Appendix A

Comments and Responses

To be included in the final Watershed Plan-Environmental Assessment.

Appendix B

Project Maps

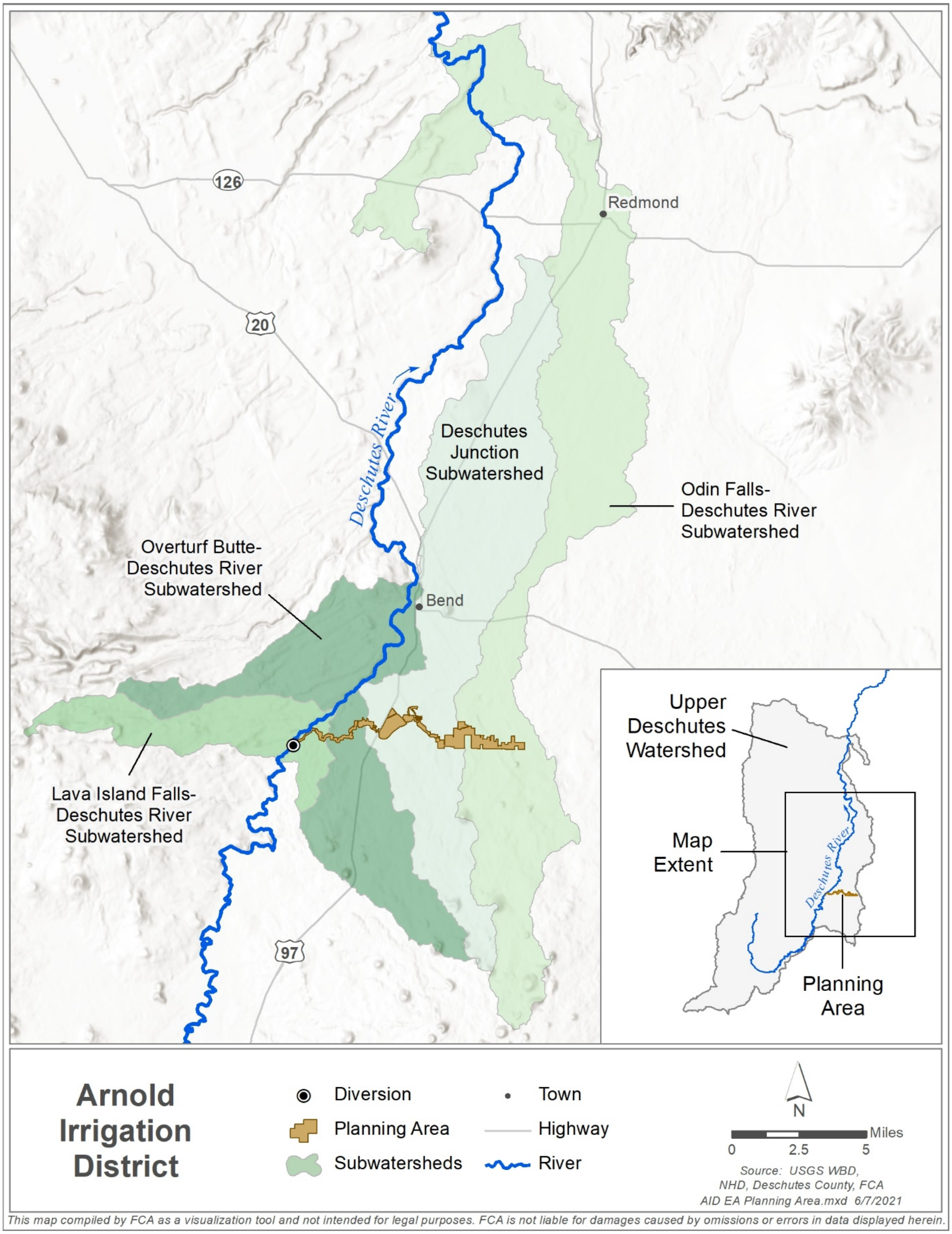


Figure B-1. The Arnold Irrigation District planning area.

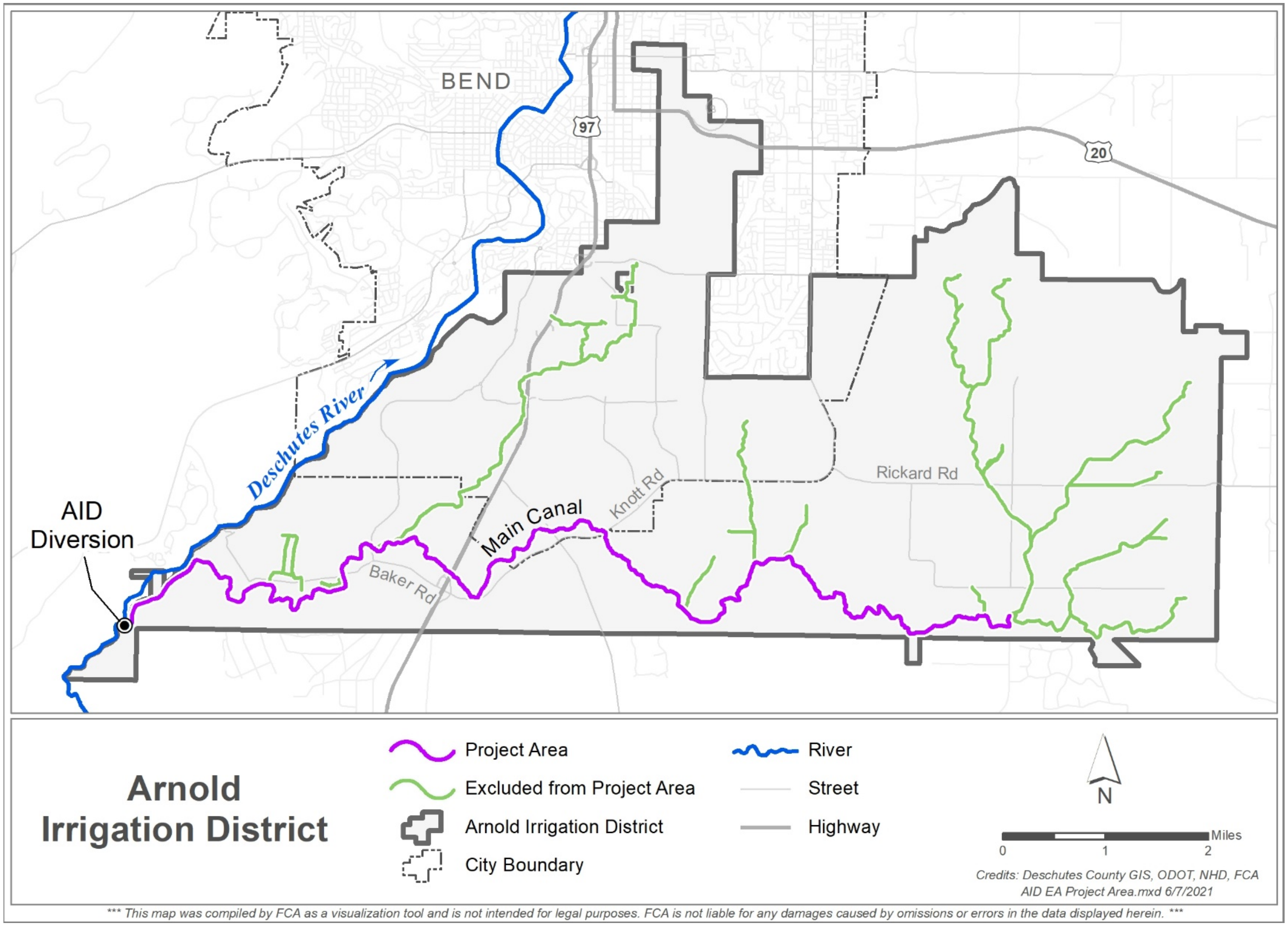


Figure B-2. Arnold Irrigation District Infrastructure Modernization Project area.

Appendix C

Supporting Maps

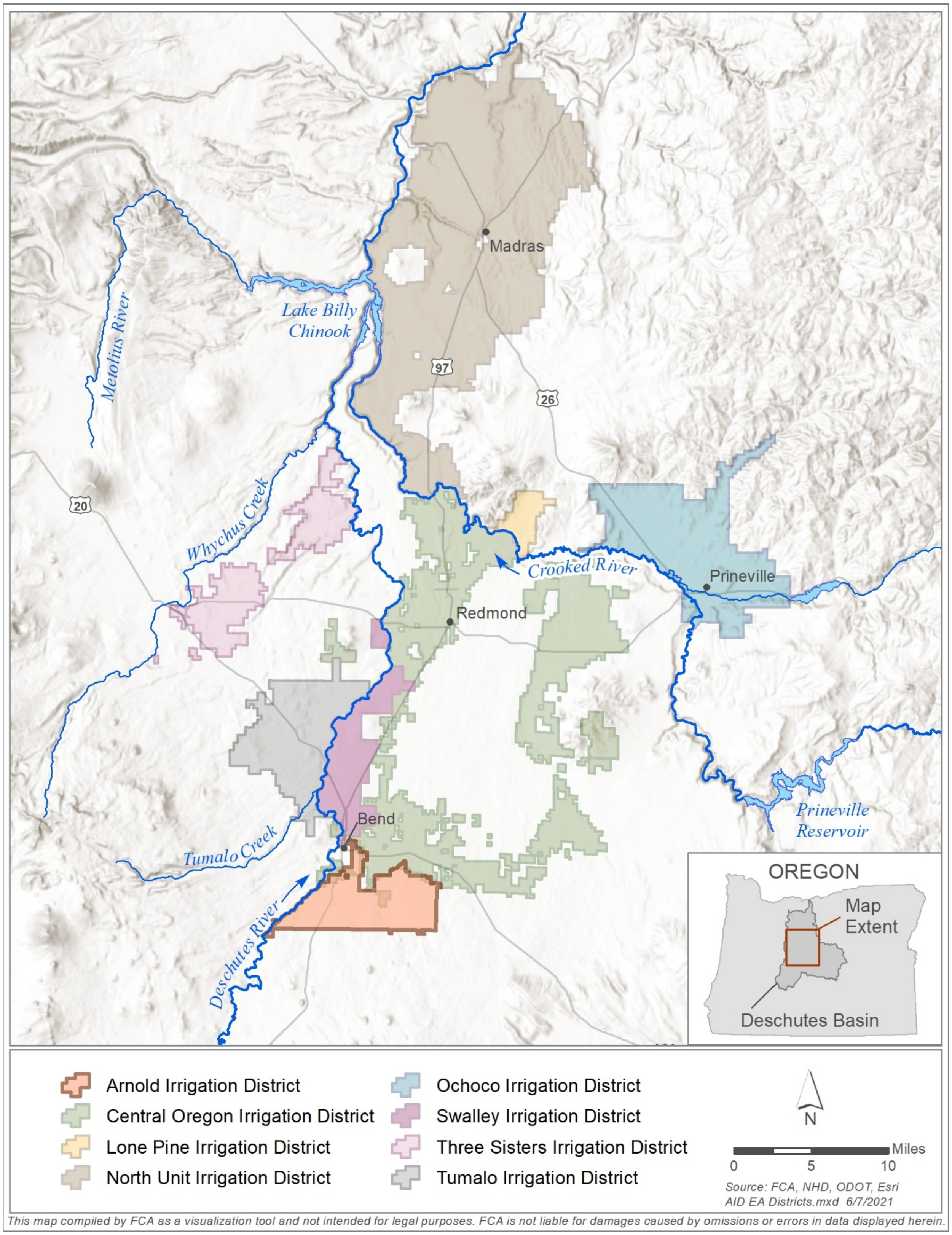
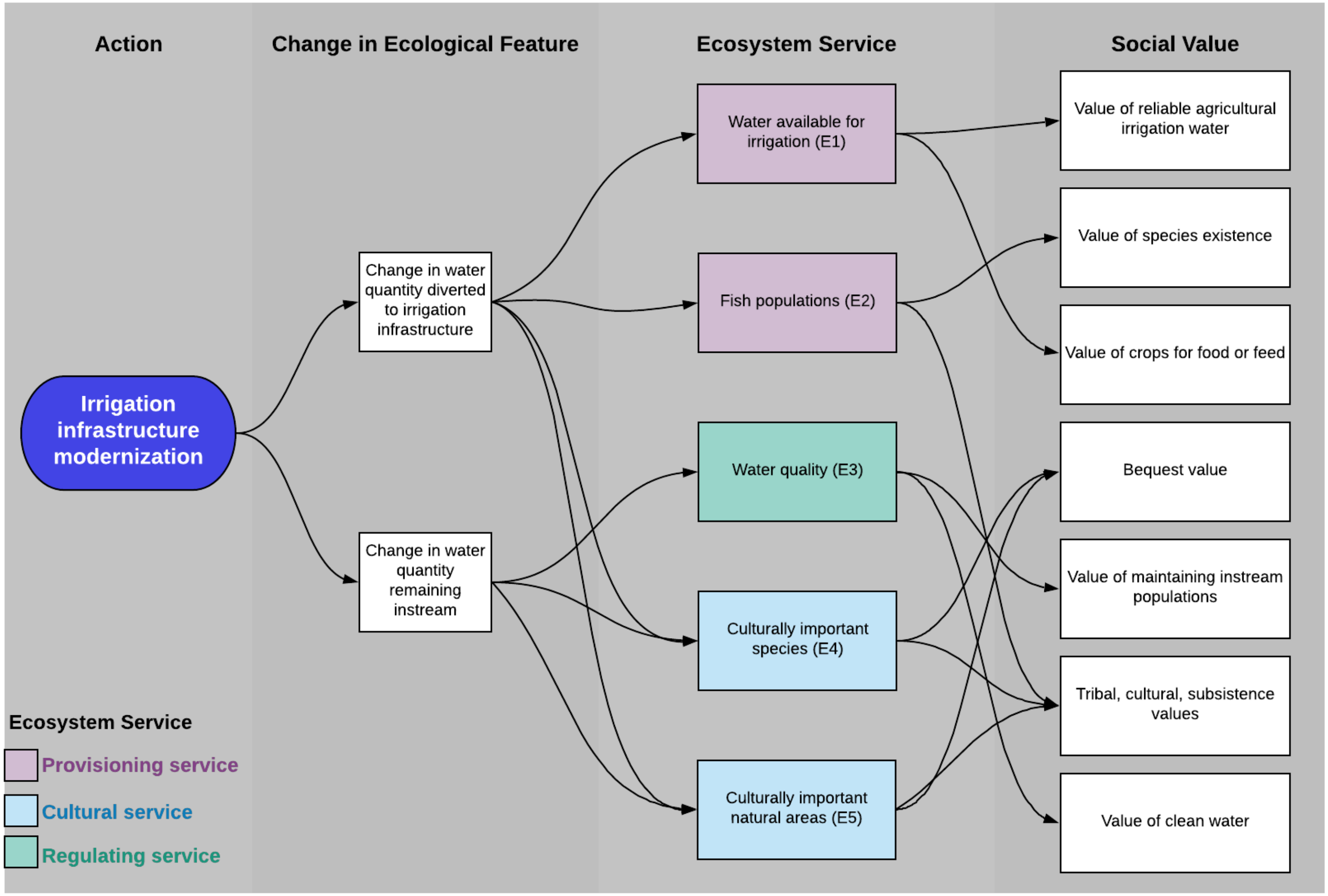


Figure C-1. Irrigation districts within the Deschutes Basin.



Note: E1 to E5 refer to ecosystem services 1 to 5. These services are referenced and explained in more detail throughout Section 4 and 6 of the Plan-EA.

Figure C-2. Arnold Irrigation District Infrastructure Modernization Project ecosystem services concept diagram.

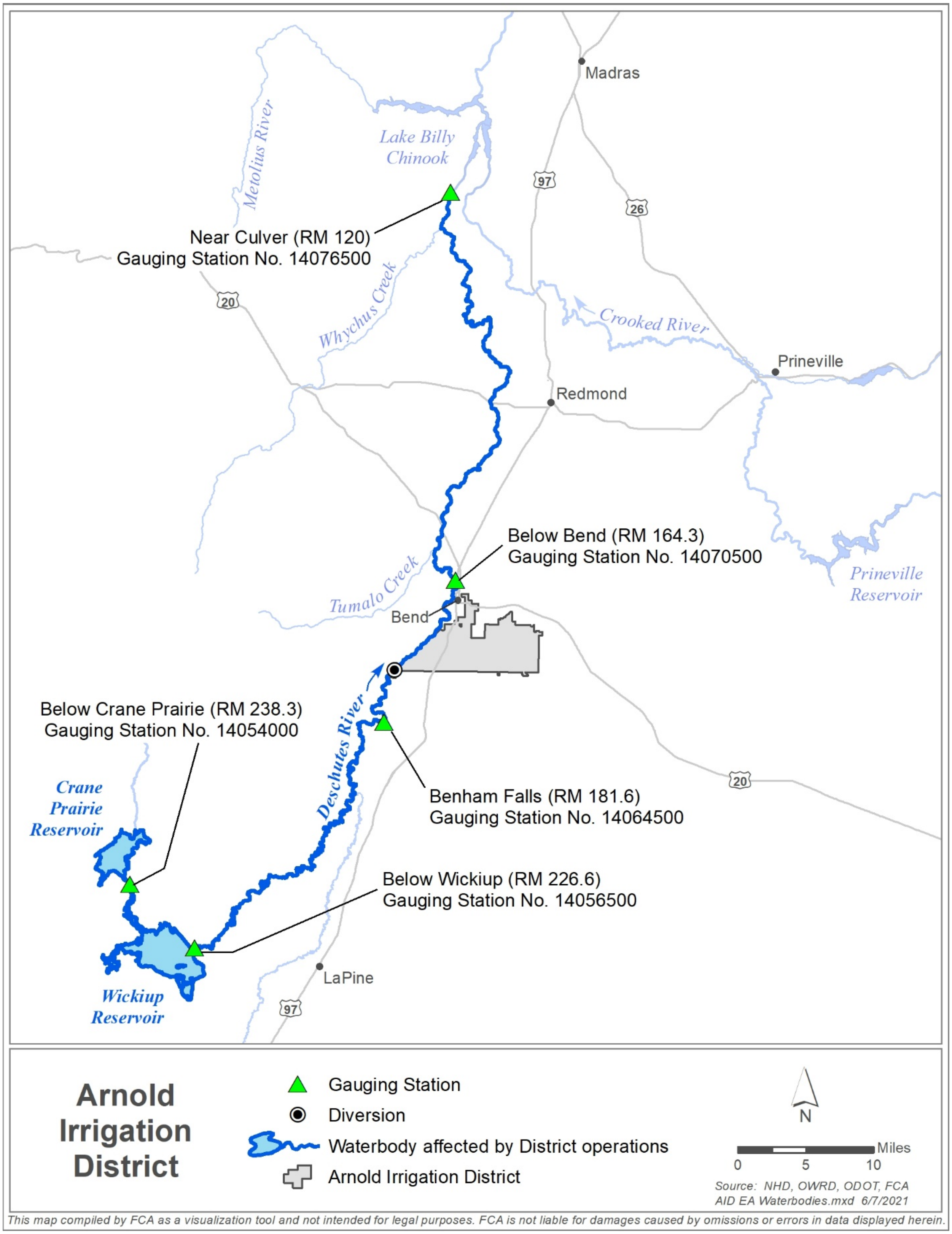


Figure C-3. Waterbodies and gauging stations associated with District operations.

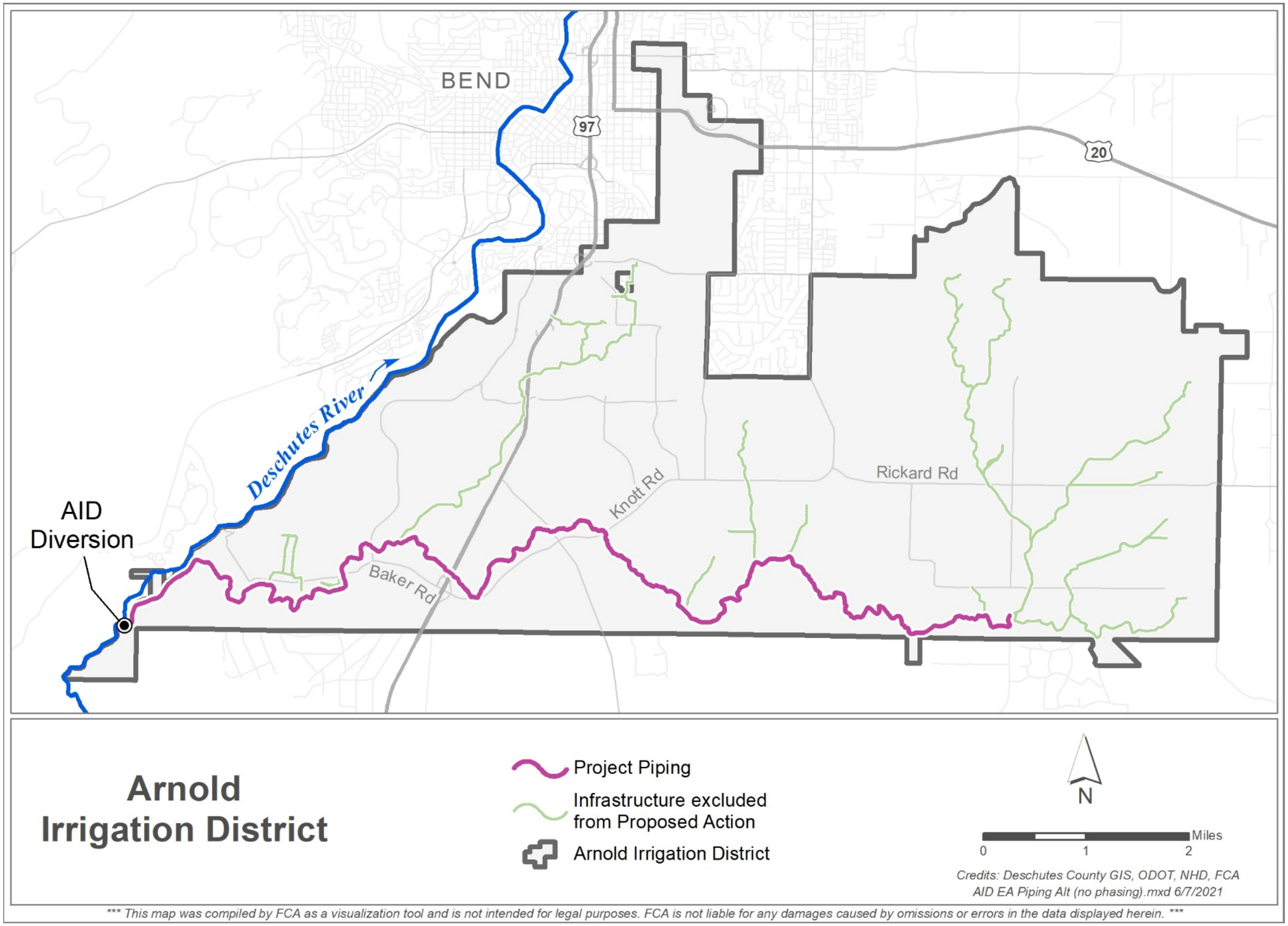


Figure C-4. Overview of the Piping Alternative for the Arnold Irrigation District Infrastructure Modernization Project.

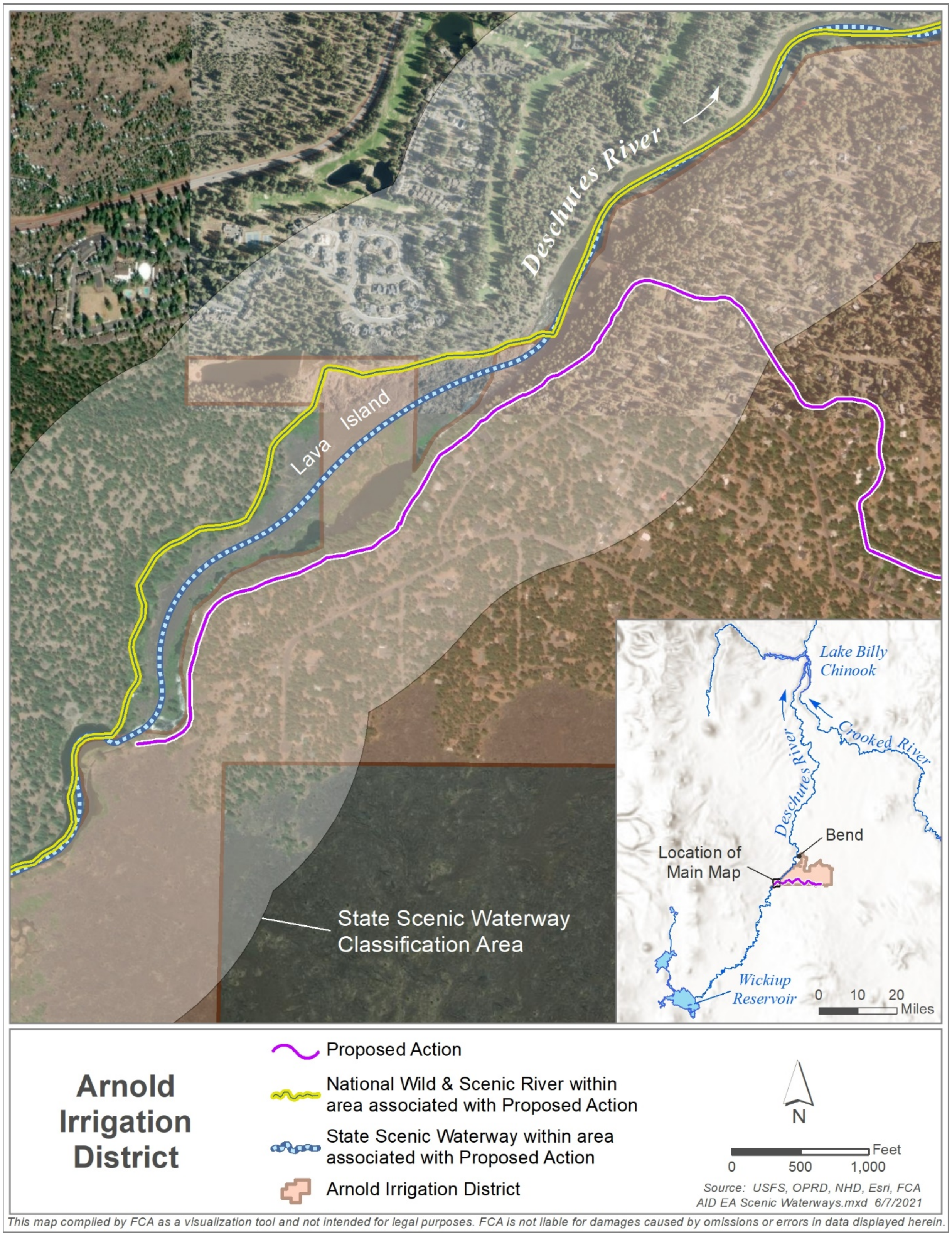


Figure C-5. Project area within State Scenic Waterway and National Wild and Scenic River boundaries.

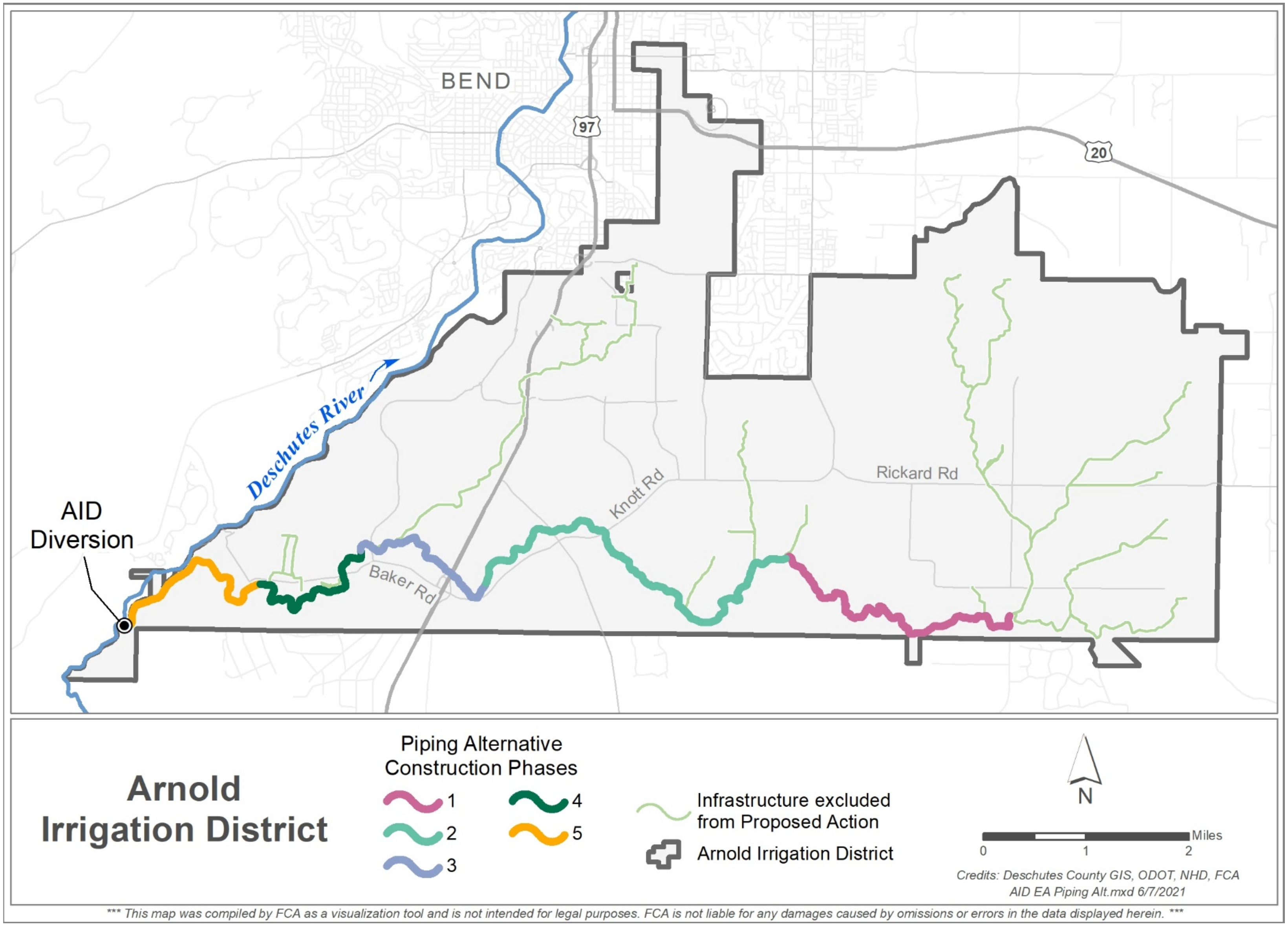


Figure C-6. Preferred Alternative construction phase map.

Appendix D

Investigation and Analysis Report

Highland Economics LLC

National Economic Efficiency Analysis

Barbara Wyse and Winston Oakley
2/8/2021

D.1 National Economic Efficiency Analysis

1.1 Piping Alternative

This section provides a National Economic Efficiency (NEE) analysis that evaluates the costs and benefits of the Piping Alternative compared to the No Action Alternative for the Arnold Irrigation District (AID) Infrastructure Modernization Project (herein referred to as the project). The analysis uses Natural Resources Conservation Service (NRCS) guidelines for evaluating NEE benefits as outlined in the NRCS Natural Resources Economics Handbook and the U.S. Department of Agriculture's (USDA) *Guidance for Conducting Analyses Under the Principles, Requirements, and Guidelines for Water and Land Related Resources Implementation Studies and Federal Water Resource Investments* (DM 9500-013; USDA 2017; herein referred to as PR&G).

All economic benefits and costs are provided in 2020 dollars and have been discounted and amortized to average annualized values using the fiscal year 2021 federal water resources planning rate of 2.5 percent.

1.1.1 Costs of the Piping Alternative

This section evaluates the costs of the Piping Alternative compared to the No Action Alternative. Under the No Action Alternative, the District would continue to operate and maintain the existing canal and lateral system in its current condition. As described below in Section 1.1.3, under the No Action Alternative the flume would likely be entirely replaced at some point over the next 15 to 20 years. As such, the cost of the Piping Alternative that exceeds the cost of the No Action Alternative (i.e., the NEE cost) is significantly less than the cost of the Piping Alternative without taking into consideration the No Action Alternative.

1.1.1.1 Analysis Parameters

This section describes the general parameters of the analysis, including funding sources and interest rates, the evaluation unit, the project implementation timeline, the period of analysis, and the project purpose. All values in this analysis are presented in 2020 dollars and rounded to the nearest $1,000.

Funding

Watershed Protection and Flood Prevention Program (Public Law [PL] 83-566) funds would cover $27,862,000 or 65 percent of the project cost. AID would be required to fund $14,897,000 or 35 percent of the project.

Evaluation Unit

The proposed project is a single project group, which is the evaluation unit. The one project group consists of piping the 13.2 miles of District-owned Main Canal (including the flume), which serves the entire District, and therefore represents a reasonable evaluation unit. In order to effectively address Watershed Problems and Resource Concerns and realize Watershed and Resource Opportunities, the purpose and need concluded that piping of the entire Main Canal, including the flume, is necessary. For the purpose of an incremental analysis (detailed in Section 1.1.4), the project group is divided into five phases of construction. Note that for the incremental analysis, costs for constructing any given project group would not change if it were the only project group to be constructed.

Project Implementation Timeline

District staff indicate that if PL 83-566 funds are made available, construction would likely be completed over approximately 7 years (see Table 8-2 in the Watershed Plan-Environmental Assessment [Plan-EA]). The project would be completed in 5 phases based on the amount of construction that could be completed during the non-irrigation season. For each phase, the analysis assumes that full benefits would be realized the year after construction is completed (e.g., for Phase 1, which would complete construction in Year 1, full benefits would be realized in Year 2).

Analysis Period

The analysis period is defined as 107 years since the installation period is 7 years and 100 years is the expected project life of buried high-density polyethylene (HDPE) pipe (Year 0 to Year 107). Construction and installation of Phase 1 is assumed to start in Year 0 and finish in Year 1, with project life from Year 2 through Year 101, and Phase 2 would have a project life from Year 4 through Year 103.

1.1.1.2 Proposed Project Costs

Table 8-3 (NWPM 506.11, Economic Table 1) and Table 8-4 (NWPM 506.12, Economic Table 2) in Section 8 of the Plan-EA summarize installation costs and distribution of costs for the Piping Alternative. Table 8-5 in the Plan-EA summarizes the annualized costs over the No Action Alternative, which are estimated at $992,000 including $987,000 in amortized installation costs and $5,000 in other annualized direct costs. Table D-2 and Table D-4 present other direct costs associated with piping (groundwater pumping and carbon costs, respectively). The subsections provide details on the derivation of the costs.

Average annual costs include those associated with installation and other direct costs. There are three primary types of other direct costs: increased pumping costs from potential increased depth to groundwater due to reduced recharge from canals, increased social cost of carbon (SCC) from increased carbon emissions, and potential reduction in aesthetic values to area residents due to the removal of canals. Of these, only the aesthetic costs are not quantified in this analysis due to a lack of available quantitative information. As AID expects cost savings, not cost increases, for infrastructure maintenance, repair, and replacement of the Piping Alternative, these are included as benefits in this analysis (Willis, 2020).

1.1.1.3 Project Installation Costs

The cost of piping and associated turnouts is projected to be approximately $38,923,000 (Farmers Conservation Alliance, 2020). See Appendix D.3.2 for detailed cost derivation by pipe size and cost category. Adding 3 percent for project administration from AID and NRCS, 8 percent for technical assistance from NRCS (applied just on the construction/engineering costs funded by NRCS), and 3 percent for permitting costs, the total cost for the Piping Alternative is estimated at $42,759,000. The average annual installation cost of the Piping Alternative is $1,083,000.

The installation costs under the Piping Alternative include the cost of piping the flume, a roughly 1-mile open structure that carries water from the Deschutes River to the Arnold Main Canal. The flume is an essential connection because it transports water for the entire District. The current flume is 73 years old and will require replacement within the next 20 years[1] under the No Action Alternative (Willis, 2020). In this analysis, the District would replace the flume between Years 15 and 20, which provides a conservative estimate of the NEE net benefits.[2] Under the No Action Alternative, once the District decides to replace the flume it would

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1 The determination that the flume would need to be replaced within the next 20 years was based on the flume's age and condition. The original flume was built in 1905 and lasted 42 years. The current flume was built in 1947 and is 73 years old. An engineering analysis in 1995 also identified many significant challenges with the current flume including water leakage, fire danger, rockslides, and difficultly in acquiring replacement parts (Steele, 1995).

2 This provides a conservative estimate of the NEE net benefits because the assumption may result in an overestimate of the NEE costs since the District may pipe the flume sooner than Year 20. Piping the flume earlier would result in higher present value costs under the No Action Alternative, which would further lower the NEE costs (as the costs under the No Action Alternative are subtracted from the costs under the Piping Alternative) and increase the NEE net benefits.

choose to pipe it rather than replace it with an identical structure as piping is estimated to be cheaper than replacement (Willis, 2020).

The costs of piping the flume under the No Action Alternative would likely be higher than under the Piping Alternative for two reasons. First, piping the flume under the No Action Alternative would require an energy dissipater because pressure would need to be dissipated at the end of the pipe where it transitions to an open canal. Second, the cost of engineering, general contractor construction management (GCCM) and contingency are expected to be higher under the No Action Alternative. This is because the District would have to hire a private engineer to design the piping, and this engineer would likely have higher associated costs than NRCS, who would be responsible under the Piping Alternative. Contingency and GCCM could be higher under the No Action Alternative because piping the flume under the No Action Alternative would occur further in the future than the Piping Alternative and therefore have greater cost uncertainty. Accordingly, construction costs are increased under the No Action Alternative.[3]

In total, piping the flume is estimated to cost $4,958,000 under the Piping Alternative and $5,265,000 under the No Action Alternative (Farmers Conservation Alliance, 2020). The annualized cost of piping the flume under the Piping Alternative are included in the total annualized project installation costs ($1,083,000). The NEE costs are the annualized costs of the Piping Alternative *above* the costs of the No Action Alternative. Therefore, the annualized cost of piping the flume under the No Action Alternative ($93,000)[4] are subtracted from the annualized installation costs under the Piping Alternative. This results in NEE annualized installation costs of $987,000, which is shown in Table 8-5 of the Plan-EA.

1.1.1.4 Other Direct Costs

Groundwater Recharge Costs

Water seepage from canals is one source of recharge for groundwater in the Deschutes Basin. Reduced recharge from canals may lead to small groundwater declines, and thereby increase pumping costs for all groundwater users in the basin. As such, it is possible that the Piping Alternative may result in a slight increase in pumping costs for groundwater users. The magnitude of this effect is evaluated based on data from a 2013 study by the U.S. Geological Survey (USGS) that estimated the effects on groundwater recharge of changes in climate (reduced precipitation), groundwater pumping, and canal lining and piping. The study focused on the Deschutes River Basin and used data from the period 1997 to 2008 (Gannett & Lite, 2013). An important caveat to using the data and findings from this study is that the effects of piping AID canals may be different than previous canal lining and piping projects that have occurred throughout the basin.

The study indicated that since the mid-1990s, groundwater levels have dropped by approximately 5 to 14 feet in the central part of the Deschutes Basin that extends north from near Benham Falls to Lower Bridge, and east from Sisters to the community of Powell Butte. It also found that approximately 10 percent of this decline in groundwater level is due to canal lining during this period, or approximately 0.5 to 1.4 foot. This was modeled as the result of reducing the recharge from irrigation canal leakage by 58,000 acre-feet (AF) annually. This NEE analysis uses this data to first estimate the approximate effect of reduced irrigation canal seepage on groundwater levels from the Piping Alternative, and then uses these data to roughly approximate the change in the cost of pumping for all groundwater users in the Deschutes Basin due to the Piping

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3 As a proportion of installation costs, engineering is assumed to be 3 percent under the Piping Alternative but is assumed to be 6 percent under the No Action Alternative. The amount of GCCM increases from 5 percent of installation costs under the Piping Alternative to 12 percent under the No Action Alternative. Contingency costs are estimated to rise from 10 percent of installation costs under the Piping Alternative to 30 percent under the No Action Alternative.

4 Using the 2.5 percent discount rate and 100-year project life, and assuming the replacement of the flume under No Action has an equal probability of occurring any time between Year 15 and 20.

Alternative. While this analysis uses generous assumptions on the potential groundwater effect, as described below, the analysis concludes that the effect on groundwater over the long-term is minor.

The cumulative effect of piping over the 12-year study period (1997 to 2008) was 58,000 AF. Assuming a uniform increase in canal lining/piping over this timeframe, in 1997 the decreased canal seepage was 4,833 AF annually, rising each year by another 4,833 AF annually until the reduced canal seepage in 2008 was 58,000 AF annually. Cumulatively, this represents 377,000 AF of reduced recharge from canals during this period. The USGS study found that this level of reduced recharge caused an overall groundwater decline in the central basin of 0.5 to 1.4 foot. These data suggest that the average relationship between canal recharge and groundwater levels in this part of the basin is approximately 1 foot of groundwater elevation drop per 377,000 AF of reduced canal recharge, though local effects may vary widely.

The Piping Alternative would reduce canal seepage and associated groundwater recharge by up to approximately 10,526 AF annually in this part of the Deschutes Basin once the project is complete (see Appendix E.4 for detailed derivation of reduced canal seepage). On average, for this part of the central basin, this would translate into a decreased groundwater elevation of approximately 0.028 foot annually (based on information presented above that a 1-foot groundwater elevation drop is expected to result from reduced recharge of 377,000 AF, so the corresponding drop from 10,526 AF is 0.028 foot since 10,526 AF divided by 377,000 AF is 0.028). Due to the 7-year construction period (and subsequent phasing of groundwater impacts) over the course of approximately 107 years (the life of the project plus the construction period), this annual drop represents a cumulative decreased average groundwater elevation in the central basin of approximately 2.6 feet. Such a drop in pumping elevation would have small effects on pumping costs but would not be expected to result in the need to drill deeper wells or replace pumps at a faster rate. An important caveat is that localized effects of the Piping Alternative on groundwater would differ throughout the central basin.

This analysis combines the decreased groundwater elevation for each year in the 107-year analysis period with the estimated volume of groundwater pumping in the central Deschutes Basin to estimate the total increased cost of groundwater pumping in the basin over time. The USGS report identified approximately 25,000 AF per year of groundwater pumping for public supply and about 25,000 AF per year of groundwater pumping for irrigation use. A 2017 study by GSI Water Solutions, Inc. on future groundwater use indicated that demand for irrigation groundwater in the basin would increase by 2,643 AF from 2016 to 2035, and by a further 1,728 AF between 2036 and 2065 (Sussman, McMurtrey, & Grigsby, 2017).[5] The same study found that demand for public supply groundwater use would increase by approximately 10,590 AF from 2016 to 2035 and by a further 6,438 AF between 2036 and 2065.[6] We adopt these projections to model the amount of groundwater pumping in the Deschutes Basin in future years, assuming that growth happens linearly during the time periods. We further assume that growth in pumping after 2065 would occur at the same rate as from 2036 to 2065. Given these assumption, total groundwater pumping over 107 years may rise to 88,000 AF annually (with about 33,000 AF going to irrigation and roughly 55,000 AF dedicated to the public water supply). Due to limitations on groundwater pumping in the region, we expect this estimate of total future

[5] This estimate combines the use categories of irrigation, agriculture, and nurseries. The projected demand from 2036 to 2065 was based on municipal demand of 300 gallons per capita per day. In a previous version of the analysis, we used a different study to project future groundwater use in the Deschutes Basin. This study found that public groundwater use may increase by an average of 2.5 percent annually (the report projected an increase of consumptive groundwater use from 35,895 to 58,594 over the 20-year period from 2005 to 2025) (Newton Consultants, 2006). Because this study was more than 10 years old, and because the study from GSI Water Solutions, Inc. was written in the last 2 years, we chose to update the analysis to incorporate the more recent estimates.

[6] This estimate combines the use categories of municipal, domestic, commercial, storage, and industrial. The projected demand from 2036 to 2065 was based on municipal demand of 300 gallons per capita per day.

pumping to be on the high side, with associated estimated costs likely higher than would be experienced in reality.

In terms of power rates, according to the 2010 *Water System Master Plan Update Optimization Study*, most of the City of Bend's 25 groundwater wells fall under Pacific Power's Rate Schedule 28, while three wells fall under Rate Schedule 30 (Optimatics, 2010). The marginal cost for the City to pump groundwater is expected to be approximately $0.0590 per kilowatt-hour (kWh) under Schedule 28 (Pacific Power, 2019). Farmers who use electricity to irrigate fall under Central Electric Cooperative's Schedule C, which charges a rate of $0.0512 per kWh; this analysis assumes this rate is the marginal cost to farmers for pumping groundwater.

Even without the Piping Alternative, groundwater levels will still decline. The USGS study noted that groundwater levels in the area between Clines Butte and Redmond[7] fell approximately 12 to 14 feet from 1994 to 2008 from a combination of climate, increases in groundwater pumping, and reduced groundwater recharge from canal lining (Gannett & Lite, 2013). This is an average drop of roughly 1 foot per year, which we assume would continue in absence of the Piping Alternative. Data from the Oregon Department of Water Resources indicate that depths to groundwater vary widely within the area; depths in Bend are around 740 feet, while depths near Redmond are about 265 feet (Oregon Department of Water Resources, 2016). Under the No Action Alternative, we assume a current average groundwater pumping depth in the central Deschutes Basin of 500 feet; assuming a 1-foot drop in groundwater depth each year over 100 years, groundwater depths would be approximately 600 feet. Over the course of 107 years (i.e., the project construction period plus the project life), the Piping Alternative would result in a pumping depth of approximately 602.6 feet or an increased depth to groundwater of 2.6 feet compared to the No Action Alternative.

Applying the electricity prices, assuming a pump irrigation efficiency of 70 percent,[8] and using the volume of pumping and pumping depths shown in Table D-1, the total cost of groundwater pumping under the No Action Alternative is projected to grow from around $2,187,000 in Year 1 to $4,377,000 in Year 106.

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7 This represents the closest area in the study to the proposed project with usable data. Other areas in the study lie closer to AID but do not have sufficient data to draw the inferences needed for this groundwater analysis. For example, the study's simulations showed greater groundwater declines around Bend than the Clines Butte/Redmond area (10 to 50 feet from pumping and 1 to 5 feet from canal lining). On the other hand, results of the study indicate the La Pine subbasin is largely unaffected by pumping and canal lining. In either case, this assumption does not impact the estimated economic impact of groundwater changes because it is used to estimate groundwater declines that occur under both the Piping and No Action Alternatives (i.e., those unassociated with project piping), and the economic impacts depend on the groundwater changes that differ between the two alternatives.

8 As assumed in the AID On-Farm Water Conservation Report completed by Black Rock Consulting and Farmers Conservation Alliance in 2018.

Table D-1. Approximate Depth to Groundwater in Central Deschutes Basin, Deschutes Watershed, Oregon.

Year	Volume Pumped (acre-feet per year)	Average Depth to Groundwater (feet)	
		No Action	Piping Alternative (NEE Alternative)
1	54,000	501.0	501.0
10	60,000	510.0	510.2
20	65,000	520.0	520.5
30	67,000	530.0	530.7
40	70,000	540.0	541.0
50	73,000	550.0	551.2
60	75,000	560.0	561.5
70	78,000	570.0	571.8
80	81,000	580.0	582.0
90	84,000	590.0	592.3
100	86,000	600.0	602.6

Prepared January 2021

The increased depth to groundwater due to reduced recharge results in higher pumping costs in the Piping Alternative. The increased cost to groundwater pumpers over the 107-year-analysis period rises each year as the cumulative effect of reduced recharge may cause the groundwater elevation to continue to decline. As a result of reduced recharge due to the installation of the project, the groundwater elevation may decline approximately 0.028 foot each year after implementation is complete, with a cumulative decline in groundwater levels of 2.6-feet by Year 106, with associated costs rising from approximately $43 in Year 2 to $20,000 in Year 106. In total, after discounting and amortizing these costs, the estimated total annual average cost across 107 years is $5,000 per year for the Piping Alternative (see Table D-2).

Table D-2. Other Direct Costs of Reduced Recharge under Piping Alternative, Deschutes Watershed, Oregon, 2020$[1]

Works of Improvement	Water Conservation (AF/Year)	Change in Groundwater Depth (foot/year)	Annual Average Cost from Reduced Groundwater Recharge
Project Group 1	10,526	0.028	$5,000
Total	**10,526**	**0.028**	**$5,000**

Note: Totals may not sum due to rounding. Prepared January 2021
1/Price Base: 2020 dollars amortized over 100 years at a discount rate of 2.5 percent.

The costs estimated in Table D-2 may overstate the costs of the Piping Alternative to groundwater pumping because AID would pass conserved water to NUID under the Piping Alternative. Some of the conserved water would be conveyed in unlined NUID canals and would seep into the ground and recharge groundwater. An analysis of NUID's conveyance system suggests that around 35 percent of the water passed by AID to NUID would be lost to seepage and evaporation for a total of 3,642 AF seeped per year (Farmers Conservation Alliance, 2021). The increased seepage in NUID would likely partially offset the decreased seepage in AID, with the result of slightly less impact on groundwater pumping costs than estimated in Table D-2. Since only the potential costs of reduced AID seepage savings are accounted for in this analysis, the result is likely an overestimate of the basin-wide increase in groundwater pumping costs. However, the conclusion remains the same that, even when likely overstated, the potential costs of reduced groundwater recharge are small compared to the benefits of the Piping Alternative.

Carbon Costs

Changes in energy use are expected to result in changes in carbon dioxide emissions from power generation. Every MWh of reduced energy use is estimated to translate into an estimated reduction of 0.7525 metric tons (Mt) of carbon emissions, and the same amount of emissions are assumed to be added for each MWh of increased energy use.[9] The Piping Alternative would decrease some carbon emissions (from eliminating some pumping energy use in the District) and increase other emissions (by increasing basin-wide pumping as a result of lower groundwater levels). Within the District, compared to the No Action Alternative, the annual energy savings (described in Section 1.1.2.5) would reduce carbon dioxide (CO_2) emissions by approximately 62 Mt (approximately 81.8 MWh multiplied by 0.7525), while energy use increases associated with lower groundwater levels would increase emissions by an average of roughly 75 Mt per year, leading to an average net annual increase in emissions of around 14 Mt (see Table D-3). Generally, there is a net decrease in emissions early on as pressurization eliminates emissions from electricity used for pumping and later a net increase when declining groundwater levels cause electricity demand (and associated emissions) to outweigh pressurization benefits.

Table D-3. Annual Average Carbon Emissions (Mt), Deschutes Watershed, Oregon. [1]

Works of Improvement	No Action		Piping Alternative		
	Average Annual Carbon Emissions, Pumping Elsewhere in Basin	Annual Carbon Emissions, AID Patron Pumping	Average Annual Carbon Emissions, Basin-wide Pumping	Annual Carbon Emissions, AID Patron Pumping	Net Annual Carbon Increase (Compared to No Action)
Project Group 1	N/A	964	N/A	902	-62
Rest of Basin	45,635	N/A	45,711	N/A	75
Total	**45,635**	**964**	**45,711**	**902**	**14**

Note: Totals may not sum due to rounding. Prepared January 2021
1/ These values show an average annual increase over 100 years. Carbon emissions rise over time because groundwater pumping volume increases throughout the basin over time, and the depth to groundwater also rises over time due to reduced recharge from canals.

To value the potential increase in carbon emissions, this analysis uses an estimate of the SCC, which is the estimated total cost to society of emitting carbon related to the expected damages associated with future climate change. There are many estimates of the SCC, and the estimates vary based on what types of damages are included, the discount rate chosen, the geographic area under consideration (such as global damages versus U.S. domestic damages), and the projected level of global warming and associated damages. SCC

[9] This assumes that marginal changes in energy demand are met with fossil fuel-based production (renewable energy is typically used first and then fossil fuel powered generation is used), such that 100 percent of energy use reduction and green energy production result in reduced fossil fuel powered generation. Furthermore, this estimate assumes 0.7521 Mt of carbon emitted from 1 MWh of fossil fuel powered electricity generation based on 1) the current proportion of fuel sources–oil, natural gas, and coal–for fossil fuel powered electrical power generation in the Western United States, and 2) the associated Mt of CO_2 produced per MWh powered by each fossil fuel source, as reported by the Energy Information Administration.

damage values used by federal agencies have varied over the years. At first, federal agencies developed and applied their own estimates. Then, the Office of Management and Budget convened an Interagency Working Group (IWG) on the Social Costs of Greenhouse Gases, which developed a set of SCC estimates that could be used across federal agencies.

In 2013, the IWG estimated that in the year 2020, SCC would be approximately $52 per Mt (Interagency Working Group on Social Cost of Greenhouse Gases, 2013).[10] However, in 2017, Executive Order 13783 disbanded the IWG, indicated that IWG estimates were not representative of government policy, and removed the requirement for a harmonized federal policy for SCC estimates in regulatory analysis. During the remainder of the Trump administration, the U.S. Environmental Protection Agency (USEPA) and other federal agencies developed interim alternative estimates of the SCC, largely relying on the methodology used by the IWG but using different discount rates and focusing on direct damages projected to occur within the borders of the United States. For example, the USEPA developed an interim SCC value of $7 per MT of carbon for 2020 (based on a 3 percent discount rate) for the *Regulatory Impact Analysis for the Repeal of the Clean Power Plan, and the Emission Guidelines for Greenhouse Gas Emissions from Existing Electric Utility Generating Units* published in June of 2019 (Environmental Protection Agency, 2019).

The Biden administration in January of 2021 issued Executive Order 13990 re-establishing the IWG, and it is likely that the IWG will re-establish values similar to those used under the Obama administration (i.e., as noted above, a value of approximately $52 per metric ton of carbon in 2020).

However, as of early February 2021, the new IWG has not yet issued new recommendations, this analysis uses the interim USEPA SCC of $7 per Mt of carbon for 2020 (3 percent discount rate) as used by the USEPA in the 2019 Clean Power Plan analysis cited above. We apply this value to the net change in carbon emissions each year throughout the project life to estimate the change in carbon emissions from the Piping Alternative. Because there is a net increase in carbon emissions, this represents a cost. However, because the net change in annual emissions and the SCC are small, when discounted, amortized, and rounded to the nearest thousand dollars there is no change in the value of carbon emissions. This is shown in Table D-4.

Table D-4. Annual Increased Average Carbon Costs of Piping Alternative, Deschutes Watershed, Oregon, 2020$.[1]

Works of Improvement	Annual Avoided Emissions (Reduced AID Patron Energy Use, Mt Carbon)	Average Annual Increased Emissions (from Reduced Recharge; Mt Carbon)[2]	Net Average Increased Emissions (Mt Carbon)	Average Annual NEE Costs (Social Cost of Carbon)[3]
Project Group 1	62	75	14	$0
Total	**62**	**75**	**14**	**$0**

Note: Totals may not sum due to rounding. Prepared January 2021
1/ Price Base: 2020 dollars amortized over 100 years at a discount rate of 2.5 percent.
2/ Additional energy use elsewhere rises through time as the effects of reduced recharge accumulate and cause groundwater depths to drop over time. The average annual energy use increase elsewhere in the basin represents the average change in energy use across the 100 project years.
3/ The average annual NEE benefits may differ from the change in tons of carbon emitted multiplied by the $7-value per Mt of carbon. The increased emissions rise through time (and are thus highest at later periods when the values are most discounted, while the decreased carbon emissions are the same through time).

[10] We adjusted the original cost of $42 in 2007 dollars to 2020 dollars using the Consumer Price Index.

Change in Aesthetics and Associated Property Values

Large sections of the project are located in suburban neighborhoods just south of the Bend city limits. The Arnold Main Canal, which would be piped under the project, runs through the neighborhoods of the Deschutes River Woods and Woodside. There are approximately 450 tax lots in the project area (Willis, 2020). For some of these properties, the Arnold Main Canal acts as a boundary with adjacent properties and provides aesthetic value to the property. Some residences have built structural and landscape features designed to view the canal. In 2019, during a project scoping meeting around 125 residents in the project area voiced concern over losing the canal as a result of piping (Willis, 2020).

Considering these facts, it is clear that the Arnold Main Canal provides some nearby residents with services that have a positive economic value that likely enhances property values. According to real estate agents in the region, many people interested in purchasing property are willing to pay more for properties that have a view of a canal. A meta-analysis of 25 studies that researched the impact of rivers, streams, and canals showed that these water features increased property values in most cases (Nicholls & Crompton, 2017). Three studies that focused on canals in the U.S. found that nearby canals increase residential property values by 10 to 30 percent (Nicholls & Crompton, 2017).

As a result, a potential direct cost of the Piping Alternative is that some local residents may experience adverse effects on property values and quality of life due to the change in aesthetics from piping the canals. On the other hand, some property owners or potential property owners may not want to have a canal adjacent to their property because of the safety hazard an open canal poses, potentially limiting the effect on property values. However, very few local residents have voiced such concerns to AID (Willis, 2020).

The potential aesthetic cost to residential landowners is not quantified due to a lack of available data on property values, the number of properties with views of canals, and the value of those views to local residents. As such, while this effect is recognized as a likely cost,[11] this analysis does not quantify the potential change in aesthetic values of the proposed project.

1.1.2 Benefits of the Piping Alternative

Table 8-7 in the Plan-EA compares the project benefits (over the No Action Alternative) to the annual average project costs presented in Table 8-5 in the Plan-EA. The remainder of this section provides details on these project benefits. Table 8-6 in the Plan-EA presents on-site damage reduction benefits that would accrue to agriculture and the local rural community, including reduced power costs. It also presents off-site quantified benefits, which include the value of reduced carbon emissions. Other benefits not included in the analysis, which may result indirectly from the Piping Alternative, include increased agricultural yields in AID and the potential for increased on-farm investments in irrigation efficiency (as patrons have more funds due to increased yields and reduced pumping costs).

1.1.2.1 Benefits Considered and Included in Analysis

Agricultural Damage Reduction Benefits

Under the Piping Alternative, AID would pass all conserved water from piping (10,526 AF per year) to North Unit Irrigation District (NUID). Because the NUID diversion point lies farther downriver than the AID

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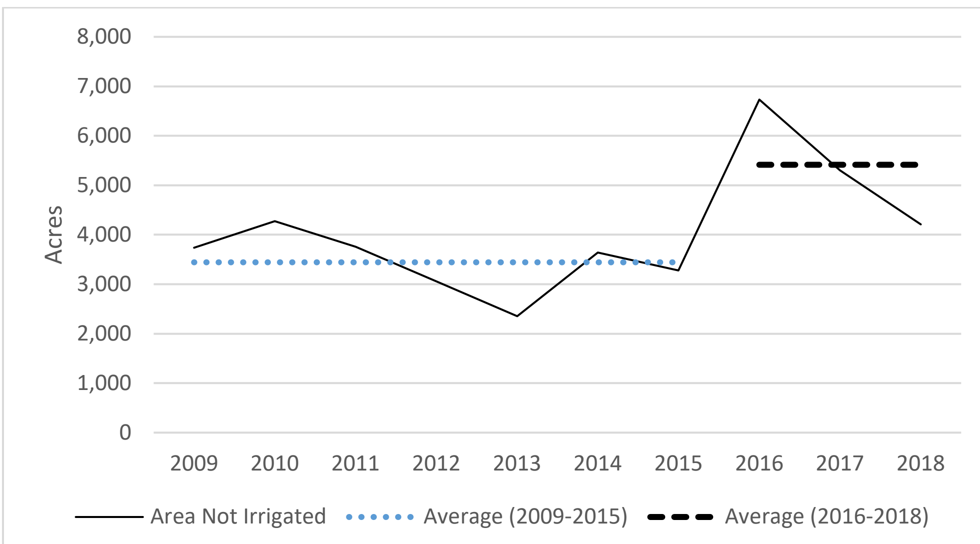
11 Note that increased agricultural production value due to a more reliable water supply to AID patrons may tend to increase property values (all else equal), which could offset the effect on property values. The value of increased water supply reliability is not quantified but is discussed in Section 1.1.2.2. While the aesthetic value and the agricultural production value are not necessarily similar in magnitude, the population affected (AID patrons) is largely the same (there may be some residents in the area who benefit from canal views who are not patrons of AID).

diversion point, a small portion of the conserved water would seep into groundwater, resulting in NUID receiving slightly less water (10,123 AF) at its diversion point than the total amount of water passed by AID (Farmers Conservation Alliance, 2021). An analysis of NUID's conveyance system indicates that it loses about 32 percent of its water from seepage and evaporation (Farmers Conservation Alliance, 2021). As a result, approximately 68 percent of the water that reaches the NUID diversion point would make it to NUID farms, or 6,885 AF per year. We use this amount of water to estimate the benefits to NUID agriculture of water conserved by piping in AID.

The 6,885-AF increase in water availability is expected to reduce the agricultural damages associated with water shortages experienced currently in NUID, as well as mitigate future larger water shortages in NUID that are expected to occur due to changes in water management required as part of the Deschutes Basin Habitat Conservation Plan (HCP) (Oregon Fish and Wildlife, 2020). Historically, NUID has experienced water shortages in which water supply is less than total water demand in the district (Britton, 2019). Since the adoption of the 2016 Settlement Agreement, which includes provisions for irrigation districts in Central Oregon to increase instream flows to support the Oregon spotted frog (OSF; which reduces water availability for irrigation), water supply reliability to NUID irrigators has been further decreased. While there have been just a few years since the Settlement Agreement, and water year type and market conditions also affect acreage planted in any given year. Figure D-1 shows that the average fallowed acreage in NUID increased from the 2009 to 2015 period to the 2016 to 2018 period.



Source: (Bohle, North Unit Irrigation District 10 Year Average Crop Report 2009-2018, 2019)

Figure D-1. NUID agricultural area not irrigated.

Based on these data and the analysis of changes in NUID water supply contained in the environmental impact statement for the HCP (Oregon Fish and Wildlife, 2020), this analysis assumes that the 6,885 AF of additional water would reduce the agricultural damages arising from decreased water availability. Specifically, the additional water would reduce deficit irrigation on hay acres that causes a loss of one hay cutting totaling 25 percent of the annual yield under full irrigation. Because this analysis focuses on the impacts to hay only and does not include potential impacts to specialty crops grown in NUID, the benefits presented in this section likely underestimate the benefits of additional water to NUID. Roughly one quarter of NUID's irrigated acres are dedicated to high-value specialty crops, which in the absence of water conservation projects like the proposed action may be impacted by water shortages as the HCP changes in water management are phased into effect in future years.[12] In other words, if future NUID water shortages reduce acreage or yields of specialty crops, the value of additional water to NUID would be higher than is presented here.

With these assumptions, to estimate the value of reduced damages from deficit irrigation, we adapted a published Washington State University (WSU) crop budget to model the net revenues of agricultural production in NUID for alfalfa hay. From this source budget, we developed crop budgets to model the net returns to hay under full irrigation and under deficit irrigation. The crop budgets are provided in Section 1.2, with detailed explanation of the methods used to update revenues and costs to 2020 dollar values. The crop budget analysis is summarized in the table below.

Table D-5. Summary of Per-Acre Hay Net Returns Under Full and Deficit Irrigation in NUID, Deschutes Watershed, Oregon, 2020$.

Economic Variable (Per Acre)	Irrigation Level	
	25% Deficit (No Action)	Full (Piping Alternative)
Production Year 1 Net Returns	$192	$364
Production Years 2-6 Net Returns	$26	$170
Weighted Average Net Returns [1]	$54	$202
Increased Value/Acre of Full Irrigation [2]	$149	
Increased Value/AF of Full Irrigation	$246	

Note: Full crop budgets are provided in Section 1.2. Prepared January 2021
1/ Averaged over a 6-year stand life with 5 years comprised of Years 2 to 6 net returns.
2/ Equal to the difference of weighted average net returns between deficit and full irrigation.
3/ Calculated assuming a 0.6 AF/acre difference between full and deficit irrigation.

Results from the analysis in Section 1.2 are that alfalfa hay under full irrigation generates average annual net returns of approximately $202 per acre, while deficit irrigation generates approximately $54 per acre. Therefore, the marginal net benefit of providing full irrigation to deficit-irrigated alfalfa is approximately $149 per acre. The weighted average full water allocation in NUID is 2.4 AF per acre.[13] With deficit irrigation at 75 percent of full irrigation, each acre would receive an additional 0.6 AF under full irrigation.[14] Dividing the marginal net returns of full irrigation ($149 per acre) by the amount of additional water (0.6 AF per acre)

12 Source for NUID crop mix: (Bohle, North Unit Irrigation District 10 Year Average Crop Report 2009-2018, 2019)
13 Water allocations in NUID differ depending on the source: Deschutes River water rights get 2.5 AF per acre while Crooked River water rights get 1.5 AF per acre. Because there are 53,721 acres supplied by the Deschutes River and 5,164 acres supplied by the Crooked River, the weighted average allocation District-wide is 2.4 AF per acre (Britton, 2019).
14 2.4 x (1 - 0.75) = 0.6 AF per acre

provides the marginal net returns to water: $246 per AF. We use this amount to estimate the damage-reduction benefit of each AF of water going to NUID under the Piping Alternative.[15]

Under the Piping Alternative, AID would pass water to NUID as water was conserved from piping (i.e., as project phases finish, beginning in Year 2). However, this analysis expects the benefits to NUID agriculture would only accrue beginning in the year 2028 (Year 7 of this analysis) when the HCP instream requirements are scheduled to increase. The increased instream flow requirements would reduce water supply further for NUID under the No Action Alternative. Under the Piping Alternative, the water passed from AID to NUID is expected to alleviate these shortages, as described above. Therefore, starting in Year 7 under the Piping Alternative, this analysis models an increase of approximately 6,885 AF per year to NUID farms. This volume of water valued at $249 per AF results in an undiscounted annual agricultural damage reduction value of about $1,696,000. When discounted and annualized, the value of the Piping Alternative in avoiding agricultural damages in NUID totals $1,489,000 (as shown in Table D-6).

Table D-6. Avoided Damages to NUID Agriculture Resulting from Piping Alternative by Project Group, Deschutes Watershed, Oregon, 2020$.[1]

Project Group	Total delivered water to NUID farms (AFY)	Undiscounted Annual Benefit to NUID Agriculture	Annualized Average Net Benefits of Piping
Project Group 1	6,885	$1,696,000	$1,489,000
Total	**6,885**	**$1,696,000**	**$1,489,000**

Note: Totals may not sum due to rounding. Prepared January 2021
1/ Price Base: 2020 dollars amortized over 100 years at a discount rate of 2.5 percent

1.1.2.2 Value of Instream Conserved Water

As described in the previous section, under the Piping Alternative AID would begin passing water conserved water to NUID as the project phases are completed. Of the 10,526 AF per year passed by AID once the project is completed, roughly 10,123 AF would reach the NUID diversion point (due to seepage and evaporation). Prior to 2028, NUID would release an equivalent amount of water (10,123 AF) from Wickiup Reservoir for instream flows during the non-irrigation (winter) season. Placing this water instream would provide instream flow benefits over the No Action Alternative in the years prior to 2028, when the HCP governing flows on the Deschutes River requires increased wintertime instream flows to increase. Under the No Action Alternative, NUID would not be required to put this additional water instream until 2028.

This section provides several types of information on the value of instream flow. First, this analysis examines the value that environmental groups, federal agencies, and other funders of conservation have been willing to pay for water conservation projects that restore flow in the Deschutes Basin. While these values are in fact costs rather than a measurement of benefit, the amounts paid in the past for water conservation projects to enhance instream flow represent the minimum value to the funding entities of conserved water projects (benefits as perceived by funding entities are expected to at least equal costs, or funding would not be provided). Similarly, there is some limited water market data available for what governmental groups have paid to directly purchase water rights and dedicate the water to instream flow. These values also represent the cost of increasing instream flow, similar to the data on costs of water conservation projects and may

[15] If 6,885 AF of additional water were distributed at 0.6 AF per acre (as is assumed in this analysis), less than 12,000 acres could receive additional water. Over the last 10 years, NUID has averaged about 37,000 acres in hay and grain, which the net returns analysis is meant to represent (Bohle, 2019). Because the total area receiving additional water is less than half the total area of relevant cropland, it is reasonable to apply the benefit per AF to all 6,885 AF.

significantly underestimate the full value of instream flow augmentation. Data on water right transactions in the Deschutes Basin were not available for this study. However, prices of water rights are often based on the value of water to agriculture (as agriculture is the most common seller of water rights for environmental or other water uses). We therefore present market information on the value of water rights to irrigators in NUID (because NUID would be putting the water instream), as this indicates the potential cost of purchasing water rights from these irrigators.

Based on the following discussion, we assume that the economic benefit of instream flow augmentation would be at least $75 per AF per year, such that this enhanced instream flow is estimated to have a value of approximately $761,000 per year once the project is complete under the Piping Alternative (because of the construction phase timing and because the instream benefits only accrue prior to Year 7, on an average annualized basis the NEE benefit is roughly $42,000 as presented in Table D-7). As most water right transactions for environmental purchases are to enhance fish habitat, this value is expected to be a conservative proxy for the value to the public of enhanced fish habitat and fish populations. (The full measure of the economic benefit of enhanced instream flow is the benefit to the public of such things as enhanced fish and wildlife populations, water quality, and ecosystem function.)

Values published in the economic literature are often quite high for enhancements to salmon, trout, and other fish and wildlife populations, such as those that would benefit from the instream flows provided by the Piping Alternative. As quantitative information on how instream flows would improve fish and wildlife populations is not available, the analysis is not able to directly measure the economic benefit of enhanced instream flow. As such, the value of conserved water is estimated in this section using the prices of water from transactions for environmental water in the western United States. Table D-7 shows the estimated average annual benefits of enhanced instream flow for the Piping Alternative.

Table D-7. Annual Estimated Instream Flow Value of Piping Alternative by Project Group, Deschutes Watershed, Oregon, 2020$. [1]

Project Group	Undiscounted Annual Benefit of Conserved Water	Annualized Average Net Benefits of Piping
Project Group 1	$761,000	$45,000
Total	**$761,000**	**$42,000**

Note: Totals may not sum due to rounding. Prepared January 2021
1/Price Base: 2020 dollars amortized over 100 years at a discount rate of 2.5 percent

The value of $75 per AF per year is based on the following information (see Table D-8):

1. **Prices paid for water by environmental buyers throughout the western United States**—In the period 2000 to 2009, purchase price of environmental water varied from just over $0 to nearly $1,765 per AF per year, with an average permanent sale transaction price of $239 per AF per year. Among the 51 permanent water right purchases with the sales price and volume recorded in the database, the permanent sales price value in 27 transactions (53 percent) was above $75 per AF per year. As discussed at length below, these values paid are expected to provide a low range estimate of instream flow value to society.

2. **Value of water to irrigators in the Deschutes Basin**—For hay and grain irrigators (relatively low valued crops, which are likely the first to sell water for environmental purposes), this is estimated at approximately $60 to $250 per AF per year. This value is important because the value of water to local agriculture is a key factor determining water sales and lease prices to environmental buyers in the project area (i.e., the marginal value of water to agriculture determines the agricultural sellers'

willingness to accept a price for water), and because conserved water avoids potential future reductions in irrigation.

Table D-8. Value per AF per Year of Water (Market Prices and Value to Agriculture), Deschutes Watershed, Oregon, 2020$.

Type of Value	Low Value	High Value	Median Value	Average Value
Permanent water right transaction in western United States, 2000 to 2009 (*Converted to Annual Values*)	~$0	$1,765	~$75	$239
Value of water to NUID irrigators (*Income Capitalization Approach*)	$60	$250	N/A	$85

Past Costs Paid as a Proxy for Value

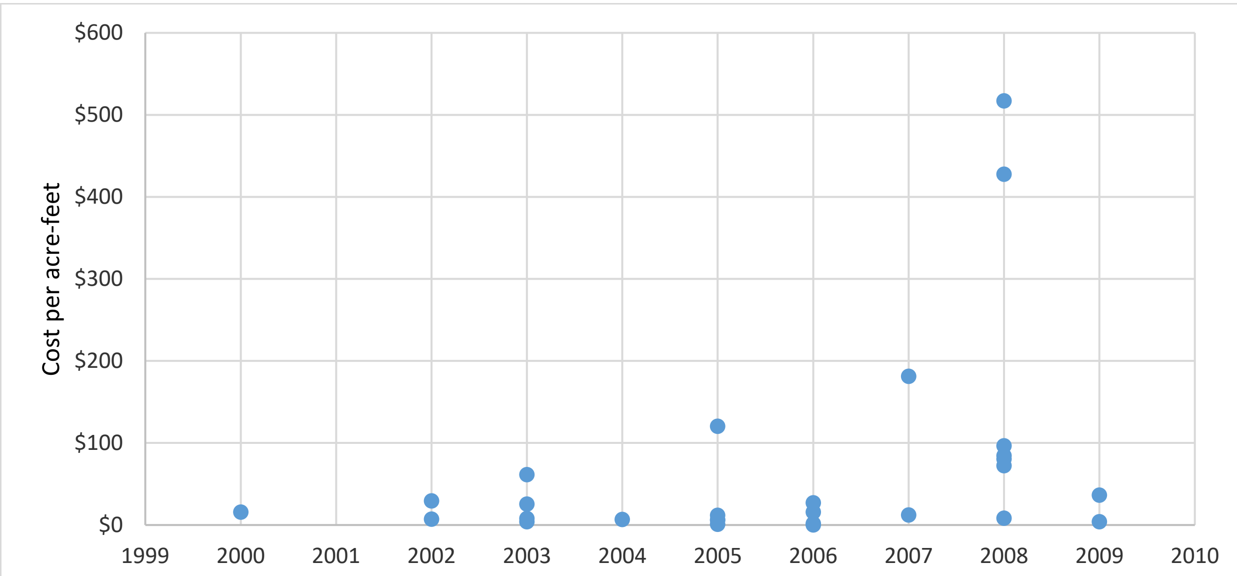
Past piping projects in the Deschutes Basin highlight the willingness of funding entities to pay for instream flow augmentation. These values are evidence of the *minimum* benefit of the instream flows purchased, as perceived, and experienced by these entities. Project costs paid are indicative of the *minimum* perceived benefit as (barring very unusual circumstances) entities only pay for projects for which they believe the benefits exceed costs. Furthermore, funding organizations do not necessarily represent all individuals who value instream flow benefits. Only if all people who value instream flow were to pay their maximum willingness to pay for instream flow restoration, then the value paid would equal the benefits received. Finally, it is important to recognize that these values fundamentally represent *costs* and not benefits; the values paid are based on the cost to conserve water or for agriculture to reduce their use of water (as evident through water right transactions from agriculture to environmental flows).

In the Deschutes Basin, approximately 90 projects have restored approximately 80,000 AF of water instream (Central Oregon Irrigation District, 2016). Based on data from the Deschutes River Conservancy (2012), costs of instream flow augmentation from piping projects have ranged from approximately $105,000 to approximately $344,000 per cubic feet per second (cfs) conserved; this may equate to roughly $300 to $1,000 per AF conserved.

Water rights can be purchased or leased in Oregon. It is important to note that the value paid per AF depends on many variables, including the value of water to the seller, funding available to the buyer, characteristics of the affected stream/river (including current flow levels, flow targets, and presence of threatened or endangered species), characteristics of the water right (e.g., seniority, time of use, point of diversion), and the size of the water right.

Water right leases and purchases for environmental purposes across the western United States were analyzed in a 2003 paper (Loomis, Quattlebaum, Brown, & Alexander, 2003). During the period between 1995 and 1999, 5 transactions of water right purchases averaged $377 per AF in Oregon, while 6 water right leases averaged $117 per AF per year. The paper also shows lease and purchase price by environmental use, including for riparian areas, wetlands, recreation, and instream flow. For instream flows, the average purchase price across 18 transactions per AF was $1,170, while across 35 lease transactions the annual price was $71 per AF.

The Bren School of Environmental Science and Management at the University of California, Santa Barbara, maintains a database of water transfers in the western United States, and distinguishes between the terms of the transaction (i.e., sale or lease) and the sector of the buyer and seller (e.g., agricultural or environmental) (Bren School of Environmental Science & Management, 2017). The two graphs shown below in Figure D-2 and Figure D-3 show more recent (from 2000 to 2009) sales and leases of water rights by environmental buyers on a price per AF per year basis. The figures show how water right transaction values vary widely, but sale prices (amortized to an annual price) typically are less than $200 per year, while 1-year leases typically fall below $800 per AF per year (with several transactions showing prices rising over a $1,000 per AF per year). Among the 51 permanent water right purchases with the sales price and volume recorded in the database, the sales price value in 27 transactions (53 percent) was above $75 per AF per year. However, it is also important to note that the amount paid per AF tends to decline with an increase in water volume traded; weighting the purchase price by the water volume sold decreases the average permanent sale transaction price to $20 per AF per year.



Note that dollar per AF purchase prices were amortized using a 2.5 percent interest rate and a 100-year period to derive dollar per AF per year values.

Figure D-2. Western water right purchases for environmental purposes, 2000 to 2009, price paid per acre-foot per year.

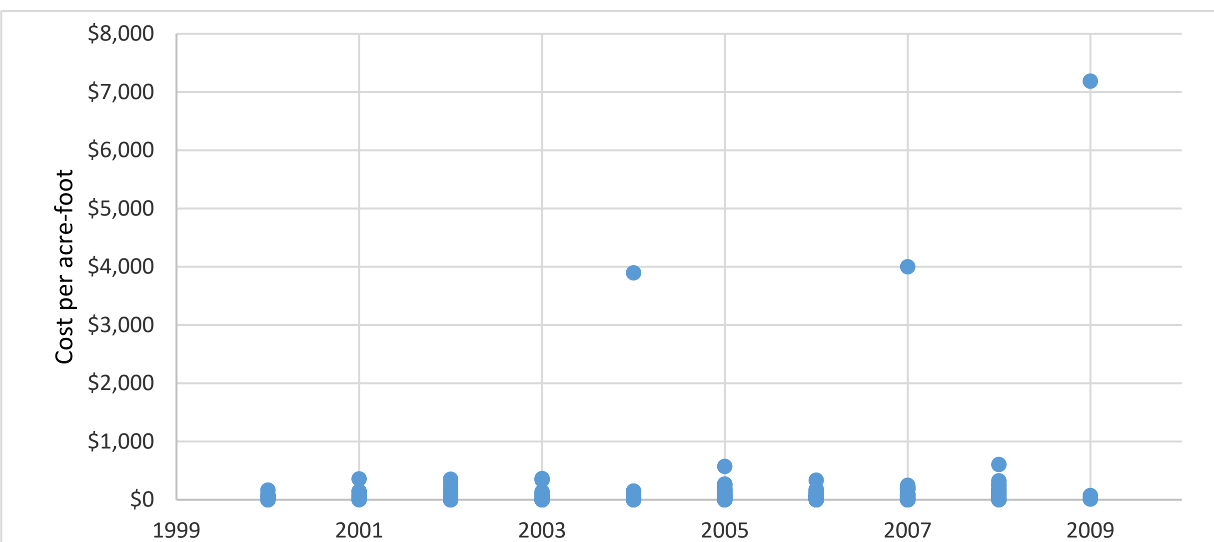


Figure D-3. 1-year water leases for environmental purposes, price paid per acre-foot in western United States.

Current and Potential Future Water Right Purchase Values in the Surrounding Area

The value of water to irrigators (i.e., the increased farm income from having access to water) is important as it is a key determinant of the price at which irrigators would be willing to sell water rights (and the price at which environmental water buyers could obtain water from agricultural water right holders, which are the primary water right holders that could sell water rights to augment instream flows). In the project region, water rights sold from one irrigator to another within the Tumalo Irrigation District (which is also located in the Deschutes Watershed) have typically had a purchase price between $5,310 to $7,970 per acre (Rieck, 2017).[16] These values are very similar to values provided by area real estate agents regarding the increased value of property in TID with irrigation water rights, with all else equal. Assuming approximately 4 AF per year delivered on average to acreage in TID, this equates to approximately $1,330 to $1,990 per AF ($5,310 to $7,970 per acre divided by 4 AF per acre delivery), or a value of approximately $40 to $70 per AF per year.

Because NUID's crop mix has a higher proportion of high-value crops that TID and higher yields, the value of NUID irrigation water is higher than for TID. Using the crop budgets created to model the agricultural benefits of the Piping Alternative (shown in detail in Section 1.2), we estimate that reduced irrigation of 0.6 AF per acre in a season causes hay growers in NUID to lose approximately $150 per acre in profits. This implies that NUID irrigators value water at the margin at approximately $250 per AF ($150 divided by 0.6). However, on average, NUID irrigators may be applying approximately 2.4 AF per acre to hay crops and getting profits of roughly $200, which implies approximately $84 per AF of value on average.

1.1.2.3 Value of Supporting the Oregon Spotted Frog

In many river systems, organizations that are leasing and purchasing water rights to restore instream flows are focused on the enhancement of fish populations. As such, water right transaction values for instream flow purchases presented in the above section may represent the value of the instream habitat enhancement for fish but may not include the value associated with conservation of other species, such as amphibians. In the Deschutes River, restoration of flows would benefit not only fish species but also benefit and help recover the Deschutes River population of the threatened OSF and enhance water quality. In this section, we describe the potential additional value of OSF conservation based on values from the literature regarding ecosystem and species conservation.

Our use of existing literature and previous studies regarding the value of ecosystem restoration and species conservation to estimate the value of OSF habitat enhancement in the Deschutes Basin is done in accordance with a methodology known as benefits transfer. Values estimated through benefits transfer are less certain and reliable than would be values estimated through a specific study of the value of OSF habitat in the Deschutes Basin, as the resource being valued (OSF) and the population valuing the resource (the Deschutes County households) may differ in substantive ways that could significantly affect the value estimate. However, developing and implementing a new study of the value of OSF habitat in the Deschutes Basin through survey-based techniques such as contingent valuation or conjoint analysis would be resource-intensive and costly. Consequently, this analysis uses benefits transfer in a manner intended to be cautious and conservative, with associated discussion on the lack of certainty in value estimates.

As an additional caveat, by estimating the habitat value of water for fish and also including a separate benefit related to the OSF, we may be over-estimating the conservation value of the enhanced instream flow. However, we think that including both a general instream flow value and an OSF-specific value does not result in overestimation for three reasons: 1) organizations acquiring environmental water for instream flow

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[16] These values have been adjusted for inflation to 2020 dollars using the Consumer Price Index.

purposes are generally focused on enhancing instream flows in order to benefit fish,[17] 2) as discussed in the preceding section, the price paid for environmental water is highly influenced by the cost to agriculture of reduced irrigation water supplies and does not necessarily reflect the total ecosystem service value of the instream flow, and 3) studies of the willingness to pay for all habitat benefits of enhanced instream flow indicate that the total value we derived by adding the per AF value from above with an OSF value (as derived below) is within the range of expected benefits to the public (on a per household per year willingness-to-pay basis) of restored aquatic ecosystems.

Long-term viability of the Deschutes population of OSF is threatened by the Deschutes River's highly modified hydrologic regime. High summer flows, rapid flow fluctuation in the fall and spring, and current low wintertime flows are incongruent with the needs of the OSF lifecycle (U.S. Fish and Wildlife Service, 2017). The U.S. Fish and Wildlife Service believes that for long-term species preservation, increased wintertime flows are necessary in the Deschutes River (the Piping Alternative would increase wintertime streamflow by up to 33.8 cfs). Although OSF and its habitat needs are still under scientific investigation, U.S. Fish and Wildlife Service currently considers that 400 cfs is the minimum target winter instream flow in the upper Deschutes River necessary for beginning OSF recovery (Moran & O'Reilly, 2018). With restoration of streamflow and habitat on the Deschutes, the target flow may change as biologists monitor how the ecosystem and the OSF adjust to changes in flow management.

The economic value of conserving amphibian populations and the OSF in particular, may stem from many types of benefits to society provided by these species. As summarized in Table D-9, social and economic benefits of OSF preservation may include enhanced cultural values, recreational values, educational values, public health values, environmental quality values, and intrinsic species existence values (i.e., the value to people of preserving the species, apart from any use of the species). Pertinent to potential medical and ecological values, researchers have identified that the OSF may have an antimicrobial chemical in its skin secretions that provides resistance to a fatal amphibian disease (chytridiomycosis), which is causing declines in many amphibian populations (Conlon, et al., 2013).

Table D-9. Sources of Economic Value from Amphibian Conservation.

Source of Value	Description
Cultural Value	Frogs have cultural value that is evident in their symbolism and use in literature, music, art, and jewelry.
Recreational value	Wildlife viewing of frogs can enhance recreational value, while intact amphibian natural areas and wetlands can also enhance recreational value by providing aesthetically pleasing and diverse recreational environments.
Educational Value	Frogs provide an opportunity for research and education for ecology, biology, anatomy, and physiology.
Mosquito Control (Human Health, Well Being)	Amphibians reduce mosquito and other pest populations through predation and competition, which can provide social and economic

[17] The Freshwater Trust in Oregon, which has as its mission to preserve and restore freshwater ecosystems, emphasizes benefits of instream flows for fish on its website. For example, it notes on its website that "We must implement practical, workable solutions that work for both fish and farmers"; presents a graphic showing that rivers sustain industry, drinking water, recreation, agriculture, and fisheries; and lists several fish-related benefits in its achievements but notes no other specific species.

Source of Value	Description
	values by reducing a nuisance as well as provide public health benefits by reducing risk of mosquito-borne illnesses (thereby improving quality of life and reducing medical costs).
Pharmaceutical Drug Development (Human Health Value)	Amphibians produce chemicals for a variety of purposes, and these chemicals can provide the basis for new drugs.
Other Medical Advances (Human Health Value)	Amphibians' ability to regenerate limbs and tails may increase knowledge about physiology and lead to human medical advances.
Environmental Quality Value	Amphibians improve soil structure and fertility through soil furrowing, decomposition, and nutrient cycling.
Species Existence Value	In addition to and separate from their values for the above uses, preservation of frog populations provides intrinsic value to people related to enjoyment of knowing the species exists and the moral/ethical values associated with the conservation of the species for others, including future generations.

Source: (Hocking & Babbitt, 2013) Prepared January 2021

Value per Household

In terms of specific dollar values for the OSF, numerous studies are available in the economic literature that estimate the willingness to pay for individual species conservation. People's values for species conservation may arise from personal use (i.e., enjoying seeing the species and/or its habitat), personal beliefs and moral ethics (i.e., believe protecting a species and its habitat is the right thing to do), altruism (i.e., believing a resource should be protected so that others can use it or benefit from it), and/or a desire to bequest the resource (i.e., believing a resource should be protected for future generations). The most common way to measure value to people of species conservation is through surveys in which people are asked about their willingness to pay to protect a species. These surveys are highly challenging to develop and implement well; results from different surveys aiming to measure similar changes in resources can be highly variable.

While results are varied, several reviews of these types of survey studies have found that people's willingness to pay (i.e., the value they hold) for species conservation typically depends most heavily on the following factors: the type of species being conserved (in general, the larger and more iconic or charismatic the species, the higher the value, with species such as marine mammals tending to have the highest values), people's knowledge of the species (the more knowledge people have regarding the species, the higher the conservation value), the usefulness of the species to people, the level of threat and species population size (the smaller and more endangered the species population, the higher the value), whether the respondent is a visitor or a resident (recreational or tourist visitors tend to have higher values than residents), and survey design (Loomis & White, 1996; Martin-Lopez, Montes, & Benayas, 2008; Amuakwa-Mensah, Barenbold, & Riemer, 2018).

As noted above, values, particularly for iconic mammals, can be quite high. For example, household willingness to pay for enhancing or preserving a species such as elk, moose, or humpback whales have been estimated to average over $150 per household per year. Values for less iconic, non-mammal species, however, are more pertinent to the OSF. Preservation of non-mammal species that are much less iconic are often valued by U.S. households in the range of $15 to $35 or more per household per year (Loomis & White, 1996; Martin-Lopez, Montes, & Benayas, 2008).[18] For example, the Palouse giant earth worm is valued at approximately $20 per year per household in eastern Washington State based on a conjoint analysis study, while the Riverside fairy shrimp is valued at approximately $35 per household per year by households in Orange County, California based on a contingent valuation study (Stanley, 2005; Decker & Watson, 2016). These two species may be similar to the OSF in that they are not iconic but may be symbols of preservation of a particular ecosystem.

While the literature does not include willingness-to-pay surveys specific to the Deschutes Basin, watershed and habitat protection are important to basin residents. A 2009 survey of 400 randomly selected Deschutes County voters highlights this (The Trust for Public Land, 2010). In terms of conservation projects, the top 5 ranking project types, all with 79 percent or more of Deschutes County respondents indicating an importance level of extremely important or very important, are 1) protecting water quality in rivers, creeks, and streams; 2) protecting and improving drinking water quality; 3) protecting wildlife habitat; 4) protecting natural areas; and 5) protecting natural watersheds. These priorities ranked more highly than protecting forests, protecting farmland, planting more trees, and improving recreational access and recreational amenities. Furthermore, the survey findings illustrate that natural environment and recreational opportunities are integral to the county's quality of life (The Trust for Public Land, 2010). In response to questions regarding the county's quality of life, the most commonly cited contributors to a high quality of life were regarding the natural environment, including outdoor recreation, open spaces, and natural areas.

Specific to values for OSF conservation in the Deschutes Basin, because the species is not a large mammal, its value to people would tend to be less. On the other hand, several factors would tend to increase its value to households in the Deschutes Basin: 1) many people know about the species, and its conservation has come to represent, to many people, the restoration of the Deschutes River ecosystem, 2) the OSF species population is threatened, and researchers have identified that the Deschutes population of OSF is genetically distinct from other OSF populations (Moran & O'Reilly, 2018),[19] such that the population size of the genetically distinct species benefiting from increased wintertime Deschutes River flows is quite small, and 3) there are many visitors to the Deschutes Basin, and visitors tend to have relatively higher values (compared to local residents) for preservations of ecosystems and species in the areas they visit.

As instream flow augmentation in the Deschutes aids not just the OSF but also improves ecological function and enhances habitat for other species, it is useful to consider studies that estimate value of local habitat restoration and species preservation more generally. As cited above, Orange County residents were estimated to value fairy shrimp recovery at $35 per household per year and $78 per household per year for preservation of all local endangered species (Stanley, 2005).[20] Perhaps more pertinently, a conjoint analysis study identifying the value of preserving one or multiple little-known fish species in Ontario, Canada, found that some improvement in the population of a single, little-known riverine species (channel darter) was valued at $11 per household per year, while conservation of three little-known riverine species (channel darter, eastern sand darter, and the spotted sucker) would increase value to $75 per household per year (Rudd, Andres, & Kilfoil, 2016). The same study found that conservation action that resulted in a large improvement to the

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18 Surveys that are conducted in other countries, including developing countries with lower incomes, often find lower willingness-to-pay values for species conservation. In general, willingness to pay for conservation increases with higher household income. For this reason, we focus on studies conducted in the United States and Canada.

19 In terms of its uniqueness, the OSF is found in Oregon, Washington, and California, but the OSF population in the Deschutes Basin have been found to be genetically distinct. In fact, even within the Deschutes Basin, evidence indicates that there are numerous genetically distinct populations of OSF due to the large distances between OSF habitat sites and the relatively limited travel distances of the frog (Moran & O'Reilly, 2018). While Deschutes OSF is still considered the same species as OSF located elsewhere, its genetic uniqueness adds to the biological and potentially economic value of its continued survival.

20 The original study cited values of $25.83 and $55.22 in 2001 dollars, which were converted into annual 2020 dollars in this study.

channel darter population was valued at $24 per household per year, while a large improvement to the three species populations resulted in value of $90 per household per year. In other words, in both studies, preserving a single species was valued at approximately $11 to $35, while preserving habitat for a broader range of species was valued at $75 to $90 per household. As shown in Table D-10, the highest values in the Ontario, Canada, study were found to be associated with water quality, which would also be improved in the Deschutes Basin due to the Proposed Action.

Table D-10. Economic Values (2020 values) for Little-Known Ontario, Canada, Aquatic Species at Risk.[21]

Type of Benefit	Some Improvement	Large Improvement
1 Riverine Species (Channel Darter)	$11	$24
3 Riverine Species (Channel Darter, Eastern Sand Darter, Spotted Sucker)	$75	$90
Water Quality Index	$98	$122

Source: (Rudd, Andres, & Kilfoil, 2016) Prepared January 2021

The instream flow value of $75 per AF per year described in the previous section translates into approximately $38 per Deschutes County household per year of conservation value.[22] Including a value of $35 per household per year for OSF habitat in addition to the instream flow values cited above provides a cumulative value per household of instream flow augmentation/habitat conservation value of $73 per Deschutes County household and tourist households. Although, as discussed above, there is significant uncertainty regarding this value, the finding appears reasonable based on the above-cited literature addressing the value of a single species conservation compared to multiple species conservation and improvements to an aquatic ecosystem.

Number of Resident and Tourist Households Holding Value for OSF and Deschutes Basin Habitat Conservation

In addition to local households, there may be many households residing outside of Deschutes County that value preservation of OSF and Deschutes Basin habitat. Some studies have found that households throughout the nation located far from a wildlife habitat area may value species preservation efforts (Loomis J. , 2000). Additionally, as noted above, visitors to an area, particularly tourists participating in outdoor recreation, may have even higher species preservation values than residents. As such, we apply the estimated OSF species conservation value not only to Deschutes County households but also to the estimated number of households who are tourists in Deschutes County each year that participate in outdoor recreation activities.[23] Based on overnight visitation data (Longwoods International , 2017) and tourism expenditure data in Central Oregon (Dean Runyan Associates, 2018), we estimate that there are 102,000 households that visit Deschutes County each year, with the main trip purpose being outdoor recreation. We focus on these visitor households because many of the surveys of visitor willingness to pay for conservation have been at outdoor

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21 The original study cited values in 2011 Canadian dollars, which we converted to 2011 USD using a conversion rate of 1.0141 (the average from 2011) and updated to 2020 USD using the Consumer Price Index (Investing.com, 2021).

22 Based on U.S. Census data, the population of Deschutes County in 2017 was 186,875 people; using the Census 2010 average household size of 2.44, this translates to approximately 76,600 households. Assuming approximately 300 AF per cfs, the 300 cfs required to support the OSF equates to roughly 90,000 AF. As such, using $75 AF per year value, the average estimated value on a per household basis translates to $38 per year ($75 x 90,000 / 178,600 = $38/household).

23 We use the Deschutes County population because the affected OSF habitat is primarily in Deschutes County.

recreation sites.[24] In sum, we estimate that approximately 178,600 households (76,600 resident households and 102,000 visitor households) may value OSF habitat conservation in the Deschutes Basin. This represents approximately 7 percent of Oregon households.

Estimated OSF Conservation Value of NUID Flow Augmentation

While there are numerous factors that create uncertainty in estimating the value of OSF habitat conservation,[25] the economic literature supports the notion that habitat conservation through flow augmentation in the Deschutes likely exceeds the instream flow values cited in the previous section that are based on market transaction data. Based on the species and habitat conservation literature as a whole, we find it reasonable that this additional value for OSF conservation may be approximately $35 per household per year. While people throughout Oregon and beyond may value OSF habitat conservation, we conservatively apply this value to the 76,600 Deschutes County households and approximately 102,000 tourism households who visit the county annually for the primary purpose of outdoor recreation, for a total of 178,600 households. In sum, this translates into an estimated value of Deschutes OSF preservation of approximately $6.25 million per year.

As discussed above, for OSF preservation, flow augmentation is needed to increase wintertime flows from the current 100 cfs to approximately 400 cfs, or an increase of 300 cfs. Under the Piping Alternative, NUID (in exchange for AID passing it water conserved from the project) would match all water passed to it with wintertime releases from Wickiup Reservoir for the initial years of the analysis period (until 2028). These releases would total approximately 33.8 cfs once the project is complete (Farmers Conservation Alliance, 2021), or approximately 11.3 percent of the additional flow anticipated to be required for OSF conservation. We thus apportion 11.3 percent of the estimated value of $6.25 million for OSF conservation to the AID proposed action, or $704,000 per year. Similar to instream flow benefits, the additional flows that benefit OSF would be required starting in Year 7 of the No Action Alternative due to the increased HCP requirements. For that reason, this analysis only includes OSF benefits under the Piping Alternative prior to Year 7, when they would be additional over the No Action Alternative. When discounted and annualized, these benefits total $39,000 as shown in Table D-11.

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[24] The tourism study by Longwoods Travel estimates that there were 4.5 million overnight person trips (a person trip is a trip of any length taken by one person) to Central Oregon in 2017. The Central Oregon region includes Deschutes, Jefferson, Crooked, and South Wasco counties. We use the proportion of visitor spending in each county to estimate the percent of the overnight person trips occurring to Deschutes County. According to the Oregon Travel Impacts report prepared for the Oregon Tourism Commission, 82 percent of 2017 visitor spending in Central Oregon occurs in Deschutes County. (Total estimated spending in Central Oregon is $776.6 million, of which $640.2 million, or 82 percent, is estimated to occur in Deschutes County.) Assuming 82 percent of Central Oregon overnight visits are in Deschutes County, there were approximately 3.71 million overnight person-visits in 2017 in Deschutes County. The Longwoods Travel survey indicates that the average household size of overnight visitors to Central Oregon is approximately 2.87 people, which translates then to approximately 1.293 million households with overnight trips to Central Oregon. The survey also indicates that approximately 62 percent of households had visited Central Oregon in the previous 12-month period. We assume that these households with previous visits to the region had visited, on average, three times per year. This translates to an average visitation rate of 2.24 across all households with overnight visits, for an estimated 577,000 separate households visiting Deschutes County. Of all visitors, the survey indicates that approximately 57 percent are tourists (i.e., not traveling for business or visiting family or friends). Of these, approximately 31 percent have outdoor recreation as the primary purpose of their visit. As such, we estimate approximately 102,000 households take at least 1 overnight tourist trip to Deschutes County annually with the primary purpose of their trip being outdoor recreation.

[25] Including, first and foremost, the uncertainty in applying values from other contexts and species to the OSF, as well as the challenge in interpreting results from previous studies given the diversity of values found and the high sensitivity of findings to study design and implementation methods.

Table D-11. Value of Supporting OSF Habitat under the Piping Alternative, Deschutes Watershed, Oregon, 2020$.

Project Group	Water Conservation (cfs)	Undiscounted Annual Benefits	Annualized Average Net Benefits
Project Group 1	33.8	$704,000	$39,000
Total	**33.8**	**$704,000**	**$39,000**

Note: Totals may not sum due to rounding Prepared January 2021
1/ Price Base: 2020 dollars amortized over 100 years at a discount rate of 2.5 percent

1.1.2.4 District Operations and Maintenance Cost Savings Benefits

AID expects operation and maintenance (O&M) of canals to decrease as a result of the Piping Alternative. In total, they expect this amount to fall by about $216,000 per year, which is comprised of the following costs:

- $7,900 to clean the Arnold Main Canal with a rented excavator,
- $26,000 for canal system maintenance,
- $13,000 for canal road maintenance,
- $159,000 for labor (including benefits), and
- $10,000 in general construction costs (Willis, 2020).

Should the Piping Alternative be implemented, the District does not plan to reduce staff or staff time in response to the avoided O&M labor costs. Instead, the District plans to assign staff to other activities that would benefit the District and its patrons. We assume that these activities would generate additional benefits that are at least equal to the cost of the staff's time, implying that the value of avoiding canal O&M would bring benefits at least equal to its current cost. In other words, if the District no longer has to pay $159,000 in labor costs to maintain canals, it would generate at least $159,000 in benefits by reallocating that labor to other valuable tasks. Accordingly, this analysis uses $216,000 to represent the annual O&M cost savings benefit to the District.

In addition to the avoided annual O&M costs, the Piping Alternative would also allow the District to avoid the one-time cost of removing 5,500 feet of canal lining. Under the No Action Alternative, this would likely occur sometime between Years 1 and 3 at a total cost of $125,000 (Willis, 2020). While the lining would be removed under the Piping Alternative, its removal would be included under the costs of canal demolition. Accordingly, under the Piping Alternative, this analysis assumes $125,000 in avoided costs have an equal chance of occurring anytime between Years 1 and 3. As shown in Table D-12 below, after discounting and amortizing, the Piping Alternative would result in an estimated $204,000 in annual O&M cost saving benefits relative to the No Action Alternative.

Table D-12. Annual Reduced Canal O&M Costs to AID Under the Piping Alternative, Deschutes Watershed, Oregon, 2020$.[1]

Works of Improvement	Length of Open Canal (miles)	Undiscounted Annual Canal O&M Costs	Undiscounted Avoided Cost of Removing Canal Lining (1x cost)	Discounted Annualized Benefit (OM&R[2] Cost Reduction)
Project Group 1	12.2	$216,000	$125,000	$204,000
Total	**12.2**	**$216,000**	**$125,000**	**$204,000**

Note: Totals may not sum due to rounding. Prepared January 2021
1/Price Base: 2020 dollars amortized over 100 years at a discount rate of 2.5 percent
2/OM&R = operation, maintenance, and replacement

In its Fiscal Year 2020 budget, the District set aside $28,404 for flume O&M (Willis, 2020). This analysis assumes that under the No Action Alternative, these costs would continue until the District piped the flume (assumed to occur between Year 15 and 20, as described in Section 1.1.1.3). Under the No Action Alternative once the flume was piped, the discounted and amortized annual avoided costs of flume O&M would total $19,000.

Therefore, the benefits under the Piping Alternative are the avoided annual O&M costs ($28,000) that occur between when the flume is replaced under the Piping Alternative (Year 6) and when the flume is replaced under the No Action Alternative (Year 20).[26] Since this analysis assumes flume replacement has an equal probability of occurring anytime between Year 15 and 20, the avoided cost benefit decreases linearly from Year 15 to 20.[27] Table D-13 shows that once discounted and amortized, the annual avoided costs of flume O&M would total around $6,000.

Table D-13. Avoided Flume O&M Costs of Piping Alternative, Deschutes Watershed, Oregon, 2020$.[1]

Works of Improvement	Undiscounted Annual Cost of Flume O&M	Total Annualized OM&R[2] Savings
Project Group 1	$28,000	$6,000
Total	**$28,000**	**$6,000**

Note: Totals may not sum due to rounding. Prepared January 2021
1/Price Base: 2020 dollars amortized over 100 years at a discount rate of 2.5 percent
2/OM&R = operation, maintenance, and replacement

1.1.2.5 Patron Irrigation Pumping Cost Savings

AID patrons currently use an estimated 1,280,419 kWh annually to power irrigation pumps (Farmers Conservation Alliance, 2020). System improvements associated with the Piping Alternative would result in a net energy savings of 81,763 kWh per year.[28] This energy cost savings is evaluated using Central Electric Cooperative's Schedule C rate for irrigation pumping: $0.0512 per kWh (Central Electric Cooperative, Inc., 2019). Table D-14 presents the energy use and cost savings to AID patrons under the Piping Alternative.

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26 The avoided cost benefit is assumed to begin in Year 7 since the flume would be constructed in Year 6, and end in Year 19 since replacement would occur in Year 20 under No Action Alternative.
27 The annual benefit of $28,000 decreases by $4,734 each year after Year 14 until it reaches zero in Year 20.
28 This is a based on an FCA analysis of AID data on energy savings.

Once the project is complete, the average annual NEE savings to AID patrons would be approximately $4,000 each year.

Table D-14. Annual Increased Average Energy Cost Savings to AID Patrons of Piping Alternative, Deschutes Watershed, Oregon, 2020$ [1]

Works of Improvement	Annual Energy Use Under Baseline Conditions (kWh)	Annual Energy Use Under Piping Alternative (kWh)	Reduced Annual Energy Use (kWh)[2]	Undiscounted Annual Energy Cost Savings	Average Annual Discounted NEE Benefits (Avoided Energy Costs)
Project Group 1	1,280,419	1,198,656	81,763	$4,000	$4,000
Total	**1,280,419**	**1,198,656**	**81,763**	**$4,000**	**$4,000**

Note: Totals may not sum due to rounding. Prepared January 2021
1/Price Base: 2020 dollars amortized over 100 years at a discount rate of 2.5 percent
2/As estimated by FCA (Farmers Conservation Alliance, 2020)

1.1.2.6 Avoided Infrastructure Failure Damages

The Arnold Main Canal has canal breaching and sinkhole incidents every year that develop as a result of the canal failing. Sinkholes form when water escapes a breach in the canal, erodes soil from underneath the surface, and eventually causes the surface to collapse. These sinkholes range in size from a softball to 8 feet by 6 feet (Willis, 2020). Between 1986 and 2018, property owners have claimed nearly $153,000 in damages associated with failures of the Arnold Main Canal.[29] There is the potential for much greater losses, as a major canal failure of the Arnold Main Canal could damage nearby properties that are valued in the millions of dollars (Willis, 2020).

Because these damages are caused solely by canal failures, the Piping Alternative would eliminate any future damages associated with the canal failures in the project area. To estimate the value of the damages avoided by the Piping Alternative, we estimate the average annual damage claim from 1986 to 2018 arising in the project area (based on data provided by the District) and assume this same annual average amount of damage would continue throughout the project life. As Table D-15 shows, the Piping Alternative would reduce damages from canal failures by an estimated $3,000 annually.

[29] These claims were made against AID and the Special Districts Association of Oregon (Willis, 2020). We adjusted each claim for inflation to 2020 dollars using the Consumer Price Index.

Table D-15. Annual Avoided Canal Failure Damage Costs of Piping Alternative, Deschutes Watershed, Oregon, 2020$. [1]

Works of Improvement	Undiscounted Average Annual Canal Failure Claims	Discounted Annualized Avoided Canal Failure Damages (Cost Savings)
Project Group 1	$3,000	$3,000
Total	**$3,000**	**$3,000**

Note: Totals may not sum due to rounding. Prepared January 2021
1/Price Base: 2020 dollars amortized over 100 years at a discount rate of 2.5 percent

In addition to the canal, failure of the flume also presents a risk of future damages that would be avoided by piping. The flume is susceptible to failure from wildfires, landslides, and aging materials (the flume was constructed around 70 years ago). If it were to fail, the flume could damage nearby residential property, adversely affect wildlife habitat, and degrade water quality in the Deschutes River, which runs adjacent to the flume. Furthermore, any failure of the flume would leave the entire District without irrigation water during the repair process. While the length of service interruption would depend on the type of failure and the availability of repair materials, a flume failure would likely leave the whole District without irrigation water for an entire growing season (Willis, 2020).

To value the benefit of avoiding a flume failure, we estimate the costs of 1) repairing the flume and 2) losing agricultural production in the District for one growing season. To estimate the cost of repairing the flume, this analysis uses the insurance premium that was offered to cover repairs in the event of flume failure (which conceptually reflects the insurance company's best assessment of the cost of potential repairs and likelihood of occurrence). In November 2019, an insurance company offered to cover damages on flume (that are not normal maintenance issues) of up to $4,599,436 for a premium of $17,750 annually (Willis, 2020). Accordingly, this analysis assumes the annualized cost of repairing a flume failure is around $17,750.

We estimate the costs to agricultural producers from two sources: the loss of revenues from losing one year of hay production, and the additional costs of prematurely re-establishing perennial hay crops (assuming that the hay crop would not survive without irrigation in the central Oregon climate). This analysis uses an enterprise budget method to model the costs and benefits of the 4,384 irrigated acres in the District.[30] Section 1.2 provides a detailed explanation of the enterprise budget method, which uses alfalfa hay to represent all irrigated land in the District. The results of the enterprise budgeting method indicate that the average acre of alfalfa hay costs $742 to establish in AID, and that preventing a flume failure and associated failure of all crops for one year results in avoided farms losses of approximately $288. We use these values to estimate the avoided costs to agricultural income of avoiding a flume failure.

The avoided cost economic values derived in this section must be weighted by the probability the loss would occur. Based on District input, this analysis assumes a 4 percent annual chance the flume would fail and cause the loss of an irrigation season prior to its removal under the No Action Alternative (Willis, 2020). Applying the 4 percent probability to each year prior to Year 20 (when the flume is likely to have been replaced) is equivalent to assuming there is a 49 percent chance the flume would fail prior to Year 14, and a decreasing probability in Years 15 to 20. To the extent that the actual probability is lower, this analysis would be overestimating the benefits of avoiding the failure; if the probability is actually higher, this analysis would provide an underestimate of the benefits.

30 Forage crops comprise 72 percent of the District's irrigated acres, while lawns and gardens make up the remaining 28 percent. (Willis, 2020).

Under a flume failure, we assume all hay crops die without irrigation and that the hay crop would need to be re-established in the following year, costing $742 per acre. We also assume no variable costs are incurred in the year of flume failure. Average stand life is 6-years, so we assume that on average, hay stands in the District are 3 years old and must be re-established 3 years earlier due to flume failure. This earlier re-establishment results in a $345-difference in present value costs between flume failure and piping. When annualized at a 2.5 percent discount rate and the 100-year project period, this difference has an annual value of $9 per acre. The annual value for all 4,384 acres in the District would be about $41,000. When multiplied by the annual probability of failure (4 percent), the value of avoiding additional establishment costs due to flume failure is approximately $1,700. For the lost agricultural revenues, the avoided loss in farm income per acre (just over $288 per acre) is applied to all 4,384 acres in the District, resulting in $1,264,000. Applying the annual probability of flume failure (4 percent) provides an estimate of the expected value of losing a year of farm income in the District: about $51,000.

Combining the cost of flume repairs and lost agricultural value generates an estimated annual value of roughly $70,000 to avoid a flume failure ($17,750 in repair costs, $1,700 in premature permanent crop re-establishment costs, and $51,000 in farm income losses). Under the No Action Alternative once the flume was piped, the discounted and amortized annual avoided costs of flume failure would total $45,000.

Under the Piping Alternative, the benefits of avoided flume failure would accrue each year the flume is piped under the Piping Alternative and not piped under the No Action Alternative. Accordingly, this analysis models $70,000 in benefits from Year 7 (when the flume is piped) to Year 14. Because this analysis assumes the flume has an equal probability of replacement from Year 15 to 20 under the No Action Alternative (as outlined in Section 1.1.1.3), the benefits of avoiding flume failure fall linearly from Year 15 to 20.[31] When discounted and annualized, the benefit of avoiding a flume failure under the Piping Alternative is $14,000 (summarized below in Table D-16).

Table D-16. Annual Avoided Flume Failure Damage Costs of Piping Alternative, Deschutes Watershed, Oregon, 2020$ [1]

Works of Improvement	Irrigated Acres	Undiscounted Annual Benefit of Avoided Flume Failure	Discounted Annualized Avoided Flume Failure Damages (Cost Savings)
Project Group 1	4,384	$70,000	$14,000
Total	**4,384**	**$70,000**	**$14,000**

Note: Totals may not sum due to rounding. Prepared January 2021
1/Price Base: 2020 dollars amortized over 100 years at a discount rate of 2.5 percent

1.1.3 Benefits Considered but Not Included in Analysis

1.1.3.1 Additional Agricultural Damage Reduction Benefits

While all conserved water under the Piping Alternative would go to NUID after Year 8, the Piping Alternative could reduce damage to District patrons' agricultural production through enhanced operational flexibility and efficiency and improved water quality (and not just through avoidance of flume failure, as estimated above). The District's antiquated canal and laterals make it difficult to deliver the correct amount of water to patrons at the correct time, particularly early and late in the irrigation season. During these periods, the District's water rights require it to divert water at a reduced rate. At these reduced flow rates, the canals

31 i.e., The annual benefits of $78,000 fall by $13,007 each year until they reach zero in Year 20.

and laterals are more sensitive to small changes in streamflow at the diversion or deliveries at each point of delivery. The reduced flow rates in the open canal and laterals make it much more challenging for the District to deliver the correct amount of water that patrons need when they need it. For example, a point of delivery near the end of a lateral may receive no water in the morning and excess water in the evening.

In addition to efficiency benefits, piping would also improve water quality, which could increase agricultural yields. In sections of the District that have been piped in the last 3 years, patrons on the piped laterals report that the delivered water is cleaner than the water delivered previously via earthen canal. This has resulted in increased crop yields, as well as fewer issues with silt in ponds and pumps plugging up (Willis, 2020). The Piping Alternative would likely bring similar benefits to patrons in other parts of the District. Although identified as potential benefits, current delivery and delivery capabilities after piping were not included in the analysis due to the limited amount of available data.

1.1.3.2 Public Safety Avoided Costs

Piping irrigation water removes the hazard of drownings in canals and eliminates the potential for earthen canals to fail, causing potential damages to downstream property and lives. While AID canal failure is very possible, the extent of damage varies dramatically depending on the timing and location of failure. A history of recent drownings in Central Oregon irrigation canals provides evidence that fast-moving water in irrigation canals, often with steep and slippery banks, can be a threat to public safety. In 2004, a toddler drowned in a Central Oregon Irrigation District canal; in 1996 and 1997, respectively, a 12-year-old boy and a 28-year-old man drowned in NUID canals (Flowers, 2004). Other drownings may have occurred in the past, as a comprehensive list of drownings in Central Oregon irrigation canals was not available from the Bureau of Reclamation or other sources. However, the data indicate at least three drownings over the last 21 years (1996 through 2016), or 0.143 death per year during this period. As the population in Central Oregon continues to grow and areas surrounding irrigation canals continue to urbanize, the risk to public safety would increase.

The Piping Alternative would pipe 12.2 miles of AID's open Main Canal. This section qualitatively discusses the potential magnitude of the public safety benefit of piping this section. The analysis presents some information on the potential public safety hazard of the existing unlined irrigation canals in AID proposed for piping (based on the recent history of drownings and the mileage of exposed canals).

Level of Public Safety Hazard

This analysis estimates the public safety hazard of open canals in AID based on past drownings in unpiped canals in Central Oregon. Based on data from the Oregon Water Resources Department (OWRD), there are 1,072 miles of irrigation canals in Central Oregon districts (see Table D-17). Starting in the late 1980s and early 1990s, sections of these canals began to be piped; today, the OWRD database records show that approximately 209 miles have been piped. Assuming piping occurred uniformly across the 21-year period from 1996 to 2016, approximately 9.9 miles were piped each year, leaving approximately 973 miles unpiped on an average annual basis during this period. Given that an average of 0.143 drowning death occurred annually during this period (3 deaths over 21 years as described above), the annual drowning risk per mile of exposed canal was 0.000147 (0.143 divided by 973). This may be an overestimate of risk if there were an abnormally high number of drownings in the last 20 years or so but may also be an underestimate of risk as the population of Bend continues to grow and the areas around irrigation canals continues to urbanize (thereby increasing the risks of drownings).

Under the No Action Alternative, AID would continue to have approximately 12.2 miles of unpiped canal. Assuming that the 3 drownings over the past 21 years are representative of future drowning risk, and that the 0.000147 death per mile of exposed canal experienced during this period is an appropriate estimate of future risk, the unpiped canals in AID carry a risk of 0.0018 death per year.

Table D-17. Irrigation Canal Mileage by District

District	Canal and Lateral Mileage
Arnold Irrigation District	47.3
Central Oregon Irrigation District	430.0
Lone Pine	2.4
North Unit Irrigation District	300.1
Ochoco Irrigation District	100.3
Swalley Irrigation District	27.6
Tumalo Irrigation District	95.8
Three Sisters Irrigation District	68.7
Total	**1,072.2**

Note: Totals may not sum due to rounding. Prepared January 2021
Source: OWRD, database maintained and provided by Jonathon LaMarche on March 9, 2017

1.1.4 Incremental Analysis

The Piping Alternative is evaluated using an incremental analysis, which identifies how total costs and benefits change as project phases are added (Table D-18). In the incremental analysis, the single project group is divided into five project phases of construction. The engineering pipeline design (pipe diameters, pressure ratings, etc.) is independent of the number of phases and the order that the phases are installed. In engineering the design of the system, the District and Black Rock Consulting mapped and collected digital elevation data to create a hydraulic model that determined pipe sizes for each pipeline (canal or lateral to be piped) in the system.

Table D-18. Incremental Analysis of Annual NEE Costs and Benefits Under the Modernization Alternative for AID, Deschutes Watershed, Oregon, 2020$.[1]

Project Groups	Total Costs	Incremental Costs	Total Benefits	Incremental Benefits	Net Benefits
1	$194,000		$620,000		$426,000
1,2	$562,000	$368,000	$1,302,000	$682,000	$740,000
1,2,3	$722,000	$160,000	$1,491,000	$189,000	$769,000
1,2,3,4	$877,000	$155,000	$1,675,000	$184,000	$798,000
1,2,3,4,5	$992,000	$115,000	$1,801,000	$126,000	$809,000

1/Price Base: 2020 dollars amortized over 100 years at a discount rate of 2.5 percent Prepared January 2021

1.1.5 References

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1.2 NEE Appendix

1.2.1 Crop Enterprise Budgets

This appendix presents the crop enterprise budgets used to estimate the benefits under the Piping Alternative of 1) avoiding agricultural damage to NUID (described in Section 1.1.2.1) and 2) a lost irrigation season due to a flume failure (described in Section 1.1.2.6). The analyses use a total of six crop budgets:

Table D-19. Summary of Crop Budgets

District	Scenario	Production Year	Budget Table
NUID	Deficit Irrigation	Year 1	Table D-20
		Years 2-6	Table D-21
	Full Irrigation	Year 1	Table D-22
		Years 2-6	Table D-23
AID	Full Irrigation Over No Irrigation	Years 2-6	Table D-24
	Full Irrigation	Establishment	Table D-25

The costs and benefits of agricultural production are estimated using an enterprise budget that represents typical costs and returns of producing crops in the Deschutes Watershed of Central Oregon. Enterprise budgets aim to reflect common practices and relevant costs for production in the region, but do not necessarily represent conditions of any particular farm. As a starting point for the crop budgets in this analysis, we used a crop budget for alfalfa hay developed by WSU and then adjusted values in the budget to account for changes in prices through time and local conditions in AID or NUID (depending on the budget). A more recent published alfalfa hay budget for Central Oregon was not available from Oregon State or WSU. The following section outlines the data and assumptions used in adjusting the Washington State alfalfa hay budget.

Under a flume failure scenario (described in Section 1.1.2.6), this analysis assumes that with total loss of irrigation water, growers in AID would still incur all fixed costs but would not pay for any of the variable costs associated with production (such as labor and inputs) and would not generate any revenues. Because the AID Production Budget (Table D-24) is used to represent the additional net returns from full irrigation versus no irrigation, costs that are common between both scenarios are excluded from the budget. These include all fixed costs (e.g., machinery depreciation, land costs, and establishment costs) and variable costs that would incur regardless of a water supply interruption (such as overhead expenses and irrigation District charges).

1.2.1.1 Alfalfa Enterprise Budgets

The alfalfa hay enterprise budgets were based on a 2012 budget developed by WSU for establishing and producing alfalfa hay in the Washington Columbia Basin (Norberg & Neibergs, 2012). We selected these budgets as the basis for AID and NUID crop production costs because they are the most recent crop budgets developed for producing alfalfa hay in an area that is relatively close to Central Oregon.

We updated the costs presented in the original budgets to account for changing values over time and to reflect conditions specific to AID or NUID (depending on the budget). Returns to alfalfa were based on average hay yields in the respective county (Deschutes County for AID and Jefferson County for NUID) and 5-year normalized average hay prices in Oregon.[32]

1.2.1.2 Modeled Farm

The modeled farm is 120 acres. The hay field is seeded in the fall following a grain crop such as wheat or barley and is harvested using 1-ton bales. Other than labor for irrigation, all labor is provided by hiring custom work (includes harvest, fertilizer application, and herbicide application). Irrigation is delivered by a center pivot.

1.2.1.3 Input Costs

For fertilizers in the non-establishment budgets, we adjust the amount used proportionally according to differences in yield from the original budget. For example, the original budget calls for 92 pounds (lb) of dry phosphate to produce 8 tons of hay per acre; in the AID Production Budget (Table D-24), we model a yield of only 4.1 tons per acre (51 percent of the original yield), so we reduce the amount of dry phosphate to 47 lb (51 percent of 92 lb). One exception to this method is the amount of dry sulfur applied, which is held constant at 30 lb per acre during production years per guidance from an OSU Extension Agent in Central Oregon (Bohle, 2020). The AID Establishment Budget (Table D-25) retains the fertilizer levels from the original budget.

All costs are adjusted from the original values in the WSU budget. We used area-specific values for fuel prices, irrigation charges, and land costs. For costs that did not have area-specific values, we adjusted the value in the original budget using the national Producer Price Indices (PPI) produced by the National Agricultural Statistics Services (NASS), which are published for a variety of farm expenses (NASS, 2020). For example, there are price indices for fertilizer, herbicides, supplies, tractors, custom work, as well as one for the farm sector in general. The PPI cost adjustments range from a 36 percent decrease in the price of Potash & Phosphorus to a 16 percent increase in Machinery costs.

For land costs in the establishment budget, we use NASS data on rental rates for irrigated cropland in the respective counties: $80 per acre in Deschutes County (for AID) and $121 per acre in Jefferson County (for NUID) (NASS, 2020).[33] Because alfalfa is seeded in the fall after another crop has been harvested, we only ascribe 25 percent of the land costs to establishing alfalfa.

1.2.1.4 Labor Costs

Because most of the labor is provided by custom work, the only direct labor costs are for irrigation labor. For the cost of this labor, we use the median hourly wage rate for the farmworkers occupation in Oregon in 2019 and adjust to 2020 dollars using the Consumer Price Index.[34] We further adjust this wage rate up by

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32 A normalized average is calculated by removing the highest and lowest values in a set of data and taking the mean of the remaining values.

33 For Deschutes County, we took the average price for irrigated cropland in the years 2010 to 2012, 2014, and 2016. Data from other years was not available. For Jefferson County, we took the normalized average price from 2011 to 2020. The normalized average is calculated by removing the high and low values from dataset and taking the mean of the remaining values.

34 This is the average wage for the Farmworkers and Laborers, Crop, Nursery, and Greenhouse (occupation code 45-2092) in the Central Oregon non-metropolitan area according to the Bureau of Labor Statistics' Occupational Employment and Wage Estimates data in May 2019 (Bureau of Labor Statistics, 2019).

20 percent to account for non-wage employment costs, such as health care and insurance.[35] This results in total labor costs of $16.95 per hour for irrigation labor.

We adjusted the cost of custom work using the Custom Work PPI. For the production budgets, we adjust some labor costs (including custom bailing, hauling, staking, and tarping) proportionally to the change in yield (e.g., if yield falls by 10 percent, the amount of labor also falls by 10 percent). To the extent that labor costs fall less than this, our results will under-estimate benefits (and vice versa). Management labor costs are estimated at 5 percent of total costs (following the original budget). Other custom labor, including swathing and raking, are adjusted based on the number of hay cuttings. The original budget modeled four cuttings; the AID Production Budget (Table D-24) models 2.5 cuttings based on District experience (Willis, 2020). The NUID Full Irrigation Budgets (Table D-22 and Table D-23) model 3 cuttings, while the NUID Deficit Irrigation Budgets (Table D-20 and Table D-21) model 2 cuttings.

1.2.1.5 Revenues

To estimate the gross revenues of alfalfa hay, we use the normalized average price per ton for alfalfa hay in Oregon from 2013 to 2019 according to NASS data: $195.20 (NASS, 2020). To estimate alfalfa yield the AID Production Budget (Table D-24), we use the average alfalfa yield in Deschutes County from 2014 to 2018 as reported by NASS: 4.1 tons per acre (NASS, 2020). For yields in NUID, we use the average yield in Jefferson County from 2013 to 2017: 5.4 tons per acre (NASS, 2020).

1.2.1.6 Alfalfa Enterprise Budget Tables

The tables below present alfalfa hay enterprise budgets used to estimate the costs and returns under different conditions (location and irrigation levels). As described above in Table D-24, only those revenues and costs under full irrigation that exceed those under lost irrigation are included in the budget.

[35] This is roughly the average proportion of non-wage labor costs for all private, part-time workers in the United States in December 2018 (Bureau of Labor Statistics, 2018).

Table D-20. Alfalfa Net Returns in NUID Under Deficit Irrigation, Production Year 1

Item	Quantity	Unit	$/Unit	Total
REVENUE				
Alfalfa Hay	4.06	ton	$195.20	$792.39
VARIABLE COSTS				
Dry Nitrogen	0.0	pound	$0.34	$0.00
Dry Phosphate	0.0	pound	$0.63	$0.00
Dry Potash	0.0	pound	$0.45	$0.00
Dry Sulfur	0.0	pound	$0.20	$0.00
Custom - Swath	2.0	acre	$23.22	$46.45
Custom - Rake	2.0	acre	$11.61	$23.22
Custom - Bail	4.1	ton	$19.74	$80.13
Custom - Haul & Stack	4.1	ton	$10.45	$42.42
Custom - Tarping	4.1	ton	$5.81	$23.57
Irrigation - power	1.0	acre	$45.09	$45.09
Irrigation - water access	1.0	acre	$3.10	$3.10
Irrigation - repairs	1.0	acre	$16.88	$16.88
Irrigation - labor	0.5	acre	$16.95	$8.47
Gopher control	1.0	acre	$5.72	$5.72
Fuel	2.3	gallon	$2.69	$6.13
Lubricants	1.0	acre	$0.92	$0.92
Machinery repairs	1.0	acre	$2.03	$2.03
Haystack Insurance	4.1	ton	$1.80	$7.33
Overhead	1.0	acre	$28.79	$28.79
Operating interest	1.0	acre	$8.51	$8.51
Total variable costs				$348.75
FIXED COSTS				
Machinery depreciation	1.0	acre	$6.37	$6.37
Machinery interest	1.0	acre	$3.66	$3.66
Machinery insurance, taxes, housing, license	1.0	acre	$2.52	$2.52
Management (5% of total cost)	1.0	acre	$24.13	$24.13
Establishment cost	1.0	acre	$93.82	$93.82
Land cost	1.0	acre	$121.20	$121.20
Total fixed costs				$251.70
Total costs				$600.45
NET RETURNS PER ACRE				**$191.94**

Table D-21. Alfalfa Net Returns in NUID Under Deficit Irrigation, Production Years 2-6

Item	Quantity	Unit	$/Unit	Total
REVENUE				
Alfalfa Hay	4.06	ton	$195.20	$792.39
VARIABLE COSTS				
Dry Nitrogen	0.0	pound	$0.34	$0.00
Dry Phosphate	46.7	pound	$0.63	$29.22
Dry Potash	71.0	pound	$0.45	$31.62
Dry Sulfur	30.0	pound	$0.20	$6.01
Zinc	2.5	pound	$2.03	$5.16
Boron	1.0	pound	$4.58	$4.65
Custom Application	1.0	acre	$10.45	$10.45
Soil Test	1.0	acre	$0.35	$0.35
Herbicide	2.0	pound	$16.97	$33.93
Custom Application	1.0	acre	$10.45	$10.45
Custom - Swath	2.0	acre	$23.22	$46.45
Custom - Rake	2.0	acre	$11.61	$23.22
Custom - Bail	4.1	ton	$19.74	$80.13
Custom - Haul & Stack	4.1	ton	$10.45	$42.42
Custom - Tarping	4.1	ton	$5.81	$23.57
Irrigation - power	1.0	acre	$50.73	$50.73
Irrigation - water access	1.0	acre	$3.10	$3.10
Irrigation - repairs	1.0	acre	$16.88	$16.88
Irrigation - labor	0.4	acre	$16.95	$6.35
Haystack insurance	4.1	ton	$1.80	$7.33
Gopher control	1.0	acre	$5.72	$5.72
Fuel	2.3	gallon	$2.69	$6.13
Lubricants	1.0	acre	$0.92	$0.92
Machinery repairs	1.0	acre	$2.03	$2.03
Overhead	1.0	acre	$43.34	$43.34
Operating interest	1.0	acre	$12.25	$12.25
Total variable costs				$502.41
FIXED COSTS				
Machinery depreciation	1	acre	$6.37	$6.37
Machinery interest	1	acre	$3.66	$3.66
Machinery insurance, taxes, housing, license	1	acre	$2.52	$2.52
Management (5% of total cost)	1	acre	$36.50	$36.50
Establishment cost	1	acre	$93.82	$93.82
Land cost	1	acre	$121.20	$121.20
Total fixed costs				$264.07
Total costs				$766.49
NET RETURNS PER ACRE				**$25.90**

Table D-22. Alfalfa Net Returns in NUID Under Full Irrigation, Production Year 1

Item	Quantity	Unit	$/Unit	Total
REVENUE				
Alfalfa Hay	5.4	ton	$195.20	$1,056.52
VARIABLE COSTS				
Dry Nitrogen	0.0	pound	$0.34	$0.00
Dry Phosphate	0.0	pound	$0.63	$0.00
Dry Potash	0.0	pound	$0.45	$0.00
Dry Sulfur	0.0	pound	$0.20	$0.00
Custom - Swath	3.0	acre	$23.22	$69.67
Custom - Rake	3.0	acre	$11.61	$34.83
Custom - Bail	5.4	ton	$19.74	$106.84
Custom - Haul & Stack	5.4	ton	$10.45	$56.56
Custom - Tarping	5.4	ton	$5.81	$31.42
Irrigation - power	1.0	acre	$45.09	$45.09
Irrigation - water access	1.0	acre	$3.10	$3.10
Irrigation - repairs	1.0	acre	$16.88	$16.88
Irrigation - labor	0.5	acre	$16.95	$8.47
Gopher control	1.0	acre	$5.72	$5.72
Fuel	2.3	gallon	$2.69	$6.13
Lubricants	1.0	acre	$0.92	$0.92
Machinery repairs	1.0	acre	$2.03	$2.03
Haystack Insurance	5.4	ton	$1.80	$9.77
Overhead	1.0	acre	$28.79	$28.79
Operating interest	1.0	acre	$10.66	$10.66
Total variable costs				$436.89
FIXED COSTS				
Machinery depreciation	1.0	acre	$6.37	$6.37
Machinery interest	1.0	acre	$3.66	$3.66
Machinery insurance, taxes, housing, license	1.0	acre	$2.52	$2.52
Management (5% of total cost)	1.0	acre	$28.53	$28.53
Establishment cost	1.0	acre	$93.82	$93.82
Land cost	1.0	acre	$121.20	$121.20
Total fixed costs				$256.11
Total costs				$692.99
NET RETURNS PER ACRE				**$363.53**

Table D-23. Alfalfa Net Returns in NUID Under Full Irrigation, Production Years 2-6

Item	Quantity	Unit	$/Unit	Total
REVENUE				
Alfalfa Hay	5.4	ton	$195.20	$1,056.52
VARIABLE COSTS				
Dry Nitrogen	0.0	pound	$0.34	$0.00
Dry Phosphate	62.2	pound	$0.63	$38.96
Dry Potash	94.7	pound	$0.45	$42.16
Dry Sulfur	30.0	pound	$0.20	$6.01
Zinc	3.4	pound	$2.03	$6.88
Boron	1.4	pound	$4.58	$6.20
Custom Application	1.0	acre	$10.45	$10.45
Soil Test	1.0	acre	$0.35	$0.35
Herbicide	2.0	pound	$16.97	$33.93
Custom Application	1.0	acre	$10.45	$10.45
Custom - Swath	3.0	acre	$23.22	$69.67
Custom - Rake	3.0	acre	$11.61	$34.83
Custom - Bail	5.4	ton	$19.74	$106.84
Custom - Haul & Stack	5.4	ton	$10.45	$56.56
Custom - Tarping	5.4	ton	$5.81	$31.42
Irrigation - power	1.0	acre	$50.73	$50.73
Irrigation - water access	1.0	acre	$3.10	$3.10
Irrigation - repairs	1.0	acre	$16.88	$16.88
Irrigation - labor	0.5	acre	$16.95	$8.47
Haystack insurance	5.4	ton	$1.80	$9.77
Gopher control	1.0	acre	$5.72	$5.72
Fuel	2.3	gallon	$2.69	$6.13
Lubricants	1.0	acre	$0.92	$0.92
Machinery repairs	1.0	acre	$2.03	$2.03
Overhead	1.0	acre	$43.34	$43.34
Operating interest	1.0	acre	$15.05	$15.05
Total variable costs				$616.86
FIXED COSTS				
Machinery depreciation	1.0	acre	$6.37	$6.37
Machinery interest	1.0	acre	$3.66	$3.66
Machinery insurance, taxes, housing, license	1.0	acre	$2.52	$2.52
Management (5% of total cost)	1.0	acre	$42.22	$42.22
Establishment cost	1.0	acre	$93.82	$93.82
Land cost	1.0	acre	$121.20	$121.20
Total fixed costs				$269.80
Total costs				$886.65
NET RETURNS PER ACRE				**$169.87**

Table D-24. Net Returns to Alfalfa Under Full Irrigation Above Those Under Flume Failure, AID

Item	Quantity	Unit	$/Unit	Total
REVENUE				
Alfalfa Hay	4.1	ton	$195.20	$800.32
VARIABLE COSTS				
Dry Phosphate	47.2	pound	$0.63	$29.51
Dry Potash	71.8	pound	$0.45	$31.93
Dry Sulfur	30.0	pound	$0.20	$6.01
Zinc	2.6	pound	$2.03	$5.21
Boron	1.0	pound	$4.58	$4.70
Custom Application	1.0	acre	$10.45	$10.45
Soil Test	1.0	acre	$0.35	$0.35
Herbicide	2.0	pound	$16.97	$33.93
Custom Application	1.0	acre	$10.45	$10.45
Custom - Swath	2.5	acre	$23.22	$58.06
Custom - Rake	2.5	acre	$11.61	$29.03
Custom - Bail	4.1	ton	$19.74	$80.93
Custom - Haul & Stack	4.1	ton	$10.45	$42.85
Custom - Tarping	4.1	ton	$5.81	$23.80
Irrigation - power	1.0	acre	$50.73	$50.73
Irrigation - repairs	1.0	acre	$16.88	$16.88
Irrigation - labor	0.5	acre	$16.95	$8.47
Haystack insurance	4.1	ton	$1.80	$7.40
Gopher control	1.0	acre	$5.72	$5.72
Fuel	2.3	gallon	$2.65	$6.04
Lubricants	1.0	acre	$0.92	$0.92
Machinery repairs	1.0	acre	$2.03	$2.03
Overhead	1.0	acre	$34.17	34.17
Operating interest	1.0	acre	$12.49	$12.49
Total variable costs				$512.06
Total additional costs due to production (excludes costs that would be incurred even with flume failure)				$512.06
ADDITIONAL NET RETURNS PER ACRE				**$288.26**

Table D-25. Costs to Establish Alfalfa, AID

Item	Quantity	Unit	$/Unit	Total
VARIABLE COSTS				
Seed	20.0	pound	$4.30	$85.91
Custom - seeding	1.0	acre	$20.90	$20.90
Dry Nitrogen	0.0	pound	$0.34	$0.00
Dry Phosphate	92.0	pound	$0.63	$57.58
Dry Potash	140.0	pound	$0.45	$62.31
Dry Sulfur	25.0	pound	$0.20	$5.01
Zinc	5.0	pound	$2.03	$10.17
Boron	2.0	pound	$4.58	$9.16
Custom Application	1.0	acre	$10.45	$10.45
Herbicide - Raptor	6.0	ounce	$5.70	$34.20
Custom - herbicide application	1.0	acre	$10.45	$10.45
Soil Test	1.0	acre	$0.35	$0.35
Custom - Disc & Pack (2x)	1.0	acre	$58.06	$58.06
Irrigation - power	0.4	acre	$45.09	$16.23
Irrigation - water access	1.0	acre	$217.97	$217.97
Irrigation - repairs	0.4	acre	$16.88	$6.08
Irrigation - labor	0.2	acre	$22.39	$4.03
Fuel	2.5	gallon	$2.65	$6.63
Lubricants	1.0	acre	$1.40	$1.40
Machinery repairs	1.0	acre	$2.52	$2.52
Machinery labor	0.25	acre	$22.39	$5.60
Overhead	1.0	acre	$31.25	$31.25
Operating interest	1.0	acre	$16.41	$16.41
Total variable costs				$672.66
FIXED COSTS				
Machinery depreciation	1.0	acre	$7.44	$7.44
Machinery interest	1.0	acre	$5.04	$5.04
Machinery insurance, taxes, housing, license	1.0	acre	$2.03	$2.03
Management (5% of total cost)	1.0	acre	$35.35	$35.35
Land cost	1.0	acre	$19.93	$19.93
Total fixed costs				$69.80
TOTAL COSTS PER ACRE				**$742.45**

D.2 Alternatives Considered During Formulation

This section presents the alternatives considered in the formulation phase.

During the formulation phase, alternatives were evaluated based on meeting both National Environmental Policy Act (NEPA) and environmental review requirements specific to NRCS federal investments in water resources projects (PR&G) (Table D-26). According to NEPA, "agencies shall rigorously explore and objectively evaluate all reasonable alternatives" (40 Code of Federal Regulations 1502.14). According to the PR&G DM9500-013 (USDA 2017), alternatives should reflect a range of scales and management measures and be evaluated against the Federal Objective and Guiding Principles; against the extent to which they address the problems and opportunities identified in the purpose and need; and against the criteria of completeness, effectiveness, efficiency, and acceptability.

1. Completeness is the extent to which an alternative provides and accounts for all features, investments, and/or other actions necessary to realize the planned effects, including any necessary actions by others. It does not necessarily mean that alternative actions need to be large in scope or scale.
2. Effectiveness is the extent to which an alternative alleviates the specified problems and achieves the specified opportunities.
3. Efficiency is the extent to which an alternative alleviates the specified problems and realizes the specified opportunities at the least cost.
4. Acceptability is the viability and appropriateness of an alternative from the perspective of the Nation's general public and consistency with existing federal laws, authorities, and public policies. It does not include local or regional preferences for particular solutions or political expediency.

Alternatives that were eliminated during formulation are shown in the table and further discussed below. Alternatives selected for further evaluation are discussed in the Plan-EA.

Table D-26. Alternatives Considered During the Formulation Phase.

Alternative	Which criteria in the PR&G does the alternative achieve?				Selected for Further Evaluation
	Completeness	Effectiveness	Efficiency	Acceptability	
Conversion to Dryland Farming			X		
Fallowing Farm Fields			X		
Voluntary Duty Reduction			X		
Partial Use of Groundwater					
On-Farm Efficiency Upgrades		X		X	
Canal Lining	X	X		X	X

Alternative	Which criteria in the PR&G does the alternative achieve?				Selected for Further Evaluation
	Completeness	Effectiveness	Efficiency	Acceptability	
No Action (Future without Federal Investment)			X		X
Piping Alternative	X	X	X	X	X

2.1 Conversion to Dryland Farming

Dryland farming is a non-structural alternative. This method of farming uses no irrigation and drought-resistant crops and practices to conserve moisture. The lack of rainfall throughout the growing season coupled with hot temperatures, desiccating winds, and generally shallow and well- to excessively drained soils with low storage potential, makes dryland farming infeasible within the District (Daly et al. 1994; Gannett et al. 2001). In the District, agricultural production would substantially decrease if dryland farming were implemented. With decreased production and income, farmers could potentially sell their land due to the development pressure Deschutes County is experiencing. Dryland farming would be inconsistent with ensuring agricultural production is maintained in an area undergoing rapid urbanization.

Conversion to dryland farming would not meet any of the purposes of the project. If water saved from conversion to dryland farming was put instream, it could meet the need of improving instream flow for fish and aquatic habitat, but this is not certain to occur because conversion to dryland farming would be voluntary, and any water saved would not necessarily be put in stream by the patrons. Conversion to dryland farming would not meet any of the other identified project needs.

Conversion to dryland farming was eliminated from further evaluation because it would not meet the project's purpose and need; its effectiveness would be uncertain since conversion to dryland farming would be voluntary; it would not be acceptable because it is inconsistent with public policy supporting and maintaining existing agricultural land use; and because it would not achieve the Federal Objective and Guiding Principles.

2.2 Fallowing Farm Fields

Fallowing farm fields is a non-structural alternative that includes permanently transferring or temporarily leasing water rights from irrigated lands or otherwise not using water rights appurtenant to irrigated lands. Fallowing farm fields would use less irrigation water within the District and would therefore allow more water to remain instream for fish, wildlife, and habitat.

Fallowing farm fields would not meet any of the project purposes. If water saved from fallowing was put instream, it could meet the need of improving instream flow for fish and aquatic habitat, but this is not certain to occur because fallowing would be voluntary, and any water saved would not necessarily be put instream by the patrons. Fallowing farm fields would not meet any of the other identified needs of the project.

Fallowing farm fields was eliminated from further evaluation because: it would not meet the project's purpose and need; its effectiveness would be uncertain since fallowing fields would be voluntary; it would not be acceptable because it is inconsistent with public policy supporting and maintaining existing agricultural land use; and because it would not achieve the Federal Objective and Guiding Principles.

2.3 Voluntary Duty Reduction

Voluntary duty reduction refers to patrons voluntarily accepting less than their full water delivery rate from the District. A reduction in duty could mean the District diverts less water, which would leave more water instream. This water would not be permanently protected instream through a new instream water right.

Voluntary duty reduction would not meet any of the project purposes. If water saved from duty reduction was put instream, it could meet the need of improving instream flow for fish and aquatic habitat, but this is not certain to occur because duty reduction would be voluntary, and any water saved would not necessarily be put instream by the patrons. Voluntary duty reduction would not meet any of the other identified needs of the project. Voluntary duty reduction was eliminated from further evaluation because it would not meet the project's purpose and need; its effectiveness would be uncertain since duty reduction would be voluntary; it would not be acceptable because it is inconsistent with public policy supporting and maintaining existing agricultural land use; and because it would not achieve the Federal Objective and Guiding Principles.

2.4 Exclusive or Partial Use of Groundwater

The exclusive or partial conversion from surface water sourced to groundwater sourced irrigation were also initially considered as possible alternatives. To use groundwater in the Deschutes Basin, the District would have to apply for groundwater rights under OWRD's Deschutes Basin Groundwater Mitigation (DBGM) program pursuant to OAR 690-505-0500. The DBGM program is part of OWRD's goal to limit groundwater use by imposing restrictions to new users obtaining groundwater rights. Under the DBGM program, only 16.65 cfs[36] is available for the whole Deschutes Basin, and it is unlikely the District could obtain rights to all the remaining water (S. Henderson, personal communication, March 11, 2021). Given only 16.65 cfs is available under this program, the District's exclusive use of groundwater to entirely replace their use of surface water is not feasible.

The partial use of groundwater for irrigation would have logistical and legal constraints. The District and patrons could use their surface water rights for groundwater mitigation credits[37] required by the DBGM program; however, the District would need the authority from each patron to convert surface rights to groundwater rights; there would be no guarantee of gaining this approval from patrons. Converting from surface water rights to groundwater rights would also affect the seniority and, therefore, the reliability of the District's water rights. The District currently has 1905 surface water rights that minimize the chance of being impacted during drought years; however, new groundwater rights would be junior (dated the year of the application and construction) and could be subject to curtailment.

Exclusive and partial use of groundwater would not meet any of the purposes of the project. If water saved from conversion to groundwater was put instream, it could meet the need of improving instream flow for fish and aquatic habitat, but this is not certain to occur because switching to groundwater would be voluntary, and any water saved would not necessarily be put instream by patrons. Partially or exclusively switching to groundwater would not meet any of the other identified needs of the project. Additionally, the District lacks the statutory authority or responsibility to carry out, operate, and maintain groundwater wells on private lands owned by AID patrons. Therefore, carrying out this alternative would be logistically complex. The exclusive and partial use of groundwater was eliminated from further evaluation because it would not meet the project's purpose and need; its effectiveness would be uncertain as conversion to groundwater would be voluntary; inefficiencies associated with logistical and legal constraints obtaining groundwater rights; low acceptability

[36] Currently OWRD has 40.9 cfs left under the 200 cfs cap; however, they have pending applications with the amount of 25.24 cfs. Although there is no guarantee that these applications will be approved or processed, it is suggested that the cap would be at 16.65 cfs remaining (S. Henderson, personal communication, March 11, 2021).
[37] AID would not create groundwater mitigation credits under either the No Action or the Piping Alternatives analyzed in this Plan-EA.

since converting to groundwater rights would result in junior water rights; and because it would not achieve the Federal Objective and Guiding Principles.

2.5 On-Farm Efficiency Upgrades

On-farm efficiency upgrades refer to AID patrons upgrading their on-farm infrastructure to use irrigation technologies that provide a more precise application of water. On-farm infrastructure is distinct from District canals and laterals because it is owned and operated by patrons. All irrigated lands within the District use sprinklers to apply water (hand move lines, side roll wheel lines, solid sets, and a few semi-big guns). Approximately 30 percent either are solid set sprinklers using portable hand lines or buried laterals. Approximately 10 percent of the solid set systems use automated timers (AID 2013). Each irrigation system has a different application efficiency (i.e., its ability to deliver the irrigation water to the crop root system across the full field being irrigated).

On-farm efficiency upgrades would not meet any of the purposes of the project. If water saved from upgrades was put instream, it could meet the need of improving instream flow for fish and aquatic habitat, but this is not certain to occur because upgrading on-farm systems would be voluntary, and any water saved would not necessarily be put instream by the patrons. On-farm efficiency upgrades would not meet any of the other identified needs of the project. Water losses would still occur through seepage; the Main Canal would remain open; water delivery reliability would not be improved due to operational efficiencies; and public safety would remain an issue.

On-farm upgrades and piping private laterals are not within the scope of actions that AID can entertain as the project sponsor under PL 83-566 because AID lacks the authority or responsibility to carry out, operate, and maintain on-farm infrastructure owned and operated by AID patrons.

In addition, if PL 83-566 funds were used to develop and implement on-farm efficiency upgrades, the use of these funds would require the District to complete a State Historic Preservation Office / National Historic Preservation Office analysis on a tax lot-by-tax lot basis,[38] as well as receive permission to then operate and maintain the system, including acquiring easements to do so. This approach is logistically complex and would increase project costs.

On-farm efficiency upgrades were eliminated from further evaluation because it would not meet the project's purpose and need; its effectiveness would be uncertain as any water saved would not necessarily be put in stream by patrons; and because it did not achieve the Federal Objective and Guiding Principles.

References

Henderson, Sarah (ORWD). 2021. Personal Communication with Amanda Schroeder (FCA). March 11.

[38] This could require AID to mitigate cultural resources on private property, potentially resulting in the District having to develop long-term maintenance or preservation agreements on lands not subject to District control.

D.3 Capital Costs

3.1 Canal Lining Alternative Costs

The capital cost of the Canal Lining Alternative (Table D-27) was estimated by calculating the length of geotextile membrane for existing open canals, assuming an anchor of membrane extending 7 feet on either side. The membrane would be covered by a 1-inch layer of shotcrete (fine-aggregate concrete sprayed in place). This estimate also includes fencing along both sides of the canal, and safety ladders every 750 feet in channels deeper than 2.5 feet. Costs related to earthwork and labor are estimated by a construction cost multiplier of 2. Turnouts were estimated using the same assumptions as the piping alternative. The cross-section dimensions for lining the canals were calculated for each corresponding pipe diameter size using transects on a digital elevation model estimated from an irrigation district in Central Oregon. Since it is not practical to replace the existing flume (both ground level and aerial) with a lined canal, the same costs are used for this section as the Preferred Alternative.

Table D-27. Canal Lining Alternative Costs.

Feature	Diameter (inch)	Quantity	Units	Cross section to be lined (foot)	Channel width (foot)	Geomembrane total ($)	Shotcrete total ($)	Fencing total ($)	Ladder total ($)	Subtotal[1]
Lining	48	15,875	Foot	25.9	4.4	$538,136	$2,259,683	$217,805	$10,583	$6,052,415
Lining	54	11,028	Foot	25.9	4.4	$373,831	$1,569,750	$151,304	$7,352	$4,204,474
Lining	63	37,586	Foot	34.4	3.9	$1,545,900	$7,108,760	$515,680	$25,057	$18,390,795
Turnout	N/A	88	Each	N/A	N/A	N/A	N/A	N/A	N/A	$704,000
4,945 feet buried HDPE pipe to replace flume										$2,439,000
450 feet aerial HDPE/steel pipe to replace flume										$1,550,000
Subtotal										**$33,340,684**
Engineering, Construction Management, Survey (3%)										$1,000,213
Construction Management / General Contractor (10%)										$3,334,043
Contingency (30%)[2]										$11,302,405
TOTAL										**$48,977,000**

Total is rounded to nearest $1,000.
[1] Includes a construction cost multiplier of 2 for installation.
[2] Contingency is higher than contingency in the Preferred Alternative to account for unknown costs related to canal lining engineering and materials.

3.2 Piping Alternative/Preferred Alternative Costs

This section presents capital costs for the Piping Alternative, which is identified as the Preferred Alternative (Table D-28). In addition to the pipe cost, the cost estimate also includes other necessary appurtenances.

A wide variety of materials are available for piping; availability of piping materials, prices, and new products change over time. Materials that could be used for the Piping Alternative include, but are not limited to, polyvinyl chloride, steel, HDPE bar-wrapped concrete cylinder, fiberglass, and ductile iron. For costing this alternative, the price of HDPE and steel was used.

At the time of project implementation, the specific piping material would be selected based on a number of considerations: the cost of the project would meet the NEE requirements, meet construction requirements, be appropriate based on local conditions and risk factors, and result in a no or minor change to project effects described in Section 6 of Plan-EA, as determined through the tiered decision framework approach outlined in Section 1.4. The NRCS State Conservationist and the Sponsoring Local Organization would possess the final discretion to select the appropriate piping material.

Table D-28. Preferred Alternative Costs.

Feature	Diameter (inch)	Quantity	Units	Unit Cost	Subtotal[1]
Pipe	48	15,875	Foot	$123	$4,604,868
Pipe	54	11,028	Foot	$156	$3,842,780
Pipe	63	42,531	Foot	$213	$20,736,661
Turnout	N/A	88	Each	$8,000	$704,000
Energy Dissipater	48	1	Each	$75,000	$75,000
Energy Dissipater	16	1	Each	$15,000	$15,000
Energy Dissipater	10	2	Each	$10,000	$20,000
Energy Dissipater	8	1	Each	$5,000	$5,000
				450 feet aerial pipe	$1,550,000
				Subtotal	**$31,553,309**
				Engineering, Construction Management, Survey (3%)	$946,599
				Construction Management / General Contractor (10%)	$2,884,558
				Contingency (10%)	$3,538,447
				TOTAL	**$38,923,000**

Total is rounded to nearest $1,000.
[1]Includes a variable construction cost multiplier for installation.

D.4 Net Present Value of the Preferred Alternative and the Canal Lining Alternative

This section presents the estimated net present value of the Preferred Alternative and the Canal Lining Alternative. This analysis compares installation and operation of pipes and canals only.

Discount Rate: 2.5%

Period of Analysis: 100 years

Table D-29. Net Present Value of the Preferred Alternative and the Canal Lining Alternative.

	Preferred Alternative	Canal Lining Alternative[1]
Design Life (years)	100	33
Capital Costs	$38,923,000	$48,977,000
Net Present Value of Replacement Costs[1]	$0	$29,985,000
Annual O&M Costs	$38,000	$56,000
Percent Change in O&M	-15%	25%
Net Present Value of O&M Costs	$1,291,000	$1,902,000
Total Net Present Value of Project	**$40,214,000**	**$80,864,000**

1 For canal lining, 100 percent was replaced at both 33 years and 66 years.

Appendix E

Other Supporting Information

E.1 Intensity Threshold Table

This section presents the intensity threshold table used to quantify effects to resources of concern because of the proposed action.

Table E-1. Intensity Threshold Table for the Arnold Irrigation District Infrastructure Modernization Project.

Negligible	Changes in the resource or resource related values would be below or at the level of detection. If detected, the effects on the resource or environment would be considered slight with no perceptible impacts.
Minor	Changes in resource or resource related values would be measurable but small. The effects on the resource or the environment would be localized.
Moderate	Changes in the resource or resource related values would be measurable and apparent. The effects on the resource or the environment would be relatively local.
Major	Changes in resource or resource related values would be measurable and substantial. The effects on the resource or the environment would be regional.
Impact Duration Definitions	
Temporary	Transitory effects, which only occur over a period of days or months
Short-term effect	Resource or resource related values recover in fewer than 5 years
Long-term effect	Resource or resource related values take greater than 5 years to recover

E.2 Supporting Information for Soil Resources

Table E-2. Project Area Length Crossing Farmland.

NRCS Farmland Class	Project Area (percent)	Project Area (miles)
Prime farmland if irrigated	1%	0.2
No digital data available	4%	0.5
Farmland of statewide importance	91%	12
Not prime farmland	4%	0.5
Total	**100%**	**13.2**

Source: NRCS gSSURGO FY2018 data

E.3 Supporting Information for Vegetation Resources

The Deschutes County Noxious Weed Policy and Classification System designates three weed categories. "A" designated weeds are of highest priority for control and are subject to intensive eradication, containment, or control measures using county resources. "B" designated weeds have a limited distribution; intensive containment control and monitoring by landowners is required, and support from the County is provided when resources allow. "C" designated weeds are the lowest priority for control. They have a widespread distribution; landowner control and monitoring is recommended (Deschutes County 2017). The following table lists the noxious weeds and corresponding classifications known to occur in the project area.

Table E-3. Noxious Weeds Occurring in the Project Area.

Vegetation Species	Scientific Name	Deschutes County Noxious Weed Rating
Buffalobur	*Solanum rostratum*	A
Bull thistle	*Cirsium vulgare*	C
Canada Thistle	*Cirsium arvense*	B
Cheatgrass	*Bromus tectorum*	C
Common mullein	*Verbascum thapsus*	C
Dalmation Toadflax	*Linaria dalmatica*	B
Diffuse knapweed	*Centaurea diffusa*	B
Eurasian Milfoil	*Myriophyllum spicatum*	A
Hoary Alyssum	*Berteroa incana*	A
Hydrilla	*Hydrilla verticillate*	A
Kochia	*Kochia scoparia*	B
Leafy Spurge	*Euphorbia esula*	A
Mediterranean Sage	*Salvia aethiopis*	A

Vegetation Species	Scientific Name	Deschutes County Noxious Weed Rating
Medusahead Rye	*Taeniatherum caput-medusea*	A
Myrtle Spurge	*Euphorbia myrsinites*	B
Orange Hawkweed	*Hieracium aurantiacum*	A
Perennial Pepperweed	*Lepidium latifolium*	A
Poison hemlock	*Conium maculatum*	B
Puncturevine	*Tribulus terrestris*	B
Purple Loosestrife	*Lythrum salicaria*	A
Ribbon Grass	*Phalaris arundinacea var. picta*	B
Russian knapweed	*Acroptilon repens*	A
Russian thistle	*Salsola spp.*	B
Saltcedar Tamarix	*Tamarix ramosissima*	A
Scotch Thistle	*Onopordum acanithum*	A
Spotted knapweed	*Centaurea stoebe*	B
Tansy Ragwort	*Senecio jacobaea*	A
Ventenata	*Ventenata dubia*	A
Whitetop; Hoary Cress	*Lepidium draba*	A
Wild Carrot	*Daucus carota*	A
Yellowflag iris	*Iris pseudacorus*	B
Yellow Floating Heart	*Nymphoides spp.*	A
Yellow Toadflax	*Linaria vulgaris*	B

Source: Arnold Irrigation District Small Grant Program Application 2015-2017
DSWCD Upland Vegetation Grant

References

Deschutes County. (2017). Deschutes County Noxious Weed List. Retrieved from https://www.deschutes.org/sites/default/files/fileattachments/road/page/567/deschutes_county_weed_list_updated_2017.pdf

E.4 Supporting Information for Water Resources

E.4.1 Water Loss Information

This appendix section presents the methodology and data used to evaluate the potential effects of the Preferred Alternative on water resources. Data used is from the Arnold Irrigation District System Improvement Plan (Crew 2017) and a follow-up water loss study by OWRD in 2020.

In 2016, Black Rock Consulting worked with the District to coordinate a seepage loss study performed by Farmers Conservation Alliance staff under direction from Black Rock Consulting/Kevin L. Crew, P.E and David C. Prull, P.E. During the summer of 2016, the Seepage Loss Assessment Program (LAP), supported by Oregon State University and the Oregon Water Resources Department, was implemented in 7 of the 8 Central Oregon irrigation districts, including AID, to inform the districts of current system losses. The program included the use of newly purchased and calibrated Sontek Flowtracker II technology, manual, and office and field training, all in accordance with the U.S. Geological Survey and U.S. Bureau of Reclamation. The program was managed by Oregon Registered Professional Engineers, Kevin L. Crew, P.E., and David C. Prull, P.E.

The primary purpose of the LAP was to perform a one-time measurement program in each District. The program provided the approximate seepage losses in elements of each system. The measurements were performed at different times of the irrigation season within each District. Therefore, the percentage of peak flow at the time of measurement varied by District as the LAP team entered, measured, and exited each District. The results were used to provide a strong indication of losses. The results were interpolated or extrapolated based upon the maximum expected loss within each District. The final loss information was used to identify losses by project phase or lateral. This loss information was then validated through a follow-up loss assessment performed by OWRD in 2020.

For AID, the LAP was implemented throughout the District's primary Main Canal and system laterals. Direct measurements identified a total seepage loss of approximately 46 cfs in the District's system. Seepage loss in the Main Canal was measured at 32.5 cfs (Table E-4).[39]

Table E-4. Arnold Irrigation District Seepage Loss in the Project Area.

	Measured Seepage Loss[1]			
	Main Canal – Tail End (cfs)	**Main Canal – Mid Section (cfs)**	**Main Canal – Upper (cfs)**	**Total (cfs)**
Seepage Loss	11.2	9.2	12.1	32.5

[1] While water loss must be initially calculated in cfs, the total volume of water lost through the season in the Main Canal was calculated to be 10,527 acre-feet.

[39] This water loss value reflects water lost in the 12.2-mile-long earthen section of the Main Canal. Water loss in the 1-mile-long flume has not been measured and is therefore not included in total water loss values. Due to the flume's close proximity to the Deschutes River, water lost from the flume likely returns to the river.

E.4.2 Instream Flow Targets

This section presents supporting calculations used when evaluating effects of the proposed action with respect to water resources.

Table E-5. Monthly Instream Flow Targets for the Deschutes River.

Source	From	To	Certificate	Priority Date	Instream Rates (cfs)											
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Deschutes River	Crane Prairie Reservoir	Wickiup Reservoir	73233	10/11/1990	130	130	130	130	130	130	130	130	130	130	130	130
Deschutes River	Wickiup Reservoir	Little Deschutes River	59776	11/3/1983	300	300	300	300	300	300	300	300	300	300	300	300
Deschutes River	Little Deschutes River	Spring River	59777	11/3/1983	400	400	400	400	400	400	400	400	400	400	400	400
Deschutes River	Spring River	North Canal Dam	59778	11/3/1983	660	660	660	660	660	660	660	660	660	660	660	660
Deschutes River	North Canal Dam	Lake Billy Chinook	70695	Pending	250	250	250	250	250	250	250	250	250	250	250	250

E.4.3 Deschutes River, Below Wickiup Reservoir

This section presents supporting calculations used when evaluating effects of the proposed action with respect to water resources in the Deschutes River at Wickiup Reservoir.

Table E-6. Deschutes River Daily Average Streamflow below Wickiup Reservoir following the 2016 Settlement Agreement.

Month	Low Streamflow (cfs) - 80% Exceedance	Lower Bar	Average Streamflow (cfs) - 50% Exceedance	Upper Bar	High Streamflow (cfs) - 20% Exceedance
Oct	107	8	115	409	524
Nov	107	10	117	13	129
Dec	103	2	105	82	187
Jan	104	4	108	92	200
Feb	101	7	108	87	195
Mar	100	8	108	86	194
Apr	415	192	607	106	712
May	728	255	983	238	1,220
Jun	1,030	180	1,210	220	1,430
Jul	1,358	52	1,410	190	1,600
Aug	1,300	120	1,420	122	1,542
Sep	690	350	1,040	220	1,260

Note: Streamflow in the Deschutes River downstream from Wickiup Reservoir at Oregon Water Resources Department Gauge No. 14056500 from the October 2016 through September 2020 water years.

Table E-7. Deschutes River Post-Project Streamflow below Wickiup Reservoir.

Month	Pre-Project Daily Average Streamflow (cfs)[1]	Streamflow Restored Through Project (cfs)	Post-Project Daily Average Streamflow (cfs)[1,2,3]	ODFW Instream Water Right[4] in the Deschutes River from Wickiup Reservoir to the mouth of the Little Deschutes River	Post-Project Percentage Increase in Average Streamflow[2,3]
Oct	115	0.0	115	300	0%
Nov	117	33.8	150.8	300	29%
Dec	105	33.8	138.8	300	32%
Jan	108	33.8	141.8	300	31%
Feb	108	33.8	141.8	300	31%
Mar	108	33.8	141.8	300	31%
Apr	607	0.0	607	300	0%
May	983	0.0	983	300	0%
Jun	1,210	0.0	1,210	300	0%
Jul	1,410	0.0	1,410	300	0%
Aug	1,420	0.0	1,420	300	0%
Sep	1,040	0.0	1,040	300	0%

Notes:
[1] Uses streamflow data in Table E-6 above.
[2] Post-Project Average Daily Streamflow does not include water saved and allocated instream in this reach from other water conservation projects currently being implemented in the Upper Deschutes Basin.
[3] This additional flow would be beneficial to the Deschutes River until Year 8 of the HCP when the minimum winter flow target is increased to 300 cfs.
[4] Certificate No. 59776

E.4.4 Deschutes River at Benham Falls

This subsection presents supporting calculations used when evaluating effects of the proposed action with respect to water resources in the Deschutes River at Benham Falls.

Table E-8. Deschutes River Daily Average Streamflow at Benham Falls following the 2016 Settlement Agreement.

Month	Low Streamflow (cfs) - 80% Exceedance	Lower Bar	Average Streamflow (cfs) - 50% Exceedance	Upper Bar	High Streamflow (cfs) - 20% Exceedance
Oct	525	114	639	399	1,038
Nov	503	65	568	68	635
Dec	519	43	562	131	693
Jan	524	48	572	163	734
Feb	524	65	589	140	729
Mar	525	146	671	151	822
Apr	1,070	160	1,230	250	1,480
May	1,370	260	1,630	112	1,742
Jun	1,530	170	1,700	150	1,850
Jul	1,710	95	1,805	255	2,060
Aug	1,670	110	1,780	200	1,980
Sep	1,190	265	1,455	215	1,670

Note: Streamflow in the Deschutes River at Benham Falls at Oregon Water Resources Department Gauge No. 14064500 vary within and between years. Data represent the October 2016 through September 2020 water years.

Table E-9. Deschutes River Post-Project Streamflow at Benham Falls.

Month	Pre-Project Daily Average Streamflow (cfs)[1]	Streamflow Restored Through Project (cfs)[2]	Post-Project Daily Average Streamflow (cfs)[1,3,4]	ODFW Instream Water Right[5] in the Deschutes River from the mouth of the Little Deschutes River to the confluence of Spring River	ODFW Instream Water Right[6] in the Deschutes River from the mouth of Spring River to the North Canal Dam at Bend	Post-Project Percentage Increase in Average Streamflow[3,4]
Oct	639	0.0	639	400	660	0%
Nov	568	29.6	597.6	400	660	5%
Dec	562	29.6	591.6	400	660	5%
Jan	572	29.6	601.6	400	660	5%
Feb	589	29.6	618.6	400	660	5%
Mar	671	29.6	700.6	400	660	4%
Apr	1,230	0.0	1,230	400	660	0%
May	1,630	0.0	1,630	400	660	0%
Jun	1,700	0.0	1,700	400	660	0%
Jul	1,805	0.0	1,805	400	660	0%
Aug	1,780	0.0	1,780	400	660	0%
Sep	1,455	0.0	1,455	400	660	0%

Notes:
[1] Uses streamflow data in Table E-8 above.
[2] This additional streamflow includes an estimated 12.5 percent channel loss from Wickiup Reservoir to Benham Falls.
[3] Post-Project Daily Average Streamflow does not include water saved and allocated instream in this reach from other water conservation projects currently being implemented in the Upper Deschutes Basin.
[4] This additional flow would be beneficial to the Deschutes River until Year 8 of the HCP when the minimum winter flow target is increased to 300 cfs.
[5] Certificate No. 59777
[6] Certificate No. 59778

E.4.5 Deschutes River at Bend, Below North Canal Dam

This subsection presents supporting calculations used when evaluating effects of the proposed action with respect to water resources in the Deschutes River at Bend, below North Canal Dam.

Table E-10. Deschutes River Daily Average Streamflow at Bend—Below North Canal Dam following the 2016 Settlement Agreement.

Month	Low Streamflow (cfs) - 80% Exceedance	Lower Bar	Average Streamflow (cfs) - 50% Exceedance	Upper Bar	High Streamflow (cfs) - 20% Exceedance
Oct	81	369	450	87	537
Nov	454	47	501	77	577
Dec	474	31	505	130	634
Jan	450	40	490	171	661
Feb	431	65	496	146	642
Mar	447	107	554	124	678
Apr	91	281	372	371	742
May	81	35	117	17	133
Jun	121	4	125	257	382
Jul	122	4	126	7	133
Aug	119	6	125	7	132
Sep	90	33	123	14	137

Note: Streamflow in the Deschutes River downstream from the City of Bend at Oregon Water Resources Department Gauge No. 14070500 from the October 2016 through September 2020 water years.

Table E-11. Deschutes River Post-Project Streamflow at Bend—Below North Canal Dam.

Month	Pre-Project Daily Average Streamflow (cfs)[1]	Streamflow Restored Through Project (cfs)[2]	Post-Project Daily Average Streamflow (cfs)[1,3,4]	Oregon Department of Fish and Wildlife Instream Water Right[5]	Post-Project Percentage Increase in Average Streamflow[3,4]
Oct	450	0.0	528	250	0%
Nov	501	27.5	528.5	250	5%
Dec	505	27.5	532.5	250	5%
Jan	490	27.5	517.5	250	6%
Feb	496	27.5	523.5	250	6%
Mar	554	27.5	581.5	250	5%
Apr	372	0.0	491	250	0%
May	117	0.0	116	250	0%
Jun	125	0.0	131	250	0%
Jul	126	0.0	133	250	0%
Aug	125	0.0	131	250	0%
Sep	123	0.0	86	250	0%

Notes:
[1] Uses streamflow data in Table E-10 above.
[2] This additional streamflow includes an estimated 7 percent channel loss from Benham Falls to the City of Bend.
[3] Post-Project Daily Average Streamflow does not include water saved and allocated instream in this reach from other water conservation projects currently being implemented in the Upper Deschutes Basin.
[4] This additional flow would be beneficial to the Deschutes River until Year 8 of the HCP when the minimum winter flow target is increased to 300 cfs.
[5] Pending Instream Application #70695

E.4.7 Reservoir Storage Allocation Agreement

This section presents the 2019 Amendment to the Arnold Irrigation District, Central Oregon Irrigation District, and Lone Pine Irrigation District Reservoir Storage Allocation Agreement.

2019 AMENDMENT TO

AID-COID-LPID RESERVOIR STORAGE ALLOCATION AGREEMENT

THIS 2019 AMENDMENT TO AID-COID-LPID RESERVOIR STORAGE ALLOCATION AGREEMENT ("2019 Amendment to AID-COID-LPID RSAA") is made this 2nd day of December 2019, by and between the Arnold Irrigation District ("AID"), the Central Oregon Irrigation District ("COID"), and the Lone Pine Irrigation District ("LPID") (collectively "the Districts"), all of which are irrigation districts operating pursuant to the provisions of Oregon Revised Statutes Chapter 545.

RECITALS

A. In 2017, the Districts entered into a Reservoir Storage Allocation Agreement ("RSAA"), attached hereto and incorporated herein, as Exhibit A.

B. At the time of the RSAA, the Districts anticipated the issuance of an interim biological opinion and incidental take statement from the U.S. Fish and Wildlife Service ("USFWS") that would result in coverage under the Endangered Species Act ("ESA") through July 31, 2019, at which time, the Districts anticipated a Habitat Conservation Plan ("HCP") would be completed and approved by USFWS, resulting in the issuance of long-term incidental take permits. While an interim biological opinion and incidental take statement were issued and are currently in effect through July 31, 2019, it is anticipated that it will take additional time beyond July 31, 2019 to complete and receive approval for the proposed HCP, and for the Districts to receive long-term incidental take permits. USFWS recently received approval from the U.S. Department of Interior for additional time to complete an environmental impact statement pursuant to the National Environmental Policy Act ("NEPA") as part of its evaluation of the proposed HCP. The Districts understand that the U.S. Bureau of Reclamation is currently consulting with USFWS, which will result in a supplemental biological opinion that extends the current incidental take statement through December 31, 2020, which will allow additional time for the NEPA evaluation to be completed, the HCP to be fully considered, and if approved, long-term incidental take permits to be issued.

C. With certain modifications as set forth below in this 2019 Amendment to AID-COID-LPID RSAA, the Districts wish to continue to operate under the RSAA for the period between the effective date of this 2019 Amendment to AID-COID-LPID RSAA and the eventual date the HCP is approved and long-term incidental take permits are issued. As such, the Districts hereby affirm their desire to work together to manage the currently available supply of water to mitigate the impacts of the ESA.

Therefore, AID, COID, and LPID now seek to amend the RSAA as follows:

1. The introductory statement following the term "AGREEMENT" is deleted in its entirety and replaced with the following:

"In recognition of the mutual benefits to be derived from this Agreement, the Districts agree as follows for the 2019 and 2020 irrigation seasons:"

Page 1 2019 AMENDMENT TO AID-COID-LPID RSAA (6/9/2019 version)

2. Sections 2 through 6 of the RSAA are deleted in their entirety and replaced with the following:

"2. The provisions of this Agreement shall terminate on the earlier of December 31, 2020 or the date the HCP is approved and incidental take permits are issued by USFWS, unless extended by the written mutual agreement of the Districts."

"3. NUID will make available up to 12,000 acre-feet of its Wickiup storage at the commencement of the irrigation season for use by AID and LPID. The specific amount of Wickiup stored water to be made available to AID and LPID will be determined by the amount of stored water in Crane Prairie that is available to "pay back" NUID later in the season, and this amount will be the difference between the highest elevation reached at the end of the fill season and the lowest elevation to which the reservoir can be drawn down consistent with the interim Biological Opinion and interim incidental take authorization issued by the USFWS. In terms of accounting, each acre foot of water released by NUID from Wickiup storage for use by AID and/or LPID will be "paid back" to NUID by AID and/or LPID from Crane Prairie in the same season.

"4. Of the available water described in Section 3 above, LPID would receive the first 5,000 acre feet out of Wickiup. AID will receive the available water up to 5,000 acre feet after LPID receives its 5,000 acre feet. If there is water available in excess of 10,000 acre feet, and up to 12,000 acre feet, it would be divided equally between LPID and AID.

"5. AID may annually make up to 1,000 AF of its unused stored water available to Tumalo Irrigation District ("TID") in exchange for TID storage in Crescent Lake.

"6 Of the available stored water that is credited to any district pursuant to Sections 3, 4 and 5 above, the other districts (including AID, COID, LPID, and NUID) may request from the credited district the use of any available unused storage water in the current irrigation season without charge, approval of which shall not be unreasonably withheld."

3. All other provisions of the RSAA remain in full force and effect.

THIS 2019 AMENDMENT TO AID-COID-LPID RESERVOIR STORAGE ALLOCATION AGREEMENT is effective as of the date set forth above.

Arnold Irrigation District ("AID")

By: [signature] Date: 12-10-19
Its Board President

By: [signature] Date: 12/10/19
Its Board Secretary

~~Central Oregon Irrigation District ("COID")~~

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By: ________________________ Date: 12-2-19
Its Board President

By: ________________________ Date: 12.2.19
Its Board Secretary

Lone Pine Irrigation District ("LPID")

By: ________________________ Date: 12-11-19
Its Board President

By: ________________________ Date: 12-11-19
Its Board Secretary

The following entity acknowledges and agrees to Paragraph 2 above:

North Unit Irrigation District ("NUID")

By: ________________________ Date: 12-2-19
Its Board President

By: ________________________ Date: 12/2/19
Its Board Secretary

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E.4.8 Summary of the Operation Measures Set forth by the Deschutes Basin Habitat Conservation Plan (2020)

This section presents a summary of the operation measures set forth by the Deschutes Basin Habitat Conservation Plan (HCP; AID et al., 2020). Figure C-3 in Appendix C includes locations of all the gages described.

1) From April 1 through September 15, flow at Oregon Water Resources Department (OWRD) Gage 14056500 will be at least 600 cfs. An adaptive management element will be used to test whether going directly to 600 cfs by April 1 provides enhanced survival of Oregon spotted frog. In coordination with U.S. Fish and Wildlife Service (USFWS), flows may be set at 400 cfs by April 1 and increased to 600 cfs within the first 2 weeks of April. Annual snowpack, weather and in-stream conditions will inform this decision.
2) From April 1 through April 30, flow at OWRD Gage 14056500 shall not exceed 800 cfs unless USFWS or a biologist approved by USFWS has verified that Oregon spotted frog eggs at Dead Slough in La Pine State Park have hatched or are physically situated in a portion of the slough where an increase in flow will not harm them.
3) If the flow at OWRD Gage 14056500 is increased above 600 cfs during the month of April, it will not subsequently be allowed to decrease more than 30 cfs, whether in a single flow adjustment or cumulatively over the course of multiple flow adjustments, until after April 30 or an earlier date approved after coordination with USFWS.
4) From May 1 through June 30, flow decrease at OWRD Gage 14056500 over any 5-day period shall be no more than 20 percent of total flow at the time the decrease is initiated.
5) Flow at OWRD Gage 14064500 shall be no less than 1,300 cfs from July 1 through at least September 15.
6) For the first 7 years of HCP implementation, flow at OWRD Gage 14056500 shall be at least 100 cfs from September 16 through March 31. Beginning in Year 1 of HCP implementation, minimum flow at OWRD Gage 14056500 from September 16 through March 31 shall be increased above 100 cfs in proportion to the amount of live Deschutes River flow made available to North Unit Irrigation District (NUID) during the prior irrigation season as a result of the piping of Central Oregon Irrigation District (COID) owned canals. For each acre-foot (or portion thereof) of live flow made available to NUID as a result of the piping of COID-owned canals after the date of incidental take permit issuance, an equal volume of water shall be added to the minimum flow below Wickiup Dam from September 16 through March 31. This water shall be in addition to the amount of water needed to maintain a flow at OWRD Gage 14056500 of at least 100 cfs. The timing for release of the additional water shall be determined in coordination with USFWS for optimal benefit to Oregon spotted frogs.
7) Beginning no later than Year 8 of HCP implementation, flow at OWRD Gage 14056500 shall be at least 300 cfs from September 16 through March 31, and not more than 1,400 cfs for more than 10 days per year between April 1 and September 15. If NUID anticipates the need to exceed 1,400 cfs at OWRD Gage 14056500 in Years 8 through 12, it will contact USFWS in advance to discuss options for minimizing the adverse effects on the Deschutes River and Oregon spotted frogs, such as conditioning the rate or timing of flow increases above 1,400 cfs.
8) Beginning no later than Year 13 of HCP implementation, minimum flow at OWRD Gage 14056500 shall be between 400 cfs and 500 cfs from September 16 through March 31, with actual flow during this period determined according to the variable flow tool described in the HCP, and not more than 1,200 cfs for more than 10 days per year between April 1 and September 15.

9) For all years, the volume of water equivalent to the amount scheduled for winter releases in excess of 100 cfs may be stored in Wickiup Reservoir for release later in the same water year. Water stored in this manner and released during the irrigation season will be treated as NUID storage and available for diversion by NUID at North Canal Dam. Water stored in this manner and not released for Oregon spotted frogs or fish by the end of the same water year can be used to meet the minimum flow requirements of this conservation measure at OWRD Gage 14056500 through March 31 of the subsequent water year. Any water stored in this manner and not released to meet HCP minimum flow requirements by March 31 will become NUID storage and available for irrigation use.
10) During the fall ramp-down, flow reductions at OWRD Gage 14056500 shall be halted for 5 days when the corresponding flow at OWRD Gage 14064500 reaches 1,200, and again for 5 days when the corresponding flow at OWRD Gage 14064500 reaches 1,100 cfs.

References

Arnold Irrigation District (AID), Central Oregon Irrigation District (COID), Lone Pine Irrigation District (LPID), North Unit Irrigation District (NUID), Ochoco Irrigation District (OID), Swalley Irrigation District (SID), Three Sisters Irrigation District (TSID), Tumalo Irrigation District (TID), City of Prineville. 2020. Deschutes Basin Habitat Conservation Plan (HCP). Retrieved from https://www.fws.gov/Oregonfwo/articles.cfm?id=149489716

E.5 Supporting Information for Fish and Aquatic Resources

This appendix section presents supporting information associated with Primary Constituent Elements for critical habitat of federally listed species.

Table E-12. Primary Constituent Elements for Oregon Spotted Frog Critical Habitat.

Primary Constituent Element (PCE) Number	Habitat Description	Characteristics
PCE 1	Nonbreeding (N), Breeding (B), Rearing (R), and Overwintering Habitat (O); Ephemeral or permanent bodies of fresh water, including, but not limited to natural or manmade ponds, springs, lakes, slow-moving streams, or pools within or oxbows adjacent to streams, canals, and ditches	Inundated for a minimum of 4 months per year (B, R) (timing varies by elevation but may begin as early as February and last as long as September)
		Inundated from October through March (O)
		If ephemeral, areas are hydrologically connected by surface water flow to a permanent waterbody (e.g., pools, springs, ponds, lakes, streams, canals, or ditches) (B, R)
		Shallow water areas (less than or equal to 30 centimeters (12 inches), or water of this depth over vegetation in deeper water (B, R)
		Total surface area with less than 50 percent vegetative cover (N)
		Gradual topographic gradient (less than 3 percent slope) from shallow water toward deeper, permanent water (B, R)
		Herbaceous wetland vegetation (i.e., emergent, submergent, and floating-leaved aquatic plants), or vegetation that can structurally mimic emergent wetland vegetation through manipulation (B, R)
		Shallow water areas with high solar exposure or low (short) canopy cover (B, R)
		An absence or low density of nonnative predators (B, R, N)

<table>
<tr><th>Primary Constituent Element (PCE) Number</th><th>Habitat Description</th><th>Characteristics</th></tr>
<tr><td rowspan="2">PCE 2</td><td rowspan="2">Aquatic movement corridors; Ephemeral or permanent bodies of fresh water</td><td>Less than or equal to 3.1 miles (5 kilometers) linear distance from breeding areas</td></tr>
<tr><td>Impediment free (including, but not limited to, hard barriers such as dams, impassable culverts, lack of water, or biological barriers such as abundant predators, or lack of refugia from predators)</td></tr>
<tr><td>PCE 3</td><td>Refugia Habitat</td><td>Nonbreeding, breeding, rearing, or overwintering habitat or aquatic movement corridors with habitat characteristics (e.g., dense vegetation and/or an abundance of woody debris) that provide refugia from predators (e.g., nonnative fish or bullfrogs)</td></tr>
</table>

Source: Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Oregon spotted frog 50 Code of Federal Regulations 17

Table E-13. Primary Constituent Elements for Bull Trout.

Primary Constituent Element (PCE) Number	Habitat Description and Characteristics
PCE 1	Springs, seeps, groundwater sources, and subsurface water connectivity (hyporheic flows) to contribute to water quality and quantity and provide thermal refugia.
PCE 2	Migration habitats with minimal physical, biological, or water quality impediments between spawning, rearing, overwintering, and freshwater and marine foraging habitats, including but not limited to permanent, partial, intermittent, or seasonal barriers.
PCE 3	An abundant food base, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish.
PCE 4	Complex river, stream, lake, reservoir, and marine shoreline aquatic environments, and processes that establish and maintain these aquatic environments, with features such as large wood, side channels, pools, undercut banks and unembedded substrates, to provide a variety of depths, gradients, velocities, and structure.
PCE 5	Water temperatures ranging from 2 to 15 degrees Celsius (36 to 59 degrees Fahrenheit), with adequate thermal refugia available for temperatures that exceed the upper end of this range. Specific temperatures within this range depend on bull trout life-history stage and form; geography; elevation; diurnal and seasonal variation; shading, such as that provided by riparian habitat; streamflow; and local groundwater influence.
PCE 6	In spawning and rearing areas, substrate of sufficient amount, size, and composition to ensure success of egg and embryo overwinter survival, fry emergence, and young-of-the-year and juvenile survival. A minimal amount of fine sediment, generally ranging in size from silt to coarse sand, embedded in larger substrates, is characteristic of these conditions. The size and amounts of fine sediment suitable to bull trout vary from system to system.
PCE 7	A natural hydrograph, including peak, high, low, and base flows within historic and seasonal ranges or, if flows are controlled, minimal flow departure from a natural hydrograph.
PCE 8	Sufficient water quality and quantity such that normal reproduction, growth, and survival are not inhibited.
PCE 9	Sufficiently low levels of occurrence of nonnative predatory (e.g., lake trout, walleye, northern pike, smallmouth bass); interbreeding (e.g., brook trout); or competing (e.g., brown trout) species that, if present, are adequately temporally and spatially isolated from bull trout.

Source: Endangered and Threatened Wildlife and Plants; Revised Designation of Critical Habitat for Bull Trout in the Coterminous United States (50 Code of Federal Regulations 17)

Table E-14. Fish and Mollusk Species within the Area Affected by District Operations for the Arnold Irrigation District Infrastructure Modernization Project.

Species Common Name	Scientific Name	Crane Prairie Reservoir	Wickiup Reservoir	Upper Deschutes River	Middle Deschutes River
Bull trout	*Salvelinus confluentus*				X
Steelhead trout	*Oncorhynchus mykiss*				X
Spring Chinook salmon	*Oncorhynchus tshawytscha*				X
Redband trout	*Oncorhynchus mykiss gairdnerii*	X	X	X	X
Kokanee Salmon	*Oncorhynchus nerka*	X	X		
Mountain whitefish	*Prosopium williamsoni*	X	X	X	X
Largescale sucker	*Catostomus marcocheilus*	X	X	X	X
Bridgelip sucker	*Catostomus columbianus*	X	X	X	X
Chiselmouth	*Acrocheilus alutaceus*	X	X	X	X
Dace species	*Rhinichthys* (spp.)	X	X	X	X
Sculpin species	Family Cottidae	X	X	X	X
Brook trout	*Salvelinus fontinalis*	X	X	X	X
Brown trout	*Salmo trutta*	X	X	X	X
Western pearlshell mussel	*Margaritifera falcata*			X	X
Western ridged mussel	*Gonidea angulata*				X

Source: AID et al. 2020

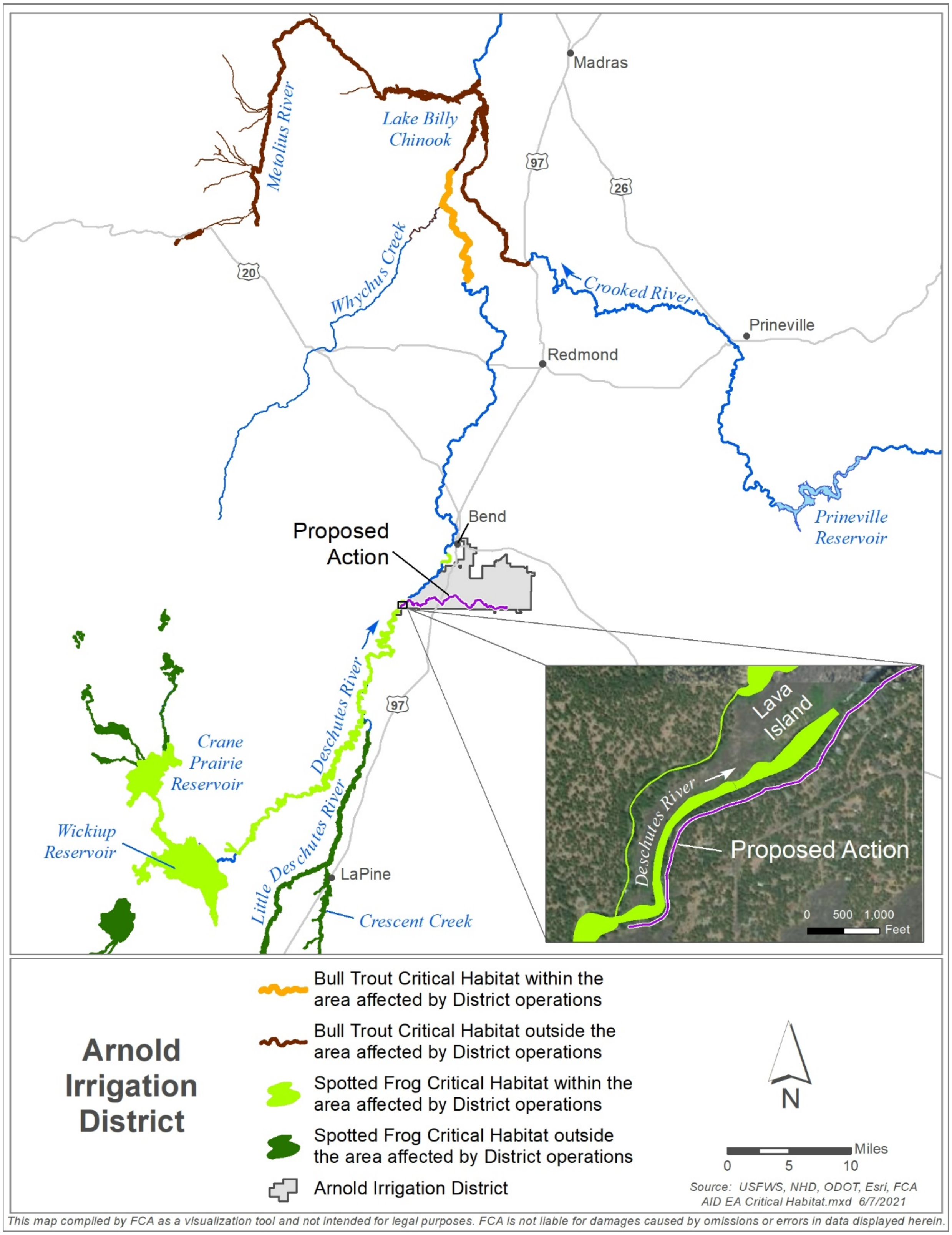

Figure E-4. Bull trout and Oregon spotted frog critical habitat within and outside the area affected by District operations.

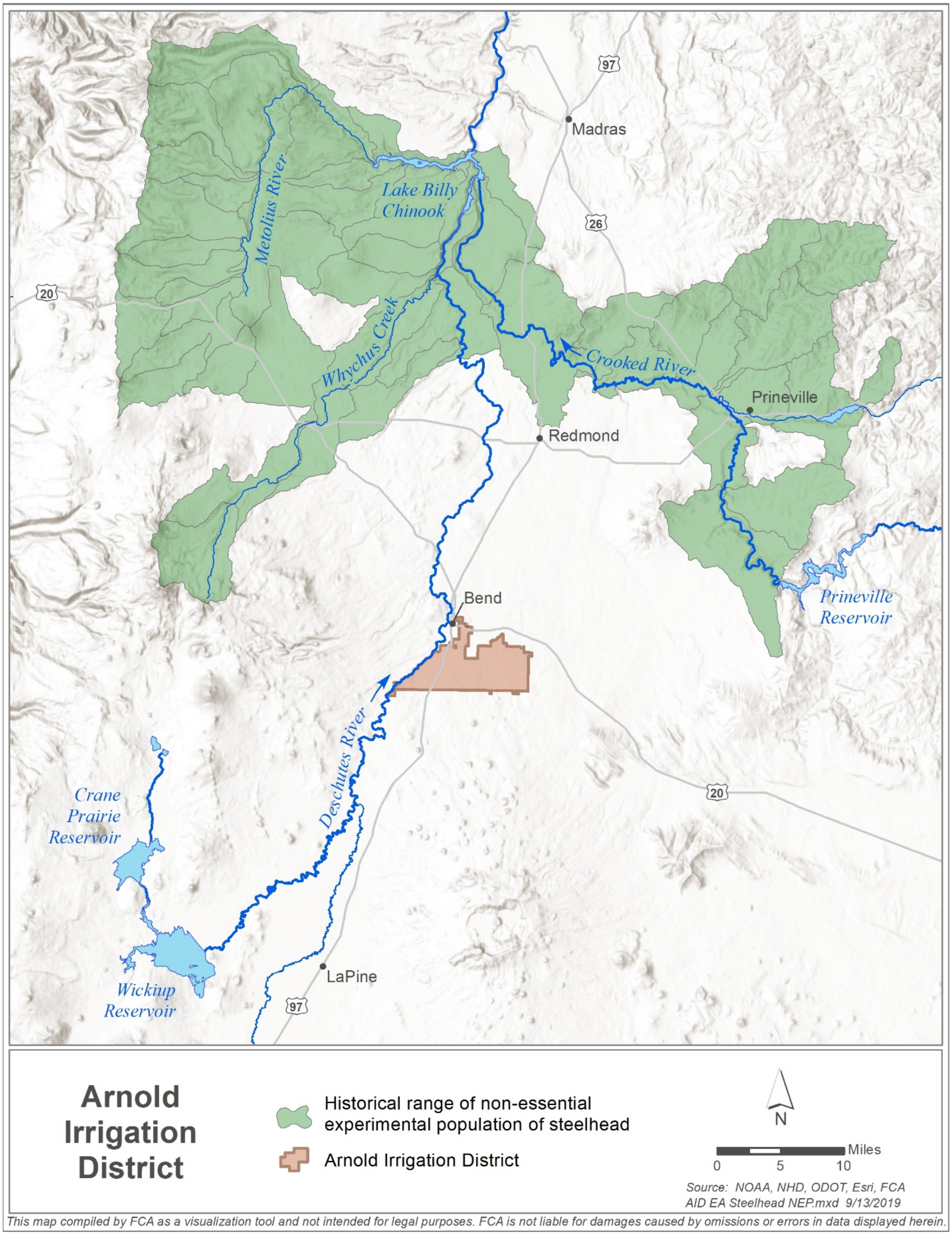

Figure E-5. Steelhead non-essential experimental population within and outside of area affected by District operations.

E.6 Supporting Information for Wildlife Resources

This section presents supporting information for the wildlife resources section.

Table E-15. Migratory Bird Treaty Act / Bald and Golden Eagle Protection Act Species Potentially Occurring within the Project Area.[1]

Migratory Bird Treaty Act/Bald and Golden Eagle Protection Act Species	Scientific Name
Bald eagle	*Haliaeetus leucocephalus*
Brewer's sparrow	*Spizella breweri*
Calliope hummingbird	*Stellula calliope*
Cassin's finch	*Carpodacus cassinii*
Eared grebe	*Podiceps nigricollis*
Flammulated owl	*Otus flammeolus*
Fox sparrow	*Passerella iliaca*
Golden eagle	*Aquila chrysaetos*
Green-tailed towhee	*Pipilo chlorurus*
Lewis's woodpecker	*Melanerpes lewis*
Loggerhead shrike	*Lanius ludovicianus*
Long-billed curlew	*Numenius americanus*
Olive-sided flycatcher	*Cantopus cooperi*
Peregrine falcon	*Falco peregrinus*
Pinyon jay	*Gymnorhinus cyanocephalus*
Rufous hummingbird	*Selasphorus rufus*
Sage thrasher	*Oreoscoptes montanus*
Short-eared owl	*Asio flammeus*
Swainson's hawk	*Buteo swainsoni*
Western grebe	*Aechmophorus occidentalis*
White-headed woodpecker	*Picoides albolavatus*
Williamson's sapsucker	*Sphyrapicus thyroidus*
Willow flycatcher	*Empidonax traillii*

Source: USFWS, 2021

[1] This is only a partial list of migratory birds that potentially occur within the project area.

References

Arnold Irrigation District (AID), Central Oregon Irrigation District (COID), Lone Pine Irrigation District (LPID), North Unit Irrigation District (NUID), Ochoco Irrigation District (OID), Swalley Irrigation District (SID), Three Sisters Irrigation District (TSID), Tumalo Irrigation District (TID), City of Prineville. 2020. Draft Deschutes Basin Habitat Conservation Plan. Retrieved from: https://www.fws.gov/Oregonfwo/articles.cfm?id=149489716 Accessed: May 27, 2021.

U.S. Fish and Wildlife Service (USFWS). 2021. IPaC ECOS (Environmental Conservation Online System). Retrieved from: https://ecos.fws.gov/ipac/.

E.7 Wild and Scenic Outstandingly Remarkable Values

This section presents supporting information associated with Outstandingly Remarkable Values identified for the upper and middle Deschutes River.

Table E-16. Outstandingly Remarkable Values for the Upper Deschutes River.

Outstandingly Remarkable Value	Outstandingly Remarkable Value Description
Vegetative	Aquatic, riparian, and upland vegetation is a significant element of all other river values. The vegetating resource is an Outstandingly Remarkable Value in Segments 3 [1] and 4 [2] because of Estes' Artemisia (*Artemesia ludoviciana spp. Estesii*), a Federal Category 2 Candidate3 for protection under the Endangered Species Act.
Cultural	The upper Deschutes Corridor contains more than 100 known prehistoric sites that are eligible for inclusion in the National Register of Historic Places, making the prehistoric resources an Outstandingly Remarkable Value. Until further research on historic and traditional uses of the corridor is complete, they will also be treated as Outstandingly Remarkable Values.
Fisheries	The brown trout fishery in segments 2 [4] and 3 is an Outstandingly Remarkable Value. The determination of value of the native redband rainbow trout population in segment 4 has been deferred until a genetic study has been completed. Until that time the population is to be treated as an Outstandingly Remarkable Value.
Geologic	The upper Deschutes River consists of two major features: the lava flows which have pushed the river west of earlier channels and created the stair step of falls and rapids, and the landforms created by the interaction of depositional and erosive actions. The river channel shape, size, and rate of change are not an Outstandingly Remarkable Value within themselves, primarily because the dynamics are so affected by human controlled flows.
Hydrology	The hydrologic resource is a significant element of several Outstandingly Remarkable Values associated with the upper Deschutes River. Most Outstandingly Remarkable Values in and along the river are protected and enhanced by an abundant, stable flow of clear, clean water.
Recreational	Recreation is an Outstandingly Remarkable Value on the upper Deschutes River because of the range of activities, the variety of interpretive opportunities, and the attraction of the river for vacationers from outside of the region.

Outstandingly Remarkable Value	**Outstandingly Remarkable Value Description**
Scenic	The mix of geologic, hydrologic, vegetative, and wildlife resources found along portions of Segments 2 and 4 of the upper Deschutes makes scenery an Outstandingly Remarkable Value. Although the level and proximity of private development intrudes on the scenic quality of Segment 3, the scenic value is still a significant element of the recreational value.
Wildlife	Wildlife populations in Segments 2 and 4 were determined to be Outstandingly Remarkable Values because of the populations of nesting bald eagles and ospreys in Segment 2 and the diversity of the bird population in Segment 4. Despite extensive private development in Segment 3, the wildlife habitat was considered to be significant because it provides important nesting habitat for birds and travel corridors for migrating game animals such as deer and elk.

Source: USDA, 1996

Notes:

[1] Segment 3 includes the south boundary of LaPine State Recreation Area to north boundary of Sunriver.

[2] Segment 4 includes the north boundary of Sunriver to the Central Oregon Irrigation District Canal.

[3] The upper Deschutes Wild and Scenic River and State Scenic Water Management Plan was written in 1996. Since the time of the management plan, this species has been reclassified as Species of Concern—Taxa for which additional information is needed to support a proposal to list under the Endangered Species Act (ORBIC, 2016).

[4] Segment 2 includes Wickiup Dam to east end of Pringle Falls Campground and the east end of Pringle Falls campground to south boundary of LaPine State Recreation Area.

Table E-17. Outstandingly Remarkable Values for the Middle Deschutes River.

Outstandingly Remarkable Value	Outstandingly Remarkable Value Description
Botany/ Ecology	The middle Deschutes River segments are in an ecological condition unusual for similar areas within the region and contain a significant portion of Estes' wormwood.
Cultural	Cultural resources on the middle Deschutes River include prehistoric and historic sites found along the corridor and traditional uses associated with the area. Evidence that rare and/or special activities took place in the river canyon areas is represented by lithic scatters or flaking stations, shell middens, rock shelters, rock features and rock art. These sites have the potential to contribute to the understanding and interpretation of the prehistory of the Deschutes River and the region and are considered to eligible for inclusion in the National Register of Historic Places.
Fisheries	Surveys have identified fishing as the number one recreation activity in the upper sections. Stories and pictures of huge catches are found in historical records of the early 1900s.
Geologic	Fifty million years of geologic history are dramatically displayed on the canyon walls of the middle Deschutes River. Volcanic eruptions which occurred over thousands of years created a large basin dramatized by colorful layers of basalt, ash and sedimentary formations. The most significant contributor to the outstandingly remarkable geologic resource are the unique intra-canyon basalt formations created by recurring volcanic and hydrologic activities.
Hydrology	Water from springs and stability of flows through the steep basalt canyons has created a stream habitat and riparian zone that is extremely stable and diverse, unique in a dry semi-arid climate environment. Features, such as Odin, Big, and Steelhead falls; springs and seeps; white water rapids; water sculpted rock; and the river canyons are very prominent and represent excellent examples of hydrologic activity within central Oregon.
Recreational	These river corridors offer a diversity of year-round, semi-primitive recreation opportunities such as fishing, hiking, backpacking, camping, wildlife and nature observation, expert kayaking and rafting, picnicking, swimming, hunting and photography. Interpretive opportunities are exceptional and attract visitors from outside the geographical area.

Outstandingly Remarkable Value	Outstandingly Remarkable Value Description
Scenic	The exceptional scenic quality along the middle Deschutes River is due to the rugged natural character of the canyons, outstanding scenic vistas, limited visual intrusions and scenic diversity resulting from a variety of geologic formations, vegetation communities and dynamic river characteristics. These canyons truly represent the spectacular natural beauty created by various forces of nature.
Wildlife	The river corridor supports critical mule deer winter range habitat and nesting/hunting habitat for bald eagles, golden eagles, ospreys, and other raptors. Bald eagles are known to winter along the Deschutes River downriver from Lower Bridge. Outstanding habitat areas include high vertical cliffs, wide talus slopes, numerous caves, pristine riparian zones, and extensive grass/sage covered slopes and plateaus.

Source: National Wild and Scenic Rivers System, 2018

References

National Wild and Scenic Rivers System. 2018. Deschutes River, Oregon. Website. Retrieved from: www.rivers.gov/rivers/deschutes.php. Accessed September 10, 2018.

Oregon Biodiversity Information Center (ORBIC). 2016. Rare, Threatened and Endangered Vascular Plant Species of Oregon. Retrieved from: https://inr.oregonstate.edu/sites/inr.oregonstate.edu/files/2016-rte-vascs.pdf. Accessed November 26, 2018.

U.S. Department of Agriculture (USDA). 1996. Upper Deschutes Wild and Scenic River and State Scenic Water Way – Comprehensive Management Plan.

E.8 Guiding Principles

Guiding Principles (USDA 2017) The Guiding Principles identified in the PR&G are considered when developing and evaluating alternatives, as described below.	
Healthy and Resilient Ecosystems	A primary objective of the PR&G analysis is the identification of alternatives that protect and restore the functions of ecosystems. Alternatives should first avoid adverse impact. When environmental consequences occur, alternatives should minimize the impact and mitigate unavoidable damage. If damage occurs, mitigation to offset environmental damage must be included in the alternative's design and costs.
Sustainable Economic Development	Alternatives for resolving water resources problems should improve the economic well-being of the Nation for present and future generations. The PR&G analysis considers the effects of alternatives on both water availability and water quality to evaluate the sustainability of economic activity and ecosystem services. Water use or management factors that provide improved sustainability or reduced uncertainty should be identified in alternatives.
Floodplains	The PR&G seek to avoid unwise use of floodplains and flood prone areas. Alternatives should avoid investments that adversely affect floodplain function, such that the floodplain is no longer self-sustaining. If an alternative impacts floodplain function, then the alternative should describe efforts to minimize and mitigate the impact and the residual loss of floodplain function. The PR&G investment evaluation of alternatives must be consistent with Executive Order 11988 of May 24, 1977 (Floodplain Management), as modified by Executive Order 13690 of January 30, 2015 (Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input), and the Federal Flood Risk Management Standard, which require executive departments and agencies to avoid, to the extent possible, the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct or indirect support of floodplain development wherever there is a practicable alternative. The PR&G investment evaluation is informed by the processes to evaluate the impacts of Federal actions affecting floodplains consistent with Executive Order 11988, as amended.
Public Safety	An objective of the PR&G is to reduce risks to people, including life, injury, property, essential public services, and environmental threats concerning air and water quality. These risks to public health and safety must be evaluated and documented for all alternatives, including those using nonstructural approaches. The residual risks to public health and safety associated with each of the water investment alternatives should be described, quantified if possible, and documented.

Environmental Justice	An objective of the PR&G investment evaluation process is the fair treatment of all people including meaningful involvement in the public comment process. Any disproportionate impact to minority, Tribal, and low-income populations should be avoided. In implementing the PR&G, agencies should seek solutions that would eliminate or avoid disproportionate adverse effects on these communities. For watershed investments, particular attention should be focused to downstream areas. The study area may need to be reexamined to include the concerns of affected communities downstream of the immediate investment area. The PR&G process should document efforts to include the above-mentioned populations in the planning process. The PR&G process must be in compliance with Executive Order 12898 of February 11, 1994 (Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations). Applications of the PR&G process in USDA agencies must be in compliance with USDA DR 5600-002 (Environmental Justice).
Watershed Approach	A watershed approach must be used when completing a PR&G analysis. This approach recognizes that there may be upstream and downstream impacts of a water resources activity that may be outside of the applicable political or administrative boundaries. A watershed approach is not necessarily limited to analyzing impacts within a specific hydrologic unit. Rather, it is broad, systems- based framework that explicitly recognizes the interconnectedness within and among physical, ecological, economic, and social/cultural systems. A watershed approach enables examination of multiple objectives, facilitates the framing of water resources problems, incorporates a broad range of stakeholders, and allows for identification of interdependence of problems and potential solutions. In many instances, a specific hydrologic unit may be the appropriate scale to examine alternatives to address water resources problems and opportunities. In this case, the watershed would become the study area. In other cases, environmental, economic, or social conditions may merit a study area that is combination of various hydrologic units or other geographic groupings. Ideally, the area of analysis should represent a geographical area large enough to ensure plans address cause and effect relationships among affected resources, stakeholders, and investment options, both upstream and downstream of an investment site. The watershed approach also establishes the framework to examine cumulative effects and the interaction of a potential Federal investment with other water resources projects and programs. When considering the impact of Federal investments against some economic and ecological measures, the analysis may need to be expanded to include regional markets and habitat considerations beyond the initial study area (e.g., beyond the immediate hydrologic unit).