Appendix A

System Improvement Plan

ARNOLD IRRIGATION DISTRICT
SYSTEM IMPROVEMENT PLAN

June 2017

Prepared by:
Kevin L. Crew, P.E.
Black Rock Consulting

BLACK ROCK

320 SW Upper Terrace Drive, Suite #102, Bend, Oregon 97702, (541)480-6257

&

Farmers Conservation Alliance

fca

101 3rd Street, Suite #101, Hood River, Oregon 97031, (541)716-6085

Prepared for:

ARNOLD
IRRIGATION DISTRICT

Table of Contents

Executive Summary

Farmers Conservation Alliance commissioned this System Improvement Plan with support from the Energy Trust of Oregon. The purpose of this System Improvement Plan (SIP) was to develop a well-considered evaluation of the District's primary and secondary canal systems, a mitigation plan for the seepage losses, and consideration of resulting pressurized deliveries. System piping was the primary method proposed for such mitigation.

In November of 2016, a meeting was held with District staff to confirm the approach on the SIP. Data requests were fulfilled by the District. The District determined that a value of 7.55 GPM/Acre should be used for hydraulic modeling and pipe sizing purposes (the water right to on-farm). The cost estimating resulting from the SIP should provide District flexibility and should provide grouped project seepage loss and cost of mitigation (through piping) information. Lastly, the model should include future acreage capacity in 6 laterals.

The District's patrons are served by one primary diversion, canal, and lateral system with approximately 46 of the irrigated acres being served directly from Deschutes River withdrawals. The current estimated acreage diverted into the primary canal serves approximately 3,963 acres. The primary canal and laterals were evaluated for seepage loss using state-of-the-art measurement equipment and it was found that approximately 56 CFS were being lost at the time of measurements. After adjustment for an approximate 10 CFS repair, the loss rate was adjusted to 45.8 CFS. Of the 45.8 CFS, it was determined that approximately 32 CFS might be conserved if the system were completely piped (assuming certificated peak flows of 7.55 GPM/Acre delivered).

The District chose to consider pressurization to patron deliveries as it rolls-out its System Improvement Plan. Fully piping the District system will accomplish moderate pressurization of the District resulting in the estimated reduction of 1.02 GWh in patron pumping costs each season. No pressure reducing valves were found to be necessary.

A pipe manufacturer/vendor was contacted to provide budgetary pipe cost information for pipe delivered to Central Oregon. This information was used to develop reconnaissance-level cost estimates to design and construct the entire piped system to all patron and private delivery points. The cost estimates were evaluated and broken into grouped cost elements. An At-A-Glance Map and summary tables are provided below indicating the summary results of this System Improvement Plan.

Section 1

At-A-Glance System Modernization Summary

Figure 1.1 At-A-Glance
Arnold Irrigation District
System Improvement Plan

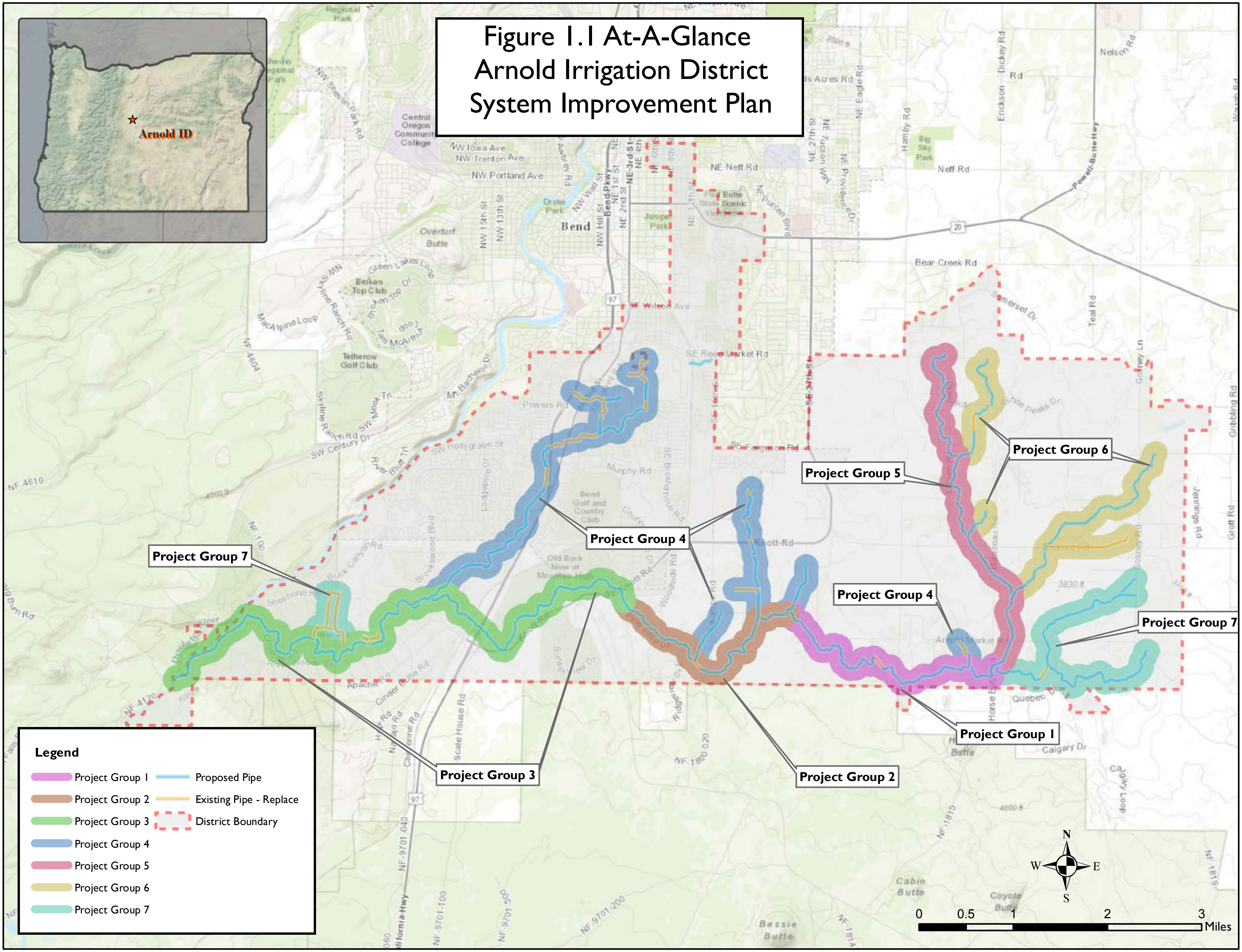


Table 1.1 At-A-Glance Main Canal and Lateral Piping Summary

AT-A-GLANCE - MAIN CANAL AND LATERAL PIPING					
PROJECT GROUP	CANAL/LATERAL	EST. WATER CONSERVATION (CFS)	EST. ENERGY CONSERVATION (KWH/YR)	LENGTH PIPED (FT)	RECON-ESTIMATED COST
1	Main Canal - Tail End	8.4	52,886	16,976	$6,011,611
2	Main Canal - Mid Section	6.9	48,519	13,963	$6,126,811
3	Main Canal - Upper	6.8	27,385	33,550	$20,292,533
3	Main Canal - Flume Replacement	0.0		5,394	$5,120,659
4	Arthur	5.8	144,923	49,415	$1,573,349
4	North				
4	Goat Farm				
4	Ladera				
4	M&M				
4	Estes				
5	Brandon	2.0	395,941	22,634	$3,355,261
6	Rastovich	1.0	256,588	31,093	$2,427,825
6	Penhollow and Billedeau Ropp				
6	McCardle				
6	Rickard				
7	Sundance	1.1	89,176	30,320	$1,919,103
7	Gosney				
7	DWC-1				
	TOTAL=	**32.0**	**1,015,417**	**203,345**	**$46,827,152**

Section 2

Project Description and Overview

2.0 Authorization

Farmers Conservation Alliance commissioned this System Improvement Plan with support from the Energy Trust of Oregon and authorized March 29, 2016 through a Consultant Services Agreement by and between the Farmers Conservation Alliance (FCA) and Black Rock Consulting (BRC).

2.1 Purpose

The Deschutes Reclamation and Irrigation Company, predecessor to Arnold Irrigation District (AID), was founded in 1899 and obtained its water rights for natural flow diversion from the Deschutes River with a priority date of September 1, 1899. From 1891 to 1923, the irrigation delivery system was constructed to serve what became the Arnold Irrigation District. The District currently serves approximately 4,384 acres (including instream leases) of irrigated lands located in the south area of Bend, Oregon, generally spanning east and west across Highway 97 and southerly of Highway 20. The District boundary is approximately 3 ½ miles (north to south) and 6 ½ miles long (east to west) and serves approximately 663 delivery accounts.

The District operates and maintains over 39-miles of main canal and laterals, including existing piped segments. The volcanic nature of the Central Oregon geology presents fractured basalt, cinder, and varied substrates that results in a propensity for seepage losses in many areas of the AID canal system.

The purpose of this System Improvement Plan (SIP) is to develop a well-considered evaluation of the District's primary and secondary canal systems, a mitigation plan for the seepage losses, and consideration of resulting pressurized deliveries. Consistent with its existing modernization program, well under way, system piping is to be the primary method proposed for such mitigation.

The plan will become a key element of the District's planning documents and is expected to become the basis for future phased construction of the District's conveyance system. Phases or portions of this plan will be implemented by the District only when, as determined by the Board, funding is available that will minimize impacts on AID patron assessments and not result in reduced on-farm deliveries.

2.2 Scope of Services

Black Rock Consulting (hereinafter "BRC") was employed to provide the following services and deliverables in conjunction with this plan:

Kickoff Meeting -

> BRC met with District staff and management to confirm approach to the study. BRC developed a list of questions to review with District staff. At these meetings BRC requested documents for major system elements that affected system hydraulic modeling, requested a copy of the District Water Conservation Plan, and requested water diversion and water right information, and associated operational input from the District.
>
> BRC discussed seepage loss information with the District and discussed the concluded loss assessment program implemented by BRC within the District.
>
> BRC inquired about energy dissipation approach preferences of the District (i.e. hydroelectric power generation and pressurized delivery preferences).

Review of Materials -

> BRC reviewed materials obtained from the District following the kick-off meetings to insure that required materials for moving the study forward were obtained or readily supplemented during the study to develop the deliverables indicated below. Data gaps that were found during the meeting process were identified and resolved with District staff.

Coordination -

> BRC coordinated with AID staff at various project milestones to confirm that the System Improvement Plan continued to be developed in accordance with the direction of AID.

Seepage Loss Study -

> BRC coordinated the development of seepage loss study with AID staff. The seepage loss study identified a program of seepage loss measurements for the AID system to support loss assumptions to be used in the SIP and to assist with water conservation estimates and system implementation phasing development.

Review of Provided Flow Data -

> BRC provided a thorough review of diversion data and on-farm delivery rates (per water right certificates) to insure a clear understanding of delivery approach. BRC coordinated with the District to insure rates used in system evaluation and modeling were as directed by the District.

AID SIP Base Map Development -

In conjunction with AID staff, BRC, AID, and FireWhat? developed a SIP primary and secondary canal and lateral system base map. The base map was populated with the AID primary and secondary canal system in its existing state.

AID SIP Improvement Map Development -

BRC (with AID input) developed a proposed primary and secondary system piping overlay on the base map. To the extent possible, existing mapping obtained as described above was used for this purpose. This map included an aerial underlay as available and as practical to manage file size.

AID SIP Hydraulic Model -

BRC confirmed approach regarding system pressurization with AID. Following the agreed approach discussed with AID and following delivery of basic system control and elevation information from FireWhat?, BRC then modeled the primary and secondary system elements (i.e. primary and secondary system canals and laterals) with EPANET hydraulic modeling software. Flow assumptions were based upon the rates agreed with AID staff. From iterations of model runs, BRC developed system elements including piping, pressure reducing elements; i.e. PRV stations, hydroelectric power plant locations, primary system valving points, etc. Pipe materials and diameters were determined during this analysis.

AID SIP Phasing Approach -

In conjunction with the system model and upon review with AID, BRC developed a system improvement cost estimate that was broken down by District lateral elements. This will allow the District flexibility in implementation development and design decisions based upon funding availability and other critical considerations.

AID SIP Conservation Table -

BRC developed a table indicating water conservation estimates based upon historic diversions, desired delivery rates within a fully piped system, and also corroborated by the loss assessment program results.

Final SIP Mapping -

In conjunction with AID staff, BRC developed a final SIP map indicating primary and secondary canal system elements, indications of existing and proposed piping, and other key system elements.

Reconnaissance-Level Cost Estimate -

> BRC coordinated with a reputable material vendor and developed reconnaissance-level cost estimating for the proposed piping system and pumping identified for the District.

SIP Reporting -

> BRC compiled the results of the SIP study into this System Improvement Plan draft report for review and comment by AID. Comments received were incorporated as appropriate into the Final SIP Report. The report includes mapping, and summarizes all findings for elements identified above.

2.3 Goals and Objectives – District Meeting(s*)*

As indicated in the scope, Black Rock Consulting met with District staff on November 3, 2016. Black Rock Consulting and District staff discussed key project parameters required to establish the approach for the SIP.

The meeting was attended by:

Shawn Gerdes, District Manager
Colin Wills, District Operations
Juanita DeJarnett, District Administrations
Kevin L. Crew, Principal, Black Rock Consulting

Key agenda items addressed were as summarized below:

1) Data Needs: District Water Right Certificates, District's Water Management and Conservation Plan, District's Most Recent Irrigated Acre Accounting (Direct River Points of Delivery and Primary Diversion).

   These materials were either provided to Black Rock Consulting and discussed in some detail, or Black Rock Consulting was directed where to obtain these materials. Clarifications were provided by the District.

2) What are the plans for piping and pressurization of the District?

   The District has some segments of piping already in place, including inverted siphons and some lateral piping. Certain segments of existing pipe may tolerate pressurization whereas others likely will not. Some larger siphons on the main canal may serve as carrier pipes (i.e. sleeves) for proposed piping. With only a few noted exceptions, the entire system should be modeled and new proposed pipe sized. The District will evaluate what pipes it may wish to preserve once it has the model results, including *anticipated pressures, etc. and as it designs and implements its improvements.*

Generally, the District plans to pipe a majority of its system, however, the prioritization and timing of piping will be an ongoing consideration by the District. Phases or portions of the plan will be implemented by the District, only when, as determined by the Board, funding is available that will minimize impacts on AID patron assessments and not result in reduced on-farm deliveries.

It is anticipated that pressures within the piped system will not support significant hydroelectric power generation potential versus the benefit of pressurization to the patrons and reduction in pumping costs.

3) Given that water rights would dictate a delivery of 21.59 GPM/Acre for peak delivery flow rate (including transmission loss) to the District's irrigated properties, what flow rate should be used in the model for peak flow rates?

   The model should use 7.55 GPM/Acre for normal delivery modeling at 5 FT/S velocities or less in system elements per NRCS guidelines. The one exception is the North Lateral that should be modeled at 5.5 GPM/Acre in anticipation of further flow rate reductions in that lateral over time. It must also be confirmed that one additional condition will work within the proposed systems: an uncommon high flow rate of 9 GPM/Acre with allowance for velocities to exceed 5 FT/S should be evaluated. This would insure that the system will operate satisfactorily under future scenarios if additional irrigated lands were attributed to the canal system and to address climate change scenarios.

4) Black Rock Consulting indicated that it planned to break the canal piping cost estimates into lateral by lateral estimates, and the remaining primary canal estimate to provide the District with a high level of flexibility in project financial planning and implementation packaging.

   The District agreed with this approach.

5) Does the District anticipate any shift of acreage or flow rates within the District boundary and service areas?

   Yes. The District sees the North Lateral as an element of the system that has slowly reduced in irrigated acreage and delivery flow rates over time due to urbanization. This lateral has some hydroelectric power production potential, however, the long term flows in that lateral and associated future reductions are a challenge for hydroelectric power plant sizing. Other laterals at the east extremity of the main canal are anticipated to *serve slightly more demand over time and this is an anticipated shift of overall demand in the system within the existing District service area.*

The District estimated irrigated acreage shifts as follows, and should be incorporated into hydraulic modeling to insure future capacity:

- *Sundance Lateral - 80 Acres*
- *Gosney Lateral - 120 Acres*
- *McCardle Lateral - 150 Acres*
- *Brandon Lateral - 50 Acres*
- *Rastovich Lateral - 50 Acres*
- *Rickard Lateral - 20 Acres*

Section 3

Existing System

3.0 Existing System Description

Please refer to Figure 3.0.1 below regarding the existing District Delivery System that indicates the District service territory boundary, measurement points, and the primary canal system.

Under its water rights, the Arnold Irrigation District diverts water directly from the Deschutes River. The source of diverted water is based upon the two water right certificates that govern the District's storage and direct river diversion limitations as indicated in Section 3.1. For storage withdrawals, the District cooperates with Central Oregon Irrigation District, North Unit Irrigation District, and Lone Pine Irrigation District based upon an inter-governmental agreement. The District diverts its water from the Deschutes River at its primary diversion point located south of Bend and next to the Newberry Monument. In addition to this main Arnold Canal diversion, the District's water rights also allow for service to six direct river deliveries. Once water is diverted into the primary Arnold Canal, the water passes the District's radial gate that regulates the intake flow rate, its vertical flat-plate fish screen, into its aerial flume, and on into its delivery network. Flows into the system are currently measured by the Oregon Water Resources Department's gauge; the District is in the process of adding measurement and control just below its fish screen.

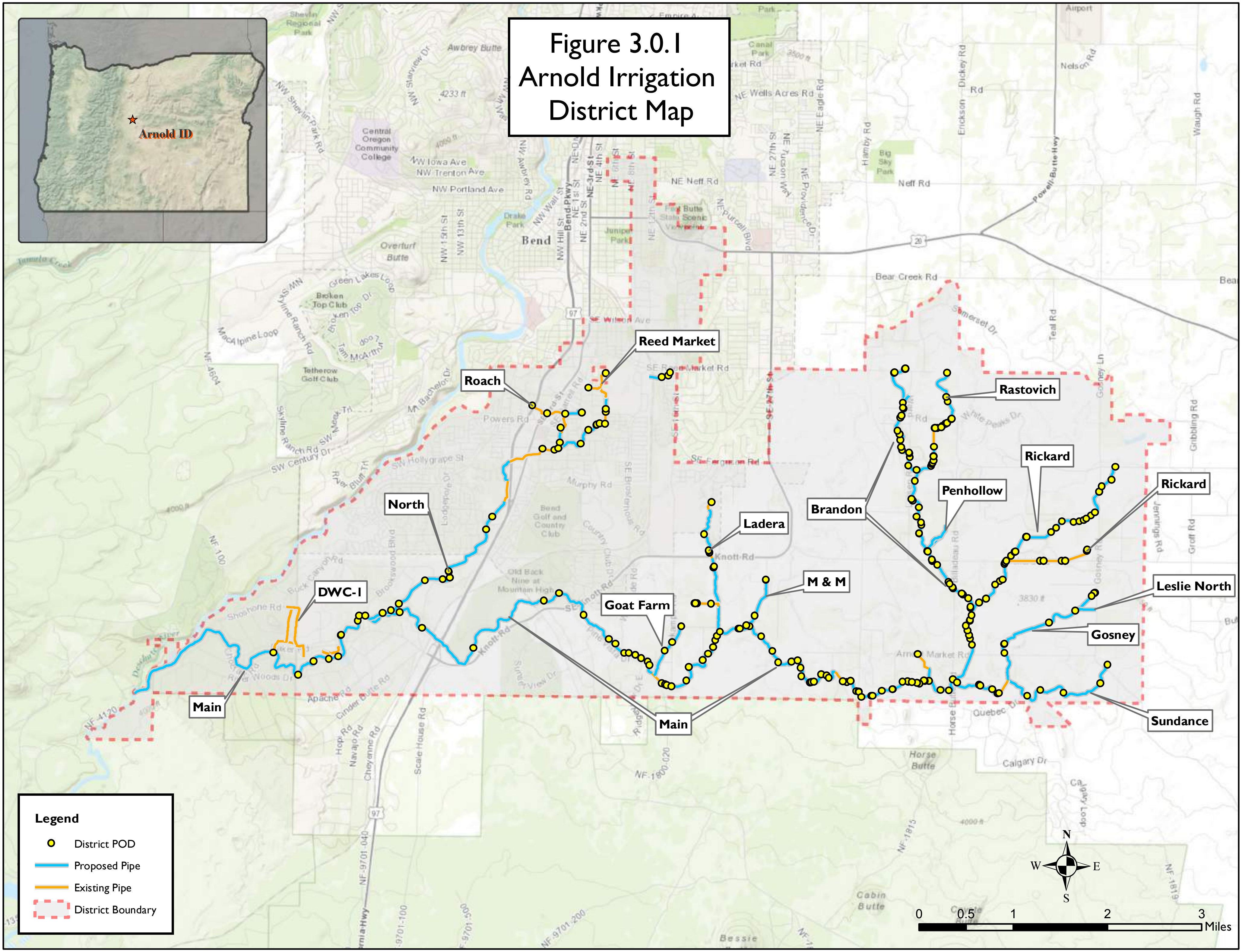
As indicated on Figure 3.0.1, the AID main canal conveys water generally north and easterly starting with an approximate 1-Mile long aerial flume and trestle system, and then transitioning to a typical earthen and rock substrate open canal. After the flume, the main canal runs approximately 12 miles from east to west, terminating in the Brandon and Sundance Laterals. Along the way it delivers to patrons and to several laterals as indicated on Figure 3.0.1; as indicated piping and siphon piping has occurred within the District. Retention of any of these pipes will be considered on a case-by-case basis by the District and in design for piping improvements. In all, the District operates and maintains over 39 miles of canal and piping in the system.

Water diverted into the Arnold Irrigation District passes through a generally topographically gradual system. The main canal falls about 60-FT from east to west in the District. The maximum differential in the District from the intake to the extremity of a lateral is approximately 200-FT.

In addition to the primary canal system, the District has several direct deliveries from the Deschutes River as indicated on Figure 3.0.1. These direct deliveries (Points of Delivery "POD"s) account for approximately 46 acres of the District's total certificated rights and are monitored and metered by the District.

Patron turnouts from the District's main canal and laterals are typically gate regulated and weir measured. The District regulates flows to each system lateral and patron turnout via its field staff.

Figure 3.0.1
Arnold Irrigation District Map



3.1 Water Supply and Certificates

The Arnold Irrigation District operates based upon two water right certificates: its direct Deschutes River diversion certificate and its Crane Prairie storage right certificate. Complete water right information is not included in this SIP but may be obtained from the Oregon Water Resources Department and viewed in the District's Water Management and Conservation Plan on file with the Oregon Water Resources Department. It should be noted that the District's water rights change from time to time with conservation activities, hydroelectric power development, transfers, and other water right activities. For the purposes of this SIP, the primary goal is to evaluate the modernization of the District's conveyance system; therefore, information regarding Water Right Certificate #74197 is provided below.

Source: Deschutes River, a tributary of the Columbia River
Priority: February 1, 1905 (25.0 CFS), April 25, 1905 (125.0 CFS)
Use: Primary source for entire District
Irrigation: 3,976.05 Acres
Pond Maintenance: 35.71 Acres/equivalent
Quasi-Municipal Use: 347.59 Acres/equivalent
Industrial: 23.2 Acres
Domestic Use and Stock Water: 1.5 Acres
Maximum Rate: 150.0 CFS
Duty: Main Canal at 15.42 AF maximum per acre at the diversion from the source. (65% transmission loss in the canal system as allowed by the Court. No transmission loss allowed for direct withdrawals at individual points of delivery from the Deschutes River.

<u>QUANTITY FOR CANAL DIVERSIONS FROM SOURCE</u>

Season 1: April 1 – May 1 and Oct. 1 – Nov. 1: 1 CFS to 51.0 Acres
Season 2: May 1- May 15 and Sept. 15-Oct. 1: 1 CFS to 39.0 Acres
Season 3: May 15- Sept. 15: 1 CFS to 20.8 Acres

For the purposes of this SIP, the most critical elements of this certificate are the duty and the rates allowable for "Canal Diversions from the Source." As indicated in the duty criteria above, there is currently an allowance of 65% for transmission losses within the canal system. This loss accounts for evapotranspiration, seepage, and other losses within the large District canal conveyance systems as water is conveyed in excavated canals that cross a variety of rocky and soil substrates. The piping evaluated to improve the canal system in the Arnold Irrigation District will mitigate system losses. The extent of mitigation is further discussed in the System Loss Assessment section of this SIP.

In terms of quantities allowed for diversion into the District canals, the peak allowable is indicated above at 1 CFS per 20.8 Acres. This equates to approximately 21.59 GPM/Acre. After multiplying this flow rate by 35%, the on-farm delivery flow rate is determined at approximately 7.55 GPM/Acre. Therefore, given a "tight" system with little or no losses, the diversion flow rate may clearly be reduced significantly. It should also be noted that at the beginning and the end of the irrigation season the allowable low flow rate for diversion from the Deschutes River is 1 CFS per 51.0 Acres (or 8.80 GPM/Acre) and to each farm is 3.08 GPM/Acre (after reducing by 65%). This is important to the SIP simply to note that system improvements should include provisions to not only accommodate peak system flow rates but to accommodate lower system flow rates that can create sedimentation issues if not properly accounted for.

3.2 On-Farm Water Demand Analysis - Acreage and Duty

As indicated above, the current allowable diversion during peak irrigation season is 15.42 AF/Acre with an assumption after losses of 5.40 AF/Acre on-farm. The rate during peak season is 7.55 GPM/Acre after reducing the diversion rate by the certificated transmission losses.

For the purposes of this SIP, and based upon District input as indicated above, a SIP design delivery flow rate to on-farm was established at the calculated on-farm rate of 7.55 GPM/Acre (with the exception of the North Lateral that was given a design delivery rate of 5.5 GPM/Acre). At these rates, and based upon the Natural Resources Conservation Service criteria, 5 FT/S was used as a maximal velocity criteria for proposed piping of the system. The pipe models were also evaluated to an extreme value of 9 GPM/Acre to insure that the system would still function properly and to insure future flexibility to the District. Under this higher flow rate per acre of irrigated area, velocities were evaluated to insure that the they did not dramatically exceed the 5 FT/S criteria.

3.3 System Loss Assessment

Black Rock Consulting worked with the District to coordinate a seepage loss study performed by Farmers Conservation Alliance staff under Black Rock Consulting/Kevin L. Crew, P.E and David C. Prull, P.E. direction. During the summer of 2016, the Seepage Loss Assessment Program (LAP), supported by Oregon State University and the Oregon Water Resources Department, was implemented in 7 of the 8 Central Oregon irrigation districts to inform the Districts of current system losses and to enhance SIP development for these Districts. The program included the use of newly purchased and calibrated Flowtracker II technology, manual, and office and field training, all in accordance with the United States Geological Survey and United States Bureau of Reclamation "Discharge Measurements at Gauging Stations – Chapter 8 of Book 3, Section A, Techniques and Methods 3-A8." The program was managed by Oregon Registered Professional Engineers, Kevin L. Crew, P.E. and David C. Prull, P.E.

The primary purpose of the LAP was to perform a one-time measurement program in each District thus providing the District SIPs of approximate seepage losses in elements of each system. The measurements were performed at different times of the irrigation season within each District, therefore the percentage of peak flow 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 maximal expected loss within each District as indicated in the SIP below. The final loss information was used to identify losses associated by project phase or lateral depending upon each specific District SIP. In instances where grants are to be allocated in direct exchange for conserved irrigation water to be dedicated by revised water rights certificates to instream flow, the grantor may be compelled to confirm these seepage loss results by conducting a subsequent loss measurement program performed by the USGS and/or the Oregon Water Resources Department prior to project implementation.

For Arnold Irrigation District, the LAP was implemented throughout the District's primary canal and system laterals. Tabular results for the LAP study within AID are included in Appendix A to this SIP. A tabulated summary version of the results are provided below in Table 3.3.1.

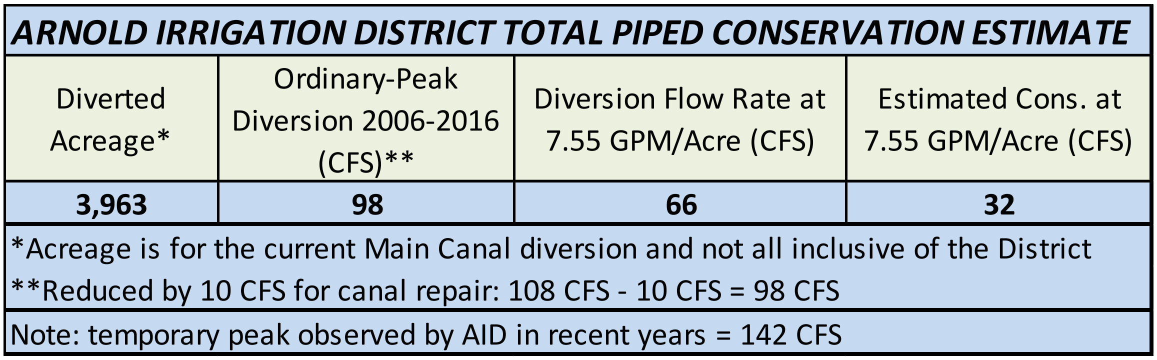
Table 3.3.1 Water Conservation Estimate by Canal and Lateral

ARNOLD IRRIGATION DISTRICT CONSERVATION ESTIMATE BY CANAL AND LATERAL					
PROJECT GROUP	CANAL/LATERAL	MEASURED (Y/N)	LOSS MEASURED (CFS)*	ADJUSTMENT FACTOR	ADJUSTED CONSERVATION ESTIMATE (CFS)
1	Main Canal - Tail End	YES	11.2	0.75	8.4
2	Main Canal - Mid Section	YES	9.2	0.75	6.9
3	Main Canal - Upper*	YES	12.1	0.56	6.8
3	Main Canal - Flume Replacement	NO	0.0	0.75	0.0
4	Arthur	YES	0.0	0.75	0.0
4	North	YES	6.1	0.75	4.5
4	Goat Farm	YES	0.0	0.75	0.0
4	Ladera	YES	1.1	0.75	0.8
4	M&M	YES	0.6	0.75	0.5
4	Estes	NO	0.0	0.75	0.0
5	Brandon	YES	2.7	0.75	2.0
6	Rastovich	YES	0.4	0.75	0.3
6	Penhollow and Billedeau Ropp	NO	0.0	0.75	0.0
6	McCardle	YES	0.9	0.75	0.7
6	Rickard	YES	0.0	0.75	0.0
7	Sundance	YES	1.0	0.75	0.8
7	Gosney	YES	0.4	0.75	0.3
7	DWC-1	NO	0.0	0.75	0.0
		TOTAL=	**45.8**		**32.0**
*Reduced by 10 CFS for repair after loss assessment was performed					

The adjustment factor provided in the table is the simple ratio of the estimated total piped conservation (fully piped system) at a delivery rate of 7.55 GPM/Acre, 32 CFS (see Table 3.3.2), versus the measured system loss of 45.8 CFS (after a 10 CFS repair-related reduction).

Total piped system conservation estimates were developed. Delivery acreages as assessed for the AID system were used to estimate the fully piped system flow rates at the peak certificate rate (7.55 GPM/Acre). Flow diversion data for the District were evaluated to determine the ordinary-peak diverted flow rate over the last seven years of operation (approximately 108 CFS peak). This ordinary-peak was compared to the peak piped flow rate to estimate potential conservation based upon a completely piped hydraulic delivery system (including all laterals and private laterals down to the individual patron turnouts). The results of this total conservation estimate are tabulated in Table 3.3.2. It should be noted that the 108 CFS ordinary-peak does not represent the highest intermittent flow rate observed by the District, that has been as high as 142 CFS. For the purposes of this SIP, however, the ordinary-peak was used to develop the potential conservation assessment for the District.

Table 3.3.2 Total Piped Water Conservation Estimate



ARNOLD IRRIGATION DISTRICT TOTAL PIPED CONSERVATION ESTIMATE			
Diverted Acreage*	Ordinary-Peak Diversion 2006-2016 (CFS)**	Diversion Flow Rate at 7.55 GPM/Acre (CFS)	Estimated Cons. at 7.55 GPM/Acre (CFS)
3,963	**98**	**66**	**32**
*Acreage is for the current Main Canal diversion and not all inclusive of the District **Reduced by 10 CFS for canal repair: 108 CFS - 10 CFS = 98 CFS			
Note: temporary peak observed by AID in recent years = 142 CFS			

Section 4

System Improvement

4.0 System Improvement Approach

The primary purpose of this SIP was to identify water conservation, hydroelectric power and pumped power conservation possibilities for the District, and to develop a mitigation strategy for system water losses. Although some limited piping has already occurred in the District, there remains a significant canal system calling for mitigation through piping. Consistent with its Scope of Services and the subsequent goals and direction provided by the District, Black Rock Consulting performed a comprehensive hydraulic and piping evaluation of the District.

There are two primary alternatives for the mitigation of seepage losses. The first is canal lining and the second is canal piping. Within each of these alternatives there are a variety of material choices. Canal lining involves the installation of an impervious system to cover the canal bottom and banks. Materials typically employed include geomembranes, rubber liners, shotcrete, or similar materials. Canal lining does not provide pressurization of the irrigation system and it also increases canal velocities, thus increasing hazard risk to people. Black Rock Consulting has performed 50-year life cycle evaluations of lining versus piping alternatives to the District and has not included these in this SIP. In summary, over a 50-year life cycle, it was found that canal lining may be less expensive to implement in its first installation cycle than piping, however canal lining requires significant maintenance and replacement cycles that ultimately cause it to exceed the cost of piping over time. Also, given the elevation differential across the District and the desire of the District to optimize pressurized deliveries to its patrons and reduce pumping electricity effects on the utility grid, piping was chosen as the District's preferred choice for canal water loss mitigation.

Black Rock Consulting commenced the process of hydraulic modeling for the Arnold Irrigation District by receiving base EPANET (.INP) files from FireWhat? in electronic form. The files were generated by FireWhat? by including spatially (i.e. northing, easting, and elevation) correct patron turnout locations including patron delivery flow rates at each turnout. Updated acreages by patron were provided by the District for this purpose. EPANET modeling is discussed further in this SIP below. From the base files, Black Rock Consulting inserted the data in EPANET and then began the process of including existing piped elements of the District. The District was modeled based upon the District's current system approach with an intake at the Deschutes River and incremental gravity pressurization of the system.

The system was evaluated as a completely closed system (i.e. fully piped and pressurized to its extremities). The completed model was calibrated and pipes were sized based upon selected pipe manufacturer information and a peak velocity of 5 FT/S for proposed piping at 7.55 GPM/Acre throughout the system (with the exception of the North Lateral that was modeled at 5.5 GPM/Acre).

Once this process was completed, the system was evaluated for cost as further detailed below. Project "Groups" were developed based upon one approach to incremental system piping as provided in this SIP. This approach is subject to modification based upon funding availability, District operation, and preference over time.

4.1 Pipe and Valve Materials

Pipe materials selections were made by Kevin L. Crew, P.E., based upon 29 years of experience with large diameter piping systems including 20 years of experience in Central Oregon. From the hydraulic model, both static and dynamic pressures were evaluated throughout the system to select appropriate pipe material options. For pipe up to 63-inches in diameter (covering all District piping needs), high density polyethylene solid-wall pipe was selected due to its outstanding abrasion resistance, longevity, and ability to be pulled into canal curve alignments. Costs for materials were obtained from large, reputable vendors that are active in bidding to Central Oregon projects.

While pressure reducing valves were not proposed in this SIP, they were evaluated in the event that any may be required for future use in parallel with hydroelectric power production or other energy dissipation needs that may arise. Valves for pressure reducing stations were technically assessed and narrowed down to plunger valves and Cla-Val valves. Both use internal energy dissipation within the valve to accomplish the needed pressure-sustaining function downstream of the valves. Cla-Val valves use a control tubing and a diaphragm/bonnet arrangement to adjust pressures within the pressure reducing apparatus. No power is necessary for the operation of a Cla-Val. Should pressure reducing valves be required in the future, Cla-Val E-90-01 pressure reducing valves should be considered.

4.2 Hydroelectric Power Potential, Pumping Mitigation, and Pressurization Approach

The hydraulic analysis for the District indicates that there is no appreciable hydroelectric power potential in the District; what pressurization exists may best be used for direct patron pumping offset benefit.

Pressurization of the system will occur as it is piped. The hydraulic model indicates that dynamic (i.e. pressures achieved during full flow operation of the system) will range from approximately 2 PSI to 46 PSI. In reality, system pressures will likely rise well above this pressure range as hydraulic losses (i.e. pressure losses) will be less if the system is moving less water. For example, if the system flows were reduced from 7.55 GPM/Acre to 5.5 GPM/Acre, the highest system pressure located at the end of the McCardle Lateral would rise from 46 PSI to 70 PSI.

Based upon the following assumptions, private patron (on-farm) pumping mitigation was also evaluated:

- 3 AC-FT/Acre of water applied to grow grass or alfalfa/season
- 70% application efficiency
- 4.28 AC-FT/Acre required to flow from the sprinkler heads/season
- 70% pumping efficiency

Where partial pressurization was anticipated by the hydraulic model, a percent of pumping mitigated was assigned to the associated lateral or main canal. The overall District private pumping mitigation and associated patron kWh savings was estimated at 1,015,417 kWh/Year.

Table 4.2.1 Estimated Pumping Power Savings Through Pressurization

ESTIMATED PUMPING POWER SAVINGS THROUGH PRESSURIZATION						
PROJECT GROUP	CANAL/LATERAL	IRRIGATED ACRES ASSOCIATED WITH SEGMENT	ESTIMATED % OF PUMPING MITIGATED	70% EFF. PUMPING PER ACRE AT 60 PSI GRASS HAY (KWH)	SAVINGS/AC (KWH)	TOTAL ESTIMATED PUMPING SAVINGS (KWH/YR)
1	Main Canal - Tail End	522.7	12%	867.3	101.2	52,886
2	Main Canal - Mid Section	479.5	12%	867.3	101.2	48,519
3	Main Canal - Upper	473.6	7%	867.3	57.8	27,385
3	Main Canal - Flume Replacement	0.0		867.3	0.0	0
4	Arthur	Incl. Below				
4	North	140.9	33%	867.3	289.1	40,722
4	Goat Farm	142.0	26%	867.3	225.5	32,019
4	Ladera	148.6	30%	867.3	260.2	38,668
4	M&M	70.1	25%	867.3	216.8	15,191
4	Estes	84.5	25%	867.3	216.8	18,322
5	Brandon	913.0	50%	867.3	433.7	395,941
6	Rastovich	149.8	50%	867.3	433.7	64,943
6	Penhollow and Billedeau Ropp	Incl. Above				
6	McCardle	356.2	58%	867.3	505.9	180,228
6	Rickard	39.5	33%	867.3	289.1	11,417
7	Sundance	232.8	22%	867.3	187.9	43,746
7	Gosney	209.5	25%	867.3	216.8	45,430
7	DWC-1	Incl. Above				
	TOTAL=	**3963**				**1,015,417**

4.3 Elevation Data

Elevation data for use in modeling was obtained through a LiDAR flight performed in March of 2016 by Quantum Spatial of Corvallis, Oregon. The data was post-processed to the requirements of FCA and Black Rock Consulting. Specifications for the data collection are provided in Table 4.3.1.

Table 4.3.1 LiDAR Parameters

Multi-Swath Pulse Density	≥ 8 pulses/m^2
Scan Angle	≤30^o (+/-15^o from Nadir)
Returns Collected Per Laser Pulse	Up to 4
Intensity Range	1-255
Swath Overlap	50% side-lap (100% overlap)
Maximum GPS Baseline	13 nautical miles

With the use of on-ground RTK and OPUS corrections, the data was provided in 1-FT contour interval format and was considered better than 1-FT accuracy vertically.

Units for the elevation information were reported and used in the following systems:

- Horizontal Projection: Oregon State Plane (ORSP) South Zone. International Feet
- Horizontal Datum: NAD83(2011)(Epoch2010.00)
- Vertical Datum: NAVD88 using Geoid12A

4.4 Future Delivery Flexibility

The District has requested system flexibility to insure that, within reason, system changes, added and subtracted irrigated acreage, effects of climate change, effects of changes in cropping patterns, and similar system demands may be addressed in this SIP.

First, with the exception of the North Lateral, the system was modeled with demands at the maximum certificated on-farm water right of 7.55 GPM/Acre. This, in and of itself, is conservative given that it is unlikely that every patron within the District is irrigating at the same moment at full water right demand.

The second system flexibility that was included in the base modeling analysis was the addition of future acreage and associated demand to the following laterals:

- Sundance Lateral - 80 Acres
- Gosney Lateral - 120 Acres
- McCardle Lateral - 150 Acres
- Brandon Lateral - 50 Acres

- Rastovich Lateral - 50 Acres
- Rickard Lateral - 20 Acres

The piping proposed by this SIP and base hydraulic model will accommodate these additional acreages that were assigned to the ends of each of the named laterals.

Modeled system demands were increased to 9 GPM/Acre. At 9 GPM/Acre, there were multiple system locations where negative pressures were predicted. This is because the primary delivery system slope is very gradual and is sensitive to minor hydraulic grade changes. Should the District believe that it will need capacity beyond the future acreages added to the laterals indicated above and with the entire system exceeding 7.55 GPM/Acre, the system should be further evaluated, modeled, and updated to accommodate such capacity prior to commencing system improvements.

4.5 Hydraulic Modeling

EPANET –

EPANET was used to model the District's proposed piped network. EPANET is a free-ware product that is maintained by the EPA. The Natural Resources Conservation Service technical offices in Oregon use EPANET exclusively for hydraulic modeling. For these reasons, EPANET was selected as the modeling software of choice for this SIP.

EPANET modeling capabilities go beyond steady-state hydraulic modeling. The software is capable of chemical transport analysis and varying flow modeling. A description of some of its capabilities follows:

EPANET is a computer program that performs extended period simulation of hydraulic and water quality behavior within pressurized pipe networks. A network consists of pipes, nodes (pipe junctions), pumps, valves, and storage tanks or reservoirs. EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of a chemical species throughout the network during a simulation period comprised of multiple time steps. In addition to chemical species, water age and source tracing can also be simulated.

EPANET is designed to be a research tool for improving our understanding of the movement and fate of drinking water constituents within distribution systems. It can be used for many different kinds of applications in distribution systems analysis. Sampling program design, hydraulic model calibration, chlorine residual analysis, and consumer exposure assessment are some examples. EPANET can help assess alternative management strategies for improving water quality throughout a system. These can include:

- Altering source utilization within multiple source systems
- Altering pumping and tank filling/emptying schedules
- Use of satellite treatment, such as re-chlorination at storage tanks
- Targeted pipe cleaning and replacement

Running under Windows, EPANET provides an integrated environment for editing network input data, running hydraulic and water quality simulations, and viewing the results in a variety of formats. These include color-coded network maps, data tables, time series graphs, and contour plots.

Hydraulic Modeling Capabilities –

Full-featured and accurate hydraulic modeling is a prerequisite for doing effective water quality modeling. EPANET contains a state-of-the-art hydraulic analysis engine that includes the following capabilities:

- Places no limit on the size of the network that can be analyzed
- Computes friction head loss using the Hazen-Williams, Darcy-Weisbach, or Chezy-Manning formulas
- Includes minor head losses for bends, fittings, etc.
- Models constant or variable speed pumps
- Computes pumping energy and cost
- Models various types of valves including shutoff, check, pressure regulating, and flow control valves
- Allows storage tanks to have any shape (i.e., diameter can vary with height)
- Considers multiple demand categories at nodes, each with its own pattern of time variation
- Models pressure-dependent flow issuing from emitters (sprinkler heads)
- Can base system operation on both simple tank level or timer controls and on complex rule-based controls

Velocity Criteria –

As stated above, the maximal velocity criteria was set at 5 FT/S for on-farm deliveries at 7.55 GPM/Acre (with the exception of the North Lateral that was modeled at 5.5 GPM/Acre). The peak evaluated flow rate was 9 GPM/Acre for future system flexibility and was allowed to increase beyond 5 FT/S in modeling as indicated above.

Elevations –

As indicated above, elevation data was derived from a 2016 LiDAR flight.

Spatially Correct Layout –

> Horizontal information for the various system elements and patron turnouts was collected through a field survey performed by District staff in 2016. Turnout locations were “snapped” to the canal centerline (perpendicular to the centerline) as determined through post-processing of the LiDAR data and locating canal and lateral centerlines. The “snapped” locations represented turnout node locations used during hydraulic modeling of the system and were represented in the model by Northing and Easting coordinates of the Oregon State Plane South Zone.

Pressure Reduction (Not Applicable to the Arnold Irrigation District) –

> Where applicable, pressure reducing stations and/or hydroelectric power plants were entered into the model as PRVs (pressure reducing valves). These valves are a programmed element in EPANET. The diameter of the valve and the downstream pressure set-point are entered to establish the downstream system pressure to be held by the PRV. PRVs were also used to emulate the pressure reduction through hydroelectric plant(s).

Pipe Diameter Selection –

> Pipe diameter selections were derived iteratively in the hydraulic model with the first iteration being a rough estimate. The second iteration utilized actual pipe diameters for high density polyethylene pipe material at the appropriate dimension ratio and pressure rating for each model “link” (pipe). Generally, the third iteration adjusted all pipes in the system to a range of 4 FT/S to 5 FT/S at the peak system flow rates based upon 7.55 GPM/Acre (and 5.5 GPM/Acre for the North Lateral).

Pipe Pressure Rating Selection –

> HDPE solid-wall pipes (PE4710 resin) were sized from HDPE pipe sizing tables for the expected static pressure for each pipe segment.

The model for the Arnold Irrigation District is included in Appendix B of this SIP.

4.6 Cost Estimating by Lateral (and Main Canal)

Pipe Estimates –

> Pipe material estimates were provided by a reputable vendor that routinely supplies pipe materials to Central Oregon projects. Pipe material budgetary estimates are provided in Appendix C for reference.

Turnouts –

For the purposes of this SIP, patron turnouts were assumed to be converted to pressurized delivery systems. A standard pressurized irrigation delivery turnout was assumed to include an appropriately sized tee from the mainline or lateral, a pressure relief valve, a gear-actuated plug valve (or gate or possibly butterfly valve in smaller turnout situations), a magnetic meter, a combination air and vacuum relief valve and associated hardware, and spool pipe segments. Based upon experience with similar installations at irrigation districts in Central Oregon, the cost of installation of a turnout was set at an estimated average cost of $8,000 per installation.

Construction –

Contractor procurement may come in several forms in Oregon. Design-Bid-Build is a conventional process wherein the survey and design is developed first and then a traditional competitive bid is held to obtain the lowest-cost responsive and responsible bidding contractor. In this process, typically the design-engineering firm will serve as the inspection/construction management firm during the course of construction. Given the magnitude of the project phases and for the purposes of this SIP, a Construction Manager General Contractor (CMGC) model was assumed. In this contractor procurement method, design would precede obtaining the contractor, however, the contractor would include construction management in its delivery of the constructed project. An estimated contractor fee structure of 12% -18% of the project value was assumed for this construction delivery method depending upon the size of the lateral or main canal project being evaluated.

Engineering, Construction Management –

Engineering and Owner's Representative/Inspection services typically range as high as 10% - 18% of construction value. For the purposes of this SIP, and assuming that project phases are constructed sequentially and annually, it was assumed that total fee of 6% - 18% for survey, engineering design, and inspection/owner's representative services would be appropriate depending upon the scale of the particular lateral or main canal project. This was based upon the experience of Black Rock Consulting on similar projects deployed in Central Oregon.

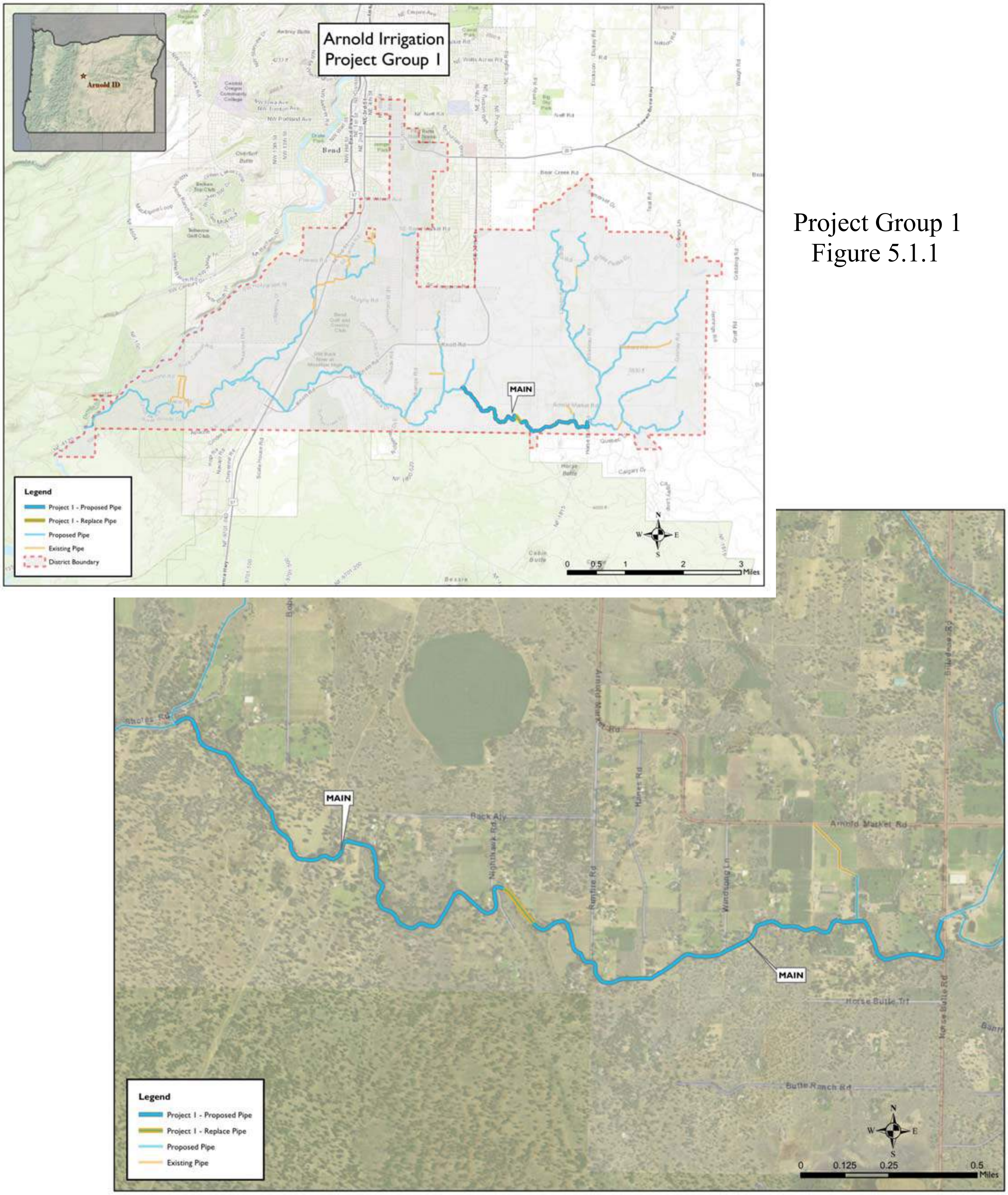
Contingency –

The contingency percentage was carefully considered. The Association for the Advancement of Cost Engineering (AACE) is a nationally recognized organization that has developed an accepted system of contingency ranges based upon project specificity level "Class." There are 5 project Classes starting from Class 5 with only conceptual project definition to Class 1 where a project has been completely developed and bid. This SIP was considered to fall within the

Class 4 definition. The AACE Class 4 project specificity level (i.e. a project at 1% - 15% definition) carries an anticipated contingency range from -15% to -30% on the low end of the range to +20% to +50% on the high end of the range. We selected a contingency value of +30% that is in the middle of the positive contingency range provided by AACE. It should be noted that the phased cost estimate is based largely upon the cost of pipe materials. Budgetary pricing for high density polyethylene pipe was found to be very competitive at the time of development of this SIP. High density polyethylene solid-wall pipe is manufactured from an oil-based pelletized product. The pellet pricing is tied directly to the cost of oil at the time of pipe manufacture ordering. Given that oil prices have been reduced in the past two years and will likely rebound, it should be anticipated that pipe material pricing will increase significantly with time. The timing of such increases will be dependent upon oil pricing, the economic conditions at the time of order, and the demand for pipe at the time of order. For construction that is completed soon after the development of this SIP, the cost estimates should remain robust. For work lagging several years beyond the development of this SIP, the risk of cost change is greater. For this reason, it is recommended that every 2 years a cost evaluation be performed to update the phased construction cost estimates.

Section 5

Arnold Irrigation Improvements by Project Group



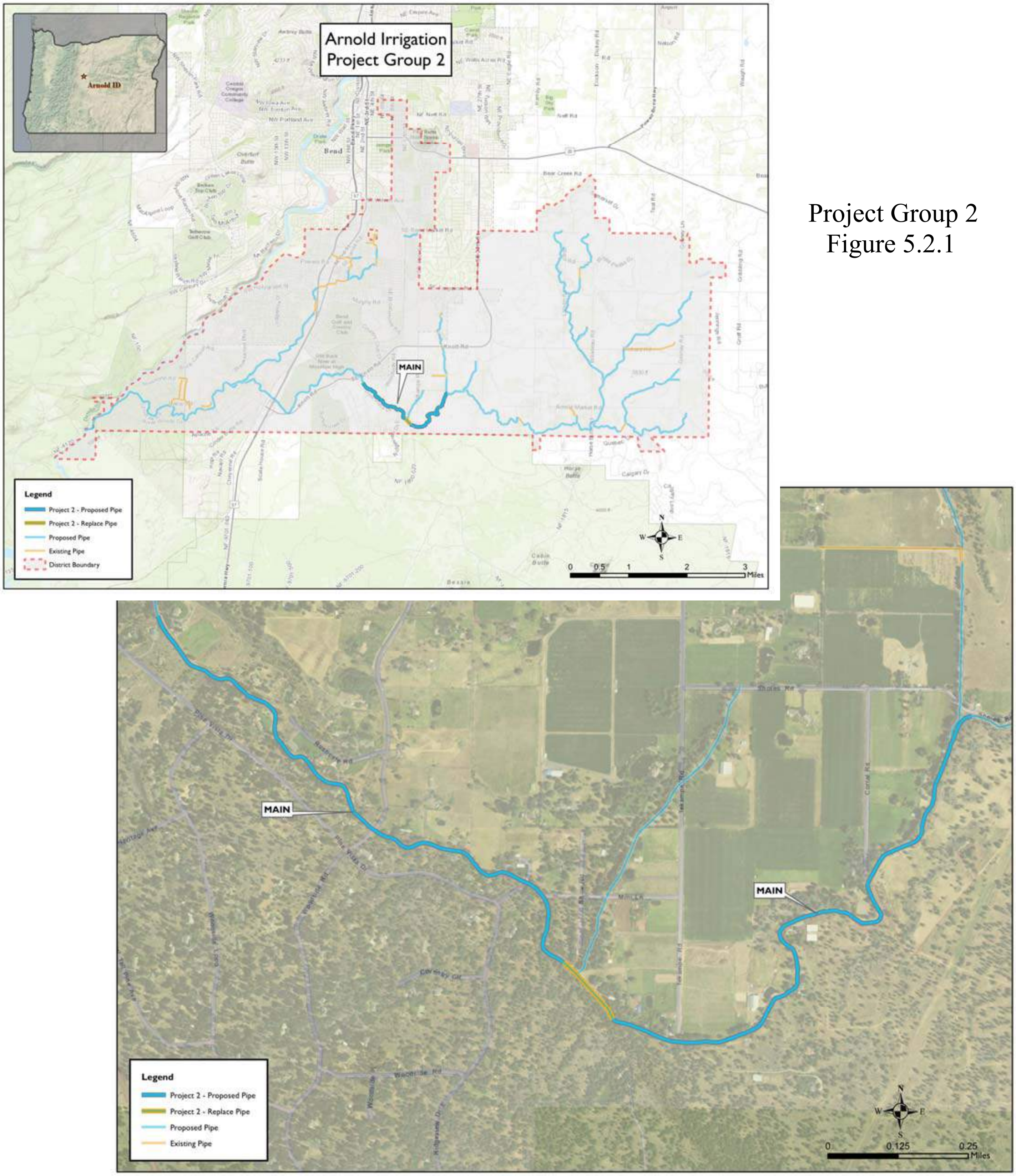
Project Group 1
Figure 5.1.1

Table 5.1.1 Main Canal - Tail End Cost Estimate

Main Canal - Tail End

Arnold Irrigation District
Reconnaissance-Level Construction Cost Estimate 11/10/2016

Feature	DR or PR	Dia. (In)	Length (ft.)	Unit	$/Unit	Total Cost
PIPE	32.5	48	16,976	LF	$212	$3,598,912
TURNOUT			40	EA	$8,000	$320,000
	SUBTOTAL					$3,918,912
	ENGINEERING, CM, SURVEY			6%		$235,135
	CMGC			12%		$470,269
	CONTINGENCY			30%		$1,387,295
	TOTAL					**$6,011,611**



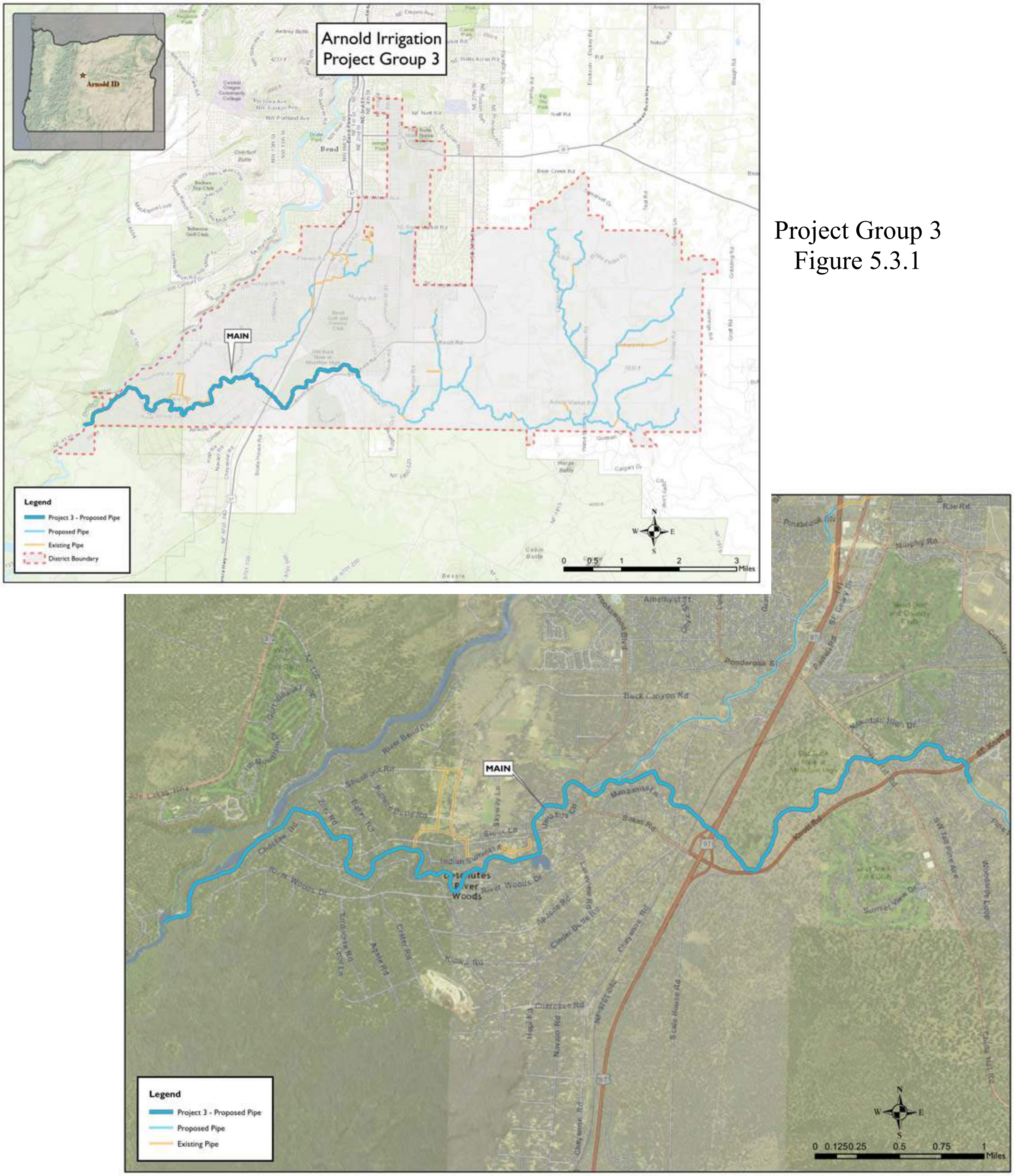
Project Group 2
Figure 5.2.1

Table 5.2.1 Main Canal - Mid Section Cost Estimate

Main Canal - Mid Section

Arnold Irrigation District
Reconnaissance-Level Construction Cost Estimate 11/10/2016

Feature	DR or PR	Dia. (In)	Length (ft.)	Unit	$/Unit	Total Cost
PIPE	32.5	54	13,963	LF	$270	$3,770,010
TURNOUT			28	EA	$8,000	$224,000
	SUBTOTAL					$3,994,010
	ENGINEERING, CM, SURVEY			6%		$239,641
	CMGC			12%		$479,281
	CONTINGENCY			30%		$1,413,880
	TOTAL					**$6,126,811**



Project Group 3
Figure 5.3.1

Table 5.3.1 Main Canal - Upper Section Cost Estimate

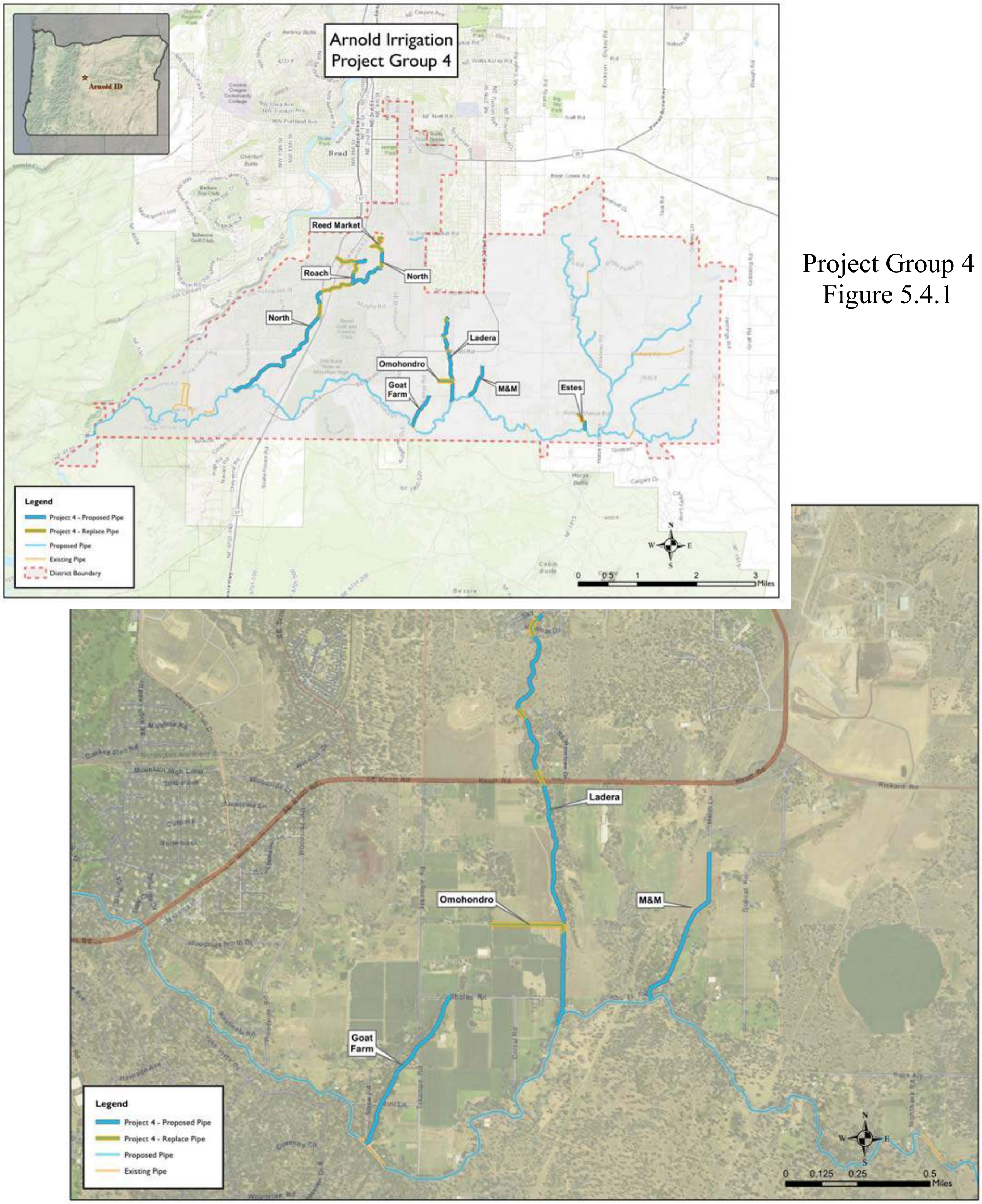
Main Canal - Upper Section
Arnold Irrigation District
Reconnaissance-Level Construction Cost Estimate 11/10/2016

Feature	DR or PR	Dia. (In)	Length (ft.)	Unit	$/Unit	Total Cost
PIPE	32.5	63	33,550	LF	$390	$13,084,509
TURNOUT			18	EA	$8,000	$144,000
	SUBTOTAL					$13,228,509
	ENGINEERING, CM, SURVEY			6%		$793,711
	CMGC			12%		$1,587,421
	CONTINGENCY			30%		$4,682,892
	TOTAL					**$20,292,533**

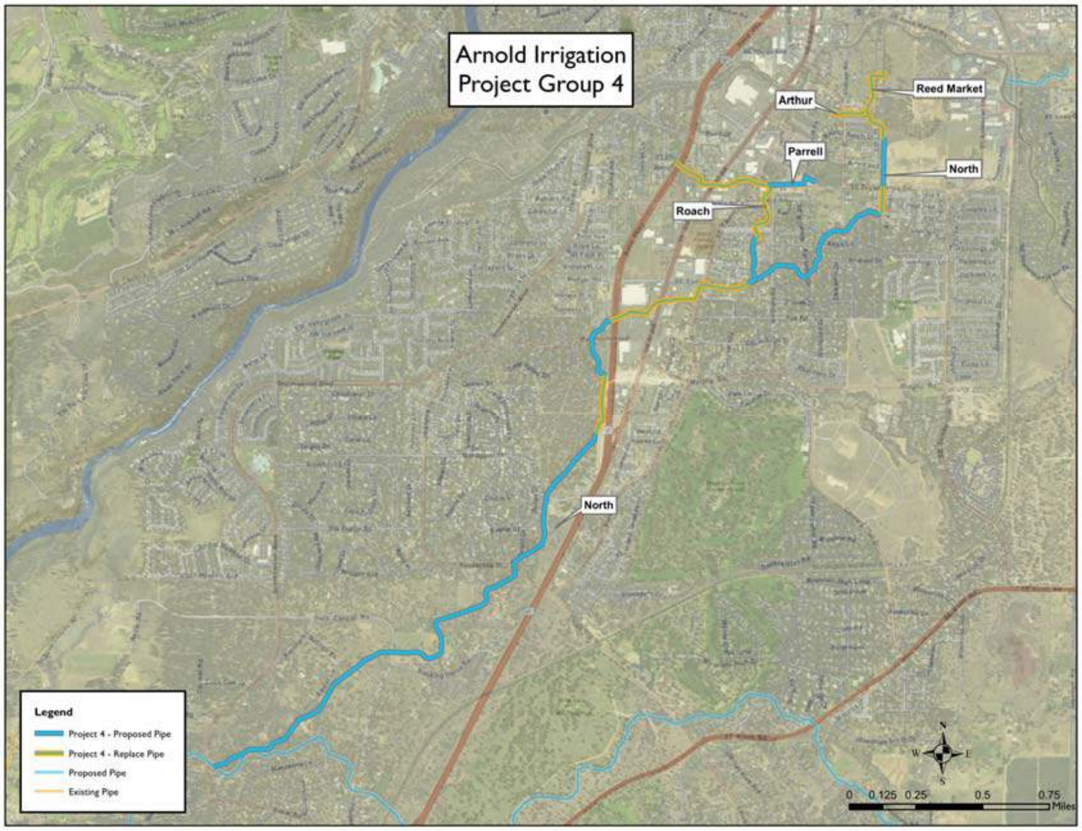
Table 5.3.2 Main Canal - Flume Replacement Cost Estimate

Main Canal - Flume Replacement
Arnold Irrigation District
Reconnaissance-Level Construction Cost Estimate 11/10/2016

Feature	DR or PR	Dia. (In)	Length (ft.)	Unit	$/Unit	Total Cost
PIPE	32.5	63	5,394	LF	$450	$2,427,300
DEMO			5,394	LF	$125	$674,250
TURNOUT			0	EA	$8,000	$0
	SUBTOTAL					$3,101,550
	PERMITS,ENGR., CM, SURVEY			15%		$465,233
	CMGC			12%		$372,186
	CONTINGENCY			30%		$1,181,691
	TOTAL					**$5,120,659**



Project Group 4
Figure 5.4.1



Project Group 4
Figure 5.4.1 cont.

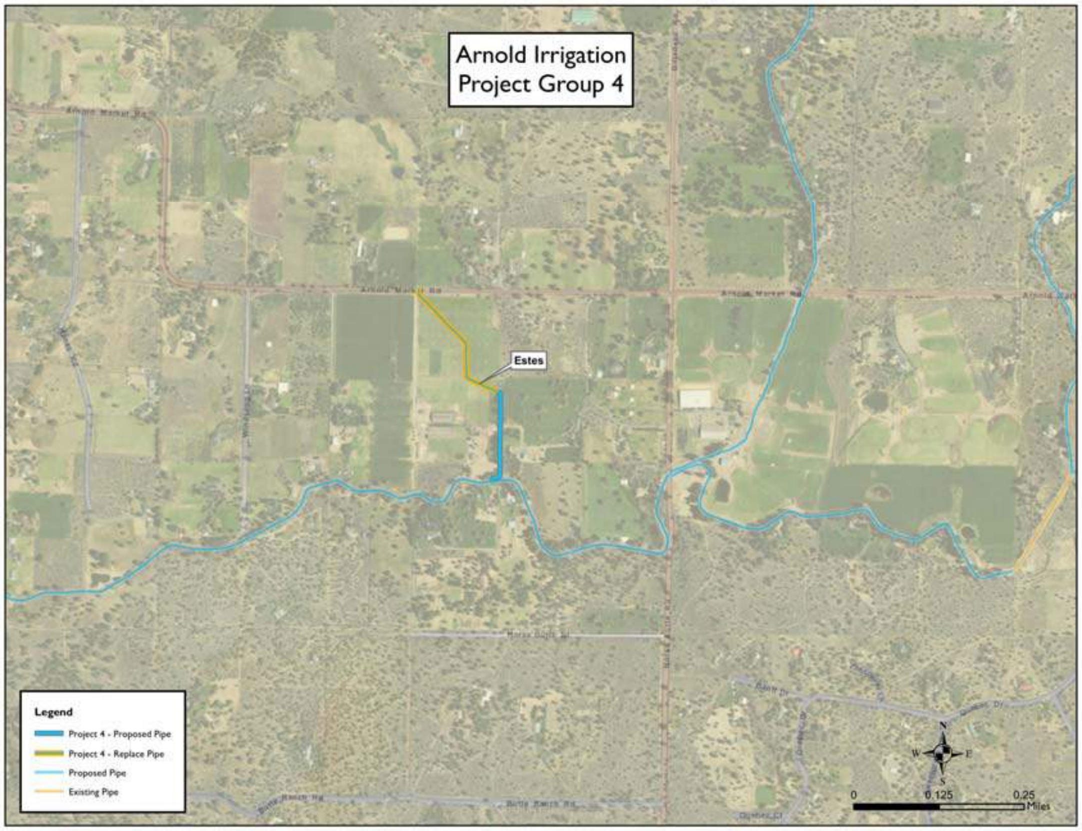


Table 5.4.1 Arthur Lateral Cost Estimate

Arthur Lateral

Arnold Irrigation District
Reconnaissance-Level Construction Cost Estimate 11/10/2016

Feature	DR or PR	Dia. (In)	Length (ft.)	Unit	$/Unit	Total Cost
PIPE	21	4	698	LF	$4	$2,792
TURNOUT			1	EA	$8,000	$8,000
	SUBTOTAL					$10,792
	ENGINEERING, CM, SURVEY			18%		$1,943
	CMGC			18%		$1,943
	CONTINGENCY			30%		$4,403
	TOTAL					**$19,080**

Table 5.4.2 North Lateral (and Parrell, Reed Market, and Roach Laterals) Cost Estimate

North Lateral (and Parrell, Reed Market, and Roach Laterals)

Arnold Irrigation District
Reconnaissance-Level Construction Cost Estimate 11/10/2016

Feature	DR or PR	Dia. (In)	Length (ft.)	Unit	$/Unit	Total Cost
PIPE	32.5	10	9,646	LF	$12	$115,757
PIPE	32.5	8	6,753	LF	$8	$54,021
PIPE	26	8	926	LF	$10	$9,265
PIPE	26	6	1,532	LF	$6	$9,195
PIPE	26	4	9,295	LF	$4	$37,182
PIPE	21	4	2,772	LF	$4	$11,086
TURNOUT			35	EA	$8,000	$280,000
	SUBTOTAL					$516,505
	ENGINEERING, CM, SURVEY			15%		$77,476
	CMGC			15%		$77,476
	CONTINGENCY			30%		$201,437
	TOTAL					**$872,894**

Table 5.4.3 Goat Farm Lateral Cost Estimate

Goat Farm Lateral

Arnold Irrigation District
Reconnaissance-Level Construction Cost Estimate 11/10/2016

Feature	DR or PR	Dia. (In)	Length (ft.)	Unit	$/Unit	Total Cost
PIPE	32.5	10	1,525	LF	$12	$18,300
PIPE	32.5	6	1,681	LF	$6	$10,086
TURNOUT			5	EA	$8,000	$40,000
	SUBTOTAL					$68,386
	ENGINEERING, CM, SURVEY			18%		$12,309
	CMGC			18%		$12,309
	CONTINGENCY			30%		$27,901
	TOTAL					**$120,906**

Table 5.4.4 Ladera Lateral (and Omohondro Lateral) Cost Estimate

Ladera Lateral (and Omohondro Lateral)

Arnold Irrigation District
Reconnaissance-Level Construction Cost Estimate 11/10/2016

Feature	DR or PR	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
PIPE	32.5	10	1,741	LF	$12	$20,891
PIPE	32.5	8	1,434	LF	$8	$11,469
PIPE	26	8	2,084	LF	$10	$20,841
PIPE	32.5	6	118	LF	$4	$472
PIPE	26	6	3,700	LF	$6	$22,198
PIPE	26	4	499	LF	$4	$1,994
PPE	32.5	4	33	LF	$3	$99
TURNOUT			16	EA	$8,000	$128,000
	SUBTOTAL					$205,964
	ENGINEERING, CM, SURVEY			18%		$37,074
	CMGC			18%		$37,074
	CONTINGENCY			30%		$84,033
	TOTAL					**$364,145**

Table 5.4.5 M&M Lateral Cost Estimate

M&M Lateral

Arnold Irrigation District
Reconnaissance-Level Construction Cost Estimate 11/10/2016

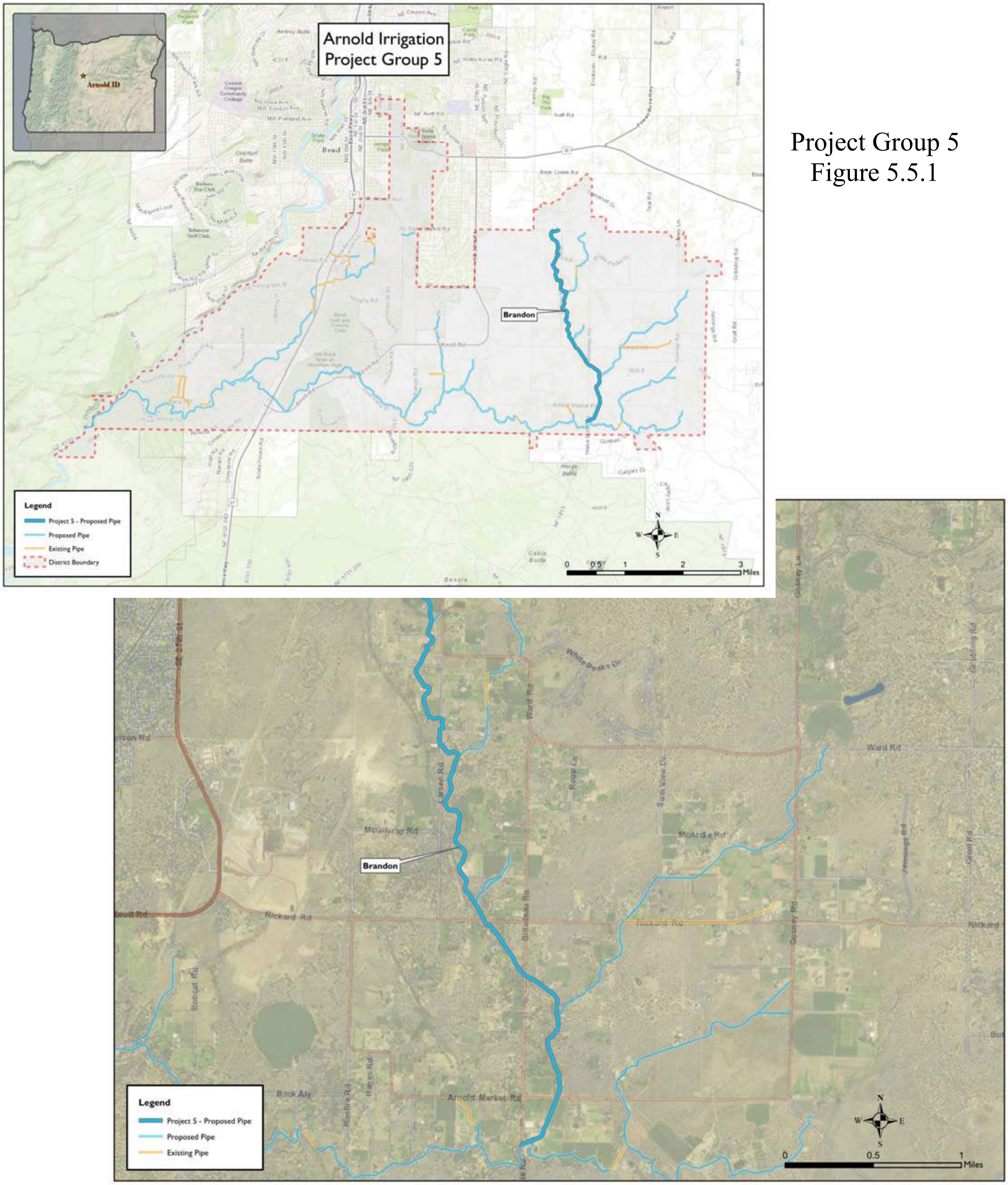
Feature	DR or PR	Dia. (In)	Length (ft.)	Unit	$/Unit	Total Cost
PIPE	32.5	8	936	LF	$8	$7,492
PIPE	32.5	6	2,196	LF	$4	$8,783
TURNOUT			5	EA	$8,000	$40,000
	SUBTOTAL					$56,275
	ENGINEERING, CM, SURVEY			18%		$10,130
	CMGC			18%		$10,130
	CONTINGENCY			30%		$22,960
	TOTAL					**$99,494**

Table 5.4.6 Estes Lateral Cost Estimate

Estes Lateral

Arnold Irrigation District
Reconnaissance-Level Construction Cost Estimate 11/10/2016

Feature	DR or PR	Dia. (In)	Length (ft.)	Unit	$/Unit	Total Cost
PIPE	32.5	8	1,846	LF	$8	$14,768
TURNOUT			5	EA	$8,000	$40,000
	SUBTOTAL					$54,768
	ENGINEERING, CM, SURVEY			18%		$9,858
	CMGC			18%		$9,858
	CONTINGENCY			30%		$22,345
	TOTAL					**$96,830**

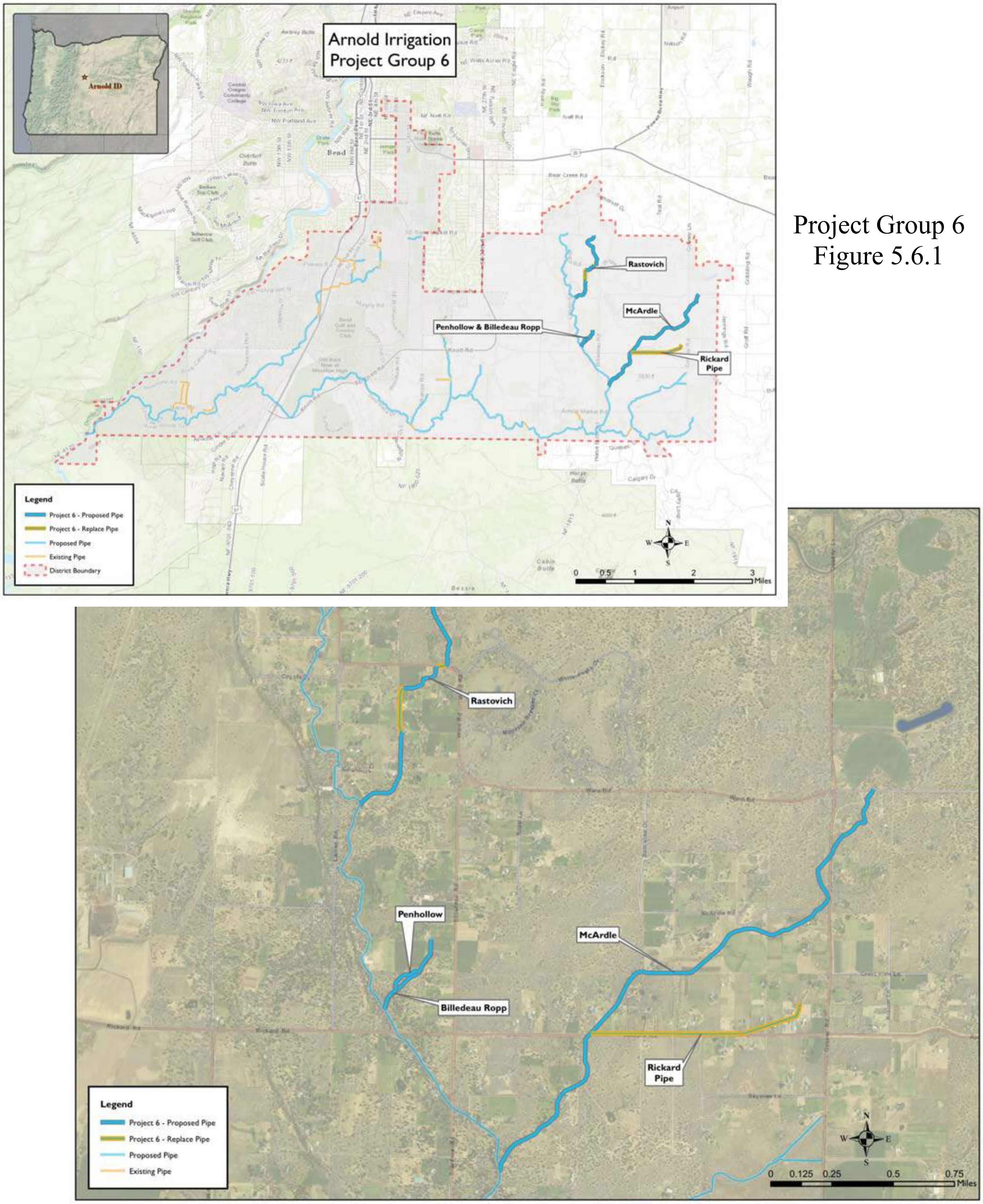


Project Group 5
Figure 5.5.1

Table 5.5.1 Brandon Lateral (and East Ward Lateral) Cost Estimate

Brandon Lateral (and East Ward Lateral)
Arnold Irrigation District
Reconnaissance-Level Construction Cost Estimate 11/10/2016

Feature	DR or PR	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
PIPE	32.5	36	4,483	LF	$126	$564,907
PIPE	32.5	30	1,266	LF	$84	$106,362
PIPE	32.5	28	1,102	LF	$76	$83,731
PIPE	26	28	1,528	LF	$90	$137,486
PIPE	26	26	604	LF	$80	$48,292
PIPE	26	24	5,159	LF	$66	$340,466
PIPE	26	16	3,178	LF	$32	$101,709
PIPE	26	14	224	LF	$26	$5,814
PIPE	21	14	1,826	LF	$28	$51,118
PIPE	21	12	2,734	LF	$24	$65,614
PIPE	21	6	531	LF	$10	$5,310
TURNOUT			80	EA	$8,000	$640,000
	SUBTOTAL					$2,150,808
	ENGINEERING, CM, SURVEY			8%		$172,065
	CMGC			12%		$258,097
	CONTINGENCY			30%		$774,291
	TOTAL					**$3,355,261**



Project Group 6
Figure 5.6.1

Table 5.6.1 Rastovich Lateral Cost Estimate

Rastovich Lateral
Arnold Irrigation District
Reconnaissance-Level Construction Cost Estimate 11/10/2016

Feature	DR or PR	Dia. (In)	Length (ft.)	Unit	$/Unit	Total Cost
PIPE	26	12	882	LF	$20	$17,640
PIPE	21	12	2,678	LF	$24	$64,276
PIPE	21	10	1,826	LF	$20	$36,518
PIPE	21	8	289	LF	$18	$5,206
PIPE	21	6	1,962	LF	$10	$19,619
TURNOUT			22	EA	$8,000	$176,000
	SUBTOTAL					$319,259
	ENGINEERING, CM, SURVEY			18%		$57,467
	CMGC			18%		$57,467
	CONTINGENCY			30%		$130,258
	TOTAL					**$564,450**

Table 5.6.2 Penhollow and Billedeau Ropp Lateral Cost Estimate

Penhollow and Billedeau Ropp Lateral
Arnold Irrigation District
Reconnaissance-Level Construction Cost Estimate 11/10/2016

Feature	DR or PR	Dia. (In)	Length (ft.)	Unit	$/Unit	Total Cost
PIPE	26	8	3,930	LF	$8	$31,443
TURNOUT			1	EA	$8,000	$8,000
	SUBTOTAL					$39,443
	ENGINEERING, CM, SURVEY			18%		$7,100
	CMGC			18%		$7,100
	CONTINGENCY			30%		$16,093
	TOTAL					**$69,736**

Table 5.6.3 McCardle Lateral Cost Estimate

McCardle Lateral

Arnold Irrigation District

Reconnaissance-Level Construction Cost Estimate 11/10/2016

Feature	DR or PR	Dia. (In)	Length (ft.)	Unit	$/Unit	Total Cost
PIPE	32.5	20	2,754	LF	$40	$110,158
PIPE	26	20	1,553	LF	$50	$77,627
PIPE	26	18	1,791	LF	$48	$85,955
PIPE	21	18	2,374	LF	$58	$137,667
PIPE	21	16	4,471	LF	$46	$205,660
PIPE	19	14	798	LF	$32	$25,538
TURNOUT			35	EA	$8,000	$280,000
	SUBTOTAL					$922,605
	ENGINEERING, CM, SURVEY			15%		$138,391
	CMGC			15%		$138,391
	CONTINGENCY			30%		$359,816
	TOTAL					**$1,559,202**

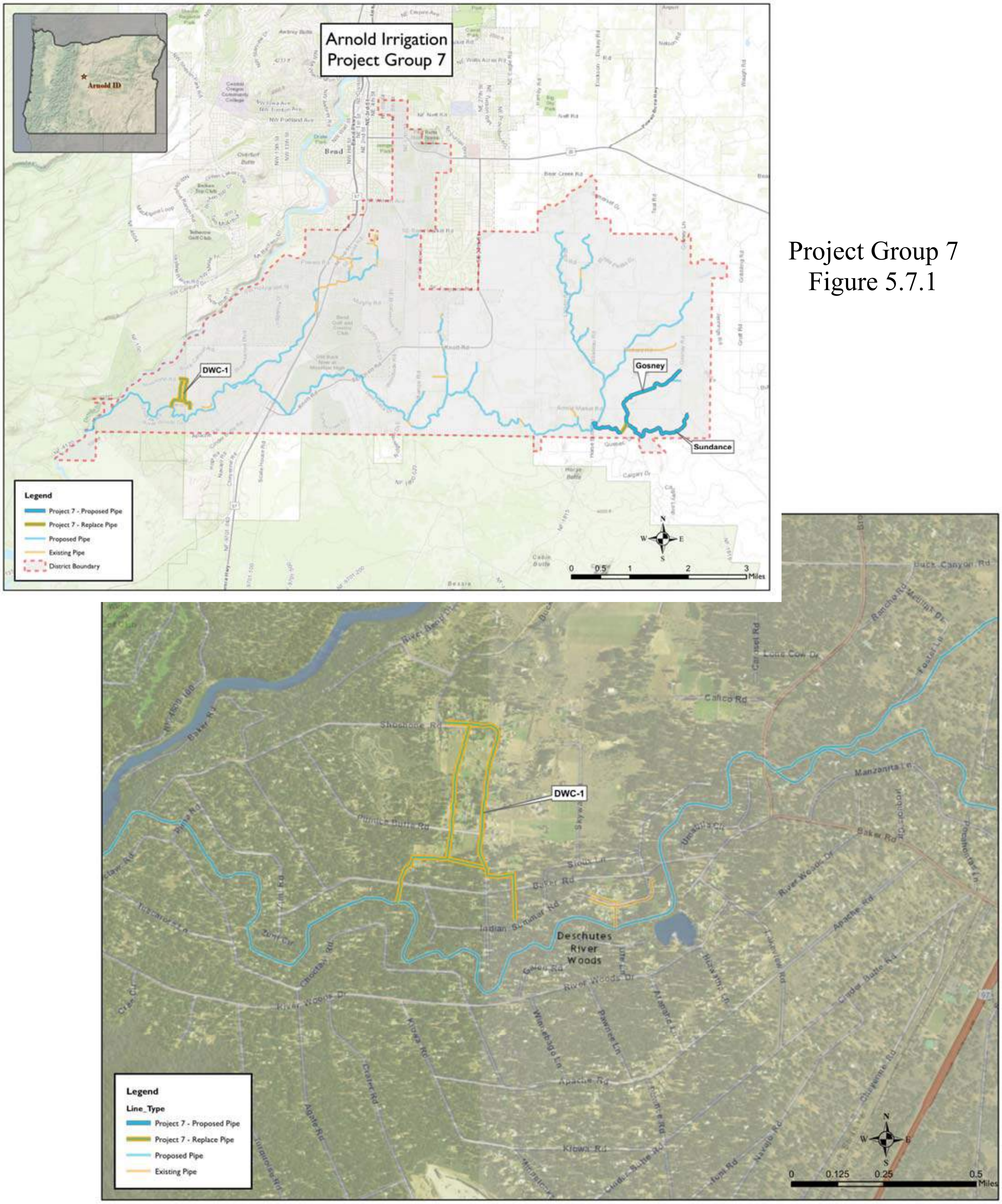
Table 5.6.4 Rickard Lateral Cost Estimate

Rickard Lateral

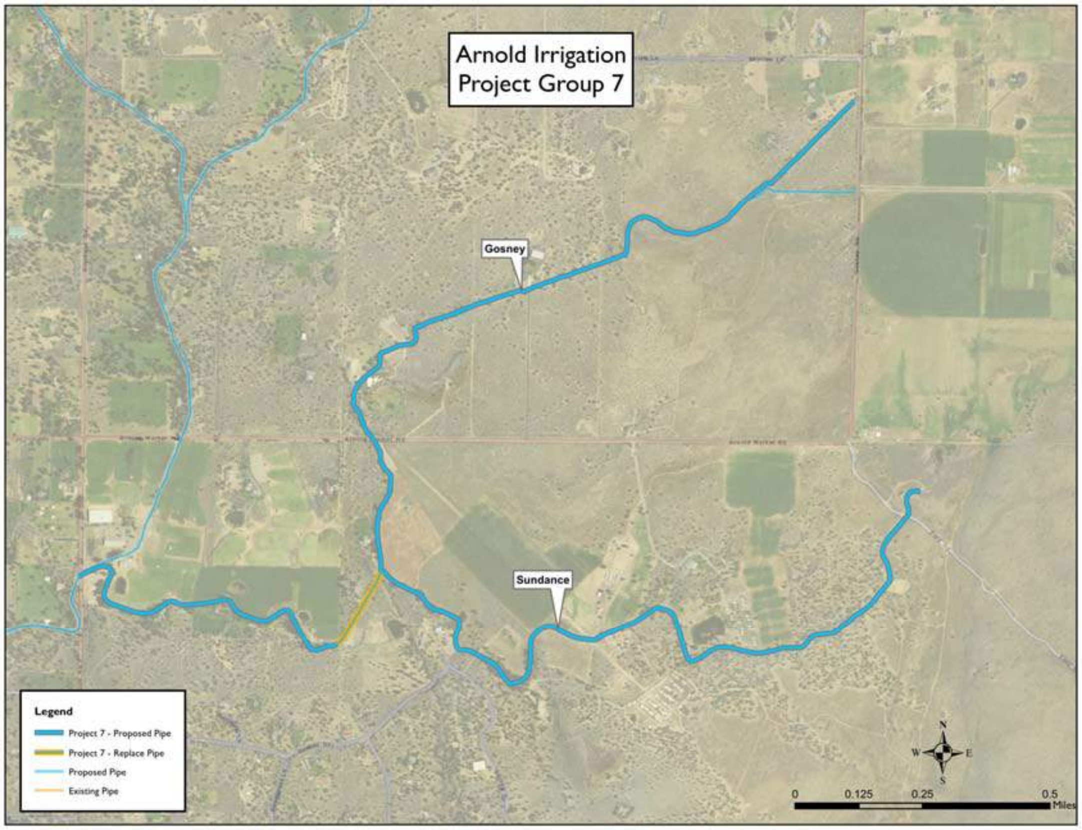
Arnold Irrigation District

Reconnaissance-Level Construction Cost Estimate 11/10/2016

Feature	DR or PR	Dia. (In)	Length (ft.)	Unit	$/Unit	Total Cost
PIPE	26	6	3,083	LF	$6	$18,498
PIPE	21	6	1,215	LF	$10	$12,150
PIPE	21	4	1,488	LF	$4	$5,952
TURNOUT			12	EA	$8,000	$96,000
	SUBTOTAL					$132,600
	ENGINEERING, CM, SURVEY			18%		$23,868
	CMGC			18%		$23,868
	CONTINGENCY			30%		$54,101
	TOTAL					**$234,437**



Project Group 7
Figure 5.7.1



Project Group 7
Figure 5.7.1 cont.

Table 5.7.1 Sundance Lateral Cost Estimate

Sundance Lateral
Arnold Irrigation District
Reconnaissance-Level Construction Cost Estimate 11/10/2016

Feature	DR or PR	Dia. (In)	Length (ft.)	Unit	$/Unit	Total Cost
PIPE	32.5	24	4,428	LF	$54	$239,123
PIPE	32.5	16	4,535	LF	$32	$145,122
PIPE	32.5	12	3,760	LF	$16	$60,153
TURNOUT			10	EA	$8,000	$80,000
	SUBTOTAL					$524,398
	ENGINEERING, CM, SURVEY			15%		$78,660
	CMGC			15%		$78,660
	CONTINGENCY			30%		$204,515
	TOTAL					**$886,233**

Table 5.7.2 Gosney Lateral (and Leslie North Lateral) Cost Estimate

Gosney Lateral (and Leslie North Lateral)
Arnold Irrigation District
Reconnaissance-Level Construction Cost Estimate 11/10/2016

Feature	DR or PR	Dia. (In)	Length (ft.)	Unit	$/Unit	Total Cost
PIPE	32.5	16	7,116	LF	$32	$227,704
PIPE	26	16	1,463	LF	$32	$46,820
PIPE	26	12	34	LF	$20	$680
PIPE	26	10	26	LF	$16	$412
PIPE	26	6	1,187	LF	$6	$7,119
TURNOUT			12	EA	$8,000	$96,000
	SUBTOTAL					$378,735
	ENGINEERING, CM, SURVEY			15%		$56,810
	CMGC			15%		$56,810
	CONTINGENCY			30%		$147,707
	TOTAL					**$640,063**

Table 5.7.3 DWC-1 Lateral Cost Estimate

DWC-1 Arnold Irrigation District Reconnaissance-Level Construction Cost Estimate						11/10/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft.)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	32.5	6	7,772	LF	$8	$62,176
TURNOUT			40	EA	$4,000	$160,000
	SUBTOTAL					$222,176
	ENGINEERING, CM, SURVEY			18%		$39,992
	CMGC			18%		$39,992
	CONTINGENCY			30%		$90,648
	TOTAL					**$392,807**

APPENDIX A
TABULATED SEEPAGE LOSS DATA

ARNOLD IRRIGATION DISTRICT - DISCHARGE FLOW MEASUREMENTS 2016

11/17/2016
Final

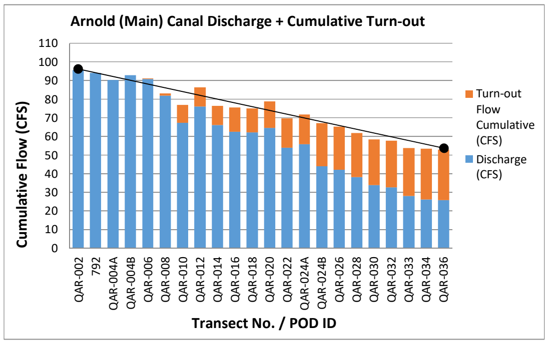
🟩	= Clock House
🟨	= Start of Canals / Laterals
🟥	= In-Canal Weirs
🟪	= Included as turn out flow in-reach, not included as turn-out flow over-all system

Transect No. POD #ID	**Discharge (CFS)**	**Turn-out Flow Rate (CFS)**	**Turn-out Flow Cumulative (CFS)**	**Comments**
Arnold (Main) Canal				
QAR-002	95.57		0.00	Measurement rated as 'Good', 6-23-16
792	94.00		0.00	OWRD/BOR Clock House
QAR-004A	90.32		0.00	50' upstream POD 4834, 6-22-16, rated 'Good'
QAR-004B	92.86		0.00	15' upstream POD 4834, 6-23-16 rated 'Good'
4834		-0.29		Start of DWC1 Lat.
8873		0.00		2 inch rectangular weir, 0.5 inch depth
9930		-0.08		Start of DWC2 Lat.
10435		-0.02		12 inch rectangular weir, 0.625 inch depth
QAR-006	90.71		0.39	Measurement rated as 'Good', 6-22-16
11820		-0.08		12 inch rectangular weir, 1.625 inch depth
11822		0.00		Off
11829		-0.05		6 inch rectangular weir, 1.25 inch depth
13292		-0.57		Start Lundy Lat. (Private), 24" weir, 2.375 in depth
13594		0.00		Flooded Back
14002		-0.06		6 inch rectangular weir, 1.375 inch depth
QAR-008	81.88		1.16	Measurement rated as 'Good', 6-22-16
14306		0.00		Start of North Lat.
QAR-010		-8.41		North Lat flow diversion measured 6-22-16
QAR-012	67.26		9.58	Measurement rated as 'Poor', 6-22-16
18262		-0.06		12 inch rectangular weir, 0.875 inch depth
22366		-0.57		24 inch rectangular weir, 2.375 inch depth
QAR-014	76.13		10.21	Measurement rated as 'Fair', 6-22-16
QAR-016	66.07		10.21	Measurement rated as 'Good', 6-22-16
28040		0.00		Off
28042		-2.16		30 inch rectangular weir, 5.0 inch depth
29015		-0.49		36 inch rectangular weir, 1.625 inch depth
QAR-018	62.57		12.87	Measurement rated as 'Good', 6-22-16
31248		-0.06		6 inch rectangular weir, 1.375 inch depth
QAR-020	62.16		12.93	Measurement rated 'Fair', 6-22-16
33258		-0.03		6 inch rectangular weir, 0.875 inch depth
33734		-0.22		12 inch rectangular weir, 2.0 inch depth
34464		-0.03		6 inch rectangular weir, 0.875 inch depth
34710		-0.18		18 inch rectangular weir, 1.75 inch depth
35106		-0.03		6 inch rectangular weir, 0.875 inch depth
35108		0.00		Flooded Back
35112		-0.60		(2) proportional weirs 12" & 20 1/8"
35478		-0.08		6 inch rectangular weir, 1.625 inch depth
35932		-0.03		6 inch rectangular weir, 0.75 inch depth
QAR-022	64.60		14.14	Measurement rated as 'Poor', 6-22-16
36152		-0.01		6 inch rectangular weir, 0.5 inch depth
36798		-1.16		Start of Goat Farm Lat., 48 in weir, 2.375 in depth
37402		-0.01		6 inch rectangular weir, 0.375 inch depth
37608		-0.14		12 inch rectangular weir, 1.5 inch depth
37610		-0.03		6 inch rectangular weir, 0.875 inch depth
37704		-0.03		6 inch rectangular weir, 0.75 inch depth
37993		0.00		Flooded back
38880		-0.30		18 inch rectangular weir, 1.875 inch depth
QAR-024A	53.89		15.82	15' upstream POD 39788, 6-22-16, rated 'Good
QAR-024B	55.86		15.82	Upstream POD 39788, 6-23-16, rated 'Good'
39788		-0.33		18 inch weir, 2 inch depth, end day 6-22-16
41062		-0.16		24 inch weir, 1 inch depth, start day 6-23-16
41550		-0.06		6 inch rectangular weir, 1.375 inch depth
41994		-0.03		6 inch rectangular weir, 0.875 inch depth
42416		-0.14		12 inch rectangular weir, 1.5 inch depth
42654		0.00		Flooded back
42658		-2.71		Start Ladera Lat., 36 inch weir, 5.125 inch depth
43001		-0.49		24 inch rectangular weir, 2.125 inch depth
44097		-0.38		36 inch rectangular weir, 1.375 inch depth
44190		-1.78		24 inch rectangular weir, 5.125 inch depth
44578		-1.07		Start M&M Lat., 24 inch weir, 3.625 inch depth
QAR-026	44.03		22.98	Measurement rated as 'Good', 6-23-16
44754		0.00		
47503		-0.22		18 inch rectangular weir, 1.5 inch depth
QAR-028	42.13		23.20	Measurement rated as 'Fair', 6-23-16
48296		-0.13		12 inch rectangular weir, 1.375 inch depth
49056		-0.03		6 inch rectangular weir, 0.75 inch depth
49604		0.00		Flooded back
50351		0.00		Flooded back
50422		-0.04		6 inch rectangular weir, 1.0 inch depth
50430		-0.08		6 inch rectangular weir, 1.625 inch depth
50600		0.00		
51278		-0.02		6 inch rectangular weir, 0.625 inch depth
51605		0.00		Flooded back
51766		-0.11		12 inch rectangular weir, 1.25 inch depth
53098		-0.14		12 inch rectangular weir, 1.5 inch depth

Arnold (Main) Canal

Over-all Arnold Discharge Measurements

Over-all System Intake to the Study Reach	=	141.85		
Over-all System Turnout + Flow Remaining	=	-86.3		
Over-all System Losses in the Study Reach	=	55.52	=	39.14%

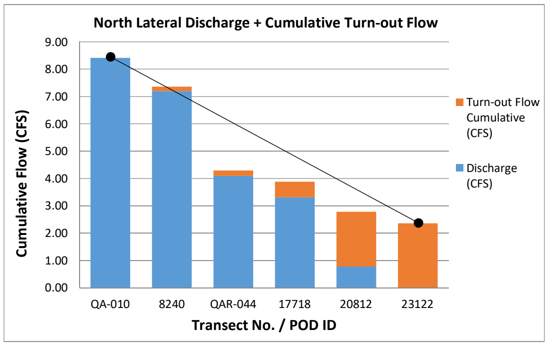


Total Arnold (Main) Canal Intake to the Study Reach	=	95.57		
Total Arnold (Main) Canal Turnout + Flow Remaining	=	-52.99		
Total Arnold (Main) Canal Losses in the Study Reach	=	42.58	=	44.55%

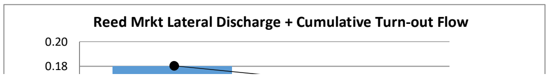
ARNOLD IRRIGATION DISTRICT - DISCHARGE FLOW MEASUREMENTS 2016

Transect No. POD #ID	**Discharge (CFS)**	**Turn-out Flow Rate (CFS)**	**Turn-out Flow Cumulative (CFS)**	**Comments**
QAR-030	38.10		23.74	Measurement rated as 'Good', 6-23-16
53356		-0.24		36 inch rectangular weir, 1.0 inch depth
53580		-0.04		6 inch rectangular weir, 1.0 inch depth
53592		0.00		Flooded back
54271		0.00		Flooded back
54418		-0.37		24 inch rectangular weir, 1.75 inch depth
54420		-0.03		12 inch rectangular weir, 0.5 inch depth
54430		-0.04		6 inch rectangular weir, 1.0 inch depth
54951		0.00		Flooded back
55302		0.00		Flooded back
55345		-0.03		6 inch rectangular weir, 0.875 inch depth
QAR-032	33.93		24.48	Measurement rated as 'Good', 6-23-16
55954		-0.02		6 inch rectangular weir, 0.625 inch depth
56580		0.00		
56584		-0.03		6 inch rectangular weir, 0.875 inch depth
56586		-0.11		12 inch rectangular weir, 1.25 inch depth
56589		-0.27		12 inch rectangular weir, 1.75 inch depth
56608		-0.05		6 inch rectangular weir, 1.125 inch depth
QAR-033	32.71		24.96	Measurement rated as 'Good', 6-23-16
56612		-0.09		12 inch rectangular weir, 1.125 inch depth
57320		-0.08		12 inch rectangular weir, 1.0 inch depth
57626		-0.29		12 inch rectangular weir, 1.5 inch depth
57679		0.00		Flooded back
57877		0.00		Off
58128		-0.28		12 inch rectangular weir, 2.375 inch depth
58281		0.00		
QAR-034	28.00		25.71	Measurement rated as 'Good', 6-23-16
58630		-0.33		12 inch rectangular weir, 2.625 inch depth
58703		0.00		
58834		-0.97		Start Estes Lat. (90% Piped), 24" weir, 3.375" depth
58836		-0.08		6 inch rectangular weir, 1.625 inch depth
QAR-036	26.27		27.08	Measurement rated as 'Good', 6-23-16
59894		-0.03		6 inch rectangular weir, 0.75 inch depth
60334		-0.11		End Arnold Canal, 12 inch weir 1.25 inch depth
QAR-038	25.77		27.22	End Arnold / start Sundance + Brandon, 'Fair'
Main Canal flow remaining	25.77		27.22	
North Lateral				
QA-010	8.41		0.00	Measurement rated 'Good', 6-22-16
824		-0.05		6 inch rectangular weir, 1.25 inch depth
1332		0.00		Flooded back
1894		0.00		Flooded back
4984		-0.05		6 inch rectangular weir, 1.25 inch depth
4986		0.00		Flooded Back
5457		0.00		Flooded Back
5459		-0.01		4 inch rectangular weir, 1.25 inch depth
5789		-0.03		6 inch rectangular weir, 0.75 inch depth
5828		-0.01		6 inch rectangular weir, 0.5 inch depth
8240	7.19		0.16	Rocking Horse Weir North Lat., 60" weir, 7" depth
9589		0.00		Off
10443		-0.03		6 inch rectangular weir, 0.875 inch depth
QAR-044	4.10		0.19	Measurement rated 'Fair', 6-22-16
16831		-0.02		6 inch rectangular weir, 0.625 inch depth
17485		0.00		6 inch rectangular weir, 0.25 inch depth
17709		-0.02		6 inch rectangular weir, 0.625 inch depth
17713		0.00		Flooded back
17715		-0.02		6 inch rectangular weir, 0.625 inch depth
17716		-0.33		Start Roach Lat., 24" weir, 1.625" depth
17718	3.30		0.58	North Lat Weir, 60" weir, 4.125" depth
19277		-1.41		24 inch rectangular weir, 4.375 inch depth
20300		0.00		
20812	0.78		2.00	North Lat. Weir, 30" weir, 2.5" depth
20912		0.00		Flooded Back
20938		-0.12		6 inch rectangular weir, 2.25 inch depth
21110		0.00		2 inch rectangular weir, 0.375 inch depth
21649		-0.02		6 inch rectangular weir, 0.625 inch depth
22322		-0.03		6 inch rectangular weir, 0.875 inch depth
22410		0.00		Flooded Back
23120		-0.18		Start Reed Mrkt Lat., piped, 12" weir, 1.75" depth
23122	0.00		2.35	North Lat. Weir / End of North Lat.
North Lat flow remaining	0.00		2.35	
Reed Market Lateral				
190	0.18		0.00	12 inch rectangular weir, 1.75 inch depth
670		-0.04		Start Arthur Lat., piped, 6" weir, 1" depth
1567	0.00		-0.13 →	

North Lateral

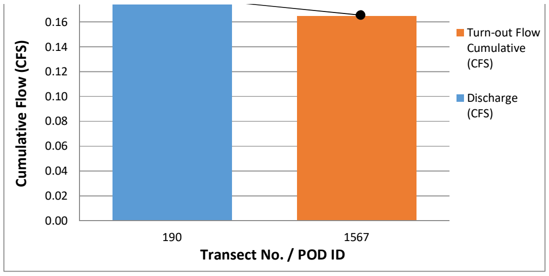


Total North Lateral Intake to the Study Reach = 8.41
Total North Lateral Turnout + Flow Remaining = -2.35
Total North Lateral Losses in the Study Reach = 6.06 = 72.01%



ARNOLD IRRIGATION DISTRICT - DISCHARGE FLOW MEASUREMENTS 2016

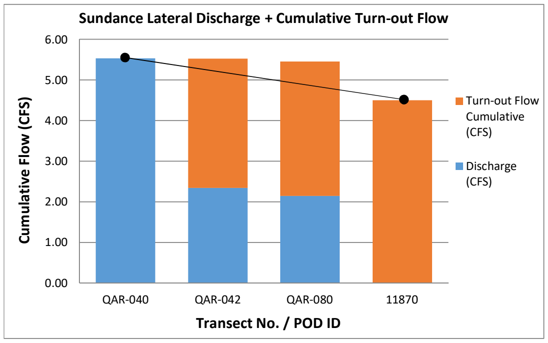
Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments	
Reed Mrkt Lat flow remaining	0.00		0.16		Reed Market Lateral
Arthur Lateral					Arthur Lateral
0	0.04		0.00	Piped, 6 inch rectangular weir, 1.0 inch depth	
729	0.00	-0.04	0.04	End Arthur Lat., 6" weir, 1" depth	
Arthur Lat flow remaining	0.00		0.04		
Goat Farm Lateral					Goat Farm Lateral
150	1.16		0.00	Start Goat Farm Lat., 48" weir, 2.375" depth	
1492		-0.37		24 inch rectangular weir, 1.75 inch depth	
1493		-0.53		Goat Farm Lat. 3-Way Ditch Weir, 24" weir, 2.25" dep	
1495		0.00		Off	
2150		-0.24		12 inch rectangular weir, 2.125 inch depth	
3177		-0.12		18 inch rectangular weir, 1.0 inch depth	
3178	0.00	-0.21	1.46	End Goat Farm Lat., 17" weir, 1.5" depth	
Goat Farm Lat flow remaining	0.00				
Sundance Lateral					Sundance Lateral
QAR-040	5.53		0.00	Measurement rated as 'Poor'	
612		-0.49		24 inch rectangular weir, 2.125 inch depth	
2060		-0.29		24 inch rectangular weir, 1.5 inch depth	
2158		0.00		Off	
3058		0.00		Off	
3441		-0.09		12 inch rectangular weir, 1.125 inch depth	
3527		-0.12		18 inch rectangular weir, 1.0 inch depth	
QAR-076		-2.19		Start Gosney Lat, measure rated 'Good', 6-27-16	
QAR-042	2.35		3.18	Measurement rated as 'Fair'	
6028		0.00			
7336		-0.13		12 inch rectangular weir, 1.375 inch depth	
QAR-080	2.15		3.30	Measurement rated as 'Excellent'	
8995		-0.67		30 inch rectangular weir, 2.25 inch depth	
10206		0.00			
11870	0.00	-0.53	4.50	End Sundance Lat., 24" weir, 2.25" depth	
Sundance Lat flow remaining	0.00		4.50		
Gosney Lateral					
QAR-076	2.19		0.00	Measurement rated as 'Good'	
1681		-0.05		6 inch rectangular weir, 1.25 inch depth	
2122		-0.02		6 inch rectangular weir, 0.625 inch depth	
2125		-0.05		6 inch rectangular weir, 1.25 inch depth	
QAR-078	1.67		0.13	Measurement rated as 'Poor'	



Total Reed Mrkt Lateral Intake to the Study Reach = 0.18
Total Reed Mrkt Lateral Turnout + Flow Remaining = -0.16
Total Reed Mrkt Lateral Losses in the Study Reach = 0.02 = 8.42%

Total Arthur Lateral Intake to the Study Reach = 0.04
Total Arthur Lateral Turnout + Flow Remaining = -0.04
Total Arthur Lateral Losses in the Study Reach = 0.00 = 0.00%

Total Goat Farm Lateral Intake to the Study Reach = 1.16
Total Goat Farm Lateral Turnout + Flow Remaining = -1.46
Total Goat Farm Lateral Losses in the Study Reach = -0.30 = -25.96%



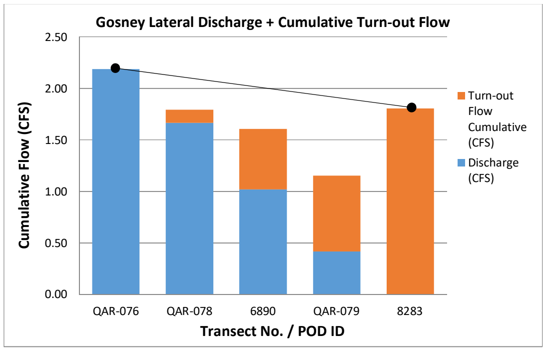
Total Sundance Lateral Intake to the Study Reach = 5.53
Total Sundance Lat Irr. Turnout + Flow Remaining = -4.50
Total Sundance Lateral Losses in the Study Reach = 1.03 = 18.63%

ARNOLD IRRIGATION DISTRICT - DISCHARGE FLOW MEASUREMENTS 2016

11/17/2016
Final

Gosney Lateral

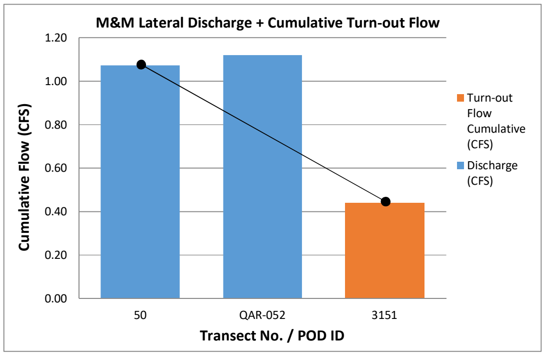
Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
3000		0.00		Off
6791		0.00		Start of Leslie North Lat.
6822		(-0.78)		Top Leslie North Weir (flow at head Leslie North lat, not included as turn-out flow)
NO #		-0.46		End of Leslie North Lat. (flow at turn-out, included as turn-out flow)
6890	1.02		0.59	Gosney Weir, 30 inch weir, 3.0 inch depth
8036		0.00		Flooded Back
8256		-0.03		6 inch rectangular weir, 0.875 inch depth
8258		-0.03		6 inch rectangular weir, 0.75 inch depth
8260		-0.10		6 inch rectangular weir, 1.875 inch depth
QAR-079	0.42		0.74	Measurement rated as 'Poor'
8266		-0.15		Proportional weirs, 7.875" weir, 2" depth
8268		0.00		Proportional weirs, Off
8270		-0.26		Proportional weirs, 13.75" weir, 2" depth
8272		-0.09		Proportional weirs, 4.375" weir, 2" depth
8274		0.00		Proportional weirs, Off
8276		-0.24		Proportional weirs, 12.5" weir, 2" depth
8279		-0.09		Proportional weirs, 4.375" weir, 2" depth
8281		-0.18		Proportional weirs, 9.375" weir, 2" depth
8283	0.00	-0.05	1.80	Prop. weirs / End Gosney Lat., 2.375" weir, 2" depth
Gosney Lat flow remaining	0.00		1.80	


Gosney Lateral Discharge + Cumulative Turn-out Flow

Total Gosney Lateral Intake to the Study Reach	=	2.19		
Total Gosney Lateral Turnout + Flow Remaining	=	-1.80		
Total Gosney Lateral Losses in the Study Reach	=	0.38	=	17.50%

M&M Lateral

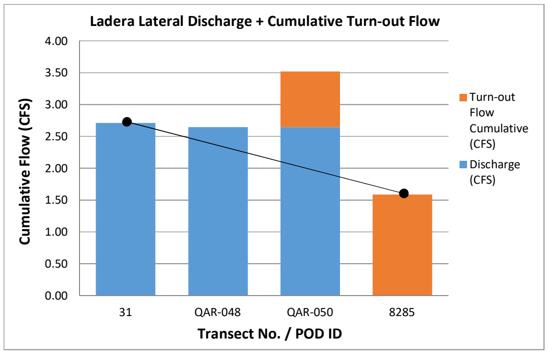
Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
M&M Lateral				
50	1.07		0.00	24 inch rectangular weir, 3.625 inch depth
QAR-052	1.12		0.00	Measurement rated as 'Fair'
176		-0.03		6 inch rectangular weir, 0.75 inch depth
782		-0.02		6 inch rectangular weir, 0.625 inch depth
783		-0.08		12 inch rectangular weir, 1.0 inch depth
3150		-0.05		6 inch rectangular weir, 1.25 inch depth
3151	0.00	-0.26	0.44	End of M&M Lat., 21.5" weir, 1.5 inch depth
M&M Lat flow remaining	0.00		0.44	


M&M Lateral Discharge + Cumulative Turn-out Flow

Total M&M Lateral Intake to the Study Reach	=	1.07		
Total M&M Lateral Turnout + Flow Remaining	=	-0.44		
Total M&M Lateral Losses in the Study Reach	=	0.63	=	58.94%

Ladera Lateral

Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
Ladera Lateral				
31	2.71		0.00	36 inch rectangular weir, 5.125 inch depth
QAR-048	2.65		0.00	Measurement rated as 'Fair'
1766		-0.87		Start Omohundro, piped, flooded back, 6-27-16
QAR-050	2.65		0.87	Measurement rated as 'Good'
4148		-0.09		12 inch rectangular weir, 1.125 inch depth
4203		-0.04		6 inch rectangular weir, 1.0 inch depth
4995		-0.05		6 inch rectangular weir, 1.25 inch depth
5013		-0.03		6 inch rectangular weir, 0.75 inch depth
5100		-0.09		12 inch rectangular weir, 1.125 inch depth
5144		-0.02		6 inch rectangular weir, 0.625 inch depth
6116		-0.06		12 inch rectangular weir, 0.875 inch depth
8285	0.00	-0.33	1.59	End Ladera Lat., 24 inch weir, 1.625 inch depth
Ladera Lat flow remaining	0.00		1.59	


Ladera Lateral Discharge + Cumulative Turn-out Flow

Total Ladera Lateral Intake to the Study Reach	=	2.71		
Total Ladera Lateral Turnout + Flow Remaining	=	-1.59		
Total Ladera Lateral Losses in the Study Reach	=	1.12	=	41.39%

ro Lateral

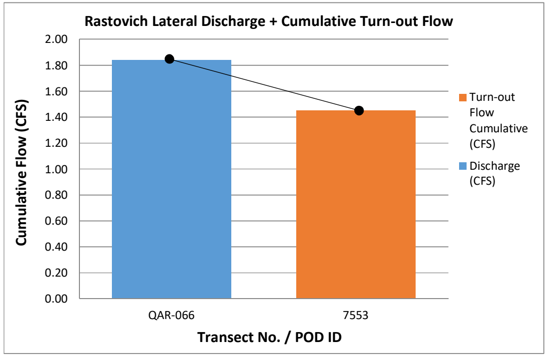
Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
Omohundro Lateral				
1766	0.87		0.00	Start Omohundro, piped, flooded back, 6-27-16
540		0.00		Off, 6-27-16
1350		-0.22		12 inch rectangular weir, 2.0 inch depth
1450		-0.16		12 inch rectangular weir, 1.625 inch depth

ARNOLD IRRIGATION DISTRICT - DISCHARGE FLOW MEASUREMENTS 2016

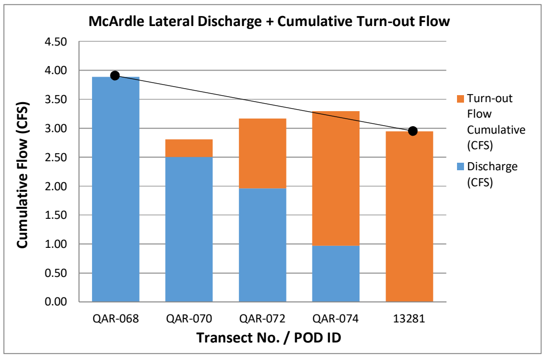
11/17/2016
Final

Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments	
1452		-0.11		12 inch rectangular weir, 1.25 inch depth	Omohunc
1475		-0.16		12 inch rectangular weir, 1.625 inch depth	
1500	0.00	-0.22	0.87	End Omohundro Lat., 12" weir, 2" depth	
Omohundro flow remaining	0.00		0.87		
Rastovich Lateral					Rastovich Lateral
QAR-066	1.84		0.00	Measurement rated as 'Fair'	
834		-0.04		6 inch rectangular weir, 1.0 inch depth	
983		-0.02		6 inch rectangular weir, 0.625 inch depth	
1031		-0.04		6 inch rectangular weir, 1.0 inch depth	
1147		-0.05		6 inch rectangular weir, 1.25 inch depth	
1391		-0.01		6 inch rectangular weir, 0.5 inch depth	
1413		0.00		Off	
1415		-0.03		6 inch rectangular weir, 0.875 inch depth	
1417		-0.03		6 inch rectangular weir, 0.875 inch depth	
1898		-0.08		12 inch rectangular weir, 1.0 inch depth	
2996		-0.06		12 inch rectangular weir, 0.875 inch depth	
2997		-0.04		12 inch rectangular weir, 0.625 inch depth	
2998		-0.04		6 inch rectangular weir, 1.0 inch depth	
3127		-0.06		18 inch rectangular weir, 0.625 inch depth	
3333		-0.04		12 inch rectangular weir, 0.625 inch depth	
3459		-0.07		6 inch rectangular weir, 1.5 inch depth	
3745		-0.04		6 inch rectangular weir, 1.0 inch depth	
3751		-0.03		6 inch rectangular weir, 0.875 inch depth	
3882		-0.01		6 inch rectangular weir, 0.5 inch depth	
4215		-0.18		12 inch rectangular weir, 1.75 inch depth	
4227		-0.04		6 inch rectangular weir, 1.0 inch depth	
5343		-0.03		6 inch rectangular weir, 0.875 inch depth	
5590		-0.14		Delivers water to 7533, big loss	
5584		-0.29		24 inch rectangular weir, 1.5 inch depth	
7553	0.00	-0.06	1.45	End Rastovich Lat., 12" weir, 0.875" depth	
Rastovich Lat flow remaining	0.00		1.45		
McArdle Lateral					McArdle Lateral
QAR-068	3.89		0.00	Measurement rated as 'Good', 6-27-16	
797		-0.05		6 inch rectangular weir, 1.125 inch depth	
1298		-0.05		6 inch rectangular weir, 1.125 inch depth	
2319		-0.07		6 inch rectangular weir, 1.5 inch depth	
2505		-0.08		12 inch rectangular weir, 1.0 inch depth	
3259		-0.06		12 inch rectangular weir, 0.875 inch depth	
QAR-070	2.50		0.31	Measurement rated as 'Poor', 6-27-16	
3338		-0.06		12 inch rectangular weir, 0.875 inch depth	
3926		-0.03		6 inch rectangular weir, 0.875 inch depth	
3930		-0.03		6 inch rectangular weir, 0.875 inch depth	
3932		-0.44		Start Rickard Pipe, staff gage	
4284		-0.01		12 inch rectangular weir, 0.25 inch depth	
4599		-0.06		6 inch rectangular weir, 1.375 inch depth	
4637		-0.04		6 inch rectangular weir, 1.0 inch depth	
5694		-0.09		6 inch rectangular weir, 1.75 inch depth	
5700		0.00		Off	
5716		0.00		Off	
5718		-0.05		6 inch rectangular weir, 1.125 inch depth	
5720		-0.04		6 inch rectangular weir, 1.0 inch depth	
5722		0.00			
5724		-0.05		6 inch rectangular weir, 1.125 inch depth	
QAR-072	1.96		1.21	Measurement rated as 'Good', 6-27-16	
7413		-0.27		18 inch rectangular weir, 1.75 inch depth	
7563		-0.22		18 inch rectangular weir, 1.5 inch depth	
8072		-0.22		12 inch rectangular weir, 2.0 inch depth	
8761		-0.04		6 inch rectangular weir, 1.0 inch depth	
9111		-0.14		12 inch rectangular weir, 1.5 inch depth	
9361		-0.08		6 inch rectangular weir, 1.625 inch depth	
9515		-0.01		6 inch rectangular weir, 1.5 inch depth	
9823		-0.03		6 inch rectangular weir, 0.75 inch depth	
10119		-0.11		18 inch rectangular weir, 1.25 inch depth	
QAR-074	0.97		2.32	Measurement rated as 'Good', 6-27-16	
11401		0.00		Flooded back	
11403		-0.03		12 inch rectangular weir, 0.5 inch depth	
11751		0.00		Flooded back	
12453		-0.02		12 inch rectangular weir, 0.375 inch depth	
13281	0.00	-0.57	2.94	End McArdle Lat., ?? Weir, 2.375 inch depth	
McArdle Lat flow remaining	0.00		2.94		
Brandon Lateral					
QAR-056	17.66		0.00	Measurement rated as 'Fair', 6-27-16	
26		-0.35		12 inch rectangular weir, 2.75 inch depth	
QAR-058	18.57		0.35	Measurement rated as 'Good', 6-27-16	

Total Omohundro Lat Intake to the Study Reach = 0.87
Total Omohundro Lateral Turnout + Flow Remaining = -0.87
Total Omohundro Losses in the Study Reach = 0.00 = 0.00%



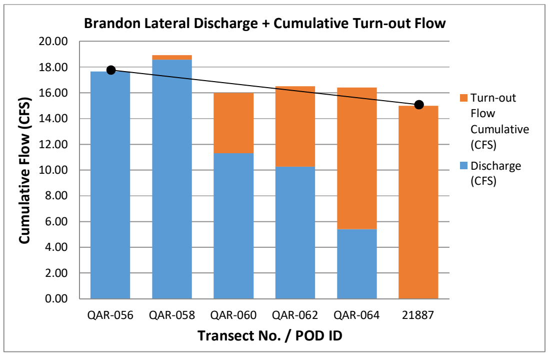
Total Rastovich Lateral Intake to the Study Reach = 1.84
Total Rastovich Lateral Turnout + Flow Remaining = -1.45
Total Rastovich Lateral Losses in the Study Reach = 0.39 = 21.06%



Total McArdle Lateral Intake to the Study Reach = 3.89
Total McArdle Lateral Turnout + Flow Remaining = -2.94
Total McArdle Lateral Losses in the Study Reach = 0.94 = 24.28%

ARNOLD IRRIGATION DISTRICT - DISCHARGE FLOW MEASUREMENTS 2016

Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments	
2496		-0.08		12 inch rectangular weir, 1.0 inch depth	Brandon Lateral
2824		-0.08		12 inch rectangular weir, 1.0 inch depth	
3064		-0.04		6 inch rectangular weir, 1.0 inch depth	
3335		-0.02		6 inch rectangular weir, 0.625 inch depth	
3764		-0.09		6 inch rectangular weir, 1.75 inch depth	
4017		0.00		Flooded back	
4056		-0.06		6 inch rectangular weir, 1.375 inch depth	
4325		0.00		Off	
QAR-068		-3.89		Transect QAR-068 at start McArdle Lat, 6-27-16	
4443	(McArdle Lat flow captured in QAR-068 above)			Ramp Flume Start of McArdle Lat	
4750		-0.07		6 inch rectangular weir, 1.5 inch depth	
4778		-0.02		6 inch rectangular weir, 0.625 inch depth	
QAR-060	11.29		4.69	Measurement rated as 'Good', 6-27-16	
5275		-0.04		12 inch rectangular weir, 0.625 inch depth	
5723		-0.03		6 inch rectangular weir, 0.875 inch depth	
5797		-0.06		12 inch rectangular weir, 0.875 inch depth	
5803		-0.07		6 inch rectangular weir, 1.5 inch depth	
6317		0.00		Flooded back	
6388		-0.22		18 inch rectangular weir, 1.5 inch depth	
6392		-0.12		18 inch rectangular weir, 1.0 inch depth	
6647		-0.16		24 inch rectangular weir, 1.0 inch depth	
6782		-0.13		12 inch rectangular weir, 1.375 inch depth	
7978		-0.22		18 inch rectangular weir, 1.5 inch depth	
8334		-0.03		6 inch rectangular weir, 0.875 inch depth	
8336		0.00		Flooded back	
8338		-0.04		6 inch rectangular weir, 1.0 inch depth	
8342		-0.18		12 inch rectangular weir, 1.75 inch depth	
8344		0.00		Flooded back	
8346		-0.03		6 inch rectangular weir, 0.75 inch depth	
8348		-0.03		6 inch rectangular weir, 0.875 inch depth	
8411		-0.03		6 inch rectangular weir, 0.875 inch depth	
8413		-0.11		12 inch rectangular weir, 1.25 inch depth	
8415		-0.03		6 inch rectangular weir, 0.875 inch depth	
8417		0.00		Flooded back	
8419		-0.04		6 inch rectangular weir, 1.0 inch depth	
QAR-062	10.24		6.26	Measurement rated 'Good', 6-27-16	
8920		-0.02		6 inch rectangular weir, 0.625 inch depth	
8963		-0.97		Private Lat. Bill / Rop, 24" weir, 3.375" depth	
8965		-0.67		Private Lat. Penhollow, 24" weir, 2.625" depth	
10098		-0.13		12 inch rectangular weir, 1.375 inch depth	
10100		-0.13		12 inch rectangular weir, 1.375 inch depth	
10110		-0.19		24 inch rectangular weir, 1.125 inch depth	
10645		-0.14		12 inch rectangular weir, 1.5 inch depth	
10787		-0.08		12 inch rectangular weir, 1.0 inch depth	
11210		-0.01		6 inch rectangular weir, 0.375 inch depth	
11793		-0.16		12 inch rectangular weir, 1.625 inch depth	
12405		0.00		Flooded back	
12503		-0.29		24 inch rectangular weir, 1.5 inch depth	
12534		-0.04		12 inch rectangular weir, 0.625 inch depth	
13673		-0.10		18 inch rectangular weir, 0.875 inch depth	
QAR-066		-1.84		Transect QAR-066 at Start of Rastovich Lat.	
14157	(Rastovich Lat flow captured in QAR-066 above)			Ramp Flume, start of Rastovich Lat	
QAR-064	5.40		11.01	Measurement rated as 'Good'	
14363		-0.03		6 inch rectangular weir, 0.75 inch depth	
14890		0.00		Flooded back	
14908		0.00		6 inch rectangular weir, 0.25 inch depth	
15451		0.00		Flooded back	
15679		-0.08		6 inch rectangular weir, 1.625 inch depth	
15715		-0.16		12 inch rectangular weir, 1.625 inch depth	
16156		0.04		6 inch rectangular weir, 1.0 inch depth	
16366		-0.05		12 inch rectangular weir, 0.75 inch depth	
16730		0.00		Flooded back	
17234		-0.11		12 inch rectangular weir, 1.25 inch depth	
17247		-0.18		12 inch rectangular weir, 1.75 inch depth	
17467		-0.01		6 inch rectangular weir, 0.5 inch depth	
18171		-0.03		6 inch rectangular weir, 0.75 inch depth	
18231		-0.06		12 inch rectangular weir, 0.875 inch depth	
18842		0.00		Flooded back	
18874		0.00		Flooded back	
18879		0.00		Flooded back	
18900		0.00		Flooded back / Proportional	
19200		-0.29		24 inch rectangular weir, 1.5 inch depth	
19203		-1.59		24 inch rectangular weir, 4.75 inch depth	
21128		-0.16		12 inch rectangular weir, 1.625 inch depth	
21146		-0.01		6 inch rectangular weir, 0.5 inch depth	
21868		0.00		Flooded back	
21882		-0.09		12 inch rectangular weir, 1.125 inch depth	
21883/21885		-1.15		End Brandon Lat, 36" weir, 2.875" depth	
21887	0.00	0.00	14.99	Off	



Total Brandon Lateral Intake to the Study Reach	=	17.66		
Total Brandon Lateral Turnout + Flow Remaining	=	-14.99		
Total Brandon Lateral Losses in the Study Reach	=	2.67	=	15.11%

ARNOLD IRRIGATION DISTRICT - DISCHARGE FLOW MEASUREMENTS 2016

Transect No. POD #ID	**Discharge (CFS)**	**Turn-out Flow Rate (CFS)**	**Turn-out Flow Cumulative (CFS)**	**Comments**
Brandon Lat flow remaining	0.00		14.99	
Rickard Pipe				
3932	0.44		0.00	Staff Gauge, 6-27-16
1874		-0.11		Piped, 12 inch weir, 1.125 inch depth, 6-27-16
2092		-0.07		6 inch rectangular weir, 1.5 inch depth
2105		-0.05		6 inch rectangular weir, 1.25 inch depth
2107		-0.03		6 inch rectangular weir, 0.875 inch depth
3090		0.00		Off
3937		-0.01		6 inch rectangular weir, 0.5 inch depth
3987		-0.03		6 inch rectangular weir, 0.875 inch depth
4275		-0.02		6 inch rectangular weir, 0.625 inch depth
4324		-0.03		6 inch rectangular weir, 0.875 inch depth
4964		-0.02		6 inch rectangular weir, 0.625 inch depth
4970	0.00	-0.06	0.44	End Rickard Pipe, 6" weir, 1.375" depth
Rickard Pipe flow remaining	0.00		0.44	
Roach Lateral				
32	0.29		0.00	24 inch rectangular weir, 1.5 inch depth, 6-27-16
394		-0.01		6 inch rectangular weir, 1.5 inch depth
1273		-0.01		6 inch rectangular weir, 0.5 inch depth
2395		-0.06		12 inch rectangular weir, 0.875 inch depth
2397		-0.04		6 inch rectangular weir, 1.0 inch depth
3537		-0.05		Proportional weirs, 6.125" weir, 1.125" depth
3538		-0.05		Proportional weirs, 6.5" weir, 1.125" depth
4479		-0.05		Proportional weirs, 5.75" weir, 1.125" depth
4480	0.00	-0.01	0.28	Proportional weirs, 0.875" weir, 1.125" depth
Roach Lat flow remaining	0.00		0.28	

Rickard Pipe

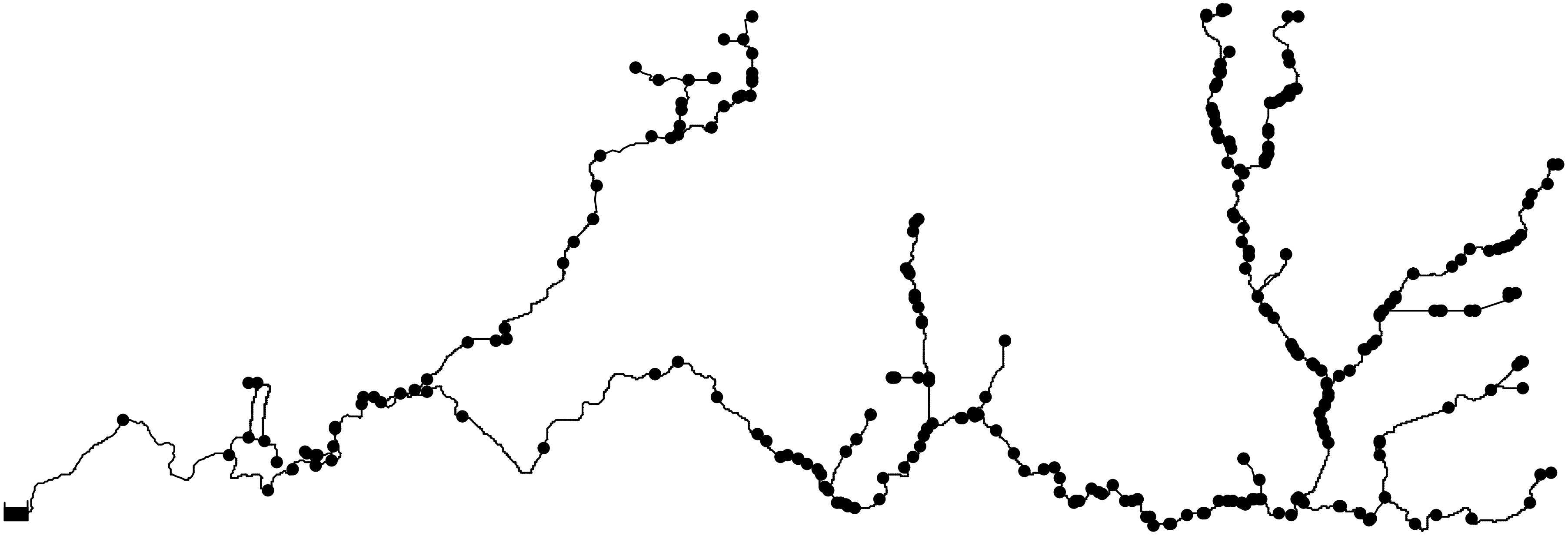
Total Rickard Pipe Intake to the Study Reach = 0.44
Total Rickard Pipe Turnout + Flow Remaining = -0.44
Total Rickard Pipe Losses in the Study Reach = 0.00 = 0.00%

Roach Lateral

Total Roach Lateral Intake to the Study Reach = 0.29
Total Roach Lateral Turnout + Flow Remaining = -0.28
Total Roach Lateral Losses in the Study Reach = 0.01 = 1.99%

APPENDIX B
EPANET HYDRAULIC MODELS

Farmers Conservation Alliance (FCA)



EPANET Node Outputs					
Node ID	Elevation ft	Base Demand GPM	Demand GPM	Head ft	Pressure psi
Junc 1-04834	3914.57	175.31	175.31	3923.41	3.83
Junc 1-07565	3912.75	2.26	2.26	3921.47	3.78
Junc 1-08873	3912.15	7.55	7.55	3920.56	3.64
Junc 1-09930	3911.82	52.47	52.47	3919.86	3.48
Junc 1-10435	3912.18	77.84	77.84	3919.51	3.18
Junc 1-11818	3910.79	22.65	22.65	3918.58	3.38
Junc 1-11820	3910.84	98.15	98.15	3918.58	3.35
Junc 1-11822	3910.91	45.3	45.3	3918.58	3.32
Junc 1-11829	3910.37	30.12	30.12	3918.55	3.54
Junc 112-01900	3821.18	456.77	456.77	3864.44	18.74
Junc 112-01902	3821.18	30.2	30.2	3864.41	18.73
Junc 112-01904	3821.11	113.25	113.25	3864.4	18.76
Junc 112-01905	3821.11	15.1	15.1	3864.39	18.76
Junc 112-01906	3821.11	22.65	22.65	3864.39	18.76
Junc 1-13292	3910.4	341.93	341.93	3917.54	3.09
Junc 1-13594	3909.97	72.48	72.48	3917.35	3.2
Junc 1-14002	3910.32	36.01	36.01	3917.1	2.94
Junc 1-16227	3905.96	3.77	3.77	3915.67	4.21
Junc 1-18262	3903.19	40.01	40.01	3914.4	4.86
Junc 1-22366	3900.39	1272.38	1272.38	3911.78	4.93
Junc 1-28040	3895.13	888.99	888.99	3908.48	5.78
Junc 1-28042	3895.24	148.13	148.13	3908.48	5.74
Junc 1-29015	3894.56	222.65	222.65	3907.93	5.79
Junc 13-00824	3903.96	27.5	27.5	3914	4.35
Junc 13-01332	3903.88	5.5	5.5	3912.31	3.65
Junc 13-01894	3903.62	11	11	3910.37	2.92
Junc 13-03950	3862.82	23.98	23.98	3903.92	17.81
Junc 13-04984	3852.01	22	22	3900.9	21.18
Junc 13-04986	3852.26	8.25	8.25	3900.9	21.07
Junc 13-05457	3851.6	13.75	13.75	3899.55	20.78
Junc 13-05459	3851.46	8.25	8.25	3899.55	20.84
Junc 13-05789	3851.83	7.15	7.15	3898.68	20.3
Junc 13-05828	3852.03	19.47	19.47	3898.55	20.16
Junc 13-09589	3816.88	18.7	18.7	3889.73	31.57
Junc 13-10443	3811.64	10.45	10.45	3884.33	31.5
Junc 1-31248	3891.52	37.75	37.75	3906.78	6.61
Junc 13-16831	3790.09	7.98	7.98	3846.68	24.52
Junc 13-17485	3785.05	2.2	2.2	3842.09	24.72
Junc 13-17709	3783.55	8.25	8.25	3840.5	24.68
Junc 13-17713	3783.43	5.5	5.5	3840.47	24.72

Junc 13-17715	3783.58	10.01	10.01	3840.45	24.64
Junc 13-19277	3770.32	289.25	289.25	3821.27	22.07
Junc 132-00950	3764.43	27.5	27.5	3809.6	19.57
Junc 132-00951	3764.38	24.75	24.75	3809.6	19.59
Junc 13-20300	3759.88	1.92	1.92	3812.49	22.8
Junc 13-20912	3757.42	7.98	7.98	3807.51	21.7
Junc 13-20938	3756.65	42.73	42.73	3807.31	21.95
Junc 13-21110	3756.45	2.75	2.75	3806.77	21.8
Junc 13-21649	3756.35	8.25	8.25	3805.85	21.45
Junc 13-22322	3753.25	13.75	13.75	3804.32	22.13
Junc 13-22410	3752.57	4.07	4.07	3804.12	22.34
Junc 133-00394	3780.29	5	5	3835.17	23.78
Junc 133-01273	3779.95	5.5	5.5	3823.95	19.07
Junc 133-02397	3778.74	18.1	18.1	3811.45	14.18
Junc 133-03538	3779.49	39.05	39.05	3807.89	12.31
Junc 133-04479	3771.86	28.6	28.6	3807.06	15.25
Junc 133-04480	3771.86	4.79	4.79	3807.04	15.24
Junc 1-33258	3890.59	26.12	26.12	3904.45	6
Junc 1-33734	3890.13	133.25	133.25	3903.94	5.98
Junc 134-00729	3750.64	16.5	16.5	3802.18	22.33
Junc 1-34464	3888.7	15.1	15.1	3903.11	6.24
Junc 1-34710	3888.81	166.47	166.47	3902.82	6.07
Junc 135-01567	3751.65	24.2	24.2	3801.83	21.74
Junc 1-35106	3889.13	46.43	46.43	3902.4	5.75
Junc 1-35108	3889.06	39.94	39.94	3902.4	5.78
Junc 1-35112	3889.29	371.45	371.45	3902.4	5.68
Junc 1-35478	3889.07	45.3	45.3	3901.97	5.59
Junc 1-35932	3888.33	18.87	18.87	3901.51	5.71
Junc 1-36152	3888.71	7.55	7.55	3901.3	5.46
Junc 1-37402	3885.84	15.1	15.1	3899.92	6.1
Junc 1-37608	3885.56	89.09	89.09	3899.71	6.13
Junc 1-37610	3885.56	18.87	18.87	3899.71	6.13
Junc 1-37704	3885.64	15.1	15.1	3899.63	6.06
Junc 1-37993	3885.41	52.85	52.85	3899.37	6.05
Junc 1-38880	3885.22	184.97	184.97	3898.43	5.72
Junc 1-39788	3883.8	196.3	196.3	3897.55	5.96
Junc 1-41062	3879.13	136.65	136.65	3896.31	7.44
Junc 1-41550	3879.87	37.75	37.75	3895.87	6.93
Junc 1-41994	3875.09	28.69	28.69	3895.42	8.81
Junc 1-42416	3873.11	45.3	45.3	3895.03	9.5
Junc 1-42654	3873.66	45.3	45.3	3894.81	9.17
Junc 1-43001	3872.11	307.66	307.66	3894.54	9.72
Junc 1-44097	3872.17	718.75	718.75	3893.6	9.29

Junc 1-44190	3871.34	856.15	856.15	3893.55	9.62
Junc 1-44754	3871.78	15.1	15.1	3893.03	9.21
Junc 1-45730	3871.18	600.36	600.36	3891.78	8.92
Junc 1-46794	3868.07	77.01	77.01	3890.54	9.74
Junc 1-47503	3868.32	283.12	283.12	3889.68	9.26
Junc 1-48296	3867.28	75.5	75.5	3888.68	9.27
Junc 1-48800	3866.63	18.87	18.87	3888.19	9.34
Junc 1-49056	3866.63	8.3	8.3	3887.64	9.1
Junc 1-49604	3867.21	30.2	30.2	3887.04	8.59
Junc 1-50351	3866.09	30.2	30.2	3886.35	8.78
Junc 1-50422	3866.31	22.65	22.65	3886.25	8.64
Junc 1-50430	3866.36	46.05	46.05	3886.25	8.62
Junc 1-50600	3866.38	20.76	20.76	3886.08	8.54
Junc 1-51278	3866.3	15.1	15.1	3885.34	8.25
Junc 1-51605	3865.42	185.95	185.95	3884.93	8.46
Junc 1-51766	3866.61	89.47	89.47	3884.74	7.86
Junc 1-53098	3865.36	83.8	83.8	3883.24	7.75
Junc 1-53356	3865.54	685.07	685.07	3882.93	7.54
Junc 1-53580	3864.76	37.75	37.75	3882.71	7.78
Junc 1-53592	3865.28	30.2	30.2	3882.72	7.56
Junc 1-54271	3863.75	67.95	67.95	3881.99	7.91
Junc 1-54418	3864.11	212.3	212.3	3881.85	7.69
Junc 1-54420	3864.11	50.06	50.06	3881.85	7.69
Junc 1-54430	3863.99	30.2	30.2	3881.84	7.74
Junc 1-54951	3863.86	30.58	30.58	3881.52	7.65
Junc 1-55302	3864	77.39	77.39	3880.98	7.36
Junc 1-55354	3863.5	34.73	34.73	3880.92	7.55
Junc 1-55954	3862.98	15.1	15.1	3880.33	7.52
Junc 1-56580	3863.36	25.37	25.37	3879.73	7.09
Junc 1-56584	3862.78	22.65	22.65	3879.73	7.34
Junc 1-56586	3863.16	56.77	56.77	3879.72	7.18
Junc 1-56588	3863.29	103.66	103.66	3879.72	7.12
Junc 1-56608	3862.87	12.08	12.08	3879.7	7.29
Junc 1-56612	3862.89	60.4	60.4	3879.7	7.28
Junc 1-57320	3862.03	45.3	45.3	3879.03	7.37
Junc 1-57626	3862.64	145.49	145.49	3878.77	6.99
Junc 1-57679	3862.6	30.2	30.2	3878.72	6.98
Junc 1-57877	3863.22	36.24	36.24	3878.54	6.64
Junc 1-58128	3862.51	151.75	151.75	3878.28	6.83
Junc 1-58281	3862.28	52.85	52.85	3878.12	6.86
Junc 1-58630	3861.61	175.91	175.91	3877.83	7.03
Junc 1-58703	3861.39	17.36	17.36	3877.76	7.09
Junc 1-58836	3862.39	37.75	37.75	3877.58	6.58

Junc 1-59894	3861.68	30.2	30.2	3876.76	6.53
Junc 16-01492	3852.07	385.04	385.04	3890.83	16.79
Junc 16-01495	3852.27	264.24	264.24	3890.8	16.7
Junc 16-02150	3841.89	158.55	158.55	3883.21	17.9
Junc 16-03177	3836.5	135.9	135.9	3877.9	17.94
Junc 16-03178	3836.5	128.35	128.35	3877.9	17.94
Junc 1-60334	3861.33	67.19	67.19	3876.37	6.52
Junc 17-04148	3770.26	90.6	90.6	3872.31	44.22
Junc 17-04203	3770.67	22.65	22.65	3871.38	43.64
Junc 17-04995	3768.93	30.2	30.2	3862.68	40.62
Junc 17-05013	3767.82	15.1	15.1	3862.52	41.03
Junc 17-05100	3767.65	55.11	55.11	3861.69	40.75
Junc 17-05144	3767.91	7.55	7.55	3861.51	40.56
Junc 17-06116	3765.24	52.85	52.85	3855.93	39.3
Junc 17-08285	3762.77	212.91	212.91	3837.75	32.49
Junc 171-00540	3814.69	139.6	139.6	3879.01	27.87
Junc 171-01350	3806.8	135.9	135.9	3875.52	29.78
Junc 171-01450	3807.62	89.92	89.92	3874.68	29.06
Junc 171-01452	3807.91	62.29	62.29	3874.66	28.92
Junc 171-01475	3807.54	90.6	90.6	3874.6	29.06
Junc 171-01500	3807.82	117.02	117.02	3874.36	28.83
Junc 18-00176	3868.33	15.1	15.1	3892.38	10.42
Junc 18-00782	3846.62	29.9	29.9	3888.75	18.26
Junc 18-00783	3846.52	60.4	60.4	3888.72	18.28
Junc 18-03150	3795.41	30.2	30.2	3862.2	28.94
Junc 18-03151	3795.88	393.35	393.35	3862.15	28.71
Junc 2-00026	3860.32	264.62	264.62	3875.63	6.63
Junc 2-02496	3822.7	60.4	60.4	3871.38	21.09
Junc 2-02824	3822.63	52.32	52.32	3870.73	20.84
Junc 2-03064	3821.68	18.87	18.87	3870.4	21.11
Junc 2-03335	3821.97	15.1	15.1	3869.91	20.77
Junc 2-03764	3821.52	50.73	50.73	3869.4	20.75
Junc 2-04017	3815.93	15.1	15.1	3868.77	22.9
Junc 2-04056	3815.37	49.07	49.07	3868.68	23.1
Junc 2-04325	3816.07	15.1	15.1	3868.21	22.59
Junc 2-04750	3814.02	49.07	49.07	3867.45	23.15
Junc 2-04778	3814.16	18.87	18.87	3867.33	23.04
Junc 2-05275	3812.96	54.36	54.36	3866.34	23.13
Junc 2-05723	3811.65	22.65	22.65	3865.67	23.41
Junc 2-05797	3810.72	52.85	52.85	3865.46	23.72
Junc 2-05803	3810.83	45.3	45.3	3865.45	23.67
Junc 2-06317	3807.76	97.39	97.39	3864.06	24.39
Junc 2-06388	3802.65	115.14	115.14	3863.88	26.53

Junc 2-06392	3802.78	126.84	126.84	3863.87	26.47
Junc 2-06647	3806.05	98.75	98.75	3863.31	24.81
Junc 2-06782	3802.68	91.2	91.2	3863.01	26.14
Junc 2-07978	3782.08	168.36	168.36	3860.27	33.88
Junc 2-08334	3781.87	22.65	22.65	3859.43	33.61
Junc 2-08336	3782	98.15	98.15	3859.43	33.55
Junc 2-08338	3781.92	32.92	32.92	3859.42	33.58
Junc 2-08342	3781.96	80.41	80.41	3859.41	33.56
Junc 2-08344	3785.76	68.7	68.7	3859.41	31.91
Junc 2-08346	3786.03	35.86	35.86	3859.41	31.79
Junc 2-08348	3786.28	22.65	22.65	3859.4	31.68
Junc 2-08411	3781.84	29.22	29.22	3859.24	33.54
Junc 2-08413	3781.84	56.62	56.62	3859.23	33.53
Junc 2-08415	3781.71	22.65	22.65	3859.23	33.59
Junc 2-08417	3781.71	26.42	26.42	3859.22	33.59
Junc 2-08419	3782.6	30.2	30.2	3859.22	33.2
Junc 2-08920	3781.44	15.1	15.1	3857.76	33.07
Junc 2-08963	3781.44	641.59	641.59	3857.68	33.04
Junc 2-08965	3781.41	472.24	472.24	3857.67	33.04
Junc 2-10098	3778.43	75.5	75.5	3854.22	32.84
Junc 2-10100	3778.12	67.95	67.95	3854.22	32.97
Junc 2-10110	3778.21	191.77	191.77	3854.2	32.93
Junc 2-10645	3778.18	101.17	101.17	3852.85	32.36
Junc 2-10787	3777.6	86.82	86.82	3852.44	32.43
Junc 2-11210	3776	7.55	7.55	3851.33	32.64
Junc 2-11793	3774.17	101.92	101.92	3849.92	32.82
Junc 2-12405	3776.02	49.07	49.07	3848.39	31.36
Junc 2-12530	3774.47	173.65	173.65	3848.14	31.92
Junc 2-12534	3774.47	30.2	30.2	3848.14	31.92
Junc 2-13673	3761.91	301.99	301.99	3845.71	36.31
Junc 2-14363	3761.68	30.2	30.2	3843.53	35.46
Junc 2-14890	3761.29	52.85	52.85	3839.89	34.06
Junc 2-14908	3760.97	15.1	15.1	3839.87	34.19
Junc 2-15451	3761.21	7.55	7.55	3836.5	32.62
Junc 2-15679	3761.22	30.2	30.2	3835.14	32.03
Junc 2-15715	3763.64	124.57	124.57	3834.77	30.82
Junc 2-16156	3757.1	37.75	37.75	3832.31	32.59
Junc 2-16366	3757.52	61.08	61.08	3831.35	31.99
Junc 2-16730	3753.77	33.97	33.97	3829.17	32.67
Junc 2-17243	3755	60.4	60.4	3826.58	31.01
Junc 2-17247	3754.81	104.41	104.41	3826.55	31.08
Junc 2-17467	3754.41	22.65	22.65	3824.66	30.44
Junc 2-18171	3742.09	22.65	22.65	3816.96	32.44

Junc 2-18231	3740.32	55.26	55.26	3815.71	32.67
Junc 2-18842	3739.93	37.75	37.75	3811.53	31.03
Junc 2-18874	3739.5	22.65	22.65	3811.26	31.09
Junc 2-18879	3739.31	30.2	30.2	3811.21	31.16
Junc 2-18900	3738.76	65.91	65.91	3810.98	31.29
Junc 2-19200	3736.97	173.65	173.65	3808.75	31.1
Junc 2-19203	3736.67	430.87	430.87	3808.7	31.21
Junc 22-00797	3805.18	49.75	49.75	3864.85	25.85
Junc 22-01298	3794.78	47.56	47.56	3863.15	29.62
Junc 22-02315	3790	16.99	16.99	3859.26	30.01
Junc 22-02319	3790	52.85	52.85	3859.22	29.99
Junc 22-02505	3790.43	58.59	58.59	3857.97	29.27
Junc 22-03258	3790.22	37.75	37.75	3857.35	29.09
Junc 22-03338	3788.22	57.98	57.98	3853.57	28.32
Junc 22-03433	3788.52	154.39	154.39	3853.2	28.03
Junc 22-03926	3788.49	13.21	13.21	3852.79	27.86
Junc 22-03930	3788.49	16.38	16.38	3852.78	27.86
Junc 22-04284	3788.23	52.7	52.7	3849.85	26.7
Junc 22-04599	3786.12	51.49	51.49	3848.54	27.04
Junc 22-04637	3785.35	22.65	22.65	3848.32	27.29
Junc 22-05694	3761.03	49.07	49.07	3843.81	35.87
Junc 22-05700	3761.03	60.4	60.4	3843.79	35.86
Junc 22-05716	3761.07	22.65	22.65	3843.78	35.84
Junc 22-05718	3761.51	15.1	15.1	3843.77	35.64
Junc 22-05720	3761.79	30.2	30.2	3843.75	35.52
Junc 22-05722	3761.77	30.2	30.2	3843.74	35.52
Junc 22-05724	3761.48	40.17	40.17	3843.73	35.64
Junc 22-07413	3744.65	163.08	163.08	3837.67	40.31
Junc 22-07563	3740.43	176.67	176.67	3836.28	41.53
Junc 22-08072	3738.8	126.16	126.16	3834.65	41.53
Junc 22-08761	3737.38	27.93	27.93	3831.09	40.61
Junc 22-09111	3736.3	113.25	113.25	3829.34	40.31
Junc 22-09361	3736.36	47.19	47.19	3828.14	39.77
Junc 22-09515	3733.93	7.55	7.55	3827.37	40.49
Junc 22-09823	3734.92	15.1	15.1	3825.94	39.44
Junc 22-10119	3733.72	162.32	162.32	3824.62	39.39
Junc 221-01874	3765.87	67.95	67.95	3824.06	25.21
Junc 221-02092	3764.03	45.3	45.3	3821.89	25.07
Junc 221-02105	3764.11	37.75	37.75	3821.85	25.02
Junc 221-02107	3764.11	22.65	22.65	3814.86	21.99
Junc 221-03090	3746.01	22.65	22.65	3808.21	26.95
Junc 221-03937	3748.21	11.32	11.32	3807.09	25.51
Junc 221-03987	3748.46	22.65	22.65	3807.12	25.42

Junc 221-04275	3748.55	15.1	15.1	3807.1	25.37
Junc 221-04324	3748.21	7.55	7.55	3807.09	25.51
Junc 221-04964	3735.42	15.02	15.02	3775.05	17.17
Junc 221-04970	3735.67	30.2	30.2	3773.19	16.26
Junc 2-21128	3721.81	98.15	98.15	3795.84	32.08
Junc 22-11401	3719.54	15.1	15.1	3819.24	43.2
Junc 22-11403	3718.66	41.52	41.52	3819.22	43.57
Junc 2-21146	3721.72	9.44	9.44	3795.7	32.06
Junc 22-11751	3717.58	41.52	41.52	3818.01	43.52
Junc 22-12453	3716.57	52.85	52.85	3815.55	42.89
Junc 22-13281	3705.3	819.16	819.16	3810.09	45.41
Junc 2-21868	3720.03	52.85	52.85	3791.69	31.05
Junc 2-21882	3720.29	56.93	56.93	3791.57	30.89
Junc 2-21883	3720.38	479.87	479.87	3791.54	30.83
Junc 2-21884	3720.38	45.3	45.3	3791.53	30.83
Junc 2-21885	3720.38	301.77	301.77	3791.52	30.82
Junc 2-21887	3720.38	104.19	104.19	3791.52	30.83
Junc 25-00834	3755.58	22.65	22.65	3839.71	36.46
Junc 25-00983	3754.39	22.65	22.65	3838.96	36.64
Junc 25-01031	3753.72	21.14	21.14	3838.51	36.74
Junc 25-01147	3752.97	26.42	26.42	3837.78	36.75
Junc 25-01391	3745.6	28.39	28.39	3836.43	39.36
Junc 25-01413	3746.25	41.52	41.52	3836.33	39.03
Junc 25-01415	3745.67	30.2	30.2	3836.34	39.29
Junc 25-01417	3745.43	33.97	33.97	3836.37	39.4
Junc 25-01898	3735.26	54.36	54.36	3833.84	42.72
Junc 25-02996	3734.11	37.75	37.75	3829.08	41.15
Junc 25-02997	3733.18	28.69	28.69	3829.06	41.54
Junc 25-02998	3736.67	42.28	42.28	3829.07	40.04
Junc 25-03127	3733.04	64.4	64.4	3828.59	41.4
Junc 25-03333	3732.48	68.1	68.1	3827.85	41.32
Junc 25-03459	3732.56	41.52	41.52	3827.56	41.16
Junc 25-03745	3731.48	29.44	29.44	3825.98	40.95
Junc 25-03751	3731.48	24.91	24.91	3825.98	40.95
Junc 25-03882	3731.24	9.81	9.81	3825.44	40.82
Junc 25-04215	3725.92	132.12	132.12	3823.27	42.18
Junc 25-04227	3725.12	30.2	30.2	3823.24	42.52
Junc 25-05343	3723.49	32.09	32.09	3819.35	41.54
Junc 25-05584	3725.03	270.28	270.28	3816.5	39.63
Junc 25-07553	3720.6	37.75	37.75	3788.97	29.62
Junc 3-00612	3861.1	343.52	343.52	3874.57	5.84
Junc 3-02060	3859.76	173.65	173.65	3871.78	5.21
Junc 3-02158	3860.4	80.48	80.48	3871.92	4.99

Junc 3-03058	3859.82	83.8	83.8	3870.38	4.58
Junc 3-03441	3859.76	63.12	63.12	3869.68	4.3
Junc 3-03527	3858.8	68.33	68.33	3869.54	4.66
Junc 3-06028	3856.75	10.57	10.57	3865.24	3.68
Junc 3-07336	3833.54	43.03	43.03	3862.94	12.74
Junc 3-08995	3829.61	408.6	408.6	3860.15	13.23
Junc 31-01681	3852.33	30.95	30.95	3861.08	3.79
Junc 3-10206	3822.07	72.48	72.48	3853.13	13.46
Junc 31-02122	3851.85	31.26	31.26	3858.72	2.98
Junc 31-02125	3852.26	30.2	30.2	3858.63	2.76
Junc 31-03000	3814.71	3.77	3.77	3846.58	13.81
Junc 31-06791	3798.91	499.05	499.05	3838.62	17.21
Junc 31-08036	3776.99	49.07	49.07	3834.99	25.13
Junc 31-08256	3775.86	39.64	39.64	3834.47	25.4
Junc 31-08258	3775.93	39.64	39.64	3834.47	25.36
Junc 31-08260	3776.34	55.34	55.34	3834.46	25.18
Junc 31-08266	3776.59	95.13	95.13	3834.39	25.04
Junc 31-08268	3776.71	15.1	15.1	3834.37	24.98
Junc 31-08270	3775.73	166.1	166.1	3834.35	25.4
Junc 31-08272	3776.56	52.85	52.85	3834.33	25.03
Junc 31-08274	3775.95	128.35	128.35	3834.3	25.28
Junc 31-08276	3775.98	151	151	3834.29	25.27
Junc 31-08279	3776.11	52.85	52.85	3834.28	25.21
Junc 31-08281	3775.76	113.25	113.25	3834.27	25.35
Junc 31-08283	3775.43	28.31	28.31	3834.25	25.49
Junc 3-11870	3808.23	409.96	409.96	3849.89	18.05
Junc HG-1	3763.02	0	0	3844.74	35.41
Junc HG-10	3868.41	0	0	3900.56	13.93
Junc HG-11	3778.85	0	0	3811.49	14.14
Junc HG-14	0	0	0	3868.16	1676.08
Junc HG-15	0	0	0	3851.52	1668.86
Junc HG-2	3815.63	0	0	3868.02	22.7
Junc HG-3	3862.05	0	0	3875.77	5.94
Junc HG-4	3857.56	0	0	3869.48	5.17
Junc HG-5	3857.73	0	0	3868.12	4.5
Junc HG-6	3861.95	0	0	3877.62	6.79
Junc HG-7	3870.66	0	0	3893.24	9.78
Junc HG-8	3874.02	0	0	3894.8	9.01
Junc HG-9	3822.04	0	0	3882.72	26.29
Junc N-1	3752.59	0	0	3803.24	21.95
Junc N-10	3774.99	0	0	3834.15	25.63
Junc N-11	3832.21	0	0	3872.26	17.35
Junc N-12	3866.26	0	0	3883.98	7.68

Junc N-13	3815.35	0	0	3882.15	28.94
Junc N-14	3769.8	0	0	3866.07	41.71
Junc N-15	3768.45	0	0	3862.76	40.86
Junc N-16	3764.98	0	0	3856.79	39.78
Junc N-17	3763.14	0	0	3855.67	40.09
Junc N-18	3762.89	0	0	3849.87	37.69
Junc N-19	3761.53	0	0	3840.99	34.43
Junc N-2	3755.99	0	0	3802.35	20.09
Junc N-20	3888.11	0	0	3900.02	5.16
Junc N-21	3886.38	0	0	3900.72	6.21
Junc N-22	3908.2	0	0	3916.91	3.77
Junc N-23	3804.02	0	0	3877.12	31.67
Junc N-24	3798.99	0	0	3869.4	30.51
Junc N-25	3791.14	0	0	3860.57	30.08
Junc N-26	3780.17	0	0	3827.97	20.71
Junc N-27	3910.33	0	0	3919.86	4.13
Junc N-28	3909.59	0	0	3919.86	4.45
Junc N-29	3908.1	0	0	3919.86	5.1
Junc N-3	3754.07	0	0	3805.89	22.45
Junc N-30	3908.02	0	0	3919.86	5.13
Junc N-31	3905.19	0	0	3919.86	6.36
Junc N-32	3908.75	0	0	3919.86	4.81
Junc N-33	3906.32	0	0	3923.41	7.4
Junc N-34	3903.5	0	0	3923.41	8.63
Junc N-35	3900.59	0	0	3923.41	9.89
Junc N-36	3905.71	0	0	3923.41	7.67
Junc N-37	3907.11	0	0	3923.41	7.06
Junc N-38	3776.8	0	0	3857.67	35.04
Junc N-39	3776.78	0	0	3857.68	35.06
Junc N-4	3754.2	0	0	3804.63	21.85
Junc N-40	3733.28	0	0	3808.7	32.68
Junc N-5	3731.98	0	0	3824.48	40.08
Junc N-6	3727.24	0	0	3823.42	41.68
Junc N-7	3736.6	0	0	3833.36	41.93
Junc N-8	3857.66	0	0	3868.18	4.56
Junc N-9	3778.53	0	0	3838.62	26.04
Junc 1	3922.17	0	0	3927.39	2.26
Junc 2	3924	0	0	3931	3.03
Junc 4	3808.23	604	604	3849.88	18.05
Junc 5	3774.99	906	906	3834.14	25.63
Junc 6	3735.67	151	151	3773.17	16.25
Junc 7	3705.3	1132.5	1132.5	3810.08	45.4
Junc 8	3720.6	377.5	377.5	3777.21	24.53

Junc 9	3720.38		377.5	377.5	3791.5	30.82
Resvr 3	3931	#N/A		-33175.05	3931	0

EPANET LINK OUTPUTS				
Pipe ID	Length ft	Diameter in	Flow GPM	Velocity fps
Pipe 1	1373.8374	58.89	32997.48	3.89
Pipe 2	566.1116	50.477	27954.17	4.48
Pipe 3	2931.42	58.89	32999.73	3.89
Pipe 4	529.8409	58.89	32937.44	3.88
Pipe 5	1056.7154	58.89	32989.93	3.89
Pipe 6	1415.3747	58.89	32859.6	3.87
Pipe 7	5899.8233	58.89	30122.17	3.55
Pipe 8	469.4841	50.477	28798.53	4.62
Pipe 9	391.0458	50.477	28483.71	4.57
Pipe 10	266.1289	50.477	28650.18	4.59
Pipe 11	768.347	50.477	28665.28	4.6
Pipe 12	207.546	50.477	27961.72	4.48
Pipe 13	436.7454	50.477	27980.59	4.49
Pipe 14	415.2274	50.477	28025.89	4.49
Pipe 15	2.4276	50.477	28443.77	4.56
Pipe 16	3.5831	50.477	28397.34	4.55
Pipe 17	1561.5388	58.89	32663.38	3.85
Pipe 18	398.9184	58.89	32248.97	3.8
Pipe 19	287.0973	58.89	32321.46	3.81
Pipe 20	43.973	58.89	32693.5	3.85
Pipe 21	1.825	58.89	32738.8	3.86
Pipe 22	2.4923	58.89	32836.95	3.87
Pipe 23	2050.755	58.89	31438.33	3.7
Pipe 24	300.265	58.89	32212.96	3.79
Pipe 25	4343.487	58.89	31394.55	3.7
Pipe 26	2134.8611	50.477	28824.65	4.62
Pipe 27	2105.9597	58.89	31434.56	3.7
Pipe 28	2226.3909	58.89	28862.4	3.4
Pipe 29	1050.6597	58.89	29085.05	3.43
Pipe 30	2.2202	58.89	29233.18	3.44
Pipe 31	110.8755	50.477	26882.09	4.31
Pipe 32	993.43	50.477	26691.08	4.28
Pipe 33	273.7657	50.477	26743.93	4.29
Pipe 34	85.2561	50.477	26759.03	4.29
Pipe 35	1.8784	50.477	26777.9	4.29
Pipe 36	212.2915	50.477	26866.99	4.31
Pipe 37	1344.3799	50.477	26309.81	4.22
Pipe 38	948.1799	50.477	26506.11	4.25
Pipe 39	616.833	44.87	21373.85	4.34
Pipe 40	539.5762	44.87	21404.05	4.34

Pipe 41	707.0268	44.87	20963.67	4.25
Pipe 42	177.5937	44.87	21053.14	4.27
Pipe 43	369.8113	44.87	21239.09	4.31
Pipe 44	671.9347	44.87	21254.19	4.31
Pipe 45	148.7574	44.87	21274.95	4.32
Pipe 46	7.835	44.87	21321	4.33
Pipe 47	88.418	44.87	21343.65	4.33
Pipe 48	496.2038	50.48	26135.41	4.19
Pipe 49	477.2141	50.477	26173.16	4.2
Pipe 50	242.9069	50.48	26061.42	4.18
Pipe 51	425.8924	50.48	26106.72	4.19
Pipe 52	890.336	44.87	21506.72	4.36
Pipe 53	745.1045	44.87	21789.84	4.42
Pipe 54	487.4922	44.87	21412.35	4.34
Pipe 55	441.0243	44.87	21431.22	4.35
Pipe 56	320.2711	50.48	24893.82	3.99
Pipe 57	1148.1537	50.48	24586.16	3.94
Pipe 58	9.8024	50.48	26016.12	4.17
Pipe 59	160.7327	44.09	22482.31	4.72
Pipe 60	940.0928	44.09	22467.21	4.72
Pipe 61	426.6396	50.48	23011.26	3.69
Pipe 62	73.788	50.48	23867.41	3.83
Pipe 63	1065.3319	44.87	21866.85	4.44
Pipe 64	290.4191	44.87	20879.87	4.24
Pipe 65	142.3549	44.87	20058.9	4.07
Pipe 66	624.3807	44.87	19623.64	3.98
Pipe 67	60.5282	44.87	19658.37	3.99
Pipe 68	568.9458	44.87	19735.76	4
Pipe 69	332.3159	44.87	19766.34	4.01
Pipe 70	8.8826	44.87	19796.54	4.02
Pipe 71	2.522	44.87	19846.6	4.03
Pipe 72	628.1039	44.87	19608.54	3.98
Pipe 73	4.0596	44.87	19583.17	3.97
Pipe 74	2.6164	44.87	19560.52	3.97
Pipe 75	2.5664	44.87	19503.75	3.96
Pipe 76	22.9642	44.87	19400.09	3.94
Pipe 77	2.408	44.87	19388.01	3.93
Pipe 78	717.5218	44.87	19327.61	3.92
Pipe 79	473.4918	44.87	17966.59	3.65
Pipe 80	755.4124	44.87	17899.4	3.63
Pipe 81	6.6667	44.87	20164.6	4.09
Pipe 82	213.3557	44.87	20194.8	4.1
Pipe 83	719.3094	44.87	20126.85	4.08

Pipe 84	291.6865	44.87	19282.31	3.91
Pipe 85	50.5919	44.87	18034.54	3.66
Pipe 86	291.8825	44.87	19070.38	3.87
Pipe 87	50.127	44.87	19136.82	3.88
Pipe 88	196.9148	44.87	19106.62	3.88
Pipe 89	184.2774	44.87	18918.63	3.84
Pipe 90	328.1654	44.87	18865.78	3.83
Pipe 91	71.4136	44.87	18689.87	3.79
Pipe 92	161.148	44.87	18672.51	3.79
Pipe 93	1021.8601	44.87	17996.79	3.65
Pipe 94	574.3783	22.44	4849.4	3.93
Pipe 95	40.8998	22.44	4036.5	3.27
Pipe 96	86.859	22.44	4104.83	3.33
Pipe 97	447.8777	22.44	4167.95	3.38
Pipe 98	852.1588	22.44	4251.75	3.45
Pipe 99	82.0087	22.44	4425.4	3.59
Pipe 100	1455.0061	22.44	4505.88	3.66
Pipe 101	1609.86	14.96	1548.64	2.83
Pipe 102	1282.3564	14.96	1538.07	2.81
Pipe 103	1642.8603	14.96	1495.04	2.73
Pipe 104	2464.6165	11.92	1086.44	3.12
Pipe 105	1294.9224	11.92	1013.96	2.92
Pipe 106	11.0187	22.44	4036.5	3.27
Pipe 107	1611.0249	14.96	2487.86	4.54
Pipe 108	2959.7426	14.96	2395.45	4.37
Pipe 109	21.8403	14.96	2425.65	4.43
Pipe 110	552.4165	14.96	2456.91	4.48
Pipe 111	1959.6998	14.96	2391.68	4.37
Pipe 112	1267.9634	14.7	1892.63	3.58
Pipe 113	188.6587	14.7	1843.56	3.49
Pipe 114	3.3432	14.7	1803.92	3.41
Pipe 115	3.1703	14.7	1764.28	3.34
Pipe 116	9.9608	11.71	1708.94	5.09
Pipe 117	21.3754	9.87	906	3.8
Pipe 118	3.3594	9.87	934.31	3.92
Pipe 119	2.8826	11.71	1047.56	3.12
Pipe 120	3.3583	11.71	1100.41	3.28
Pipe 121	2.9848	11.71	1251.41	3.73
Pipe 122	5.9733	11.71	1379.76	4.11
Pipe 123	2.7547	11.71	1432.61	4.27
Pipe 124	3.0273	11.71	1598.71	4.76
Pipe 125	3.0582	11.71	1613.81	4.81
Pipe 126	1186.5587	6.08	0	0

Pipe 127	78.8989	33.65	13050	4.71
Pipe 128	2432.1514	33.65	12785.38	4.61
Pipe 129	195.4345	33.65	12672.66	4.57
Pipe 130	373.1003	33.65	12724.98	4.59
Pipe 131	116.5548	33.65	12508.69	4.51
Pipe 132	276.141	33.65	12523.79	4.52
Pipe 133	57.919	33.65	12572.86	4.54
Pipe 134	370.736	33.65	12587.96	4.54
Pipe 135	297.8114	33.65	12638.69	4.56
Pipe 136	284.6433	33.65	12653.79	4.56
Pipe 137	301.0952	28.04	8237.57	4.28
Pipe 138	557.595	26.17	7994.47	4.77
Pipe 139	5.9036	26.17	8039.77	4.8
Pipe 140	81.8616	26.17	8092.62	4.83
Pipe 141	367.6278	28.04	8115.27	4.22
Pipe 142	534.0334	28.04	8169.63	4.24
Pipe 143	63.4576	28.04	8188.5	4.25
Pipe 144	135.7234	26.17	7556.35	4.51
Pipe 145	368.1402	25.72	7296.79	4.51
Pipe 146	1146.7479	25.72	7465.15	4.61
Pipe 147	242.6792	26.17	7655.1	4.57
Pipe 148	2.8199	26.17	7781.94	4.64
Pipe 149	75.1371	26.17	7897.08	4.71
Pipe 150	28.0136	23.88	6755.24	4.84
Pipe 151	1144.4507	22.04	5641.4	4.74
Pipe 152	5.2439	23.88	6113.65	4.38
Pipe 153	508.4592	23.88	6770.34	4.85
Pipe 154	2.0479	23.88	6800.54	4.87
Pipe 155	1.3227	23.88	6826.96	4.89
Pipe 156	1.264	23.88	6849.61	4.91
Pipe 157	1.5654	23.88	6906.23	4.95
Pipe 158	55.7377	23.88	6935.45	4.97
Pipe 159	1.525	25.72	6958.1	4.3
Pipe 160	1.7672	25.72	6993.96	4.32
Pipe 161	1.8036	25.72	7062.66	4.36
Pipe 162	3.4995	25.72	7143.07	4.41
Pipe 163	2.0782	25.72	7175.99	4.43
Pipe 164	2.0602	25.72	7274.14	4.49
Pipe 165	560.5421	22.04	5110.64	4.3
Pipe 166	441.3697	22.04	5118.19	4.3
Pipe 167	160.8112	22.04	5205.01	4.38
Pipe 168	498.9683	22.04	5306.18	4.46
Pipe 169	6.9937	22.04	5497.95	4.62

Pipe 170	2.2581	22.04	5565.9	4.68
Pipe 171	1103.8744	22.04	4755.8	4
Pipe 172	1.8892	22.04	4786	4.02
Pipe 173	106.3362	22.04	4959.65	4.17
Pipe 174	631.9081	22.04	5008.72	4.21
Pipe 175	186.5388	14.7	2945.67	5.57
Pipe 176	551.2415	14.7	2847.52	5.38
Pipe 177	3.4124	14.7	2862.62	5.41
Pipe 178	569.733	14.7	2915.47	5.51
Pipe 179	499.1696	22.04	4453.81	3.75
Pipe 180	519.147	14.7	2552.4	4.83
Pipe 181	427.9423	14.7	2586.37	4.89
Pipe 182	178.8825	14.7	2647.45	5
Pipe 183	449.1808	14.7	2685.2	5.08
Pipe 184	61.8299	14.7	2809.77	5.31
Pipe 185	224.8954	14.7	2839.97	5.37
Pipe 186	482.3803	12.59	2287.03	5.89
Pipe 187	138.3293	12.59	2342.29	6.04
Pipe 188	835.5622	12.59	2364.94	6.09
Pipe 189	223.5973	12.86	2387.59	5.9
Pipe 190	5.6065	14.7	2492	4.71
Pipe 191	293.7872	12.59	2130.52	5.49
Pipe 192	1986.9942	11.46	1526	4.75
Pipe 193	8.7156	12.59	1956.87	5.04
Pipe 194	28.5362	12.59	2196.43	5.66
Pipe 195	5.419	12.59	2226.63	5.74
Pipe 196	32.912	12.59	2249.28	5.8
Pipe 197	0.0616	5.96	783.46	9.01
Pipe 198	709.8973	11.46	1418.41	4.41
Pipe 199	24.8213	11.46	1427.85	4.44
Pipe 200	0.8412	7.75	679.27	4.62
Pipe 201	3.4121	9.66	828.76	3.63
Pipe 202	2.6492	9.66	1308.63	5.73
Pipe 203	9.545	9.66	1365.56	5.98
Pipe 204	991.318	11.46	1226.84	3.82
Pipe 205	2.6472	11.46	1189.09	3.7
Pipe 206	196.2042	9.66	879.94	3.85
Pipe 207	790.3438	18.7	4271.12	4.99
Pipe 208	433.5778	18.7	4221.37	4.93
Pipe 209	1013.0568	18.7	4173.81	4.88
Pipe 210	334.8277	18.7	4103.97	4.79
Pipe 211	10.2484	18.7	4156.82	4.86
Pipe 212	973.9906	18.37	4007.63	4.85

Pipe 213	171.9005	18.7	4045.38	4.73
Pipe 214	117.7945	18.37	3795.26	4.59
Pipe 215	96.2334	18.37	3949.65	4.78
Pipe 216	1060.6345	16.53	3189.69	4.77
Pipe 217	49.0572	16.53	3212.34	4.8
Pipe 218	296.2516	16.53	3263.83	4.88
Pipe 219	364.5279	16.53	3316.53	4.96
Pipe 220	2.7838	18.37	3782.05	4.58
Pipe 221	1490.3178	16.18	2941.9	4.59
Pipe 222	3.2885	16.53	2982.07	4.46
Pipe 223	3.1617	16.53	3012.27	4.5
Pipe 224	3.0089	16.53	3042.47	4.55
Pipe 225	2.8049	16.53	3057.57	4.57
Pipe 226	4.0009	16.53	3080.22	4.6
Pipe 227	378.9491	16.18	2778.82	4.34
Pipe 228	254.2107	14.38	2334.81	4.61
Pipe 229	341.6278	14.38	2448.06	4.84
Pipe 230	678.0092	14.38	2475.99	4.89
Pipe 231	504.297	16.18	2602.15	4.06
Pipe 232	316.6893	14.38	2280.07	4.5
Pipe 233	295.3073	14.38	2264.97	4.47
Pipe 234	170.5942	14.38	2287.62	4.52
Pipe 235	328.7811	14.38	2046.03	4.04
Pipe 236	4.8096	14.38	2087.55	4.12
Pipe 237	1387.9657	14.38	2102.65	4.15
Pipe 238	692.8657	14.38	2004.51	3.96
Pipe 239	798.0558	12.44	1951.66	5.15
Pipe 240	878.1717	22.44	4036.5	3.27
Pipe 241	1920.5127	7.92	0	0
Pipe 242	2010.4086	7.92	0	0
Pipe 243	153.3355	50.477	27954.17	4.48
Pipe 244	557.178	50.477	26882.09	4.31
Pipe 245	690.9478	44.87	20963.67	4.25
Pipe 246	751.1866	8.06	637.97	4.01
Pipe 247	1094.6003	8.06	637.97	4.01
Pipe 248	0.4587	4.21	37.75	0.87
Pipe 249	1.586	4.21	151	3.48
Pipe 250	1.4119	4.21	181.2	4.18
Pipe 251	170.3821	8.06	528.95	3.33
Pipe 252	7.9867	8.06	483.95	3.04
Pipe 253	2190.992	6.19	423.55	4.52
Pipe 254	758.073	8.06	513.85	3.23
Pipe 255	4.8759	6.19	393.35	4.19

Pipe 256	1525.5318	10.05	1072.08	4.34
Pipe 257	1051.5314	6.19	264.25	2.82
Pipe 258	629.2065	6.19	422.8	4.51
Pipe 259	3.2589	8.06	687.04	4.32
Pipe 260	0.2184	4.21	128.35	2.96
Pipe 261	1740.9495	10.05	1122.3	4.54
Pipe 262	2084.0835	7.92	486.97	3.17
Pipe 263	507.2172	6.08	373.72	4.13
Pipe 264	79.8225	6.08	396.37	4.38
Pipe 265	7.4521	6.08	373.72	4.13
Pipe 266	847.781	6.08	265.76	2.94
Pipe 267	29.5688	6.08	273.31	3.02
Pipe 268	100.8141	6.08	328.42	3.63
Pipe 269	18.1285	6.08	343.52	3.8
Pipe 270	1567.5896	6.08	212.91	2.35
Pipe 271	132.9684	4.13	212.91	5.1
Pipe 272	132.1042	8.06	486.97	3.06
Pipe 273	315.7279	6.08	373.72	4.13
Pipe 274	153.3799	6.08	265.76	2.94
Pipe 275	72.1378	6.08	212.91	2.35
Pipe 276	365.617	4.13	212.91	5.1
Pipe 277	833.6024	10.05	774.63	3.13
Pipe 278	516.1818	10.05	747.13	3.02
Pipe 279	2058.4679	10.05	730.63	2.95
Pipe 280	602.738	10.05	741.63	3
Pipe 281	1022.7237	10.05	706.65	2.86
Pipe 282	3725.1013	10.05	627.78	2.54
Pipe 283	50.5676	10.05	647.25	2.62
Pipe 284	0.7011	8.06	668.15	4.2
Pipe 285	340.5727	10.05	654.4	2.65
Pipe 286	493.8555	10.05	676.4	2.74
Pipe 287	1.8811	10.05	684.65	2.77
Pipe 288	1134.7416	8.06	598.63	3.76
Pipe 289	824.4135	8.06	609.08	3.83
Pipe 290	1389.9775	8.06	598.63	3.76
Pipe 291	1532.4926	6.08	411.4	4.55
Pipe 292	1010.0169	4.13	122.15	2.93
Pipe 293	308.2974	4.13	66.77	1.6
Pipe 294	176.9193	4.13	69.52	1.66
Pipe 295	27.3365	4.13	112.25	2.69
Pipe 296	590.195	4.13	120.23	2.88
Pipe 297	125.1071	4.05	58.52	1.46
Pipe 298	701.5813	4.05	40.7	1.01

Pipe 299	138.0798	4.05	44.77	1.11
Pipe 303	1216.531	8.06	598.63	3.76
Pipe 304	2186.9112	8.06	598.63	3.76
Pipe 305	237.1998	7.92	588.45	3.83
Pipe 306	4.2012	7.92	574.7	3.74
Pipe 307	4.319	7.92	580.2	3.78
Pipe 308	680.7316	7.92	590.65	3.85
Pipe 309	15.3172	4.13	66.77	1.6
Pipe 310	548.6928	4.13	58.52	1.4
Pipe 311	717.2351	4.05	40.7	1.01
Pipe 312	1089.6186	4.05	24.2	0.6
Pipe 313	697.7943	4.05	16.5	0.41
Pipe 314	1158.4463	6.19	0	0
Pipe 315	570.1612	6.19	-15.38	0.16
Pipe 316	1216.43	6.19	0.01	0
Pipe 317	2025.4717	6.19	15.39	0.16
Pipe 318	2472.3432	6.19	15.38	0.16
Pipe 319	329.4413	6.19	0	0
Pipe 320	311.783	6.19	0.01	0
Pipe 321	68.1157	6.19	0.01	0
Pipe 322	830.3152	6.19	0	0
Pipe 323	419.241	6.19	0	0
Pipe 324	61.4558	6.19	0	0
Pipe 325	395.9871	6.19	0	0
Pipe 326	526.2339	5.96	0	0
Pipe 327	322.9342	4.13	148.29	3.55
Pipe 328	1074.3286	4.13	142.79	3.42
Pipe 329	1052.4366	4.13	33.39	0.8
Pipe 330	7.1328	4.13	90.54	2.17
Pipe 331	1080.0131	4.13	72.44	1.73
Pipe 332	1047.687	4.13	52.25	1.25
Pipe 333	4.1514	4.13	24.75	0.59
Pipe 334	398.7564	4.13	153.29	3.67
Pipe 335	578.8286	4.13	148.29	3.55
Pipe 336	881.9768	11.71	1508.14	4.49
Pipe 337	123.4026	11.46	1485.49	4.62
Pipe 338	110.8772	11.46	1226.84	3.82
Pipe 339	4.1322	11.46	1352.92	4.21
Pipe 340	2.981	11.46	1322.72	4.11
Pipe 341	531.4558	11.46	1281.2	3.99
Pipe 342	11.6172	11.46	1386.89	4.31
Pipe 343	240.1771	11.46	1415.28	4.4
Pipe 344	125.5416	11.46	1441.7	4.48

Pipe 345	74.2241	11.46	1462.84	4.55
Pipe 346	3.9429	11.46	1146.81	3.57
Pipe 347	100.312	11.46	985.62	3.07
Pipe 348	179.0795	9.66	879.94	3.85
Pipe 349	0.9627	9.66	919.19	4.02
Pipe 350	98.5857	9.66	889.75	3.89
Pipe 351	258.0087	9.66	944.1	4.13
Pipe 352	128.9873	11.46	1118.12	3.48
Pipe 353	226.5619	11.46	1053.72	3.28
Pipe 354	28.2372	9.66	879.94	3.85
Pipe 355	1056.9887	9.66	717.62	3.14
Pipe 356	7.8577	9.66	747.82	3.27
Pipe 357	1961.8867	5.96	415.25	4.78
Pipe 358	289.2241	7.75	685.53	4.66
Pipe 359	94.006	4.05	181.2	4.51
Pipe 360	5.2363	6.08	335.89	3.71
Pipe 361	199.5133	6.08	381.19	4.21
Pipe 362	1864.7421	6.08	449.14	4.96
Pipe 363	2.305	5.96	215.09	2.47
Pipe 364	3.2007	5.96	230.19	2.65
Pipe 365	194.8761	5.96	252.84	2.91
Pipe 366	0.4544	5.96	207.54	2.39
Pipe 367	1013.6057	5.96	275.49	3.17
Pipe 368	1393.7133	4.05	196.22	4.89
Pipe 369	33.0228	4.21	117.02	2.7
Pipe 370	4.3743	6.19	269.91	2.88
Pipe 371	19.6284	6.21	207.62	2.2
Pipe 372	93.8517	6.19	359.83	3.84
Pipe 373	778.724	8.06	495.73	3.12
Pipe 374	522.7932	8.06	635.33	4
Pipe 375	4.0009	16.53	3140.62	4.7
Pipe 376	0.4587	4.21	22.65	0.52
Pipe 377	1052.4366	4.13	4.79	0.11
Pipe 378	1013.6057	6.08	298.14	3.29
Pipe 379	11.0187	14.96	2487.86	4.54
Pipe 380	364.5279	18.37	3765.67	4.56
Pipe 381	5967.43	58.891	-33175.05	3.91
Pipe 382	5394.67	58.89	-33175.05	3.91
Pipe 383	1	58.89	-33175.05	3.91
Pipe 384	1	8.06	604	3.8
Pipe 385	1	9.87	906	3.8
Pipe 386	1	4.05	151	3.76
Pipe 387	1	9.55	1132.5	5.07

Pipe 388	1000	5.96	377.5	4.34
Pipe 389	1	5.96	377.5	4.34

APPENDIX C
PIPE BUDGET ESTIMATES FROM VENDORS

From: **Theetge, Mark A** <Mark.Theetge@hdsupply.com>
Date: Thu, Sep 15, 2016 at 8:55 AM
Subject: RE: Swalley Pipe Lengths
To: Kevin Crew <blackrockci@gmail.com>

Great to hear! I have attached basic pricing that I may end up refining for my own interest and share that later. The cost that I have used is based on actual footage which could include partial loads. The freight cost I have included is for the furthest distance which would be Kingman AZ. I have also included cost for a tech and equipment to weld the material. I used current project pricing levels and a conservative mark up about 12%. All of this could change with the market so for basic estimation only!!

If it was my district I might want to include cost for fusion equipment purchase in the cost of the project. For material 24” and down or possibly 18” and down based on the cooperation of other districts. Given Marc has a 36” machine and since there is not a whole lot of larger pipe it would make sense to rent possibly. Just a thought?

Thanks,

Mark A. Theetge

Fusible Plastics Specialist

HD Supply WaterWorks

M 503 341 3614

F 855 222-0361

	Proposed DR32.5		Proposed DR26		Proposed DR21	
54in	0.00		0.00		0.00	
48in	2,094.13	$105.50	0.00		0.00	
42in	4,559.92	$81.92	0.00		0.00	
36in	6,708.70	$62.89	0.00		0.00	
34in	1,932.25	$54.73	0.00		0.00	
32in	830.58	$4,703	0.00		0.00	
30in	2,558.88	$42.15	0.00		0.00	
28in	3,085.71	$37.05	1,664.91	$44.98	0.00	
26in	0.00	$0.00	2,745.63	$39.95	0.00	
24in	5,727.49	$26.86	2,533.51	$32.98	0.00	
22in	0.00	$0.00	0.00		0.00	
20in	6,350.76	$19.45	1,282.68	$24.15	0.00	
18in	5,644.83	$15.41	347.84	$23.97	319.85	$28.14
16in	2,295.26	$15.27	1,926.59	$15.61	3,038.68	$22.13
14in	9,163.29	$9.48	1,119.91	$12.78	1,565.95	$13.77
12in	8,351.11	$7.81	4,588.71	$9.56	2,437.56	$11.35
10in	9,020.98	$5.82	2,197.32	$7.23	2,380.32	$8.75
8in	13,531.69	$3.93	4,736.81	$4.68	525.96	$10.16

Appendix B

Other Supporting Information

B.1 Supporting Calculations for Water Resources

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

Table B-1. ODFW Instream Water Rights for the Deschutes River and the Crooked 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	59776	11/3/1983	300	300	300	300	300	300	300	300	300	300	300	300
Deschutes River	Little Deschutes	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	Round Butte Reservoir	Pending	9/24/1990	250	250	250	250	250	250	250	250	250	250	250	250
Crooked River	Bowman Dam	Mouth	Pending	10/11/1990	75	75/150	225	225	225	150	75	75	75	75	75	75

Deschutes River below Crane Prairie Reservoir

This appendix subsection presents supporting calculations used when evaluating the affected environment with respect to water resources in the Deschutes River below Crane Prairie Reservoir. Streamflows from the 1994 to 2014 water years represent average baseline conditions. Streamflows in the October 2016 to September 2017 water year represent modified baseline conditions following the Stipulated Settlement Agreement with the Center for Biological Diversity. Data are sourced from Oregon Water Resources Department (OWRD) Gauge No. 14054000.

Table B-2. Deschutes River Below Crane Prairie Reservoir—Streamflow Prior to the 2016 Settlement Agreement and Daily Average Streamflow Following the 2016 Settlement Agreement

Month	Low Streamflows (cfs) Prior to the 2016 Settlement Agreement[1]	Lower Bar	Daily Average Streamflows (cfs) Prior to the 2016 Settlement Agreement[2]	Upper Bar	High Streamflows (cfs) Prior to the 2016 Settlement Agreement[3]	Daily Average Streamflows (cfs) Following the 2016 Settlement Agreement
Oct	151	94	245	74	319	196
Nov	95	82	177	63	239	204
Dec	98	61	159	41	200	179
Jan	110	38	148	61	209	178
Feb	89	36	125	64	189	148
Mar	79	46	125	47	172	80
Apr	89	54	143	54	197	271
May	196	89	285	127	412	410
Jun	239	148	387	71	458	430
Jul	239	129	368	108	476	319
Aug	231	80	311	128	439	434
Sep	208	75	283	99	382	461

Notes:

[1] Data are derived from water years 1994-2014 (80% Exceedance).

[2] Data are derived from water years 1994-2014 (50% Exceedance).

[3] Data are derived from water years 1994-2014 (20% Exceedance).

Deschutes River below Wickiup Reservoir

This appendix subsection presents supporting calculations used when evaluating the affected environment with respect to water resources in the Deschutes River below Wickiup Reservoir. Streamflows from the 1994 to 2014 water years represent average baseline conditions. Streamflows in the October 2016 to September 2017 water year represent modified baseline conditions following the Stipulated Settlement Agreement with the Center for Biological Diversity. Data are sourced from OWRD Gauge No. 14056500.

Table B-3. Deschutes River Below Wickiup Reservoir—Streamflow Prior to the 2016 Settlement Agreement and Daily Average Streamflow Following the 2016 Settlement Agreement

Month	Low Streamflows (cfs) Prior to the 2016 Settlement Agreement[1]	Lower Bar	Daily Average Streamflows (cfs) Prior to the 2016 Settlement Agreement[2]	Upper Bar	High Streamflows (cfs) Prior to the 2016 Settlement Agreement[3]	Daily Average Streamflows (cfs) Following the 2016 Settlement Agreement
Oct	36	263	299	545	844	111
Nov	30	17	47	238	284	119
Dec	30	26	56	321	376	103
Jan	30	57	87	362	449	105
Feb	31	97	128	397	525	101
Mar	32	220	252	262	514	99
Apr	338	244	582	223	805	617
May	824	266	1090	240	1330	786
Jun	1000	270	1270	160	1430	1080
Jul	1340	110	1450	150	1600	1460
Aug	1290	130	1420	90	1510	1590
Sep	967	203	1170	170	1340	1150

Notes:

[1] Data are derived from water years 1994-2014 (80% Exceedance).

[2] Data are derived from water years 1994-2014 (50% Exceedance).

[3] Data are derived from water years 1994-2014 (20% Exceedance).

Deschutes River at Benham Falls

This appendix subsection presents supporting calculations used when evaluating the affected environment with respect to water resources in the Deschutes River at Benham Falls. Streamflows from the 1994 to 2014 water years represent average baseline conditions. Streamflows in the October 2016 to September 2017 water year represent modified baseline conditions following the Stipulated Settlement Agreement with the Center for Biological Diversity. Data are sourced from OWRD Gauge No. 14064500.

Table B-4. Deschutes River at Benham Falls—Streamflow Prior to the 2016 Settlement Agreement and Daily Average Streamflow Following the 2016 Settlement Agreement

Month	Low Streamflows (cfs) Prior to the 2016 Settlement Agreement[1]	Lower Bar	Daily Average Streamflows (cfs) Prior to the 2016 Settlement Agreement[2]	Upper Bar	High Streamflows (cfs) Prior to the 2016 Settlement Agreement[3]	Daily Average Streamflow (cfs) Following the 2016 Settlement Agreement
Oct	504	375	879	481	1360	640
Nov	460	76	536	339	875	596
Dec	492	102	594	476	1070	573
Jan	501	205	706	434	1140	577
Feb	540	191	731	499	1230	688
Mar	559	265	824	456	1280	841
Apr	954	316	1270	270	1540	1500
May	1600	250	1850	140	1990	1700
Jun	1660	230	1890	210	2100	1790
Jul	1850	120	1970	120	2090	1980
Aug	1820	90	1910	110	2020	2010
Sep	1450	230	1680	170	1850	1640

Notes:

[1] Data are derived from water years 1994-2014 (80% Exceedance).

[2] Data are derived from water years 1994-2014 (50% Exceedance).

[3] Data are derived from water years 1994-2014 (20% Exceedance).

Deschutes River below North Canal Dam

This appendix subsection presents supporting calculations used when evaluating the affected environment with respect to water resources in the middle Deschutes River below North Canal Dam. Streamflows from the 1994 to 2014 water years represent average baseline conditions. Streamflows in the October 2016 to September 2017 water year represent modified baseline conditions following the Stipulated Settlement Agreement with the Center for Biological Diversity. Data are sourced from OWRD Gauge No. 14070500.

Table B-5. Deschutes River Below North Canal Dam—Streamflow Prior to the 2016 Settlement Agreement and Daily Average Streamflow Following the 2016 Settlement Agreement

Month	Low Streamflows (cfs) Prior to the 2016 Settlement Agreement[1]	Lower Bar	Daily Average Streamflows (cfs) Prior to the 2016 Settlement Agreement[2]	Upper Bar	High Streamflows (cfs) Prior to the 2016 Settlement Agreement[3]	Daily Average Streamflows (cfs) Following the 2016 Settlement Agreement
Oct	504	447	537	40	577	350
Nov	90	29	533	21	554	464
Dec	504	18	506	27	533	537
Jan	488	15	498	186	684	610
Feb	483	88	556	71	627	569
Mar	468	98	689	255	944	682
Apr	591	187	662	298	959	298
May	474	12	113	10	123	107
Jun	101	7	124	10	133	108
Jul	117	3	128	2	130	103
Aug	125	4	123	3	126	100
Sep	119	13	139	48	187	105

Notes:

[1] Data are derived from water years 1994-2014 (80% Exceedance).

[2] Data are derived from water years 1994-2014 (50% Exceedance).

[3] Data are derived from water years 1994-2014 (20% Exceedance).

Crooked River below Osborne Canyon

This appendix subsection presents supporting calculations used when evaluating the affected environment with respect to water resources in the Crooked River below Osborne Canyon. Streamflows from the 2003 to 2014 water years represent average baseline conditions. Data are sourced from OWRD Gauge No. 14087380.

Table B-6. Crooked River below Osborne Canyon—Daily Average Streamflow Between 2003–2014

Month	Low Streamflows (cfs)[1]	Lower Bar	Daily Average Streamflows (cfs)[2]	Upper Bar	High Streamflows (cfs)[3]
Oct	211	46	257	46	303
Nov	188	21	209	38	246
Dec	176	26	202	47	249
Jan	181	45	226	298	524
Feb	195	32	227	271	498
Mar	204	64	268	493	761
Apr	345	299	644	1076	1720
May	159	241	400	495	895
Jun	142	95	237	183	419
Jul	110	31	141	43	184
Aug	117	46	163	35	198
Sep	177	53	230	47	276

Notes:

[1] Data are derived from water years 2003-2014 (80% Exceedance).

[2] Data are derived from water years 2003-2014 (50% Exceedance).

[3] Data are derived from water years 2003-2014 (20% Exceedance).

Crooked River below Opal Springs

This appendix subsection presents supporting calculations used when evaluating the affected environment with respect to water resources in the Crooked River below Opal Springs. Streamflows from the 1984 to 2014 water years represent average baseline conditions. Data are sourced from OWRD Gauge No. 14087400.

Table B-7. Crooked River below Opal Springs—Daily Average Streamflow Between 1984–2014

Month	Low Streamflows (cfs)[1]	Lower Bar	Daily Average Streamflows (cfs)[2]	Upper Bar	High Streamflows (cfs)[3]
Oct	1310	60	1370	90	1460
Nov	1300	40	1340	30	1370
Dec	1280	40	1320	80	1400
Jan	1280	50	1330	152	1482
Feb	1270	80	1350	0	1350
Mar	1280	150	1430	786	2216
Apr	1280	350	1630	1050	2680
May	1220	130	1350	550	1900
Jun	1210	80	1290	190	1480
Jul	1200	50	1250	50	1300
Aug	1210	50	1260	70	1330
Sep	1240	90	1330	80	1410

Notes:

[1] Data are derived from water years 1984-2014 (80% Exceedance).

[2] Data are derived from water years 1984-2014 (50% Exceedance).

[3] Data are derived from water years 1984-2014 (20% Exceedance).

B.2 Allocation of Conserved Water Program

This appendix section presents information on the State of Oregon's Allocation of Conserved Water Program. Oregon Revised Statutes 537.455-500 authorize this program. Per OWRD (2017),

> The Allocation of Conserved Water Program allows a water user who conserves water to use a portion of the conserved water on additional lands, lease or sell the water, or dedicate the water to instream use. Use of this program is voluntary and provides benefits to both water right holders and instream values.
>
> The statutes authorizing the program were originally passed by the Legislative Assembly in 1987. The primary intent of the law is to promote the efficient use of water to satisfy current and future needs--both out-of-stream and instream. The statute defines conservation as "the reduction of the amount of water diverted to satisfy an existing beneficial use achieved either by improving the technology or method for diverting, transporting, applying or recovering the water or by implementing other approved conservation measures."
>
> In the absence of Department approval of an allocation of conserved water, water users who make the necessary investments to improve their water use efficiency are not allowed to use the conserved water to meet new needs; instead any unused water remains in the stream where it is available for the next appropriator. In exchange for granting the user the right to "spread" a portion of the conserved water to new uses, the law requires allocation of a portion to the state for instream use.
>
> After mitigating the effects on any other water rights, the Water Resources Commission allocates 25 percent of the conserved water to the state (for an instream water right) and 75 percent to the applicant, unless more than 25 percent of the project costs come from federal or state non-reimbursable sources or the applicant proposes a higher allocation to the state. A new water right certificate is issued with the original priority date reflecting the reduced quantity of water being used with the improved technology. A certificate[sic] is issued for the state's instream water right, and, if requested, a certificate is issued for the applicant´s portion of the conserved water. The priority dates for the state's instream certificate and the applicant's portion of conserved water must be the same date and will be either the same date as the original water right or one minute[sic] junior to the original right.

References

Oregon Water Resources Department (OWRD). (2017). *Allocation of Conserved Water*. Retrieved from: http://www.oregon.gov/owrd/pages/mgmt_conserved_water.aspx. Accessed: November 10, 2017.