efficiency of 70% (28,300 af/y*0.6*0.7/3 af/y=~4,000 acres). Crop mix is assumed to equal the average crop mix across DBBC districts, excluding North Unit ID.

[b] Includes all small farms, many of which are within Urban Growth Boundary. Irrigated land primarily includes pasture/hay, but also turf and some specialty crops.

Table 2. Existing Conditions Estimated Irrigated Acreage by DBBC District and Crop Type, Dry Water Year

	DBBC Districts											
Crop Type	**Arnold**	**Central Oregon**	**Lone Pine**	**North Unit**	**Ochoco**	**Swalley**	**Three Sisters**	**Tumalo**	**Total, DBBC Districts**	**Other Irrigated Lands[a]**	**Total**	**Change from Median Year**
Other Hay/Pasture Alfalfa Grains	3,400	38,100	1,500	28,500	14,200	2,700	6,000	5,000	99,400	3,300	102,700	-8,100
Carrot and Other Seed	0	0	0	6,700	400	0	200	0	7,400	0	7,400	0
Peppermint/Other Herbs	0	0	500	1,000	200	0	0	0	1,700	0	1,700	0
Grass Seed/Sod/Nursery	0	400	0	8,500	300	0	0	0	9,200	0	9,300	0
Other Crops	0	2,900	200	900	0	100	500	1,000	5,700	200	5,900	0
Urban	500	400	0	0	3,400	1,200	0	0	5,600	300	5,800	0
Irrigated Acres	3,900	41,900	2,300	45,600	18,600	4,000	6,600	6,000	128,900	3,800	132,800	0
Change from Median Year	0	-200	-100	-6,600	-200	0	-900	0	-8,100	0	-8,100	0

Sources: Highland Economics analysis using water supply for the dry water year irrigation diversions estimated by RiverWare for the no-action alternative. Gerdes pers. comm.; Farmers Conservation Alliance 2018a; Central Oregon Irrigation District 2012; Horrell pers. comm. [a]; Farmers Conservation Alliance 2018c; Farmers Conservation Alliance 2018b; Rieck pers. comm.; Britton and Horrell pers.comm.; Bohl pers. comm.; Ochoco Irrigation District 2012; Thalacker pers. comm.; Rieck pers. comm.; Farmers Conservation Alliance 2018c.

[a] Includes estimated acreage for Walker ID People's Canal, Low Line Canal, Crooked River Central Canal, Rice Baldwin Canal, and the small private canal above Feed Canal.

Crop water demand is measured by crop ET. Crop ET includes all water that evaporates from soil and plant surfaces and transpiration from the plant to the atmosphere. Crop ET varies by crop (based on crop height, reflection, groundcover, and root characteristics), and by location due to differences in climate, soil, and other environmental factors. Crop ET can also vary by year due to variation in environmental factors such as temperature (e.g., the hotter the year, the higher the ET). As such, this analysis uses data on crop ET from throughout the study area, as well as over a 10-year period in order to best represent the annual average crop water needs for each district.

Data on crop water demand is from the Bureau of Reclamation AgriMET Cooperative Agricultural Weather Network. This network includes several stations that measure crop evapotranspiration (ET) for specific crops grown in the region. This analysis used the crop ET data from the three stations closest to study area irrigated lands: the Madras station (MRSO), the Bend station (BEWO), and the Powell Butte station (POBO). These data provide annual per acre ET totals by crop from 1988 to 2015 (more recent data were not available). This analysis used the average ET by crop from 2006 to 2015, as provided in **Table 3**. Each district was assigned to an AgriMET station based on geographical proximity; the station assignment and associated crop ET for each district is identified in **Table 4**. Due to variation in crop mix as well as variation in ET requirements by location in the basin, the weighted average per acre ET for grain and forage crops (see last row in **Table 4**) varies among the districts from 2.3 af/y per acre in Lone Pine ID to 2.8 af/y per acre in North Unit ID. These ET estimates by district are the per acre crop consumptive demand used in the analysis to estimate effects on grain and forage acreage of reductions in water supplies.

Table 3. Average Annual Crop Water Demand (ET) at Deschutes Basin AgriMet Weather Stations, 2006–2015

	AgriMET Station (acre-feet per year)		
Crop	**Madras**	**Powell Butte**	**Bend**
Alfalfa	3.3	3.0	2.5
Pasture	2.6	3.1	2.0
Hay	3.3	3.1	2.5
Carrot Seed	1.0	N/A	N/A
Peppermint	2.2	2.1	N/A
Bluegrass Seed	1.4	1.4	N/A
Winter Grain	1.9	1.9	1.6
Spring Grain	2.1	1.9	1.6
Lawn	N/A	2.9	2.4

Source: Highland Economics analysis of Bureau of Reclamation 2016.

Table 4. Annual per Acre Crop Water Demand (Evapotranspiration, ET) at Deschutes Basin AgriMet Weather Stations (acre-feet per year)

Crop Type	Arnold	Central Oregon	Lone Pine	North Unit	Ochoco	Swalley	Three Sisters	Tumalo	Other Irrigated Lands
Station	*Bend*	*Average of Bend, Powell Butte*	*Powell Butte*	*Madras*	*Powell Butte*	*Bend*	*Powell Butte*	*Bend*	*Average of Bend, Powell Butte, Madras*
Grass Hay/Pasture	2.5	2.8	3.1	3.3	3.1	2.5	3.1	2.5	3.0
Alfalfa	2.5	2.7	3.0	3.3	3.0	2.5	3.0	2.5	2.9
Grains	1.6	1.8	1.9	2.0	1.9	1.6	1.9	1.6	1.8
Carrot/Other Seed	N/A	N/A	N/A	1.0	N/A	N/A	N/A	N/A	1.0
Peppermint/Other Herbs	N/A	2.1	2.1	2.2	2.1	N/A	N/A	/A	2.1
Grass Seed/Sod/Nursery		1.4	1.4	1.4	1.4		1.4		1.4
Other Crops	1.6	1.8	1.9	2.0	1.9	1.6	1.9	1.6	1.8
Urban (Turf)[a]	2.4	2.6	2.9	2.6	3.1	2.4	2.9	2.4	2.6
Weighted Average Grain and Forage Crops (Hay/Pasture, Alfalfa)	*2.5*	*2.7*	*2.3*	*2.8*	*2.7*	*2.5*	*2.5*	*2.5*	*2.7*

Source: Highland Economics analysis of Bureau of Reclamation 2016.

[a] For Ochoco, 'urban' crop water use per acre is set at the hay/pasture crop water demand as most of the acreage classified as 'urban' is used for hay/pasture.

Table 5 summarizes total annual crop water demand by district, calculated by multiplying the district acreage by crop with the per acre crop water demand (from **Table 4**). The table highlights that the vast majority of agricultural diversion water is used to irrigate grain and forage crops, which are the crops projected in this analysis to be affected by reduced irrigation water diversions (both due to their prevalence and the fact that they are relatively lower valued than other crops grown in the region). As indicated above in **Table 4**, due to variation in crop mix as well as variation in ET requirements by location in the basin, the average per acre ET for these crops varies among the districts from 2.3 af/y per acre in Lone Pine ID to 2.8 af/y per acre in North Unit ID. The proportion of total crop water use by these crops varies from 68% in Swalley ID (which has a relatively high proportion of urban acreage) to 94% in Central Oregon ID, as shown in **Table 5**. This high proportion of water use by grain and forage crops supports the approach/assumption in this analysis that reduced water supplies would affect grain and forage crops, with little to no impact on other crop types.

Since this analysis is by irrigation subseason and not an annual analysis, **Table 6** summarizes grain and forage crop water demand by DBBC districts/Other Irrigated Lands by month. The separation of annual ET into monthly requirements is based on the average percent delivery by DBBC district/Other Irrigated Lands by month in a median water year.[7] This is the basis for estimating the amount of irrigated acreage by month that is affected by reduced irrigation water supplies (i.e., the total reduction in water supply divided by the average per acre crop water demand for that month equals the estimated affected acreage in that month).

[7] Distribution of crop deliveries by month were estimated to best approximate irrigation practices and scheduling under existing conditions, and so were used instead of actual ET crop requirements by month from AgriMet.

Table 5. Annual Consumptive Crop Water Demand (Evapotranspiration, ET) by DBBC District, Crop Type (acre-feet per year)

	DBBC Districts										
Crop Type	Arnold	Central Oregon	Lone Pine	North Unit	Ochoco	Swalley	Three Sisters	Tumalo	DBBC Districts	Other Irrigated Lands	All Lands
Grain	0	1,481	721	11,496	3,411	0	2,274	0	19,382	362	19,744
Forage (Hay/Pasture/Alfalfa)	8,773	104,278	3,720	97,327	38,293	6,763	17,411	12,658	289,222	9,441	298,664
Other crops	1,208	6,888	1,512	22,958	11,096	3,142	1,052	1,602	49,459	1,248	50,707
All Crops	9,981	112,647	5,953	131,781	52,800	9,905	20,737	14,259	358,063	11,051	369,114
% Crop Water by Grain and Forage Crops (Crops Modeled to be Impacted)	88%	94%	75%	83%	79%	68%	95%	89%	86%	89%	86%

Source: Highland Economics analysis.

Table 6. Estimated Annual per Acre Grain and Forage Crop Water Demand (Evapotranspiration, ET) by DBBC District, Month

Subseason	Arnold	Central Oregon	Lone Pine	North Unit	Ochoco	Swalley	Three Sisters	Tumalo	Other Irrigated Lands
May	0.4	0.4	0.4	0.5	0.5	0.4	0.5	0.5	0.4
June/July	0.9	0.9	0.9	1.1	1.0	1.0	1.0	0.9	0.9
August/September	0.9	0.9	0.8	0.7	0.8	0.9	0.6	0.8	0.9
May–September	2.2	2.2	2.1	2.4	2.3	2.4	2.1	2.3	2.2
Annual Total	*2.5*	*2.7*	*2.3*	*2.8*	*2.7*	*2.5*	*2.5*	*2.5*	*2.7*

Source: Highland Economics analysis of RiverWare water delivery by month and ET data.

Water Available for Diversion under the Proposed Action and Alternatives

This section presents the water available for diversion under the proposed action and action alternatives, compared to the no-action alternative, as estimated by the RiverWare model. This analysis used output from the model on the monthly total af of delivery to each diversion canal. All diversion canals to a single district were summed into a monthly total diversion supply for each DBBC district/Other Irrigated Lands. Dry water years represent the 20th percentile year (only 20% of years are drier) and the median water years represent the 50th percentile year (half of water years are drier).[8] This section presents the water available for diversion, while the next section accounts for how on-farm and District water conservation measures would affect water available to crops.

Under the proposed action and action alternatives, RiverWare results suggest that there would be a marked change in water available (more than one-third of water supply) for diversion in some water year types and permit years compared to the no-action alternative for North Unit ID, and potential impacts (equal to or less than 12% reductions) in Arnold ID, Tumalo ID, and Lone Pine ID. There may be some effects that are not reflected in RiverWare results. Specifically, district managers in Ochoco ID expect that if release of Ochoco ID storage water is required to meet the 50 cubic feet per second (cfs) minimum flow requirement under HCP Conservation Measure CR-1 in a dry year, it could result in a deficit for Ochoco ID of up to 6,000 af) (Rhoden and Scanlon pers. comm.). RiverWare does not project this impact in dry water years; therefore, this Ochoco ID deficit is not presented in the quantitative results in the tables. In contrast, while RiverWare identifies a small percentage reduction in water available for diversion by Central Oregon ID (up to 1% reduction under the proposed action and action alternatives compared to the no-action alternative), Central Oregon ID management believes that operational improvements from piping and other district initiatives would compensate for these reduced diversions and result in little to no impact on Central Oregon ID patrons. As such, no quantitative impact is estimated for Central Oregon ID. Based on RiverWare modeling and interviews with district managers, there are no expected impacts on Three Sisters ID, Swalley ID, or Other Irrigated Lands of the proposed action and action alternatives.

As there are small to no projected changes in wet water year deliveries under the proposed action and action alternatives compared to the no-action alternative, wet years are not analyzed.

No-Action Alternative

Operation assumptions for covered facilities are the same under the no-action alternative as existing operations and would therefore not change the amount of water available for diversion under the no-action alternative. However, climate change effects anticipated over the analysis period could affect the amount and timing of water available for diversion under the no-action alternative compared to existing conditions.

[8] Diversions in an actual past water year were selected for each district that best represented the 80th percentile and 20th percentile water years (based on water available for diversion). As such, the past water year that represents the dry and median water year differs by district.

Proposed Action

Table 7 summarizes the water available for diversion under the proposed action over the permit term compared to the no-action alternative. As highlighted in the table, Lone Pine ID, and North Unit ID are the districts primarily affected by the proposed action. Central Oregon ID, Tumalo ID, and Arnold ID are projected to experience very small changes in water supply amounting to less than a 1% decrease in water supply. As noted above, although not projected in RiverWare nor analyzed quantitatively, Ochoco ID may possibly experience a reduction as discussed above. Consistent with other resource analyses, this analysis does not consider quantitatively the very dry water year. However, modeling indicates that a repeat of the worst dry year from the period of record from 1996 to 2018 would result in much larger reductions in water available for diversion than the dry year analyzed. For example, in the most extreme dry years during the final phase of the proposed action (years 13–30), reductions would be up to 53% for North Unit ID and 11% for Arnold ID and Ochoco ID compared to no-action alternative.

Figure 1 shows how the reduction in water is distributed across the irrigation season, highlighting that reductions are more acute typically in June/July/August/September than the average seasonal reduction. Analysis of full season irrigation reductions would underestimate impacts since more severe shortages in one month would result in greater crop impacts than a smaller impact distributed evenly throughout the season. For this reason, the analysis separately considers crop impacts for three separate time periods within the irrigation season: May, June/July, and August/September.

Figures 2 and **3** summarize RiverWare results on water available for diversion by month and water year type for the potentially affected districts of Lone Pine ID and North Unit ID. The proposed action (over four periods of the permit term) is compared to the no-action alternative.

Table 7. Changes in Annual Water Available (acre-feet) for Diversion by District, under the Proposed Action Compared to the No-Action Alternative, Median and Dry Water Years

District	Years 1–7		Years 8–12		Years 13–30		% Change
	Median	Dry	Median	Dry	Median	Dry	
Arnold	0	25	0	-68	0	-135	0%
Central Oregon	-430	-36	-436	-263	-448	-481	0%
Lone Pine	364	-917	-130	-1,212	-1,341	-1,734	2% to -12%
North Unit	0	10,334	-3,461	-34,691	-20,638	-56,580	6% to -30%
Ochoco	0	0	0	0	0	0	0%
Swalley	0	0	0	0	0	0	0%
Three Sisters	0	0	0	0	0	0	0%
Tumalo	0	202	0	178	0	194	0%
Other Irrigated Lands	0	-4	0	-25	0	-40	0%
Total	**-66**	**9,604**	**-4,027**	**-36,081**	**-22,426**	**-58,776**	**1 to -9%**

Figure 1. Water Available for Diversion by Month for Each Water Year Type over the Permit Term for All Irrigated Lands under the Proposed Action as a Percentage of Water Available under the No-Action Alternative

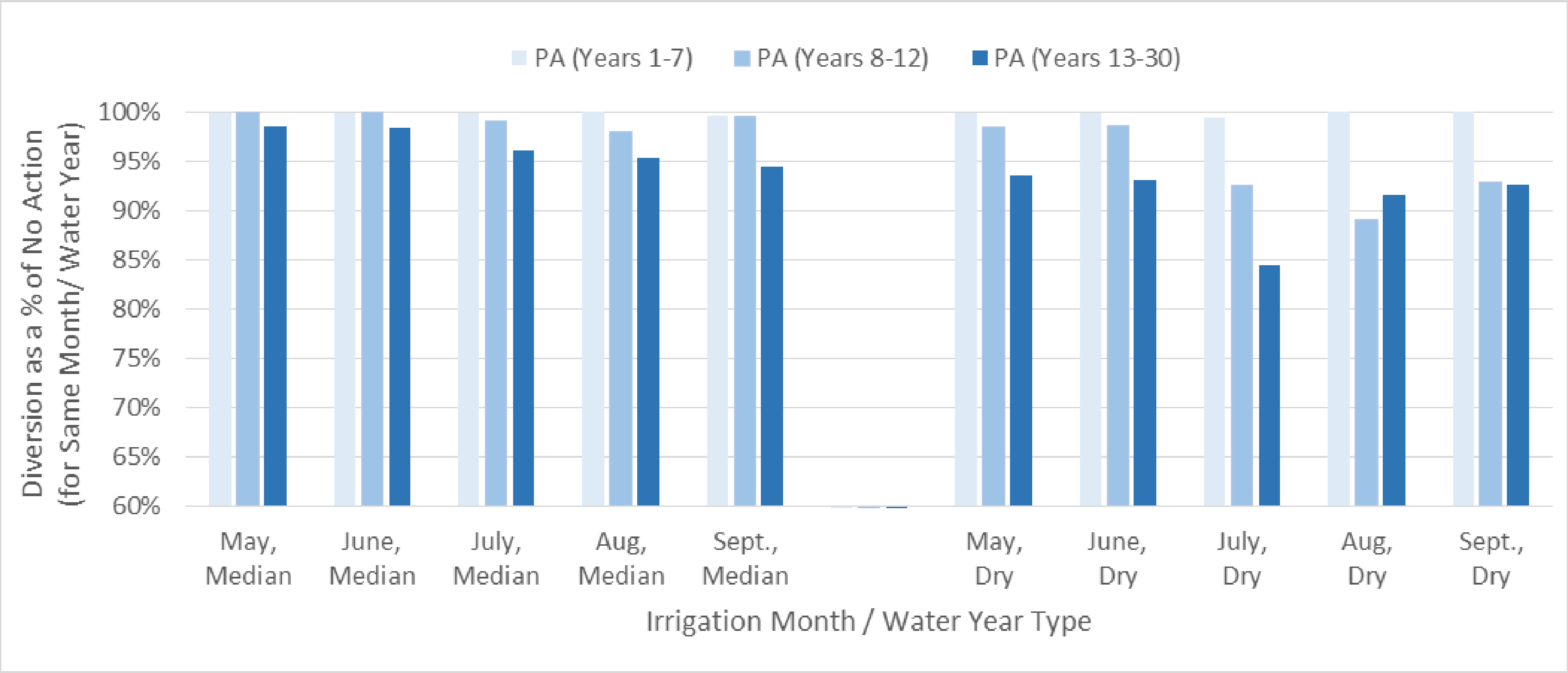


Figure 2. Lone Pine Irrigation District: Water Available for Diversion under Proposed Action Relative to No-Action Alternative

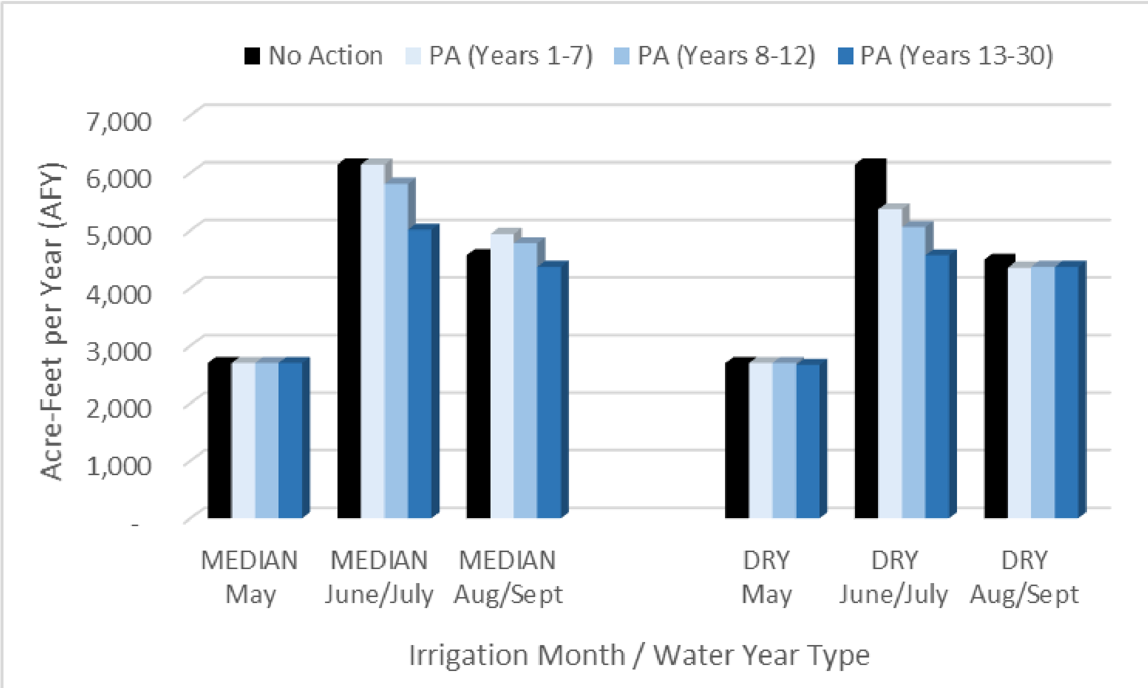
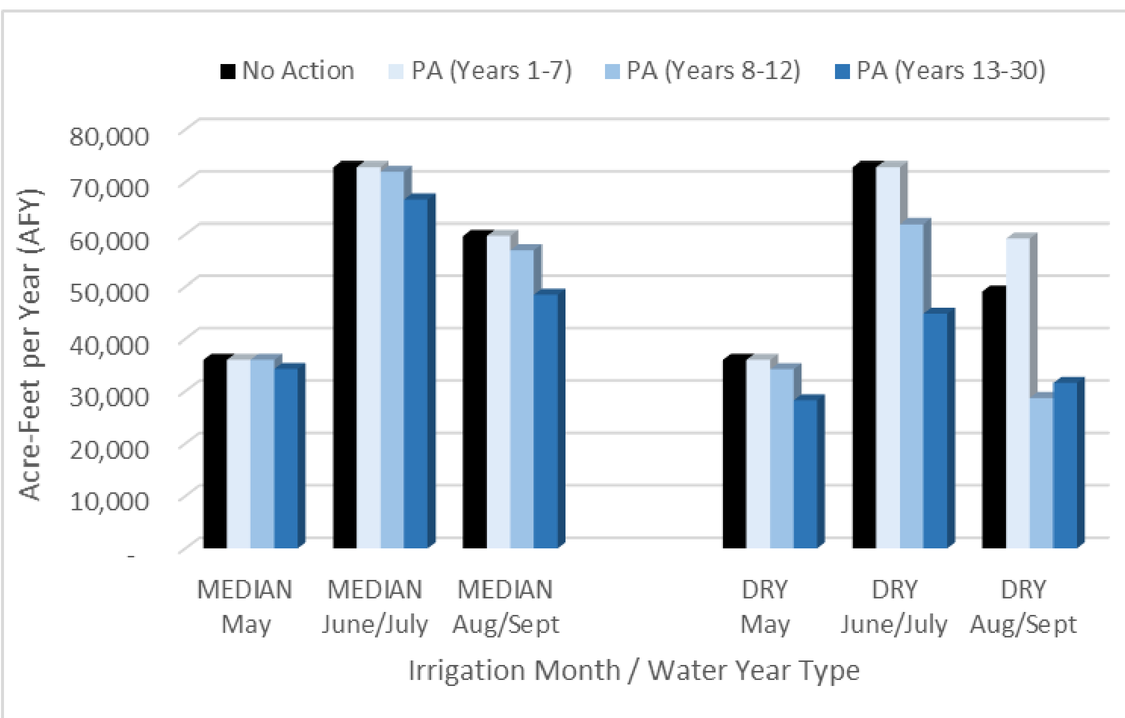


Figure 3. North Unit Irrigation District: Water Available for Diversion under Proposed Action Relative to No-Action Alternative



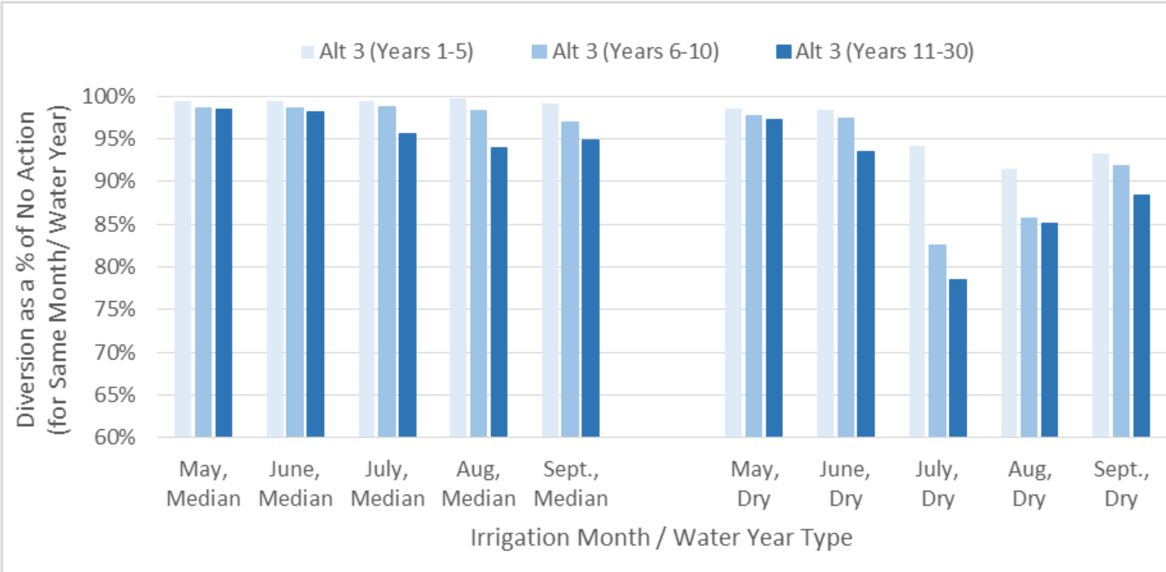
Alternative 3

Table 8 and **Figure 4** summarize the water available for diversion under Alternative 3 over the permit term compared to the no-action alternative. The percent reduction in water available for diversion under Alternative 3 over the entire permit term would be very similar to the changes under the proposed action. The chief difference is that larger reductions in diversions would occur earlier in the permit term under Alternative 3. Further, North Unit ID would experience a greater percent reduction in water available for diversion in dry years (up to -37%) than under the proposed action (up to -30%). In the most extreme dry years, during the final phase of Alternative 3 (years 11–30) reductions would be up 55% for North Unit ID compared to the no-action alternative (a 2% greater reduction than under the proposed action).

Table 8.Changes in Annual Water Available (acre-feet) for Diversion by District under Alternative 3 Compared to the No-Action Alternative, Median and Dry Water Years

District	Years 1–5		Years 6–10		Years 11–30		% Change
	Median	Dry	Median	Dry	Median	Dry	
Arnold	0	-701	0	-1,695	0	-1,781	0% to -6%
Central Oregon	-430	-1,462	-440	-2,304	-444	-2,179	0% to -1%
Lone Pine	364	-1,212	364	-1,218	364	-1,338	2% to -9%
North Unit	-2,945	-26,892	-12,493	-53,627	-25,673	-68,211	-2% to -37%
Ochoco	0	0	0	0	0	0	0%
Swalley	0	0	0	0	0	0	0%
Three Sisters	0	0	0	0	0	0	0%
Tumalo	0	178	0	160	0	160	0%
Other Irrigated Lands	0	-40	0	-49	0	-40	0%
Total	**-3,010**	**-30,129**	**-12,568**	**-58,733**	**-25,753**	**-73,391**	**0% to -10%**

Figure 4. Percentage of Water Available for Diversion by Month for Each Water Year Type over the Permit Term for All Irrigated Lands under Alternative 3 as a Percentage of Water Available under the No-Action Alternative



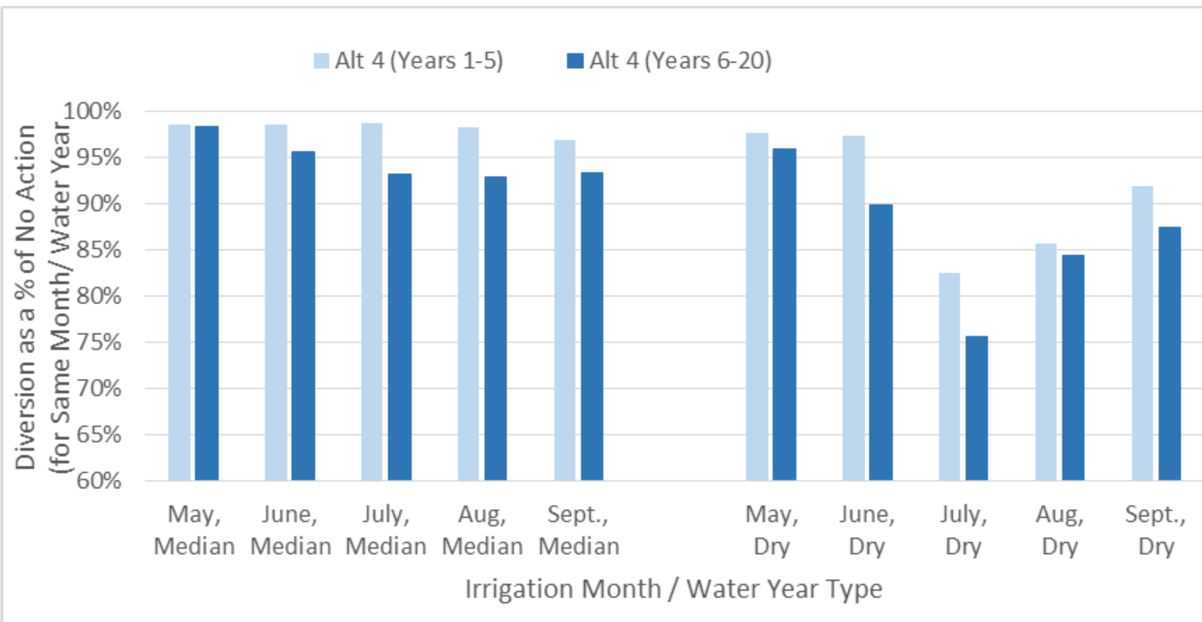
Alternative 4

Table 9 and **Figure 5** summarize the water available for diversion under Alternative 4 over the permit term compared to the no-action alternative. The percent reduction in water available for diversion under Alternative 4 over the permit term would be very similar to the changes under the proposed action. Compared to the proposed action and Alternative 3, larger reductions in diversions would occur earlier in the permit term. Further, North Unit ID would experience a greater percent reduction in water available for diversion in dry years (up to -43%) than under the proposed action and Alternative 3 (up to -30% or -37%). In the most extreme dry years, during the final phase of Alternative 4 (years 6–20), reductions would be up to 55% for North Unit ID compared to the no-action alternative (same as Alternative 3; a 2% greater reduction than under the proposed action).

Table 9.Changes in Annual Water Available (acre-feet) for Diversion by DBBC District under Alternative 4 Compared to the No-Action Alternative, Median and Dry Water Years

	Years 1–5		Years 6–20		
District	**Median**	**Dry**	**Median**	**Dry**	**% Change**
Arnold	0	-1,695	0	-2,102	0% to -7%
Central Oregon	-440	-2,304	-445	-2,700	0% to -1%
Lone Pine	364	-1,218	364	-1,389	2% to -9%
North Unit	-12,493	-53,627	-35,549	-79,263	-6% to -43%
Ochoco	0	0	0	0	0%
Swalley	0	0	0	0	0%
Three Sisters	0	0	0	0	0%
Tumalo	0	160	0	160	0%
Other Irrigated Lands	0	-49	0	-49	0%
Total	**-12,568**	**-58,733**	**-35,630**	**-85,343**	**-2% to -12%**

Figure 5. Percentage of Water Available for Diversion by Month for Each Water Year Type over the Permit Term for All Irrigated Lands under Alternative 4 as a Percentage of Water Available under the No-Action Alternative



Agricultural Water Use Efficiency

Agricultural water use efficiency is a key determinant of the amount of water diverted for agricultural use. The greater the amount of water that is lost to seepage or evaporation (either during conveyance of irrigation water to the crop field or during the irrigation process), the greater the amount of water is required to meet crop water needs. For example, if an acre of alfalfa consumes 3 af/y of water, but canal conveyance efficiency is 55% and on-farm irrigation efficiency is

70%, then to ensure that 3 af/y of water reaches the crop, the diversion requirement is 7.8 af/y, or more than double the crop water requirement.[9]

The surface soils and rocks in much of the Deschutes Basin, due to their volcanic nature, are highly permeable (Lite and Gannett 2002). Due to this high permeability, high water losses from seepage are evident in many irrigation districts in the Deschutes Basin. Much of the irrigation infrastructure in the Deschutes Basin was originally developed in the early 20th century, and consisted of unlined irrigation canals with high seepage rates of 30% or more.

Similarly, historically, much of the farmland in the Deschutes Basin was flood irrigated, which is an irrigation method that typically has a higher seepage rate and evaporation rate relative to many other irrigation methods. In recent years, irrigation districts and farmers in the basin have been making significant investments in improving agricultural water use efficiency in the basin. This includes a number of district piping projects that eliminate seepage from district canals (in the stretches that are piped), and on-farm conversion to more efficient sprinkler and drip irrigation technologies (completed voluntarily by individual farmers). For example, between 2006 and 2013, approximately 40,000 af/y was permanently conserved through a range of projects in the basin (Deschutes River Conservancy and Deschutes Water Alliance 2013). Prior to 2006, 45,360 af/y was permanently conserved in-stream through district piping projects in Central Oregon ID, North Unit ID, Swalley ID, Three Sisters ID, and Tumalo ID (Newton and Perle 2006).

Due to these projects, the volume of diversion water required for a given level of crop production has been decreasing over time. In other words, by increasing conveyance and/or on-farm efficiencies, the diversion requirement can be reduced while maintaining the same level of crop production. As such, the effect on agriculture of reducing the amount of water available for diversion depends on the assumed future agricultural water use efficiencies. This analysis accounts for potential future increased conveyance and on-farm efficiencies by using two scenarios regarding future conservation. The analysis includes a low conservation scenario, which assumes only limited future piping occurs to increase district conveyance efficiencies, and there is limited additional on-farm irrigation efficiency improvement. The analysis also includes a high conservation scenario, which assumes that nearly all district piping projects (as outlined in current district planning documents) proceed and higher on-farm irrigation efficiencies are achieved over a realistic timeframe. The high conservation scenario assumes that the Districts are able to obtain outside funding and permits/approvals for the proposed District projects (as yet not obtained for most projects), or that District patrons fully fund both District piping and on-farm improvements (which would likely limit the projects completed and/or slow the timeline of completion). The on-farm efficiency improvements assumed under the high conservation scenario area also outside the control of the Districts and are voluntary measures that may be adopted by District patrons.

This section briefly describes the past conservation efforts to increase agricultural water use efficiency in the basin, and then focuses on identifying the range of potential conservation projects that may be implemented in the future. The purpose of the section is to project the range of potential agricultural water use efficiency over the analysis period for each district.

[9] The calculation is 3.0 acre-feet / 0.55 / 0.70 = 7.8 acre-feet.

Irrigation District Water Efficiency: Piping of Canals

As noted above, piping of district canals is an ongoing effort in the Deschutes Basin. Through 2013, district projects resulted in at least 85,360 af/y of permanent water conservation (Newton and Perle 2006) (Deschutes River Conservancy and Deschutes Water Alliance 2013), funded through a combination of user assessments on district patrons and grants obtained from local, state, and federal funding sources. Particularly pertinent to this analysis, there are numerous potential future district piping projects. For the past several years, in an ongoing district modernization effort, Deschutes Basin irrigation districts have been developing System Improvement Plans (SIPs) that quantify water seepage from canals, identify proposed canal segments to be piped, and estimate the water savings and construction costs of piping those segments. These System Improvement Plans are the basis for the districts developing Environmental Assessments (EAs) to support their request for federal funding through the Natural Resources Conservation Service (NRCS). **Table 10** summarizes the status of these proposed district piping projects. The values in the table are estimates only, and the impact of piping on water conservation may be higher in lower than the values presented. Water conservation estimates are based on measurements taken at various locations in the District canal systems, and actual conservation will vary over time and location within a canal system. Conserved water amounts will also vary by water year type.

Based on the data sources in **Table 10**, as well as interviews with district managers, this analysis identified a range of potential district conveyance efficiency improvements over the next 30 years, as presented in **Table 11**. These conveyance efficiencies are a key parameter in estimating how changes in diversions affect changes in crop water supplies. Specifically, conveyance efficiencies are multiplied by the water volume available for diversion for each district in a given irrigation subseason/water year type/permit year to estimate the amount of water delivered to farms in that subseason/water year type/permit year.

Table 10. Status of Future Piping of District Canals in the Deschutes Basin

DBBC District	Potential Peak CFS Conservation	Potential Acre-Feet Per Year Conservation	Status	Source
Tumalo	48	15,116	Permitted for federal funding, project to be implemented over next 11 years to 20 years, depending on funding	Tumalo Environmental Assessment, interview with district manager
North Unit	174.4	71,000	System improvement plan developed, no funding procured/applied for	North Unit System Improvement Plan and interviews with district manager
Central Oregon[a]	137.9	44,013	System improvement plan, federal permitting/funding received for 29.4 cfs that is incorporated into RiverWare	Central Oregon ID System Improvement Plan and interviews with district manager
Swalley	19.2	4,629	Application for federal permitting/funding submitted	Swalley Environmental Assessment
Arnold	32	N/A	System improvement plan developed, funding/permit process not yet completed	Arnold Preliminary Investigative Report, district manager interview
Ochoco	41	N/A	System improvement plan developed, funding/permit process not yet completed	Ochoco Irrigation District System Improvement Plan, district manager interview
Lone Pine	8.8	3,219	System improvement plan developed, funding/permit process not yet completed, but much funding procured	LPID Preliminary Investigative Report, district manager interview

Sources: Britton and Horrell pers.comm.; Farmers Conservation Alliance 2018c; Farmers Conservation Alliance 2018a; Farmers Conservation Alliance 2018b; Horrell pers. comm.[b]; Gerdes pers. comm.; Rhoden and Scanlon pers. comm.; Thalacker pers. comm.; Rieck pers. comm.; Black Rock Consulting and Farmers Conservation Alliance 2018.

[a] This is the piping for which Central Oregon ID is currently seeking funding; total potential cfs conservation from piping in Central Oregon ID is higher. Funding secured for piping that will result in 29.4 cfs is included in the RiverWare modeling.

In general, the high conservation scenario for district piping assumes that federal funding for piping is procured at the level being sought in the ongoing watershed planning processes being undertaken by the districts in collaboration with the Natural Resources Conservation Service and Farmers Conservation Alliance. (See for example, the Final Watershed Plan-Environmental Assessment for the Tumalo Irrigation District Modernization Project (Farmers Conservation Alliance 2018b)). Tumalo ID has completed the federal permitting process, and has federal funding for its proposed piping projects procured through 2020. Swalley ID is near completion with the permitting process, while Central Oregon ID, Ochoco ID, Arnold ID, and Lone Pine ID are in the midst of the federal permitting/funding process. The Three Sisters ID has been piping for the last 20 years and will be completely piped in a year (Thalacker pers. comm.). Additionally, Lone Pine ID has secured most of the funding necessary for piping and the district manager considers piping to be almost certain to occur (Smith pers. comm.).

In the absence of federal funding, only Central Oregon ID plans to pipe in a manner that will result in meaningful conservation of water. Due to the high costs of piping, district managers for Arnold ID and Ochoco ID expect only limited piping would occur without federal funds (Gerdes pers. comm.) (Rhoden and Scanlon pers. comm.). As such, for the low conservation scenario these districts are assumed to have constant district conveyance efficiency through time. In a low conservation scenario, the Tumalo ID manager estimated that completing the piping projects might require 20 years instead of 10 (Rieck pers. comm.). In the low scenario for Lone Pine ID, the same doubling of time required for piping (6 years instead of 3 years) is assumed.

No district piping is assumed for North Unit ID canals even in the high conservation scenario as costs per acre-foot conserved through North Unit ID piping are high relative to other districts (see 2018 Draft Upper Deschutes Basin Study and (Britton and Horrell pers.comm.)). As it is more cost effective, North Unit ID is instead focusing its efforts and financial resources on collaborating with and supporting Central Oregon ID to increase their water savings from piping (which in turn, the districts expect to benefit North Unit ID water supplies) (Britton and Horrell pers.comm.). Because Central Oregon ID water conservation is assumed to benefit North Unit ID, and because the water available for diversion to Central Oregon ID varies minimally between water year types and scenarios, instead of showing district efficiency for Central Oregon ID, this analysis estimates the af of water available to North Unit ID based on conservation projections for Central Oregon ID for each permit year, as shown in **Table 4**. Although not benefiting other water supplies to North Unit ID, the water made available by Central Oregon ID to North Unit would be conveyed in Central Oregon ID pipe for approximately half of the distance to North Unit ID farms. As such, the analysis assumes that once Central Oregon ID piping is complete, the seepage loss for this water will be approximately half of the average seepage loss for North Unit ID farm deliveries (i.e., conveyance efficiency will be 80% instead of 60%), as shown in the last columns of **Table 11**.

Table 11. District Conveyance Efficiencies

	Arnold		Lone Pine		Ochoco		Tumalo		North Unit	Efficiency for Water Made Available by Central Oregon to North Unit	
Year	High	Low	High	Low	High	Low	High	Low	High/Low	High	Low
2019 (Existing Conditions)	61%	61%	80%	80%	59%	59%	54%	54%	60%	60%	60%
2020 (Permit Year 1)	63%	61%	87%	83%	61%	59%	58%	56%	60%	62%	61%
2021	66%	61%	93%	87%	63%	59%	62%	59%	60%	64%	61%
2022	68%	61%	100%	90%	65%	59%	67%	61%	60%	67%	62%
2023	71%	61%	100%	93%	67%	59%	71%	63%	60%	69%	63%
2024	73%	61%	100%	97%	69%	59%	75%	66%	60%	71%	64%
2025	76%	61%	100%	100%	71%	59%	79%	68%	60%	73%	64%
2026	78%	61%	100%	100%	73%	59%	83%	70%	60%	76%	65%
2027	81%	61%	100%	100%	75%	59%	87%	72%	60%	78%	66%
2028	83%	61%	100%	100%	77%	59%	92%	75%	60%	80%	67%
2029	86%	61%	100%	100%	79%	59%	96%	77%	60%	80%	67%
2030	88%	61%	100%	100%	81%	59%	100%	79%	60%	80%	68%
2031	88%	61%	100%	100%	81%	59%	100%	82%	60%	80%	69%
2032	88%	61%	100%	100%	81%	59%	100%	84%	60%	80%	70%
2033	88%	61%	100%	100%	81%	59%	100%	86%	60%	80%	70%
2034	88%	61%	100%	100%	81%	59%	100%	89%	60%	80%	71%
2035	88%	61%	100%	100%	81%	59%	100%	91%	60%	80%	72%
2036	88%	61%	100%	100%	81%	59%	100%	93%	60%	80%	73%
2037	88%	61%	100%	100%	81%	59%	100%	95%	60%	80%	73%
2038	88%	61%	100%	100%	81%	59%	100%	98%	60%	80%	74%
2039–2049	88%	61%	100%	100%	81%	59%	100%	100%	60%	80%	75%, rising to 80% by 2046

Sources: Farmers Conservation Alliance 2018a; Farmers Conservation Alliance 2018c; Farmers Conservation Alliance 2018b; Black Rock Consulting and Farmers Conservation Alliance 2018; Gerdes pers. comm.; Rhoden and Scanlon pers. comm,; Horrell pers. comm. [b]; Rieck pers. comm.; Britton and Horrell pers. comm.; Smith pers. comm.

The Central Oregon ID System Improvement Plan has identified that piping the Pilot Butte Canal, which would result in an estimated 167.3 cfs of water conservation, equal to 53,400 af/y of conserved water once this piping is completed (approximately 319 af per cfs) (Horrell pers. comm. [b]). Central Oregon ID has received federal permitting and funding for Phase 1 of this piping, which will pipe 7.9 miles starting in 2020, and will result in 29.4 cfs (9,392 af/y) of water conservation. Central Oregon ID is continuing to pursue funding of other piping projects. If federal funds are procured for the remaining piping, then this piping is projected to be completed over the next 11 years. This equates to approximately 44,000 af/y of additional conserved water each year until 2028, as shown in **Table 12**. If federal funding is not procured, Central Oregon ID expects to continue piping over the next 30 years at an average rate of conservation of 5 cfs per year (as it has averaged in recent years), equivalent to approximately 1,600 af/y of water conservation (5 cfs multiplied by 319 af/y per cfs is approximately 1,600 af/y) (Horrell pers. comm. [b]). To allocate these seasonal values to months within the irrigation season, the analysis assumes that water conservation by month is proportionate to total diversion volume by month. Of Central Oregon ID's annual diversions, approximately 16% is in May, 37% is in June/July, and 35% is in August/September. These proportions were applied to the seasonal estimated water conservation to estimate the volume of water conserved in Central Oregon ID in each month that may be available to North Unit ID.

Table 12. Central Oregon Irrigation District, Conserved Water from Piping, Assumed to be Made Available to North Unit Irrigation District

	Season Total		May		June/July		August/ September	
Year	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**
2019 (Existing conditions)	4,400	1,600	707	257	1,610	586	1,528	556
2020 (Permit Year 1)	8,800	3,200	1,415	514	3,221	1,171	3,056	1,111
2021	13,200	4,800	2,122	772	4,831	1,757	4,583	1,667
2022	17,600	6,400	2,829	1,029	6,441	2,342	6,111	2,222
2023	22,000	8,000	3,537	1,286	8,052	2,928	7,639	2,778
2024	26,400	9,600	4,244	1,543	9,662	3,514	9,167	3,333
2025	30,800	11,200	4,951	1,800	11,273	4,099	10,695	3,889
2026	35,200	12,800	5,658	2,058	12,883	4,685	12,223	4,445
2027	39,600	14,400	6,366	2,315	14,493	5,270	13,750	5,000
2028	44,000	16,000	7,073	2,572	16,104	5,856	15,278	5,556
2029	44,000	17,600	7,073	2,829	16,104	6,441	15,278	6,111
2030	44,000	19,200	7,073	3,086	16,104	7,027	15,278	6,667
2031	44,000	20,800	7,073	3,344	16,104	7,613	15,278	7,222
2032	44,000	22,400	7,073	3,601	16,104	8,198	15,278	7,778
2033	44,000	24,000	7,073	3,858	16,104	8,784	15,278	8,334
2034	44,000	25,600	7,073	4,115	16,104	9,369	15,278	8,889
2035	44,000	27,200	7,073	4,372	16,104	9,955	15,278	9,445
2036	44,000	28,800	7,073	4,630	16,104	10,541	15,278	10,000
2037	44,000	30,400	7,073	4,887	16,104	11,126	15,278	10,556
2038	44,000	32,000	7,073	5,144	16,104	11,712	15,278	11,111
2039	44,000	33,600	7,073	5,401	16,104	12,297	15,278	11,667

Year	Season Total		May		June/July		August/ September	
	High	Low	High	Low	High	Low	High	Low
2040	44,000	35,200	7,073	5,658	16,104	12,883	15,278	12,223
2041	44,000	36,800	7,073	5,916	16,104	13,469	15,278	12,778
2042	44,000	38,400	7,073	6,173	16,104	14,054	15,278	13,334
2043	44,000	40,000	7,073	6,430	16,104	14,640	15,278	13,889
2044	44,000	41,600	7,073	6,687	16,104	15,225	15,278	14,445
2045	44,000	43,200	7,073	6,944	16,104	15,811	15,278	15,000
2046	44,000	44,000	7,073	7,073	16,104	16,104	15,278	15,278
2047	44,000	44,000	7,073	7,073	16,104	16,104	15,278	15,278
2048	44,000	44,000	7,073	7,073	16,104	16,104	15,278	15,278
2049 (Permit year 30)	44,000	44,000	7,073	7,073	16,104	16,104	15,278	15,278

Sources: Highland Economics analysis of Horrell pers. comm. [b,c]; Black Rock Consulting 2016.

On-Farm Water Efficiency: Irrigation and Conveyance

On-farm water conservation investments may include investing in more efficient irrigation technologies and equipment, lining ponds and on-farm canals, and changing irrigation timing. By reducing the amount of water lost to seepage or evaporation, more efficient irrigation systems or more efficient on-farm conveyance systems reduce the amount of water that needs to be delivered to the farm to meet a given level of crop water need. While most lands throughout the basin are irrigated with sprinklers, there are some flood irrigated lands in the basin, which tend to have much lower irrigation efficiency. Even for lands that are irrigated with sprinklers, there is variation in efficiency among different types of sprinklers, between different nozzle sizes, and with different irrigation management and timing. Efficiency of flood may vary from 30 to 45% while efficiency of sprinkler methods, including sprinkler guns, hand lines, wheel lines, and center pivots may vary from 55 to 95% (Central Oregon Irrigation District 2012).

This analysis estimates current on-farm efficiency by comparing historical diversions (as reported by district managers and the 2013 Deschutes Water Planning Initiative Water Supply Goals and Objectives report) with conveyance efficiencies and average crop water requirement (as estimated under *Existing Conditions: Crop Acreage and Crop Water Demand*). Also taken into consideration were previous estimates of on-farm efficiency, including data from district modernization reports, the 2006 Irrigation District Water Efficiency Study (Newton and Perle 2006), and the 2013 report on the Deschutes Water Planning Initiative Water Supply Goals and Objectives (Deschutes River Conservancy and Deschutes Water Alliance 2013) as well as interviews with district managers, Oregon State University Extension, and with local area irrigation equipment providers (Bohle pers. comm. [a]), (Gerdes pers. comm.) (Rhoden and Scanlon pers. comm.), (Rieck pers. comm.), (Britton and Horrell pers. comm.), (Horrell pers. comm. [b]). In general, with the exception of North Unit ID, districts are estimated to have on-farm irrigation efficiency of approximately 65 to 70% currently.

Districts have no direct control over on-farm efficiency improvements. However, districts that have been piping have noted that piping often spurs patrons to invest in more efficient irrigation technologies (partly to take advantage of the pressurized water that often comes with piping) (Thalacker pers. comm.) (Rieck pers. comm.), with increases in irrigation efficiency of 10% or more. As identified by a Central Oregon ID study, piping of district canals and pressurization of water to patron turnouts can decrease by 50% the cost to patrons of converting from flood irrigation to more efficient irrigation technologies (Central Oregon Irrigation District 2017). As such, with increased piping in the high conservation scenario, this analysis also assumes increased on-farm irrigation efficiency.

Specifically, this analysis assumes that average on-farm efficiency in nearly all districts would increase to 80% in the high conservation scenario (**Table 13**). North Unit ID is currently estimated to have an irrigation efficiency of 87%, reflecting partly the use by some patrons of drip irrigation, which can approach 100% irrigation efficiency. Due to the differences between North Unit ID and other districts (crops grown, size of farms, etc.), this analysis does not expect that on-farm irrigation efficiencies in other DBBC districts and irrigated lands would reach the same level as those in North Unit ID, even in the high conservation scenario. Growers in districts with predominantly lower-value crops like hay and pasture are less likely to have the financial resources and management capacity to invest in expensive irrigation technology that would optimize on-farm efficiency (Oregon Environmental Council 2012)**.**

Regarding Central Oregon ID water conservation from on-farm efficiency improvements, this analysis estimates the amount of conserved water using data from two studies of Central Oregon ID on-farm efficiency: the 2011 Central Oregon ID Water Management Conservation Plan and the 2017 Preliminary On-Farm Efficiency Study. The 2011 Central Oregon ID Water Management Conservation Plan estimated that 40% of Central Oregon ID patrons were flood irrigating (or approximately 16,850 acres, assuming 40% of 42,133 acres) (Central Oregon Irrigation District 2012). The remaining 60% were using a sprinkler method, including sprinkler guns, hand lines, wheel lines, and center pivots with efficiency varying from 55 to 95%. By 2017, the 2017 Central Oregon ID Preliminary On-Farm Efficiency Study estimated that there were 11,240 acres that were flood irrigated (Central Oregon Irrigation District 2017).[10] Using these data, from 2011 to 2017 there was likely a conversion of 5,610 acres from flood irrigation to sprinkler irrigation. On an average annual basis, this equates to approximately 800 acres converted per year conserving approximately 1,160 af/y of additional water per year.[11]

In the low conservation scenario, this analysis assumes that Central Oregon ID patrons continue to conserve water at approximately this rate (1,000 af/y) until the 5,610 acres are converted to sprinkler irrigation (over the course of 14 years, assuming 800 acres per year), for approximately 14,000 af/y of cumulative conservation.[12] In the high conservation scenario, the analysis assumes that this conservation rate is doubled, to 2,000 af/y per year and continues through the analysis period (60,000 af/y cumulatively, see **Table 14**). Consultation with the Central Oregon ID district manager indicated that these are reasonable estimates (Horrell pers. comm. [b]). As a proportion of total potential on-farm conservation, this also appears reasonable. The 2017 Central Oregon ID Preliminary On-Farm Efficiency Study estimates that 48,255 af/y annually could be conserved by on-farm irrigation improvements and 35,284 af/y from piping of private ditches (downstream of Central Oregon ID delivery points), for a total potential of 83,539 af/y. As such, conservation of 14,000 af/y (in the low scenario) equates to approximately 17% of potential on-farm conservation, while conservation of 60,000 af/y (in the high scenario) equates to 74% of potential on-farm conservation.

[10] The calculation is: 16,850 acres -11,240 acres =5,610 acres.

[11] The calculation is: 5,610 acres / 7 years = ~800 acres / year.

[12] The calculation is: 11,240 acres / 800 acres per year = ~14 years.

Table 13. Estimated On-Farm Efficiencies by DBBC District and Permit Year

Year	Arnold		Lone Pine		Ochoco		Tumalo		Other Irrigated Lands	North Unit
	High	Low	High	Low	High	Low	High	Low	High/Low	High/Low
2019 (Existing Conditions)	65%	65%	67%	67%	70%	70%	70%	70%	65%	87%
2020 (Permit Year 1)	66%	65%	68%	67%	71%	70%	71%	71%	65%	87%
2021	68%	66%	69%	67%	72%	70%	72%	71%	65%	87%
2022	69%	66%	70%	68%	73%	70%	73%	72%	65%	87%
2023	70%	67%	72%	68%	74%	70%	74%	72%	65%	87%
2024	72%	67%	73%	68%	75%	70%	75%	73%	65%	87%
2025	73%	68%	74%	69%	75%	70%	75%	73%	65%	87%
2026	75%	68%	75%	69%	76%	70%	76%	74%	65%	87%
2027	76%	69%	76%	69%	77%	70%	77%	74%	65%	87%
2028	77%	69%	78%	69%	78%	70%	78%	75%	65%	87%
2029	79%	70%	79%	70%	79%	70%	79%	75%	65%	87%
2030	80%	70%	80%	70%	80%	70%	80%	76%	65%	87%
2031	80%	70%	80%	70%	80%	70%	80%	76%	65%	87%
2032	80%	70%	80%	70%	80%	70%	80%	77%	65%	87%
2033	80%	70%	80%	70%	80%	70%	80%	77%	65%	87%
2034	80%	70%	80%	70%	80%	70%	80%	78%	65%	87%
2035	80%	70%	80%	70%	80%	70%	80%	78%	65%	87%
2036	80%	70%	80%	70%	80%	70%	80%	79%	65%	87%
2037	80%	70%	80%	70%	80%	70%	80%	79%	65%	87%
2038	80%	70%	80%	70%	80%	70%	80%	80%	65%	87%
2039–2049	80%	70%	80%	70%	80%	70%	80%	80%	65%	87%

Sources: Highland Economics analysis and Deschutes River Conservancy and Deschutes Water Alliance 2013; Central Oregon Irrigation District 2017; Newton and Perle 2006; Gerdes pers. comm.; Britton and Horrell pers. comm.; Rieck pers. comm.; Rhoden and Scanlon pers. comm.; Thalacker pers. comm.

Table 14. Central Oregon Irrigation District On-Farm Conservation, Acre-Feet Per Year Cumulative Over Time, Available for Use by North Unit

	Season		May		June/July		August/ September	
Year	High	Low	High	Low	High	Low	High	Low
2019 (Existing Conditions)	2,000	1,000	322	161	732	366	695	347
2020 (Permit Year 1)	4,000	2,000	643	322	1,464	732	1,389	695
2021	6,000	3,000	965	482	2,196	1,098	2,084	1,042
2022	8,000	4,000	1,286	643	2,928	1,464	2,778	1,389
2023	10,000	5,000	1,608	804	3,660	1,830	3,473	1,736
2024	12,000	6,000	1,929	965	4,392	2,196	4,168	2,084
2025	14,000	7,000	2,251	1,125	5,123	2,562	4,862	2,431
2026	16,000	8,000	2,572	1,286	5,855	2,928	5,557	2,778
2027	18,000	9,000	2,894	1,447	6,587	3,294	6,251	3,126
2028	20,000	10,000	3,215	1,608	7,319	3,660	6,946	3,473
2029	22,000	11,000	3,537	1,768	8,051	4,026	7,640	3,820
2030	24,000	12,000	3,859	1,929	8,783	4,392	8,335	4,168
2031	26,000	13,000	4,180	2,090	9,515	4,758	9,030	4,515
2032	28,000	14,000	4,502	2,251	10,247	5,123	9,724	4,862
2033	30,000	14,000	4,823	2,251	10,979	5,123	10,419	4,862
2034	32,000	14,000	5,145	2,251	11,711	5,123	11,113	4,862
2035	34,000	14,000	5,466	2,251	12,443	5,123	11,808	4,862
2036	36,000	14,000	5,788	2,251	13,175	5,123	12,503	4,862
2037	38,000	14,000	6,109	2,251	13,907	5,123	13,197	4,862
2038	40,000	14,000	6,431	2,251	14,639	5,123	13,892	4,862
2039	42,000	14,000	6,752	2,251	15,370	5,123	14,586	4,862
2040	44,000	14,000	7,074	2,251	16,102	5,123	15,281	4,862
2041	46,000	14,000	7,396	2,251	16,834	5,123	15,976	4,862
2042	48,000	14,000	7,717	2,251	17,566	5,123	16,670	4,862
2043	50,000	14,000	8,039	2,251	18,298	5,123	17,365	4,862
2044	52,000	14,000	8,360	2,251	19,030	5,123	18,059	4,862
2045	54,000	14,000	8,682	2,251	19,762	5,123	18,754	4,862
2046	56,000	14,000	9,003	2,251	20,494	5,123	19,449	4,862
2047	58,000	14,000	9,325	2,251	21,226	5,123	20,143	4,862
2048	60,000	14,000	9,646	2,251	21,958	5,123	20,838	4,862
2049 (Permit Year 30)	62,000	14,000	9,968	2,251	22,690	5,123	21,532	4,862

Sources: Highland Economics analysis and Central Oregon Irrigation District 2017; Central Oregon Irrigation District 2012; Horrell pers. comm. [b].

Water Available for Crops (Accounting for Efficiency)

To estimate the water supply available to meet crop water requirements (crop ET), this analysis combined water available for diversion data from RiverWare (*Water Available for Diversion under Proposed Action and Alternatives*) with the estimated district conveyance and on-farm efficiencies provided above (*Agricultural Water Use Efficiency*). In other words, water available for diversion in each alternative and water year type over the permit term was multiplied by the estimated conveyance efficiency and on-farm efficiency to estimate total water available by crop in each water year type, permit year, conservation scenario, and alternative. No data are presented for Swalley ID because its water supply would not be affected by the proposed action and action alternatives.

Existing Conditions

Table 15 and **Table 16** summarize, respectively, the median and dry water year availability of water to crops under existing conditions by district based on water available for diversion and estimated existing district and on-farm efficiencies. (This is using data from RiverWare for the no-action alternative, which is expected to be very similar to existing conditions). As apparent in comparing values in **Table 15** and **Table 16**, under existing conditions, there is less water available for diversion in some districts in dry water years, particularly (in terms of percentage reductions) in North Unit ID and Three Sisters ID. For all districts that face a shortage under existing conditions (and likewise the no-action alternative), any reduction in water diversions resulting from the proposed action and action alternatives would compound an existing crop water shortage.

As discussed above under assumptions, potential increases in water available to crops are not an effect of the proposed action and action alternatives, but rather an outcome that would similarly affect all future conditions. Furthermore, whether conservation efforts could result in more water being made available to agriculture in the future than under existing conditions is uncertain, as districts and growers (and funding agencies) would likely be most incentivized to invest in conservation that would reduce water shortfalls rather than increase water available to crops beyond current conditions. As such, the analysis caps the total water available to the crop (after accounting for conveyance and irrigation efficiencies) in median and dry water year types in all future years to the median existing conditions water available to the crop.

Table 15. Water Available for Diversions and Water Available to Crops by District under Existing Conditions, Median Water Year

District	Water Available for Diversion, acre-feet per year			District Conveyance Efficiency	On-Farm Efficiency	Water Available to Crop, acre-feet per year		
	May	June/July	Aug/Sept			May	June/July	Aug/Sept
Arnold	5,232	10,951	11,099	61%	65%	2,075	4,342	4,401
Central Oregon	46,248	105,296	99,899	68%	60%	18,869	42,961	40,759
Lone Pine[a]	2,699	6,147	4,577	80%	67%	1,446	3,295	2,453
North Unit	36,019	72,823	59,691	60%	87%	18,802	38,014	31,158
Ochoco	13,781	28,435	24,732	59%	70%	5,692	11,744	10,214
Tumalo	8,610	19,622	18,553	54%	70%	3,255	7,417	7,013
Three Sisters	5,154	11,751	7,451	100%	70%	3,686	8,406	5,329
Other Irrigated Lands	4,990	9,501	8,493	60%	65%	1,946	3,705	3,312

Sources: Highland Economics analysis of data provided in sections entitled *Water Available for Diversion under the Proposed Action and Alternatives, Agricultural Water Used Efficiency, and Water Available for Crops (Accounting for Efficiency)*.

[a] District conveyance efficiency is based on canals within Lone Pine ID, not including conveyance loss in Pilot Butte Canal. The water available for diversion to Lone Pine ID is based on the amount of water at the diversion location on the Pilot Butte Canal.

Table 16. Water Available for Diversions and Water Available to Crops by District under Existing Conditions, Dry Water Year

District	Water Available for Diversion			District Conveyance Efficiency	On-Farm Efficiency	Water Available to Crop			
	May	June/ July	Aug/ Sept			May	June/ July	Aug/ Sept	% of Median (May–Aug)
Arnold	5,232	10,951	11,009	61%	65%	2,075	4,342	4,365	100%
Central Oregon	46,248	105,170	99,360	68%	60%	18,869	42,909	40,539	100%
Lone Pine[a]	2,699	6,147	4,495	80%	67%	1,446	3,295	2,409	99%
North Unit	36,019	72,823	49,081	60%	87%	18,802	38,014	25,620	94%
Ochoco	13,781	28,064	24,732	59%	70%	5,692	11,591	10,214	99%
Tumalo	8,610	19,622	18,352	54%	70%	3,255	7,417	6,937	100%
Three Sisters	4,563	11,504	6,937	100%	70%	3,264	8,229	4,962	94%
Other Irrigated Lands	4,979	9,400	8,331	60%	65%	1,942	3,666	3,249	99%

Sources: Highland Economics analysis of data provided in sections entitled *Water Available for Diversion under the Proposed Action and Alternatives, Agricultural Water Used Efficiency, and Water Available for Crops (Accounting for Efficiency)*.

[a] District conveyance efficiency is based on canals within Lone Pine ID, not including conveyance loss in Pilot Butte Canal. The water available for diversion to Lone Pine ID is based on the amount of water at the diversion location on the Pilot Butte Canal.

No-Action Alternative

Water available to crops in the no-action alternative is expected to be the same as existing conditions for median water years.[13] However, the water available to crops in dry water years in the no-action alternative is anticipated to increase over time compared to existing conditions due to conservation. **Table 17** summarizes increased water available to crops over the analysis period in dry water years under the no-action alternative compared to existing conditions (from **Table 16**). As highlighted in the table, on-farm and district conservation of water is particularly expected to benefit North Unit ID. Note that no additional water is assumed to be permanently available for Central Oregon ID (as all conservation is assumed to be made available to North Unit ID), although Central Oregon ID management expects that increased operational efficiencies will result in increased water availability for Central Oregon ID patrons in dry water years. Also, for purposes of this analysis, the water supply is capped at the existing average water year supply (i.e., no increased future average water supply is projected to be available).

Table 17. Increased Water Available to Crops by District in No-Action Alternative Compared to Existing Conditions, Dry Water Year (acre-feet per year)

Irrigation District/ Year	Low Conservation			High Conservation		
	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept
Arnold						
2020	0	0	0	0	0	0
2025	0	0	0	0	0	0
2030	0	0	0	0	0	0
2040	0	0	0	0	0	0
2049	0	0	0	0	0	0
Central Oregon						
2020	0	0	0	0	0	0
2025	0	0	0	0	0	0
2030	0	0	0	0	0	0
2040	0	0	0	0	0	0
2049	0	0	0	0	0	0
Lone Pine						
2020	0	0	50	0	0	50
2025	0	0	50	0	0	50
2030	0	0	50	0	0	50
2040	0	0	50	0	0	50
2049	0	0	50	0	0	50

[13] As noted above, because future crop water supply in median water years is not allowed to exceed median crop water supply in existing conditions, there is no increased water supply to crops in future median water years under the no-action alternative.

Irrigation District/ Year	Low Conservation			High Conservation		
	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept
North Unit						
2020	0	0	1,000	0	0	2,400
2025	0	0	3,500	0	0	5,500
2030	0	0	5,500	0	0	5,500
2040	0	0	5,500	0	0	5,500
2049	0	0	5,500	0	0	5,500
Ochoco						
2020	0	0	0	0	150	0
2025	0	0	0	0	150	0
2030	0	0	0	0	150	0
2040	0	0	0	0	150	0
2049	0	0	0	0	150	0
Three Sisters						
2020	0	0	0	0	0	0
2025	0	0	0	0	0	0
2030	0	0	0	0	0	0
2040	0	0	0	0	0	0
2049	0	0	0	0	0	0
Tumalo						
2020	0	0	100	0	0	100
2025	0	0	100	0	0	100
2030	0	0	100	0	0	100
2040	0	0	100	0	0	100
2049	0	0	100	0	0	100
Other Irrigated Lands						
2020	0	0	0	0	0	0
2025	0	0	0	0	0	0
2030	0	0	0	0	0	0
2040	0	0	0	0	0	0
2049	0	0	0	0	0	0

Proposed Action

Table 18 presents the estimated change in water available to crops by each district under the proposed action compared to the no-action alternative. The alternatives are compared for the same conservation scenario and water year type. A positive number in the table indicates an increased water supply, while a negative number indicates a decreased water supply. After accounting for water conservation, the only affected districts in median or dry water years are Lone Pine ID and North Unit ID, with impacts limited to dry water years.

Table 18. Change in Water Available to Crops (acre-feet per year) by District under the Proposed Action Compared to the No-Action Alternative

Irrigation District/ Year	Dry Water Year						Median Water Year					
	Low Conservation			High Conservation			Low Conservation			High Conservation		
	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept
Arnold												
2020	0	0	0	0	0	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0
2040	0	0	0	0	0	0	0	0	0	0	0	0
2049	0	0	0	0	0	0	0	0	0	0	0	0
Central Oregon												
2020	0	0	0	0	0	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0
2040	0	0	0	0	0	0	0	0	0	0	0	0
2049	0	0	0	0	0	0	0	0	0	0	0	0
Lone Pine												
2020	0	-300	0	0	-100	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0
2040	0	0	0	0	0	0	0	0	0	0	0	0
2049	0	0	0	0	0	0	0	0	0	0	0	0
North Unit												
2020	0	0	4,600	0	0	3,100	0	0	0	0	0	0
2025	0	0	2,000	0	0	0	0	0	0	0	0	0
2030	0	0	-9,800	0	0	0	0	0	0	0	0	0
2040	0	-2,800	-3,400	0	0	0	0	0	0	0	0	0
2049	0	0	-700	0	0	0	0	0	0	0	0	0

Irrigation District/ Year	Dry Water Year						Median Water Year					
	Low Conservation			High Conservation			Low Conservation			High Conservation		
	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept
Ochoco												
2020	0	0	0	0	0	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0
2040	0	0	0	0	0	0	0	0	0	0	0	0
2049	0	0	0	0	0	0	0	0	0	0	0	0
Tumalo												
2020	0	0	0	0	0	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0
2040	0	0	0	0	0	0	0	0	0	0	0	0
2049	0	0	0	0	0	0	0	0	0	0	0	0
Three Sisters												
2020	0	0	0	0	0	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0
2040	0	0	0	0	0	0	0	0	0	0	0	0
2049	0	0	0	0	0	0	0	0	0	0	0	0
Other Irrigated Lands												
2020	0	0	0	0	0	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0
2040	0	0	0	0	0	0	0	0	0	0	0	0
2049	0	0	0	0	0	0	0	0	0	0	0	0

Alternative 3

Table 19 presents the estimated change in water available to crops under Alternative 3 compared to the no-action alternative. The alternatives are compared for the same conservation scenario and water year type. Because the reductions in water available for diversion are occurring earlier in the permit term (with a different level of conservation achieved) in Alternative 3 compared to the proposed action, the reduction in water available to crops may differ for a given diversion reduction.

Table 19. Reduction in Water Available to Crops (acre-feet per year) by District under Alternative 3 Compared to the No-Action Alternative

Irrigation District/ Year	Dry Water Year						Median Water Year					
	Low Conservation			High Conservation			Low Conservation			High Conservation		
	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept
Arnold												
2020	0	-100	-100	0	0	0	0	0	0	0	0	0
2025	0	0	-400	0	0	0	0	0	0	0	0	0
2030	0	0	-100	0	0	0	0	0	0	0	0	0
2040	0	0	-100	0	0	0	0	0	0	0	0	0
2049	0	0	-100	0	0	0	0	0	0	0	0	0
Central Oregon												
2020	0	0	0	0	0	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0
2040	0	0	0	0	0	0	0	0	0	0	0	0
2049	0	0	0	0	0	0	0	0	0	0	0	0
Lone Pine												
2020	0	-500	0	0	-300	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0
2040	0	0	0	0	0	0	0	0	0	0	0	0
2049	0	0	0	0	0	0	0	0	0	0	0	0
North Unit												
2020	-500	-3,400	-8,100	0	-1,900	-8,100	0	0	0	0	0	0
2025	0	-9,700	-11,700	0	-3,000	-7,300	0	0	0	0	0	0
2030	0	-11,400	-13,800	0	-800	-3,700	0	0	-500	0	0	0
2040	0	-6,300	-8,900	0	0	0	0	0	0	0	0	0
2049	0	-3,400	-6,200	0	0	0	0	0	0	0	0	0

Irrigation District/ Year	Dry Water Year						Median Water Year					
	Low Conservation			High Conservation			Low Conservation			High Conservation		
	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept
Ochoco												
2020	0	0	0	0	0	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0
2040	0	0	0	0	0	0	0	0	0	0	0	0
2049	0	0	0	0	0	0	0	0	0	0	0	0
Tumalo												
2020	0	0	0	0	0	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0
2040	0	0	0	0	0	0	0	0	0	0	0	0
2049	0	0	0	0	0	0	0	0	0	0	0	0
Three Sisters												
2020	0	0	0	0	0	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0
2040	0	0	0	0	0	0	0	0	0	0	0	0
2049	0	0	0	0	0	0	0	0	0	0	0	0
Other Irrigated Lands												
2020	0	0	0	0	0	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0
2040	0	0	0	0	0	0	0	0	0	0	0	0
2049	0	0	0	0	0	0	0	0	0	0	0	0

Alternative 4

Table 20 presents the estimated change in water available to crops under Alternative 4 compared to the no-action alternative. The alternatives are compared for the same conservation scenario and water year type. Because the reductions in water available for diversion are occurring earlier in the permit term (with a different level of conservation achieved) in Alternative 4 compared to the proposed action and Alternative 3, the reduction in water available to crops may differ for a given diversion reduction.

Table 20. Reduction in Water Available to Crops (acre-feet per year) by District under Alternative 4 Compared to the No-Action Alternative

Irrigation District/ Year	Dry Water Year						Median Water Year					
	Low Conservation			High Conservation			Low Conservation			High Conservation		
	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept
Arnold												
2020	0	-200	-500	0	0	-300	0	0	0	0	0	0
2025	0	-500	0	0	0	0	0	0	0	0	0	0
2030	0	-300	0	0	0	0	0	0	0	0	0	0
2039	0	-300	0	0	0	0	0	0	0	0	0	0
Central Oregon												
2020	0	0	0	0	0	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0
2039	0	0	0	0	0	0	0	0	0	0	0	0
Lone Pine												
2020	0	-500	0	0	-400	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0
2039	0	0	0	0	0	0	0	0	0	0	0	0
North Unit												
2020	-1,000	-12,500	-11,700	-300	-10,900	-11,700	-500	-900	-1,800	0	0	-400
2025	-900	-18,800	-15,100	0	-12,000	-10,700	0	-4,100	-4,900	0	0	0
2030	0	-15,700	-14,200	0	-5,200	-4,200	0	-1,000	-2,000	0	0	0
2039	0	-11,200	-9,900	0	-600	0	0	0	0	0	0	0
Ochoco												
2020	0	0	0	0	0	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0
2039	0	0	0	0	0	0	0	0	0	0	0	0

Irrigation District/ Year	Dry Water Year						Median Water Year					
	Low Conservation			High Conservation			Low Conservation			High Conservation		
	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept
Tumalo												
2020	0	0	0	0	0	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0
2039	0	0	0	0	0	0	0	0	0	0	0	0
Three Sisters												
2020	0	0	0	0	0	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0
2039	0	0	0	0	0	0	0	0	0	0	0	0
Other Irrigated Lands												
2020	0	0	0	0	0	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0
2039	0	0	0	0	0	0	0	0	0	0	0	0

Farm Response to Crop Water Shortages: Change in Acreage

This section summarizes how estimated changes in water availability to crops (as presented in ***Water Available for Crops (Accounting for Efficiency)***) translate into changes in farm acreage/crop production. Given the current cropping pattern, growers could respond to reduction in water supplies in the following ways:

- Reduce harvested acreage due to fallowing of lands or crop failure.
- Reduce yields due to deficit irrigation (irrigation less than crop water requirement).

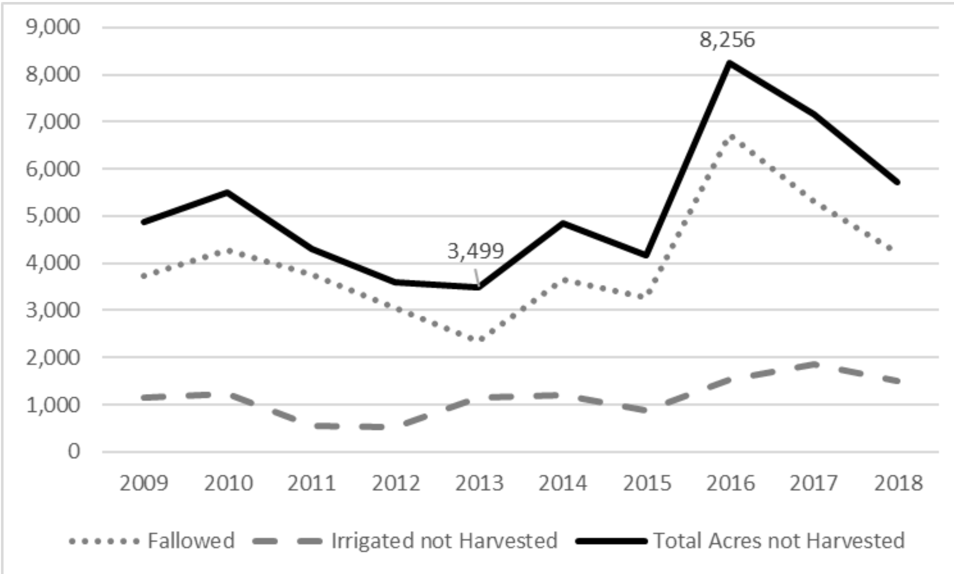
Growers may also transition to lower water use crops if such a transition is economically viable. However, as noted in *Methods, Key Assumptions, and Data Sources,* this analysis assumes that when water supply is available, the future crop mix and acreage will remain similar to the current cropping pattern. In particular, the analysis assumes that forage crops will remain the predominant crop in the study area, which is consistent with the historical agricultural pattern in the region. As the market and economic potential, as well as farmer preference, for large-scale transition to other crops is not known and is speculative, this analysis estimates the effects of changes in water availability assuming the current cropping pattern. To the extent that other relatively lower water use crops replace forage crops on a wide-scale basis, the effects analyzed in this section would likely be overestimated due to the lower water requirement of these crops.

Assuming grower response options are fallowing and deficit irrigation, with a 10% reduction in water availability, a grower could a) reduce water application on all acres by 10%, b) fallow 10% of ground, or c) do a mixture of deficit irrigation and fallowing. As impacts on alfalfa and grass hay yield are roughly linear (i.e., a 10% reduction in water application may result in a 10%, or even more, reduction in yield) (Bohle pers. comm. [a]), the impact on total agricultural production of fallowing and of deficit irrigating may be fairly similar. This analysis assumes that all reductions in water supply result in fallowed acreage (rather than deficit irrigation) for the following reasons:

- Yield responses to water supply are complex, and the effect of reduced water application on yield, particularly of grass hay, may be proportionately greater than the decrease in water application.
- Forage crop quality may suffer with reduced water application (less water can lead to nitrate accumulation in hay, which creates problems in animals) (Bohle pers. comm. [a]).

Lands are fallowed in the study area in all years for various agronomic and farm-specific reasons, but annual acreage data from North Unit ID supports the assumption that more lands are fallowed in dry years. As shown in **Figure 6,** acreage not harvested in the last 10 years in North Unit ID (including both fallowed and irrigated and not harvested lands) has varied from approximately 3,500 acres to 8,250 acres. The highest level of fallowing occurred in 2016, a dry year with low water availability (North Unit Irrigation District 2016).

Figure 6. Annual North Unit Irrigation District Acres Not Harvested, 2009–2018



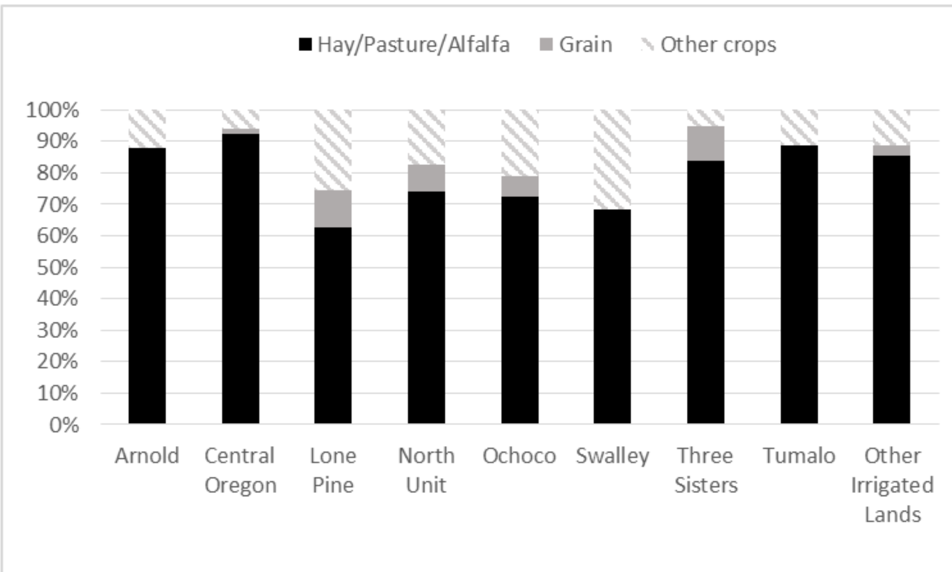
Source: Highland Economics analysis of North Unit ID crop acreage provided by Bohle pers. comm. [b].

When faced with water shortages, the decision to fallow versus deficit irrigate will vary by farm. As a consequence of assuming that all reductions in water supply result in fallowing acreage (rather than deficit irrigation), the estimated impacts on irrigated acreage presented in the summary tables below are expected to be the *maximum* agricultural acreage that may be fallowed in any given scenario/permit year (i.e., the maximum potential expected impact). As such, fewer acres than presented here may be impacted during certain periods of the irrigation season when more irrigation water is available relative to crop water demand.

The subseason analysis shows that many acres would likely be irrigated in April and May (months in which, in nearly all years and in all districts, irrigation water supplies are sufficient to meet crop water demand, see **Figure 1.**) Then, when facing reduced irrigation water supplies in later summer months (when water supplies relative to crop demand are proportionately lower in many districts), growers would deficit irrigate or potentially cease to irrigate these acres for the remainder of the season. The first cutting of alfalfa and grass hay is often at the beginning of June, so with full irrigation water supplies in April and May, one cutting of hay (approximately one-third of annual yield) would likely still be achieved on many of the acres projected to be affected in this section. For example, if estimated impacts in a district are limited to 100 acres in May through July, but are estimated at 500 acres in August/September, the maximum potential acreage impact presented for the year is 500 acres. In summary, if a maximum of 500 acres may be impacted in a given year, it is likely that one cutting, or approximately one-third of yield on these 500 acres would still be feasible on this acreage (this is accounted for in the socioeconomics that analyzes the impacts on total agricultural production value and the agricultural economy).

The analysis also assumes, consistent with economic theory and grower and Oregon State Extension interviews, that growers would minimize negative effects on profit of water supply changes, and would thus seek to limit impacts on higher value, specialty crops (Bohle pers. comm. [a]) (Richards pers. comm.). In other words, the analysis assumes that growers would fallow or deficit irrigate grains and forage crops (hay, pasture, and alfalfa) before reducing water to high-value specialty crops such as mint, carrot seed, or grass seed. As highlighted in **Figure 7**, in all districts, grain and forage crops are the predominant water users (representing at least 75% of crop water requirement across districts affected by the proposed action and action alternatives) and so would bear the brunt of reduced water supplies. Nearly all districts have at least some high value, specialty crop acreage such as carrot seed, peppermint, grass seed, and vegetables. However, these specialty crops are typically grown in rotation with grains and alfalfa and thus growers would likely be able to fallow their grain/forage crops and minimize impacts on their specialty crops, or) potentially purchase water from other farms growing predominantly forage crops in their district (Bohle pers. comm. [a]) (Richards pers. comm.).

Figure 7. Forage, Grain, and Other Crop Water Requirement by DBBC District: Current Cropping Pattern



Source: Highland Economics analysis of acreage and ET data presented in *Existing Conditions: Crop Acreage and Crop Water Demand*.

In sum, the analysis assumes that growers prioritize irrigating their higher-valued, lower-water use crops. In all alternatives, in all permit years/water year types/conservation scenario combinations, the RiverWare water supply model indicates that there is sufficient water to continue to irrigate the current acreage of these higher-valued crops (i.e., at the district level of analysis it is feasible to only reduce water to forage/grain crops and maintain crop water supply to specialty crops). While reduced water supplies impair the flexibility of growers to increase acreage of these specialty crops, this analysis indicates that continued full irrigation of current acreages of these high-value crops is possible if irrigating these crops is prioritized by growers. (As discussed in the socioeconomics analysis, this prioritization may come at a cost to specialty crop growers if their operation is heavily concentrated in high-value crops and they need to purchase water from other growers with predominantly hay/grain crops.) To the extent that an individual farmer does not have sufficient forage/grain crop acreage to enable on-farm re-allocation of water to high value crops, or is not able to purchase water from other forage/grain crop growers, high-value crops may be impacted.

In general, the findings on potentially affected acreage presented below highlight that three irrigation districts would be affected by the proposed action and action alternatives: North Unit ID, Arnold ID, and Lone Pine ID. The water supply model shows minor reduced water availability for Central Oregon ID, but as noted above, Central Oregon ID expects that continued piping as well as modifications to district operations in the shoulder seasons would ensure that this change has little to no effect on patron deliveries (Horrell pers. comm. [a,b]). As described above, there are also potential impacts on Ochoco ID in dry water years that are not projected in RiverWare and not analyzed herein.

Further, the values presented below represent the range in the maximum affected acreage in any one irrigation season, with variation across the permit years, water year types, and conservation scenarios. Water availability to crops moves up and down across the analysis period since conveyance and on-farm conservation increases water supply availability, while the increased instream flow requirements reduce water supply availability.

The subseason impacts are the basis to estimate the maximum affected acreage at any point in the irrigation season shown**.** However, for dry years, the maximum affected acreage in any one subseason for a given district/year/scenario would only necessarily equal the maximum annual impact if the maximum subseason acreage impact in the no-action alternative and proposed action occurs in the same irrigation subseason. This is also true for the alternatives presented below. Also of note is that in some cases, the impact of the proposed action and action alternatives does not differ between the low and high conservation scenarios. This is because the same water conservation is assumed under all alternatives, so the impact of the proposed action and action alternatives (i.e., the difference in acreage from the no-action alternative) under both conservation scenarios is similar in some cases.

Agricultural Acreage: No-Action Alternative

In each water year type, the amount of water available for diversion under the no-action alternative would be similar to existing conditions. As such, the average acreage irrigated by district under the no-action alternative is expected to be very similar to the acreage presented above in **Table 1**. Similarly, in the initial years of the analysis period, the no-action alternative dry year agricultural acreage would be similar to existing conditions as presented above in **Table 2**. However, due to water conservation over the analysis period, under no-action alternative, water available to crops in dry water years may increase over time compared to existing conditions, which may lead to increased acreage and/or yields in dry water years over the analysis period. **Table 21** summarizes the effect on irrigated acreage under the no-action alternative in dry water years throughout the analysis period. **Table 22** presents detail on effects by irrigation subseason for a dry year.

Table 21. Estimated Minimum Irrigated Acreage under No-Action Alternative Compared to Existing Condition, Dry Water Year

	DBBC Districts										
Year	**Arnold**	**Central Oregon**	**Lone Pine**	**North Unit**	**Ochoco**	**Swalley**	**Three Sisters**	**Tumalo**	**Total, DBBC Districts**	**Other Irrigated Lands**	**All Lands**
Existing Condition Dry	3,900	41,900	2,300	45,600	18,600	4,000	6,600	6,000	128,900	3,800	132,800
No-Action Alternative (Dry Water Year, Low Conservation Scenario)											
2020	4,000	41,900	2,400	46,800	18,600	4,000	6,600	6,000	130,200	3,800	134,100
2025	4,000	41,900	2,400	49,900	18,600	4,000	6,600	6,000	133,300	3,800	137,100
2030	4,000	41,900	2,400	52,200	18,600	4,000	6,600	6,000	135,700	3,800	139,500
2040	4,000	41,900	2,400	52,200	18,600	4,000	6,600	6,000	135,700	3,800	139,500
2049	4,000	41,900	2,400	52,200	18,600	4,000	6,600	6,000	135,700	3,800	139,500
No-Action Alternative (Dry Water Year, High Conservation Scenario)											
2020	4,000	41,900	2,400	48,500	18,700	4,000	6,600	6,000	132,100	3,800	135,900
2025	4,000	41,900	2,400	52,200	18,700	4,000	6,600	6,000	135,800	3,800	139,700
2030	4,000	41,900	2,400	52,200	18,700	4,000	6,600	6,000	135,800	3,800	139,700
2040	4,000	41,900	2,400	52,200	18,700	4,000	6,600	6,000	135,800	3,800	139,700
2049	4,000	41,900	2,400	52,200	18,700	4,000	6,600	6,000	135,800	3,800	139,700

Source: Highland Economics analysis.
Note: This table presents minimum irrigated acreage as only acreage that can be irrigated all season is presented here. If there is not sufficient water in any irrigation subseason (May or June/July or August/September) to irrigate a given acre, then that acreage is not included in the table.

Table 22. Estimated Maximum Increased Irrigated Acreage by Subseason under No-Action Alternative Compared to Existing Condition, Dry Water Year

Irrigation District/ Year	Low Conservation			High Conservation		
	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept
Arnold						
2020	0	0	0	0	0	0
2025	0	0	0	0	0	0
2030	0	0	0	0	0	0
2040	0	0	0	0	0	0
2049	0	0	0	0	0	0
Central Oregon						
2020	0	0	0	0	0	0
2025	0	0	0	0	0	0
2030	0	0	0	0	0	0
2040	0	0	0	0	0	0
2049	0	0	0	0	0	0
Lone Pine						
2020	0	0	100	0	0	100
2025	0	0	100	0	0	100
2030	0	0	100	0	0	100
2040	0	0	100	0	0	100
2049	0	0	100	0	0	100
North Unit						
2020	0	0	1,100	0	0	2,900
2025	0	0	4,200	0	0	6,600
2030	0	0	6,600	0	0	6,600
2040	0	0	6,600	0	0	6,600
2049	0	0	6,600	0	0	6,600
Ochoco						
2020	0	0	0	0	200	0
2025	0	0	0	0	200	0
2030	0	0	0	0	200	0
2040	0	0	0	0	200	0
2049	0	0	0	0	200	0
Three Sisters						
2020	0	0	0	0	0	0
2025	0	0	0	0	0	0
2030	0	0	0	0	0	0
2040	0	0	0	0	0	0
2049	0	0	0	0	0	0

Irrigation District/ Year	Low Conservation			High Conservation		
	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept
Tumalo						
2020	0	0	0	0	0	0
2025	0	0	0	0	0	0
2030	0	0	0	0	0	0
2040	0	0	0	0	0	0
2049	0	0	0	0	0	0
Other Irrigated Lands						
2020	0	0	0	0	0	0
2025	0	0	0	0	0	0
2030	0	0	0	0	0	0
2040	0	0	0	0	0	0
2049	0	0	0	0	0	0

Source: Highland Economics analysis.

Agricultural Acreage: Proposed Action

Table 23 presents the estimated range of potentially affected irrigated agricultural acreage (fallowed or deficit irrigated) within an irrigation season. The estimate presented is expected to be a maximum impact for any given year as it corresponds to the lowest subseason water supply relative to existing crop water demand within each district. In dry water years under the low water conservation scenario, water to crops in the proposed action compared to the no-action alternative would decline in North Unit ID throughout the permit term, and in Lone Pine ID in the initial years of the permit term. However, impacts in dry water years in the high conservation scenario are expected to be limited to North Unit ID and Lone Pine ID in just the initial few years of the permit period. In median water years, under both conservation scenarios, there would be no impacts on acreage, as shown in **Table 23**.

In summary, across all irrigated lands over the permit term in a median water year, there is no expected fallowing/deficit irrigation, while in a dry year affected acreage may range from 0 to 11,600 acres (up to 9% of acreage under no-action alternative). **Table 24** presents acreage impacts by district and conservation scenario in a dry water year, while **Table 25** highlights how acreage impacts may vary within each dry year irrigation subseason (May, June/July, and August/September).

Table 23. Range of Potentially Impacted Grain and Forage Acreage (Reduced Irrigation, Possible Fallowing) across All Irrigated Lands, Proposed Action Compared to the No-Action Alternative

	Water Year Type			
Year	**Wet**	**Median**	**Dry**	**Average, All Water Year Types[a]**
2020	0	0	3,600 to 5,200	1,300 to 1,800
2025	0	0	0 to 2,400	0 to 840
2030	0	0	0 to -11,600	0 to -4,100
2040	0	0	0 to -4,100	0 to -1,400
2049	0	0	0 to -800	0 to -300
% Change	**0%**	**0%**	**4% to -9%**	**0 to -3%**

Source: Highland Economics analysis.

[a] Average computed assuming that the wet year represents approximately 35% of years (water years in the 65th to 100th percentile), the median represents 30% of water years (water years in the 35th to 65th percentile), and the dry water year represents approximately 35% of water years (water years in the 0th to the 35th percentile).

Table 24. Estimated Maximum[a] Potentially Impacted Irrigated Acreage by District under the Proposed Action Compared to the No-Action Alternative, Dry Water Year

	DBBC Districts										
Year	Arnold	Central Oregon	Lone Pine	North Unit	Ochoco	Swalley	Three Sisters	Tumalo	Total, DBBC Districts	Other Irrigated Lands	All Lands
Low Conservation											
2020	0	0	-300	5,500	0	0	0	0	5,200	0	5,200
2025	0	0	0	2,400	0	0	0	0	2,400	0	2,400
2030	0	0	0	-11,600	0	0	0	0	-11,600	0	-11,600
2040	0	0	0	-4,100	0	0	0	0	-4,100	0	-4,100
2049	0	0	0	-800	0	0	0	0	-800	0	-800
% Change	0%	0%	0 to -13%	12 to -22%	0%	0%	0%	0%	4 to -9%	0 %	4 to -8%
High Conservation											
2020	0	0	-100	3,700	0	0	0	0	3,600	0	3,600
2025	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0
2040	0	0	0	0	0	0	0	0	0	0	0
2049	0	0	0	0	0	0	0	0	0	0	0
% Change	0%	0%	-0 to -4%	0% to 8%	0%	0%	0%	0%	0% to 3%	0%	0 to 3%

Source: Highland Economics analysis. Note that since the no-action alternative acreage is higher in the high conservation scenario, the percent difference from the no-action alternative for the same reduction in acreage due to the proposed action is lower in the high conservation scenario than in the low conservation scenario.

[a] This table presents maximum impacted irrigated acreage as it includes any acreage that would be fallowed or deficit irrigated in any subseason (May or June/July or August/September).

Table 25. Estimated Maximum Potentially Affected Acreage by Subseason by District under the Proposed Action Compared to the No-Action Alternative

	Dry Water Year						Median Water Year					
	Low Conservation			High Conservation			Low Conservation			High Conservation		
Irrigation District	May	June /July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept
Lone Pine												
2020	0	-300	0	0	0	-100	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0
2040	0	0	0	0	0	0	0	0	0	0	0	0
2049	0	0	0	0	0	0	0	0	0	0	0	0
North Unit												
2020	0	0	5,500	0	0	3,700	0	0	0	0	0	0
2025	0	0	2,400	0	0	0	0	0	0	0	0	0
2030	0	0	-11,600	0	0	0	0	0	0	0	0	0
2040	0	-2,700	-4,100	0	0	0	0	0	0	0	0	0
2049	0	0	-800	0	0	0	0	0	0	0	0	0

Source: Highland Economics analysis.

Agricultural Acreage: Alternative 3

Table 26 presents the estimated range of potentially affected irrigated agricultural acreage (fallowed or deficit irrigated) within an irrigation season, with detail by district provided in **Tables 27**, **28, and 29**. The values in **Table 26** represent the range in the maximum affected acreage in any one irrigation season, with variation across the permit years, water year types, and conservation scenarios. Water availability to crops moves up and down across the permit term since conveyance and on-farm conservation increases water supply availability, while the increased instream flow requirements reduce water supply availability. Across all irrigated lands over the permit term in a median water year, fallowing/deficit irrigation may affect 0 to 600 acres (up to 1% of acreage under no-action alternative), while a in dry year affected acreage may range from 0 to 16,500 acres (0 to 12% of acreage under no-action alternative). Apart from some dry year acreage impacts in Lone Pine ID and Arnold ID, acreage impacts are experienced in North Unit ID.

Table 26. Range of Potentially Affected Grain and Forage Acreage (Reduced Irrigation, Possible Fallowing) across All Irrigated Lands under Alternative 3 Compared to the No-Action Alternative

	Water Year Type			Average, All Water Year Types[a]
Year	**Wet**	**Median**	**Dry**	
2020	0	0	-9,900 to -10,200	-3,500 to -3,600
2025	0	0	-8,700 to -14,300	-3,000 to -5,000
2030	0	0 to -600	-4,400 to -16,500	-1,500 to -6,000
2040	0	0	0 to -10,700	0 to -3,700
2049	0	0	0 to -7,400	0 to -2,600
% Change	**0%**	**0%**	**0 to -12%**	**0 to -4%**

[a] Average computed assuming that the wet year represents approximately 35% of years (water years in the 65th to 100th percentile), the median or median represents 30% of water years (water years in the 35th to 65th percentile), and the dry water year represents approximately 35% of water years (water years in the 0th to the 35th percentile).

Table 27. Estimated Maximum[a] Potentially Impacted Acreage by District under Alternative 3 Compared to the No-Action Alternative, Median Water Year

Year	DBBC Districts										
	Arnold	Central Oregon	Lone Pine	North Unit	Ochoco	Swalley	Three Sisters	Tumalo	Total, DBBC Districts	Other Irrigated Lands	All Lands
Low Conservation											
2020	0	0	0	0	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	-600	0	0	0	0	-600	0	-600
2040	0	0	0	0	0	0	0	0	0	0	0
2049	0	0	0	0	0	0	0	0	0	0	0
% Change	0%	0%	0%	0% to -1%	0%	0%	0%	0%	0%	0%	0%
High Conservation											
2020	0	0	0	0	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0
2040	0	0	0	0	0	0	0	0	0	0	0
2049	0	0	0	0	0	0	0	0	0	0	0
% Change	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Source: Highland Economics analysis.

[a] This table presents maximum impacted irrigated acreage as it includes any acreage that would be fallowed or deficit irrigated in any subseason (May or June/July or August/September).

Table 28. Estimated Maximum[a] Potentially Impacted Acreage by DBBC District under Alternative 3 Compared to the No-Action Alternative,[b] Dry Water Year

	DBBC Districts										
Year	Arnold	Central Oregon	Lone Pine	North Unit	Ochoco	Swalley	Three Sisters	Tumalo	Total, DBBC Districts	Other Irrigated Lands	All Lands
Low Conservation											
2020	-100	0	-500	-9,600	0	0	0	0	-10,200	0	-10,200
2025	-400	0	0	-13,900	0	0	0	0	-14,300	0	-14,300
2030	-100	0	0	-16,400	0	0	0	0	-16,500	0	-16,500
2040	-100	0	0	-10,600	0	0	0	0	-10,700	0	-10,700
2049	-100	0	0	-7,300	0	0	0	0	-7,400	0	-7,400
% Change	-3 to -10%	0%	0 to -21%	-14 to -31%	0%	0%	0%	0%	-5 to -12%	0%	-5 to -12%
High Conservation											
2020	0	0	-300	-9,600	0	0	0	0	-9,900	0	-9,900
2025	0	0	0	-8,700	0	0	0	0	-8,700	0	-8,700
2030	0	0	0	-4,400	0	0	0	0	-4,400	0	-4,400
2040	0	0	0	0	0	0	0	0	0	0	0
2049	0	0	0	0	0	0	0	0	0	0	0
% Change	0%	0%	0 to -13%	0 to -20%	0%	0%	0%	0%	-0 to-7%	0%	0 to -7%

Source: Highland Economics analysis.

[a] This table presents maximum impacted irrigated acreage as it includes any acreage that would be fallowed or deficit irrigated in any subseason (May or June/July or August/September).

[b] Since the no-action alternative acreage is higher in the high conservation scenario, the percent difference from the no-action alternative for the same reduction in acreage due to Alternative 3 would be lower in the high conservation scenario than in the low conservation scenario.

N/A=Not Applicable.

Table 29. Estimated Maximum Potentially Impacted Acreage by Subseason by District under Alternative 3 Compared to the No-Action Alternative

	Dry Water Year						Median Water Year					
	Low Conservation			High Conservation			Low Conservation			High Conservation		
Irrigation District/Year	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept
Arnold												
2020	0	-100	-100	0	0	0	0	0	0	0	0	0
2025	0	0	-400	0	0	0	0	0	0	0	0	0
2030	0	0	-100	0	0	0	0	0	0	0	0	0
2040	0	0	-100	0	0	0	0	0	0	0	0	0
2049	0	0	-100	0	0	0	0	0	0	0	0	0
Lone Pine												
2020	0	-500	0	0	-300	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0
2040	0	0	0	0	0	0	0	0	0	0	0	0
2049	0	0	0	0	0	0	0	0	0	0	0	0
North Unit												
2020	-1,000	-3,400	-9,600	0	-1,900	-9,600	0	0	0	0	0	0
2025	0	-9,500	-13,900	0	-2,900	-8,700	0	0	0	0	0	0
2030	0	-11,100	-16,400	0	-800	-4,400	0	0	-600	0	0	0
2040	0	-6,100	-10,600	0	0	0	0	0	0	0	0	0
2049	0	-3,300	-7,300	0	0	0	0	0	0	0	0	0

Source: Highland Economics analysis.

Agricultural Acreage: Alternative 4

Table 30 presents the estimated range of potentially affected irrigated agricultural acreage (fallowed or deficit irrigated) within an irrigation season, with detail by district provided in **Tables 31**, **32, and 33**. The values in **Table 30** represent the range in the maximum affected acreage in any one irrigation season, with variation across the permit years, water year types, and conservation scenarios. Water availability to crops moves up and down across the permit term since conveyance and on-farm conservation increases water supply availability, while the increased instream flow requirements reduce water supply availability. Across all irrigated lands over the permit term, in a median water year fallowing/deficit irrigation may affect 0 to 5,800 acres (0 to 4% of acreage under no-action alternative), while a in dry year affected acreage may range from 600 to 18,500 acres (0 to 13% of acreage under no-action alternative). Apart from some dry year acreage impacts in Lone Pine ID and Arnold ID, acreage impacts are experienced in North Unit ID.

Table 30. Range of Potentially Impacted Grain and Forage Acreage (Reduced Irrigation, Possible Fallowing) across All Irrigated Lands under Alternative 4 Compared to the No-Action Alternative

Year	Water Year Type			Average, All Water Year Types[a]
	Wet	Median	Dry	
2020	0	-400 to -2,200	-14,600 to -14,900	-5,200 to -5,900
2025	0	0 to -5,800	-12,800 to -18,500	-4,500 to -8,200
2030	0	0 to -2,400	-5,000 to -17,300	-1,800 to -6,800
2039	0	0 to 0	-600 to -12,200	-200 to -4,300
% Change	**0%**	**0 to -4%**	**0 to -13%**	**0 to -6%**

[a] Average computed assuming that the wet year represents approximately 35% of years (water years in the 65th to 100th percentile), the median or median represents 30% of water years (water years in the 35th to 65th percentile), and the dry water year represents approximately 35% of water years (water years in the 0th to the 35th percentile).

Table 31. Estimated Maximum[a] Potentially Impacted Acreage by District under Alternative 4 Compared to the No-Action Alternative, Median Water Year

	DBBC Districts										
Year	Arnold	Central Oregon	Lone Pine	North Unit	Ochoco	Swalley	Three Sisters	Tumalo	Total, DBBC Districts	Other Irrigated Lands	All Lands
Low Conservation											
2020	0	0	0	-2,200	0	0	0	0	-2,200	0	-2,200
2025	0	0	0	-5,800	0	0	0	0	-5,800	0	-5,800
2030	0	0	0	-2,400	0	0	0	0	-2,400	0	-2,400
2039	0	0	0	0	0	0	0	0	0	0	0
% Change	0%	0%	0%	0 to -11%	0%	0%	0%	0%	0 to-4%	0%	0 to-4%
High Conservation											
2020	0	0	0	-400	0	0	0	0	-400	0	-400
2025	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0
2039	0	0	0	0	0	0	0	0	0	0	0
% Change	0%	0%	0%	0 to -1%	0%	0%	0%	0%	0%	0%	0%

Source: Highland Economics analysis. Note that since the no-action alternative acreage is higher in the high conservation scenario, the percent difference from the no-action alternative for the same reduction in acreage due to Alternative 4 would be lower in the high conservation scenario than in the low conservation scenario.

[a] This table presents maximum impacted irrigated acreage as it includes any acreage that would be fallowed or deficit irrigated in any subseason (May or June/July or August/September).

Table 32. Estimated Maximum Potentially Impacted Acreage by District under Alternative 4 Compared to the No-Action Alternative, Dry Water Year

	DBBC Districts										
Year	Arnold	Central Oregon	Lone Pine	North Unit	Ochoco	Swalley	Three Sisters	Tumalo	Total, DBBC Districts	Other Irrigated Lands	All Lands
Low Conservation											
2020	-500	0	-500	-13,900	0	0	0	0	-14,900	0	-14,900
2025	-500	0	0	-18,000	0	0	0	0	-18,500	0	-18,500
2030	-400	0	0	-16,900	0	0	0	0	-17,300	0	-17,300
2040	-400	0	0	-11,800	0	0	0	0	-12,200	0	-12,200
% Change	-10 to -13%	0%	0 to -21%	-23 to -36%	0%	0%	0%	0%	-9 to -14%	0%	-9 to -13%
High Conservation											
2020	-300	0	-400	-13,900	0	0	0	0	-14,600	0	-14,600
2025	0	0	0	-12,800	0	0	0	0	-12,800	0	-12,800
2030	0	0	0	-5,000	0	0	0	0	-5,000	0	-5,000
2039	0	0	0	-600	0	0	0	0	-600	0	-600
% Change	0 to -8%	0%	0 to -17%	-1 to -29%	0%	0%	0%	0%	0 to -11%	0%	0 to -11%

Source: Highland Economics analysis. Note that since the no-action alternative acreage is higher in the high conservation scenario, the percent difference from the no-action alternative for the same reduction in acreage due to Alternative 4 would be lower in the high conservation scenario than in the low conservation scenario.

Table 33. Estimated Maximum Potentially Impacted Acreage by Subseason by DBBC District under Alternative 4 Compared to the No-Action Alternative

Irrigation District/ Year	Dry Water Year						Median Water Year					
	Low Conservation			High Conservation			Low Conservation			High Conservation		
	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept
Arnold												
2020	0	-200	-500	0	0	-300	0	0	0	0	0	0
2025	0	-500	0	0	0	0	0	0	0	0	0	0
2030	0	-400	0	0	0	0	0	0	0	0	0	0
2039	0	-400	0	0	0	0	0	0	0	0	0	0
Lone Pine												
2020	0	-500	0	0	-400	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0
2039	0	0	0	0	0	0	0	0	0	0	0	0
North Unit												
2020	-1,900	-12,100	-13,900	-600	-10,600	-13,900	-1,000	-800	-2,200	0	0	-400
2025	-1,700	-18,300	-18,000	0	-11,700	-12,800	0	-4,000	-5,800	0	0	0
2030	0	-15,300	-16,900	0	-5,000	-5,000	0	-1,000	-2,400	0	0	0
2039	0	-10,900	-11,800	0	-600	0	0	0	0	0	0	0

Source: Highland Economics analysis.

Agricultural Production Value and Economic Contribution

The gross value of crop production (i.e., total gross value at the farmgate of crops produced) depends on the acreage in production (as estimated in the sections above), as well as the yields and prices of each crop. The economic contribution to the community of agricultural production, in turn, depends on the jobs and income supported by this level of crop production. Following a brief discussion of methods and data, this section summarizes both the crop production value and the economic contribution of crop production under existing conditions, and the EIS alternatives.

As noted above, the high conservation scenario assumes investment in on-farm and District water conservation, which would serve to maintain agricultural production value and the economic contribution of agriculture. However, to the extent that these investments are funded by District patrons (and not outside funding sources), this represents an economic cost to patrons. For example, one proposed Central Oregon ID piping projects expected to cost approximately $40 million may require approximately $843,000 in annual payments by Central Oregon ID and North Unit ID districts (assuming the districts are responsible for 50% of the cost), which would represent approximately a 10% increase in the operating costs of the two districts (approximately 12% in Central Oregon ID and approximately 9% in North Unit ID) (Bozett pers. comm.). However, this is just one small element of all Central Oregon ID proposed piping. According to the Central Oregon ID System Improvement Plan (Black Rock Consulting, 2016), piping the Pilot Butte Canal would cost approximately $183 million, and piping the Central Oregon Canal would cost approximately $238 million. As such, depending on funding mechanisms and the level of piping implemented, costs to patrons may go up by a much larger percentage in Central Oregon ID and North Unit ID. Similarly, depending on the funding mechanisms and level of infrastructure investments, patron costs in other districts may also rise to fund district and on-farm efficiency improvements.

In terms of economic contribution to the local study area, these investments in irrigation efficiency and District piping will redirect some patron spending to irrigation infrastructure and away from other types of spending. As this is a redirection of household spending in the local area and not a reduction of spending, the net effect of investments in irrigation infrastructure on the total employment and income in the local study area is likely small.

Methods, Key Assumptions, Data Sources

To estimate impacts on agricultural production value, this analysis took a four-step approach (*key data sources are provided in italics*):

1. Estimate the value per acre of forage and grain production based on county data on yield and prices.
    a. Yield data is for the last 5 years as reported by the *U.S. Department of Agriculture National Agricultural Statistics Service (NASS)*.
    b. Price data is from the *U.S. Department of Commerce Economic Research Service (ERS)* 5-year normalized average for all hay and all wheat in the State of Oregon.

2. Estimate the approximate value of forage and grain production in each irrigation subseason based on estimated timing of cutting and yield of each cutting. *Data on yield by cutting from the Central Oregon Agricultural Research and Extension Center.*
3. Estimate the change in forage and grain production value under the EIS alternatives by combining the impacted acreage by subseason estimated in above (*Farm Response to Crop Water Shortages: Change in Acreage*) with the value of forage/grain production in each subseason.
4. Estimate the direct, indirect and induced effects (i.e., ripple effects) of changes in agricultural production value on employment (full- and part-time jobs) and labor income (employee compensation and proprietor income)[14] in agriculture and supporting sectors. Effects were estimated using *IMPLAN economic models* of each county in the study area. Indirect effects include effects on jobs and income in sectors providing inputs to the agricultural sector, such as farm equipment suppliers, seed suppliers, and legal and financial services. Induced effects include effects on industries that are supported by spending of agricultural income including retail and service businesses. The sum of direct, indirect, and induced effects is the total economic contribution of agricultural production.
    a. The analysis is a multi-regional analysis estimating the total economic contribution (including indirect and induced ripple effects) of crop production in Crook, Deschutes, and Jefferson Counties. The multi-regional analysis enables estimation of the total economic contribution of agricultural production in each county to that county (e.g., the effect in Crook County of Crook County agriculture), as well as the spillover economic contribution from the other counties (e.g., Deschutes and Jefferson) that arises as businesses and consumers purchase goods/services from across county boundaries. As the retail and services center of the region, Deschutes County in particular experiences measurable effects from agricultural production in the other two counties.
    b. The analysis adjusted the employment data in the farm sectors in IMPLAN data to match the *5-year average farm worker employment reported for each county in the study area* from the *Oregon Department of Employment* (the ratio of employment in each IMPLAN agricultural sector was maintained).
    c. The analysis adjusted IMPLAN output data for grain and forage crops (the gross value of agricultural production) to match the total value of these crops, by county, as estimated in this section (and presented in **Table 60**).
    d. The analysis adjusted all other IMPLAN data for grain and forage crops proportionate to the output adjustment. In other words, if grain and forage output was increased by 10% in a county, then other economic values such as total proprietor income and taxes paid were also increased by 10%.

[14] The net economic value of agricultural production is the net profit (above wages/salaries and management labor costs) of farm operations, so labor income (much of which is a cost to farm operations) should not be interpreted as the net economic value.

In addition to the key assumptions outlined above regarding the methodology to estimate acreage impacts on forage and grain production, key assumptions include the following.

1. The county average yield data and the state-level price data provide a good representation of the average value produced per acre in the study area (acknowledging that agricultural production value per acre varies substantially from farm to farm).
2. Prices are not affected by the reduction in production in Central Oregon counties as forage and grain are commodity markets, with both forage and grain being shipped out of Central Oregon to many other markets.
3. The impact on yield of forage crops provides an acceptable proxy for the impact of yield of grain crops (grain crops are relatively low acreage compared to forage crops).
4. Once an acre ceases to receive irrigation water, the analysis assumes that the forage or grain crop goes dormant and that it does not provide additional cuttings or economic value for the rest of the season. In other words, if a 100-acre impact is estimated for June/July (with no yield assumed for that grass hay cutting), but there is then full irrigation water availability in August/September (with an estimated 0 acres impacted as shown in above in the *Farm Response to Crop Water Shortages: Change in Acreage* section), the analysis still assumes that there is no yield from those 100 acres in August/September. This is because yield recovery in that season is expected to be minimal after a crop goes dormant).
5. The analysis assumes all forage acres have three cuttings and spreads the total average county hay cutting across the three cuttings. The analysis does not include revenue from grazing due to the relatively small income from pasture relative to forage production (estimated at less than 10% of forage revenue, as discussed below). To the extent that farms manage their forage such that the bulk of hay production occurs in the first or second cuttings (which are generally least affected by water reductions), with aftermath grazing later in the season, then the analysis may overestimate forage production value impacts. The potential for overestimation of impacts, however, is reduced by the fact that after-grazing revenue is not included in the analysis.
6. As only forage and grain crop acreage is modeled to be affected by reduced irrigation water supplies (as estimated in the previous section), the value of other crop production is assumed to be unaffected. As noted above, to the extent that specialty crops are adversely affected, the analysis may underestimate economic impacts. Barring extensive changes in water supplies due to climate change, the potential for high value specialty crops to be impacted is expected to be limited, however, for the following reasons:
   - Forage/grain crops account for approximately 80% of crop water usage in Jefferson and Crook counties (**Table 5**), where nearly all specialty crops in the region are grown
   - The feasibility of a basin-wide water transaction program is currently being explored (Central Oregon Irrigation District 2017), which if developed would facilitate transfers of water to high value crops between districts and farmers, and
   - Perhaps most importantly, because of projected conservation through time (even in the low conservation scenario) that would increase water available to North Unit ID (where the majority of specialty crop acreage is grown), the available water supplies under the proposed action dry year are expected to be relatively close to the amount of water available

to crops in North Unit ID under the existing condition dry water year (i.e., before projected future conservation).[15]

7. Farm employment and labor income change proportionately with changes in crop production value (i.e., if forage and grain production value decreases by 10%, then forage and grain employment and income also decreases by 10%).

Data on Forage and Grain Gross Production Value Per Acre by Season and Subseason

This section summarizes the per acre forage and grain production value across the irrigation season based on average county yields and prices. As the vast majority of acreage in the study area is in forage crops, the analysis models the impact on forage/grain yield based on yield impacts on forage crops (specifically hay crops). The section then presents data on forage yield dependent on each irrigation subseason (May, June/July, and August/September), and estimates the production value per acre for each irrigation subseason. **Tables 34, 35, and 36** present the data used to estimate the average annual per acre production value from forage and grain crops for each district (presented in **Table 37**), which varies from approximately $920 per acre in North Unit to approximately $700 to $720 per acre in other districts. In addition to hay yield, many acres of hay are also 'after-grazed' by livestock and provide some additional value. The additional value of grazing after hay production is likely small (less than approximately 10 percent) relative to the per acre average forage/grain production value and is not included in this analysis. (The rental rate for an entire season of irrigated pasture in the study area (as estimated by NASS survey data from 2014 to 2017) is less than $35 per acre, although average rental value based on forage production level (animal unit month supported) may be up to approximately $80 per acre. However, there is acreage that is used solely as pasture and is not harvested for hay. By assuming all forage acreage is used to produce hay, the analysis may actually overestimate total average forage production value per acre.)

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[15] In years 1 through 7 of the permit term under the proposed action from May through September, reduced water available for diversion (compared to the no-action alternative) to North Unit ID in a dry water year is estimated at 10,100 acre-feet per year, but conserved water available to North Unit ID in year 1 is estimated to be at least 5,200 acre-feet per year, rising to at least 10,400 acre-feet per year by year 3 (low conservation scenario). In years 8 through 12 from May through September, reduced water available for diversion to North Unit ID in a dry water is estimated to be at least 33,100 acre-feet per year, but conserved water available to North Unit ID in year 8 is estimated to be at least 23,400 acre-feet per year, rising to at least 28,600 acre-feet per year by year 10 (low conservation scenario). In permit years 13 through 30 from May through September, reduced water available for diversion to North Unit ID in a dry water year is estimated at 53,300 acre-feet per year, but conserved water available to North Unit ID in year 13 is estimated to be at least 36,400 acre-feet per year, rising to at least 50,800 by year 22 (low conservation scenario).

Table 34. Estimated 5-Year Average Hay Yield[a]

County	Yield (Tons/Acre)		Acreage (Percent)		Average All Hay Yield (Tons/Acre)
	Alfalfa	Other Hay	Alfalfa	Other Hay	
Crook	4.7	2.6	42%	58%	3.4
Deschutes	4.1	2.9	40%	60%	3.4
Jefferson	5.6	3.5	50%	50%	4.5
All Counties	4.9	2.9	44%	56%	3.8

Source: U.S. Department of Agriculture, National Agricultural Statistics Service 2010–2017.

[a] Using the most recent 5 years of data available, usually 2012–2017. Due to non-reporting of data in some years, the most recent 5 years of available data goes back to 2010 for some data.

Table 35. Estimated 5-Year Average Wheat Yield[a]

County	Yield (Bushels/Acre)		Acreage (Percent)		Average All Wheat Yield (Bushels/Acre)
	Spring	Winter	Spring	Winter	
Crook	86.3	111.9	32%	68%	103.7
Deschutes	N/A[b]	88.9	0%[b]	100%	88.9
Jefferson	107.8	126.2	47%	53%	117.6
All Counties	105.1	119.6	42%	58%	113.6

Source: U.S. Department of Agriculture, National Agricultural Statistics Service 2010–2017.

[a] Using the most recent 5 years of yield data available from NASS, usually 2012–2017. Due to non-reporting of data in some years, the most recent 5 years of available data goes back to 2010 for some data.

[b] There is likely spring wheat grown in Deschutes County, but it is not reported by NASS.

Table 36. Estimated 5-Year Average Yield, Price, and Revenue per Acre for Wheat and Hay by County

County	Yield (ton/bushel)[a]	Price per ton/bushel	Revenue Per Acre
All Hay			
Crook	3.4	$209.63	$721
Deschutes	3.4	$209.63	$716
Jefferson	4.5	$209.63	$950
All Counties	3.8	$209.63	$794
All Wheat			
Crook	103.7	$6.65	$690
Deschutes	88.9	$6.65	$591
Jefferson	117.6	$6.65	$782
All Counties	113.6	$6.65	$755

Source: U.S. Department of Agriculture, National Agricultural Statistics Service for yields, 2010–2017. Economic Research Service 2018 Normalized 5-Year State Average Prices for all hay and all wheat.

[a] Hay yield is measured in tons; wheat yield is measured in bushels.

Table 37. Average Revenue per Acre for Wheat and Hay by District

District	Average Revenue/Acre		Acres		Average Revenue/Acre for Hay/Pasture and Grains Combined
	Hay/Pasture	Wheat	Hay/Pasture	Wheat	
Arnold	$716	$591	1,876	0	$716
Central Oregon	$716	$591	37,498	843	$713
Lone Pine	$721	$690	1,225	377	$714
North Unit	$950	$782	29,400	5,703	$923
Ochoco	$721	$690	12,574	1,783	$717
Swalley	$716	$591	2,669	0	$716
Three Sisters	$716	$591	5,717	1,189	$694
Tumalo	$716	$591	5,000	0	$716
Other Irrigated Lands	$721	$690	3,151	194	$720

Source: Highland Economics Analysis of District acreage and U.S. Department of Agriculture, National Agricultural Statistics Service data.

This analysis estimates potential impacts of reduced water available to crops on a subseason basis based on the cutting periods for grass hay and alfalfa. **Table 38** summarizes data from the Central Oregon Agricultural Research and Extension Center on the cutting periods and yield by cutting for orchard grass hay and alfalfa hay. The yields at the Research and Extension Center exceed average yields in the study area (yields are often much higher at research centers where production is at a smaller scale and is highly managed), but this analysis assumes that the proportion of yield in each cutting would be similar across the study area. As shown in **Table 38**, alfalfa and grass hay may have three to four cuttings each irrigation season. The analysis assumes that the yield in the first cutting of grass hay or alfalfa hay (completed in late May or early June) is dependent on the availability of irrigation water in May (it is also dependent on irrigation water available in April, but that is not assessed in this analysis as irrigation water supplies in April across the proposed action and alternatives are nearly always 100% of demand). Similarly, the analysis assumes that the yield in the second cutting of grass hay and the second/third cuttings of alfalfa hay that occur in early to late July are dependent on the availability of irrigation water in the June/July subseason. Finally, the analysis assumes that the yield in the final cutting of grass hay and alfalfa hay is dependent on the availability of irrigation water in the September/October subseason.

Table 39 summarizes the expected yield that is dependent on each irrigation subseason: approximately 40% of the season's yield is dependent on the water availability in the May irrigation subseason, approximately 40% is dependent on the June/July irrigation subseason, and approximately 20% is dependent on the September/October subseason. **Table 40** applies these percentages to the average annual revenue per acre for forage and hay crops for each District, as presented in **Table 37**.

Table 38. Alfalfa and Orchard Grass Yield by Cutting at Central Oregon Agricultural Research and Extension Center

Cutting Period	Key Irrigation Month(s) Determining Yield	Yield (ton/acre)		% Yield for Season	
		Orchard grass	Alfalfa	Orchard grass	Alfalfa
Late May/early June	May	3.28	3.69	50%	30%
Early July	June		3.17		26%
End of July	June/July	2.14		33%	
Early August	July		2.34		19%
Mid-September–Mid-October	August/September	1.16	3.17	18%	26%

Sources: Highland Economics analysis of Bohle et al.1992; Butler et al. 2015.

Table 39. Summary of Alfalfa and Orchard Grass Yield by Irrigation Subseason

Irrigation Subseason	Season Yield: % Dependent on Each Irrigation Subseason		
	Orchard Grass Hay	Alfalfa Hay	Average
May	49.8%	29.9%	39.9%
June/July	32.5%	44.5%	38.5%
August/September	17.6%	25.6%	21.6%
Season	100%	100%	100%

Sources: Highland Economics analysis of Bohle et al. 1992; Butler et al. 2015.

Table 40. Forage/Grain Revenue per Acre Dependent on Each Irrigation Subseason

District	Average Per Acre Revenue for Forage/Grain Crops Dependent on Each Irrigation Subseason			
	Annual	May	June/July	August/September
Arnold	$716	$286	$286	$143
Central Oregon	$713	$285	$285	$143
Lone Pine	$714	$286	$286	$143
North Unit	$923	$369	$369	$185
Ochoco	$717	$287	$287	$143
Swalley	$716	$286	$286	$143
Three Sisters	$694	$278	$278	$139
Tumalo	$716	$286	$286	$143
Other Irrigated Lands	$720	$288	$288	$144

Source: Highland Economics analysis.

As noted throughout this analysis, the approach assumes that farmers prioritize irrigating higher value/lower water use specialty crops (grass seed/peppermint/vegetable seed) and deficit irrigate or fallow the lower value/higher water use grain and forage crops. However, it is possible that some high value specialty crops may be affected by reduced water supply availability as well. For this reason, and to illustrate the potential economic impact if high value crops were to be affected, **Table 41** summarizes the value per acre and the value per af of available water for specialty crops in the region. The value per acre of these crops from 2009 to 2013 (the most recent years for which published data are available from the Central Oregon Agriculture Research and Extension Center) is approximately $2,400, which with inflation equals approximately $2,750 in 2019 dollars.

Table 41. Per Acre Revenue from Central Oregon Specialty Crops (Vegetable Seed, Grass Seed, Peppermint, Other)

Year	Acreage	Crop Gross Revenue	Gross Revenue/Acre (Nominal)	Gross Revenue/Acre (2019$)
2013	14,053	$32,251,908	$2,300	$2,530
2012	13,256	$34,116,580	$2,570	$2,860
2011	12,882	$35,455,537	$2,750	$3,120
2010	13,269	$29,807,165	$2,250	$2,640
2009	14,279	$31,160,736	$2,180	$2,610
Average	13,548	$32,558,385	$2,410	$2,750

Source: Highland Economics Analysis of Central Oregon Agriculture Research and Extension Center 2013, 2012, 2011, 2010, 2009; Bureau of Labor Statistics 2019.

Approximately 90% of specialty crop acreage in the region are grown in Jefferson County, with most of the remainder in Crook County (Central Oregon Agriculture Research and Extension Center 2013, 2012, 2011, 2010, 2009). The gross production value per acre for specialty crops is roughly 300% the gross value of forage/crop production in Jefferson County (approximately $2,750 versus approximately $920 per acre). However, the crop water requirement (as presented in **Table 4**) for specialty crops is roughly one-half the crop water requirement for grain/forage crops.[16] As such, the gross production value per af of water use on specialty crops is approximately 600% the gross production value per af of water use on grain/forage crops. As highlighted in **Table 5**, water use for forage and grain crops is approximately 80% of total water use in Jefferson County and Crook County irrigation districts, with specialty crops accounting for the remaining 20% of water use.

The maximum potential economic impacts that could result (assuming current cropping patterns) would occur if farmers did not prioritize high value crops but instead reduced water proportionally to all crops, regardless of economic value. This is not a realistic outcome but is presented as the theoretical upper bound of potential adverse impacts if high value crops were affected. Under this scenario, 80% of the economic impacts estimated in the sections below would occur as projected (i.e., would be impacts on forage/grain), and approximately 20% of the water reductions would instead affect high value crops, with the associated production value impacts approximately 6 times higher than estimated (as the gross value per acre-foot of water reduction is approximately 6 times higher). The employment and income effects for a given level of agricultural production value are generally similar, so the agricultural income and employment effects per af of water use would also be approximately 6 times higher for specialty crops than for forage/grain production. Increasing 20% of the estimated effects by 600%, results in a total impact of approximately 200%.[17] In summary, under a hypothetical worst-case scenario where farmers do not prioritize high-value

[16] For example, for the Madras station in Jefferson County, the per acre forage/grain production crop ET requirement is 2.8 af/acre, while peppermint is 2.2 af/acre, grass seed is 1.4 af/acre, and carrot seed is 1.0 af/acre.

[17] For example, if the sections below estimate an impact of $4 million in forage/grain production value, then 80% of this impact is $3.2 million, and 20% of this impact is $0.8 million. If the $0.8 million impact is increased by 600%, to $4.8 million, the total impact would $8 million ($3.2 million plus $4.8 million), or double the estimated impact based on forage/grain production value (i.e., 80% + 120% X 20% = 200%).

crops, the total economic impacts on Jefferson County and Crook County gross agricultural production value, agricultural jobs, and agricultural income, would be approximately double those estimated in the sections below.

Agricultural Production Value

This section describes agricultural production value (total gross value at the farmgate of crops produced) under existing conditions, and then estimates the potential change in value under EIS alternatives. These changes are based on the data in **Table 40**, and the estimated potential change in irrigated agricultural acreage presented in the above section (Farm Response to Crop Water Shortages: Change in Acreage). This section presents the potential change in crop production value under the EIS alternatives.

Existing Conditions

This section summarizes total agricultural production value in the study area under existing conditions. As presented in **Table 42**, according to the 2017 Census of Agriculture (U.S. Department of Agriculture 2019), total crop sales in the study area in 2017 were nearly $83.5 million, of which $54.8 million was in Jefferson County, $16.5 million was in Deschutes County and $12.1 million was in Crook County. Total 2017 crop acreage harvested in the study area was estimated at 109,420, of which 96,235 acres were irrigated (approximately 90% of all harvested cropland in the study area). As the acreage and the per acre production value of dryland cropping is relatively low in the region, nearly all crop production value is from irrigated lands. Note that the acreage under existing conditions in all Districts is estimated at approximately 140,000 acres (**Table 1**), indicating that this analysis may overestimate the average total irrigated acreage in the study area. To the extent this is the case, the analysis overestimates the economic impact of reduced irrigation water supplies.

As highlighted in **Table 42**, the average crop sales value per irrigated acre varies widely in the study area, from approximately $400 per acre in Crook County to approximately $690 per acre in Deschutes County, up to approximately $1,310 per acre in Jefferson County.[18] The higher value in Jefferson County reflects the high value of specialty crops such as mint, grass seed, and vegetable seed that are grown on a higher percentage of acres in Jefferson County than elsewhere in the study area. The relatively low crop sales value per irrigated acre in Crook County reflects the fact that much of Crook County crop production is forage used on-farm to support animal production and animal sales and thus does not count as 'crop sales'.[19] Animal sales in Crook County are the highest in the study area at $32.5 million, representing 57% of animal sales in the study area. Forage crop production in Deschutes and Jefferson County also supports animal production and sales, with total study area animal sales in 2017 estimated at $57.3 million. Combined, animal and crop sales in the study area in 2017 totaled $140.8 million, of which 59% was crop sales.

[18] This estimate is derived assuming all crop sales are derived from irrigated lands. Actual value of crop sales per irrigated acre are slightly lower than these estimates as some value is produced from dryland farmed acres.

[19] The average annual value of forage and grain production in Crook County in the period 2012 to 2017 is over 200% of the value of 2017 crop sales in the county.

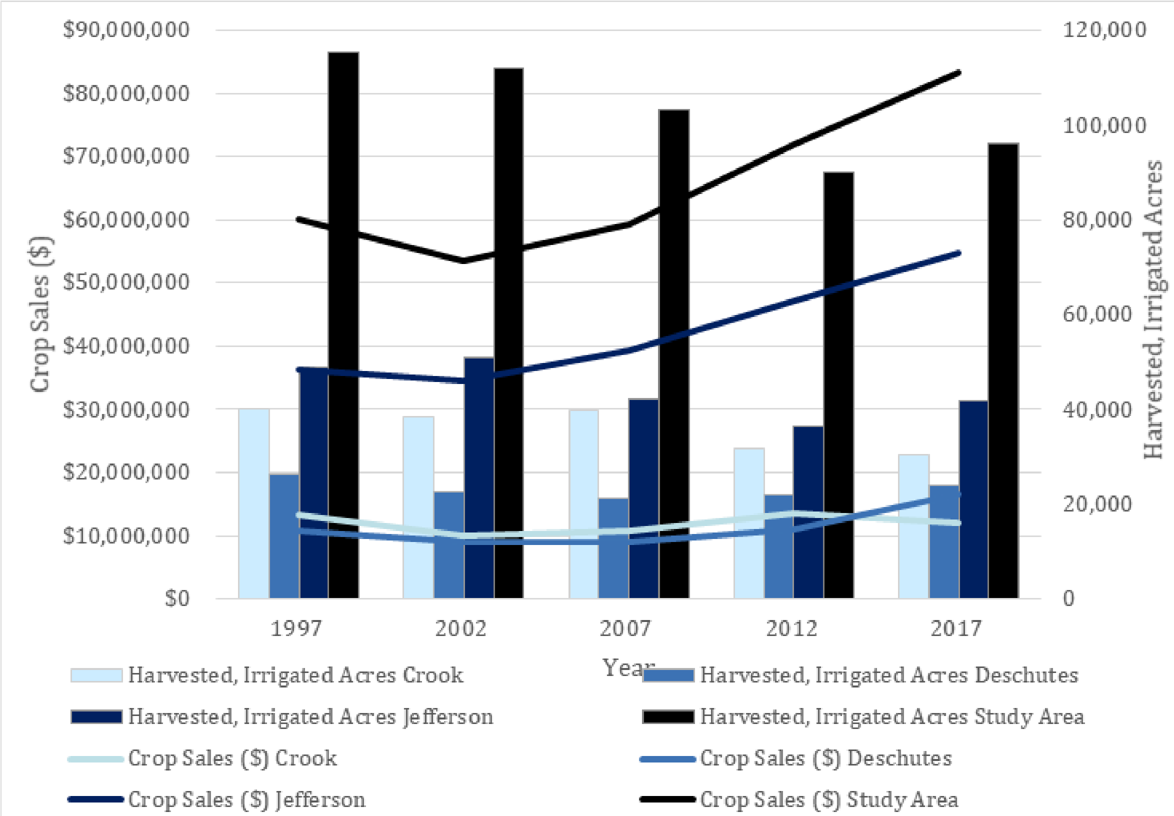
Table 42. Harvested, Total Crop and Animal Sales in Study Area, 2017

Production Type	Crook	Deschutes	Jefferson	Study Area
Crop Production				
Crop Sales	$12,094,000	$16,543,000	$54,792,000	$83,429,000
Harvested, Irrigated Acres	30,421	23,983	41,831	96,235
Approx. Sales per Irrigated Acre	$398	$690	$1,310	$867
Animal Production				
Animal Sales (including products)	$32,470,000	$12,226,000	$12,645,000	$57,341,000
Agricultural (Crop and Animal) Production				
Crop and Animal Sales	$44,564,000	$28,769,000	$67,437,000	$140,770,000
% Crop Sales	27%	58%	81%	59%

Source: Highland Economics analysis of U.S. Department of Agriculture, National Agricultural Statistics Service data from the 2017 of Agriculture.

Figure 8 highlights how crop sales and irrigated acreage may have generally shifted over the last 20 years, with the bars representing irrigated acres and the lines representing crop sales. In viewing these data, it is important to note that the Census of Agriculture captures crop production in one year, and does not account for variation occurring in that year due to water availability or weather. However, the data indicate that in Jefferson County (dark blue line and bars), harvested, irrigated acreage may have trended downwards, but total crop sales have shifted upwards (representing increasing crop sales per acre harvested). Harvested, irrigated acreage in Crook County may be trending downward over the last 20 years, but the pattern in Deschutes County is more mixed, with a potential downward trend from 1997 to 2007, but trending upwards again since 2007 (though still lower than the 1997 levels). Value of crop production in Crook and Deschutes Counties appears to have been more or less stable since 1997.

Figure 8. Harvested, Irrigated Acreage and Total Crop Sales from 1997 to 2017



Source: U.S. Department of Agriculture, National Agricultural Statistics Service 1997, 2002, 2007, 2012, 2017 Census of Agriculture.

Applying the per acre forage and grain revenue (from **Table 40**) to the acreage irrigated in each District (from **Table 1**) under existing conditions median year provides the estimated total forage/grain production value by District under existing conditions in a median year, as shown in **Table 43**. **Table 44** summarizes how production value may change in a dry year under existing conditions. Across all districts, forage/grain production is estimated at $85.2 million under existing conditions in an average water year. This exceeds the value of crop sales in the region for 2017 as reported by the U.S. Census of Agriculture, for two reasons: 1) much of the forage production in the study area is used on-farm for livestock feed and is not sold (and, therefore, not included in crop sales statistics), and 2) the reported irrigated acreage in the 2017 census is lower than the District-reported irrigated acreage used in this analysis.

Table 43. Estimated Annual Forage/Grain Production Value by District under Existing Conditions, Median Water Year

	Forage/Grain	
District	**Acreage**	**Production Value**
Arnold	1,876	$1,342,000
Central Oregon	38,341	$27,329,000
Lone Pine	1,602	$1,144,000
North Unit	35,103	$32,383,000
Ochoco	14,357	$10,300,000
Swalley	2,669	$1,910,000
Three Sisters	6,906	$4,794,000
Tumalo	5,000	$3,578,000
Other Irrigated Lands	3,345	$2,407,000
Total	109,198	$85,186,000

Source: Highland Economics analysis of District acreage and U.S. Department of Agriculture, National Agricultural Statistics Service data.

Table 44. Estimated Annual Forage/Grain Production Value by District under Existing Conditions, Dry Water Year Compared to Median Water Year

	Acreage Impact				Change in Production Value				Production Value
Irrigation District	**May**	**June/ July**	**Aug/ Sept**	**Max Impact**	**May**	**June/July**	**Aug/Sept**	**Season**	**Season**
Arnold	0	0	-40	-40	$0	$0	-$6,000	-$6,000	$1,336,000
Central Oregon	0	-60	-240	-240	$0	-$16,000	-$35,000	-$51,000	$27,278,000
Lone Pine	0	0	-60	-60	$0	$0	-$9,000	-$9,000	$1,135,000
North Unit	0	0	-6,580	-6,580	$0	$0	-$1,215,000	-$1,215,000	$31,168,000
Ochoco	0	-160	0	-160	$0	-$45,000	-$22,000	-$67,000	$10,233,000
Swalley	0	0	0	0	$0	$0	$0	$0	$1,910,000
Three Sisters	0	0	-30	-30	$0	$0	-$4,000	-$4,000	$4,790,000
Tumalo	-950	-170	-570	-950	-$271,000	-$271,000	-$135,000	-$677,000	$2,901,000
Other Irrigated Lands	-10	-40	-80	-80	-$2,000	-$12,000	-$11,000	-$2,029,000	$2,382,000
Total	-960	-430	-7,600	-8,140	-$273,000	-$344,000	-$1,437,000	-$4,058,000	$83,132,000

Source: Highland Economics analysis.
Note: Change in production value in August/September may be lower even if affected acreage is higher or the same because the value of the final cutting of hay is expected to be lower than other cuttings. Also, acreage impacted earlier in the season is expected to continue to be impacted the remainder of the season. For example, for Tumalo ID, 950 acres are estimated to be affected in May; for the remainder of the season the economic impacts assume 950 acres impacted.

No-Action Alternative

As the amount of water available for diversion under the no-action alternative would be similar to existing conditions, the average agricultural production value under the no-action alternative is expected to be very similar to the value presented above in **Table 43.** Similarly, in the initial years of the analysis period, the no-action dry year agricultural production value would be similar to existing conditions as presented above in **Table 44**. However, due to water conservation over the analysis period, under the no-action alternative, water available to crops in dry water years may increase over time compared to existing conditions. This may lead to increased acreage and/or yields in dry water years over the analysis period. **Table 45** summarizes the estimated effect on irrigated acreage under the no-action alternative in dry water years throughout the analysis period. **Table 46** presents detail on effects by irrigation subseason for a dry year for affected irrigation districts.

Table 45. Estimated Potential Increase in Annual Forage/Grain Production Value by District under the No-Action Alternative Compared to Existing Conditions, Dry Water Year

	DBBC Districts										
Year	Arnold	Central Oregon	Lone Pine	North Unit	Ochoco	Swalley	Three Sisters	Tumalo	Total, DBBC Districts	Other Irrigated Lands	All Lands
Low Conservation											
2020	$0	$0	$14,000	$203,000	$0	$0	$0	$0	$217,000	$0	$217,000
2025	$0	$0	$14,000	$775,000	$0	$0	$0	$0	$789,000	$0	$789,000
2030	$0	$0	$14,000	$1,218,000	$0	$0	$0	$0	$1,232,000	$0	$1,232,000
2040	$0	$0	$14,000	$1,218,000	$0	$0	$0	$0	$1,232,000	$0	$1,232,000
2049	$0	$0	$14,000	$1,218,000	$0	$0	$0	$0	$1,232,000	$0	$1,232,000
High Conservation											
2020	$0	$0	$14,000	$535,000	$0	$0	$0	$0	$549,000	$0	$549,000
2025	$0	$0	$14,000	$1,218,000	$0	$0	$0	$0	$1,232,000	$0	$1,232,000
2030	$0	$0	$14,000	$1,218,000	$0	$0	$0	$0	$1,232,000	$0	$1,232,000
2040	$0	$0	$14,000	$1,218,000	$0	$0	$0	$0	$1,232,000	$0	$1,232,000
2049	$0	$0	$14,000	$1,218,000	$0	$0	$0	$0	$1,232,000	$0	$1,232,000

Source: Highland Economics analysis.

Table 46. Estimated Potential Increase in Annual Forage/Grain Production Value by Subseason Under No-Action Alternative Compared to Existing Condition, Dry Water Year

Irrigation District / Year	Low Conservation				High Conservation			
	May	June/July	Aug/Sept	Total	May	June/July	Aug/Sept	Total
Lone Pine								
2020	$0	$0	$14,000	$14,000	$0	$0	$14,000	$14,000
2025	$0	$0	$14,000	$14,000	$0	$0	$14,000	$14,000
2030	$0	$0	$14,000	$14,000	$0	$0	$14,000	$14,000
2040	$0	$0	$14,000	$14,000	$0	$0	$14,000	$14,000
2049	$0	$0	$14,000	$14,000	$0	$0	$14,000	$14,000
North Unit								
2020	$0	$0	$203,000	$203,000	$0	$0	$535,000	$535,000
2025	$0	$0	$775,000	$775,000	$0	$0	$1,218,000	$1,218,000
2030	$0	$0	$1,218,000	$1,218,000	$0	$0	$1,218,000	$1,218,000
2040	$0	$0	$1,218,000	$1,218,000	$0	$0	$1,218,000	$1,218,000
2049	$0	$0	$1,218,000	$1,218,000	$0	$0	$1,218,000	$1,218,000

Source: Highland Economics analysis.

Proposed Action

Table 47 presents the estimated range of changes in forage/grain production value within an irrigation season under the proposed action compared to the no-action alternative. In dry water years under the low conservation scenarios production value would decline in North Unit ID and Lone Pine ID, although effects in Lone Pine ID are limited to the first several years of the permit term while effects on North Unit ID are limited to later years. In dry water years under the high conservation scenario, production value impacts would be limited to an approximate 1% decline in Lone Pine ID in the initial years of the permit term. In median water years, under the high conservation scenario, there would be no impacts on production value, as shown in **Table 47**.

Across all irrigated lands over the permit term in a median water year, changes in annual forage/grain production value are not expected to change, while in a dry year annual changes in agricultural production value may range from $0 to -$2.1 million (up to 2% of forage/grain production value under the no-action alternative). Across all water year types, the annual average forage/grain production value may decrease by 1% compared to the no-action alternative. When considering the value of all agricultural production in the county (all crop and animal sales), agricultural production value may fall by up to 0.5% across all water year types.

For dry water year types, **Table 48** presents change in estimated forage production value by district and conservation scenario, while **Table 49** highlights how forage production value impacts vary within each irrigation subseason (May, June/July, and August/September).

Table 47. Range of Potential Change in Annual Forage/Grain Production Value across All Irrigated Lands, Proposed Action Compared to the No-Action Alternative

Year	Water Year Type			Average, All Water Year Types[a]
	Wet	Median	Dry	
2020	$0	$0	-$14,000 to -$129,000	-$5,000 to -$45,000
2025	$0	$0	$0	$0
2030	$0	$0	$0 to $2,140,000	0 to -$749,000
2040	$0	$0	$0 to -1,752,000	$0 to -$613,000
2049	$0	$0	$0 to -$148,000	$0 to -$52,000
% Change (Forage/Grain Production Value)[b]	0%	0%	0 to -2%	0 to -1%
% Change Agricultural Sales[c]				0 to -0.5%

Source: Highland Economics analysis.

[a] Average computed assuming that the wet year represents approximately 35% of years (water years in the 65th to 100th percentile), the median or median represents 30% of water years (water years in the 35th to 65th percentile), and the dry water year represents approximately 35% of water years (water years in the 0th to the 35th percentile).

[b] Relative to estimated forage/grain production value under existing conditions, as presented in Tables 43 and 44.

[c] Relative to total study area animal and crop sales as estimated in the 2017 Census of Agriculture.

Table 48. Estimated Potential Change in Forage/Grain Production Value by District under the Proposed Action Compared to the No-Action Alternative, Dry Water Year

Year	DBBC Districts								Total, DBBC Districts	Other Irrigated Lands	All Lands
	Arnold	Central Oregon	Lone Pine	North Unit	Ochoco	Swalley	Three Sisters	Tumalo			
Low Conservation											
2020	$0	$0	-$129,000	$0	$0	$0	$0	$0	-$129,000	$0	-$129,000
2025	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2030	$0	$0	$0	-$2,140,000	$0	$0	$0	$0	-$2,140,000	$0	-$2,140,000
2040	$0	$0	$0	-$1,752,000	$0	$0	$0	$0	-$1,752,000	$0	-$1,752,000
2049	$0	$0	$0	-$148,000	$0	$0	$0	$0	-$148,000	$0	-$148,000
% Change	0%	0%	0 to -11%	0 to -7%	0%	0%	0%	0%	0 to -2%	0%	0 to -2%
High Conservation											
2020	$0	$0	-$14,000	$0	$0	$0	$0	$0	-$14,000	$0	-$14,000
2025	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2030	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2040	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2049	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
% Change	0%	0%	0 to -1%	0%	0%	0%	0%	0%	0%	0%	0%

Source: Highland Economics analysis. Note that since the no-action alternative acreage is higher in the high conservation scenario, the percent difference from the no-action alternative for the same reduction in acreage due to the proposed action is lower in the high conservation scenario than in the low conservation scenario.

Table 49. Estimated Potential Change in Forage/Grain Production Value by Subseason by District under the Proposed Action Compared to the No-Action Alternative

	Dry Water Year						Median Water Year					
	Low Conservation			High Conservation			Low Conservation			High Conservation		
District	May	June /July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept
Lone Pine												
2020	$0	-$86,000	-$43,000	$0	$0	-$14,000	$0	$0	$0	$0	$0	$0
2025	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2030	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2040	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2049	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
North Unit												
2020	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2025	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2030	$0	$0	-$2,140,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
2040	$0	-$996,000	-$756,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
2049	$0	$0	-$148,000	$0	$0	$0	$0	$0	$0	$0	$0	$0

Source: Highland Economics analysis.

Alternative 3

Table 50 presents the estimated range of potential change in annual forage/grain production value under Alternative 3 compared to the no-action alternative, with detail by district provided in **Tables 51**, **52, and 53**. The values in **Table 50** represent the potential changes in annual forage/grain production value, with variation across the permit years, water year types, and conservation scenarios. Across all irrigated lands over the permit term in a median water year, the change in annual forage/grain production value may vary from approximately $0 to -$111,000 (less than 1% of forage/grain production value under the no-action alternative), while in a dry year the change in annual forage/grain production value may range from $0 to -$7.1 million (0 to 8% of dry year regional forage/grain production value under no-action alternative, with the majority of impacts in North Unit ID). Across all water year types, the annual average forage/grain production value may decrease by up to 3% compared to the no-action alternative. When considering the value of all agricultural production in the county (all crop and animal sales), agricultural production value may fall by up to 2% across all water year types. **Table 51** and **Table 52** present changes in estimated forage/grain production value by district and conservation scenario, for median and dry water years, respectively. **Table 54** highlights how forage/grain production value impacts vary within each irrigation subseason (May, June/July, and August/September).

Table 50. Range of Potential Change in Annual Forage/Grain Production Value across All Irrigated Lands under Alternative 3 Compared to the No-Action Alternative

	Water Year Type			Average, All Water Year Types[a]
Year	**Wet**	**Median**	**Dry**	
2020	$0	$0	-$3,652,000 to -$2,601,000	-$1,278,000 to -$910,000
2025	$0	$0 to -$111,000	-$6,128,000 to -$2,675,000 to	-$2,145,000 to -$936,000
2030	$0	$0	-$7,136,000 to -$1,107,000	-$2,531,000 to -$387,000
2040	$0	$0	-$4,221,000 to $0	-$1,477,000 to $0
2049	$0	$0	-$2,579,000 to $0	-$903,000 to $0
% Change (Forage/Grain Production Value)[b]	0%	0%	0 to -8%	0 to -3%
% Change Agricultural Sales[c]				-1 to - 2%

Source: Highland Economics analysis.

[a] Average computed assuming that the wet year represents approximately 35% of years (water years in the 65th to 100th percentile), the median or median represents 30% of water years (water years in the 35th to 65th percentile), and the dry water year represents approximately 35% of water years (water years in the 0th to the 35th percentile).

[b] Relative to estimated forage/grain production value under existing conditions, as presented in Tables 43 and 44.

[c] Relative to total study area animal and crop sales as estimated in the 2017 Census of Agriculture.

Table 51. Estimated Potential Change in Annual Forage/Grain Production Value by District under Alternative 3 Compared to the No-Action Alternative, Median Water Year

	DBBC Districts										
Year	Arnold	Central Oregon	Lone Pine	North Unit	Ochoco	Swalley	Three Sisters	Tumalo	Total, DBBC Districts	Other Irrigated Lands	All Lands
Low Conservation											
2020	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2025	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2030	$0	$0	$0	-$111,000	$0	$0	$0	$0	-$111,000	$0	-$111,000
2040	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2049	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
% Change	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
High Conservation											
2020	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2025	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2030	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2040	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2049	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
% Change	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Source: Highland Economics analysis. Note that since the no-action alternative acreage is higher in the high conservation scenario, the percent difference from the no-action alternative for the same reduction in acreage due to Alternative 3 would be lower in the high conservation scenario than in the low conservation scenario.

Table 52. Estimated Potential Change in Annual Forage/Grain Production Value by District under Alternative 3 Compared to the No-Action Alternative, Dry Water Year

	DBBC Districts										
Year	Arnold	Central Oregon	Lone Pine	North Unit	Ochoco	Swalley	Three Sisters	Tumalo	Total, DBBC Districts	Other Irrigated Lands	All Lands
Low Conservation											
2020	-$43,000	$0	-$214,000	-$3,395,000	$0	$0	$0	$0	-$3,652,000	$0	-$3,652,000
2025	-$57,000	$0	$0	-$6,071,000	$0	$0	$0	$0	-$6,128,000	$0	-$6,128,000
2030	-$14,000	$0	$0	-$7,122,000	$0	$0	$0	$0	-$7,136,000	$0	-$7,136,000
2040	-$14,000	$0	$0	-$4,207,000	$0	$0	$0	$0	-$4,221,000	$0	-$4,221,000
2049	-$14,000	$0	$0	-$2,565,000	$0	$0	$0	$0	-$2,579,000	$0	-$2,579,000
% Change	-1 to -4%	0%	0 to -19%	-8 to -22%	0%	0%	0%	0%	-3 to -8%	0%	-3 to -8%
High Conservation											
2020	$0	$0	-$129,000	-$2,472,000	$0	$0	$0	$0	-$2,601,000	$0	-$2,601,000
2025	$0	$0	$0	-$2,675,000	$0	$0	$0	$0	-$2,675,000	$0	-$2,675,000
2030	$0	$0	$0	-$1,107,000	$0	$0	$0	$0	-$1,107,000	$0	-$1,107,000
2040	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2049	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
% Change	-25 to -53%	0%	0 to -11%	0 to -8%	0%	0%	0%	0%	0 to -3%	0%	0 to -3%

Source: Highland Economics analysis.

Table 53. Estimated Potential Change in Annual Forage/Grain Production Value by Subseason by DBBC District under Alternative 3 Compared to the No-Action Alternative

Irrigation District/ Year	Dry Water Year						Median Water Year					
	Low Conservation			High Conservation			Low Conservation			High Conservation		
	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept
Arnold												
2020	$0	-$29,000	-$14,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
2025	$0	$0	-$57,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
2030	$0	$0	-$14,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
2040	$0	$0	-$14,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
2049	$0	$0	-$14,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
Lone Pine												
2020	$0	-$143,000	-$71,000	$0	-$86,000	-$43,000	$0	$0	$0	$0	$0	$0
2025	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2030	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2040	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2049	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
North Unit												
2020	-$369,000	-$1,255,000	-$1,771,000	$0	-$701,000	-$1,771,000	$0	$0	$0	$0	$0	$0
2025	$0	-$3,506,000	-$2,565,000	$0	-$1,070,000	-$1,605,000	$0	$0	$0	$0	$0	$0
2030	$0	-$4,096,000	-$3,026,000	$0	-$295,000	-$812,000	$0	$0	-$111,000	$0	$0	$0
2040	$0	-$2,251,000	-$1,956,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
2049	$0	-$1,218,000	-$1,347,000	$0	$0	$0	$0	$0	$0	$0	$0	$0

Source: Highland Economics analysis.

Alternative 4

Table 54 presents the estimated potential change in annual forage/grain production value under Alternative 4 compared to the no-action alternative, with detail by district provided in **Tables 55, 56, and 57**. The values in **Table 54** represent the range of changes in annual forage/grain production value season, with variation across the permit years, water year types, and conservation scenarios. Across all irrigated lands over the permit term in a median water year, the change in annual forage/grain production value may vary from approximately $0 to -$2.5 million (up to 3% of regional forage/grain production value under the no-action alternative, with all impacts in North Unit ID), while in a dry year the change in annual forage/grain production value may range from -$332,000 to -$11.0 million (0 to 12% of dry year forage/grain production value under no-action alternative). Across all water year types, the annual average forage/grain production value may decrease by up to 5% compared to the no-action alternative. When considering the value of all agricultural production in the county (all crop and animal sales), agricultural production value may fall by up to 3% across all water year types.

Table 54. Range of Estimated Potential Change in Annual Forage/Grain Production Value across All Irrigated Lands under Alternative 4 Compared to the No-Action Alternative

	Water Year Type			
Year	**Wet**	**Median**	**Dry**	**Average, All Water Year Types**[a]
2020	$0	-$74,000 to -$1,144,000	-$8,074,000 to -$6,912,000	-$2,441,000 to -$3,169,000
2025	$0	$0 to -$2,546,000	-$10,971,000 to -$6,679,000	-$2,338,000 to -$4,604,000
2030	$0	$0 to -$812,000	-$8,935,000 to -$2,768,000	-$969,000 to -$3,371,000
2039	$0	$0	-$6,370,000 to -$332,000	-$116,000 to -$2,230,000
% Change (Forage/Grain Production Value)[b]	0%	0 to -3%	0 to -12%	0 to -5%
% Change Agricultural Sales[c]				0 to -3%

Source: Highland Economics analysis.

[a] Average computed assuming that the wet year represents approximately 35% of years (water years in the 65th to 100th percentile), the median represents 30% of water years (water years in the 35th to 65th percentile), and the dry water year represents approximately 35% of water years (water years in the 0th to the 35th percentile).

[b] Relative to estimated forage/grain production value under existing conditions, as presented in Tables 43 and 44.

[c] Relative to total study area animal and crop sales as estimated in the 2017 Census of Agriculture.

Table 55. Estimated Potential Change in Annual Forage/Grain Production Value by District under Alternative 4 Compared to the No-Action Alternative, Median Water Year

	DBBC Districts										
Year	Arnold	Central Oregon	Lone Pine	North Unit	Ochoco	Swalley	Three Sisters	Tumalo	Total, DBBC Districts	Other Irrigated Lands	All Lands
Low Conservation											
2020	$0	$0	$0	-$1,144,000	$0	$0	$0	$0	-$1,144,000	$0	-$1,144,000
2025	$0	$0	$0	-$2,546,000	$0	$0	$0	$0	-$2,546,000	$0	-$2,546,000
2030	$0	$0	$0	-$812,000	$0	$0	$0	$0	-$812,000	$0	-$812,000
2039	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
% Change	0%	0%	0%	0 to -8%	0%	0%	0%	0%	0 to -3%	0%	0 to -3%
High Conservation											
2020	$0	$0	$0	-$74,000	$0	$0	$0	$0	-$74,000	$0	-$74,000
2025	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2030	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2039	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
% Change	0%	0%	0%	-0%	0%	0%	0%	0%	-0%	0%	0%

Source: Highland Economics analysis.

Table 56. Estimated Potential Change in Annual Forage/Grain Production Value by District under Alternative 4 Compared to the No-Action Alternative, Dry Water Year

	DBBC Districts										
Year	Arnold	Central Oregon	Lone Pine	North Unit	Ochoco	Swalley	Three Sisters	Tumalo	Total, DBBC Districts	Other Irrigated Lands	All Lands
Low Conservation											
2020	-$129,000	$0	-$214,000	-$7,731,000	$0	$0	$0	$0	-$8,074,000	$0	-$8,074,000
2025	-$215,000	$0	$0	-$10,756,000	$0	$0	$0	$0	-$10,971,000	$0	-$10,971,000
2030	-$171,000	$0	$0	-$8,764,000	$0	$0	$0	$0	-$8,935,000	$0	-$8,935,000
2039	-$171,000	$0	$0	-$6,199,000	$0	$0	$0	$0	-$6,370,000	$0	-$6,370,000
% Change	-16 to -10%	0%	0 to -19%	-19 to -34%	0%	0%	0%	0%	-7 to -13%	0%	-7 to -12%
High Conservation											
2020	-$43,000	$0	-$171,000	-$6,698,000	$0	$0	$0	$0	-$6,912,000	$0	-$6,912,000
2025	$0	$0	$0	-$6,679,000	$0	$0	$0	$0	-$6,679,000	$0	-$6,679,000
2030	$0	$0	$0	-$2,768,000	$0	$0	$0	$0	-$2,768,000	$0	-$2,768,000
2039	$0	$0	$0	-$332,000	$0	$0	$0	$0	-$332,000	$0	-$332,000
% Change	0 to -3%	0%	0 to -15%	-1 to -21%	0%	0%	0%	0%	0 to -8%	0%	0 to -8%

Source: Highland Economics analysis.

Table 57. Estimated Potential Change in Annual Forage/Grain Production Value by Subseason by DBBC District under Alternative 4 Compared to the No-Action Alternative

Irrigation District/ Year	Dry Water Year						Median Water Year					
	Low Conservation			High Conservation			Low Conservation			High Conservation		
	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept	May	June/ July	Aug/ Sept
Arnold												
2020	$0	-$57,000	-$72,000	$0	$0	-$43,000	$0	$0	$0	$0	$0	$0
2025	$0	-$143,000	-$72,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
2030	$0	-$114,000	-$57,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
2039	$0	-$114,000	-$57,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
Lone Pine												
2020	$0	-$143,000	-$71,000	$0	-$114,000	-$57,000	$0	$0	$0	$0	$0	$0
2025	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2030	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2039	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
North Unit												
2020	-$701,000	-$4,465,000	-$2,565,000	-$221,000	-$3,912,000	-$2,565,000	-$369,000	-$369,000	-$406,000	$0	$0	-$74,000
2025	-$627,000	-$6,753,000	-$3,376,000	$0	-$4,317,000	-$2,362,000	$0	-$1,476,000	-$1,070,000	$0	$0	$0
2030	$0	-$5,646,000	-$3,118,000	$0	-$1,845,000	-$923,000	$0	-$369,000	-$443,000	$0	$0	$0
2039	$0	-$4,022,000	-$2,177,000	$0	-$221,000	-$111,000	$0	$0	$0	$0	$0	$0

Source: Highland Economics analysis.

Economic Contribution of Agricultural Production

This section describes the economic contribution of agricultural production in terms of the direct, indirect, and induced jobs and income supported under existing conditions and the EIS alternatives. Agricultural production spurs economic activity in the local economy through on-farm income generation and farm worker employment, as well as through farm spending at local businesses for agricultural supplies, services, and equipment (indirect impacts). Agricultural support businesses, in turn, purchase goods and services from other businesses in the local area, generating other local economic activity (more indirect impacts). Furthermore, employees and proprietors in the farm sector and all supporting industries spend their income at local businesses such as retail stores and service businesses, which further supports economic activity (induced impacts). The sum of direct, indirect, and induced impacts represent the total economic contribution of agricultural production to the local economy. This section presents estimates of the total economic contribution under existing conditions and the EIS alternatives.

If agricultural production declines, as projected in the proposed action and action alternatives, the total economic contribution of agriculture (i.e., the regional jobs and income supported by agriculture) also would decline. However, it is important to note that the economic contribution of agricultural production *does not* equal the economic impact (i.e., the change in jobs and income in the local economy) that would result from reduced agricultural production. The actual economic impact, particularly in the long-term, would be smaller as at least some portion of the affected workers and businesses would likely find alternative sources of income generation and employment.

Existing Conditions

Agricultural Economy

This section summarizes published data from the Bureau of Economic Analysis (BEA), the Oregon Department of Employment, and the U.S. Census of Agriculture on total employment and income in the farm sector in the study area. These data include employment and income from both crop and animal production. The various data sources indicate different levels of farm worker employment (with BEA indicating higher farm worker employment, particularly in Deschutes County than Oregon Department of Employment), and different levels of net farm income to proprietors (with BEA indicating lower net income than the U.S. Census of Agriculture). The following tables and figures summarize these data.

BEA data provide a consistent basis for comparing the farm sector with other economic sectors, as these data include income and employment data for both workers and proprietors. Including farm proprietors (many of whom may be part-time farmers), BEA data indicate that farm-related employment may account for up to approximately 12 to 13% of total employment in Crook and Jefferson Counties, and up to approximately 1% of total labor income. In Deschutes County, farm sector employment and income represent up to approximately 2% of the county economy. Following this overview of published data, this section provides estimates of the economic contribution of existing forage and grain production under median and dry water years. Farm worker data from the Oregon Department of Employment (2014, 2015, 2016, 2017, 2018) indicate that the number of farm workers in the study area may be lower than reported by the Bureau of Economic Analysis (2019) in **Table 58**.

Table 58. 2017 Farm and Other Sector Employment and Income, Bureau of Economic Analysis

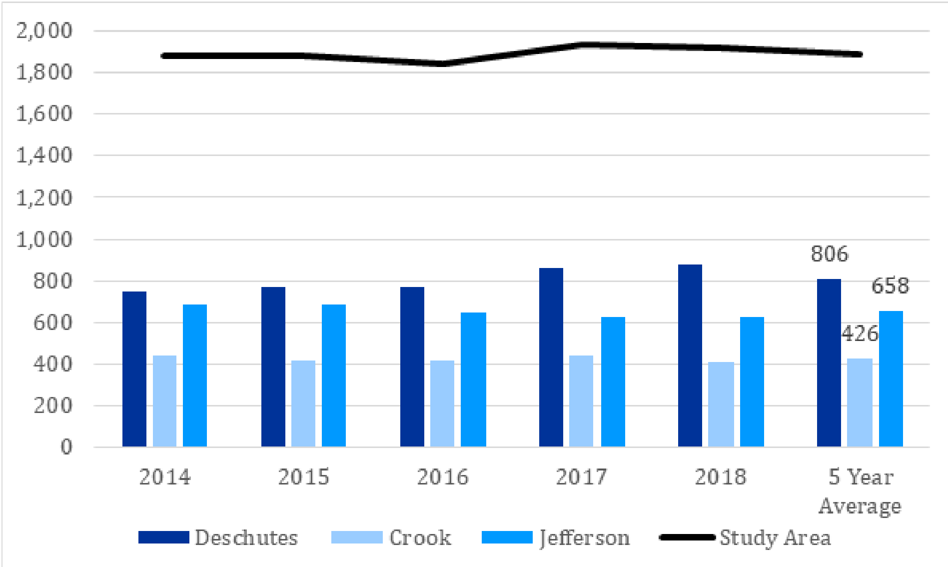
Sector	Jobs	Income[a]
Crook		
Farm workers	700	$5,375,000
Farm proprietors	519	-$1,277,000
Total farm-related	1,219	$4,098,000
All other sectors, workers and proprietors	8,607	$452,606,000
Total	9,826	$456,704,000
% farm-related	12%	1%
Deschutes		
Farm workers	1,206	$8,390,000
Farm proprietors	1206	-$17,511,000
Total farm-related	2,412	-$9,121,000
All other sectors, workers and proprietors	115,747	$6,191,292,000
Total	118159	$6,182,171,000
% farm-related	2%	N/A
Jefferson		
Farm workers	774	$12,438,000
Farm proprietors	424	-$16,191,000
Total farm-related	1,198	-$3,753,000
All other sectors, workers and proprietors	8,081	$277,405,000
Total	9279	$273,652,000
% farm-related	13%	N/A

Source: Bureau of Economic Analysis 2019: Tables CAINC5N Personal Income by Major Component and Earnings by NAICS Industry and CAEMP25N Total Full-Time and Part-Time Employment by NAICS Industry for Crook, Deschutes, and Jefferson Counties.

[a] Including supplements to wages and salaries.

Figure 9 shows Oregon Department of Employment data for farm workers for the period 2014 to 2018. The 5-year average for this time period indicates that there were approximately 1,900 farm workers employed throughout the study area in crop and animal production, with approximately 800 farm workers in Deschutes County, 430 farm workers in Crook County, and approximately 660 farm workers in Jefferson County.

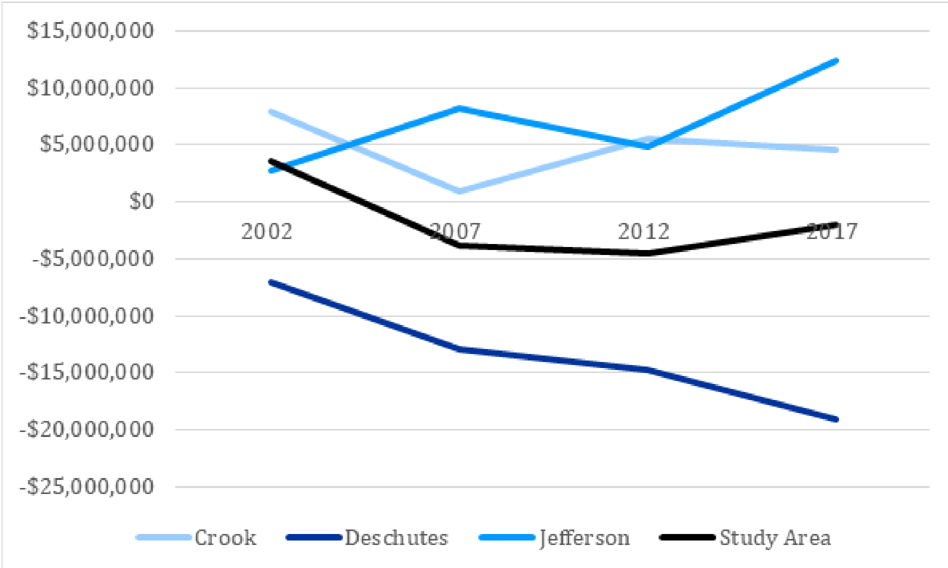
Figure 9. Study Area Farm Worker (Crop and Animal Production) Employment from 2014 to 2018



Source: Oregon Department of Employment 2014–2018.

While the data from the Bureau of Economic Analysis (2019) indicate that total net cash farm income (a measure of farm profit that does not include such non-cash items as depreciation) is negative across all farms in the three counties, data from the 2017 Census of Agriculture (2019) indicate that net cash farm income in Jefferson and Crook is positive. Only in Deschutes County, which has many smaller lifestyle farms, shows a negative net cash farm income across all farms (although some farms will be positive and some negative; see **Figure 10**). It is important to note that a negative net cash farm income does not necessarily mean a negative economic value to the proprietor. Many farm proprietors derive enjoyment from a rural, agricultural lifestyle and also benefit through being able to support their livestock animals through on-farm forage production.

Figure 10. Net Cash Farm Income (to Proprietors) by County (2017)



Source: 2017 Census of Agriculture (2019).

Economic Contribution of Forage and Grain Production

To provide a baseline for the change in the economic contribution under the EIS alternatives, this section presents estimates of the economic contribution of existing forage and grain production under median and dry water years. **Table 59** summarizes by county the value of forage and grain production presented in the section above for a median water year under existing conditions. For this level of production, **Table 60** presents the estimated direct, indirect, and induced economic contribution in each county and the study area as a whole**.** Indirect and induced effects in sectors supporting agriculture and agricultural workers include those arising from agricultural production within the county, as well as those arising from agricultural production in the other two study area counties (e.g., if a farm in Crook County purchased supplies from a Deschutes County farm supplier, or vice versa). **Tables 61 and 62** present the same data for a dry water year.

Table 59. Forage and Grain Production Value by County under Existing Conditions, Median Water Year

District	County			Study Area
	Crook	Deschutes	Jefferson	
Arnold	$0	$1,342,000	$0	$1,342,000
Central Oregon	$13,664,000	$13,664,000	$0	$27,328,000
Lone Pine	$1,144,000	$0	$0	$1,144,000
North Unit	$0	$0	$32,383,000	$32,383,000
Ochoco	$10,300,000	$0	$0	$10,300,000
Swalley	$0	$1,910,000	$0	$1,910,000
Three Sisters	$0	$4,794,000	$0	$4,794,000
Tumalo	$0	$3,578,000	$0	$3,578,000
Other Irrigated Lands	$2,407,000	$0	$0	$2,407,000
Total	**$27,515,000**	**$25,287,000**	**$32,383,000**	**$85,186,000**

Source: Highland Economics analysis of District Acreage data and U.S. Department of Agriculture, National Agricultural Statistics Service yield and price data. Study area totals may not sum due to rounding.

Table 60. Forage/Grain Production Economic Contribution: Employment and Income under Existing Conditions, Median Water Year

Type of Economic Impact	County			Study Area
	Crook	Deschutes	Jefferson	
Employment (Full and Part-Time Jobs)				
Direct	230	520	400	1,150
Indirect & Induced (from County Production)	100	170	100	370
Indirect & Induced (from Elsewhere Study Area Production)	0	70	0	80
Total	**330**	**760**	**500**	**1,590**
Income (Employee Compensation and Proprietor Income)				
Direct	$11,589,000	$9,024,000	$7,322,000	$27,935,000
Indirect & Induced (from County Production)	$3,669,000	$6,826,000	$5,097,000	$15,592,000
Indirect & Induced (from Elsewhere Study Area Production)	$227,000	$3,002,000	$225,000	$3,454,000
Total	**$15,485,000**	**$18,852,000**	**$12,644,000**	**$46,981,000**

Source: Highland Economics analysis using 2017 IMPLAN data and models of Crook, Deschutes, and Jefferson Counties. Study area totals may not sum due to rounding.

Table 61. Forage and Grain Production Value by County under Existing Conditions, Dry Water Year

District	County			Study Area
	Crook	Deschutes	Jefferson	
Arnold	$0	$1,336,000	$0	$1,336,000
Central Oregon	$13,639,000	$13,639,000	$0	$27,278,000
Lone Pine	$1,135,000	$0	$0	$1,135,000
North Unit	$0	$0	$31,168,000	$31,168,000
Ochoco	$10,233,000	$0	$0	$10,233,000
Swalley	$0	$1,910,000	$0	$1,910,000
Three Sisters	$0	$4,790,000	$0	$4,790,000
Tumalo	$0	$2,901,000	$0	$2,901,000
Other Irrigated Lands	$2,382,000	$0	$0	$2,382,000
Total	**$27,389,000**	**$24,576,000**	**$31,168,000**	**$83,133,000**

Source: Highland Economics analysis of District Acreage data and U.S. Department of Agriculture, National Agricultural Statistics Service yield and price data. Study area totals may not sum due to rounding.

Table 62. Forage/Grain Production Economic Contribution: Employment and Income under Existing Conditions, Dry Water Year

Type of Economic Impact	County			Study Area
	Crook	Deschutes	Jefferson	
Employment (Full and Part-Time Jobs)				
Direct	220	500	390	1,120
Indirect & Induced (from County Production)	100	160	90	360
Indirect & Induced (from Elsewhere Study Area Production)	0	70	0	80
Total	**330**	740	490	1,550
Income (Employee Compensation and Proprietor Income)				
Direct	$11,536,000	$8,770,000	$7,047,000	$27,353,000
Indirect & Induced (from County Production)	$3,652,000	$6,634,000	$4,906,000	$15,192,000
Indirect & Induced (from Elsewhere Study Area Production)	$219,000	$2,943,000	$222,000	$3,384,000
Total	**$15,408,000**	**$18,348,000**	**$12,176,000**	**$45,932,000**

Source: Highland Economics analysis using 2017 IMPLAN data and models of Crook, Deschutes, and Jefferson Counties. Study area totals may not sum due to rounding.

No-Action Alternative

In wet and median water year types, the total economic contribution under the no-action alternative would be similar to existing conditions. In the initial years of the analysis period, the no-action alternative dry year economic contribution also would be similar to existing conditions. However, due to water conservation over the analysis period, under the no-action alternative, water available to crops in dry water years may increase over time compared to existing conditions, which may lead to increased acreage and/or yields and associated economic activity in dry water years over the analysis period. **Table 63** summarizes the effect on the total economic contribution of forage and grain production in terms of annual jobs and income supported under the no-action alternative in dry water years throughout the analysis period and provides a comparison to existing conditions. **Tables 64 and 65** provide detail by year and low and high conservation scenarios.

Table 63. Forage/Grain Production Economic Contribution: Annual Total Employment and Income from Forage/Grain Production under No-Action Alternative Compared to Existing Conditions, Dry Water Year

	County			
Type of Economic Impact	**Crook**	**Deschutes**	**Jefferson**	**Study Area**
Employment (Full and Part-Time Jobs)				
Jobs	330	740	490 to 500	1,560 to 1,570
Change from existing conditions	0	0 to 5	5 to 15	5 to 20
% Change	0	0 to 1%	1 to 3%	0 to 1%
Income (Employee Compensation and Proprietor Income)				
Income (Millions $)	$15.4	$18.4	$12.3 to $12.7	$46.0 to $46.4
Change from existing conditions (Millions $)	$0	$0	$0.1 to $0.5	$0.1 to $0.5
% Change	0%	0%	1 to 4%	0 to 1%

Source: Highland Economics analysis using IMPLAN. Study area totals may not sum due to rounding. Total employment and income includes direct, indirect, and induced effects.

Table 64. Estimated Annual Total Employment (Direct, Indirect, Induced Effects of Forage/Grain Production) under No-Action Alternative, Dry Water Year

	County			
Year	**Crook**	**Deschutes**	**Jefferson**	**Study Area**
Low Conservation				
2020	330	740	490	1,560
2025	330	740	500	1,570
2030	330	740	500	1,570
2040	330	740	500	1,570
2049	330	740	500	1,570
High Conservation				
2020	330	740	490	1,560
2025	330	740	500	1,570
2030	330	740	500	1,570
2040	330	740	500	1,570
2049	330	740	500	1,570

Source: Highland Economics analysis using 2017 IMPLAN data and models of Crook, Deschutes, and Jefferson Counties. Study area totals may not sum due to rounding.

Table 65. Estimated Annual Total Income (Direct, Indirect, Induced Effects of Forage/Grain Production) under No-Action Alternative, Dry Water Year

	County			
Year	**Crook**	**Deschutes**	**Jefferson**	**Study Area**
Low Conservation				
2020	$15,416,000	$18,357,000	$12,254,000	$46,027,000
2025	$15,416,000	$18,357,000	$12,477,000	$46,250,000
2030	$15,416,000	$18,357,000	$12,650,000	$46,423,000
2040	$15,416,000	$18,357,000	$12,650,000	$46,423,000
2049	$15,416,000	$18,357,000	$12,650,000	$46,423,000
High Conservation				
2020	$15,416,000	$18,357,000	$12,383,000	$46,156,000
2025	$15,416,000	$18,357,000	$12,650,000	$46,423,000
2030	$15,416,000	$18,357,000	$12,650,000	$46,423,000
2040	$15,416,000	$18,357,000	$12,650,000	$46,423,000
2049	$15,416,000	$18,357,000	$12,650,000	$46,423,000

Source: Highland Economics analysis using 2017 IMPLAN data and models of Crook, Deschutes, and Jefferson Counties. Study area totals may not sum due to rounding.

Proposed Action

Table 66 summarizes the estimated potential change in annual total economic contribution in terms of jobs and income (direct, indirect, and induced) supported by forage/grain production under the proposed action relative to the no-action alternative for the same water year type, conservation scenario, and permit year. The greatest potential impacts would be experienced in dry water years under the low conservation scenario, where economic contribution would decline by less than 1% in Crook and Deschutes Counties and up to 7% in Jefferson County. In dry water years under the high conservation scenario and in wet and median water years under both conservation scenarios, economic contribution would be unchanged in all counties. Across all water year types, average annual total economic contribution is expected to decline by up to 2% in Jefferson County, but remain unchanged in Crook and Deschutes Counties.[20]

Tables 67 and 68 provide detailed data on estimated potential change in annual employment and income by county by permit year and conservation scenario for dry water years.

[20] See Appendix 3.1-C, *Analysis of RiverWare Model Version 18 Outputs and Implications for Final EIS*, for correction due to modeling update.

Table 66. Range of Potential Change in Annual Total Economic Contribution from Forage and Grain Production by County, Proposed Action Compared to the No-Action Alternative

County	Water Year Type			Average, All Water Year Types[a]
	Wet	Median	Dry	
Crook				
Employment (Full- and part-time jobs)	0	0	0	0
Income (Millions)	$0	$0	-$0.1 to $0	$0
% Change (Forage Production Contribution)	0%	0%	0%	0%
Deschutes				
Employment (Full- and part-time jobs)	0	0	0%	0%
Income (Millions)	$0	$0	$0.0	$0.0
% Change (Forage Production Contribution)	0%	0%	0%	0%
Jefferson				
Employment (Full- and part-time jobs)	0	0	-30 to 0	-10
Income (Millions)	$0	$0	-$0.8 to $0	-$0.3 to $0
% Change (Forage Production Contribution)	0%	0%	-7 to 0%	-2 to 0%
Study Area				
Employment	0	0	-40 to 0	-10 to -0
Income (Millions)	$0	$0	-$0.8 to -$0	-0$.3 to $0
% Change (Forage Production Contribution)	0%	0%	-3 to 0%	-1 to 0%

Note: Totals may not sum due to rounding.
Source: Highland Economics analysis using 2017 IMPLAN data and models of Crook, Deschutes, and Jefferson Counties. Study area totals may not sum due to rounding. Total economic contribution includes direct, indirect, and induced effects.
[a] Average computed assuming that the wet year represents approximately 35% of years (water years in the 65th to 100th percentile), the median represents 30% of water years (water years in the 35th to 65th percentile), and the dry water year represents approximately 35% of water years (water years in the 0th to the 35th percentile).

Table 67. Estimated Potential Change in Annual Total Employment (Direct, Indirect, Induced Effects) by County under Proposed Action Compared to the No-Action Alternative, Dry Water Year

	County			
Year	Crook	Deschutes	Jefferson	Study Area
Low Conservation				
2020	0	0	0	0
2025	0	0	0	0
2030	0	0	-30	-40
2040	0	0	-30	-30
2049	0	0	0	0
High Conservation				
2020	0	0	0	0
2025	0	0	0	0
2030	0	0	0	0
2040	0	0	0	0
2049	0	0	0	0

Source: Highland Economics analysis using 2017 IMPLAN data and models of Crook, Deschutes, and Jefferson Counties. Study area totals may not sum due to rounding.

Table 68. Estimated Potential Change in Annual Total Income (Direct, Indirect, Induced Effects) by County under Proposed Action Compared to the No-Action Alternative, Dry Water Year

	County			
Year	Crook	Deschutes	Jefferson	Study Area
Low Conservation				
2020	-$73,000	$0	$0	-$73,000
2025	$0	$0	$0	$0
2030	$0	$0	-$836,000	-$836,000
2040	$0	$0	-$684,000	-$684,000
2049	$0	$0	-$58,000	-$58,000
High Conservation				
2020	-$8,000	$0	$0	-$8,000
2025	$0	$0	$0	$0
2030	$0	$0	$0	$0
2040	$0	$0	$0	$0
2049	$0	$0	$0	$0

Source: Highland Economics analysis using 2017 IMPLAN data and models of Crook, Deschutes, and Jefferson Counties. Study area totals may not sum due to rounding.

Alternative 3

Table 69 summarizes the estimated potential change in annual total economic contribution in terms of jobs and income (direct, indirect, and induced) supported by forage/grain production under Alternative 3 relative to the no-action alternative for the same water year type, conservation scenario, and permit year. The greatest potential impacts would be experienced in dry water years under the low conservation scenario, where economic contribution would decline by less than 1% in Crook County and up to 22% in Jefferson County but would remain unchanged in Deschutes County. In dry water years under the high conservation scenario and in wet and median water years under both conservation scenarios, economic contribution would be unchanged (or changed by less than 1%) in all counties. Across all water year types, average annual total economic contribution is expected to decline by up to 8% in Jefferson County, but remain unchanged in Crook and Deschutes Counties.

Tables 70 and 71 provide detailed data on the estimated potential change in annual employment and income by county by permit year and conservation scenario for dry water years.

Table 69. Range of Potential Change in Annual Total Economic Contribution from Forage and Grain Production by County, Alternative 3 Compared to the No-Action Alternative

County	Water Year Type: Wet	Water Year Type: Median	Water Year Type: Dry	Average, All Water Year Types[a]
Crook				
Employment (Full- and part-time jobs)	0	0	0	0
Income (Millions)	$0	$0	-$0.1 to $0	$0
% Change (Forage Production Contribution)	0%	0%	-1 to 0%	0%
Deschutes				
Employment (Full- and part-time jobs)	0	0	0	0
Income (Millions)	$0	$0	$0	$0
% Change (Forage Production Contribution)	0%	0%	0%	0%
Jefferson				
Employment (Full- and part-time jobs)	0	0	-110 to 0	-40 to 0
Income (Millions)	$0	$0	-$2.8 to -$0	-$1.0 to $0
% Change (Forage Production Contribution)	0%	0%	-22 to 0%	-8 to 0%
Study Area				
Employment (Full- and part-time jobs)	0	0	-130 to -0	-50 to 0
Income (Millions)	$0	$0	-$2.8 to $0	-$1.0 to $0
% Change (Forage Production Contribution)	0%	0%	0 to -8%	-3 to 0%

Source: Highland Economics analysis using 2017 IMPLAN data and models of Crook, Deschutes, and Jefferson Counties. Study area totals may not sum due to rounding. Total economic contribution includes direct, indirect, and induced effects.

[a] Average computed assuming that the wet year represents approximately 35% of years (water years in the 65th to 100th percentile), the median represents 30% of water years (water years in the 35th to 65th percentile), and the dry water year represents approximately 35% of water years (water years in the 0th to the 35th percentile).

Table 70. Estimated Potential Change in Annual Total Employment (Direct, Indirect, Induced Effects) by County under Alternative 3 Compared to the No-Action Alternative, Dry Water Year

	County			
Year	Crook	Deschutes	Jefferson	Study Area
Low Conservation				
2020	0	0	-50	-70
2025	0	0	-90	-110
2030	0	0	-110	-130
2040	0	0	-70	-80
2049	0	0	-40	-50
High Conservation				
2020	0	0	-40	-50
2025	0	0	-40	-50
2030	0	0	-20	-20
2040	0	0	0	0
2049	0	0	0	0

Source: Highland Economics analysis using 2017 IMPLAN data and models of Crook, Deschutes, and Jefferson Counties. Study area totals may not sum due to rounding.

Table 71. Estimated Potential Change in Annual Total Income (Direct, Indirect, Induced Effects) by County under Alternative 3 Compared to the No-Action Alternative, Dry Water Year

	County			
Year	Crook	Deschutes	Jefferson	Study Area
Low Conservation				
2020	-$120,000	-$32,000	-$1,326,000	-$1,478,000
2025	$0	-$43,000	-$2,371,000	-$2,414,000
2030	$0	-$10,000	-$2,782,000	-$2,792,000
2040	$0	-$10,000	-$1,643,000	-$1,653,000
2049	$0	-$10,000	-$1,002,000	-$1,012,000
High Conservation				
2020	-$73,000	$0	-$966,000	-$1,039,000
2025	$0	$0	-$1,045,000	-$1,045,000
2030	$0	$0	-$432,000	-$432,000
2040	$0	$0	$0	$0
2049	$0	$0	$0	$0

Source: Highland Economics analysis using 2017 IMPLAN data and models of Crook, Deschutes, and Jefferson Counties. Study area totals may not sum due to rounding.

Alternative 4

Table 72 summarizes the estimated potential change in annual total economic contribution in terms of annual jobs and income (direct, indirect, and induced) supported by forage/grain production under Alternative 4 relative to the no-action alternative for the same water year type, conservation scenario, and permit year. The greatest potential impacts would be experienced in dry water years under the low conservation scenario, where economic contribution would decline by less than 1% in Crook and Deschutes Counties and up to 34% in Jefferson County. In dry water years under the high conservation scenario, economic contribution would decline by 1% in Jefferson County and be unchanged in Crook and Deschutes Counties. In wet and median water years under both conservation scenarios, economic contribution would be unchanged in all counties, except a potential decrease of up to 8% in Jefferson County in median water years under the low conservation scenario. Across all water year types, average annual total economic contribution is expected to decline by up to 14% in Jefferson County, less than 1% in Deschutes County, and remain unchanged in Crook County. **Tables 73, 74, 75**, and **76** provide detailed data on the estimated potential change in annual employment and income by county by permit year and conservation scenario for median and dry water years.

Table 72. Range of Potential Change in Annual Total Economic Contribution from Forage and Grain Production by County, Alternative 4 Compared to the No-Action Alternative

	Water Year Type			Average, All Water Year Types[a]
County	**Wet**	**Median**	**Dry**	
Crook				
Employment (Full- and part-time jobs)	0	0	0	0
Income (Millions)	$0	$0	-$0.1 to $0	$0
% Change (Forage Production Contribution)	0%	0%	-1 to 0%	0%
Deschutes				
Employment (Full- and part-time jobs)	0	0	-10 to 0	0
Income (Millions)	$0	$0	-$0.2 to -$0	-$0.1 to $0
% Change (Forage Production Contribution)	0%	0%	-1 to 0%	0%
Jefferson				
Employment (Full- and part-time jobs)	0	-40 to 0	-170 to -10	-70 to 0
Income (Millions)	$0	-$1.0 to $0	-$4.2 to -$0.1	-$1.5 to $0
% Change (Forage Production Contribution)	0%	-8 to 0%	-34 to -1%	-14 to 0%
Study Area				
Employment (Full- and part-time jobs)	0	-50 to 0	-200 to -10	-90 to 0
Income (Millions)	$0	-$1.0 to $0	-$4.4 to -$0.1	-$1.5 to $0
% Change (Forage Production Contribution)	0%	-3 to -0%	-13 to -1%	-5 to 0%

Source: Highland Economics analysis using 2017 IMPLAN data and models of Crook, Deschutes, and Jefferson Counties. Study area totals may not sum due to rounding. Total economic contribution includes direct, indirect, and induced effects.

[a] Average computed assuming that the wet year represents approximately 35% of years (water years in the 65th to 100th percentile), the median represents 30% of water years (water years in the 35th to 65th percentile), and the dry water year represents approximately 35% of water years (water years in the 0th to the 35th percentile).

Table 73. Estimated Potential Change in Annual Total Employment (Direct, Indirect, Induced Effects) by County under Alternative 4 Compared to the No-Action Alternative, Median Water Year

	County			
Year	Crook	Deschutes	Jefferson	Study Area
Low Conservation				
2020	0	0	-20	-20
2025	0	0	-40	-50
2030	0	0	-10	-20
2039	0	0	0	0
High Conservation				
2020	0	0	0	0
2025	0	0	0	0
2030	0	0	0	0
2039	0	0	0	0

Source: Highland Economics analysis using 2017 IMPLAN data and models of Crook, Deschutes, and Jefferson Counties. Study area totals may not sum due to rounding.

Table 74. Estimated Potential Change in Annual Total Income (Direct, Indirect, Induced Effects) by County under Alternative 4 Compared to the No-Action Alternative, Median Water Year

	County			
Year	Crook	Deschutes	Jefferson	Study Area
Low Conservation				
2020	$0	$0	-$447,000	-$447,000
2025	$0	$0	-$994,000	-$994,000
2030	$0	$0	-$317,000	-$317,000
2039	$0	$0	$0	$0
High Conservation				
2020	$0	$0	-$29,000	-$29,000
2025	$0	$0	$0	$0
2030	$0	$0	$0	$0
2039	$0	$0	$0	$0

Source: Highland Economics analysis using 2017 IMPLAN data and models of Crook, Deschutes, and Jefferson Counties. Study area totals may not sum due to rounding.

Table 75. Estimated Potential Change in Annual Total Employment (Direct, Indirect, Induced Effects) by County under Alternative 4 Compared to the No-Action Alternative, Dry Water Year

Year	County			Study Area
	Crook	Deschutes	Jefferson	
Low Conservation				
2020	0	0	-120	-150
2025	0	-10	-170	-200
2030	0	-10	-140	-170
2039	0	-10	-100	-120
High Conservation				
2020	0	0	-100	-130
2025	0	0	-100	-120
2030	0	0	-40	-50
2039	0	0	-10	-10

Source: Highland Economics analysis using 2017 IMPLAN data and models of Crook, Deschutes, and Jefferson Counties. Study area totals may not sum due to rounding.

Table 76. Estimated Potential Change in Annual Total Income (Direct, Indirect, Induced Effects) by County under Alternative 4 Compared to the No-Action Alternative, Dry Water Year

Year	County			Study Area
	Crook	Deschutes	Jefferson	
Low Conservation				
2020	-$120,000	-$96,000	-$3,020,000	-$3,236,000
2025	$0	-$161,000	-$4,201,000	-$4,362,000
2030	$0	-$128,000	-$3,423,000	-$3,551,000
2039	$0	-$128,000	-$2,421,000	-$2,549,000
High Conservation				
2020	-$96,000	-$32,000	-$2,616,000	-$2,744,000
2025	$0	$0	-$2,609,000	-$2,609,000
2030	$0	$0	-$1,081,000	-$1,081,000
2039	$0	$0	-$130,000	-$130,000

Source: Highland Economics analysis using 2017 IMPLAN data and models of Crook, Deschutes, and Jefferson Counties. Study area totals may not sum due to rounding.

References Cited

Printed References

Black Rock Consulting and Farmers Conservation Alliance. 2018. *Ochoco Irrigation District System Improvement Plan.* Ochoco Irrigation District.

Black Rock Consulting. 2016. *Central Oregon Irrigation District System Improvement Plan.* Central Oregon Irrigation District.

Bohle, M., Ballerstadt, P., and James, S. 1992. *Quality and Yield Comparison of Orchard Grass Varieties in their Fourth Year.* Central Oregon Agriculture Research and Extension Center. Available: http://oregonstate.edu/dept/coarc/sites/default/files/publication/04_orchardgrass_fourth_year.pdf.

Bureau of Economic Analysis (BEA). 2019. *County, Metro, and Other Local Areas*. Available: https://www.bea.gov/data/by-place-county-metro-local

Bureau of Labor Statistics. 2019. *All Urban Consumers-Consumer Price Index*. Available: https://www.bls.gov/cpi/.

Butler, M., Oppenlander, I., and Ralls, K. 2015. *Central Oregon Agricultural Research Center.* Central Oregon Agriculture Research and Extension Center: Alfalfa: 2015 Alfalfa Variety Trials. Available: http://oregonstate.edu/dept/coarc/alfalfa-hay.

Central Oregon Agriculture Research and Extension Center. 2013, 2012, 2011, 2010, 2009. *Agricultural Statistics – Vegetable Seed, Grass Seed, Peppermint, Other Crops.* Local Ag statistics. Available: http://oregonstate.edu/dept/coarc/local-ag-statistics.

Central Oregon Irrigation District (COID). 2012. *2011 Water Conservation Management Plan.* Central Oregon Irrigation District.

Central Oregon Irrigation District (COID). 2017. *2017 COID Preliminary On-Farm Efficiency Study.* Central Oregon Irrigation District.

Deschutes River Conservancy and Deschutes Water Alliance. 2013. *Deschutes Water Planning Initiative Water Supply Goals and Objectives.* Bend, OR.

Farmers Conservation Alliance. 2018a. *Preliminary Investigative Report for the Arnold Irrigation District Irrigation Modernization Project.* Natural Resources Conservation Service.

Farmers Conservation Alliance. 2018b. *Tumalo Irrigation District Irrigation Modernization Project Watershed Plan-Environmental Assessment.* Natural Resource Conservation Service.

Farmers Conservation Alliance. 2018c. *Draft Preliminary Investigative Report for the Lone Pine Irrigation District Irrigation Modernization Project.* Natural Resources Conservation Service.

Lite, Kenneth E., and Marshall W. Gannett. 2002. *Geologic Framework of the Regional Ground-Water Flow System in the Upper Deschutes Basin, Oregon.* Portland: U.S. Geological Survey.

Newton, David, and Mathias Perle. 2006. *Irrigation District Water Efficiency Cost Analysis and Prioritization DWA Final Report.* Bureau of Reclamation.

North Unit Irrigation District. 2016. "North Unit Irrigation District Newsletters: 2016." *North Unit Irrigation District News.* December Volume 16, Issue 4. http://www.northunitid.com/index.php?option=com_content&view=article&id=23&Itemid=&dir=JSROOT%2Fnewsletters/2016.

Ochoco Irrigation District. 2012. *Ochoco Irrigation District Water Management and Conservation Plan.* Ochoco Irrigation District.

Oregon Environmental Council. 2012. *Making Water Work: Strategies for Advancing Water Conservation in Oregon Agriculture.* Portland: Oregon Environmental Council.

U.S. Department of Agriculture (USDA) National Agricultural Statistics Service (NASS). Census of Agriculture for 1997, 2002, 2007, 2012, 2017; Table 2 Market Value of Agricultural Products Sold Including Direct Sales, Table 6: Income from Farm-Related Sources, and Table 10 Irrigation for Crook, Deschutes, and Jefferson Counties *Quick Stats, Census. Quick Stats*. Available: https://quickstats.nass.usda.gov/.

U.S. Department of Agriculture Economic Research Service (ERS). 2018. *Table 3 - State-level normalized price received estimates for commodities (ERS Report Year = 2018).* Available: https://www.ers.usda.gov/data-products/normalized-prices/. Accessed: September 27, 2019.

U.S. Department of Agriculture National Agricultural Statistics Service (NASS). 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017. Average annual yield and acreage data for spring wheat, winter wheat, alfalfa, and other hay in Crook, Deschutes, and Jefferson Counties. *Quick Stats: Survey Data*. Available: https://quickstats.nass.usda.gov/.

U.S. Department of Agriculture National Agricultural Statistics Service (NASS). 2014, 2015, 2016, 2017. *Surveys: Cash Rents*. Retrieved from Data, Rent, Cash, Pastureland-Expense, Measured in $/Acre. Available: https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Cash_Rents_by_County/.

U.S. Department of Agriculture. 2012. *2012 Census of Agriculture.*

U.S. Department of Agriculture. 2019. *Census of Agriculture, 2017 Publications*. Available: https://www.nass.usda.gov/Publications/AgCensus/2017/.

U.S. Department of the Interior Bureau of Reclamation (Reclamation). 2016. *AgriMet Cooperative Agricultural Weather Network.* Evapotranspiration totals and averages Madras (MRSO), Bend (BEWO), and Powell Butte (POBO) stations for 2006 through 2015. Available: https://www.usbr.gov/pn/agrimet/h2ouse.html.

U.S. Department of the Interior Bureau of Reclamation (Reclamation). 2019. *AgriMet Historical Archive Weather Data Access*, precipitation data for Years 2010 through 2018 May through September. January. Available: https://www.usbr.gov/pn/agrimet/wyreport.html.

Personal Communications

Bohle, Mylen [a]. Agent. Oregon State University Extension. November 27, 2018—Interview by Winston Oakley, Economist, Highland Economics.

Bohle, Mylen [b]. Agent. Oregon State University Extension. November 30, 2018—Electronic document sent to Winston Oakley, economist, Highland Economics: *NUID Crop Mixes 2009–2018*.

Bozett, Chase. Senior Analyst. FCS Group. May 22, 2019—Email to Barbara Wyse, Economist, Highland Economics.

Britton, Mike and Craig Horrell. District Managers. Central Oregon Irrigation District and North Unit Irrigation District. January 18, 2019—Email to Barbara Wyse, Principal, Highland Economics.

Gerdes, Shawn. District Manager. Arnold Irrigation District. January 16, 2019—Interview by Barbara Wyse, Principal, Highland Economics.

Horrell, Craig. [a] District Manager. Central Oregon Irrigation District. November 13, 2018—Interview by Barbara Wyse, Principal, Highland Economics.

Horrell, Craig. [b] District Manager. Central Oregon Irrigation District. January 24, 2019—Interview by Barbara Wyse, Principal, Highland Economics.

Rhoden, Russ, and Bruce Scanlon. District Managers. Ochoco Irrigation District. January 17, 2019—Interview by Barbara Wyse, Principal, Highland Economics.

Richards, Martin. Board Member. North Unit Irrigation District. November 21, 2018—Interview by Barbara Wyse, Principal, Highland Economics.

Rieck, Ken. District Manager. Tumalo Irrigation District. February 13, 2019—Interview by Barbara Wyse, Principal, Highland Economics.

Smith, Terry. District Manager. Lone Pine Irrigation District. April 2, 2019—Interview by Winston Oakley, Economist, Highland Economics.

Thalacker, Mark. District Manager. Three Sisters Irrigation District. February 8, 2019—Interview by Barbara Wyse.

Appendix 3.10-A
Cultural Resource Technical Supplement

Reservoir Surface Water Elevation

This section presents a hydrograph of the study area reservoirs based on RiverWare model outputs for daily water surface elevation over the course of the calendar year aggregated over the 38-year modeling period. The hydrographs show the median water surface elevation (line) and the 20% and 80% exceedance (shading) elevations for the proposed action, Alternative 3, and Alternative 4 compared to the no-action alternative. The hydrographs represent the proposed action, Alternative 3, and Alternative 4 at full implementation (i.e., when fall/winter releases below Wickiup Reservoir are at their highest). This information is used to support the analysis of effects on cultural resources.

Crane Prairie Reservoir

Figure 1. Crane Prairie Reservoir Water Surface Elevation under Proposed Action Compared to No-Action Alternative

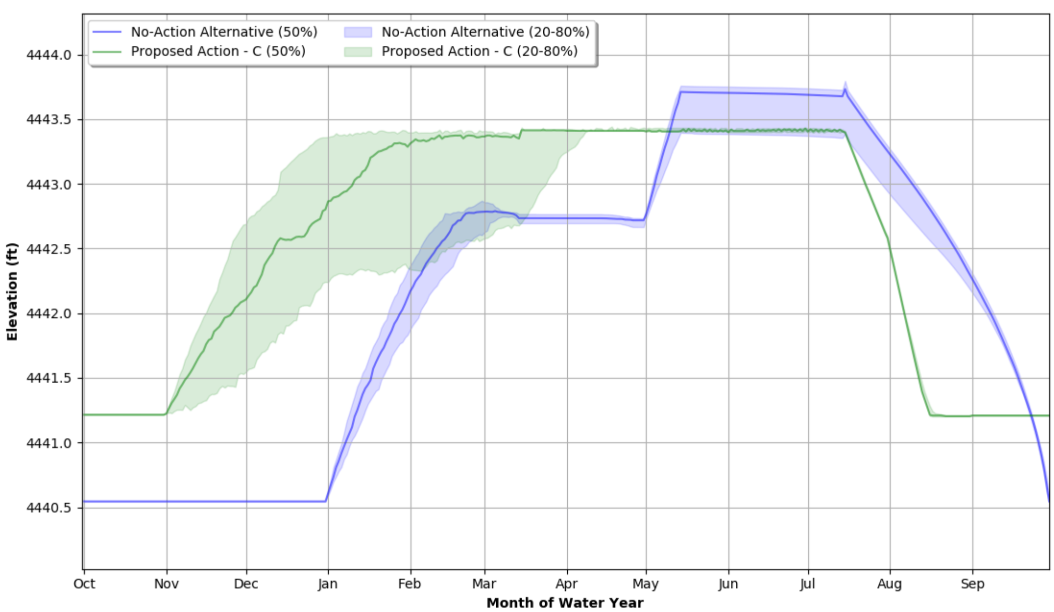


Figure 2. Crane Prairie Reservoir Water Surface Elevation under Alternative 3 Compared to No-Action Alternative

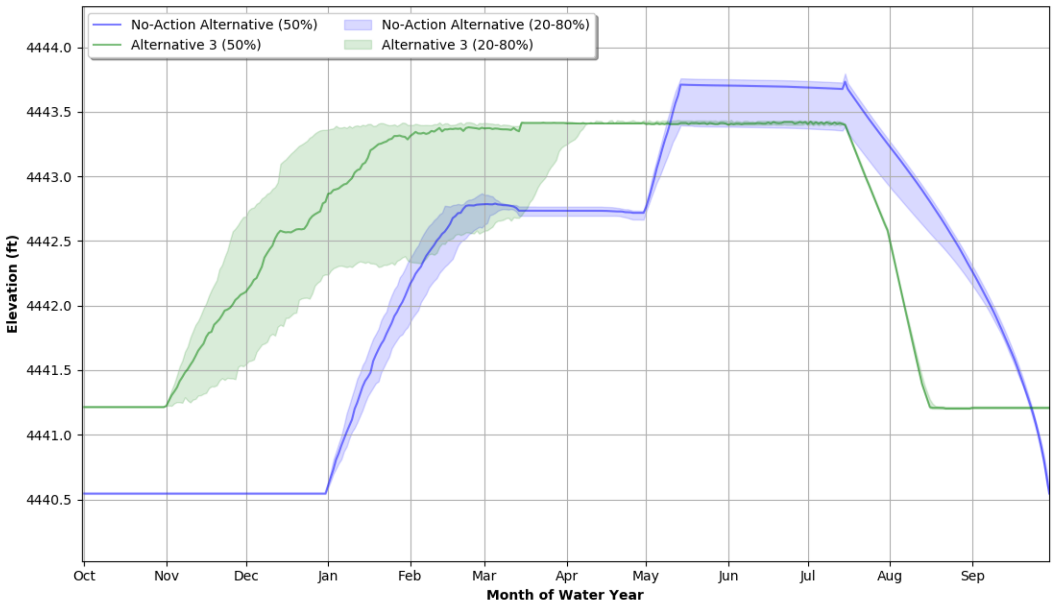
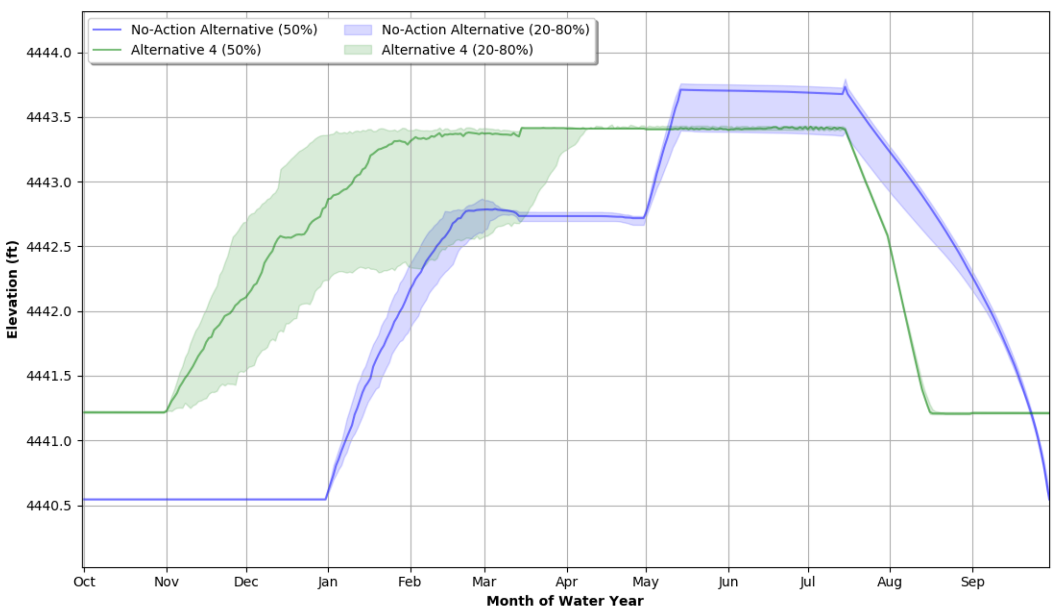


Figure 3. Crane Prairie Reservoir Water Surface Elevation under Alternative 4 Compared to No-Action Alternative



Wickiup Reservoir

Figure 4. Wickiup Reservoir Water Surface Elevation under Proposed Action Compared to No-Action Alternative

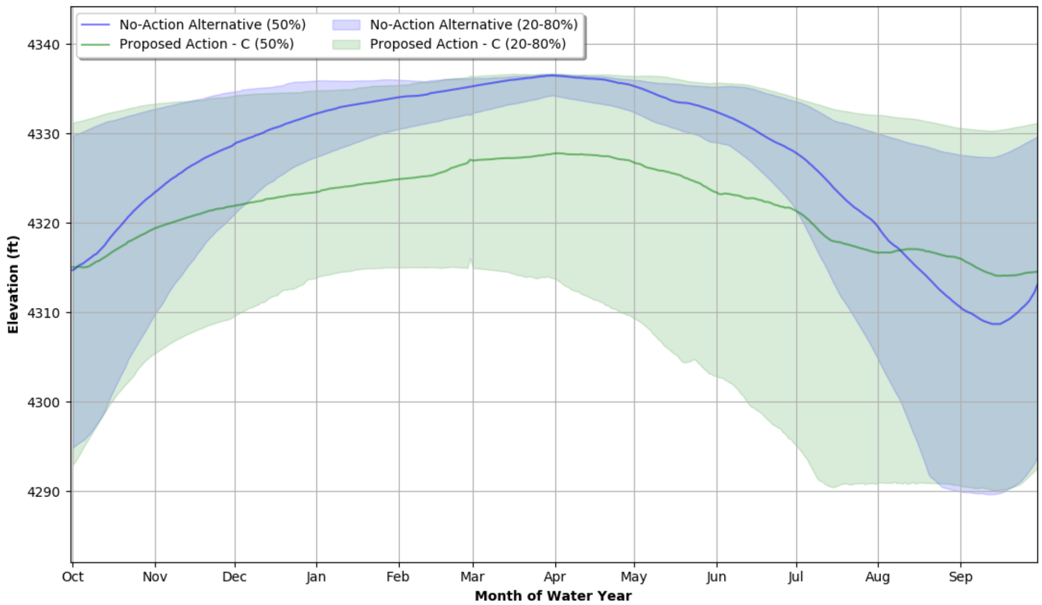


Figure 5. Wickiup Reservoir Water Surface Elevation under Alternative 3 Compared to No-Action Alternative

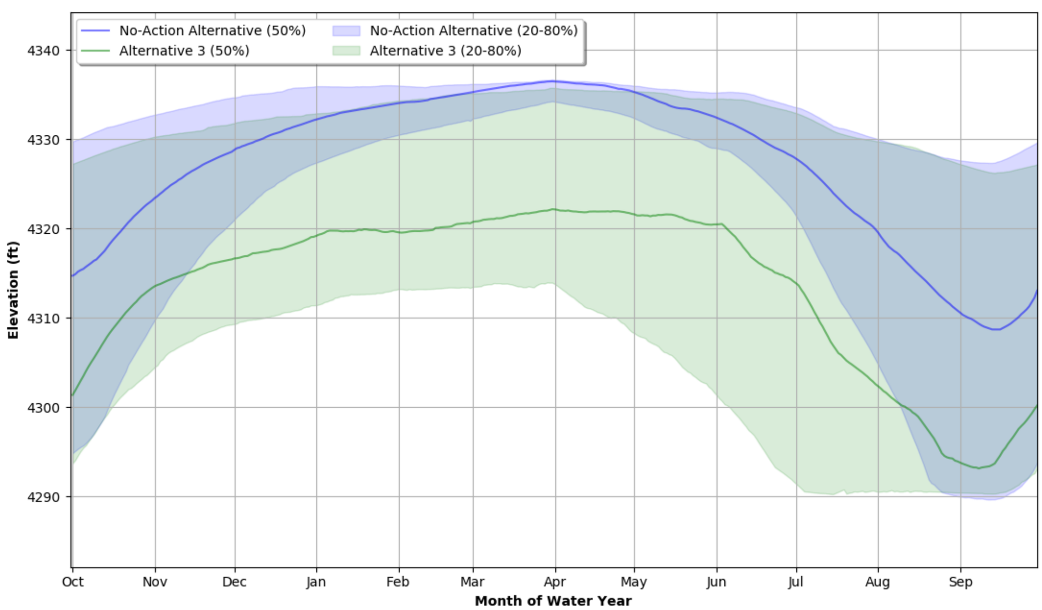
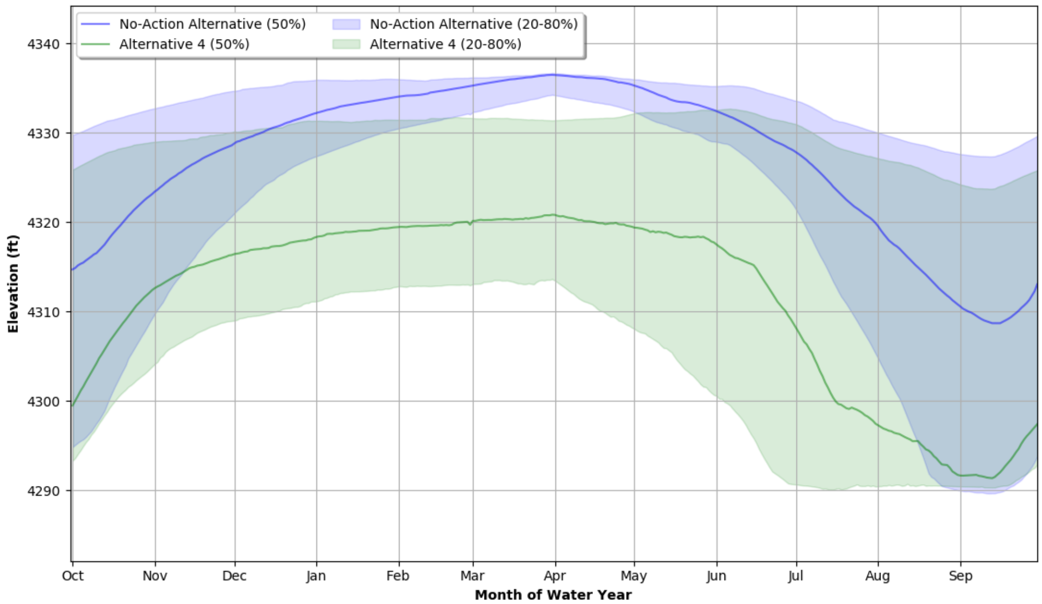


Figure 6. Wickiup Reservoir Water Surface Elevation under Alternative 4 Compared to No-Action Alternative



Crescent Lake Reservoir

Figure 7. Crescent Lake Reservoir Water Surface Elevation under Proposed Action Compared to No-Action Alternative

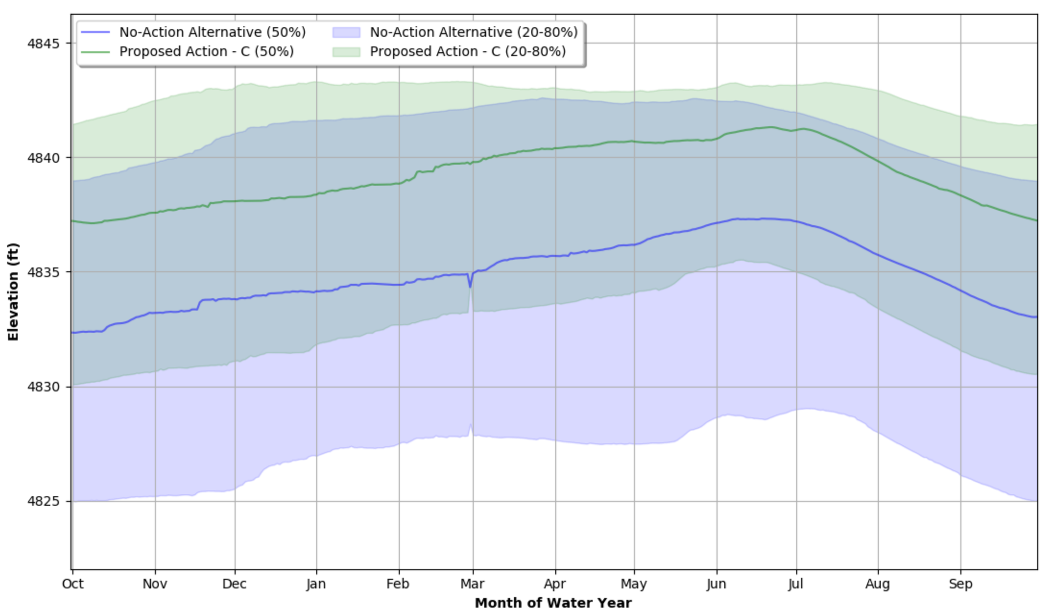


Figure 8. Crescent Lake Reservoir Water Surface Elevation under Alternative 3 Compared to No-Action Alternative

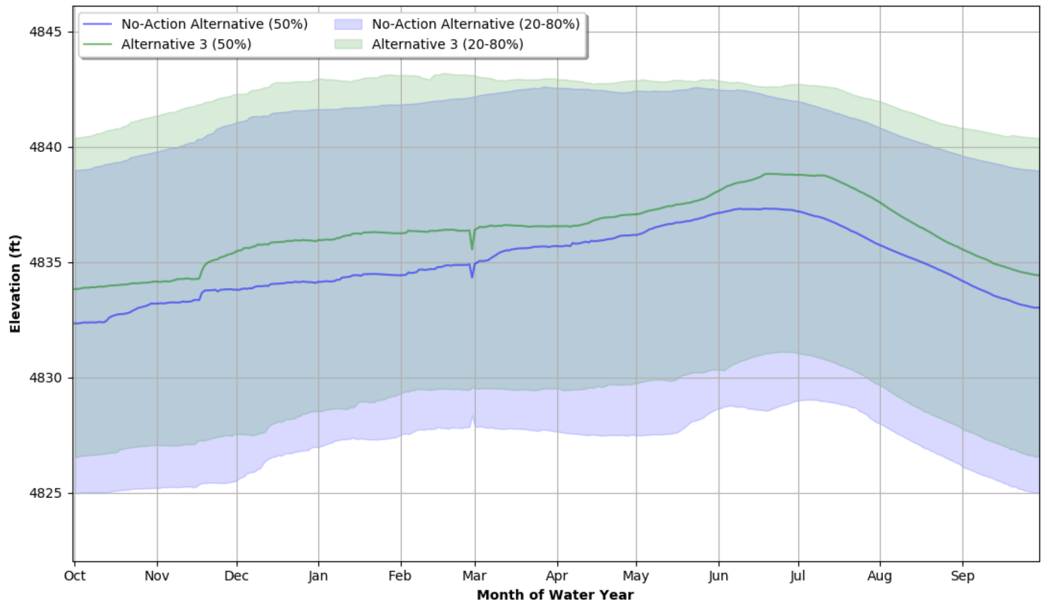
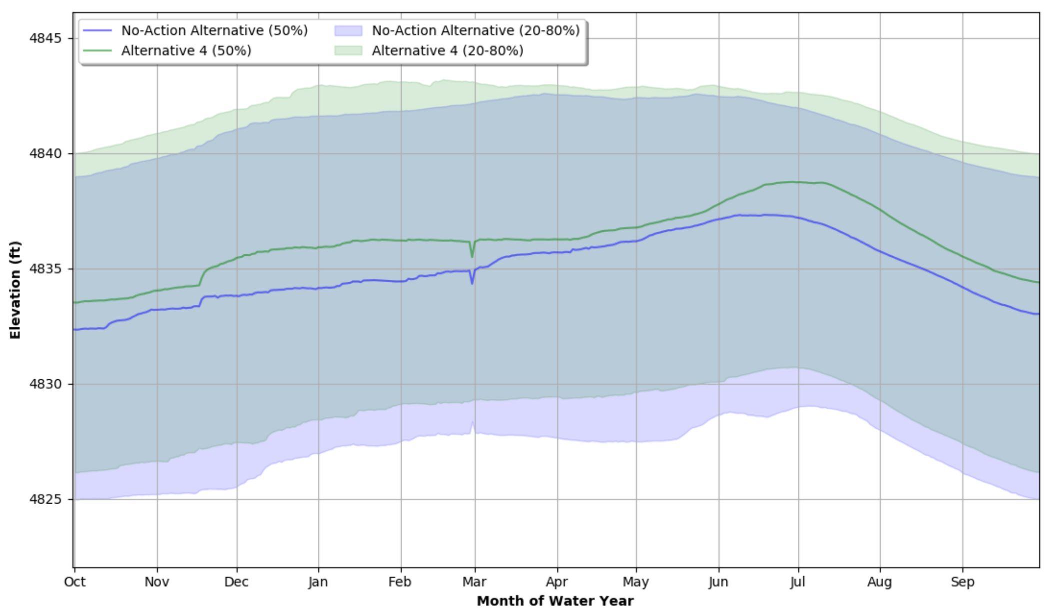


Figure 9. Crescent Lake Reservoir Water Surface Elevation under Alternative 4 Compared to No-Action Alternative



Prineville Reservoir

Figure 10. Prineville Reservoir Water Surface Elevation under Proposed Action Compared to No-Action Alternative

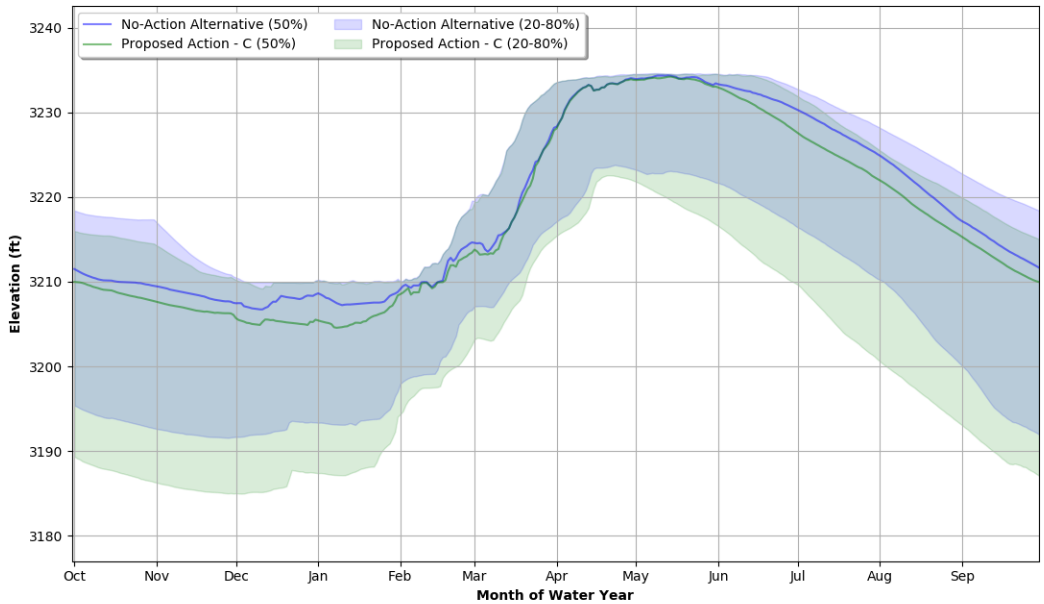


Figure 11. Prineville Reservoir Water Surface Elevation under Alternative 3 Compared to No-Action Alternative

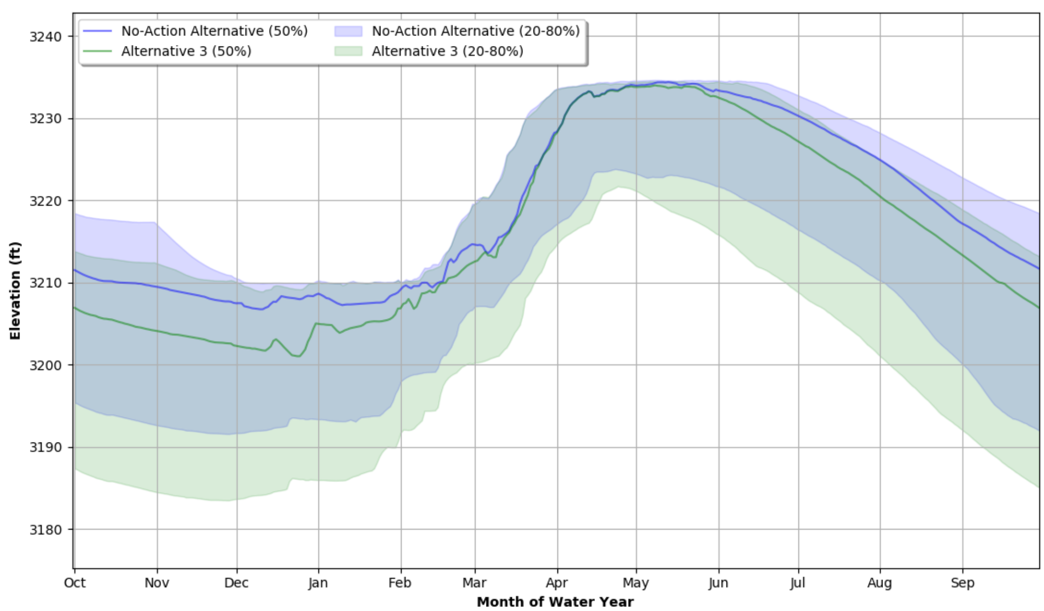
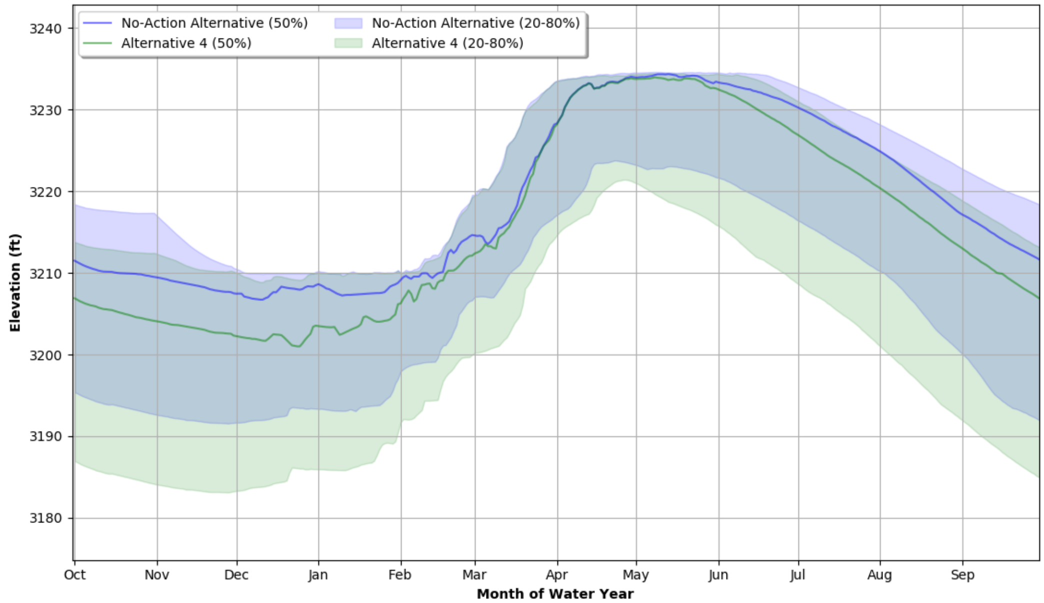


Figure 12. Prineville Reservoir Water Surface Elevation under Alternative 4 Compared to No-Action Alternative



Ochoco Reservoir

Figure 13. Ochoco Reservoir Water Surface Elevation under Proposed Action Compared to No-Action Alternative

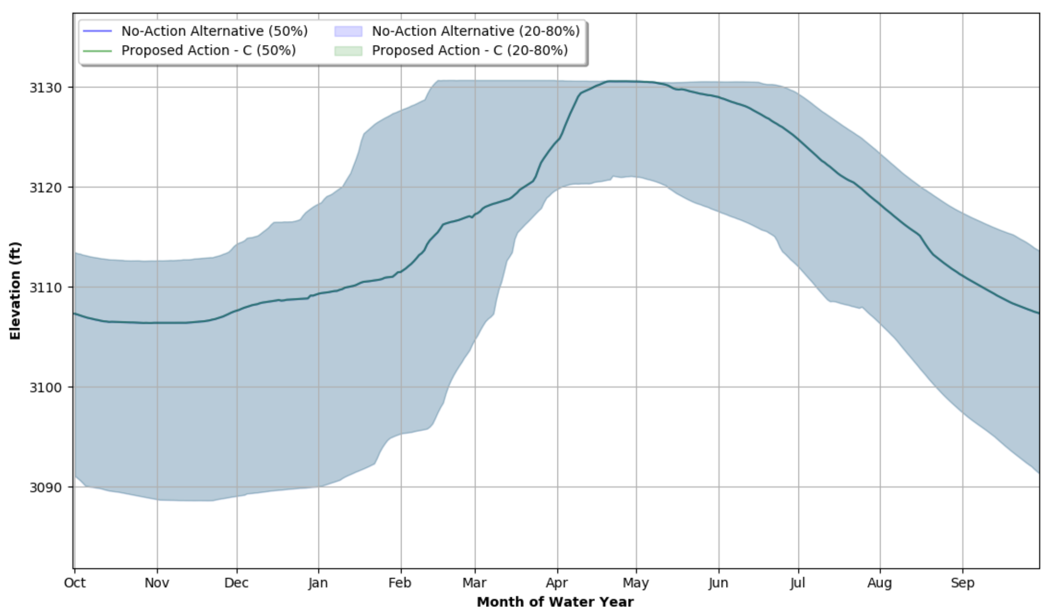


Figure 14. Ochoco Reservoir Water Surface Elevation under Alternative 3 Compared to No-Action Alternative

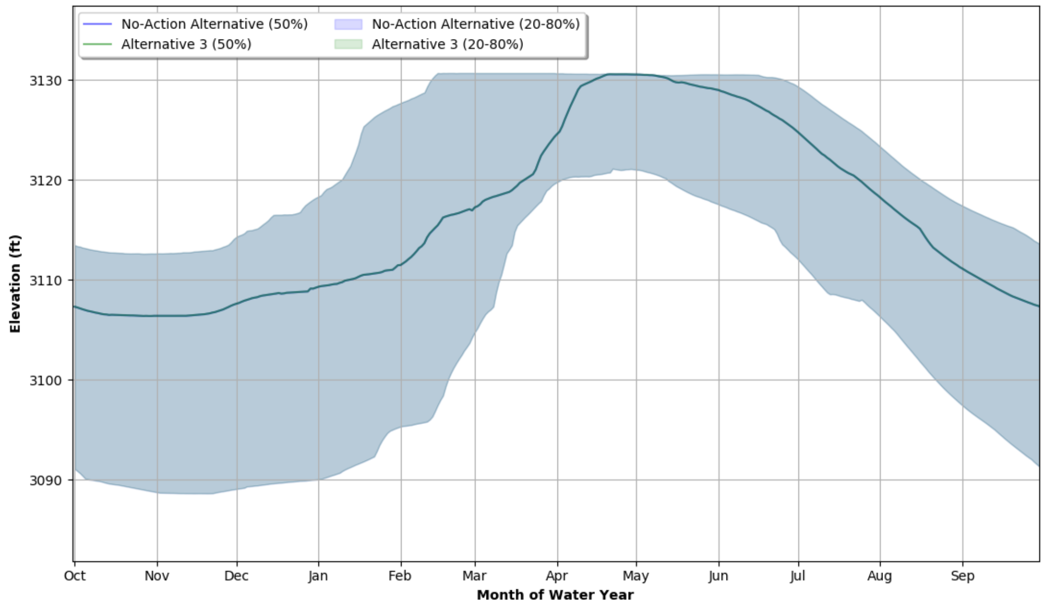
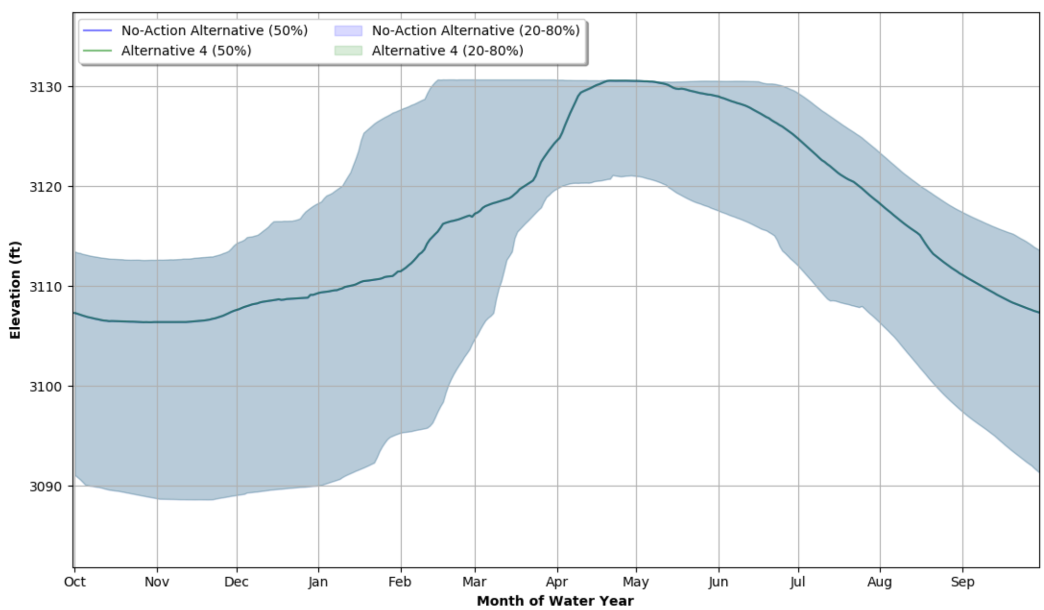


Figure 15. Ochoco Reservoir Water Surface Elevation under Alternative 4 Compared to No-Action Alternative



Literature Review

Existing Data and Background Data

ICF archaeologist Kainoa Little performed a record search on using the Archaeological Inventory Database managed by the Oregon State Historic Preservation Office (SHPO) to identify previously documented archaeological, ethnographic, and historic period resources within a 0.25-mile radius of the Wickiup Reservoir. The database contains all records and reports on file with the Oregon SHPO, including completed cultural resources survey reports, properties listed in or determined eligible for listing in the National Register of Historic Places (NRHP), archaeological sites, cemeteries, and inventoried built environment resources. Other agencies (e.g., U.S. Forest Service) and Tribes retain records that are not available on the Oregon SHPO database, and these likely contain information about archaeological resources. These other data sources were not reviewed for this EIS but should be part of a Section 106 compliance effort. Archaeological resources that were recorded as submerged or partially submerged are specifically considered in this analysis. Additionally, some archaeological sites with poorly defined boundaries may extend into the area that would typically be submerged.

Previous Cultural Resource Studies

A total of 30 cultural resource studies have been conducted within 0.25 mile of the Wickiup Reservoir Affected Environment (Table 1). The studies vary greatly in size and intensity. Several of the studies are large-scale landscape surveys (e.g., Davis 1983; Dudley et al. 1979; Appleby 1984a) while some were very small projects covering a specific activity (e.g., Fowler 1981; Lipscomb 2007; Purdy and Byram 2009). On the north bank, the studies are generally timber sale surveys.

Archaeological resources will be cited for given cultural resources studies within the Wickiup Reservoir Affected Environment if the resource is within approximately 100 meters of the high-water line of the reservoir.

Table 1. Previously Conducted Cultural Resources Surveys within 0.25 Mile of Wickiup Reservoir

Author/Date	Investigation Type/NADB #	Title	Archaeological Resources
Appleby 1984a	Survey Report; #1295814	*West Wickiup, Cultural Resources Report, Deschutes National Forest, Bend Ranger District*	Sites: 35DS288, 35DS291, 35DS292,35DS293, 35DS294, 35DS295, 35DS296, 35DS297 35DS299
Carlson 1984	Survey Report; #1295821	*Wampus, Cultural Resources Report, Deschutes National Forest, Bend Ranger District*	Two possible rockshelters mentioned north and west of Eaton Butte – no site numbers

Author/Date	Investigation Type/NADB #	Title	Archaeological Resources
Cassidy 1994	Survey Report; Biblio #14814	*Cultural Resource Survey Report: Unclaimed Lavas Project, Crescent Ranger District, Deschutes National Forest, USDA, Forest Service*	None
Cressman 1937	Site report	*The Wickiup Dam Site No. 1 Knives*	Wickiup Dam Site No. 1
Davis 1983	Inventory Plan; #1293250	*Deschutes National Forest Cultural Resources Inventory Plan*	None
Dudley et al. 1979	Cultural Resources Overview; #1291758	*Cultural Resources Overview: Deschutes National Forest*	None
Ertle 1986	Survey Report; #1297496	*Browns Mountain Project Cultural Resource Report, Deschutes National Forest, Bend Ranger District*	Site: 35DS421
Fowler 1979	Survey Report; #1294618	*Deschutes National Forest, Bend Ranger District, Environmental Analysis Report for the Proposed Brown's Mountain Salvage Sale*	None
Fowler 1981	Survey Report; # 1291586	*Cultural Resource Report Wickiup Reservoir Powerhouse Project*	None
Fowler 1983a	Survey Report; #1295100	*Twin-Gull Timber Sale, Cultural Resource Report, Deschutes National Forest, Bend Ranger District*	Sites: 35DS227, 35DS228
Hatfield and Stellmacher 1988	Survey Report; Biblio #11530	*Twin Lakes Timber Sale. Cultural Resources Report, Bend Ranger District, Deschutes National Forest*	Site: 35DS619 Isolates: 14-BRD-87, 15-BRD-87, 17-BRD-87
Hickerson 2006	Survey Report; Biblio #23941	*Five Buttes Interface Project*	None
Hickerson 2004a	Survey Report; Biblio #18999	*Davis Fire Recovery Projects*	Sites: 35DS1640, 35DS389
Hickerson 2001	Survey Report; Biblio #23932	*Seven Buttes Return Analysis Area*	None
Hickerson 1997	Survey Report Biblio #23929	*Cultural Resource Survey Report for Eagle Rock and Seven Buttes, Crescent Ranger District, Deschutes National Forest, USDA, Forest Service*	None
Johnson 1982	Survey Report; #1292999	*Dilman-Table L.P. Timber Sales, Cultural Resource Report, Deschutes National Forest, Bend Ranger District*	None
Lipscomb 1989	Survey Report; Biblio #11527	*Caretaker Timber Sale, Cultural Resource Report, Bend Ranger District, Deschutes National Forest*	Site: 35DS586 Isolate: 81-BRD-89

Author/Date	Investigation Type/NADB #	Title	Archaeological Resources
Lipscomb 1990	Survey Report; Biblio #11777	*Dillwick Salvage Sale, Cultural Resource Report, Bend Ranger District, Deschutes National Forest*	None
Lipscomb 1992a	Survey Report; Biblio #13095	*Jingle Salvage Sale, Cultural Resource Inventory Report*	None
Lipscomb 2007	Survey Report; Biblio #21354	*Gull Point Boat Ramps Improvement*	None
Mawhirter 2015	Survey Report; Biblio #28337	*Browns Creek Burned Area Replanting*	None
McFarland and Stellmacher 1988	Survey Report; Biblio #11765	*End Table Timber Sale, Cultural Resource Report, Bend Ranger District, Deschutes National Forest*	None
McFarland 1985a	Survey Report; #1296488	*Cultural Resource Survey Report Short Form for South Twin Campground Hazard Tree Removal*	None
Menefee and Spencer 1992	Survey Report; Biblio #13333	*Mechanical Slash Project, Cultural Resource Inventory Report*	None
Mulligan 1991	Survey Report; Biblio #13276	*1990 Small Sales Project Timber Sale Cultural Resource Inventory Report, Crescent Ranger District, Deschutes National Forest*	None
Purdy and Byram 2009	Survey Report; Biblio #23177	*Archaeological Survey of the Wickiup Dam Hydroelectric*	None
Walker and Lipscomb 1989	Data Recovery Program; #1297078	*Caretaker Timber Sale Cultural Resource Report, Bend Ranger District, Deschutes National Forest*	None

Previously Recorded Archaeological Resources

There have been 21 sites and 9 isolates identified within 0.25 mile of Wickiup Reservoir. Two "possible rockshelters" were identified but not given number designations and do not appear to have been revisited for confirmation (Carlson 1984). The possible rockshelters are located near the southeast bank of Wickiup Reservoir. One, just west of Eaton Butte, is shown on the Oregon SHPO database without accompanying data, while the other, north of Eaton Butte, was not shown on the SHPO database but is noted in Carlson (1984).

Site types within the 0.25-mile search radius include precontact lithic materials, a multicomponent site consisting of a lithic scatter and notched logs that appear to be remnants of a trapper's cabin (Hickerson 2004b), and one isolate (80-BRD-89), which was considered multicomponent with both lithic debitage and a ceramic sherd with floral patterns. Seven of these sites have been formally determined eligible for listing in the NRHP. The remainder of the sites and isolates are yet unevaluated for NRHP eligibility.

Doncaster and Horting-Jones (2013) discuss a substantial camp used by the Civilian Conservation Corps (CCC Camp Wickiup) and later by World War II Conscientious Objectors during construction of the dam and nearby tree clearing. This site is not identified in the Oregon SHPO database and lacks a formal archaeological site Smithsonian Trinomial. The site is submerged, can be seen during low water periods, but has not been formally evaluated for NRHP eligibility.

Notably, the site designated 35DS619 (FS 13-BRD-87) has artifacts that are visible when Wickiup Reservoir is at low pool in the late summer and early fall, then is inundated again when the reservoir fills (Hatfield and Stellmacher 1988). Hatfield and Stellmacher noted that the artifacts within the scatter might vary in visibility or location year to year.

Thirteen archaeological resources appeared on the Oregon SHPO database without accompanying data. Based on their locations, all were identified using the survey reports from the same areas and all but one had SHPO trinomials associated with them.

Table 2. Previously Recorded Archaeological and Historic Resources within 0.25 Mile of Wickiup Reservoir

Citation	Trinomial/ Forest Service Site Number	Site Type	Description	NRHP Eligibility Status
Fowler 1983b	35DS227	Precontact lithic material	Debitage	Unevaluated
Fowler 1983c	35DS228	Precontact lithic material	Debitage	Unevaluated
Appleby 1984b	35DS288	Precontact lithic material	Projectile point fragment, flaked tool, debitage	Unevaluated
Appleby 1984c	35DS291	Precontact lithic material	Projectile point and debitage	Unevaluated
Appleby 1984d	35DS292	Precontact lithic material	Projectile point fragment and debitage	Determined eligible (Lipscomb 1996)
Appleby 1984e	35DS293	Precontact lithic material	Debitage	Unevaluated
Appleby 1984f	35DS294	Precontact lithic material	Projectile point fragment and debitage	Unevaluated
Appleby 1984g	35DS295	Precontact lithic material	Projectile point and debitage	Determined eligible (Mulligan 1991)
Appleby 1984h	35DS296	Precontact lithic material	Debitage	Determined eligible (Lipscomb 1996)
Appleby 1984i	35DS297	Precontact lithic material	Projectile point fragment, flaked tool, debitage	Unevaluated
Appleby 1984j	35DS299	Precontact lithic material	Debitage	Unevaluated
McFarland 1985b	35DS380	Precontact lithic material	Debitage	Unevaluated
McFarland 1985c	35DS389	Precontact lithic material	Debitage	Determined eligible

Citation	Trinomial/ Forest Service Site Number	Site Type	Description	NRHP Eligibility Status
Ertle 1986	35DS420	Precontact lithic material	Debitage	Determined eligible
Ertle 1986	35DS421	Precontact lithic material	Debitage	Determined eligible
Hatfield 1988	35DS619	Precontact lithic material	Debitage	Unevaluated
Lipscomb 1992b	35DS990	Precontact lithic material	Debitage	Unevaluated
Hickerson 1997	35DS1135	Precontact feature	Peeled tree	Unevaluated
Hickerson 2004a	35DS1640	Precontact lithic material and historic-period structure	Debitage, log cabin wall remnants, tin can	Unevaluated
Mawhirter 2014	35DS2946	Precontact lithic material	Debitage	Determined eligible
Hatfield and Stellmacher 1988	13-BRD-87	Precontact lithic material	Debitage	Unevaluated
Doncaster and Horting-Jones 2013	Unknown	CCC Camp	Historic features and artifacts	Unevaluated
Hatfield and Stellmacher 1988	14-BRD-87	Precontact isolate	Debitage	Unevaluated
Hatfield and Stellmacher 1988	15-BRD-87	Precontact isolate	Debitage	Unevaluated
Hatfield and Stellmacher 1988	17-BRD-87	Precontact isolate	Debitage	Unevaluated
McFarland and Stellmacher 1988	51-BRD-88	Historic-period isolate	Can dump, stove pipe, and car body	Unevaluated
Lipscomb 1989	77-BRD-89	Precontact isolate	Debitage	Unevaluated
Lipscomb 1989	80-BRD-89	Precontact and historic-period isolates	Debitage and ceramic fragment	Unevaluated
Lipscomb 1989	81-BRD-89	Precontact isolate	Debitage	Unevaluated
Hickerson 2004b	2141-09P	Precontact isolate	Debitage	Unevaluated
Carlson 1984	N/A	Possible rockshelter	Not confirmed	Unevaluated
Carlson 1984	N/A	Possible rockshelter	Not confirmed	Unevaluated

Bibliography

Appleby, Rex. 1984a. West Wikiup Cultural Resources Report, Deschutes National Forest, Bend Ranger District. Final. NADB #1295814. Bend, OR. Prepared by Deschutes National Forest.

Appleby, Rex. 1984b. Cultural Resource Inventory Record Form—35DS288. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Appleby, Rex. 1984c. Cultural Resource Inventory Record Form—35DS291. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Appleby, Rex. 1984d. Cultural Resource Inventory Record Form—35DS292. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Appleby, Rex. 1984e. Cultural Resource Inventory Record Form—35DS293. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Appleby, Rex. 1984f. Cultural Resource Inventory Record Form—35DS294. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Appleby, Rex. 1984g. Cultural Resource Inventory Record Form—35DS295. Final. Bend, OR. Prepared by Deschutes National Forest.

Appleby, Rex. 1984h. Cultural Resource Inventory Record Form—35DS296. Final. Bend, OR. Prepared by Deschutes National Forest.

Appleby, Rex. 1984i. Cultural Resource Inventory Record Form—35DS297. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Appleby, Rex. 1984j. Cultural Resource Inventory Record Form—35DS299. Final. Bend, OR. Prepared by Deschutes National Forest.

Carlson, Richard. 1984. Wampus Cultural Resource Report, Deschutes National Forest, Bend Ranger District. Final. NADB #1295821. Bend, OR. Prepared by Deschutes National Forest.

Cassidy, Elizabeth J. 1994. *Unclaimed Lavas Project Cultural Resource Survey Report, Crescent Ranger District, Deschutes National Forest, USDA, Forest Service*. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Cressman, Luther S. 1937. The Wikiup Damsite No. I Knives 55. *American Antiquity* 3.1 (1937): 53–67.

Davis, Carl M. 1983. Deschutes National Forest Cultural Resource Inventory Plan. Final. NADB #1293250. Bend, OR. Prepared by Deschutes National Forest.

Doncaster, Kelsey and Chris Horting-Jones. 2013. Sagebrush to Clover: the U.S. Bureau of Reclamation's North Unit of the Deschutes Project. *North Unit Irrigation District Deschutes and Jefferson Counties, Oregon. Volume 1.* November.

Dudley, James, Rick Bryant, and David Eisler. 1979. Cultural *Resources Overview: Deschutes National Forest, Oregon, Vol. II*. Final. NADB #1291758. Eugene, OR. Prepared by Professional Analysts.

Ertle, Lynne. 1986. *Browns Mountain Project Cultural Resource Report, Deschutes National Forest, Bend Ranger District*. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Fowler, Ed. 1979. *Deschutes National Forest, Bend Ranger District, Environmental Analysis Report for the Proposed Brown's Mountain Salvage Sale*. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Fowler, Ed. 1983a. *Twin-Gull Timber Sale Cultural Resource Report, Deschutes National Forest, Bend Ranger District*. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Fowler, Ed. 1983b. Cultural Resource Inventory Record Form—35DS227. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Fowler, Ed. 1983c. Cultural Resource Inventory Record Form—35DS228. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Fowler, Ed. 1981. *Wickiup Reservoir Powerhouse Project Cultural Resource Report*. Final. NADB #1291586. Bend, OR. Prepared by the National Forest Service.

Hatfield, David. 1988. Cultural Resource Inventory Record Form—35DS619. Final. Bend, OR. Prepared by the National Forest Service.

Hatfield, David and Adam C. Stellmacher. 1988. *Twin lakes Timber Sale Cultural Resources Report, Bend Ranger District, Deschutes National Forest*. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Hickerson, Leslie M. 1997. *Eagle Rock and Seven Buttes Cultural Resource Survey Report, Crescent Ranger District, Deschutes National Forest, USDA, Forest Service*. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Hickerson, Leslie M. 2001. *Seven Buttes Return Analysis Area, Crescent Ranger District, Deschutes National Forest*. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Hickerson, Leslie M. 2004a. Cultural Resource Site Inventory—35DS1640. Final. Prepared by the National Forest Service.

Hickerson, Leslie M. 2004b. *Davis Fire Recovery Projects, Crescent Ranger District, Deschutes National Forest*. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Hickerson, Leslie M. 2006. *Five Buttes Interface Project, Crescent Ranger District, Deschutes National Forest*. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Johnson, Dwight D. 1982. *Dilman-Table L.P. Timber Sales Cultural Resources Report, Deschutes National Forest, Bend Ranger District*. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Lipscomb, Christine. 1989. *Caretaker Timber Sale, Cultural Resource Report, Bend Ranger District, Deschutes National Forest.* On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Lipscomb, Christine. 1990. *Dillwick Salvage Sale, Cultural Resource Report, Bend Ranger District, Deschutes National Forest*. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Lipscomb, Christine. 1992a. *Jingle Salvage Sale Cultural Resource Inventory Report, Bend Ranger District, Deschutes National Forest, USDA Forest Service*. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Lipscomb, Christine. 1992b. Cultural Resource Site Report—35DS990. Final. Bend, OR. Prepared by the National Forest Service.

Lipscomb, Christine. 1996. *Letter of Eligibility Determinations for Site 35DS292 and 35DS296 from Christine Lipscomb, Archaeologist, USDA Forest Service To Rex Appleby. Archaeologist, USDA Forest Service.*

Lipscomb, Christine. 2007. *Gull Point Boat Ramps Improvement*. Final. Report #11527. Bend, OR. Prepared by the National Forest Service.

Mawhirter, Matthew. 2014. Cultural Resource Site Report—35DS2946. Final. Bend, OR. Prepared by the National Forest Service.

Mawhirter, Matthew. 2015. *Browns Creek Burned Area Replanting Cultural Resource Survey*. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

McFarland, Janine R. 1985a. *South Twin Campground Hazard Tree Removal Cultural Resource Survey Short Form, Deschutes National Forest*. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

McFarland, Janine R. 1985b. Cultural Resource Site Report—35DS380. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

McFarland, Janine R. 1985c. Cultural Resource Site Report—35DS389. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

McFarland, Janine R. and Adam Stellmacher. 1988. *End Table Timber Sale Cultural Resource Report, Bend Ranger District, Deschutes National Forest*. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Menefee, Christine and Eileen Spencer. 1992. *Mechanical Slash Project, Cultural Resource Inventory Report, Bend Ranger District, Deschutes National Forest, USDA, Forest Service*. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Mulligan, Daniel M. 1991. 1990 *Small Sales Project Timber Sale Cultural Resource Inventory Report, Crescent Ranger District, Deschutes National Forest, USDA, Forest Service*. On file at the Oregon State Historic Preservation Office in Salem, Oregon.

Purdy, Sarah, and Scott Byram. 2009. *Archaeological Survey of the Wickiup Dam Hydroelectric Project Area near La Pine, Oregon.* FERC Project 12965.

Walker, Jeff, and Christine Lipscomb. 1989. *Caretaker Timber Sale Cultural Resources Report, Bend Ranger District, Deschutes National Forest*. Final. Report #11527. Bend, OR. Prepared by the National Forest Service.