COVER DOCUMENT:
Upper Deschutes Basin Study

TECHNICAL MEMO: Water Conservation Assessment

DATE: December 15, 2017

PREPARED BY: Watershed Professionals Network

BASIN STUDY INTRODUCTION:

The Upper Deschutes River basin in central Oregon includes the Deschutes, Crooked, and Whychus river systems. Surface water in the Upper Deschutes River basin has been almost fully allocated since the early 1900s, primarily for agricultural uses. Prior studies assessed projected water supplies and demands through 2050 and indicated an overall 230,000 acre-foot unmet annual average demand, including agricultural, instream flow, and groundwater (municipal) needs.

Building off past studies, Reclamation and the Deschutes Basin Study Work Group (BSWG) will complete the Upper Deschutes River Basin Study (Basin Study). The Basin Study began in 2015 and is scheduled for completion within 3 years at an estimated total cost of $1.5 million. Reclamation and Oregon Water Resource Department are each contributing 50 percent of the study costs. The objectives of the Basin Study are to:

- Analyze water supply and demand, including the impacts of climate change.
- Analyze how existing operations and infrastructure will perform under the projected future water supply conditions and demands.
- Collaboratively develop options for addressing identified water imbalances, providing a common understanding of the interconnected effects of options that may move water between uses and users.
- Complete a tradeoff analysis to compare relative cost, environmental impact, risk, stakeholder response, and other common attributes of identified options. While the study will not propose any specific project, program, or plan, it will provide a current and broadly-shared basis for future water management in the basin.

To fulfill these objectives, the Basin Study is performing detailed analysis of each of the individual components of the water resource system and then will subsequently bringing all of the individual pieces of the system together in a water resource model to evaluate the effectiveness and trade-offs of water management scenarios. This technical memo focuses on one specific individual component of the water resource system. This memo's scope, schedule, and context in the overall Basin Study are described on the following page.

SCOPE AND CONTEXT OF THIS TECHNICAL MEMORANDUM:

This report summarizes water conservation potential and associated project costs for the eight irrigation districts within the Deschutes Basin Study project area based upon information from the following sources:

- System Improvement Plans by Farmers Conservation Alliance.
- On-Farm Reports by Farmers Conservation Alliance (COID, NUID).
- District Water Management and Conservation Plans.
- Deschutes Soil and Water Conservation District private lateral study.
- Information obtained directly from district managers.
- Analysis by WPN based on information from the above sources.

Although results are not available for each district/project type, the report attempts to present water conservation potential available in each district divided out between piping district-owned canals, piping private laterals, and on-farm conservation. It should be stresses that results presented in this report are high-level summaries only. Simplifications and assumptions are made in this report and the reader should see the source documents for more detailed information.

BUDGET OF THIS TECHNICAL MEMORANDUM:

This technical memorandum was completed under an amendment to the Technical Director budget. The total budget was $7,000.

REVIEW PROCESS OF THIS TECHNICAL MEMORANDUM:

This technical memorandum is to be reviewed by first by the DBBC, then the Basin Study Planning Team, and finally the Basin Study Workgroup. Edits shall be made to the document based on reviewer feedback at each stage of the review process. Key review dates are:

August 15, 2017:	Draft Technical Memorandum sent to DBBC parties for review
August 31, 2017:	Draft Technical Memorandum sent to Planning Team for review
September 30, 2017	Draft Technical Memorandum sent to BSWG for review
December 15, 2017	Final Technical Memorandum complete (edits include inclusion of AID and LPID, plus edited results for NUID on-farm conservation)

RECOMMENDATIONS OF THIS TECHNICAL MEMORANDUM:

This report does not present recommendations but simply states the amount of water conservation potential available and associated project costs within each district. The report documents that approximately 200,000 AF can be conserved through piping all district-owned canals, 35,000 AF can be conserved though piping private laterals in COID, and 63,000 AF can be conserved through on-farm upgrades in COID and NUID.

Deschutes Basin Study:
Water Conservation Assessment

December 15, 2017

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Executive Summary

This report summarizes multiple sources of information (see notes under Table 1) to estimate water conservation potential and associated project costs for the eight irrigation districts within the Deschutes Basin Study project area. Results presented are high-level summaries only. Simplifications and assumptions are made in this report and the reader should see the source documents for more detailed information.

Where supporting information is available, results are presented for each district's water conservation potential and cost divided out between piping district-owned canals, piping private laterals, and on-farm upgrades. The cost-effectiveness shown in Table 1 (cost/AF) is based on the total values, and the reader should see the main body of the report for more detailed cost-effectiveness of projects (e.g., Table 1 shows piping of COID-owned canals at an average of $7,200/AF conserved, while the COID section of the report breaks this value down between 17 different project phases). Although information is not presented for all three types of water conservation potential in all districts, it is believed that the results represent the vast majority of water conservation potential and hence are sufficient for use in the Basin Study.

Table 1. Summary of water conservation potential and associated costs for irrigation districts in the Deschutes Basin Study project area.

	District-Owned Canals			Private Laterals[1]			On-Farm		
	AF[2]	Cost	Cost/AF[3]	AF	Cost	Cost/AF	AF	Cost[4]	Cost/AF[4]
AID	11,405	$46.8M	$4,106						
COID	89,000	$643M	$7,200	35,280	$36M	$1,030	48,255	$302M	$6,260
LPID[5]	1,853	$6.84M	$3,693						
OID	14,646	$255M	$17,430						
NUID	62,156	$1.35B	$21,730				16,813	$326M	$19,390
SID	6,433	$15.6M	$2,420						
TID	17,820	$42.3M	$2,370						
TSID	497	$5.2M	$10,460						
Total	**203,810**	**$2.365B**	**$11,600**						

Notes: Cells highlighted in blue are based on information from FCA System Improvement Plans,
Cells highlighted in dark orange are based on information from FCA on-farm studies,
Cells highlighted in yellow are based on information from FCA but modified by WPN for the Basin Study to represent 75-yr NPV.
Cells highlighted in green are based on information from district managers.

[1] Private lateral results based on FCA COID On-Farm Report, see Section 2.2 for additional analysis.
[2] Where applicable, AF is calculated by converting the rate in CFS to 180 days (see Note 1 in Introduction Section).
[3] Cost per AF is averaged over all piping or private lateral upgrades; see main body of report for more detailed cost-effectiveness.
[4] On-farm cost and cost per AF based on 75-years and 75-yr Net Present Value, see Section 2.3 and Appendix A for details. Cost shown in Table 1 and Figure 1 based on conversion of all acreage; individual conversions (i.e. converting from flood) are more cost effective.
[5] Results from LPID are for Alternative A (see Section 9 for details).

While actual project implementation is likely to be based on additional factors than just cost-effectiveness, Figure 1 gives coarse information that can be used in the Basin Study for the question of "how much water is available through district piping and at what cost" which otherwise may be difficult to determine by looking at the tables in this report. This figure contains information for COID, NUID, TID, SID, AID and LPID only as OID and TSID do not receive water from the Upper Deschutes Basin.

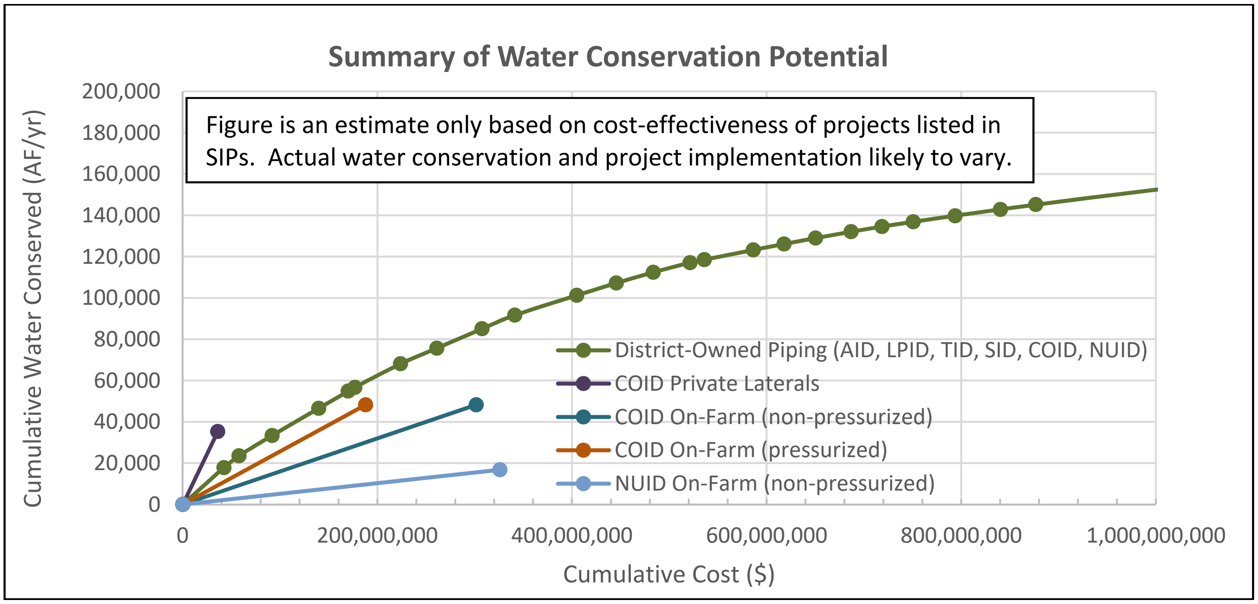

Figure 1. Cumulative water conservation potential for Deschutes Basin (COID, NUID, SID, and TID) district-owned infrastructure, COID private laterals, and COID and NUID on-farm ranked by cost-effectiveness.

Notes: [1] Cost-effectiveness of TID, AID, LPID and SID piping based on complete district piping; COID and NUID cost-effectiveness based on individual phases as presented in SIPs. OID and TSID not shown.
[2] COID Private Lateral based on FCA COID On-Farm Report results.
[3] Results for on-farm conservation based on AF calculated by the FCA On-Farm studies and 75-year NPV costs calculated by WPN. Costs shown in Figure 1 based on conversion of all acreage; some individual conversions (i.e. converting from flood) are more cost-effective.

Although the information in this report is general in nature and not based on detailed implementation plans, the following conclusions may be made:

Piping District-Owned Canals: The cost-effectiveness of piping district-owned canals varies considerably between districts as well as within each district. The SIPs break projects into discreet phases (e.g., COID phases consist of multiple pipe segments that total approximately $30,000,000), with actual construction of each phase typically requiring OWRD, DEQ, or federal support for implementation.

Piping Private Laterals: Piping of private laterals offers the most cost-effective water conservation at roughly $500-$1,000 per AF conserved. However, there's currently limited motivation for patrons to take on this cost, and hence an incentive (e.g., pressured water, financial support, or other) may be required for widespread piping of private lateral piping.

On-Farm Upgrades: On-farm upgrades can reduce on-farm water use by approximately 30% in COID and by up to 15% in NUID. The most cost-effective is converting from flood irrigation on sandy loam (8,428 acres in COID at 27% efficiency) to center-pivots, however lot sizes may prohibit installation of many center-pivots. Alternatively, installation of K-lines are only slightly less cost-effective but can be installed on smaller lots sizes. Conversion from wheel-line to center-pivots saves roughly 0.7 AF/acre/year but includes significant costs associated with upgrading to center-pivots, and hence the cost per AF conserved is roughly double that of converting from flood irrigation. In NUID, due to limited water availability and tiered pricing policies, patrons currently deficit irrigate and hence some amount of the calculated water savings from on-farm efficiency upgrades may go to meeting currently unmet crop demand versus overall water use reduction. Similar to piping private laterals, there's also limited motivation for patrons to take on this cost and an incentive may be required for widespread on-farm upgrades.

1 Introduction

This report summarizes information on water conservation potential and associated project costs for the eight irrigation districts within the Deschutes Basin Study project area. This report relies on information from: 1) System Improvement Plans (SIPs) and On-Farm Reports by Farmers Conservation Alliance where available, 2) District Water Management and Conservation Plans, 3) a Deschutes Soil and Water Conservation District (SWCD) private lateral study, and 4) information obtained directly from district managers. It should be understood that information in this report does not supersede information in the more detailed SIPs and WMCPs. Additionally, it should be understood that this report is a coarse summary of water conservation potential and associated costs and makes general assumptions (see example of conversion from CFS to AF below), and that actual water savings and cost may vary with project implementation due to project phasing and other operational considerations.

This report focuses on water conservation potential and costs associated with piping district-owned canals (this was the focus of the SIPs), however, where supporting data is available information is presented for piping private laterals (COID and SID) and on-farm conservation (COID and NUID). Although information may not be presented for piping private laterals or on-farm conservation in certain districts, it is reasonable to believe that water conservation potential exists in those areas, but it is difficult (and likely incorrect) to extrapolate from one district to others.

Note 1: Conversion from CFS to AF:
The main unit of water used in the Deschutes Basin Study is AF and hence this report converts CFS from other reports to AF. The CFS value most often documented in other reports is measured seepage lost around the first of August, which corresponds to the period of peak diversions (Figure 2). It's unlikely that this seepage rate is constant over the entire 214-day irrigation season, yet it's also unlikely that it's exactly proportional with the diversion rate. As such, this report converts from CFS to AF by applying the CFS rate over a 180-day period. Although this method is not exact, it's believed to be close (e.g., within 2% of the AF estimate from COID's SIP).

Note 2: Water conservation estimates for district-owned canal piping:
Water conservation estimates presented in this report for piping district-owned canals are copied from each district's System Improvement Plan. The method used in these System Improvement Plans is to subtract off an estimated on-farm diversion rate from the historical maximum diversion to get an overall system water conservation estimate. For example, in NUID the peak historical diversion over the last 10 years was 990 CFS (includes Deschutes and Crooked diversions), an estimated on-farm delivery rate of 7 GPM/acre is 816 CFS, which calculates to an overall water conservation potential of 174 CFS (990 CFS – 816 CFS = 174 CFS). FCA also performed flow measurements to determine seepage loss in individual canal segments. The numbers from the seepage loss estimates were adjusted by the method described above to determine potential water conservation from piping each segment. The reader is referred to the System Improvement Plans for additional details.

Note 3: Consideration of reduced conveyance loss with on-farm conservation:

The water conservation estimates presented in this report for on-farm upgrades are specifically the amount of water that could be saved on-farm (i.e. not during conveyance to the farm). If the districts were to remain an open canal system with conveyance losses, then any water saved on-farm would also be water that is no longer subject to conveyance losses. For example, if an on-farm conversion saved 2 AF/yr and conveyance losses were 25%, then the total water savings (on-farm plus reduced conveyance loss) would be 2.5 AF/yr.

Although the above statement is generally true, this report does not include the additional conveyance loss savings in the on-farm estimates for two reasons. First, conversion to a piped system would eliminate conveyance losses, and hence any on-farm upgrades done in a piped system would not have additional conveyance savings. Second, although conveyance losses are often estimated simply as a percent of the amount of water being conveyed (e.g., the 25% example given above), the relationship is typically more complicated. Seepage losses per CFS of conveyance may be greater at low flows (wetting of the canal bottom) than at higher flows (where increases in flow add limited hydraulic head and wetted area). Although this report does not quantify additional savings through reduced conveyance loss associated with on-farm improvements, it is likely there would be additional water savings benefits unless the systems become piped.

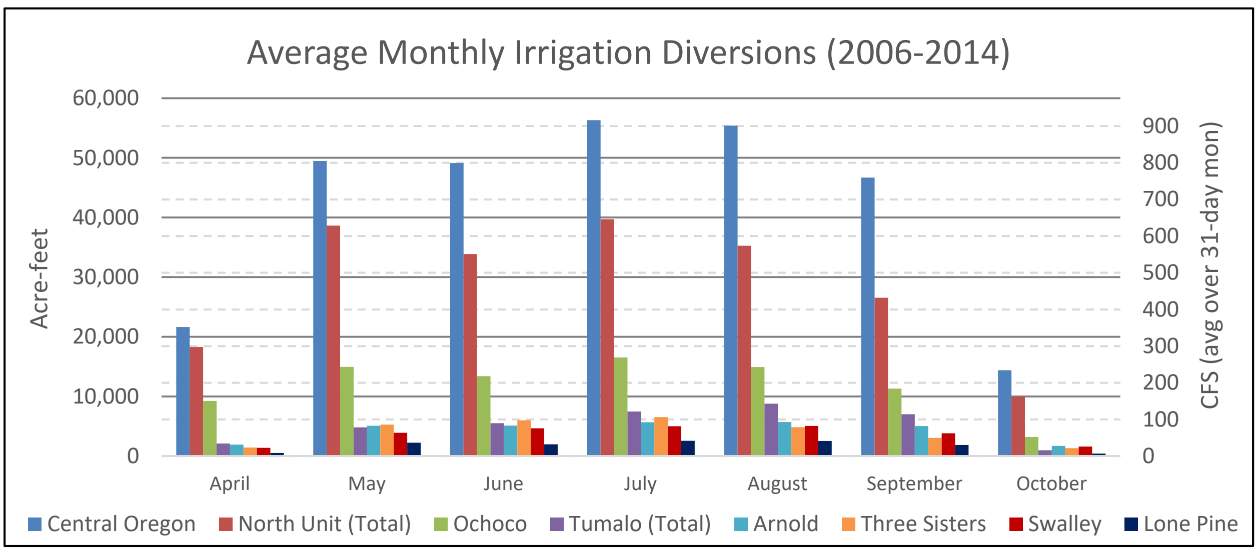

Figure 2. Average monthly water diverted by irrigation districts in the study area (GSI, 2016).

2 Central Oregon Irrigation District

Information is presented below for piping COID-owned infrastructure (based on COID's SIP), piping private laterals (based on COID's SIP/On-Farm Study and Deschutes SWCD Study), and on-farm upgrades (based on COID On-Farm Study and WPN analysis).

2.1 District-Owned Infrastructure

A loss assessment was completed as part of COID's SIP (FCA, 2016) which measured seepage loss in district-owned canals with flow greater than 5 CFS. This loss assessment measured 55 CFS of loss in the Central Oregon Canal and 125 CFS of loss in the Pilot Butte Canal. Additionally, the COID SIP also estimated the cumulative loss in each canal/lateral system based on a historical maximum diversion rate (970 CFS based on the period 2006-2016) minus an estimate private delivery rate of 7.62 gpm/acre, from which 156 CFS loss in the Pilot Butte and 99 CFS loss in the Central Oregon Canal areas were estimated (see Note 2 in Introduction Section). Summary information from the COID SIP is based on the second method above, with the COID SIP Executive Summary reporting water conservation and cost of district-owned canal piping as listed in Table 2 below. In Table 2, the conversion to AF (columns "Est. Water Cons (AF)" and "Est. Cost per AF ($/AF)") were calculated by WPN based on the COID SIP numbers.

Table 2. Water conserved, cost, and cost per AF from COID SIP.

Project Group[1]		Water Cons. (CFS)[1,2]	Est. Water Cons. (AF)[3]	Cost (canals > 5CFS) ($)[1]	Cost (canals < 5CFS) ($)[1, 4]	Est. Cost per AF ($/AF)[3]
Pilot Butte Canal	Rivers Edge	36.89	13,148	$ 47,196,271	640,256	$3,638
	Des. Market	26.32	9,380	$ 44,218,201	2,305,649	$4,960
	Canal	27.61	9,840	$ 32,010,349	1,985,492	$3,455
	Vetrns. Way	26.99	9,619	$ 56,088,221	7,501,352	$6,611
	Redmond	6.34	2,260	$ 31,251,083	741,939	$14,159
	King Way	13.34	4,754	$ 43,385,157	7,070,890	$10,613
	Smith Rock	18.51	6,597	$ 30,726,893	2,979,283	$5,109
	PB Total	156	55,598	$ 284,876,175	23,224,861	$5,542
Central Oregon Canal	Dry Canyon	4	1,426	$ 12,657,410	1,928,692	$10,232
	Brasada	4.65	1,657	$ 26,174,209	4,174,173	$18,312
	Copley	7.87	2,805	$ 30,985,574	1,369,848	$11,535
	Powell Butte	6.01	2,142	$ 37,133,798	238,271	$17,448
	Alf. Market	21.22	7,563	$ 36,131,095	1,205,148	$4,937
	Sky Wagon	23.29	8,301	$ 29,532,668	824,871	$3,657
	Gosney	5.62	2,003	$ 38,646,550	5,080,514	$21,831
	Bear Creek	8.11	2,890	$ 27,514,015	4,053,452	$10,921
	Ferguson	13.05	4,651	$ 33,051,702	4,860,458	$8,151
	Brookswood	5.18	1,846	$ 38,756,678	350,641	$21,183
	CO Total	99	35,284	$ 310,583,699	24,086,068	$9,485
PB + CO Total		**255**	**89,000**	**$595,459,874**	**$ 47,310,929**	**$7,200**

Notes:
[1] Project Group, Water Conserved (CFS), and Cost copied from Executive Summary of COID SIP.
[2] Water Conserved is from COID SIP and is based on comparison of maximum diversion rate versus patron delivery of 7.62 gpm/acre.
[3] Conversion from CFS to AF is approximate, see note in Introduction Section. "PB + CO Total" AF value is from COID SIP.
[4] Cost of canals with flows less than 5 CFS from FCA, 2017A.

Although the prioritization for piping district-owned canals will include other considerations, such as facilitating private lateral piping and on-farm upgrades as discussed in the Executive Summary, Figure 3 below shows the cumulative cost and cumulative water savings from the projects in Table 2 ranked by the cost-effectiveness of the large canal piping (i.e. the Pilot Butte Canal/Canal is the data point closest to the graph's origin since its cost per AF of water conserved is the lowest). The reader should by no means expect COID to construct projects in this exact order, but the graph does give useful information for the Deschutes Basin Study which otherwise may be difficult to determine by looking at Table 2. Additionally, the slope of the line also provides information, such as the minor inflexion point (steeper slope to the left and flatter slope to the right) at 88 CFS (31,000 AF) and $108,000,000, indicating a break in the cost-effectiveness of projects.

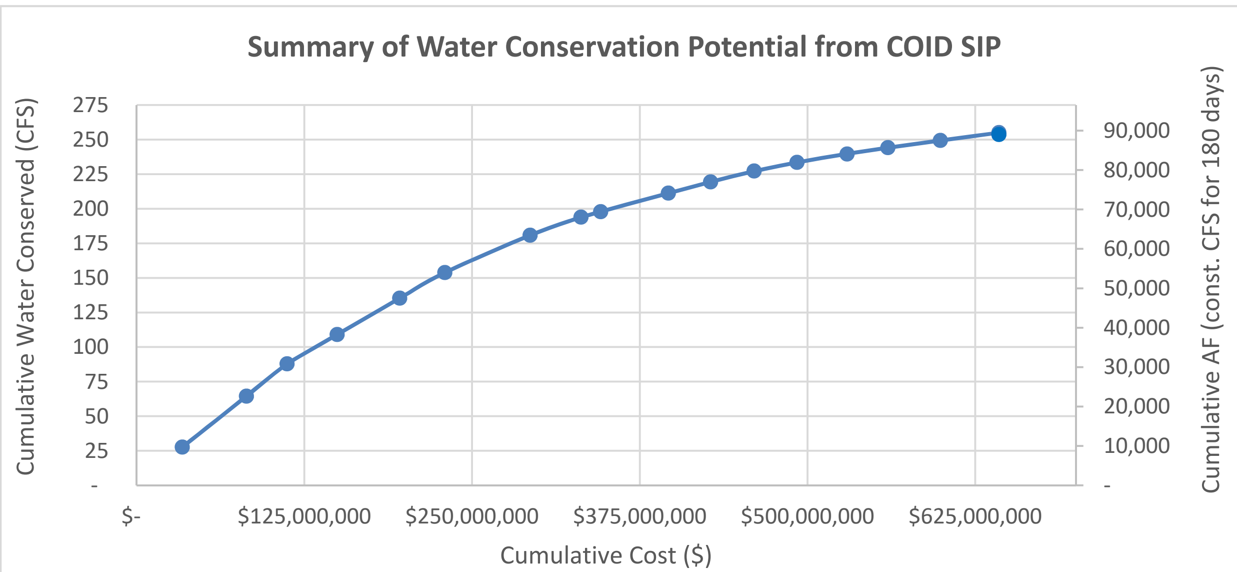

Figure 3. Cumulative cost and water conservation from COID SIP for district-owned piping ranked by cost-effectiveness.

2.2 Private Laterals

COID has approximately 250 miles of private laterals that experience seepage loss and potentially end-spills, and although a detailed private lateral loss assessment has not been completed, two sources of information are available. The first is a section in the FCA On-Farm Report (FCA, 2017B) which makes an assessment of private lateral loss based on average inflow to private laterals serving 10,646 acres. The second source of information is an ongoing Deschutes Soil and Water Conservation District (DSWCD) study that is in the process of evaluating water conservation potential and cost at two specific private laterals, one of which is in COID and the other in SID.

Information from COID On-Farm Report

The COID On-Farm Report estimated loss in the laterals by measuring the diversion into them and subtracting off an expected on-farm delivery of 6 GPM/acre (approximately 4.5 AF/yr). This assessment was carried out for 10,646 acres, of which the results were extrapolated to the other 12,066 acres that have shared private laterals (for a total of 22,712 acres which is 54% of COID).

The difference between the measure inflow to the private laterals (average of 8.29 GPM/acre) and the expected on-farm delivery (assumed 6 GPM/acre) is 2.29 GPM/acre which over the 22,712 acres is equal to approximately 35,284 AF per year (115 CFS). It should be noted that any difference in the assumed on-farm delivery rate used in the analysis (assumed 6 GPM/acre in the analysis which is equal to 4.5 AF/yr) would affect the estimated water conservation potential. For example, an assumed on-farm delivery rate of 5.4 GPM/acre (3.8 AF/ac) would result in an estimated conservation potential of 46,970 AF, while an assumed on-farm delivery rate of 7 GPM/acre (4.8 AF/acre) would result in an estimated conservation potential of 20,000 AF.

The planning-level cost for piping the 250 miles of private laterals is $36,516,480, which is equal to $1,034.93 per AF of water conserved. This costs includes 12-inch pipe throughout, and markups of 15% for engineering, 18% for construction management, and a 30% contingency. Although beyond the scope of the high-level planning-level cost estimate, it's likely that actual design would use less than 12-inch pipe in many locations (12-inch pipe was specified to have a velocity of less than 2 feet per second at the initial head-end of the laterals, and as water is turned out to individual patrons the pipe diameter may be reduced) and some cost savings could be realized.

Information from Deschutes SWCD Private Lateral Study

The Deschutes SWCD Study covers two private lateral systems, one of which covers 126 acres with 8 patrons in SID, and one of which covers 160 acres with 8 patrons in COID. Both laterals had measured inflow to the head-gate of approximately 7 AF/acre per year but do not have any flow measurements of what gets turned out to each patron (DSWCD, 2017). Although a generalization that likely contains some error, one can round-up the current average calculated on-farm delivery from the COID On-Farm Report of 3.76 AF/acre per year (see Section 2.3) to 4 AF and use that value as an estimate of what gets delivered to each patron. Based on 7 AF/acre turned into the private lateral head-gate and 4 AF/acre delivered on farm, the potential water conservation for piping the private lateral is 3 AF/acre served, for a total of 858 AF between the two private lateral systems.

Cost estimates for materials for piping the two private laterals in the Deschutes SWCD Study were $67,800 for SID and $107,050 for COID. A general rule of thumb is to double the materials cost to get the overall construction costs (i.e. materials, design, and installation), hence overall costs are approximately $135,600 for SID and $214,100 for COID. Dividing the cost by the acreage equals costs of $1,076/acre in SID, and $1,338/acre. Combining the higher cost estimate of $1,338 per acre with the savings of 3 AF/acre equals a cost-effectiveness of $468 per AF.

Although combining the 3 AF/acre savings with the 22,712 acres served by private laterals in COID yields a private lateral loss of 68,136 AF/yr, it should be stressed the canals in the SWCD study are individual data points and therefore this information cannot be extrapolated to private laterals as a whole. The values presented above are based on an estimated on-farm diversion of 4 AF/yr; if 5 AF/yr were assumed instead, then the savings would be 2 AF/acre and in COID sum to 45,424 AF/yr. Nonetheless, the values above indicate that piping some private laterals may result in very cost-effective water conservation.

2.3 On-Farm

FCA estimated on-farm water conservation potential using standard NRCS methods and application type conversions as follows:

- Irrigation systems on tax lots greater than 20 acres were upgraded to center-pivot
- Irrigation systems on tax lots from 5 acres to 20 acres were upgraded to wheel-line
- Irrigation systems on tax lots from 0.5 acres to 5 acres were upgraded to K-Line
- Irrigation systems on tax lots less than 0.5 acres were not changed

For crop water demand, over 96% of COID is pasture and so pasture was assumed as the crop type for the entire district. Pasture has a Net Irrigation Requirement (NIR) of 20.4 inches per year, which combined with application efficiencies from the NRCS Water Savings Calculator estimate the water use for each application type as shown in Table 3. Based on aerial photos and patron surveys of current application types, a current water use of 153,606 AF/yr was calculated (columns 5 and 6 in Table 3). Converting to more efficient application methods per the acreage/upgrades listed above (as well as other details that can be found in the COID On-farm Study), future water use is estimated at 105,351 AF for a total on-farm water conservation of approximately 48,255 AF.

It should be noted that not all upgrades are equal in terms of efficiency gains. For example, conversion from flood on sandy loam to a center pivot conserves 3.8 AF/acre, while conversion from wheel-line to center-pivot conserves 0.7 AF/acre. As such, Table 4 shows the water savings from converting from flood to certain application types, as well as from wheel-line to center-pivot.

Table 3. Water use efficiency by application type, and current and upgraded on-farm water use.

Application Type	Water Use by Application Type			Current		W/ On-farm Upgrades	
	Applicat. Effic. (%)	Sys. Effic. (%)	Water Use per Acre (ft)	Acres (ac)	Est. Water[1] Use (AF/yr)	Acres (ac)	Est. Water[1] Use (AF/yr)
Flood (SL)	30	27	6.2	8,428	52,545	4	26
Flood (CL)	50	46	3.7	2,463	9,013	0	0
Flood & WL	42.5	40.5	4.1	3,176	13,201	10	43
Flood, WL, CP	51.7	50	3.4	1,140	3,838	10	35
Flood & CP	50	48	3.5	3,262	11,440	10	36
Wheel-line	55	54	3.1	8,935	27,853	6,580	20,510
WL & CP	62.5	61.5	2.7	1,453	3,977	10	28
Center-Pivot	70	69	2.4	9,351	22,813	32,980	80,458
Other	20-69	18-68	2.5-3.9	2,914	9,380	0	0
Drip	80	79	2.1	0	0	288	613
K-Line	60	60	2.8	0	0	1,193	3,346
Total				41,122	**153,606**	41,085	**105,351**

Notes: [1] Estimated water use for individual application types (rows 2-12) done by WPN while total water savings (row 13) from COID On-Farm Report. Values are within 2% of each other.

The COID On-Farm Study estimates a cost of $622,549,000 for conserving the 48,255 AF (for an average cost of $12,700 per AF), or if the district has already been pressurized, a cost of $308,589,600 (for an average cost of $6,395 per AF). The estimates in the COID On-Farm Study include the capital cost plus the net 30-year operating costs included in the costs presented above.

The 30-year operating costs used include 1/30th of the total capital cost per year (i.e. the system is assumed to have a 30-year lifespan), which includes refurnishing and installing the irrigation system, bringing in power, pumps, manifolds, valves, supply line, and re-grading the field. For cost-estimates based on a non-pressurized system, the annual costs also include the loss of field production due to an irrigation pond and electricity consumption.

Although lumping the 30-year operating costs in with the capital cost is a valid approach, the Deschutes Basin Study is evaluating other water supply alternatives that have an approximately 75-year lifespan, as well as alternatives that have annual costs, and hence the cost estimate line items in the on-farm study we reevaluated by WPN to estimate one-time capital costs plus reoccurring annual costs (still based on a 30-year lifespan of equipment), from which a 75-year Net Present Value (NPV) was calculated. The 75-year NPV for on-farm conversion in an unpressurized system (i.e. open canals with each patron using a pump for pressurization) is estimated at $301,692,000, while the 75-year cost under a pressurized system is estimated at $187,800,000. Detailed cost estimates are shown in Appendix A and summarized below in Table 4. The discount rate used in the NPV calculation is 3.5% as agreed upon by the BSWG.

Table 4. Water conservation and costs for application type upgrades in COID.

Conversion Type[1]		Acres	Water Savings per Acre (feet)	Total Potential Cons. (AF)	Capital Cost per Acre ($)	Capital Cost per AF($/AF)	Annual Cost per Acre ($)	75-yr Cost per Acre ($)	75-yr Cost per AF ($)
Non-Prsr	Flood to 5 ac K-Ln	1,185	2.8 [2,3]	3,318	$12,827	$4,581	$266	$19,161	$6,843
	Fld to 10 ac W-L	3,070	2.5 [2,3]	7,675	$11,069	$4,428	$277	$17,743	$7,097
	Fld to 31 ac C-P	6,636	3.2 [2,3]	21,235	$8,231	$2,572	$247	$14,248	$4,452
	WL to 31 ac C-P [4]	16,989	0.94 [4]	~16,000	$4,837	$5,146	$117	$7,650	$8,138
	Total	**27,880**		**48,255**					
Pressure	Flood to 5 ac K-Ln	1,185	2.8 [2,3]	3,318	$2,621	$936	$73	$4,384	$1,566
	Fld to 10 ac W-L	3,070	2.5 [2,3]	7,675	$4,319	$1,728	$97	$6,641	$2,656
	Fld to 31 ac C-P	6,636	3.2 [2,3]	21,235	$4,796	$1,499	$116	$7,588	$2,371
	WL to 31 ac C-P [4]	16,989	0.94 [4]	~16,000	$4,024	$4,281	$106	$6,585	$7,005
	Total	**27,880**		**48,255**					

Notes: [1] "Non-pressure" and "Pressure" refer to whether the distribution system provides pressurized water.
[2] Current flood irrigation is estimated at 10,891 acres (Table 3), which leaves 6,636 acres to be converted to center-pivots after subtracting off the K-line and wheel-line conversions.
[3] Calculation assumes flood uses 5.6 feet since that's the weighted average of flood area on sandy/clay loam (Table 3).
[4] Conversion from wheel-line to center-pivot also includes acreage from Figure 2 of COID On-Farm Study listed as "Flood, Center-Pivot, and Wheel-Line Combination". Water savings per acre is estimated at 0.94 AF/Acre to match COID On-Farm Study total amount of 48,255 AF/yr. Conversion from just wheel-line to center-pivot saves roughly 0.7 feet per year, but the additional 0.24 feet per year likely accounts for some acreage that is flood irrigated.

3 North Unit Irrigation District

Information is presented below for piping NUID-owned infrastructure (based on NUID's SIP) and on-farm upgrades (based on NUID On-Farm Study and WPN analysis). No information is presented for water conservation potential and costs associated with piping NUID's private laterals.

3.1 District-Owned Infrastructure

NUID's SIP estimates that 174 CFS (approximately 62,156 AF/yr) can be saved by piping NUID's distribution system at a cost of $1,350,000,000 ($21,700 per AF of water) (FCA, 2017C). The most cost-effective phases are Phase 1 and 7, which are expected to save 30 CFS (11,200 AF) at a cost of $78,600,000 (approximately $7,000 per AF). See Table 5 for phases, water conserved, and costs from the NUID SIP, and see Figure 4 for a plot of the phases ranked by cost-effectiveness (i.e. the most cost-effective phases are plotted closest to the graph's origin).

Table 5 . Water conserved, cost, and cost per AF for piping NUID-owned infrastructure.

Phase [1]	Water Conserved (CFS) [1]	Estimated Water Conserved (AF)	Cost ($)[1]	Estimated Cost per AF ($/AF)
1	16.6	5,916	$ 40,642,819	$6,869.70
2	8.2	2,922	$ 43,158,359	$14,767.72
3	5.8	2,067	$ 39,811,799	$19,259.55
4	6.7	2,388	$ 36,381,425	$15,235.87
5	7	2,495	$ 31,862,852	$12,771.71
6	3.9	1,390	$ 47,084,538	$33,874.74
7	4.5	1,604	$ 41,024,060	$25,579.29
8	3.2	1,140	$ 38,868,763	$34,081.06
9	5.7	2,031	$ 47,301,562	$23,284.29
10	2.8	998	$ 35,005,569	$35,078.53
11	14.7	5,239	$ 37,963,533	$7,246.22
12	8.7	3,101	$ 46,479,322	$14,990.04
13	4.4	1,568	$ 39,076,882	$24,918.94
14	6.6	2,352	$ 46,875,195	$19,927.90
15	8.8	3,136	$ 36,447,344	$11,621.05
16	4.2	1,497	$ 51,386,830	$34,329.29
17	4.6	1,639	$ 45,311,639	$27,638.49
18	4.6	1,639	$ 52,668,291	$32,125.78
19	5.1	1,818	$ 52,443,438	$28,852.49
20	12.4	4,419	$ 125,079,066	$28,302.53
21	35.9	12,795	$ 222,731,721	$17,408.04
22	0	0	$ 192,959,211	N/A
TOTAL	**174.4**	**62,156**	**$ 1,350,564,218**	**$21,728.57**

Notes: [1] Project Group, Water Conserved (CFS), and Cost copied from Executive Summary of NUID SIP.
[2] Conversion from CFS to AF is approximate, see note in Introduction Section.

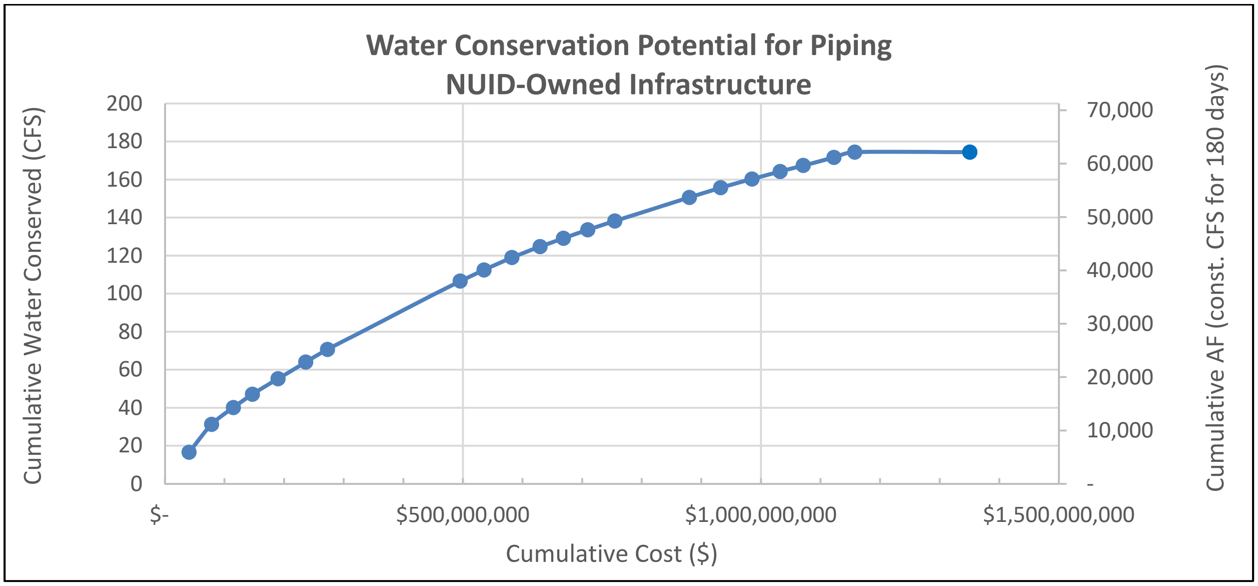

Figure 4. Cumulative cost and water conservation from piping NUID-owned canals ranked by cost-effectiveness.

3.2 Private Laterals

Information is not presented in this report for water conservation potential or costs of piping NUID's private laterals for the following reasons; 1) the NUID SIP did not cover private laterals, 2) NUID has fewer private laterals per acre than the other districts (NUID has ~5 versus COID has ~300), and 3) NUID experiences water scarcity and therefore patrons make significant effort to eliminate or reduce private lateral loss.

3.3 On-Farm

NUID's On-Farm Study (FCA, 2017D) used the same methods as those used in COID's On-Farm Study except adjusted for NUID's crop types, application types, climate, soil types, plus an adjustment factor to make calculated water use equal measured water use. Based on the NUID specific information, the NRCS Water Savings Calculator estimated that NUID on-farm upgrades would conserve 16,814 AF/yr. However, due to the relationship between of crop ET demand and actual NUID patron delivery, WPN believes the 16,814 AF/yr should be seen as an initial estimate and that subsequent studies may want to further evaluate crop demand with respect to patron deliveries to refine the overall conservation estimate.

For example, the NRCS Water Savings Calculator states that alfalfa (27.1% of NUID acreage, net irrigation requirement of 2.77 feet/year) being irrigated with a wheel-line (54% efficient) currently receives 5.1 feet/year of irrigation, while alfalfa irrigated with a center-pivot (69% efficient) receives 4.0 feet/year (for a water saving from conversion of 1.1 feet/year). However, due to NUID water availability and tiered water pricing policies, NUID patrons currently deficit irrigate (using closer to 2 AF/yr.), and hence some of the additional water availability from the efficiency increase may go to meet actual crop demand that is not currently being met. This would result in increased productivity (e.g., additional cuttings) from the same amount of water use, but would not necessarily result in a decrease in overall water use. The 75-year Net Present Value of the on-farm upgrades in an unpressurized system is $336,278,000 (see Section 2.3 for more information on the 75-year Net Present Value calculation).

Table 6. Water conservation and costs for application type upgrades in NUID.

Conversion Type[1]		Acres	Water Savings per Acre (feet) [2]	Total Potential Cons. (AF)	Capital Cost per Acre ($)	Capital Cost per AF($/AF)	Annual Cost per Acre ($)	75-yr Cost per Acre ($)	**75-yr Cost per AF ($)**
Non-Prsr	Flood to 5 ac K-Ln	58	1.09	63	$12,827	$11,809	$266	$19,161	$17,640
	Fld to 10 ac W-L	255	1.10	280	$11,069	$10,081	$277	$17,743	$16,159
	Fld to 31 ac C-P	1,656	0.91	1,505	$8,231	$9,057	$247	$14,248	$15,678
	WL to 31 ac C-P	40,137	0.37	14,965	$4,837	$12,973	$117	$7,650	$20,518
	Total	**42,106**		**16,813**					

Notes: [1] "Non-pressure" refers to whether the distribution system provides pressurized water.
[2] Actual "Water Savings per Acre" is dependent on the combination of crop and application type. Values presented here are derived from Table 5 of the NUID On-Farm report.

4 Swalley Irrigation District

The SID SIP (FCA, 2017E) focused on district-owned infrastructure, the results of which are presented below in Section 4.1. Additional discussion is presented for private laterals (Section 4.2) and on-farm (Section 4.3), however these sections are based on limited data and are provided for general order of magnitudes only.

4.1 District-Owned Infrastructure

SID's SIP estimates that 16 CFS (approximately 6,433 AF/yr) can be saved by piping SID's distribution system at a cost of $15,600,000 ($2,420 per AF of water). Table 7 below shows information on water savings and cost for each lateral/canal; however a figure that presents canal/laterals by cost effectiveness (e.g., a figure similar to Figure 3 for COID) is not shown. This figure is not presented due to the relatively small cost of complete district-owned piping, the likelihood that complete district-owned piping is moving forward, as well as a figure as such would likely misrepresent system intricacies and operational considerations.

Table 7. Water conserved, cost, and cost per AF for piping SID-owned infrastructure.

Lateral/Canal [1]	Water Conserved (CFS) [1]	Approx. Water Conserved (AF) [2, 3]	Cost ($) [1]	Approx. Cost per AF ($/AF) [2]
Kotzman [3]	0	0	$ 272,311	N/A
NC1 [3]	0	0	$ 247,942	N/A
Rogers [3]	3.1	1,105	$ 3,270,003	$ 2,960
Rogers sublateral	0.2	71	$ 450,806	$ 6,324
Riley	0.7	249	$ 893,412	$ 3,581
Riley sublateral	0.2	71	$ 528,676	$ 7,417
Deschutes [4]	0	0	$ -	N/A
Elder	2.1	748	$ 1,456,611	$ 1,946
Butte	0.2	71	$ 423,631	$ 5,943
Frakes [4]	0	0	$ -	N/A
Mickelson	0	0	$ 194,879	N/A
Main Canal	9.6	3,421	$ 7,260,586	$ 2,122
400 HP Pump Sta			$ 591,500	N/A
TOTAL	**16**	**6,433**	**$15,590,357**	**$2,420**

Notes: [1] Lateral/Canal, Water Conserved (CFS), and Cost copied from Executive Summary of SID SIP.

[2] Conversion from CFS to AF for each later/canal is approximate. The conversion is done by multiplying the CFS rate by 180 days. It should be noted that SID's diversion season is seven months (~213 days), however two months have a diversion of 43% of the maximum rate, and one month has a diversion of 53% of the maximum rate (for a weighted season of 162 days of 100% rate). This conversion is an estimate only and is believed to be within 10%-18% (162/180 = 90%; 213/180 = 118%).

[3] Total AF conserved taken from SID SIP.

[4] Existing lateral partially piped.

[5] Existing lateral piping to remain.

4.2 Private Laterals

The SID SIP focused primarily on district-owned infrastructure and therefore water conservation potential and cost estimates are not provided for piping private laterals. Nonetheless, some information is presented below for general magnitudes; however it is stressed that the reader not extrapolate the percentage loss numbers below to the entire SID acreage. For one, the percentage loss numbers below are based on a limited data set (3 of the approximately 35-40 private laterals in SID), and second, not all of SID is served by private lateral and hence extrapolation of the numbers below should only be to the applicable acreage that is served by private laterals.

Although the SID SIP focused primarily on district-owned infrastructure, it also included loss assessments on two private laterals, of which the Brady private lateral had a loss of 21% and the Tower Box lateral had a loss of 30%. Additionally, the Deschutes SWCD IWM Study measured an average of 7 AC-FT/AC diverted into the Swalley Private Lateral Point of Delivery, and while a specific on-farm study was not completed for SID, the SID SIP estimates that 4.28 AC-FT/yr are delivered on-farm (of the 7 AC-FT/AC diversion), which represents a private lateral loss of 36%.

The SID SIP did not generate cost estimates for piping private laterals, however, the COID On-Farm Study and Deschutes SWCD IWM Study estimated a cost-effectiveness between $446 and $1,038 per AF for piping private laterals. See Section 2.2 of this report for further discussion. As stated in Section 2.2, these costs are based on limited data points and results cannot be extrapolated to SID as a whole.

4.3 On-farm

The SID SIP focused primarily on district-owned infrastructure and therefore on-farm water conservation potential was not estimated. Additionally, only four out of SID's 662 patrons flood irrigate (with the remaining patrons using various types of sprinkler irrigation) so on-farm water conservation potential, as well as cost-effectiveness of upgrades, is not as great as within other districts such as COID. For example, Table 4 in Section 2.2 (COID On-Farm), conversion from wheel-line to center-pivots only conserves 0.7 feet per year, and at a 75-yr cost per AF higher than both district-owned and private lateral piping. Additionally, due to parcel size the author believes there may be limited area to undergo conversion to center-pivots. As such, although on-farm water conservation should always be pursued (and specifically for the four patrons that flood irrigate), the author believes that the main focus in SID should be piping district-owned canals and private laterals.

5 Tumalo Irrigation District

The TID SIP (FCA, 2017F) focused on district-owned infrastructure, the results of which are presented below in Section 5.1. Limited information is available on private canal and on-farm losses and therefore no information is presented on them in this report.

5.1 District-Owned Infrastructure

The TID SIP estimated that 50 CFS (approximately 17,820 AF/yr) can be conserved by piping TID-owned infrastructure, of which approximately 62% would be saved from Tumalo Creek and 38% from the Crescent Creek (Table 8).

Table 8. Water conserved, cost, and cost per AF for piping TID-owned infrastructure.

Phase [1]	Water Conserved (CFS) [1]	Approx. Water Conserved (AF) [2]	Cost ($) [1]	Approx. Cost per AF ($/AF/yr) [2]
1 & 2	11.1	3,956	$11,671,470	2,950.29
3	0.2	71	$2,913,083	40,868.17
4	7.8	2,780	$3,079,404	1,107.73
5	4.2	1,497	$3,495,568	2,335.24
6	4.8	1,711	$3,868,267	2,261.19
7	3.5	1,247	$3,338,263	2,676.18
8	7.9	2,816	$2,547,536	904.81
9	4.1	1,461	$1,481,684	1,013.99
10	2.0	713	$5,468,931	7,672.46
11	4.5	1,604	$4,433,245	2,764.21
Total	**50.0**	**17,820**	**$42,297,451**	**2,373.59**

Notes: [1] Phase, Water Conserved, and Cost copied from Executive Summary of TID SIP.
[2] Conversion from CFS to AF is approximate. The conversion is done by multiplying the CFS rate by 180 days.

6 Ochoco Irrigation District

The OID SIP (FCA, 2017G) focused on district-owned infrastructure, the results of which are presented below in Section 6.1. Limited information is available on private canal and on-farm losses and therefore no information is presented on them in this report.

6.1 District-Owned Infrastructure

FCA measured 53 CFS of seepage loss and 19.2 CFS of end-spills in the summer of 2016, which is equal to approximately 18,889 and 6,843 AF/yr, respectively (Tables 9 and 10). Additionally, OID measured overflows from 2007-2011 and found end-spills averaged 18,613 AF/yr (Table 10, OID, 2013).

Table 9. Measured seepage loss (CFS), estimated seepage loss (AF), adjustment factor, and potential water conservation (CFS and AF).

Canal/Lateral[1]	Measured Loss (CFS)[1]	Estimated Loss (AF/yr)[2]	Adjustment Factor[1]	Conservation Estimate (CFS)[1]	Conservation Estimate (AF/yr)[2]
Ochoco Main Canal	17.5	6,237	0.77	13.5	4,802
Grimes Flat East and West Lateral	4.9	1,746	0.77	3.8	1,345
Crooked River Diversion Canal	12	4,277	0.77	9.2	3,293
Crooked River Distribution Canal	17.8	6,344	0.77	13.7	4,885
Breese Lateral	0.8	285	0.77	0.6	220
Johnson Creek Lateral	0	-	0.77	0.0	0
Lytle Creek Lateral	0	-	0.77	0.0	0
Rye Grass Canal	0	-	0.77	0.0	0
Total	**53**	**18,889**	**0.77**	**41.0**	**14,612**

Notes: [1] Canal/Lateral, Measured Loss (CFS), Adjustment Factor, and Conservation Estimate (CFS) copied from OID SIP.
[2] Conversion from CFS to AF is approximate, see note in Introduction Section.

Table 10. End-spills measured by FCA (2016), and end-spills measured by OID (2007-2011).

Location	Entity / Year	CFS[1]	AF/yr[1]
Lytle Creek / Rye Grass	FCA, 2016	13.9	4,954
Ochoco Canal	FCA, 2016	5.3	1,889
Sum of Reynolds, Lytle, Ochoco, and Gap	OID (OID, 2012)		18,613

Notes: [1] FCA presents end-spill values in CFS which have been converted to AF as discussed in Introduction Section. OID's Water Management and Conservation Plan (OID 2012) presents values in AF only.

Based on information presented in Tables 9 and 10, the OID SIP concludes that 41.1 CFS of water can be conserved at a cost of $255,253,685, which is equal to $17,426 per AF/yr (Table 11). It should be noted that the 41.1 CFS is less than the measured loss and does not include any end-spills.

Table 11. Water conservation (CFS and AF), length piped, cost, and cost effectiveness for project groups in OID.

Project Group[1]	Water Conservation (CFS)[1]	Water Conservation (AF/yr)[2]	Length Piped (ft)[1]	Cost ($)[1]	Cost Effectiveness ($/AF/yr)[2]
1	1.1	392	15,322	$14,779,690	$37,699
2	3.8	1,354	43,165	$3,354,419	$2,477
3	0	0	33,566	$1,899,966	N/A
4	4.8	1,711	57,490	$18,910,266	$11,054
5	2.9	1,034	82,723	$36,887,476	$35,690
6	4.8	1,711	87,864	$58,694,977	$34,310
7	7.6	2,709	76,330	$17,127,118	$6,323
8	6.2	2,210	53,551	$41,299,550	$18,690
9	9.3	3,315	39,610	$52,622,431	$15,876
10	0.6	214	79,414	$9,677,792	$45,257
Total	**41.1**	**14,648**	**569,035**	**$255,253,685**	**$17,426**

Notes: [1] Information from OID SIP.
[2] Conversion from CFS to AF is approximate, see note in Introduction Section.

7 Three Sisters Irrigation District

A SIP was not completed for TSID; however the TSID manager indicated that 8.2 miles of district-owned canals and laterals remain to be piped (Phase 9), with an estimated water conservation potential of 1.17 CFS (497 AF based on 214 day irrigation season) for a cost of $5,200,000. Additionally, it should be noted for use in the Basin Study that Phase 7 and Phase 8 were recently completed and conserved 2.6 CFS (977 AF).

8 Arnold Irrigation District

The AID SIP (FCA, 2017H) focused on district-owned infrastructure, the results of which are presented below in Section 8.1. Limited information is available on private canal and on-farm losses and therefore no information is presented on them in this report.

8.1 District-Owned Infrastructure

The loss assessment completed as part of AID's SIP measured 56 CFS of loss in district-owned canals (including a 10 CFS leak that was repaired), of which the SIP concluded that 32 CFS would be conserved if the system were piped (see AID SIP and Note 1 in the Introduction Section for information on difference between measured loss and water conservation estimate). The estimated cost for piping the district is $46,827,152 (Table 12).

Table 12. Water conserved, cost, and cost per AF for piping AID-owned infrastructure.

Project Group [1]	Canal / Lateral [1]	Water Conserved (CFS) [1]	Water Conserved (AF) [2]	Cost ($) [1]	Approximate Cost per AF ($/AF/yr) [2]
1	Main Canal - Tail End	8.4	2,994	$6,011,611	$ 2,008
2	Main Canal - Middle	6.9	2,459	$6,126,811	$ 2,491
3	Main Canal - Upper Main Canal - Flume Replacement	6.8	2,424	$25,413,192	$ 10,486
4	Arthur North Goat Farm Ladera M & M Estes	5.8	2,067	$1,573,349	$ 761
5	Brandon	2	713	$3,355,261	
6	Rastovich Pen., Bill., Ropp McCardle Rickard	1	356	2,427,825	$ -
7	Sundance Gosney DWC-1	1.1	392	$1,919,103	$ 4,895
Total		**32**	**11,405**	**$46,827,152**	**$ 4,106**

Notes: [1] Project Group, Canal/Lateral, Water Conserved, and Cost copied from Executive Summary of AID SIP.
[2] Conversion from CFS to AF is approximate. The conversion is done by multiplying the CFS rate by 180 days.

9 Lone Pine Irrigation District

The LPID SIP (FCA, 2017I) focused on district-owned infrastructure, the results of which are presented below in Section 9.1. Limited information is available on private canal and on-farm losses and therefore no information is presented on them in this report.

9.1 District-Owned Infrastructure

The loss assessment completed as part of LPID's SIP measured 8.8 CFS of seepage loss in district-owned canals, of which the SIP concluded that 5.2 CFS would be conserved if the system were piped (see LPID SIP and Note 2 in the Introduction Section for information on difference between measured loss and water conservation estimate).

The SIP presents two alternatives for piping LPID. Alternative A costs $6,843,389 and uses the NUID flume over the Crooked River (and then water would be pumped out of the NUID canal into the LPID system). Alternative B costs $9,750,454 and uses the existing LIPD suspension bridge over the Crooked River, however it should be noted that the LPID suspension bridge is outdated and may be in need of upgrades (hence additional costs).

Table 13. Water conserved, cost, and cost per AF for Alternative A piping LPID-owned infrastructure.

Canal / Lateral [1]	Water Conserved (CFS) [1]	Approx. Water Conserved (AF) [2]	Cost ($) [1]	Approx. Cost per AF ($/AF/yr) [2]
Middle Lateral	2.3	820	$3,308,703	4,036
Lower Lateral	1.0	356	$1,056,767	2,965
Main Canal	1.9	644	$2,477,919	3,659
Total	**5.2**	**1,853**	**$6,843,389**	**3,693**

Notes: [1] Canal/Lateral, Water Conserved, and Cost copied from Executive Summary of LPID SIP.
[2] Conversion from CFS to AF is approximate. The conversion is done by multiplying the CFS rate by 180 days.

Table 14. Water conserved, cost, and cost per AF for Alternative B piping LPID-owned infrastructure.

Canal / Lateral [1]	Water Conserved (CFS) [1]	Approx. Water Conserved (AF) [2]	Cost ($) [1]	Approx. Cost per AF ($/AF/yr) [2]
Middle Lateral	2.3	820	$3,730,885	4,551
Lower Lateral	1.0	356	$1,581,193	4,437
Main Canal	1.9	644	$4,438,376	6,554
Total	**5.2**	**1,853**	**$9,750,454**	**5,261**

Notes: [1] Canal/Lateral, Water Conserved, and Cost copied from Executive Summary of LPID SIP.
[2] Conversion from CFS to AF is approximate. The conversion is done by multiplying the CFS rate by 180 days.

10 References

DSWCD, 2017 — Deschutes Irrigation Water Management Project, Deschutes Soil and Water Conservation District, 2015-2017. Focus Area Action Plan and Reporting Form Quarter 8 Report.

DWA, 2006 — Irrigation District Water Efficiency Cost Analysis and Prioritization, prepared by Newton Consultants, August 2006.

FCA, 2016 — System Improvement Plan for Central Oregon Irrigation District, Prepared by Farmers Conservation Alliance and Black Rock Consulting, June 2016

FCA, 2017A — System Improvement Plan – Peak Flow Less than 5 CFS - for Central Oregon Irrigation District, Prepared by Farmers Conservation Alliance and Black Rock Consulting, June 2017

FCA, 2017B — On-Farm Water Conservation Report for Central Oregon Irrigation District, Prepared by Farmers Conservation Alliance and Black Rock Consulting, May 2017

FCA, 2017C — System Improvement Plan for North Unit Irrigation District, Prepared by Farmers Conservation Alliance and Black Rock Consulting, June 2017

FCA, 2017D — On-Farm Water Conservation Report for North Unit Irrigation District, Prepared by Farmers Conservation Alliance and Black Rock Consulting, June 2017

FCA, 2017E — System Improvement Plan for Swalley Irrigation District, Prepared by Farmers Conservation Alliance and Black Rock Consulting, January 2017

FCA, 2017F — System Improvement Plan for Tumalo Irrigation District, Prepared by Farmers Conservation Alliance and Black Rock Consulting, April 2017

FCA, 2017G — System Improvement Plan for Ochoco Irrigation District, Prepared by Farmers Conservation Alliance and Black Rock Consulting, August 2017

FCA, 2017H — System Improvement Plan for Arnold Irrigation District, Prepared by Farmers Conservation Alliance and Black Rock Consulting, June 2017

FCA, 2017I — System Improvement Plan for Lone Pine Irrigation District, Prepared by Farmers Conservation Alliance and Black Rock Consulting, August 2017

GSI, 2016 — Summary of Principle Water Demands in the Deschutes Basin, Prepared by GSI Water Solutions, March 2016

OID, 2012 — Ochoco Irrigation District Water Management and Conservation Plan, prepared by Ochoco Irrigation District, November 2012.

NRCS, 2016 — National Engineering Handbook, Chapter 11, Sprinkler Irrigation. United States Department of Agriculture, Natural Resource Conservation Service, 2016.

USBR, 1997 — Upper Deschutes Basin Water Conservation Study, Special Report, Crook, Deschutes, and Jefferson Counties, Prepared by the United States Department of Reclamation, 1997

Appendix A – On-Farm Water Conservation Costs

FCA on-farm costs are summarized into an overall 30 year cost per acre, while the Deschutes Basin Study requires costs to be comparable to other alternatives being evaluated (e.g., storage, leasing, piping), and as such requires costs to be divided out between capital and annual costs.

To generate new costs estimates, WPN used FCA's on-farm cost estimates and divided out capital and annual costs. See FCA on-farm reports for details on FCA methodology, however, the major differences on the two costs estimates are:

FCA on-farm costs are estimated by:

- calculating the initial capital costs,
- assuming all capital costs need to be replaced during a 30 year period (i.e. includes capital costs twice),
- calculating energy cost for 30 years,
- including a 30% contingency on all items,
- Summarizing for a total 30-year cost per acre.

WPN on-farm costs are estimated by:

- calculates the initial capital costs (assumes all the same line items as FCA's costs),
- replaces select items every 30 years (e.g., replaces sprinkler systems and pumps but does not regrade field or refurnish electrical power)
- uses same annual energy costs as FCA,
- includes a 20% contingency on all items,
- Summarized for an initial capital cost and annual costs. Annual costs includes energy costs plus replacement of equipment,
- Uses capital and annual costs to generate an overall 75-year cost.

Flood irrigation upgrade to:	Non-Pressurized		Pressurized	
5 Acre K-Line Pod System (13 Pods)	FCA	WPN	FCA	WPN
Furnish and install K-Line System	$ 3,000	$ 3,000		$ 3,000
Furnish and Install Electrical System	$ 20,000	$ 20,000		
Furnish and install 5 HP Pump, Manifold, Valves	$ 10,000	$ 10,000		
Furnish and install 6" suppy pipe	$ 6,400	$ 6,400		$ 6,400
Grade field	$ 1,000	$ 1,000		$ 1,000
Construct irrigation pond	$ 7,500	$ 7,500		
line irrigation pond	$ 3,000	$ 3,000		
SUBTOTAL CAPITAL COST	$ 50,900	$ 50,900		$ 10,400
engineering	$ 2,545	$ 2,545		$ 520
TOTAL CAPITAL COST	**$ 53,445**	**$ 53,445**		**$ 10,920**
ANNUAL COSTS				
Loss of field production at pond	$ 150	$ 150		
Energy cost ($0.10/kWh and 867 kWh/acre/year	$ 434	$ 434		
O&M	$ 1,697	$ 747		$ 364
TOTAL ANNUAL OPERATING COST	$ 2,280	$ 1,330		$ 364
TOTAL 30-YEAR OPERATING COST	**$ 68,405**			

Part of FCA Cost ONLY	$ 36,555			
- FCA and WPN costs not directly comparable, see	**$ 158,405**			
note at start of Appendix	**$ 31,681**			
	$ 37,541,985			

Used for WPN Cost ONLY		$ 64,134		$ 13,104
- FCA and WPN costs not directly comparable, see	$/ac	**$ 12,827**		**$ 2,621**
note at start of Appendix	AC-FT/AC	$ 2.8		$ 2.8
	$/ac-ft	$ 4,581		$ 936
		$ 266		**$ 73**

Note: water savings per acre dependent on district (e.g., crop, soil, climate). Values presented in this table are for COID.

Flood irrigation upgrade to:	Non-Pressurized		Pressurized	
10 Acre Wheel-Line System	FCA	WPN	FCA	WPN
Furnish and Install Wheel-Line	$ 19,500	$ 19,500		$ 19,500
Furnish and Install Electrical System	$ 20,000	$ 20,000		
Furnish and install 7.5 HP Pump, Manifold, Valves	$ 15,000	$ 15,000		
Furnish and install 6" suppy pipe	$ 9,600	$ 9,600		$ 9,600
Grade field	$ 2,500	$ 2,500		$ 2,500
Construct irrigation pond	$ 15,000	$ 15,000		
line irrigation pond	$ 6,250	$ 6,250		
SUBTOTAL CAPITAL COST	$ 87,850	$ 87,850		$ 31,600
engineering	$ 4,393	$ 4,392.50		$ 4,393
TOTAL CAPITAL COST	**$ 92,243**	**$ 92,243**		**$ 35,993**
ANNUAL COSTS				
Loss of field production at pond	$ 225	$ 225		
Energy cost ($0.10/kWh and 867 kWh/acre/year	$ 867	$ 867		
O&M (assumes full capital over 30 years)	$ 2,928	$ 1,678.33		$ 970
TOTAL ANNUAL OPERATING COST	$ 4,020	$ 2,770		$ 970
TOTAL 30-YEAR OPERATING COST	**$ 120,610**			

Part of FCA Cost ONLY	$ 63,856			
- FCA and WPN costs not directly comparable, see	**$ 276,708**			
note at start of Appendix				
	$ 27,671			
	$ 84,949,433			

Used for WPN Cost ONLY		$ 110,691		$ 43,191
- FCA and WPN costs not directly comparable, see	$/ac	**$ 11,069**		**$ 4,319**
note at start of Appendix	AC-FT/AC	2.50		2.50
	$/ac-ft	$ 4,428		$ 1,728
		$ 277		**$ 97**

Note: water savings per acre dependent on district (e.g., crop, soil, climate). Values presented in this table are for COID.

Flood irrigation upgrade to:	Non-Pressurized		Pressurized	
31 Acre Center-Pivot System	FCA	WPN	FCA	WPN
Furnish and Install 1,320 LF Pivot	$ 92,000	$ 92,000		$ 92,000
Furnish and Install Electrical System	$ 25,000	$ 25,000		
Furnish and install 15 HP Pump, Manifold, Valves	$ 20,000	$ 20,000		
Furnish and install 8" suppy pipe	$ 16,000	$ 16,000		$ 16,000
Grade field	$ 10,000	$ 10,000		$ 10,000
Construct irrigation pond	$ 27,000	$ 27,000		
line irrigation pond	$ 12,500	$ 12,500		
SUBTOTAL CAPITAL COST	$ 202,500	$ 202,500		$ 118,000
engineering	$ 10,125	$ 10,125.00		$ 5,900
TOTAL CAPITAL COST	**$ 212,625**	**$ 212,625**		**$ 123,900**
ANNUAL COSTS				
Loss of field production at pond	$ 300	$ 300		n/a
Energy cost ($0.10/kWh and 867 kWh/acre/year	$ 2,688	$ 2,688		n/a
O&M (assumes full capital over 30 years)	$ 6,750	$ 4,683		$ 3,600
TOTAL ANNUAL OPERATING COST	$ 9,738	$ 7,671		$ 3,600
TOTAL 30-YEAR OPERATING COST	**$ 292,131**	n/a		n/a

Part of FCA Cost ONLY	$ 151,427			
- FCA and WPN costs not directly comparable, see note at start of Appendix	**$ 656,183**			
	$ 21,167			
	$ 140,465,454			

Used for WPN Cost ONLY		$ 255,150		$ 148,680
- FCA and WPN costs not directly comparable, see note at start of Appendix	$/ac	**$ 8,231**		**$ 4,796**
	AC-FT/AC	3.20		3.20
	$/ac-ft	$ 2,572		$ 1,499
		$ 247		**$ 116**

Note: water savings per acre dependent on district (e.g., crop, soil, climate). Values presented in this table are for COID.

Wheel-line upgrade to:	Non-Pressurized		Pressurized	
31 Acre Center-Pivot System	FCA	WPN	FCA	WPN
Furnish and Install 1,320 LF Pivot	$ 92,000	$ 92,000		$ 92,000
Upgrade Electrical System	$ 10,000	$ 10,000		
Upgrade Pumping System	$ 10,000	$ 10,000		
Furnish and install 8" suppy pipe	$ 7,000	$ 7,000		$ 7,000
SUBTOTAL CAPITAL COST	$ 119,000	$ 119,000		$ 99,000
engineering	$ 5,950	$ 5,950.00		$ 4,950
TOTAL CAPITAL COST	**$ 124,950**	**$ 124,950**		**$ 103,950**
ANNUAL COSTS				
Loss of field production at pond		$ -		
Energy cost ($0.10/kWh and 867 kWh/acre/year		$ -		
O&M (assumes full capital over 30 years)	$ 3,967	$ 3,633.33		$ 3,300
TOTAL ANNUAL OPERATING COST	$ 3,967	$ 3,633		$ 3,300
TOTAL 30-YEAR OPERATING COST	**$ 119,000**			

Part of FCA Cost ONLY	$ 73,185			
- FCA and WPN costs not directly comparable, see note at start of Appendix	$ 317,135			
	$ 10,230			
	$ 23,488,450			

Used for WPN Cost ONLY		$ 149,940		$ 124,740
- FCA and WPN costs not directly comparable, see note at start of Appendix	$/ac	**$ 4,837**		**$ 4,024**
	AC-FT/AC	0.94		0.94
	$/ac-ft	$ 5,146		$ 4,281
		$ 117		**$ 106**

Note: Water savings per acre dependent on district (e.g., crop, soil, climate). Values presented in this table are for COID.
See note 4 below Table 4 in main report for reason 0.94 AC-FT/AC is used instead of 0.7 AF/AC.