Appendix A

Comments and Responses

Table A-1. Topics and Associated Codes.

[To be completed after public review of the Draft Plan-EA.]

Table A-2. Responses to Comments Received During the Public Comment Period for North Unit Irrigation District Watershed Plan-EA.

[To be completed after public review of the Draft Plan-EA.]

Appendix B

Project Maps

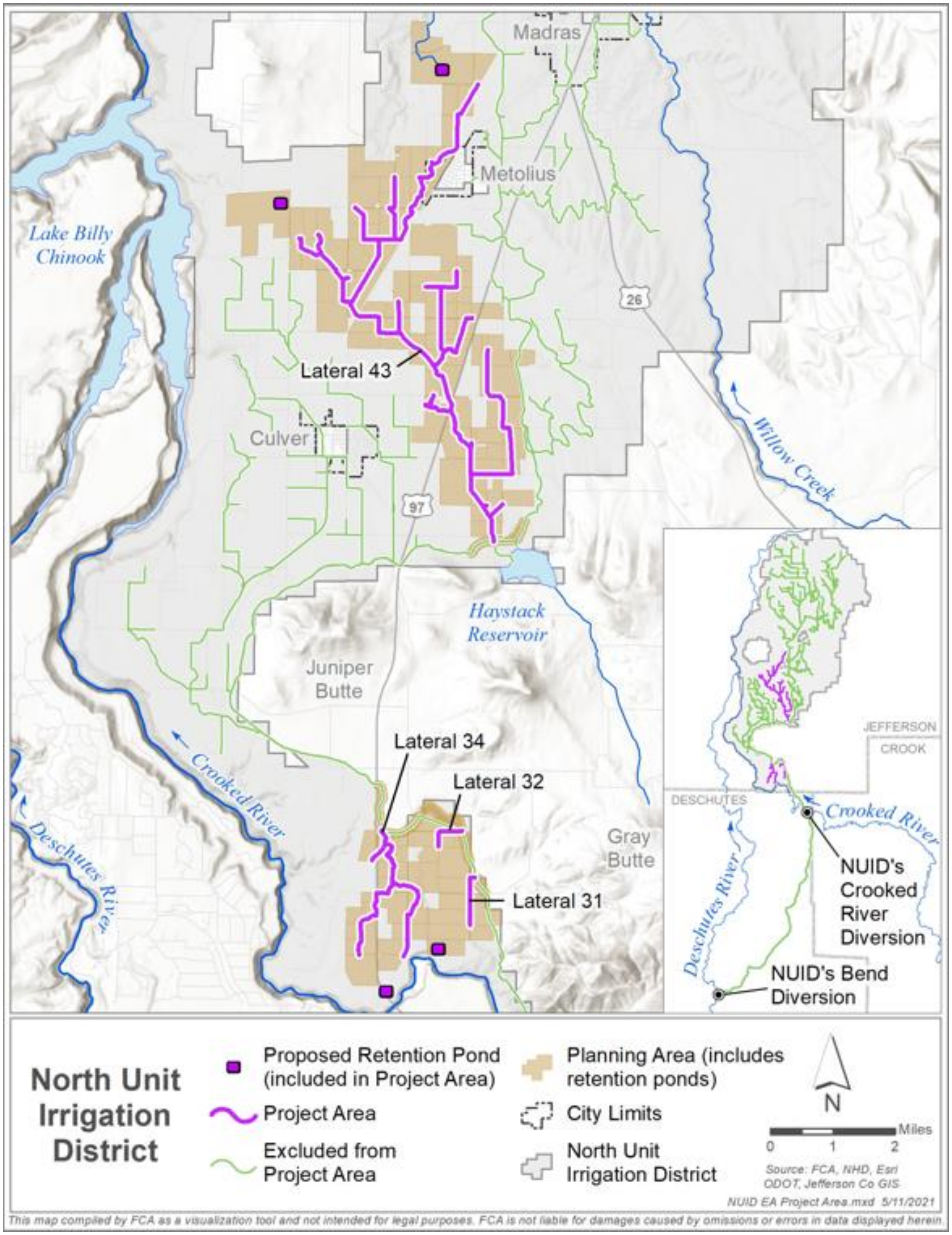

Figure B-1. North Unit Irrigation District Infrastructure Modernization Project area.

Appendix C

Supporting Maps

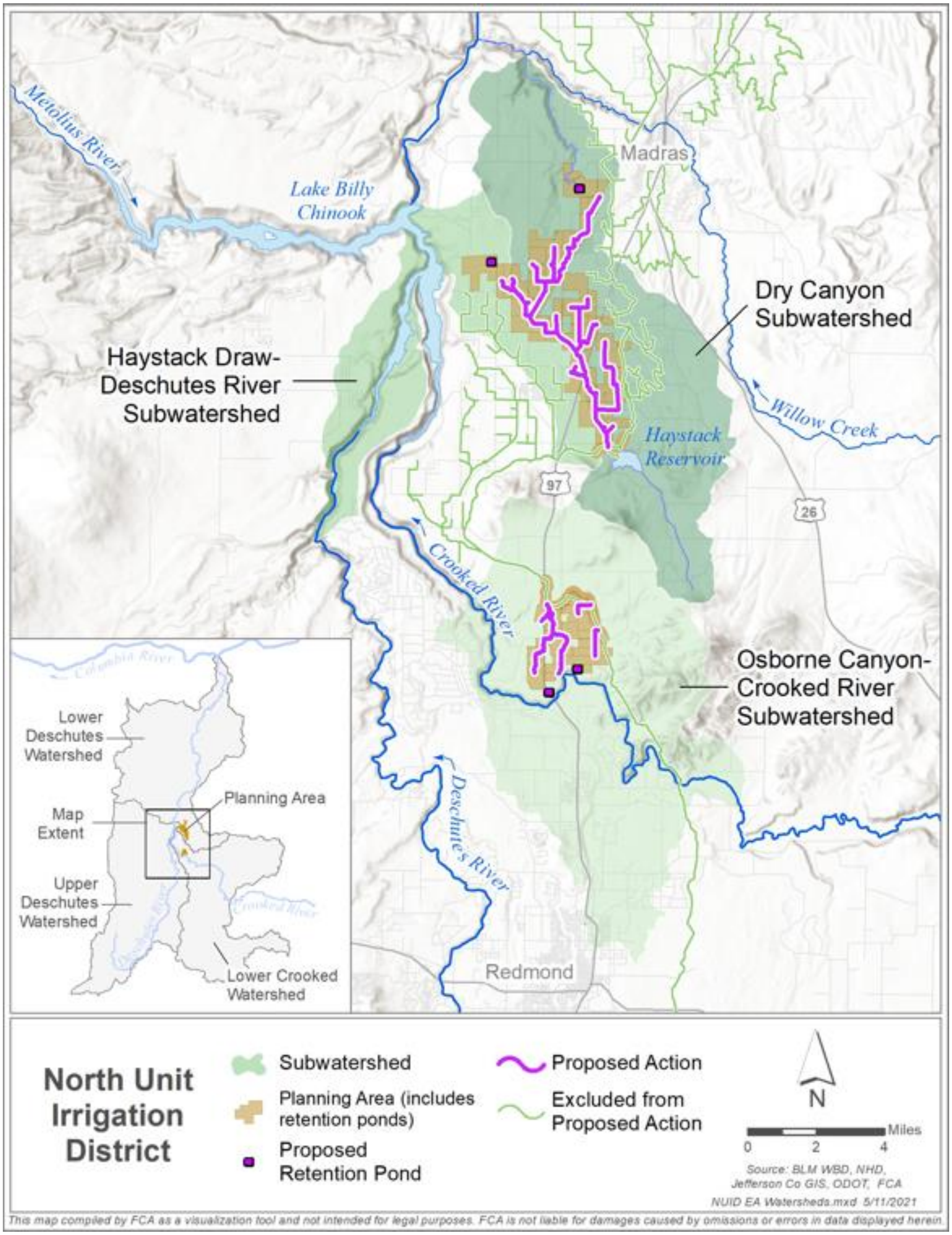

Figure C-1. The North Unit Irrigation District planning area.

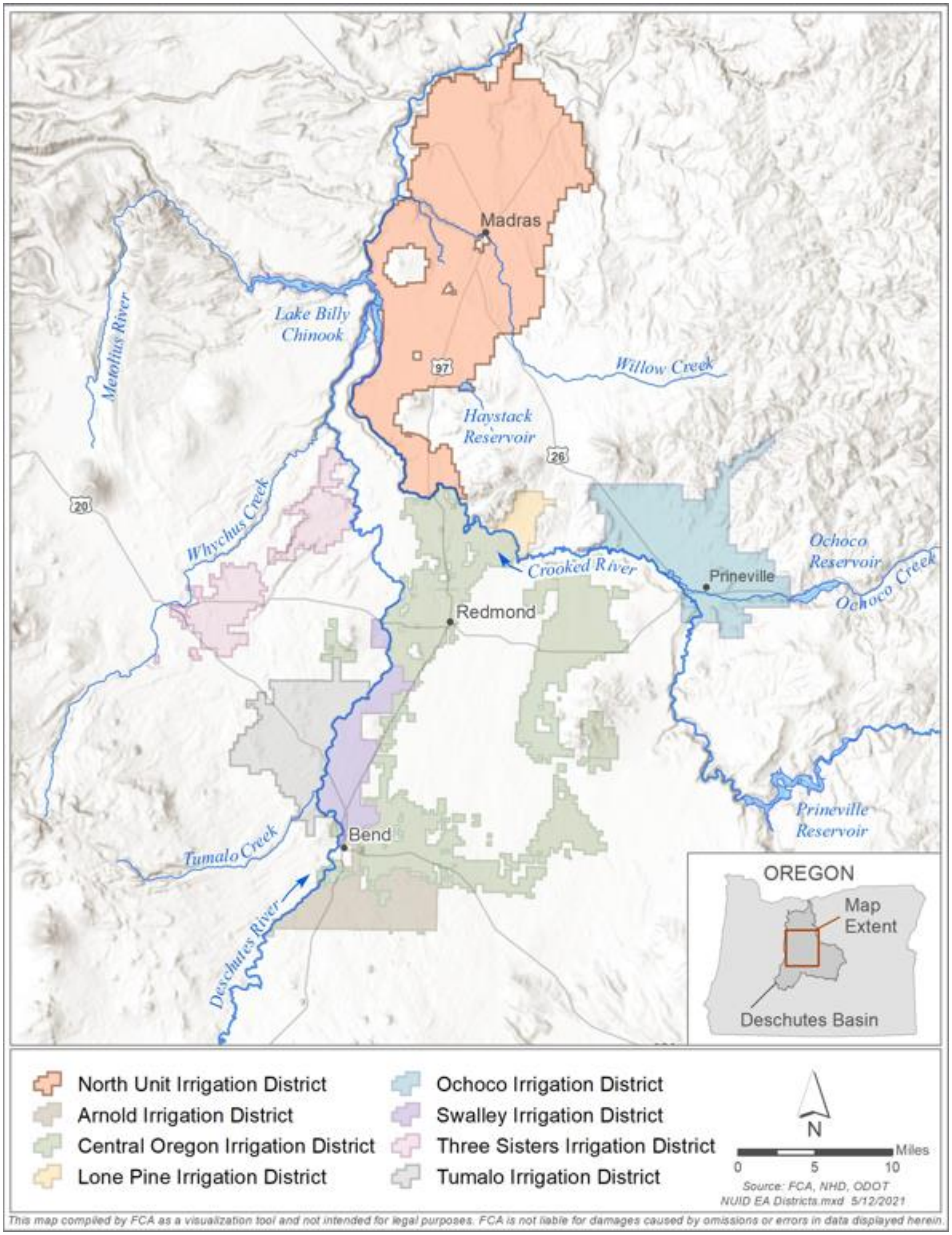

Figure C-2. Irrigation districts within the Deschutes Basin.

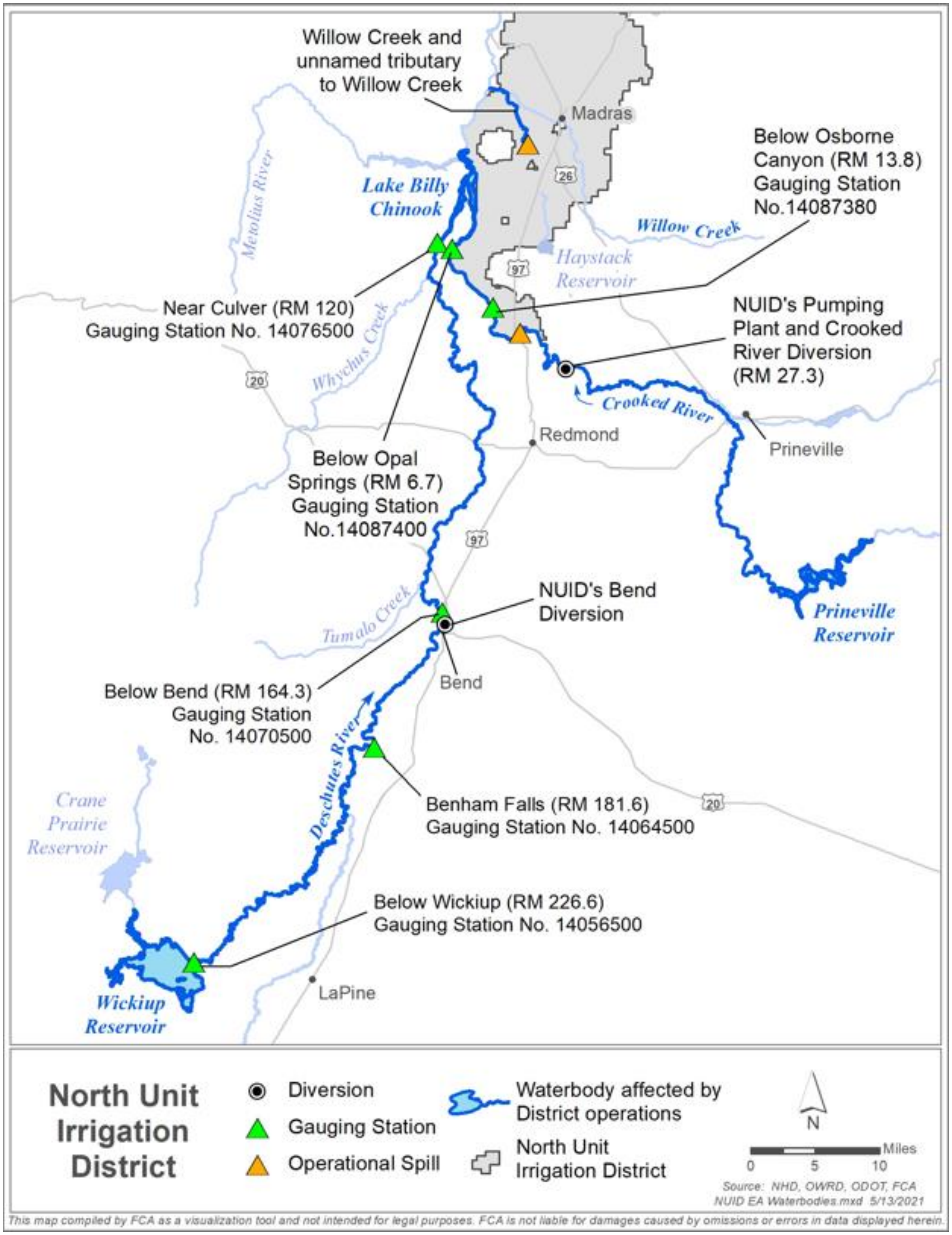

Figure C-3. Waterbodies and gauging stations associated with District operations.

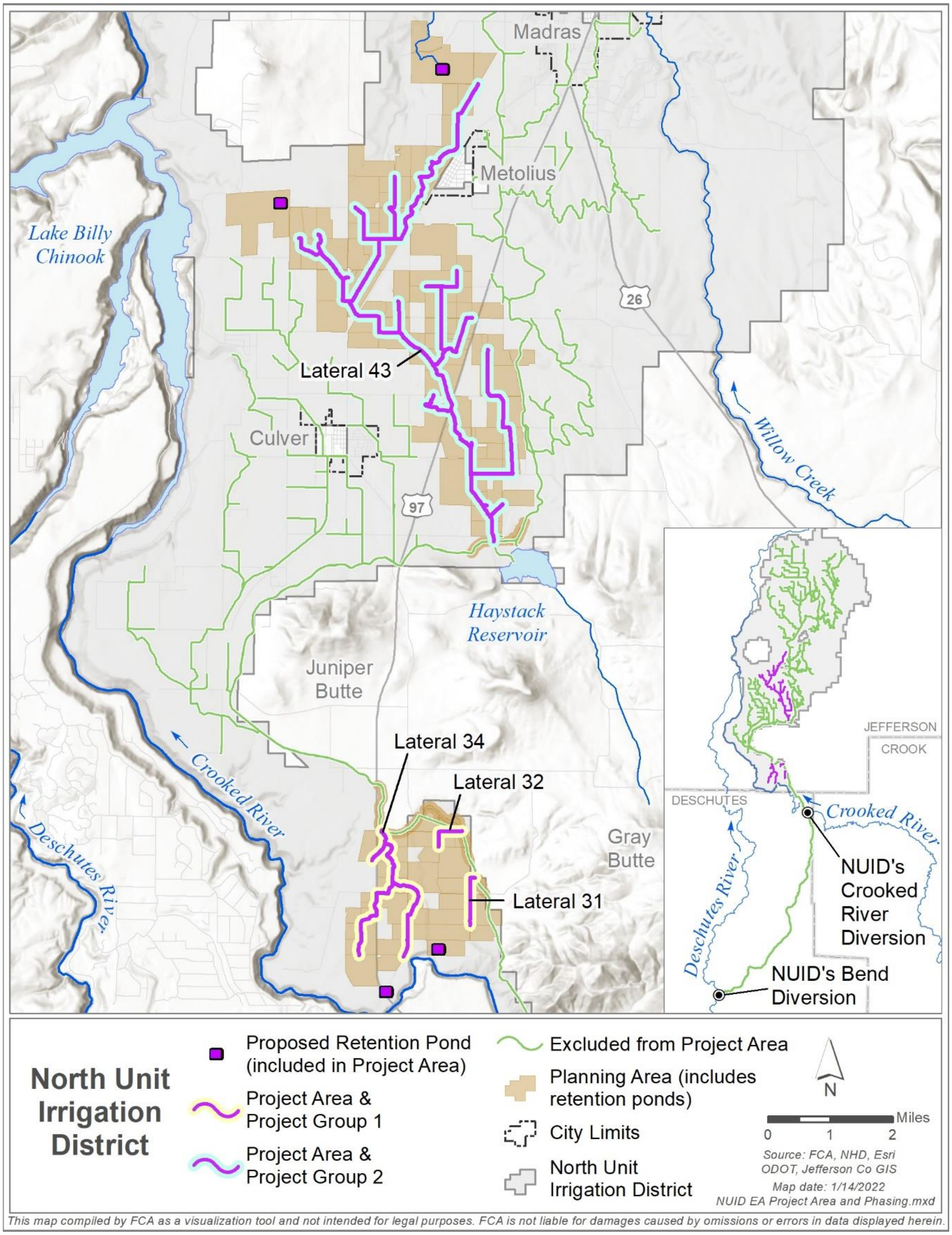

Figure C-4. Overview of the Modernization Alternative for the North Unit Irrigation District Infrastructure Modernization Project.

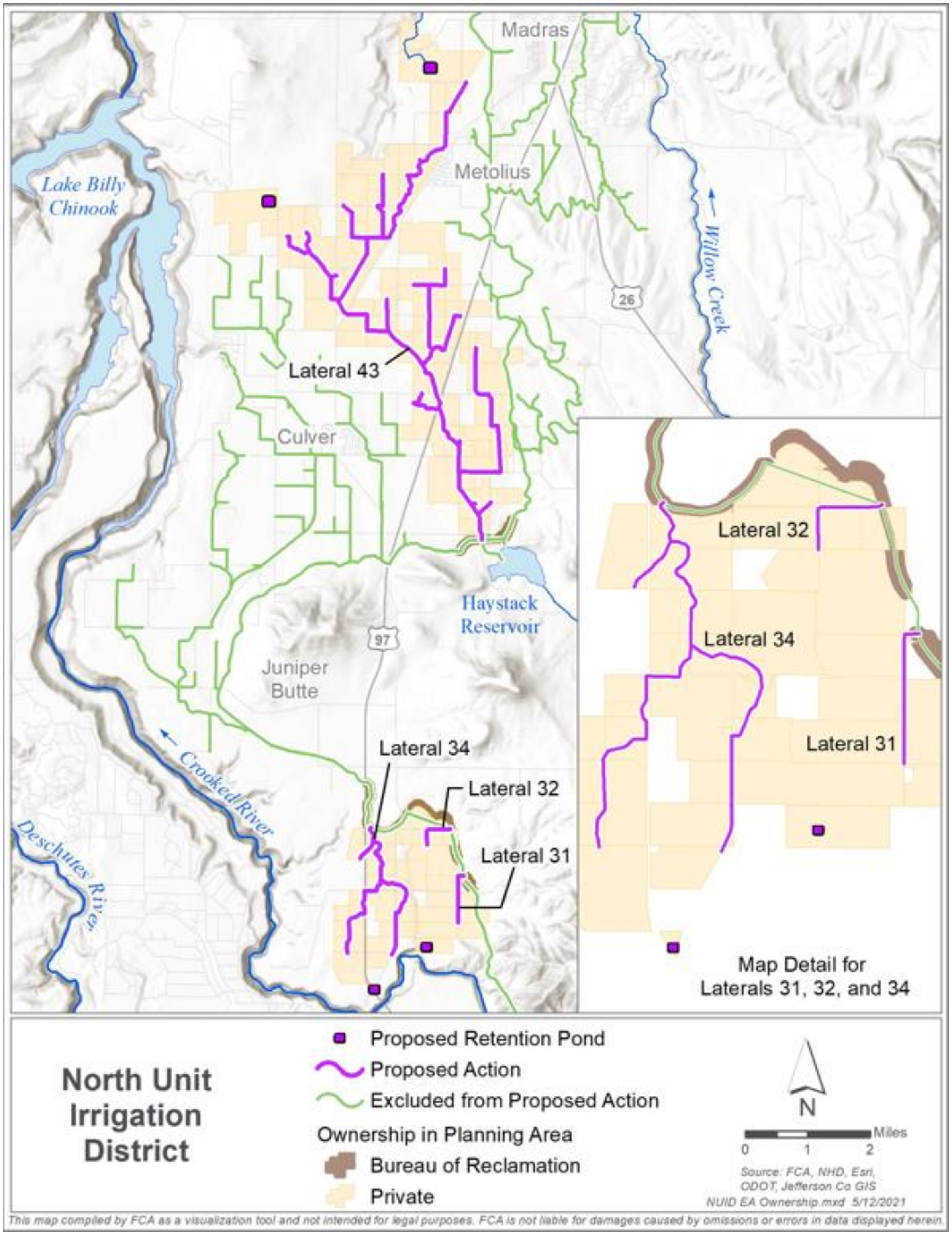

Figure C-5. Land ownership in the planning area

Appendix D

Investigation and Analyses Report

D.1. National Economic Efficiency Analysis

Highland Economics LLC

National Economic Efficiency Analysis

Barbara Wyse and Winston Oakley
3/31/2021

D.1.1. Costs of the Modernization Alternative

This National Economic Efficiency (NEE) analysis evaluates the costs and benefits of the Modernization Alternative over the No Action Alternative for the North Unit Irrigation District (herein referred to as NUID or the District) Infrastructure Modernization 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).

All economic benefits and costs are provided in 2020 dollars and have been discounted and amortized (following the approach described in the NRCS Water Resources Handbook for Economics) to average annualized values using the fiscal year 2021 federal water resources planning rate of 2.5 percent. In this approach, all costs and benefits are evaluated at the 2020 price level in all analysis years, then they are converted to a present value over the analysis period using the 2.5 percent planning rate as the discount rate, and then finally are amortized to annual average values over the analysis period using the 2.5 percent planning rate.

This section evaluates the costs of the Modernization Alternative over 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.

D.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 proposed project purpose. All values in this analysis are presented in 2020 dollars and rounded to the nearest $1,000.

D.1.1.1.1. Funding

P.L. 83-566 funds would cover $25,810,000 or 76 percent of the project cost. NUID would be required to fund $8,210,000 or 24 percent of the proposed project.

D.1.1.1.2. Evaluation Unit

The proposed project comprises two project groups, which are the evaluation units for this analysis. Project Group 1 consists of piping laterals 31, 32, and 34, which total 6 miles, and associated retention ponds. Project Group 2 consists of piping Lateral 43, which is 21.4 miles, and associated retention ponds. 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.

D.1.1.1.3. Project Implementation Timeline

District staff indicate that if P.L. 83-566 funds are made available, construction would likely be completed over approximately 6 years (see Table 8-2 in the Plan-EA). The proposed project would be completed in the two project groups described above. For each project group, this analysis assumes that full benefits would be realized the year after construction is completed (e.g., for Project Group 1, which would complete construction in Year 1, full benefits would be realized in Year 2).

D.1.1.1.4. Analysis Period

The analysis period is defined as 106 years since the installation period is 6 years and 100 years is the expected project life of the buried pipe (Year 0 to Year 105). Construction and installation of Project Group 1 is assumed to start in Year 0 and finish in Year 1, with project life extending from Year 2 through Year 101. Project Group 2 would begin construction in Year 2, finish in Year 5, and have a project life extending from Year 6 through Year 105.

D.1.1.1.5. PROJECT PURPOSE

The purpose of the proposed project is to improve water conservation in District infrastructure, improve water supply management and delivery reliability to District patrons, increase drought resilience throughout the District, and improve public safety on up to 24.9 miles of the District-owned canals.[1]

D.1.1.2. Proposed Project Costs

Table 8-3 (NWPM 506.11, Economic Table 1) and Table 8-3 (NWPM 506.12, Economic Table 2) in Chapter 8 of the Plan-EA summarize installation costs, distribution of costs, and total annual average costs for the Modernization Alternative. Project installation costs include mobilization and staging of construction equipment, delivery of piping to construction areas, excavation of trenches, fusing of pipelines, removal of existing pipe in certain areas, placement of pipe, compaction of backfill, and restoration and reseeding of the disturbed areas. Table 8-5 in the Plan-EA summarizes the annualized costs over the No Action Alternative, which are estimated at $859,000 in amortized installation costs. The subsections included in this report provide detail on the derivation of the values in the tables of the Plan-EA.

D.1.1.3. Project Installation Costs

The total cost for the Modernization Alternative is estimated at $34,020,000 (Farmers Conservation Alliance, 2021). This includes the costs of construction and engineering, as well as an additional 3 percent for project administration from NUID and NRCS, 8 percent for technical assistance from NRCS (applied just on the $23,388,000 in construction/engineering costs funded by NRCS), and 1 percent for permitting costs. See Appendix D.4.2 for detailed cost derivation by pipe size, cost category, etc. The average annual installation cost of the Modernization Alternative is $859,000, and because no other potential costs are quantified in this analysis, this is also the estimated total annual cost of the proposed project.

D.1.1.4. Other Direct Costs

Water seepage from canals is one source of recharge for groundwater in the Deschutes Basin. Reduced recharge from canals may lead to groundwater declines and thereby increase pumping costs for all groundwater users in the basin. As such, it is possible that the Modernization 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 that estimated the effects on Central Deschutes Basin groundwater recharge from changes in climate (reduced precipitation), groundwater pumping, and canal lining and piping (Gannett & Lite, 2013). The U.S. Geological Service estimated that since the mid-1990s, groundwater levels have dropped by approximately 5 to 14 feet in the central part of the Deschutes Basin,[2] with approximately 10 percent of this decline (0.5 to 1.4 feet) in groundwater level. The cumulative effect of piping over the 12-year study period (1997 to 2008) was 58,000 acre-feet of reduced recharge annually by 2008.[3] The Modernization Alternative would reduce canal seepage, other conveyance inefficiencies, and

1 The total project length is 27.4 miles, of which 24.9 miles are open canal. The remaining 2.6 miles are piping that would be replaced under the Modernization Alternative.

2 This refers to the portion of the basin that extends north from near Benham Falls to Lower Bridge and east from Sisters to the community of Powell Butte.

3 Assuming a uniform increase in canal lining/piping over this timeframe, in 1997 the decreased canal seepage was 4,833 acre-feet, rising each year by another 4,833 acre-feet until the reduced canal seepage in 2008 was 58,000 acre-feet. Cumulatively, this represents 377,000 acre-feet of reduced recharge from canals during this period.

associated groundwater recharge by up to approximately 6,089 acre-feet annually in this part of the Deschutes Basin (Farmers Conservation Alliance, 2021). Given the relatively small change in groundwater elevations estimated from 58,000 acre-feet of reduced recharge annually, very minor changes in local groundwater elevations and associated groundwater pumping costs in the region due to the Modernization Alternative are anticipated, and thus this study does not quantify these potential other direct costs.

D.1.2. Benefits of the Modernization Alternative

Table 8-7 in the Plan-EA compares the proposed 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 proposed 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 such as reduced agricultural damages and power costs. It also presents off-site quantified benefits, which include the value of reduced carbon emissions. The conserved water from the proposed project is anticipated to be used by NUID irrigators with no expected direct benefit to other consumptive water users in the region or to non-consumptive instream water uses such as habitat or recreation. However, water savings from the proposed project and other similar projects in the region may, in the long run, benefit other users (through water trading or other mechanisms) due to the increased flexibility and resiliency to the region that comes from increased water availability.

Other benefits not included in the analysis, which may result indirectly from the Modernization Alternative, include further reduced agricultural damages for NUID patrons (greater than those modeled in Appendix D.1.2.1.1), the potential for increased on-farm investments in irrigation efficiency (as patrons have more funds due to increased yields and reduced pumping costs), increased drought resilience throughout the District, and the potential to enhance instream flow. It is also possible that there may be increased carbon sequestration from increased crop yields (although these may be somewhat offset by increased carbon emissions from additional usage of harvest equipment) or slight water quality benefits if the increased water use efficiency associated with the proposed project results in reduced agricultural return flows to waterways. As these are anticipated to be very minor potential effects, they are not quantified.

D.1.2.1. Benefits Considered and Included in Analysis

D.1.2.1.1. AGRICULTURAL DAMAGE REDUCTION BENEFITS

Under the Modernization Alternative, NUID would conserve approximately 6,089 acre-feet of water annually (see Appendix E.5 for a description of the method used for estimating the volume of water saved by the proposed project). The District plans to continue to divert and use all this saved water to supplement farm irrigation water supply. From the point at which water is diverted at the NUID diversion until it is delivered on-farm, roughly 30 percent of the conserved water from the Modernization Alternative would be lost to seepage in the remaining unpiped District laterals (Farmers Conservation Alliance, 2021). This would leave about 4,274 acre-feet of the conserved water that could be used on NUID farms (see Appendix E.5 for a description of the method used for estimating the volume of water available for on-farm deliveries). The 4,274 acre-feet increase in water availability is anticipated to reduce the agricultural damages associated with water shortages currently experienced in the District, as well as mitigate future larger water shortages in the District that are anticipated to occur due to changes in water management required as part of the Deschutes Basin Habitat Conservation Plan (HCP).

Historically, NUID has experienced water shortages in which water supply is less than total water demand in the District (Britton, NUID District Manager, 2020). Since the adoption of the 2016 Settlement Agreement, which includes provisions for irrigation districts in Central Oregon to increase instream flows to support Oregon spotted frog (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 the District increased from the 2009–2015 period to the 2016–2018 period.

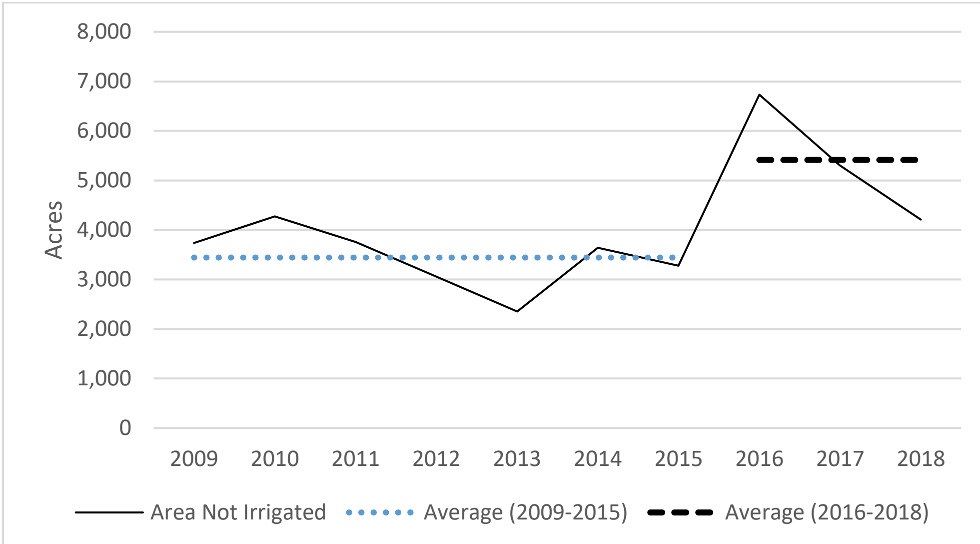

Figure D-1. District agricultural area not irrigated. [4]

NUID currently experiences an estimated annual average shortage in on-farm deliveries of nearly 25,500 acre-feet per year. This is based on data presented in the Environmental Impact Statement (EIS) for the HCP (Oregon Fish and Wildlife, 2020), which modeled recent historical and expected future water supply under the HCP for NUID and other Deschutes Basin irrigation districts. The modeling for the EIS estimated that under current conditions (100 cubic feet per second [cfs] winter releases from Wickiup Reservoir), NUID is able to divert, on average, 196,800 acre-feet per year. Given an average system conveyance efficiency in the District of 64 percent (Farmers Conservation Alliance 2021), this translates to an average of approximately 126,000 acre-feet per year delivered to farms. The agricultural economics analysis in the EIS estimated that crop water demand (evapotranspiration requirements) in the District was 131,800 acre-feet per year (based on average annual crop acreage, crop mix, and crop-specific evapotranspiration requirement) (Oregon Fish and Wildlife, 2020). Based on an estimated District on-farm irrigation efficiency of 87 percent (Oregon Fish and Wildlife, 2020), this indicates an on-farm delivery demand of approximately 151,500 acre-feet per year. Comparing the on-farm demand of approximately 151,500 acre-feet per year with the average on-farm delivery of approximately 126,000 acre-feet per year results in a shortage of approximately 25,500 acre-feet per year currently.

Further, in 2030 (Year 7 of this analysis) when the HCP requirement increases to 300 cfs, the on-farm shortage is projected to grow to approximately 36,500 acre-feet per year if there are no water conservation measures implemented in NUID or other districts. Further, the on-farm shortages are projected to reach about 45,400 acre-feet per year when the HCP requirement increases to 400 cfs in 2035 (Year 12) if no conservation measures are implemented in NUID or other districts. These shortage estimates are based on the data in the EIS[5] on changes in diversions under each release scenario (i.e., releases of 100 cfs versus 300 cfs versus 400 cfs) combined with the data presented above on average NUID system conveyance

4 Source: (Bohle, North Unit Irrigation District 10 Year Average Crop Report 2009-2018, 2019)
5 The data used in this analysis is from the Riverware Version 18 final run, as presented in EIS Appendix 3.1-C.

efficiency.[6] These analyses clearly indicate that NUID would derive agricultural benefits from improved water supply currently, with benefits expected to increase in the future as shortages increase.

This analysis estimates the economic benefit of the 4,274 acre-feet of additional water in reducing agricultural damages arising from water shortages. Specifically, the analysis estimates the benefit of additional water that is expected to reduce deficit irrigation on hay acres that causes a loss of one hay cutting (estimated to total 25 percent of the annual yield under full irrigation or 1.35 tons of the estimated average yield of 5.41 tons). This estimated 25 percent of yield from the final cutting is based on information from published sources and interviews with local experts, which indicate the final hay cutting is approximately 25 percent of the total yield (Bohle, 2018; Butler & Oppenlander, 2015; Butler & Ralls, Alfalfa Variety Trials, Second Cutting Results, 2015; Butler & Ralls, Alfalfa Variety Trials, Third Cutting Results, 2015). Because this analysis focuses on the impacts to hay only and does not include potential impacts to higher value specialty crops grown in the District, the benefits presented in this section likely underestimate the benefits of additional water to the District. 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 Piping Alternative, may be impacted by water shortages as the HCP changes in water management are phased into effect in future years.[7]

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. Further, the full irrigation hay yield used in this analysis likely is an underestimate of yield under full irrigation, which would also result in an underestimate of agricultural damage reduction benefits. To be conservative, the analysis uses National Agricultural Statistics Services (NASS)-reported recent county average hay yields as the expected "full irrigation" yield, although these yields are from a period when irrigators were experiencing some water shortages. Interviews with a local agricultural extension agent also indicated that the yield for full irrigation in the District used in this analysis may be an underestimate (Bohle, 2018).

Under this approach, to estimate the value of reduced damages from deficit irrigation, with input from a local agricultural extension agent familiar with alfalfa hay production in the District (Bohle, 2020), a published Washington State University crop budget was adapted to model the net revenues of agricultural production in the District for alfalfa hay. From this source budget, crop budgets were developed to model the net returns to hay under full irrigation and under deficit irrigation. The crop budgets are provided in Section D.2 with detailed explanation of the methods used to update costs to 2020-dollar values and adjust costs to local NUID conditions. Revenues used in the budget are based on local yields and prices. A Washington State budget was used as the basis for costs in this analysis as the most recent Central Oregon alfalfa budget is

6 Specifically, the data used include diversions available for NUID under a normal water year type are 196,800 acre-feet per year with 100 cfs outflow, 188,200 acre-feet per year under 300 cfs outflow, and 171,200 acre-feet per year under 400 cfs outflow. Under a dry-water year, the diversions available for NUID under a normal-water year, are 188,500 acre-feet per year with 100 cfs outflow, 146,700 with 300 cfs outflow, and 121,600 acre-feet per year with 400 cfs outflow. Taking the difference in each scenario by water year type and multiplying it by the probability of the water year type, results in a reduction in NUID diversions of approximately 17,200 acre-feet per year when moving from 100 cfs to 300 cfs outflows, and a reduction in average diversions of 31,100 acre-feet per year when moving from 100 cfs to 400 cfs. As in the EIS, this analysis estimated average annual shortages by assuming the normal (50 percent exceedance) water year supply represents 30 percent of water years and dry water years represent 35 percent of water years. Multiplying this average estimated change in diversions by the system conveyance efficiency of 64 percent and adding it to the current estimated shortage of approximately 25,500 results in the estimated shortage in on-farm deliveries under each release scenario of 36,500 acre-feet per year under the 300 cfs release and 45,400 acre-feet per year under the 400 cfs release. Note that wet years were not analyzed in the agricultural economics analysis in the EIS as the water available in wet years in all scenarios was estimated to be sufficient to meet crop water demand.

7 Source for NUID crop mix: (Bohle, North Unit Irrigation District 10 Year Average Crop Report 2009-2018, 2019)

from 1995 and crop production costs have significantly changed since that time. The crop budget analysis is summarized in Table D-1.

Table D-1. 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 (Modernization 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/Acre-foot of Full Irrigation [3]	$246	

Note: Full crop budgets are provided in Section D.2.1.5. Prepared March 2021
1/ Averaged over a 6-year stand life with 5 years comprised of Years 2–6 net returns.
2/ Equal to the difference of weighted average net returns between deficit and full irrigation.
3/ Calculated assuming a 0.6 acre-foot/acre difference between full and deficit irrigation.

Results from the analysis in NEE Appendix D.2.1 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 the District is 2.4 acre-feet per acre.[8] With deficit irrigation at 75 percent of full irrigation, on average each acre would receive an additional 0.6 acre-foot under full irrigation.[9] Dividing the marginal net returns of full irrigation ($149 per acre) by the amount of additional water (0.6 acre-foot per acre) provides the marginal net returns to water: $246 per acre-foot. This amount was used to estimate the damage-reduction benefit of each acre-foot of water going to NUID under the Modernization Alternative.[10] Note that the effect of water application on yields of alfalfa are fairly linear, so for any given change in water application to an acre of alfalfa, regardless of the current level of water application, the effect on alfalfa yield (and net revenues) would be expected to be similar (Bohle, 2018) (Orloff, Bali, Putnam, 2014).

Under the Modernization Alternative, the NUID-conserved water would help alleviate the shortages described above. Therefore, this analysis models the value of an increase of approximately 4,274 acre-feet per year delivered to NUID farms once both project groups are complete. Valued at $246 per acre-foot, this volume of water results in an undiscounted annual agricultural damage reduction value of about $1,053,000.

8 Water allocations in NUID differ depending on the source and type of water year (wet-year water allocations will be greater and in dry years water allocations will be less): Deschutes River water rights get 2.5 acre-feet per acre during a normal water year while Crooked River water rights get 1.5 acre-feet per acre during a normal water year. 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 acre-feet per acre (Britton, NUID District Manager, 2019).

9 2.4 x (1 - 0.75) = 0.6 acre-foot per acre

10 If 4,274 acre-feet of additional water were distributed at 0.6 acre-foot per acre (as is assumed in this analysis), less than 8,000 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 one-quarter the total area of relevant cropland, it is reasonable to apply the benefit per acre-foot to all 4,274 acre-feet.

When discounted and annualized, the value of the Modernization Alternative in avoiding agricultural damages in the District totals $945,000 (as shown in Table D-2).

Table D-2. Avoided Damages to NUID Agriculture Resulting from the Modernization Alternative by Project Group, Deschutes Watershed, Oregon, 2020$.[1]

Project Group	Water contributed to NUID farms (acre-feet)	Undiscounted Annual Benefit of Increased Acres	Annualized Average Net Benefits of Piping
Phase 1	639	$157,000	$153,000
Phase 2	3,636	$896,000	$792,000
Total	**4,274**	**$1,053,000**	**$945,000**

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

D.1.2.1.2. PATRON IRRIGATION PUMPING COST SAVINGS

NUID patrons currently use an estimated 3,778,035 kWh annually to power on-farm irrigation pumps (Farmers Conservation Alliance, 2021). System improvements associated with the Modernization Alternative would result in a net energy savings of 2,740,411 kWh per year.[11] This energy cost savings was evaluated using Pacific Power's Schedule 41 rate for irrigation pumping: $0.0888 per kWh (Pacific Power, 2020). Pacific Power is the primary power provider in the District (Britton, NUID District Manager, 2020). At this price, the energy savings would provide NUID patrons with approximately $244,000 in (undiscounted) annual savings once all project phases were completed. Table D-3 presents the energy use and cost savings to NUID patrons under the Modernization Alternative. Once the project is complete, the average annual NEE savings to NUID patrons would be approximately $217,000 each year.

Table D-3. Annual Increased Average Energy Cost Savings to NUID Patrons from the Modernization Alternative, Deschutes Watershed, Oregon, 2020$.[1]

Works of Improvement	Annual Energy Use Under Baseline Conditions (kWh)	Annual Energy Use Under Modernization Alternative (kWh)	Reduced Annual Energy Use (kWh)[2]	Undiscounted Annual Energy Cost Savings	Average Annual Discounted NEE Benefits (Avoided Energy Costs)
Phase 1	886,282	747,653	138,629	$13,000	$13,000
Phase 2	2,891,753	289,971	2,601,782	$231,000	$204,000
Total	**3,778,035**	**1,037,623**	**2,740,411**	**$244,000**	**$217,000**

Note: Totals may not sum due to rounding. Prepared March 2021
NEE = National Economic Analysis
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, 2021).

By providing a pressurized piping conveyance system, the Modernization Alternative would allow some irrigators to eliminate the need for pumping altogether. This would reduce pump operations, maintenance,

11 This is a based on an FCA analysis of NUID data on energy savings (Farmers Conservation Alliance, 2020).

and replacement (OM&R) costs to some NUID patrons. Data collected by NUID found that there are 109 irrigation pumps within Project Group 2 of the proposed project that would be eliminated under the Modernization Alternative (Windom, 2020).[12]

To estimate the avoided OM&R costs of pumping, the annual power company fixed service charge, estimated annual pump repair costs, and the estimated annual pump replacement costs were added. Pacific Power charges a minimum annual service fee of $65 for agricultural pumping service under Schedule 41 (Pacific Power, 2020). For annual repair costs, interviews with irrigation pump professionals indicated that surface irrigation pumps typically require maintenance every 3 to 5 years, which costs $300 to $800 per instance (Scarborough, 2019; Mark, 2019). From this, it is assumed that the average irrigation pump receives maintenance once every 4 years, which costs about $550 (the midpoint of the cost range); this results in an average annual cost of approximately $140 per year. Based on interviews with irrigation pump experts and published sources, replacement costs were estimated for a 10-hp irrigation pump at $3,000 (including installation), and assume replacement is required on average every 10 years (Haun, 2019; Fey, 2019). Amortizing this at the 2.5-percent annual rate, the annualized cost of replacing a 10-hp pump is about $350. Given that over 80 percent of the eliminated pumps are larger than 10 hp (Windom, 2020) and that larger pumps are more expensive, $350 may underestimate the annualized cost of replacing pumps in the District and therefore may understate the benefits of avoided OM&R savings under the Modernization Alternative.

Combining the annual service charge ($65), repair costs ($140), and annualized replacement costs ($350) results an estimated total annual cost of approximately $550 per year per pump. This cost was applied to each eliminated pump to derive the annual benefit. Using this method, the 109 pumps eliminated would provide annual benefits of roughly $60,000 as shown in Table D-4. When discounted, the avoided OM&R cost would provide annualized benefits of $53,000 over the No Action Alternative.

Table D-4. Annual Increased Pump Maintenance Cost Savings to NUID Patrons Under the Modernization Alternative by Project Group, Deschutes River Watershed, Oregon, 2020$.[1]

Works of Improvement	Pumps Eliminated under the Modernization Alternative [2]	Undiscounted Annual OM&R Costs Avoided	Discounted Annualized OM&R Costs Avoided
Phase 1	0	$0	$0
Phase 2	109	$60,000	$53,000
Total	**109**	**$60,000**	**$53,000**

Note: Totals may not sum due to rounding. Prepared March 2021
OM&R = operation, maintenance, and repair
1/ Price Base: 2020 dollars amortized over 100 years at a discount rate of 2.5 percent.
2/ As estimated by NUID (Windom, 2020).

D.1.2.1.3. CARBON EMISSION REDUCTIONS

Changes in energy use are expected to result in changes in carbon dioxide emissions from power generation. Every megawatt-hour (MWh) of reduced energy use is estimated to translate into an estimated reduction of

12 The Modernization Alternative is not expected to result in sufficient pressurization to eliminate the need for existing pumps in Phase 1.

0.7525 metric tons (Mt) of carbon emissions.[13] The Modernization Alternative would decrease carbon emissions by eliminating some of the energy used by NUID patrons for pumping. Within the District, compared to the No Action Alternative, the annual energy savings (described in Section D.1.2.1.2) would reduce CO_2 emissions by approximately 2,062 Mt (approximately 2,740 MWh multiplied by 0.7525).

To value the potential decrease in carbon emissions, this analysis used the social cost of carbon (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 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 on the Social Costs of Greenhouse Gases, which in 2013 developed a set of SCC estimates that could be used across federal agencies (Interagency Working Group on Social Cost of Greenhouse Gases, 2013). In February 2021, the Interagency Working Group updated its estimates of the SCC. It estimated that in the year 2020, at a 3 percent discount rate, the SCC value was $51 per Mt (Interagency Working Group on Social Cost of Greenhouse Gases, 2021). This value was applied to the net change in carbon emissions each year throughout the project life to estimate the change in carbon emissions from the Modernization Alternative.

At this value, the reduction of 2,062 Mt of CO_2 emissions under the Modernization Alternative would bring annual benefits of $105,000. When discounted and annualized, the benefits of reduced CO_2 emissions under the Modernization Alternative would be roughly $93,000. This is shown in Table D-5.

Table D-5. Annual Average Reduction in Carbon Costs of Modernization Alternative, Deschutes Watershed, Oregon, 2020$.[1]

Works of Improvement	Annual Avoided Emissions (Reduced NUID Patron Energy Use, Mt Carbon)	Undiscounted Annual Average Benefit of Avoided Emission	Average Annual NEE Benefit (Social Cost of Carbon)
Phase 1	104	$5,000	$5,000
Phase 2	1,958	$100,000	$88,000
Total	**2,062**	**$105,000**	**$93,000**

Note: Totals may not sum due to rounding. Prepared March 2021
Mt = metric ton; NEE = National Economic Analysis; NUID = North Unit Irrigation District
1/ Price Base: 2020 dollars amortized over 100 years at a discount rate of 2.5 percent.

13 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 metric tons of carbon emitted from one 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 West, and (2) the associated metric tons of CO_2 produced per MWh powered by each fossil fuel source, as reported by the Energy Information Administration.

D.1.2.2. Benefits Considered but Not Included in Analysis

D.1.2.2.1. PUBLIC SAFETY AVOIDED COSTS

Piping irrigation water removes the hazard of drownings in canals and eliminates the potential for earthen canals to fail, which causes potential damages to downstream property and lives. While NUID 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, and in 1996 and 1997, respectively, a 12-year-old boy and a 28-year-old man drowned in North Unit Irrigation District 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 indicates at least three drownings over the last 21 years (1996 through 2016) or 0.143 deaths 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 Modernization Alternative would pipe 24.9 miles[14] of NUID's open canals. The next 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 NUID irrigation canals proposed for piping (based on the recent history of drownings and the mileage of exposed canals).

Level of Public Safety Hazard

This analysis estimated the public safety hazard of open canals in the District based on past drownings in unpiped canals in Central Oregon. Based on data from the Oregon Water Resources Department (OWRD) on canals in Central Oregon, there are 1,072 miles of irrigation canals in Central Oregon irrigation districts (see Table D-6). 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 deaths occurred annually during this period (three 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 it 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, NUID would continue to have approximately 24.9 miles of unpiped canal. Assuming that the three drownings from 1996 to 2016 are representative of future drowning risk, and that the 0.000147 deaths per mile of exposed canal experienced during this period is an appropriate estimate of future risk, the unpiped canals in NUID carry a risk of 0.0037 deaths per year.

14 The total project length is 27.5 miles, of which 24.9 miles are open canal. The remaining 2.6 miles is piping that would be replaced under the Modernization Alternative

Table D-6. Irrigation Canal Mileage by District.

Irrigation 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 March 2021
Source: Oregon Water Resources Department, database maintained and provided by Jonathon LaMarche on March 9, 2017.

D.1.2.3. Incremental Analysis

The Modernization Alternative was evaluated using an incremental analysis, which identifies how total costs and benefits change as project phases are added. The engineering pipeline design (pipe diameters, pressure ratings, etc.) is independent of the number of phases and the order in which the phases are installed. The laterals that make up Project Group 1 and Project Group 2 are in two different areas of the District; the locations determined their grouping into the separate project groups. 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-7 presents the individual increments of benefits and costs associated with each lateral. Table D-8 presents the increments of how costs and benefits change as the project phases are added. As seen in Table D-8, there is an increased net benefit by adding Project Group 2 to Project Group 1.

Table D-7. Incremental Analysis of Annual NEE Costs and Benefits Under the Modernization Alternative for NUID by Lateral, Deschutes Watershed, Oregon, 2020$.[1]

Works of Improvement	Agriculture-related			Non-agricultural	Average Annual Benefits	Average Annual Cost[2]	Benefit Cost Ratio
	Agricultural Benefits	Energy Cost Savings	Reduced OM&R	Carbon Value			
Project Group 1: Lateral 31	$60,000	$5,000	$0	$2,000	$67,000	$13,000	5.2
Project Group 1: Lateral 32	$22,000	$1,000	$0	$0	$23,000	$2,000	11.5
Project Group 1: Lateral 34	$71,000	$7,000	$0	$3,000	$81,000	$80,000	1.0
Project Group 2: Lateral 43	$792,000	$204,000	$53,000	$88,000	$1,137,000	$764,000	1.5
Total	$945,000	$217,000	$53,000	$93,000	$1,307,000	$859,000	1.5

Notes:
OM&R = operation, maintenance, and replacement

Table D-8. Incremental Analysis of Annual NEE Costs and Benefits Under the Modernization Alternative for NUID, Deschutes Watershed, Oregon, 2020$.[1]

Project Phases	Total Costs	Incremental Costs	Total Benefits	Incremental Benefits	Net Benefits
1	$95,000		$171,000		$76,000
1, 2	$859,000	$764,000	$1,308,000	$1,137,000	$449,000

Notes: Prepared March 2021
[1]/Price Base: 2020 dollars amortized over 100 years at a discount rate of 2.5 percent.

D.1.3. References

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D.2. NEE Appendix

D.2.1. Crop Enterprise Budgets

This appendix presents the crop enterprise budgets used to estimate the benefits under the Modernization Alternative of avoiding agricultural damage to NUID (described in Section D.1.2.1.1). The analyses used a total of four crop budgets:

Table D-9. Summary of Crop Budgets.

Scenario	Production Year [1]	Budget Table
Deficit Irrigation	Year 1	**Error! Reference source not found.**Table D-10
	Years 2–6	Table D-11
Full Irrigation	Year 1	Table D-12
	Years 2–6	Table D-13

Notes:
1/ This refers to years in the alfalfa rotation and is not the same as the years measuring the study period in the analysis.

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 they do not necessarily represent conditions of any particular farm. As a starting point for the crop budgets in this analysis, a crop budget for alfalfa hay developed by Washington State University was selected and then values in the budget were adjusted to account for changes in prices through time and local conditions in the District. A more recently published alfalfa hay budget for Central Oregon was not available from Oregon State or Washington State University. The following section outlines the data and assumptions used in adjusting the Washington State alfalfa hay budget.

D.2.1.1. Alfalfa Enterprise Budgets

The alfalfa hay enterprise budgets were based on a 2012 budget developed by Washington State University for establishing and producing alfalfa hay in the Washington Columbia Basin (Norberg & Neibergs, 2012). These budgets were selected as the basis for 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.

Costs presented in the original budgets were updated to account for changing values over time and to reflect conditions specific to NUID. Returns to alfalfa were based on average hay yields in Jefferson County and 5-year normalized average hay prices in Oregon.[15]

15 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.

D.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 one-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.

Input Costs

For fertilizers in the non-establishment budgets, the amount used was adjusted proportionally according to differences in yield from the original budget. For example, the original budget calls for 92 pounds (lbs) of dry phosphate to produce 8 tons of hay per acre; in the Deficit Irrigation Production Budget (Table D-11), a yield of only 4.1 tons per acre (51 percent of the original yield) was modeled, so the amount of dry phosphate was reduced to 47 lbs (51 percent of 92 lbs). One exception to this method is the amount of dry sulfur applied, which was held constant at 30 lbs per acre during production years per guidance from an OSU Extension Agent in Central Oregon (Bohle, 2020). The Year 1 Production budgets (Table D-10 and Table D-12) retain the fertilizer levels from the original budget.

All costs are adjusted from the original values in the Washington State University budget. Area-specific values for fuel prices, irrigation charges, and land costs were used. For costs that did not have area-specific values, the value in the original budget was adjusted using the national Producer Price Indices (PPI) produced by NASS, which are published for a variety of farm expenses (NASS, 2020). For example, there are price indices for fertilizer, herbicides, supplies, tractors, and 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 and phosphorus to a 16 percent increase in machinery costs.

For land costs in the establishment budget, NASS data was used on rental rates for irrigated cropland in Jefferson County ($121 per acre) (NASS, 2020).[16] Because alfalfa is seeded in the fall after another crop has been harvested, 25 percent of the land costs were ascribed to establishing alfalfa.

D.2.1.3. 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, the analysis used the median hourly wage rate for the farmworkers occupation in Oregon in 2019 and adjusted it to 2020 dollars using the Consumer Price Index.[17] This wage rate was further increased by 20 percent to account for non-wage employment costs such as health care and insurance.[18] This resulted in total labor costs of $16.95 per hour for irrigation labor.

The cost of custom work was adjusted using the Custom Work PPI. For the production budgets, some labor costs (including custom bailing, hauling, staking, and tarping) were adjusted 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, the results will underestimate benefits (and vice versa). Management labor costs are estimated at 5 percent of total costs (following the original budget). Other custom labor, including swathing

16 For Jefferson County, the normalized average price from 2011–2020 was used. The normalized average was calculated by removing the high and low values from dataset and taking the mean of the remaining values.

17 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).

18 This is roughly the average proportion of non-wage labor costs for all private, part-time workers in the U.S. in December 2018 (Bureau of Labor Statistics, 2018).

and raking, were adjusted based on the number of hay cuttings. The original budget modeled four cuttings; the Full Irrigation Budgets (Table D-12and Table D-13) model three cuttings, while the Deficit Irrigation Budgets (Table D-10 and Table D-11) model two cuttings.

D.2.1.4. Revenues

To estimate the gross revenues of alfalfa hay, the analysis used the normalized average price per ton for alfalfa hay in Oregon from 2013 to 2019 according to NASS data: $195.20 (NASS, 2020). For NUID yields, the analysis used the average yield in Jefferson County from 2013 to 2017: 5.4 tons per acre (NASS, 2020).

D.2.1.5. Alfalfa Enterprise Budget Tables

The tables below present alfalfa hay enterprise budgets used to estimate the costs and returns under different irrigation levels.

Table D-10. Alfalfa Net Returns 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	lb	$0.34	$0.00
Dry Phosphate	0.0	lb	$0.63	$0.00
Dry Potash	0.0	lb	$0.45	$0.00
Dry Sulfur	0.0	lb	$0.20	$0.00
Custom - Swath	2.0	ac	$23.22	$46.45
Custom - Rake	2.0	ac	$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	ac	$45.09	$45.09
Irrigation - water access	1.0	ac	$3.10	$3.10
Irrigation - repairs	1.0	ac	$16.88	$16.88
Irrigation - labor	0.5	ac	$16.95	$8.47
Gopher control	1.0	ac	$5.72	$5.72
Fuel	2.3	gal	$2.69	$6.13
Lubricants	1.0	ac	$0.92	$0.92
Machinery repairs	1.0	ac	$2.03	$2.03
Haystack Insurance	4.1	ton	$1.80	$7.33
Overhead	1.0	ac	$28.79	$28.79

Item	Quantity	Unit	$/Unit	Total
Operating interest	1.0	ac	$8.57	$8.57
Total variable costs				$348.75
FIXED COSTS				
Machinery depreciation	1.0	ac	$6.37	$6.37
Machinery interest	1.0	ac	$3.66	$3.66
Machinery insurance, taxes, housing, license	1.0	ac	$2.52	$2.52
Management (5% of total cost)	1.0	ac	$24.26	$24.26
Establishment cost	1.0	ac	$93.82	$93.82
Land cost	1.0	ac	$121.20	$121.20
Total fixed costs				$251.84
Total costs				$600.45
NET RETURNS PER ACRE				**$191.94**

Notes: ac = acre; gal = gallon; lb = pound

Table D-11. Alfalfa Net Returns 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	lb	$0.34	$0.00
Dry Phosphate	46.7	lb	$0.63	$29.22
Dry Potash	71.0	lb	$0.45	$31.62
Dry Sulfur	30.0	lb	$0.20	$6.01
Zinc	2.5	lb	$2.03	$5.16
Boron	1.0	lb	$4.58	$4.65
Custom Application	1.0	ac	$10.45	$10.45
Soil Test	1.0	ac	$0.35	$0.35
Herbicide	2.0	lb	$16.97	$33.93
Custom Application	1.0	ac	$10.45	$10.45
Custom - Swath	2.0	ac	$23.22	$46.45
Custom - Rake	2.0	ac	$11.61	$23.22
Custom - Bail	4.1	ton	$19.74	$80.13

Item	Quantity	Unit	$/Unit	Total
Custom - Haul & Stack	4.1	ton	$10.45	$42.42
Custom - Tarping	4.1	ton	$5.81	$23.57
Irrigation - power	1.0	ac	$50.73	$50.73
Irrigation - water access	1.0	ac	$3.10	$3.10
Irrigation - repairs	1.0	ac	$16.88	$16.88
Irrigation - labor	0.4	ac	$16.95	$6.35
Haystack insurance	4.1	ton	$1.80	$7.33
Gopher control	1.0	ac	$5.72	$5.72
Fuel	2.3	gal	$2.69	$6.13
Lubricants	1.0	ac	$0.92	$0.92
Machinery repairs	1.0	ac	$2.03	$2.03
Overhead	1.0	ac	$43.34	$43.34
Operating interest	1.0	ac	$12.25	$12.25
Total variable costs				$502.41
FIXED COSTS				
Machinery depreciation	1	ac	$6.37	$6.37
Machinery interest	1	ac	$3.66	$3.66
Machinery insurance, taxes, housing, license	1	ac	$2.52	$2.52
Management (5% of total cost)	1	ac	$36.50	$36.50
Establishment cost	1	ac	$93.82	$93.82
Land cost	1	ac	$121.20	$121.20
Total fixed costs				$264.07
Total costs				$766.49
NET RETURNS PER ACRE				**$25.90**

Notes: ac = acre; gal = gallon; lb = pound

Table D-12. Alfalfa Net Returns 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	lb	$0.34	$0.00
Dry Phosphate	0.0	lb	$0.63	$0.00

Item	Quantity	Unit	$/Unit	Total
Dry Potash	0.0	lb	$0.45	$0.00
Dry Sulfur	0.0	lb	$0.20	$0.00
Custom - Swath	3.0	ac	$23.22	$69.67
Custom - Rake	3.0	ac	$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	ac	$45.09	$45.09
Irrigation - water access	1.0	ac	$3.10	$3.10
Irrigation - repairs	1.0	ac	$16.88	$16.88
Irrigation - labor	0.5	ac	$16.95	$8.47
Gopher control	1.0	ac	$5.72	$5.72
Fuel	2.3	gal	$2.69	$6.13
Lubricants	1.0	ac	$0.92	$0.92
Machinery repairs	1.0	ac	$2.03	$2.03
Haystack Insurance	5.4	ton	$1.80	$9.77
Overhead	1.0	ac	$28.79	$28.79
Operating interest	1.0	ac	$10.72	$10.72
Total variable costs				$436.89
FIXED COSTS				
Machinery depreciation	1.0	ac	$6.37	$6.37
Machinery interest	1.0	ac	$3.66	$3.66
Machinery insurance, taxes, housing, license	1.0	ac	$2.52	$2.52
Management (5% of total cost)	1.0	ac	$28.67	$28.67
Establishment cost	1.0	ac	$93.82	$93.82
Land cost	1.0	ac	$121.20	$121.20
Total fixed costs				$256.25
Total costs				$692.99
NET RETURNS PER ACRE				**$363.53**

Notes: lb = pound; Gal = gallon; ac = acre

Table D-13. Alfalfa Net Returns 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	lb	$0.34	$0.00
Dry Phosphate	62.2	lb	$0.63	$38.96
Dry Potash	94.7	lb	$0.45	$42.16
Dry Sulfur	30.0	lb	$0.20	$6.01
Zinc	3.4	lb	$2.03	$6.88
Boron	1.4	lb	$4.58	$6.20
Custom Application	1.0	ac	$10.45	$10.45
Soil Test	1.0	ac	$0.35	$0.35
Herbicide	2.0	lb	$16.97	$33.93
Custom Application	1.0	ac	$10.45	$10.45
Custom - Swath	3.0	ac	$23.22	$69.67
Custom - Rake	3.0	ac	$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	ac	$50.73	$50.73
Irrigation - water access	1.0	ac	$3.10	$3.10
Irrigation - repairs	1.0	ac	$16.88	$16.88
Irrigation - labor	0.5	ac	$16.95	$8.47
Haystack insurance	5.4	ton	$1.80	$9.77
Gopher control	1.0	ac	$5.72	$5.72
Fuel	2.3	gal	$2.69	$6.13
Lubricants	1.0	ac	$0.92	$0.92
Machinery repairs	1.0	ac	$2.03	$2.03
Overhead	1.0	ac	$43.34	$43.34
Operating interest	1.0	ac	$15.05	$15.05
Total variable costs				$616.86
FIXED COSTS				
Machinery depreciation	1.0	ac	$6.37	$6.37

Item	Quantity	Unit	$/Unit	Total
Machinery interest	1.0	ac	$3.66	$3.66
Machinery insurance, taxes, housing, license	1.0	ac	$2.52	$2.52
Management (5% of total cost)	1.0	ac	$42.22	$42.22
Establishment cost	1.0	ac	$93.82	$93.82
Land cost	1.0	ac	$121.20	$121.20
Total fixed costs				$269.80
Total costs				$886.65
NET RETURNS PER ACRE				**$169.87**

Notes: ac = acre; gal = gallon; lb = pound

D.3. 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 NEPA and environmental review requirements specific to NRCS federal investments in water resources projects (USDA *Guidance for Conducting Analyses Under the Principles, Requirements, and Guidelines for Water and Land Related Resources Implementation Studies and Federal Water Resource Investments* [PR&G]) (Table D-14). According to NEPA, "agencies shall rigorously explore and objectively evaluate all reasonable alternatives" (40 CFR 1502.14). According to the PR&G DM 9500-013, 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 eliminated during formulation are shown in Table D-14 and discussed below. Alternatives selected for further evaluation are discussed in the Plan-EA.

Table D-14. 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		
Voluntary Duty Reduction			X		
Partial Use of Groundwater					
On-Farm Efficiency Upgrades		X		X	
Piping Private Laterals		X		X	
Canal Lining	X	X		X	X
Piping Across NUID		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
Modernization Alternative	X	X	X	X	X

Notes:
NUID = North Unit Irrigation District; PR&G = Guidance for Conducting Analyses Under the Principles, Requirements, and Guidelines for Water and Land Related Resources Implementation Studies and Federal Water Resource Investments

D.3.1. 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, as well as generally shallow and well- to excessively drained soils with low storage potentials, 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 the area is experiencing. Dryland farming would not meet any of the purposes of the project and would be inconsistent with ensuring agricultural production is maintained in an area undergoing rapid urbanization.

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

D.3.2. 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. Voluntary duty reduction would not meet any of the proposed project purposes. The District already sets limits on patrons' annual usage in the District, and additional duty reductions would reduce a patron's reliable agricultural water supply and decrease agricultural production, which would impact the local rural community. Voluntary duty reduction would not meet any of the other identified needs of the proposed project.

Voluntary duty reduction was eliminated from further evaluation because it would not meet the proposed 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.

D.3.3. Partial Use of Groundwater

The partial conversion from surface-water-sourced- to groundwater-sourced-irrigation was also initially considered as a possible alternative. To use groundwater in the Deschutes Basin, the District would have to apply for groundwater rights under the OWRD 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[19] 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).

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[20] 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.

Exclusive and partial use of groundwater would not meet any of the purposes of the proposed project. If water saved from conversion to groundwater was applied to other uses in the District, it could improve water availability for agricultural use in the District, but this is not certain to occur because switching to groundwater would be voluntary. Additionally, the District lacks the statutory authority or responsibility to carry out, operate, and maintain groundwater wells on private lands owned by NUID patrons. Therefore, carrying out this alternative would be logistically complex. The partial use of groundwater was eliminated from further evaluation because it would not meet the proposed project's purpose and need; its effectiveness would be uncertain since conversion to groundwater would be voluntary; of inefficiencies associated with logistical and legal constraints obtaining groundwater rights; of low acceptability since converting to groundwater rights would result in junior water rights; and because it would not achieve the Federal Objective and Guiding Principles.

D.3.4. On-Farm Efficiency Upgrades

On-farm efficiency upgrades refer to patrons upgrading their on-farm infrastructure to use irrigation technologies that provide a more precise application of water. On-farm infrastructure is distinct from the District's infrastructure because it is owned and operated by patrons. Once delivered by the District and arriving on-farm, water can either be released to flow over the land for flood irrigation or stored in a holding pond and later pumped out for sprinkler irrigation systems. Typical on-farm irrigation systems include center-pivots, wheel-lines, hand-lines, K-lines, drip systems, and flood irrigation. 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). Farms within the District are irrigated almost entirely through sprinkler irrigation[21] (97 percent of the total acreage in NUID; NUID 2016).

Voluntary programs to increase on-farm water use efficiency by other agencies and organizations are ongoing within the District and the Deschutes Basin. However, on-farm efficiency upgrades would not meet the proposed project purpose. Water loss due to seepage would still occur in District infrastructure as would operational inefficiencies. Water delivery reliability would not be improved and would remain an issue.

If P.L. 83-566 funds were used to develop and implement on-farm efficiency upgrades, the use of these funds would require NUID to complete a SHPO/NHPA analysis for each individual property owner. It would potentially put NUID into a position of having to mitigate cultural resources on private property and could result in NUID having to develop long-term maintenance or preservation agreements on lands not subject to NUID control. This approach is logistically complex and would increase costs of the proposed project.

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[19] 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).

[20] NUID would not create groundwater mitigation credits under either the No Action or the Modernization Alternatives analyzed in this Plan-EA.

[21] This includes all sprinkler application methods including center-pivot, wheel-line, hand-line, etc.

Additionally, NUID lacks the authority or responsibility to carry out, operate, and maintain on-farm infrastructure owned by NUID patrons which would add to logistical complexity. The on-farm efficiency upgrade alternative was eliminated from further study because it does not meet the purpose and need of the proposed project, would be logistically unreasonable, and because it did not achieve the Federal Objective and Guiding Principles.

D.3.5. Piping Private Laterals

Piping private laterals refers to converting patron-owned open laterals to piped laterals from the NUID point of delivery to the point of use on-farm. Private laterals are owned and operated by patrons; NUID does not have responsibility for the operation or maintenance of private laterals.

Since NUID lacks the authority or responsibility to carry out, operate, and maintain private laterals owned by NUID patrons, this alternative would have the same logistical complexities, which make this alternative unreasonable.

Piping private laterals, similar to on-farm irrigation upgrades, would not meet the project purpose of conserving water or improving water delivery reliability on District-owned infrastructure. Piping private laterals was eliminated from further study because it does not meet the purpose of the propose project and would be logistically unreasonable.

D.3.6. Piping Entire District

In 2016, NUID worked with Black Rock Engineering to perform a water loss assessment and to identify potential energy and water conservation projects along NUID-owned infrastructure. The result of this work was a System Improvement Plan (2017) which included a 10 percent engineering design of the entire system piped and the associated costs, energy conservation/generation, and potential water savings.

When NUID developed the System Improvement Plan, it was identified that piping the District ($809M), plus the Main Feed Canal from Bend ($540M) would cost $1.35B (2017 dollars). This would be logistically unreasonable for NUID to pursue, as it would not reasonably be able to find match funding for a project of this size. However, upon completion of the System Improvement Plan and during the P.L. 83-566 scoping process, NUID assessed what areas of its District had high water loss and other benefits, would be acceptable to patrons, and would address the resource concerns within the District. Based on these criteria, laterals 31, 32, 34, and 43 were determined to be of high priority. After initial analysis, Lateral 43 was shortened because it was shown that the benefits from piping the full extent of the lateral would not outweigh the costs.

Piping across the entire district was eliminated because it would be logistically unreasonable to find the match funding for a project of this scale. However, piping laterals 30, 32, 34 and 43 were moved forward for detailed analysis.

D.4. Capital Costs

D.4.1. Canal Lining Alternative Costs

The capital cost of the Canal Lining Alternative (Table D-15) was estimated by calculating the length of geotextile membrane for existing open canals assuming an anchor of membrane extends 7 feet on either side. The membrane would be covered by a 1-inch-thick 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 were 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, which were 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 were used for this section as were used for the Preferred Alternative.

Table D-15. Canal Lining Alternative Costs.

Feature	Equivalent Pipe Diameter (inches)	Length (feet) or Quantity	Cross section (feet)	Channel Width (feet)	Channel Depth (feet)	Materials & Construction ($)
Lining	72	2,543	31.4	29.3	5.2	$1,148,000
Lining	66	2,393	29.2	27.2	4.9	$1,013,000
Lining	63	11,866	34.4	32.7	3.9	$5,810,000
Lining	54	29	23.6	23.6	4.3	$11,000
Lining	48	5,661	25.9	23.5	4.4	$2,699,000
Lining	42	4,523	25.3	22.8	4.6	$2,098,000
Lining	36	5,473	22.2	19.5	4.9	$2,268,000
Lining	34	4,818	19.7	18.5	3.3	$1,807,000
Lining	32	1,302	25.3	24.0	3.3	$604,000
Lining	28	1,749	23.6	22.5	3.0	$764,000
Lining	26	3,917	23.6	22.5	3.0	$1,355,000
Lining	24	19,133	23.8	22.6	3.1	$10,098,000
Lining	20	8,872	22.2	20.9	3.2	$4,404,000
Lining	18	8,974	14.5	13.1	2.8	$3,171,000
Lining	16	17,743	14.8	14.1	2.3	$6,274,000
Lining	14	4,329	12.5	11.8	2.2	$1,360,000
Lining	12	14,022	12.7	11.8	2.4	$4,445,000
Lining	10	12,879	12.7	11.8	2.4	$4,729,000
Lining	8	5,832	12.3	11.6	2.0	$1,896,000
Lining	6	8,815	12.3	11.6	2.0	$3,059,000
Turnouts	N/A	153	N/A	N/A	N/A	$153,000

Feature	Equivalent Pipe Diameter (inches)	Length (feet) or Quantity	Cross section (feet)	Channel Width (feet)	Channel Depth (feet)	Materials & Construction ($)
Retention Ponds	N/A	4	N/A	N/A	N/A	$160,000
					Subtotal	$59,325,000
					Engineering, Construction Management, and Survey (10%)	$5,933,000
					Construction Manager/General Contractor (10%)	$5,933,000
					Contingency (15%)	$10,679,000
					Total	$81,869,000

Notes: Prepared March 2021
N/A = not applicable. Totals rounded to nearest $1,000 and may not sum.

D.4.2. Modernization Alternative/Preferred Alternative Costs

This section presents capital costs for the Modernization Alternative, which is the Preferred Alternative (Table D-16).

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 Modernization Alternative include, but are not limited to, polyvinyl chloride, steel, high-density polyethylene (HDPE), bar-wrapped concrete cylinder, fiberglass, and ductile iron. The Modernization Alternative was priced using HDPE pipe, which at the time of this analysis was considered to be the most cost-effective material.

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

Table D-16. Preferred Alternative Costs.

Feature	Diameter (in)	Quantity	Units	Materials & Construction
Piping	6	8,815	feet	$73,000
Piping	8	5,832	feet	$93,000
Piping	10	12,878	feet	$267,000
Piping	12	14,023	feet	$414,000
Piping	14	4,328	feet	$150,000
Piping	16	17,743	feet	$741,000
Piping	18	8,974	feet	$569,000
Piping	20	8,872	feet	$652,000
Piping	24	19,133	feet	$2,123,000
Piping	26	3,917	feet	$344,000
Piping	28	1,749	feet	$239,000
Piping	32	1,302	feet	$255,000
Piping	34	4,818	feet	$1,063,000
Piping	36	5,473	feet	$892,000
Piping	42	4,523	feet	$1,172,000
Piping	48	5,661	feet	$2,229,000
Piping	54	29	feet	$13,000
Piping	63	11,866	feet	$7,025,000

Feature	Diameter (in)	Quantity	Units	Materials & Construction
Piping	66	2,393	feet	$1,198,000
Piping	72	2,543	feet	$1,515,000
Turnouts	N/A	153	each	$1,224,000
Retention Reservoirs	N/A	4	each	$160,000
Energy Dissipator	N/A	2	each	$116,000
Pressure Reducing Valve	N/A	4	each	$145,000
			Subtotal	$22,670,000
			Engineering, Construction Management, and Survey (10%)	$2,267,000
			Construction Manager/General Contractor (10%)	$2,267,000
			Contingency (15%)	$4,081,000
			Total	$31,284,000

Notes: Prepared March 2021
N/A = not applicable. Totals rounded to nearest $1,000 and may not sum.

D.6. Net Present Value of the Preferred Alternative

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

Discount Rate: 2.5%

Period of Analysis: 100 years

Table D-17. Net Present Value of the Preferred Alternative and the Canal Lining Alternative.

	Preferred Alternative	Canal Lining Alternative[1]
Design Life	100 years	33 years
Capital Costs	$29,014,000	$81,437,000
Net Present Value of Replacement Costs[1]	$0	$65,016,000
Annual O&M Costs	$0	$116,000
Percent Change in O&M	0%	+.25%
Net Present Value of O&M Costs	$0	$4,233,000
Total Net Present Value of Project	$29,014,000	$150,686,000

Notes: Prepared March 2021
Totals rounded to nearest $1,000.
N/A = not applicable; O&M = operation and maintenance
[1] For canal lining, 100 percent was replaced at both 33 years and 66 years.

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Appendix E

Other Supporting Information

E.1. Intensity Threshold Table

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

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

Beneficial	Changes in the resource or resource-related values are favorable or advantageous with respect to the resource. The effects on the resource or environment may range from slight to regional.
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 more than 5 years to recover.

E.2. Supporting Information for Land Use

Table E-2. Project Area Land Use.

Land Ownership	Project Area Length	Project Area Length Crossing each Land Use Class (miles)
Federal (Reclamation)	66%	18.2
Private	34%	9.25
State/ Local Government [1]		
Total	**100%**	**27.45**

Notes:
Source: Deschutes County GIS; Jefferson County GIS
[1] All roadway, mostly Jefferson County with a small amount occurring in City of Metolious and some Oregon Department of Transportation.

E.3. Supporting Information for Soil Resources

Table E-3. Project Area Length Crossing Farmland.

NRCS Farmland Class	Project Area	Project Area (miles)
Prime Farmland if Irrigated	66%	18.2
Farmland of Statewide Importance	34%	9.25
Total	**100%**	**27.45**

Notes:
Source: NRCS gSSURGO FY2020 data.

E.4. Supporting Information for Vegetation Resources

The Jefferson County Noxious Weed Policy and Classification System designates three weed categories. Weeds designated "A" are of highest priority for control and are subject to intensive eradication, containment, or control measures using County resources. Weeds designated "B" have a limited distribution; intensive containment control and monitoring by landowners is required, and support from the County is provided when resources allow. Weeds designated "C" are the lowest priority for control. They have a widespread distribution, and landowner control and monitoring are recommended (Jefferson County, 2018). Table E-4 lists the noxious weeds and corresponding classifications known to occur in the project area.

Table E-4. Noxious Weeds Occurring in Jefferson County, Oregon.

Vegetation Species	Scientific Name	Jefferson County Noxious Weed Rating
Buffalobur	*Solanum rostratum*	A
Dalmation Toadflax	*Linaria dalmatica*	A
Eurasian Milfoil	*Myriophyllum spicatum*	A
Houndstongue	*Cynoglossum officinale*	A
Iberian and Purple Starthistle	*Hydrilla verticillate*	A
Japanese Knotweed	*Polygonum cuspidatum*	A
Jointed Goatgrass	*Aegilops cylindrica*	A
Leafy Spurge	*Euphorbia esula*	A
Meadow Knapweed	*Centaurea debeauxii*	A
Musk Thistle	*Carduus acanthoides*	A
Perennial Pepperweed	*Lepidium latifolium*	A
Purple Loosestrife	*Lythrum salicaria*	A
Rush Skeletonweed	*Chondrilla juncea*	A
Scotch Broom	*Cytisus scoparius*	A
Scotch Thistle	*Onopordum acanthium*	A
Slender False Broom	*Brachypodium sylvaticum*	A
Spotted Knapweed	*Centaurea stoebe*	A
Squarrosa Knapweed	*Centaurea virgata*	A
Tansy Ragwort	*Senecio jacobaea*	A
Ventenata	*Ventenata dubia*	A
Wild Carrot	*Daucus carota*	A
Yellow Flag Iris	*Iris pseudacorus*	A
Yellow Starthistle	*Centaurea solstitialis*	A

Vegetation Species	Scientific Name	Jefferson County Noxious Weed Rating
Canada Thistle	*Cirsium arvense*	B
Canadian Goldenrod	*Solidago canadensis*	B
Common Groundsel	*Senecio vulgaris*	B
Curly Dock	*Rumex crispus*	B
Diffuse knapweed	*Centaurea diffusa*	B
Field Bindweed (Morning Glory)	*Convolvulus arvensis*	B
Flixweed	*Descurainia sophia*	B
Kochia	*Kochia scoparia*	B
Marestail	*Conyza canadensis*	B
Myrtle Spurge	*Euphorbia myrsinites*	B
Puncturevine	*Tribulus terrestris*	B
Quack Grass	*Elytrigia repens*	B
Russian Knapweed	*Acroptilon repens*	B
Ribbon Grass	*Phalaris arundinacea* var. *picta*	B
Russian Thistle (Tumbleweed)	*Salsola* spp.	B
Tumble Mustard	*Sisymbrium altissimum*	B
White Top Hoary Cress	*Cardaria chalepensis*	B
Common Mullein	*Verbascum thapsus*	C
Common St. Johnswort	*Hypericum perforatum*	C
Dead Nettle (Henbit)	*Lamium amplexicaule*	C
Medusahead Rye	*Taeniatherum caput-medusae*	C
Purple Mustard	*Chorispora tenella*	C
Rattail Fescue	*Vulpia myuros*	C
Western Salsify	*Tragopogon dubius*	C

Vegetation Species	Scientific Name	Jefferson County Noxious Weed Rating
Wild Oat	*Avena fatua*	C
Yellow Sweet Clover	*Melilotus officinalis*	C

Notes:
Noxious weeds occur throughout Jefferson County but not all may be in the project area.
Source: Jefferson County Public Works, Vegetation Management.

References

Jefferson County. (2018, March 28). *Jefferson County noxious weed list*. Jefferson County, Oregon. Retrieved from **https://www.jeffco.net/publicworks/page/weed-control-and-abatement**

E.5. Supporting Information for Water Resources

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

E.5.1. Method of Estimating Volume of Water Savings following Completion of the Proposed Project

In 2016, Black Rock Consulting worked with NUID to coordinate a seepage loss study performed by Farmers Conservation Alliance staff under direction the direction of Kevin L. Crew, P.E., and David C. Prull, P.E. of Black Rock Consulting. During the summer of 2016, the Seepage Loss Assessment Program (LAP), supported by Oregon State University and the Oregon Water Resources Department (OWRD), was implemented in seven of the eight Central Oregon irrigation districts, including NUID, to inform the districts of current system losses. The program included the use of newly purchased and calibrated Sontek Flowtracker II flow meters and office and field training in accordance with U.S. Geological Survey and U.S. Bureau of Reclamation practices (USGS 2010).

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 the 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.

For NUID, the LAP was implemented throughout the District's Main Canal and system laterals. Direct measurements identified a total seepage loss of approximately 18.7 cfs in laterals 31, 32, 34, and 43 (Black Rock 2017).

To calculate a volume (acre-feet) of water loss in each irrigation season, the estimated loss rate (see footnotes for fourth through seventh columns in Table E-5) was multiplied by the number of days in each period (third column of Table E-5) and again by the conversion factor of 1.9835 (acre-feet per cfs per day). The product is shown in the fourth through seventh columns of Table E-5, Estimated Volume of Loss in each lateral.

NUID diversion rates vary across the season, and the start of the irrigation season is dependent on many external and internal factors. To calculate the volume as described in the paragraph above, the mean number of days for irrigation years 2002 through 2018 was determined using data from OWRD Gauge No. 14069000 (Table E-6). April and October were typically the only two months during the irrigation season when the number of days varied from year to year.

For purposes of quantifying the volume of loss (acre-feet) in a system where loss is variable and dependent on many external factors, this appeared to be the most accurate approach for this level of analysis.

Table E-5. Calculations for Estimating Volume of Water Savings following Completion of the Proposed Project.

Time Period	2001–2018 Percentage of Maximum Average Diversion Rate [1]	Number of Days used in Volume Calculation [2]	Estimated Loss Volume in Lateral 31 (acre-feet/ time period) [3]	Estimated Loss Volume in Lateral 32 (acre-feet/ time period) [4]	Estimated Loss Volume in Lateral 34 (acre-feet/ time period) [5]	Estimated Loss Volume in Lateral 43 (acre-feet/ time period) [6]
April 1–April 30	74%	22	35.4	12.9	41.9	513.3
May 1–May 31	100%	31	67.8	24.6	80.1	982.1
June 1–June 30	97%	30	63.4	23.1	75.0	919.3
July 1–July 31	100%	31	67.5	24.6	79.8	978.4
Aug 1–Aug 30	88%	31	59.9	21.8	70.8	868.3
Sept 1–Sept 30	69%	30	45.5	16.5	53.8	659.1
Oct 1–Oct 31	58%	14	17.8	6.5	21.1	258.7

Notes:
[1] The season average was only taken during the days the district was diverting water. See Table E-6 showing the length of irrigation season.
[2] Estimated Loss Rate (cfs) in Lateral 31 is 1.1 cfs (Black Rock 2017).
[3] Estimated Loss Rate (cfs) in Lateral 32 is 0.4 cfs (Black Rock 2017).
[4] Estimated Loss Rate (cfs) in Lateral 34 is 1.3 cfs (Black Rock 2017).
[5] Estimated Loss Rate (cfs) in Lateral 43 is 15.9 cfs (Black Rock 2017).

Table E-6. Length of Irrigation Season.

Year	Irrigation Start Date [1]	Irrigation End Date [1]
2002	4/8/2002	10/12/2002
2003	4/18/2003	10/11/2002
2004	4/13/2004	10/12/2003
2005	4/4/2005	10/8/2005
2006	4/19/2006	10/20/2006
2007	4/2/2007	10/17/2007
2008	4/7/2008	10/23/2008
2009	4/13/2009	10/13/2009
2010	4/9/2010	10/15/2010
2011	4/12/2011	10/13/2011
2012	4/9/2012	10/18/2012
2013	4/3/2013	10/9/2013
2014	4/16/2014	10/17/2014
2015	4/7/2015	10/6/2015
2016	4/1/2016	10/12/2016
2017	4/10/2017	10/13/2017
2018	4/2/2018	10/9/2018

Notes:
Percentage of Maximum Average Diversion Rate used data from OWRD Gauge No. #14069000.

References

Black Rock. (2017). North Unit Irrigation District System Improvement Plan. Bend, Oregon.

United States Geological Survey (USGS). (2010). Discharge measurements at gaging stations: U.S. Geological Survey Techniques and Methods Book 3, Chap. A8, 87 p.

E.5.2. Method of Estimating the Volume of Water Available for On-Farm Deliveries

This section describes the method used to quantify the estimated volume of water available for deliveries throughout the District that would be realized through the proposed project. This calculation used data derived from the water loss assessment performed during the summer of 2016, see the previous section for more information. The loss measured in laterals 31, 32, 34, and 43 during this assessment was 18.7 cfs (Black Rock 2017). Table E-7 and Table E-8 provide the data used in these calculations.

To provide a water loss estimate for the NUID Main Canal, the canal was divided into three reaches (Table E-7):

1. Reach 1 – Main Canal from Deschutes River to Crooked River Inflow
2. Reach 2 – Crooked River Inflow to Haystack Reservoir
3. Reach 3 – Haystack Reservoir to Tail

System losses in Reach 1 were measured to provide an estimated volume at the start of Reach 2 (Table E-8). Although losses in this part of the system occur, for this calculation it was assumed that this water would not be conserved, as it is conveyed through open canals that are not included in the proposed project and that would remain open for the reasonably foreseeable future.

To estimate losses in Reach 2, the Estimated Volume at the Start of Main Canal Reach 2 (second column of Table E-8 under Reach 2) was multiplied by 10.13 percent, the average loss in Main Canal Reach 2 (Table E-7), and then again by 10.31 percent, the weighted average loss in laterals served off of the Main Canal in Reach 2 (Table E-7). The product is shown in column six of Table E-8 under Reach 2, the Estimated Volume at Start of Main Canal Reach 3.

To estimate losses in Reach 3, the Estimated Volume at Start of Main Canal Reach 3 (second column of Table E-8 under Reach 3) was multiplied by 13.99 percent, the average loss in Main Canal Reach 3 (Table E-7), and then again by 9.93 percent, the weighted average loss in laterals served off of the Main Canal in Reach 3 (Table E-7). The product is shown in column six of Table E-8 under Reach 3.

The sum of the total losses is shown in column two of Table E-8 under Total Loss in System and Estimated On-Farm Delivery. Column three of Table E-8 under Total Loss in System and Estimated On-Farm Delivery is the sum of the Estimated Seepage and Evaporative Loss in System (1,814.5 acre-feet/year) and the Reach 3 Tailwater (167.3 acre-feet/year). The Estimated On-Farm Delivery was then calculated by subtracting the Estimated Seepage and Evaporative Loss in System (1,814.5 acre-feet/year) from the Total Savings (6,088.9 acre-fee/year).

For purposes of quantifying the volume of loss (acre-feet) in a system where loss is variable and dependent on many external factors, this was determined to be the most accurate and conservative approach for this level of analysis. All water savings will be verified following completion of the conservation project by OWRD.

Table E-7. Measured Loss Percentages.

Lateral/Canal Name	Measured Discharge (cfs) [1]	Percent Loss [1]	Group	Weight (Measured Discharge/ Subtotal Measured Discharge)	Weighted Loss
MAIN CANAL					
Reach 1 – Main Canal from Deschutes River to Crooked River Inflow					
At Start of Reach	483.75	NA	--	--	--
Delivered to Laterals	0	--	--	--	--
Measured Loss	0	0.00% [2,3]	--	--	--
Flow Remaining	483.75	--	--	--	--
Reach 2 – Crooked River Inflow to Haystack Reservoir					
At Start of Reach	531.44	--	--	--	--
Delivered to Laterals in Reach 2 (see below)	129.75	--	--	--	--
Measured Loss	53.82	10.13% [2]	--	--	--
Flow Remaining	347.87	--	--	--	--
Reach 3 – Haystack to Tail					
At Start of Reach	232.57	--	--	--	--
Delivered to Laterals in Reach 3 (see below)	192.73	--	--	--	--
Measured Loss	32.53	13.99% [2]	--	--	--
Flow Remaining	7.31	--	--	--	--
LATERALS IN REACH 2					
Lateral 34	0	8.34%	Reach 2 Laterals	0.00%	0.00%
Lateral 34-2	0	4.12%	Reach 2 Laterals	0.00%	0.00%
Lateral 37	61.27	5.47%	Reach 2 Laterals	42.73%	2.34%
Lateral 37-3	20.62	3.59%	Reach 2 Laterals	14.38%	0.52%
Lateral 37-4	7.97	14.93%	Reach 2 Laterals	5.56%	0.83%
Lateral 37-5	2.96	29.51%	Reach 2 Laterals	2.06%	0.61%
Lateral 37-8	3.42	47.57%	Reach 2 Laterals	2.39%	1.13%
Lateral 38	2.33	53.65%	Reach 2 Laterals	1.62%	0.87%
Lateral 41	30.76	14.98%	Reach 2 Laterals	21.45%	3.21%
Lateral 41-5	4.83	10.14%	Reach 2 Laterals	3.37%	0.34%
Lateral 41-8	2.09	15.64%	Reach 2 Laterals	1.46%	0.23%

Lateral/Canal Name	Measured Discharge (cfs) [1]	Percent Loss [1]	Group	Weight (Measured Discharge/ Subtotal Measured Discharge)	Weighted Loss
Lateral 41-10	3.27	-1.22%	Reach 2 Laterals	2.28%	-0.03%
Lateral 41-11	3.87	9.30%	Reach 2 Laterals	2.70%	0.25%
Lateral 43	0	16.20%	Reach 2 Laterals	0.00%	0.00%
Lateral 43-2	0	10.37%	Reach 2 Laterals	0.00%	0.00%
Lateral 43-7	0	47.21%	Reach 2 Laterals	0.00%	0.00%
Lateral 43-7-2	0	12.70%	Reach 2 Laterals	0.00%	0.00%
Lateral 43-9	0	46.67%	Reach 2 Laterals	0.00%	0.00%
Lateral 43-10-1	0	5.19%	Reach 2 Laterals	0.00%	0.00%
Lateral 43-12	0	1.59%	Reach 2 Laterals	0.00%	0.00%
Subtotal	143.39	--	--	100%	10.31%
LATERALS IN REACH 3					
Lateral 45	19.5	13.28%	Reach 3 Laterals	5.02%	0.67%
Lateral 45-1	2.52	4.37%	Reach 3 Laterals	0.65%	0.03%
Lateral 45-2	6.3	5.40%	Reach 3 Laterals	1.62%	0.09%
Lateral 50	3.4	11.45%	Reach 3 Laterals	0.88%	0.10%
Lateral 51	24.96	4.79%	Reach 3 Laterals	6.43%	0.31%
Lateral 51-1	6.93	13.42%	Reach 3 Laterals	1.78%	0.24%
Lateral 55	2.5	18.04%	Reach 3 Laterals	0.64%	0.12%
Lateral 55-1	1.23	18.56%	Reach 3 Laterals	0.32%	0.06%
Lateral 56	1.2	8.33%	Reach 3 Laterals	0.31%	0.03%
Lateral 57	13.79	18.13%	Reach 3 Laterals	3.55%	0.64%
Lateral 57-2	3	59.67%	Reach 3 Laterals	0.77%	0.46%
Lateral 57-6	0.42	9.52%	Reach 3 Laterals	0.11%	0.01%
Lateral 58	94.78	6.40%	Reach 3 Laterals	24.41%	1.56%
Lateral 58-2	2.08	2.40%	Reach 3 Laterals	0.54%	0.01%
Lateral 58-3	6.02	12.13%	Reach 3 Laterals	1.55%	0.19%
Lateral 58-8	6.44	13.07%	Reach 3 Laterals	1.66%	0.22%
Upper Lateral 58-11	68.37	9.23%	Reach 3 Laterals	17.61%	1.63%
Lower Lateral 58-11	44.36	4.81%	Reach 3 Laterals	11.43%	0.55%
Lateral 59	7.62	8.27%	Reach 3 Laterals	1.96%	0.16%
Lateral 59-2	1.69	2.96%	Reach 3 Laterals	0.44%	0.01%

Lateral/Canal Name	Measured Discharge (cfs) [1]	Percent Loss [1]	Group	Weight (Measured Discharge/ Subtotal Measured Discharge)	Weighted Loss
Lateral 59-3	4.03	7.69%	Reach 3 Laterals	1.04%	0.08%
Lateral 59-5	1.17	12.72%	Reach 3 Laterals	0.30%	0.04%
Lateral 60	5.33	4.69%	Reach 3 Laterals	1.37%	0.06%
Lateral 61	4.2	3.88%	Reach 3 Laterals	1.08%	0.04%
Lateral 61-1	3.83	56.37%	Reach 3 Laterals	0.99%	0.56%
Lateral 63	14.65	11.60%	Reach 3 Laterals	3.77%	0.44%
Lateral 63-1	5.49	13.66%	Reach 3 Laterals	1.41%	0.19%
Lateral 63-1-1	3.05	24.93%	Reach 3 Laterals	0.79%	0.20%
Lateral 63-4	3.11	6.75%	Reach 3 Laterals	0.80%	0.05%
Lateral 64	16.77	20.57%	Reach 3 Laterals	4.32%	0.89%
Lateral 64-4	7.42	9.03%	Reach 3 Laterals	1.91%	0.17%
Lateral 64-5	1.72	27.91%	Reach 3 Laterals	0.44%	0.12%
Lateral 64-6	0.37	5.41%	Reach 3 Laterals	0.10%	0.01%
Subtotal	388.25	--	--	100%	9.93%

Notes:
cfs = cubic feet per second
[1] Source: Black Rock 2017
[2] This percent loss is derived from measured loss divided by start of reach.
[3] It is assumed that there is zero loss in the NUID Main Canal between the NUID diversion on the Deschutes River and Lateral 43 as this water would have already been lost in the system to get to the laterals proposed for piping.

Table E-8. Estimated Volume of Water Available for On-Farm Deliveries.

Reach 1				
Project Group	**Estimated Savings in the NUID Proposed Project (acre-feet/year)**	**Estimated Volume at Start of Main Canal Reach 1 - Deschutes River to Crooked River Inflow (acre-feet/year)**	**Loss in Main Canal Reach 1 (acre-feet/year) [1]**	**Estimated Volume at Start of Main Canal Reach 2 - Crooked River Inflow to Haystack Reservoir (acre-feet/year) [1]**
1	909.8	909.8	0.0	909.8
2	5,179.2	5,179.2	0.0	5,179.2
Total	**6,088.9**	**6,088.9**	**0.0**	**6,088.9**

Reach 2					
Project Group	**Estimated Volume at Start of Main Canal Reach 2 - Crooked River Inflow to Haystack Reservoir (acre-feet/year)**	**Loss in Main Canal Reach 2 (acre-feet/year)**	**Delivery to Main Canal Reach 2 Laterals (acre-feet/year)**	**Loss in Main Canal Reach 2 Laterals (acre-feet/year)**	**Estimated Volume at Start of Main Canal Reach 3 - Haystack Reservoir to Tail (acre-feet/year)**
1	909.8	92.1	22.5	2.3	795.1
2	5,179.2	524.5	128.1	13.2	4,526.6
Total	**6,088.9**	**616.6**	**150.6**	**15.5**	**5,321.8**

Reach 3					
Project Group	**Estimated Volume at Start of Main Canal Reach 3 - Haystack Reservoir to Tail (acre-feet/year)**	**Loss in Main Canal Reach 3 (acre-feet/year)**	**Delivery to Main Canal Reach 3 Laterals (acre-feet/year)**	**Loss in Main Canal Reach 3 Laterals (acre-feet/year)**	**Reach 3 Tailwater (acre-feet/year)**
1	795.1	111.2	658.9	65.4	25.0
2	4,526.6	633.3	3,751.2	372.4	142.3
Total	**5,321.8**	**744.5**	**4,410.1**	**437.8**	**167.3**

Total Loss in System and Estimated On-Farm Delivery			
Project Group	**Estimated Seepage and Evaporative Loss in System (acre-feet/year)**	**Estimated Total Loss in System (acre-feet/year)**	**Estimated On-Farm Delivery (acre-feet/year)**
1	271.1	296.1	638.7
2	1,543.4	1,685.7	3,635.8
Total	**1,814.5**	**1,981.8**	**4,274.4**

Notes:
[1] It is assumed that there is zero loss in this reach, as this water would have already been lost in the system to get to the laterals proposed for piping.

E.5.3. Instream Flow Targets

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

Table E-9. 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

Notes:
cfs = cubic feet per second

E.5.4. 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-10. 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	614	38	653	418	1,070
Nov	595	31	626	68	693
Dec	571	69	640	66	706
Jan	572	91	663	83	746
Feb	665	57	722	28	749
Mar	705	57	762	195	956
Apr	1,130	345	1,475	55	1,530
May	1,640	70	1,710	288	1,998
Jun	1,688	137	1,825	75	1,900
Jul	1,950	45	1,995	105	2,100
Aug	1,890	35	1,925	95	2,020
Sep	1,320	230	1,550	206	1,756

Notes:
cfs = cubic feet per second
Streamflow in the Deschutes River at Benham Falls at OWRD Gauge No. 14064500 varies within and between years. Data represents the October 2016 through September 2018 water years.

E.5.5. 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-11. 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	82	447	528	45	573
Nov	515	49	564	44	607
Dec	500	81	581	71	652
Jan	487	12	499	179	677
Feb	509	117	626	42	667
Mar	607	61	668	184	851
Apr	163	328	491	234	725
May	95	20	116	15	131
Jun	122	9	131	4	135
Jul	128	5	133	3	136
Aug	122	9	131	3	134
Sep	91	42	133	18	151

Notes:
cfs = cubic feet per second
Streamflow in the Deschutes River downstream from the City of Bend at OWRD Gauge No. 14070500 from the October 2016 through September 2018 water years.

E.5.6. Crooked River Below Osborne Canyon

This section presents supporting calculations used when evaluating the effects of the proposed action with respect to water resources in the Crooked River below Osborne Canyon.

Table E-12. Crooked River Pre-Project Average Daily Mean Streamflow Below Osborne Canyon.

Month	Low Streamflow (cfs) – 80% Exceedance	Lower Bar	Average Streamflow (cfs) – 50% Exceedance	Upper Bar	High Streamflow (cfs) – 20% Exceedance
Oct	208	31	239	55	294
Nov	186	17	203	33	236
Dec	173	19	192	44	236
Jan	180	40	220	220	440
Feb	191	42	233	291	524
Mar	200	68	268	804	1,072
Apr	269	304	573	1,079	1,652
May	150	164	314	515	829
Jun	136	66	202	177	378
Jul	114	29	143	41	184
Aug	124	32	156	33	189
Sep	166	56	222	56	278

Notes:
cfs = cubic feet per second
Streamflow in Crooked River at OWRD Gauge No. 14087380 from the 2003 through 2018 water years.

E.5.7. Crooked River Below Opal Springs

This subsection presents supporting calculations used when evaluating effects of the proposed action with respect to water resources in the Crooked River below Opal Springs.

Table E-13. Crooked River Pre-Project Average Daily Mean Streamflow Below Opal Springs.

Month	Low Streamflow (cfs) – 80% Exceedance	Lower Bar	Average Streamflow (cfs) – 50% Exceedance	Upper Bar	High Streamflow (cfs) – 20% Exceedance
Oct	1,330	40	1,370	70	1,440
Nov	1,310	30	1,340	30	1,370
Dec	1,300	30	1,330	30	1,360
Jan	1,300	40	1,340	250	1,590
Feb	1,310	50	1,360	320	1,680
Mar	1,320	80	1,400	840	2,240
Apr	1,400	325	1,725	1,105	2,830
May	1,260	220	1,480	540	2,020
Jun	1,260	75	1,335	195	1,530
Jul	1,240	20	1,260	60	1,320
Aug	1,240	30	1,270	50	1,320
Sep	1,280	70	1,350	70	1,420

Notes:
cfs = cubic feet per second
Streamflow in Crooked River at OWRD Gauge No. 14087400 from the 2003 through 2018 water years.

E.5.8. Summary of the Requirements Set forth by the Deschutes Basin Habitat Conservation Plan

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

1. From April 1 through September 15, flow at 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 the 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 NUID during the prior irrigation season as a result of the piping of 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 frog.
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 frog, 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 frog 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 cfs, 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*. Retrieved from **https://www.fws.gov/Oregonfwo/articles.cfm?id=149489716**

E.6. Supporting Information for Fish and Aquatic Resources

This section presents supporting information associated with Primary Constituent Elements for critical habitat of federally listed species and their associated Biological Opinions.

Table E-14. 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 water body (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)

Primary Constituent Element (PCE) Number	Habitat Description	Characteristics
PCE 2	Aquatic movement corridors; Ephemeral or permanent bodies of fresh water	Less than or equal to 3.1 miles (5 kilometers) linear distance from breeding areas
		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)
PCE 3	Refugia Habitat	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)

Notes:
Source: Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Oregon Spotted Frog 50 CFR 17

Table E-15. Primary Constituent Elements for Bull Trout.

Primary Constituent Element 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.

Primary Constituent Element Number	Habitat Description and Characteristics
PCE 5	Water temperatures ranging from 2 to 15°C (36 to 59°F), with adequate thermal refugia available for temperatures that exceed the upper end of this range. Specific temperatures within this range will 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 will likely vary from system to system.
PCE 7	A natural hydrograph, including peak, high, low, and base flows within historical 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.

Notes:
Source: Endangered and Threatened Wildlife and Plants; Revised Designation of Critical Habitat for Bull Trout in the Coterminous United States, 50 CFR 17

Table E-16. Fish and Mollusk Species within the Area Affected by District Operations for the North Unit Irrigation District Infrastructure Modernization Project.

Species Common Name	Scientific Name	Wickiup Reservoir	Upper Deschutes River	Middle Deschutes River	Crooked River
Bull trout	*Salvelinus confluentus*			X	X
Steelhead trout	*Oncorhynchus mykiss*			X	X
Spring Chinook salmon	*Oncorhynchus tshawytscha*			X	X
Sockeye salmon	*Oncorhynchus nerka*				X
Redband trout	*Oncorhynchus mykiss gairdneri*	X	X	X	X
Kokanee Salmon	*Oncorhynchus nerka*	X	X	X	
Mountain whitefish	*Prosopium williamsoni*	X	X	X	X
Largescale sucker	*Catostomus macrocheilus*	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	X
Western ridged mussel	*Gonidea angulata*			X	X

Source: Arnold et al 2019

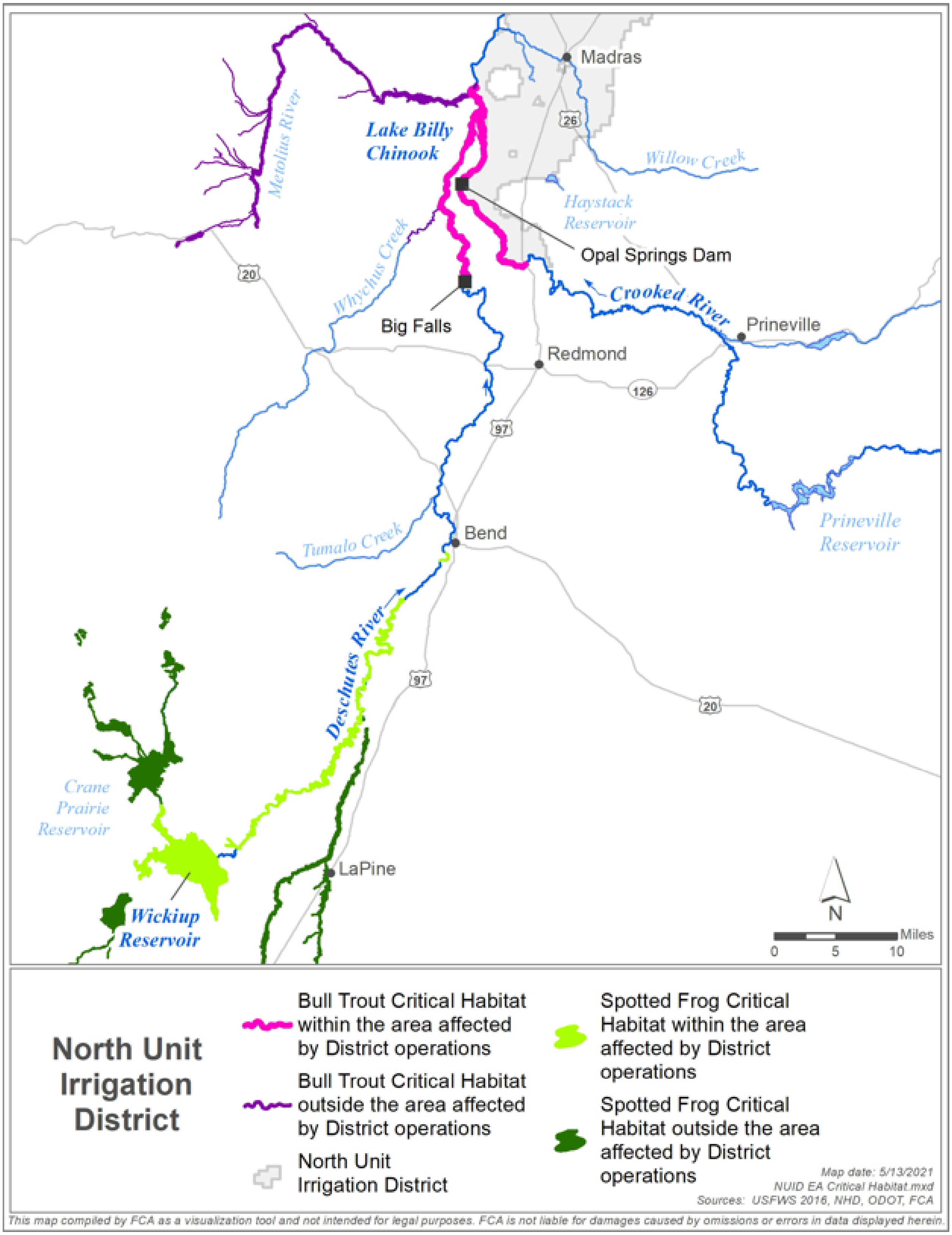

Figure E-1. Bull trout and Oregon spotted frog critical habitat within and outside the area affected by District operations.

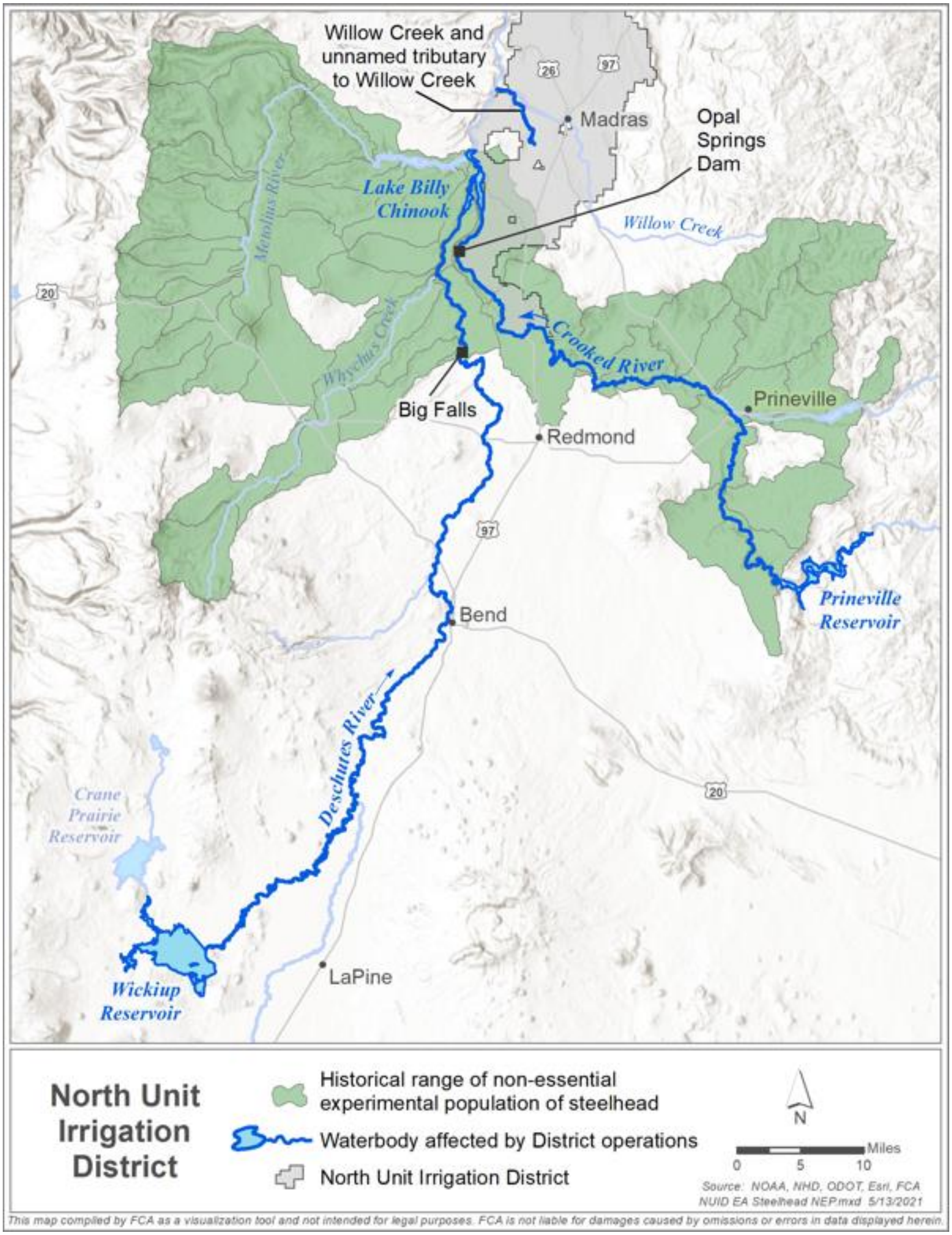

Figure E-2. Steelhead non-essential experimental population within and outside of area affected by District operations.

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Bend Field Office
63095 Deschutes Market Road
Bend, Oregon 97701
(541) 383-7146 FAX: (541) 383-7638

In Reply Refer To:
01EOFW00-2017-F-0528-R001
X-Ref: 01EOFW00-2017-F-0528

JUL 26 2019

Memorandum

To: Deputy Area Manager, Bureau of Reclamation
Columbia-Cascades Area Office
Yakima, Washington

From: Field Supervisor, Bend Field Office
Bend, Oregon

Subject: Reinitiation of Formal Consultation on Bureau of Reclamation Approval of Contract Changes to the 1938 Inter-District Agreement for the Operation of Crane Prairie and Wickiup Dams, and Implementation of the Review of Operations and Maintenance (ROM) and Safety Evaluation of Existing Dams (SEED) Programs at Crane Prairie and Wickiup Dams, Deschutes Project, Oregon (2017-2019)

This memorandum responds to your June 17, 2019 request for reinitiation of formal consultation on the subject actions. Please attach it to the U.S. Fish and Wildlife Service (Service) September 29, 2017 Biological Opinion (Service reference no. 01EOFW00-2017-F-0528) addressing the same actions. Collectively, these documents represent your new Biological Opinion (Opinion) on the effects of the subject actions on the threatened Oregon spotted frog (*Rana pretiosa*) and its critical habitat (CH). Please note that the Incidental Take Statement (ITS) accompanying the 2017 Opinion has also been revised and is included in this memorandum. The revised Opinion and ITS were prepared in accordance with the requirements of section 7 of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 et seq.). Your request for reinitiation of formal consultation was received on June 17, 2019.

Figure E-3. USFWS 2019 Biological Opinion Cover page. *Reinitiation of Formal Consultation on Bureau of Reclamation Approval of Contract Changes to the 1938 Inter-District Agreement for the Operation of Crane Prairie and Wickiup Dams, and Implementation of the Review of Operations and Maintenance (ROM) and Safety Evaluation of Existing Dams (SEED) Programs at Crane Prairie and Wickiup Dams.* Deschutes Project, Oregon (2017-2019), July 26, 2019.

FINAL
Deschutes Basin
Habitat Conservation Plan

Volume I: Chapters 1-12

Submitted by:

Arnold Irrigation District
Lone Pine Irrigation District
Ochoco Irrigation District
Three Sisters Irrigation District
City of Prineville, Oregon
Central Oregon Irrigation District
North Unit Irrigation District
Swalley Irrigation District
Tumalo Irrigation District

October 2020

Figure E-4. Cover page of the Final DBHCP submitted by the eight irrigation districts of the Deschutes Basin to USFWS and National Marine Fisheries Service.

E.7. Supporting Information for Wildlife Resources

This section presents supporting information for the wildlife resources section.

Table E-17. 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	*Contopus 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*

Migratory Bird Treaty Act/Bald and Golden Eagle Protection Act Species	Scientific Name
Western grebe	*Aechmophorus occidentalis*
White-headed woodpecker	*Picoides albolarvatus*
Williamson's sapsucker	*Sphyrapicus thyroideus*
Willow flycatcher	*Empidonax traillii*

Notes:
Source: USFWS 2021
[1] This is only a partial list of migratory birds that potentially occur within the project area.

References

U.S. Fish and Wildlife Service (USFWS). (2021). *IPaC information for planning and consultation,* Retrieved from https://ecos.fws.gov/ipac/

E.8. Supporting Information for Energy Savings

This section presents supporting information associated with energy savings realized by implementation of the Preferred Alternative.

Table E-18.Table E-18. Estimated Pump Energy Conservation Realized by Implementation of the Preferred Alternative.

Lateral	Phase	Proposed Pressure (psi)[1]	Irrigated Lands (acres)	Existing Pump Energy (kWh)[2,3,4]	Proposed Pump Energy (kWh)[2,4,5]	Pump Energy Conservation (kWh)[2,6]
Lateral 31	Phase 1	3.09	81.1	33,586	30,992	2,595
Lateral 31	Phase 1	3.32	20	8,283	7,595	687
Lateral 31	Phase 1	3.99	76.8	31,805	28,633	3,173
Lateral 31	Phase 1	7.50	103.9	43,028	34,960	8,068
Lateral 31	Phase 1	12.27	103.1	42,697	29,600	13,097
Lateral 31	Phase 1	14.38	99.9	41,372	26,499	14,873
Lateral 31	Phase 1	14.91	79.6	32,965	20,677	12,288
Lateral 32	Phase 1	0.94	21.5	8,904	8,695	209
Lateral 32	Phase 1	0.94	32.6	13,501	13,183	317
Lateral 32	Phase 1	1.19	109.5	45,347	43,998	1,349
Lateral 32	Phase 1	12.57	44.1	18,263	12,524	5,739
Lateral 34	Phase 1	0.81	1.7	704	690	14
Lateral 34	Phase 1	0.83	65.5	27,126	26,563	563
Lateral 34	Phase 1	0.96	31.8	13,169	12,853	316
Lateral 34	Phase 1	1.36	38.7	16,027	15,482	545
Lateral 34	Phase 1	1.91	16.1	6,668	6,349	318
Lateral 34	Phase 1	1.91	123.8	51,269	48,821	2,448
Lateral 34	Phase 1	1.97	71.1	29,445	27,995	1,450

Lateral	Phase	Proposed Pressure (psi)[1]	Irrigated Lands (acres)	Existing Pump Energy (kWh)[2,3,4]	Proposed Pump Energy (kWh)[2,4,5]	Pump Energy Conservation (kWh)[2,6]
Lateral 34	Phase 1	2.00	70.6	29,238	27,776	1,462
Lateral 34	Phase 1	2.36	34.6	14,329	13,484	845
Lateral 34	Phase 1	2.40	34.4	14,246	13,391	855
Lateral 34	Phase 1	3.01	7	2,899	2,681	218
Lateral 34	Phase 1	3.32	6.7	2,775	2,544	230
Lateral 34	Phase 1	3.72	158.3	65,557	59,460	6,097
Lateral 34	Phase 1	3.85	30.8	12,755	11,528	1,228
Lateral 34	Phase 1	3.96	27.3	11,306	10,187	1,119
Lateral 34	Phase 1	4.48	36.3	15,033	13,349	1,684
Lateral 34	Phase 1	4.52	35.8	14,826	13,151	1,675
Lateral 34	Phase 1	7.48	14.3	5,922	4,815	1,107
Lateral 34	Phase 1	7.48	35.2	14,577	11,851	2,726
Lateral 34	Phase 1	7.77	36.9	15,281	12,313	2,968
Lateral 34	Phase 1	7.83	29.8	12,341	9,925	2,416
Lateral 34	Phase 1	7.83	75.1	31,101	25,013	6,088
Lateral 34	Phase 1	8.03	135.8	56,239	44,949	11,290
Lateral 34	Phase 1	8.34	72.8	30,149	23,863	6,286
Lateral 34	Phase 1	9.83	21.6	8,945	6,747	2,198
Lateral 34	Phase 1	10.39	35.4	14,660	10,852	3,808
Lateral 34	Phase 1	11.16	12.9	5,342	3,852	1,490
Lateral 34	Phase 1	13.02	36.4	15,074	10,168	4,907
Lateral 34	Phase 1	13.37	16.2	6,709	4,466	2,242

Lateral	Phase	Proposed Pressure (psi)[1]	Irrigated Lands (acres)	Existing Pump Energy (kWh)[2,3,4]	Proposed Pump Energy (kWh)[2,4,5]	Pump Energy Conservation (kWh)[2,6]
Lateral 34	Phase 1	13.39	55.1	22,819	15,180	7,639
Lateral 43	Phase 2	1.50	102.9	42,614	41,016	1,598
Lateral 43	Phase 2	2.26	126.8	52,512	49,545	2,967
Lateral 43	Phase 2	2.33	49.1	20,334	19,149	1,184
Lateral 43	Phase 2	11.69	12.8	5,301	3,752	1,549
Lateral 43	Phase 2	12.38	17.1	7,082	4,890	2,192
Lateral 43	Phase 2	14.02	56.2	23,274	15,117	8,158
Lateral 43	Phase 2	14.21	16.3	6,750	4,352	2,398
Lateral 43	Phase 2	18.37	346.7	143,579	77,640	65,939
Lateral 43	Phase 2	18.81	99.5	41,206	21,829	19,377
Lateral 43	Phase 2	18.82	40.3	16,689	8,837	7,852
Lateral 43	Phase 2	19.13	117.9	48,826	25,475	23,351
Lateral 43	Phase 2	29.57	71.5	29,610	7,721	21,889
Lateral 43	Phase 2	29.57	75.3	31,184	8,131	23,053
Lateral 43	Phase 2	35.15	48.2	19,961	2,420	17,541
Lateral 43	Phase 2	38.72	1.5	621	20	601
Lateral 43	Phase 2	38.85	6.4	2,650	76	2,574
Lateral 43	Phase 2	42.21	65.8	27,250	-	27,250
Lateral 43	Phase 2	42.83	15.3	6,336	-	6,336
Lateral 43	Phase 2	43.70	39.6	16,400	-	16,400
Lateral 43	Phase 2	44.46	12	4,970	-	4,970
Lateral 43	Phase 2	44.50	13.4	5,549	-	5,549

Lateral	Phase	Proposed Pressure (psi)[1]	Irrigated Lands (acres)	Existing Pump Energy (kWh)[2,3,4]	Proposed Pump Energy (kWh)[2,4,5]	Pump Energy Conservation (kWh)[2,6]
Lateral 43	Phase 2	44.51	61.7	25,552	-	25,552
Lateral 43	Phase 2	44.54	66.8	27,664	-	27,664
Lateral 43	Phase 2	44.68	81.4	33,710	-	33,710
Lateral 43	Phase 2	44.74	26.5	10,974	-	10,974
Lateral 43	Phase 2	44.88	152	62,948	-	62,948
Lateral 43	Phase 2	45.00	0.6	248	-	248
Lateral 43	Phase 2	46.26	38.8	16,068	-	16,068
Lateral 43	Phase 2	47.22	32.5	13,459	-	13,459
Lateral 43	Phase 2	48.20	37.7	15,613	-	15,613
Lateral 43	Phase 2	49.75	17	7,040	-	7,040
Lateral 43	Phase 2	49.78	63.4	26,256	-	26,256
Lateral 43	Phase 2	50.02	75.7	31,350	-	31,350
Lateral 43	Phase 2	50.06	42.1	17,435	-	17,435
Lateral 43	Phase 2	50.27	36.7	15,199	-	15,199
Lateral 43	Phase 2	50.32	39	16,151	-	16,151
Lateral 43	Phase 2	50.62	65.3	27,043	-	27,043
Lateral 43	Phase 2	51.39	129.7	53,713	-	53,713
Lateral 43	Phase 2	51.68	31.8	13,169	-	13,169
Lateral 43	Phase 2	52.82	6.3	2,609	-	2,609
Lateral 43	Phase 2	52.94	14.9	6,171	-	6,171
Lateral 43	Phase 2	53.71	37.4	15,489	-	15,489
Lateral 43	Phase 2	53.91	78.8	32,634	-	32,634

Lateral	Phase	Proposed Pressure (psi)[1]	Irrigated Lands (acres)	Existing Pump Energy (kWh)[2,3,4]	Proposed Pump Energy (kWh)[2,4,5]	Pump Energy Conservation (kWh)[2,6]
Lateral 43	Phase 2	54.50	146.8	60,794	-	60,794
Lateral 43	Phase 2	54.57	3.8	1,574	-	1,574
Lateral 43	Phase 2	54.69	69.4	28,741	-	28,741
Lateral 43	Phase 2	54.69	92.1	38,141	-	38,141
Lateral 43	Phase 2	55.11	41	16,979	-	16,979
Lateral 43	Phase 2	55.34	9.6	3,976	-	3,976
Lateral 43	Phase 2	55.37	28.2	11,678	-	11,678
Lateral 43	Phase 2	55.54	36.6	15,157	-	15,157
Lateral 43	Phase 2	55.66	118.5	49,075	-	49,075
Lateral 43	Phase 2	55.78	62.5	25,883	-	25,883
Lateral 43	Phase 2	55.97	74.7	30,936	-	30,936
Lateral 43	Phase 2	55.98	128.4	53,174	-	53,174
Lateral 43	Phase 2	56.01	33.7	13,956	-	13,956
Lateral 43	Phase 2	56.32	76.8	31,805	-	31,805
Lateral 43	Phase 2	56.46	80.5	33,338	-	33,338
Lateral 43	Phase 2	57.58	76	31,474	-	31,474
Lateral 43	Phase 2	57.58	113.2	46,880	-	46,880
Lateral 43	Phase 2	58.20	15.9	6,585	-	6,585
Lateral 43	Phase 2	59.07	149.3	61,830	-	61,830
Lateral 43	Phase 2	59.61	35.3	14,619	-	14,619
Lateral 43	Phase 2	59.67	79.3	32,841	-	32,841
Lateral 43	Phase 2	59.98	31.4	13,004	-	13,004

Lateral	Phase	Proposed Pressure (psi)[1]	Irrigated Lands (acres)	Existing Pump Energy (kWh)[2,3,4]	Proposed Pump Energy (kWh)[2,4,5]	Pump Energy Conservation (kWh)[2,6]
Lateral 43	Phase 2	59.99	134.7	55,783	-	55,783
Lateral 43	Phase 2	60.00	18	7,454	-	7,454
Lateral 43	Phase 2	60.00	99	40,999	-	40,999
Lateral 43	Phase 2	60.00	36.4	15,074	-	15,074
Lateral 43	Phase 2	60.00	77.5	32,095	-	32,095
Lateral 43	Phase 2	60.00	49.4	20,458	-	20,458
Lateral 43	Phase 2	60.00	35	14,495	-	14,495
Lateral 43	Phase 2	60.00	75.4	31,225	-	31,225
Lateral 43	Phase 2	60.00	135.2	55,991	-	55,991
Lateral 43	Phase 2	60.00	39	16,151	-	16,151
Lateral 43	Phase 2	60.00	89.9	37,230	-	37,230
Lateral 43	Phase 2	60.00	80.6	33,379	-	33,379
Lateral 43	Phase 2	60.00	77.3	32,012	-	32,012
Lateral 43	Phase 2	60.00	106.9	44,271	-	44,271
Lateral 43	Phase 2	60.00	2	828	-	828
Lateral 43	Phase 2	60.00	104.5	43,277	-	43,277
Lateral 43	Phase 2	60.00	102.6	42,490	-	42,490
Lateral 43	Phase 2	60.00	78.2	32,385	-	32,385
Lateral 43	Phase 2	60.00	129.1	53,464	-	53,464
Lateral 43	Phase 2	60.00	5.6	2,319	-	2,319
Lateral 43	Phase 2	60.00	24.5	10,146	-	10,146
Lateral 43	Phase 2	60.00	3.2	1,325	-	1,325

Lateral	Phase	Proposed Pressure (psi)[1]	Irrigated Lands (acres)	Existing Pump Energy (kWh)[2,3,4]	Proposed Pump Energy (kWh)[2,4,5]	Pump Energy Conservation (kWh)[2,6]
Lateral 43	Phase 2	60.00	8.6	3,562	-	3,562
Lateral 43	Phase 2	60.00	75.9	31,433	-	31,433
Lateral 43	Phase 2	60.00	77.6	32,137	-	32,137
Lateral 43	Phase 2	60.00	75.4	31,225	-	31,225
Lateral 43	Phase 2	60.00	13.6	5,632	-	5,632
Lateral 43	Phase 2	60.00	107.2	44,395	-	44,395
Lateral 43	Phase 2	60.00	92.4	38,266	-	38,266
Lateral 43	Phase 2	60.00	14.5	6,005	-	6,005
Lateral 43	Phase 2	60.00	31.5	13,045	-	13,045
Lateral 43	Phase 2	60.00	70.8	29,320	-	29,320
Lateral 43	Phase 2	60.00	78.2	32,385	-	32,385
Lateral 43	Phase 2	60.00	117	48,453	-	48,453
Lateral 43	Phase 2	60.00	77.5	32,095	-	32,095
Lateral 43	Phase 2	60.00	139	57,564	-	57,564
Lateral 43	Phase 2	60.00	12.7	5,259	-	5,259
Lateral 43	Phase 2	60.00	38.8	16,068	-	16,068
Lateral 43	Phase 2	60.00	43.9	18,180	-	18,180
Lateral 43	Phase 2	60.00	24.7	10,229	-	10,229
Lateral 43	Phase 2	60.00	75.7	31,350	-	31,350
Lateral 43	Phase 2	60.00	72.2	29,900	-	29,900
Lateral 43	Phase 2	60.00	68.9	28,534	-	28,534
Lateral 43	Phase 2	60.00	3	1,242	-	1,242

Lateral	Phase	Proposed Pressure (psi)[1]	Irrigated Lands (acres)	Existing Pump Energy (kWh)[2,3,4]	Proposed Pump Energy (kWh)[2,4,5]	Pump Energy Conservation (kWh)[2,6]
Lateral 43	Phase 2	60.00	6	2,485	-	2,485
Lateral 43	Phase 2	60.00	51.3	21,245	-	21,245
Lateral 43	Phase 2	60.00	128.6	53,257	-	53,257

Notes:
[1] Pounds per square inch (psi)
[2] Kilowatt-hour (kwh)
[3] Existing pump energy was calculated by assuming all patrons are currently pumping and no gravity pressure is provided in the open canal system.
[4] Existing and proposed pump energy was calculated assuming alfalfa was the predominate crop and has annual consumptive use of 3 feet, application efficiency is 70 percent, a pump efficiency of 70 percent, a minimum pressure of 60 psi, and an irrigation season of 180 days.
[5] Proposed pump energy was calculated by incorporating the partial pressure that would be provided as part of the preferred alternative.
[6] Pump energy conserved was calculated by taking the difference between existing and proposed pump energy.

E.9. 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 will 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 will consider 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 a 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).