Preliminary Investigative Report for the Arnold Irrigation District Infrastructure Modernization Project

Prepared by Farmers Conservation Alliance

Submitted to Natural Resources Conservation Service

Spring 2019

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Acronyms

°C	degree Celsius
AID or District	Arnold Irrigation District
BGEPA	Bald and Golden Eagle Protection Act
cfs	cubic feet per second
CWA	Clean Water Act
EA	Environmental Assessment
EFU	Exclusive Farm Use
ESA	Endangered Species Act
FCA	Farmers Conservation Alliance
HDPE	high-density polyethylene
HUC	Hydrologic Unit Code
IPaC	Information for Planning and Conservation
MBTA	Migratory Bird Treaty Act
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NRCS	Natural Resources Conservation Service
OAR	Oregon Administrative Rule
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
ODSL	Oregon Department of State Lands
ORS	Oregon Revised Statute
OWRD	Oregon Water Resources Department
O&M	operations and maintenance
PCE	Primary Constituent Element
PIR	Preliminary Investigative Report
PVC	polyvinyl chloride
Reclamation	United States Bureau of Reclamation
RM	river mile
ROW	right-of-way
SHPO	State Historic and Preservation Office

SIP	System Improvement Plan
UGB	Urban Growth Boundary
U.S./US	United States
U.S.C.	United States Code
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
Watershed Plan-EA	Watershed Plan-Environmental Assessment

1 Introduction

Aging infrastructure, growing populations, shifting rural economies, and changing climate conditions have increased pressure on water resources across the western United States (US). Within the Deschutes Basin, irrigated agriculture (the primary out-of-stream water use in the area) relies on infrastructure that can be over 100-years old to store, divert, and deliver water to farms, ranches, and other users across the region. Irrigation canals have become a public safety risk, and they require increasing maintenance due to their age. These aging canals contribute to water supply insecurity for out-of-stream users and limit streamflow, affecting water quality and instream habitat in the Deschutes River and its tributaries. To address these issues associated with its aging infrastructure, Arnold Irrigation District (herein referred to as AID or the District), must invest increasing amounts of funding in canal maintenance and modernization.

Approximately 39 percent of water passing through AID's open canal and laterals[1] currently seeps into the area's porous, volcanic soil prior to reaching farms. Modernizing AID's aging water distribution system would increase system efficiency and allow AID to divert less water. Modernizing aging irrigation infrastructure offers an opportunity to enhance aquatic species habitat, reduce public safety risks, and support and maintain existing agricultural land use through enhanced water supply reliability.

In total, the District operates and maintains approximately 39 miles of main canal and laterals, including 7.5 miles of piped lateral segments. The District proposes to modernize its infrastructure over time as it is deemed affordable by the District Board, by converting the remaining 31.5 miles of open canal and laterals and aging aerial flume to pipe.

Piping would result in pressurized water deliveries;[2] help to alleviate local and watershed-scale water quality, instream flow, and habitat issues; and provide financial and operational benefits to the District and its patrons. Specific details regarding the District's proposed project are available in its System Improvement Plan (SIP) (AID 2017) and are further described in Section 7.3.1.

2 Consultation and Participation with Local Partners, Agencies and Tribes

This Preliminary Investigative Report (PIR) was prepared to introduce the AID Infrastructure Modernization Project (herein referred to as the "project"), introduce the project's goals and objectives, and provide the information necessary for all stakeholders to evaluate the project and guide development. This project development process is designed to work collaboratively with partners, agencies, tribes, and other stakeholders so that there is transparency, ownership, and cooperation towards a solution that fits within the framework of the purpose and need for action (Section 3). There are many organizations involved in the Deschutes Basin; therefore, during the

1 "Laterals" refer to canals that branch off from Arnold's main canal.

2 Piping would provide varying levels of pressurization depending on the section of the system. In some sections full pressurization would not be possible but there would be a reduction in patron pumping.

development of this PIR, project sponsors conducted initial consultation with natural resource agencies and other stakeholders. AID and its partners will conduct further comprehensive public scoping prior to the preparation of the Watershed Plan-Environmental Assessment (Watershed Plan-EA) as described in the scope of the Environmental Assessment (Section 4).

2.1 Sponsors, Local Partners, Agencies and Tribal Participation

For the purposes of the project, sponsors are the agencies involved in scheduling, facilitating communication, project design and development, and document writing. The primary sponsor for the project is:

- Deschutes Basin Board of Control

Supporting sponsors for the project are:

- AID
- Natural Resources Conservation Service (NRCS)

Local entities that have land ownership or a shared resources associated with the project:

- United States Forest Service (USFS)

Agencies that are involved with the project include the following state and federal resource agencies:

- Oregon Department of Fish and Wildlife (ODFW)
- Oregon Water Resources Department (OWRD)
- Oregon Parks and Recreation Department (OPRD)
- State Historic Preservation Office (SHPO)
- Oregon Department of Environmental Quality (ODEQ)
- U.S. Fish and Wildlife Service (USFWS)
- U.S. Bureau of Land Management (BLM)
- U.S. Bureau of Reclamation (Reclamation)

Tribes consulted regarding the project include:

- Confederated Tribes of Warm Springs

Other stakeholders for this project are any interested parties. These include, but are not limited to:

- City of Bend
- Deschutes County
- Upper Deschutes Watershed Council
- Deschutes River Conservancy
- Oregon Governor's Office
- Deschutes Soil and Water Conservation District
- WaterWatch of Oregon
- Trout Unlimited
- Central Oregon Land Watch
- Coalition for the Deschutes

- Interested public
- Patrons of the District

2.2 Permits and Compliance

Partners anticipate that this project will utilize NRCS federal dollars for funding. Therefore, it will require a Watershed Plan-EA. This process will include compliance with all relevant state and federal permits and regulations, including Section 106 of the National Historic Preservation Act (NHPA) of 1966 (managed by SHPO), Section 7 of the Endangered Species Act (ESA) (managed by the National Oceanic and Atmospheric Administration Fisheries and USFWS), and Sections 404 and 401 of the Clean Water Act (CWA) (managed by the Oregon Department of State Lands [ODSL] and U.S. Army Corps of Engineers [USACE]).

2.3 Mitigation

Following consultation with SHPO and the public scoping process, there may be a requirement for mitigation for loss of historic irrigation canals or other cultural resources. Mitigation for any potential impacts of the project will be outlined, designed, and completed following consultation with the corresponding agencies.

3 Purpose and Need for Action

The purpose of this project is to improve water conservation, water delivery reliability, and public safety on District-owned canals and laterals.

Federal action is needed in addressing the following watershed problems and resource concerns: water loss in District conveyance systems, water delivery and operations inefficiencies, instream flow for fish and aquatic habitat, and risks to public safety from open irrigation canals. The District has begun to address these concerns as funding opportunities allow. These funding opportunities are not reasonably certain to occur if the District continues to follow their current approach. Federal action would enable the District to follow a strategic, comprehensive approach to securing additional funding and addressing these issues, which are discussed below in more depth.

3.1 Watershed Problems and Resource Concerns

3.1.1 Water Loss in District Conveyance Systems

Conserving water is a key objective of the District. The District has already invested in segments of lateral piping projects (approximately 7.5 miles of the total system) and, as funds become available, generally plans to continue to pipe the majority of its system. Currently, the District's remaining antiquated canal infrastructure loses about 39 percent of ordinary-peak flow to seepage and other conveyance inefficiencies. Details of water losses and demands can be found in the appendix of the District's SIP (AID 2017). Water losses due to inefficient conveyance systems can prevent the District from delivering to its patrons the full rate and duty associated with each water right.

3.1.2 Water Delivery and Operation Inefficiencies

The District's canals and laterals do not transport and deliver water as precisely, accurately, or efficiently as a modernized system would. Over the years, the District has developed rigorous measurement methods that have greatly increased District efficiency; however, high seepage loss rates make it challenging to deliver the patrons' desired delivery rate throughout the irrigation season causing delivery shortages during the peak season (May 15 through September 14).

In addition to seepage and evaporation losses, the geology of the District's earthen canals results in infrastructure failures (e.g., sinkholes) and long recharge periods, making it difficult to efficiently deliver sufficient volumes of water to the ends of the District's laterals for patron use. Patrons are required to request changes to water deliveries 36 hours in advance; without pressurization, District patrons incur approximately $331,000 per year in pumping costs. As a result of aging infrastructure causing system failures and more intensive management of District infrastructure and deliveries, the District's maintenance and operation costs continue to increase.

3.1.3 Instream Flow for Fish and Aquatic Habitat

The Deschutes River and its tributaries experience low streamflow every year due to the storage and diversion of water for agricultural use, and resource agencies have identified streamflow as a primary concern in the river (UDWC 2014). The Deschutes River and its tributaries support many fish, bird, and wildlife species. Among these are several sensitive species such as steelhead trout, redband trout, and Chinook salmon, as well as Oregon spotted frog and bull trout listed as threatened under the ESA. For many of these species, low streamflow in the Deschutes River and its tributaries limit habitat and accessing habitat that would otherwise be available. Reduced habitat associated with low streamflow increases competition between populations, which often favors non-native brown trout over native redband trout and can concentrate fish populations and increase susceptibility to predators and disease.

Low streamflow in late fall, winter, and early spring associated with upstream reservoir storage limits riparian vegetation in the Deschutes River (RDG 2005). Low streamflow along these reaches can expose the channel bed and river banks, facilitating increased erosion and fine sediment delivery following freeze-thaw processes and increased spring streamflow (RDG 2005). As riparian areas become hydrologically disconnected from their adjacent stream due to consistently low streamflow, they lose many of their ecological functions. Reestablishing a more natural hydrologic regime in these reaches allows the river channel to supply water to riparian areas via infiltration through channel banks, thus enhancing riparian function by facilitating processes such as hyporheic exchange, physical and chemical transformations, and supporting riparian plant communities and aquatic habitat (National Research Council 2002).

3.1.4 Risks to Public Safety

Open canals pose a risk to public safety during the irrigation season. In addition to multiple instances of injury, several drowning deaths or near-drowning instances have occurred in adjacent district canals in 1996, 1997, 2004, 2016, and 2018 (Flowers 2004; Matsumoto 2016; Beechem 2018). The District's location in a partly urbanized area heightens the potential for an accident, as the canals

and laterals pass through urban areas, rural residences, private lands, public lands, and irrigated fields.

During the summer, water depths in the District's canal and laterals range between 2 and 4 feet, with velocities up to 5 cubic feet per second (cfs). These conditions make it difficult for a healthy, strong adult to stand in or climb out of a canal without assistance. A child or non/weak-swimmer would have an even higher risk of drowning in a canal with these attributes. If a person or animal falls into a canal, they could have serious difficulty gaining hold on the banks in order to climb out due to the volume and speed of the moving water. Barriers or fences at the top banks of the canals are not currently installed.

Deschutes County was the fastest growing county in Oregon in 2015 based on the Oregon Population Report (PSU 2015); these public safety risks will continue to grow as urbanization expands into rural areas such as AID's service area.

3.2 Watershed and Resource Opportunities

The following is a list of resource opportunities that would be realized through implementation of the project. Quantification of these opportunities is provided in other sections of this report and in subsequent studies and reports, as appropriate.

- Improve irrigation water management and irrigation water delivery to AID patrons by improving conveyance efficiencies and pressurizing deliveries.
- Improve streamflow, enhance water quality, and enhance aquatic habitat availability within the Deschutes River from the Crane Prairie Dam (RM 226) to Lake Billy Chinook (RM 120).
- Minimize the potential for injury and loss of life associated with the open AID canal and laterals.
- Reduce the operations and maintenance (O&M) involved in delivering irrigation water to AID patrons.
- Reduce energy costs by reducing use or size of individual on-farm irrigation pumps.

4 Scope of the Environmental Assessment

NRCS and AID will conduct public scoping as the National Environmental Policy Act (NEPA) review process moves forward. Public scoping will seek additional issues of economic, environmental, cultural, and social importance in the watershed. NRCS and AID will organize agency and public scoping meetings that will provide an opportunity to review and evaluate the project alternatives, express concerns, and gain further information. Following the scoping process, a Watershed Plan-EA will be drafted to determine if the proposed project meets the program criteria found in Title 390, National Watershed Program Manual, Part 500, Subpart A, Sections 500.3 and 500.4.

5 Affected Environment–Existing Conditions

5.1 Project Setting

The District is located in central Oregon, in the northern half of Deschutes County, and is situated south of the City of Bend. The District contains 4,384 irrigated acres used by 646 patrons. The District is about 3.5 miles long (north to south) and 6.5 miles wide (east to west). The main point of diversion is at the Arnold Diversion on the Deschutes River (RM 174.6). There are an additional six private direct withdrawals from the Deschutes River that irrigate 30 acres of the District.

The District's service area and the project are located in six subwatersheds which cover a total of 225,875 acres (Table 5-1). These subwatersheds comprise the AID Watershed Planning Area and are located within the Upper Deschutes watershed (Hydrologic Unit Code [HUC] 17070301) (Figure 5-1). Also referenced in the document is the "project area". The project area is defined as the canal and laterals to be modernized, as well as, associated rights-of-way (ROWs) and/or easements where construction would occur.

Table 5-1. Arnold Irrigation District Watershed Planning Area

12-digit Hydrologic Unit Code	Name	Area (acres)
170703010405	Lava Island Falls-Deschutes River	12,518
170703050805	Reynolds Pond	44,407
170703010406	Overturf Butte-Deschutes River	31,374
170703010805	Odin Falls-Deschutes River	66,353
170703010801	Deschutes Junction	47,337
170703050901	Central Oregon Irrigation Canal	23,886
	Total	**225,875**

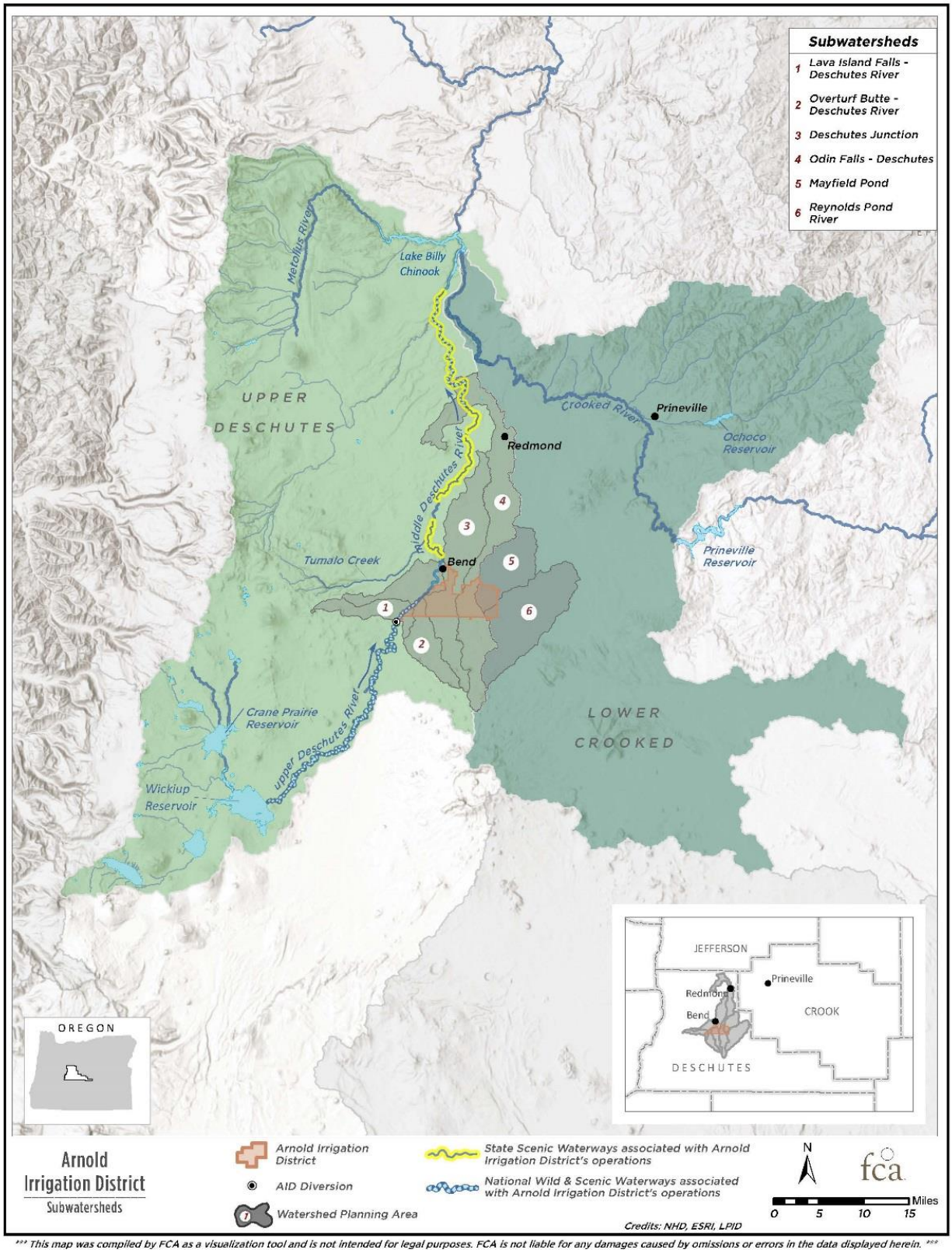


Figure 5-1. Arnold Irrigation District Watershed Planning Area.

5.2 Current Infrastructure

The District operates an intake structure, the Arnold Canal Diversion, on the Deschutes River (RM 174.6). Once diverted, water passes through a radial gate that regulates the intake flow rate and through a vertical flat-plate fish screen into the Arnold Canal. Flows into the system are measured by the OWRD's gauge number 14065500; the District is in the process of adding remote measurement and control systems just below its fish screen. The AID main canal (the Arnold Canal) conveys water generally northeast, starting with an approximately 1-mile-long aerial flume and trestle system and then transitioning to a typical earthen and rock substrate open canal. After the flume, the Arnold Canal runs approximately 12 miles from west to east, terminating in the Brandon and Sundance Laterals. Along the way it delivers to patrons and multiple laterals.

AID has already piped several laterals stemming from the Arnold Canal, including the M&M, Estes, Rickard, Omahandro, and DWC-1 and DWC-2 laterals. Several laterals that branch off the Arnold Canal have had some sections piped but primarily remain open, including the North, Goat Farm, Ladera, Roach, Brandon, Gosney, Rastovitch, Penhollow, McArdle, and Sundance laterals. In total, AID has already piped approximately 22 percent of its system. Figure 5-2 provides an illustration of AID's current infrastructure.

Multiple privately owned conveyances, including both pipes and open canals, stem off of the District's system. Patron turnouts from the District's Arnold Canal and laterals to these private conveyances are all gate-regulated and weir-measured. The District field staff regulates flows to each system lateral and patron turnout. There are 30 acres within the District that are irrigated by pumps directly from the river and are monitored and metered by the District.

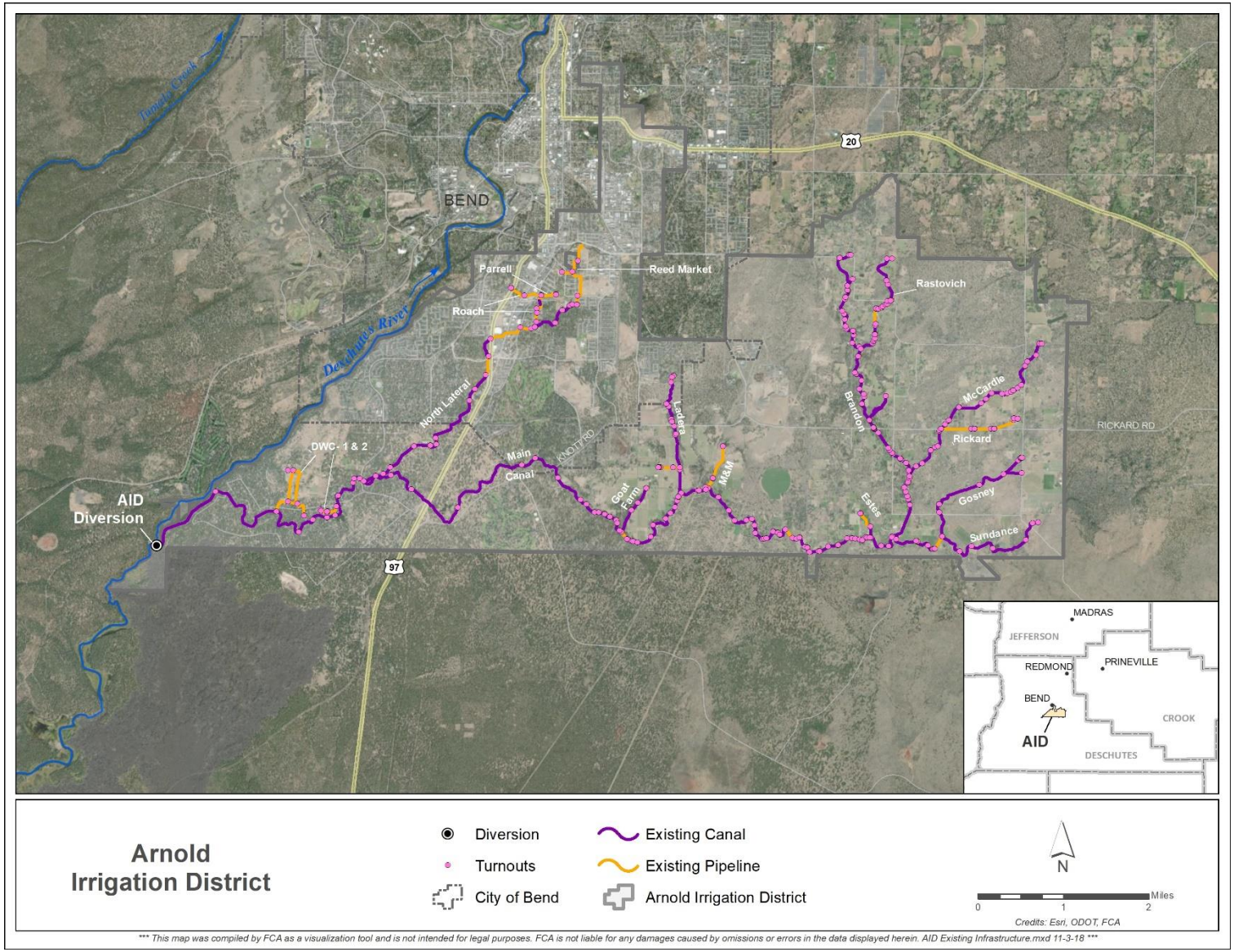


Figure 5-2. Arnold Irrigation District's current infrastructure.

5.3 Topography

The land within the District is slightly undulating. The main Arnold Canal Diversion is at 3,925 feet above sea level. There is approximately 60 feet of elevation loss between the main diversion and the end of the Arnold Canal. The maximum differential in the District from the diversion to the extremity of a lateral is approximately 200 feet.

5.4 Climate

The District is set within a semi-arid region of high-desert scrubland, with scattered peaks and small mountain ranges. This region is located in the rain shadow of the Cascade Mountain range, where precipitation diminishes rapidly moving from west to east across central Oregon, away from the Cascade Mountains. The District's annual average precipitation is 12 to 15 inches (Gannett et al. 2001), most of which arrives in the winter months, with a secondary maximum during the late spring and early summer. Irrigation is essential to crop production, and AID irrigators rely on stored water and diversions from the Deschutes River for adequate water supplies. Summer high temperatures in the District range from 23.9 to 35 degrees Celsius (°C) and winter lows range from -6.1 to 6.7 °C. The average growing season is approximately 70 to 100 days.

Recent yet consistent changes in climate show signs of future increased temperatures and changes in precipitation patterns. These changes will fundamentally alter the seasonal distribution of streamflow in the area, and may have serious implications for natural resource managers and local farmers (Vano et al. 2015). Variable Infiltration Capacity simulations show a substantial decrease in annual streamflow. The probable response to changes in precipitation patterns and increased temperatures is a transition from snow to rain at intermediate and low elevations in the Cascade Range, causing earlier runoff and reduction in the pulse of runoff and groundwater recharge associated with spring snowmelt (Waibel 2010). Winter (October through March) warming is estimated to stimulate greater winter streamflow immediately, which partly compensates for a subsequent decrease in summer streamflow that happens because less water is available (Das et al. 2011). Increased summer (April through September) warming is estimated to increase the rate of spring snowmelt, subsequently decreasing late summer streamflow in response to the reduction of summer snow reserves.

5.5 Cultural and Historic Properties

Section 106 of the NHPA requires federal agencies to take into account the potential effects of a project on historic properties listed in, or eligible for listing in, the National Register of Historic Places. Implementation of NHPA in Oregon is overseen by the Oregon Parks and Recreation Department's SHPO. Recommendations of eligibility for the National Register require consultation with SHPO, and a determination of effects must be agreed upon by the consulting parties. A finding of historic properties adversely affected requires that the consulting parties enter into a Memorandum of Agreement with stipulations for certain actions and timelines that mitigate the adverse effects and are acceptable to all of the consulting parties.

The District's canal and laterals have not been surveyed for cultural and historic resources to date, and the District does not have any features listed or pending for listing on the National Register.

Consultation with SHPO will be necessary to determine the potential for effect on cultural and historic resources, if any, from the project.

5.6 Fish and Aquatic Species

District irrigation infrastructure itself does not support game fish, salmonids, or threatened and endangered aquatic species. The District installed an ODFW-compliant vertical flat-plate fish screen on the Arnold Canal Diversion in 2000 (BPES and RRC 2013). This screen separates water diverted for consumptive use from water left instream, and prevents any fish from entering the District's irrigation conveyance system. The conveyance system does not support resident or anadromous fish or threatened and endangered aquatic species.

Waterbodies affected by District operations that support fish and aquatic species include the upper Deschutes River between Crane Prairie Dam (RM 238.5) and Wickiup Reservoir (RM 226.6), from Wickiup Reservoir Dam (RM 226.8) to North Canal Dam (RM 164.8), and the middle Deschutes River from North Canal Dam (RM 164.8) to Lake Billy Chinook (RM 120) (Table 5-2).

Table 5-2. Waterbodies Associated with District Operations

Name	Reach	Size	Tributary To	Project Nexus
Crane Prairie Reservoir	NA	55,300 acre-feet	N/A	AID holds 10,500 acre-feet of storage water rights.
Upper Deschutes River	Crane Prairie Reservoir (RM 238.5) to Wickiup Reservoir (RM 226.8)	N/A	Columbia	Releases from District reservoir affect flows in this reach.
Wickiup Reservoir	N/A	200,000 acre-feet	N/A	Irrigation water is conveyed through Wickiup Reservoir.
Upper Deschutes River	Wickiup Reservoir (RM 226.8) to North Canal Dam (RM 164.8)	N/A	Columbia River	Releases from Crane Prairie Reservoir and AID diversions both affect flows in this reach.
Middle Deschutes River	North Canal Dam (RM 164.8) to Lake Billy Chinook (RM 120)	N/A	Columbia River	AID diversion immediately upstream affects flows in this reach.

There are 18 species of fish documented in reaches of the Deschutes River that are affected by District operations (Table 5-3). Fish species commonly found in Crane Prairie and Wickiup reservoirs include rainbow trout, kokanee, mountain whitefish, and largemouth bass. Fish species also commonly found in Wickiup Reservoir include brook trout, brown trout, and brown bullhead catfish, while additional fish species in the Crane Prairie Reservoir include black crappie, three-spined stickleback, and tui chub (USFWS 2018).

The dominant salmonid fish species present in the middle and upper Deschutes River are largely similar. Between 2012 and 2014, Carrasco and Moberly found fish assemblages in the middle Deschutes River (RM 120-165) to be dominated by indigenous mountain whitefish and redband trout, and nonnative brown trout. Also present are brown bullhead, mottled sculpin,

tui chub, and bridgelip sucker (Carrasco and Moberly 2014). This species assemblage is similar to the species that ODFW found in an electrofishing occupancy study in the same reach of the Deschutes River (Starcevich 2016). The dominant fish species present in the upper Deschutes River, from North Canal Dam (RM 164.8) upstream to Wickiup Dam (RM 226.8), reflect the salmonid assemblage of the middle Deschutes River (Starcevich and Bailey 2017; Starcevich et al. 2015). Unlike the fish assemblage in the middle Deschutes River, non-salmonid sculpin and three-spined stickleback species are present in high abundance in the Upper Deschutes River.

Table 5-3. Fish Species within the Waterbodies Associated with District Operations

Fish Species	Scientific Name	Origin
Bridgelip sucker	*Catastomus columbianus*	indigenous
Brook trout	*Salvelinus fontinalis*	introduced
Brown bullhead catfish	*Ictalurus nebulosus*	introduced
Brown trout	*Salmo trutta*	introduced
Bull trout	*Salvelinus confluentus*	indigenous
Chinook salmon	*Oncorhynchus tshawytscha*	indigenous
Chiselmouth	*Acrocheilus alutaceus*	indigenous
Dace species	*Rhinichthys spp.*	indigenous
Largescale sucker	*Catastomus macrocheilus*	indigenous
Mountain whitefish	*Prosopium williamsoni*	indigenous
Northern pike minnow	*Ptychocheilus oregonensis*	indigenous
Rainbow trout	*Oncorhynchus mykiss*	introduced
Redband trout	*Oncorhynchus mykiss*	indigenous
Sculpin species	*Cottus spp.*	indigenous
Sockeye salmon/kokanee	*Oncorhynchus nerka*	indigenous
Summer steelhead	*Oncorhynchus mykiss*	indigenous
Three-spined stickleback	*Gasterosteus aculeatus*	introduced
Tui chub	*Gila (Siphateles) bicolor*	introduced

Source: Starcevich and Bailey 2017; Starcevich et al. 2015; Carrasco and Moberly 2014; Bohling et al. 2017

Prior to development of irrigated agricultural, the spring-fed Deschutes River had relatively consistent streamflow seasonally and annually (DRC 2012). The steady streamflow created fish habitat with cold, clear water and consistent hydrology. Since the late 1800s, changes to the Deschutes River's surface water flows, construction of fish passage barriers, and reservoir management have created a very different aquatic environment with resulting changes to fish species assemblage. The species currently present in the middle and upper Deschutes River are a reflection of the available habitat conditions.

Elevated water temperatures in the upper and middle Deschutes River (see Section 5.14.3) negatively impact salmonid growth and survival (Recsetar et al. 2012). Availability of cold water for temperature-sensitive fish species is of key importance as warmer water temperatures–those above acceptable standards and out of the normal range for fish–can increase fish physiologic stress, increase susceptibility to predators, and influence growth rates, feeding, metabolism, and development.

In addition to fish, other aquatic species that may occur within or along waterbodies associated with District operations include bullfrog (*Lithobates catesbeianus*), Oregon spotted frog (*Rana pretiosa*), western toad (*Anaxyrus boreas*), Pacific treefrog (*Pseudacris regilla*), and long-toed salamander (*Ambystoma macrodacylum*). Western toad, Pacific treefrog, and long-toed salamander are native to Oregon and may be present in open irrigation canals and adjacent banks where there is suitable vegetation (S. Wray, personal communication, November 17, 2017). Bullfrog is considered an invasive species and was introduced to Oregon in the early 1900s. Bullfrogs are voracious predators that eat any animal they can swallow. With the exception of the Oregon spotted frog, listed as vulnerable, all of these amphibians are listed as species of least concern by the International Union for Conservation of Nature (IUCN 2017).

5.6.1 Federally Listed Fish and Aquatic Species

The ESA (16 Unites Sates Code [U.S.C.] 1531 *et seq*), as amended in 1988, establishes a national program for the conservation of species listed as threatened or endangered, and the preservation of the habitats on which they depend. The ESA defines procedures for listing species, designating critical habitat for listed species, and preparing recovery plans. Section 7 of the ESA, as amended, requires organizations to consult with the USFWS if listed species or designated critical habitat may be affected by a proposed project. If adverse impacts would occur, the ESA requires federal agencies to evaluate the likely effects of the proposed project, and ensure that the project neither risks the continued existence of federally listed ESA species, nor results in the destruction or adverse modification of designated critical habitat.

A list of fish and aquatic species protected under the ESA that are known or expected to occur in waterbodies associated with District operations was obtained using USFWS Environmental Conservation Online System Information for Planning and Conservation (IPaC). The IPaC indicated that two federally listed fish and aquatic species, bull trout and Oregon spotted frog, and their designated critical habitat are, or may be found in the waterbodies associated with AID operations (USFWS 2018). Neither of these species is known to occur nor is suitable habitat available within the AID's irrigation infrastructure.

The threatened Oregon spotted frog and its designated critical habitat occur in the Deschutes River upstream of the City of Bend (RM 173), in Wickiup Reservoir, and in Crane Prairie Reservoir. USFWS has identified Primary Constituent Elements (PCEs) for Oregon spotted frog critical habitat (Endangered and Threatened Wildlife and Plants 2016). They represent the biological and physical features that are essential to the conservation of a species and describe habitat components that support one or more life stages of the species. PCEs for the Oregon spotted frog describe areas that have appropriate water depths and refuge from predators, aquatic connectivity, and an absence of

non-native predators. Water management practices that alter water levels have reduced habitat suitability for this frog in the river and its tributaries.

USFWS also lists bull trout as threatened under the ESA. Bull trout are known to be present in the Deschutes River from Big Falls (RM 132) to Lake Billy Chinook (RM 120) and approximately 0.6 miles upstream of Lake Billy Chinook to Opal Springs Dam on the Crooked River (ODFW 2003; ODFW 1996; USFWS 2002). These sections of river are also designated critical habitat (USFWS 2002). The PCEs for bull trout describe habitat that has aquatic connectivity, complex habitat structure, water temperatures ranging from 2 to 15 °C, natural variability in streamflow, a sufficient food base, and the absence of non-native predatory and competing fish (Endangered and Threatened Wildlife and Plants 2005).

5.6.2 State Listed Fish and Aquatic Species

The ODFW maintains a list of native fish and wildlife species in Oregon that have been determined by the state to be either "threatened" or "endangered" according to criteria set forth by rule (OAR 635-100-0105) (ODFW 2017). There are no ODFW threatened, endangered, or candidate aquatic species known to occur within the District's irrigation canals or in areas that are affected by its operations.

5.7 Geology and Soils

5.7.1 Geology

The District is located east of the Cascade Mountains. The Cascades were formed 2 to 4 million years ago during the Pliocene and Pleistocene Epochs, and they changed the landscape of the Deschutes Basin. This volcanic activity resulted in complex assemblages of vents, lava flows, pyroclastic deposits, and volcanically derived sedimentary deposits. Over the last 2 to 4 million years, erosion, sedimentation, and volcanic activity resulted in more layers of alluvium, ash, and andesite over areas of the Deschutes Formation and the Newberry Volcano Formation. The geologic units found in the District are primarily basalt with some sand and gravel deposits, and some small areas of tuff deposits. The region's geology influences its hydrology; many stream reaches lose water to the underlying aquifers or gain water through springs, both of which were created by these layers of volcanic rock.

5.7.2 Soils

The predominant soil map units in the project area and lands served by the District are Wanoga-Fremkle-Rock complex, 0 to 15 percent slopes, and Deskamp-Gosney complex, 0 to 8 percent slopes. Wanoga-Fremkle-Rock soils are moderately deep and well drained; they formed in volcanic ash over bedrock. Deskamp-Gosney soils are somewhat excessively drained, moderately deep, and were formed in ash. Less predominant soil units in the area include Wanoga-Fremkle-Henkle complex, 0 to 15 percent slopes, Laidlaw sandy loam, 0 to 15 percent slopes, and Wanoga sandy loam, 0 to 15 percent slopes. Approximately 8 percent of soils in the District are classified by NRCS as Prime Farmland if irrigated and 81 percent are classified as Farmland of Statewide Importance.

5.8 Land Use

5.8.1 Land Ownership

The majority of land adjacent to the project area is privately owned. The District has either documented easements or legal ROW underlying all of its infrastructure. The District's ROW was granted under the Carey Desert Land Act of 1894 (Carey Act). Under the Carey Act, AID's ROW extends 50 feet on each side of the canal from the toe of the bank for a total width of 100 feet plus the width of the canal. Over the course of the last 100 years, there have been re-negotiations in specific areas with regards to AID's easements and ROW to make them more realistic for modern infrastructure, but they have continued to keep their easement and ROW coverage intact for the entire District. AID is engaged in continual efforts to re-map and re-survey its infrastructure and ROW and easements to track changes over time.

5.8.2 Land Use

Within the District boundary, the project area traverses lands served by the District and lands not served by the District. Data from AID's SIP and the National Land Cover Dataset and corresponding land cover classes were used to illustrate land use in the areas served by the District. Rural areas are primarily located in the eastern half of the District. These rural areas are made up of undeveloped land covered in juniper, ponderosa pine, and scrub-shrub species interspersed with agricultural lands and rural residences. The eastern half of the District is also where the majority of agricultural land is found. Agricultural lands are primarily used for growing alfalfa/grass hay, pasture, and turf. Farmers typically get two to three cuttings per year on hay and pasture grass.

A large proportion of the agricultural land and rural area in the eastern half of the District is zoned by Deschutes County as Exclusive Farm Use (EFU). The county is required to inventory and protect farm lands under Statewide Goal 3, Agricultural Land, Oregon Revised Statute (ORS) 215 and Oregon Administrative Rule (OAR) 660-033. The EFU designation serves to accomplish Statewide Goal 3. In 1992, Deschutes County identified seven EFU subzones based on the average number of acres irrigated. The EFU designation is meant to maintain the agricultural economy of the state, assure the adequate provision of healthy food, preserve and maintain agricultural lands, and serve as a sanctuary for farm uses. The District includes lands within the Tumalo/Bend/Redmond Subzone. Parcels within the subzones must retain a minimum of a specific number of irrigated acres per type of farmland (Deschutes County 2010).

The western half of the District is more urban than the eastern half and is composed of residential and commercial areas including Deschutes River Woods, a census-designated place and unincorporated community. AID serves approximately 408 acres of water rights in the more urbanized western half of the lands within the District. The City of Bend is a patron of the District and their quasi-municipal water rights are used to supply pressurized water to subdivisions within Deschutes River Woods. Additionally, Avion Water Company is an AID patron and supplies irrigation water to parcels with individual water rights. Lands within the western half of the District fall within the Bend Urban Growth Boundary (UGB) and Urban Area Reserve boundary. These boundaries are set to control urban sprawl and encroachment on agricultural and rural lands by mandating that the area inside the UGB be used for higher-density urban development.

5.9 Public Safety

The District has 31.5 miles of canal and laterals that are open and accessible to the public. These areas pose a risk to public safety during the summer months when water is at peak flow in the canal. The District's open canal and laterals can contain areas of deep, swift water that can make it difficult for a child or non-swimmer to safely exit the canal. The District's canal and laterals pass through many residential developments and rural residences, which heighten the potential for accidents. Two recent deaths have occurred in other districts' canals in the Deschutes Basin, and District personnel and patrons would like to eliminate such risks.

5.10 Recreation

There are very few recreational opportunities on and adjacent to AID facilities. Recreational use of maintenance roads adjacent to the canal and laterals is not sanctioned by the District. The project area crosses the Eastgate Natural Area, a 742.8-acre undeveloped area managed by Bend Park and Recreation District (BPRD 2012). The canal and laterals do not contain fish due to a functioning fish screen at the Arnold Diversion. Use of the canal and laterals for recreational activities (i.e., swimming or floating) is strictly prohibited.

The Deschutes River from the Crane Prairie Reservoir to Lake Billy Chinook would be indirectly affected by the project due to increased streamflow. Multiple reaches of this section of the Deschutes River are designated as a Wild and Scenic River (Section 5.14.5). Crane Prairie Reservoir is commonly used for boating, fishing, and camping. Downstream from the reservoir until the District's diversion, the Deschutes River winds through Deschutes National Forest, which allows for river recreation, bird watching, hiking, and hunting. The Bend Whitewater Park is located downstream from the District's diversion and is used for activities including tubing, kayaking, and surfing. Tumalo State Park, also located downstream from the diversion, provides numerous recreational activities including rafting, kayaking, floating, stand-up paddle boarding, fishing, and hiking.

5.11 Socioeconomics

The project area falls wholly within Deschutes County and includes the communities of Bend and one unincorporated community, Deschutes River Woods. These areas have seen steady growth over the past 11 years (2005 to 2016). The county has grown by 19 percent between 2006 and 2015, while the state had a growth rate of 10 percent during the same period of time. Table 5-4 shows population estimates for the state of Oregon, Deschutes County, and the nearby communities of Bend and the Deschutes River Woods. The Oregon Office of Economic Analysis estimates that Deschutes County could reach a population of 241,223 by 2040. As of 2017, Deschutes County's unemployment rate was 4.1 percent (USBLS 2017). Educational services, health care, and social assistance provide the highest number of employment positions (20.7 percent) throughout the county. Agriculture provides 3.1 percent of employment positions.

Table 5-4. Population characteristics, 2005 and 2016

Area	Year 2005 Population (number of people)	Year 2016 Population (number of people)	Population Growth Rate 2005 to 2016	Year 2016 Population per Square Mile (number of people)
State of Oregon	3,631,440	3,982,267	10%	40
Deschutes County	143,490	170,813	19%	56
City of Bend	70,330	84,416	20%	2,537
Deschutes River Woods	5,077 [1]	5,993	18%	999

Source: U.S. Census Bureau 2005, 2010, and 2016
Notes:
[1] Population for year 2005 was unavailable. This data shows population for 2010.

5.12 Vegetation

AID lies in the high lava plains province and within the western juniper forest zone of Central Oregon (Johnson and O'Neil 2001). Over the past 100 years, land use has changed much of the vegetation within the District. Urban development, roads, irrigated agriculture, land management, and livestock grazing are the primary causes of change to the plant communities. The introduction of cheatgrass has also threatened the survival and diversity of native perennial grasses and forbs, while increasing the risk of severe hot wild fire in the project area and adjacent undeveloped lands.

The common upland vegetation found within the project area is big sagebrush and low sagebrush, western juniper, and rubber rabbit brush. Ponderosa pine, wild rye and bunch grasses, some species of wildflowers, and other plant species commonly found in the dry Central Oregon steppe environment are also present within the project area. In some sections of the project area, a fringe of opportunistic hydrophytic (water-loving) plants has sporadically formed along the margins of the top of the canal bank represented predominately by bulrush, black cottonwood, and willow.

5.12.1 Special Status Species

No plants that are ESA or Oregon-listed as endangered, threatened, species of concern, or their designated critical habitats are known to occur within the project area.

5.13 Visual Resources

The District is part of a larger region that is valued by residents and visitors for it open spaces, including extensive farms and forests and scenic views. The Deschutes County Comprehensive Plan, adopted in Ordinance 2011-003, identified the scenic resources in the County as, "… high mountain peaks, open meadows, riparian corridors, wetlands, and forests. These areas contribute to the high quality of life for county residents" (Deschutes County 2010).

Generally speaking, the District's canal and laterals are flat against the landscape; in some segments of AID's system, the canal and laterals are a few feet lower than the landscape level and the canal and lateral banks are part of the landscape. The project area includes vegetation and dirt or gravel maintenance roads that AID uses for canal and lateral maintenance. Herbaceous vegetation, grasses, shrubs, and trees growing within the project area can obscure the view of the canal and laterals from adjacent lands.

The view of the canal and laterals differs throughout the year. The District's irrigation season typically extends from April through mid-October. During this time, the District's canal and laterals carry water. From November through March, the canal and laterals do not carry water and are dry. The District provides "stock runs," water delivered through the system to fill patrons' ponds for livestock, several times outside of the irrigation season. Although the canal is not a naturally formed waterway, some viewers may consider it to be a water feature during the irrigation season.

The western side of the project area passes through residential developments in Deschutes River Woods, while the east side of the project area passes through agricultural and undeveloped lands. The open canal and laterals can be seen from residences as well as public road crossings, including where U.S. Highway 97 crosses the Arnold Canal. The Arnold Diversion and flume are visible to both recreationists floating, paddling, or swimming in the Deschutes River around RM 174.6 and hiking on the Deschutes River Trail (located on the west shore of the Deschutes River)

5.14 Water Resources

5.14.1 Water Supply

Waterbodies associated with District operations include Crane Prairie Reservoir, Wickiup Reservoir, and the Deschutes River (see Table 5-2 in Section 5.6 for the list of waterbodies and their associated river miles). The upstream end of Lake Billy Chinook, at the confluence of the Deschutes, Crooked, and Metolius Rivers, serves as the downstream boundary of the area in which District operations can influence streamflow.

The District diverts both live flow and stored water from the Deschutes River at the Arnold Diversion (RM 174.6) near Bend, Oregon, to meet its patrons' water needs. The District's primary source of water is live flow. AID's water right Certificate 74197 has a priority date of April 1, 1905 for 25 cfs and April 15, 1905 for 125 cfs. AID's water right Certificate 76714 is a storage right at Crane Prairie Reservoir with a priority date of February 28, 1913, for 10,500 acre-feet and for an additional 1/5 of the total amount of between 30,000 and 45,000 acre-feet stored in the reservoir. AID's stored water right is supplemental and is used on an as-needed basis.

Crane Prairie Reservoir is primarily fed by annual snowmelt, precipitation, and inflow from the Deschutes River. It is relatively shallow and holds 55,300 acre-feet at full capacity. Although Reclamation owns the reservoir, daily responsibility for O&M has been transferred to and is financed by COID. Crane Prairie Reservoir is federally authorized for irrigation use and state authorized for multiple purposes, including instream flows for fish and wildlife. Three irrigation districts hold water rights to store a combined 50,000 acre-feet in the reservoir: Lone Pine Irrigation District (10,500 acre-feet), AID (10,500 acre-feet), and COID (26,000 acre-feet). Water from Crane

Prairie Reservoir is released throughout the year and during the irrigation season; discharge rates are increased to meet demand. Water is released from Crane Prairie east down the Deschutes River, through Wickiup Reservoir, and then north through the Deschutes River to the various irrigation district diversions.

The irrigation season is divided into three seasons, each with different certified delivery rates (Table 5-5). During the shoulder seasons (season 1 and season 2), the District's certificated water delivery rates are less than the full season water delivery rate (season 3). During the late summer and fall, stored water may be used to supplement reduced live-flow availability caused by drought and prolonged heat.

Table 5-5. Arnold Irrigation District Certificated Diversion Flow Rates and Irrigation Season Dates per Water Right Certificate 74197

Season	Start Date	End Date	Start Date	End Date	Season Duration (Days)	Priority Date	Certificated Diversion Flow Rates (cfs)	Percent of Full Rate
1	April 1	April 30	Oct. 1	Nov. 1	62	2/1/1905	14.33	41%
						4/25/1905	71.63	41%
2	May 1	May 14	Sept. 15	Sept. 30	30	2/1/1905	18.73	53%
						4/25/1905	93.68	53%
3	May 15	Sept. 14	N/A	N/A	122	2/1/1905	25.00	100%
						4/25/1905	125	100%

5.14.2 Surface Water Hydrology

5.14.2.1 Deschutes River (RM 226.8) to the North Canal Dam (RM 164.8)

Prior to development of irrigated agriculture, the spring-fed Deschutes River had relatively consistent streamflow seasonally and annually (DRC 2012). Construction and operation of reservoirs, dams, and diversions on the river and its tributaries changed hydrologic conditions in the Deschutes River. Management of surface water for irrigation use results in lower flows downstream from reservoirs during the storage season (i.e., late fall, winter, and early spring), higher flows downstream from reservoirs during the irrigation season (April 1 to November 1), and lower flows in the middle Deschutes River downstream from irrigation diversions during the irrigation season.

Over the past 15 years, streamflow in the Deschutes River has steadily increased due to collaborative restoration efforts by the irrigation districts and their partners. July median streamflow in the Deschutes River at North Canal Dam (RM 164.8) more than tripled from 47 cfs to 158 cfs between 2002 to 2012 (Mork 2016). July median streamflow dropped in 2013 to 129 cfs due to a reduction in instream leases and water voluntarily left instream by irrigation districts. It has steadily crept upward since 2013 to a 2015 July median flow of 136 cfs (Mork 2016). OWRD monitors streamflow and ensures that leases, transfers, and conserved water from piping and other conservation projects remain instream.

The Deschutes Basin has experienced a general drying trend for several decades (Gannett and Lite 2013) and is susceptible to future changes in precipitation and changes in the amount and timing of spring runoff (Shelton and Fridirici 2001). Models suggest that increased rain and a decreased snowpack combined with an accelerated rate of spring snowmelt will have a growing influence on future water supply in the area; these changes will make managing water supplies more difficult (Shelton and Fridirici 2001; Reclamation 2016).

AID's irrigation operations affect water storage in Crane Prairie Reservoir and streamflow in the Deschutes River between Crane Prairie and Lake Billy Chinook. The total streamflow of the Deschutes River between Wickiup Reservoir Dam (RM 226.8) and Lake Billy Chinook (RM 120) is a product of reservoir releases (by Lone Pine Irrigation District, COID, AID, and North Unit Irrigation District), tributary inflows, irrigation diversions, and groundwater interactions. Reservoir storage and releases contribute to lower winter streamflow and higher summer streamflow in the Deschutes River upstream from irrigation diversions (e.g., AID diversion and North Canal Dam). Downstream from irrigation diversions, the diversions contribute to lower streamflow during the irrigation season (Source: Central Oregon Irrigation District

Figure 5-3).

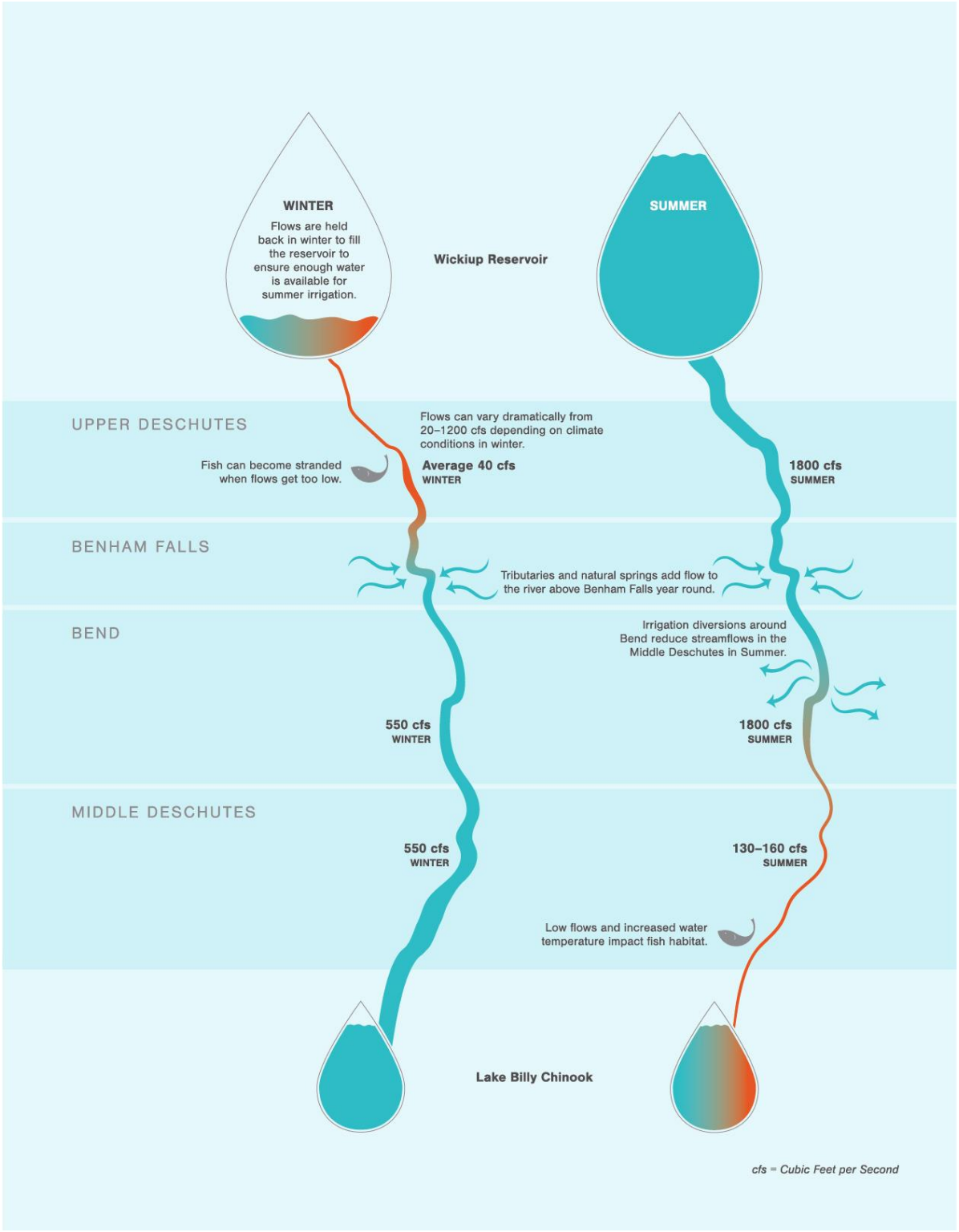
Outside of the irrigation season, irrigation districts have historically released a minimum of 20 cfs from Wickiup Reservoir (DRC 2012). In 2016, AID and the other districts that store water in Crane Prairie Reservoir and Wickiup Reservoir agreed to voluntarily release additional streamflow from Wickiup Reservoir outside of the irrigation season. These releases were intended to benefit Oregon spotted frog populations in the Deschutes River (Stipulated Settlement Agreement; Center for Biological Diversity, et. al. v. U.S. Bureau of Reclamation and Arnold Irrigation District, et al. 2016). The purpose of these releases is to improve aquatic resources and their habitat. Under the Stipulated Settlement Agreement, AID and the other districts agreed to maintain a minimum of 100 cfs in the upper Deschutes River outside of the irrigation season. These additional reservoir releases are not legally protected instream at this time.

The Deschutes River downstream from Crane Prairie Reservoir has instream water rights that have served as preliminary streamflow targets. The instream water rights were intended to support aquatic life and minimize pollution. These water rights are as follows:

- 130 cfs with an October 11, 1990 priority date between Crane Prairie Reservoir (RM 237.0) and Wickiup Reservoir (RM 238.5) (certificate #73233)
- 300 cfs with a November 3 1983 priority date between Wickiup Reservoir Dam (RM 226.8) and the confluence with the Little Deschutes River (RM 192.5) (certificate #59776)
- 400 cfs with a November 3, 1983 priority date between the mouth of the Little Deschutes River (RM 192.5) and the mouth of the Spring River (RM 190.4) (certificate #59777)
- 660 cfs with a November 3, 1983 priority date between the mouth of the Spring River (RM 190.4) and the North Canal Dam (RM 164.8) (certificate #59778)

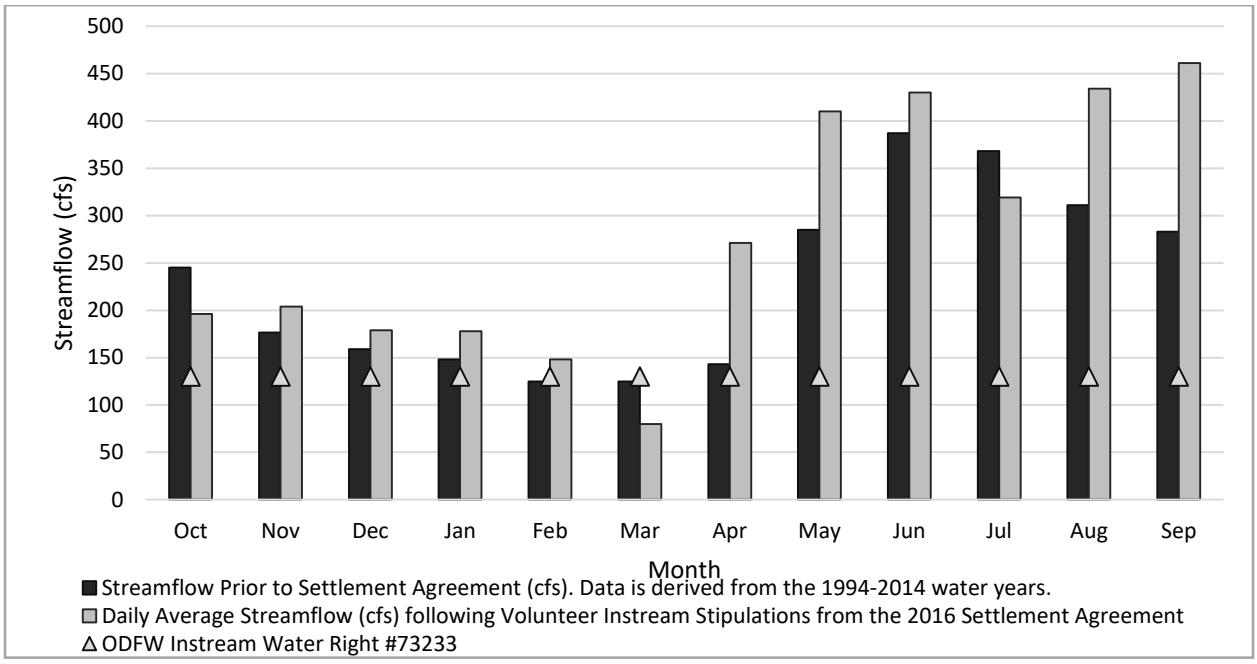
Figure 5-4, Figure 5-5, and Figure 5-6 display the Deschutes' daily average streamflow prior to the Stipulated Settlement Agreement (1994 to 2014) and the daily average streamflow (October 2016 to September 2017) following the Stipulated Settlement Agreement. Beginning in the 1990s, irrigation

districts began conservation projects that resulted in the opportunity to begin allocating water to instream use; therefore, streamflow prior to the Stipulated Settlement Agreement are better represented using data from the 1994 to 2014 water years.



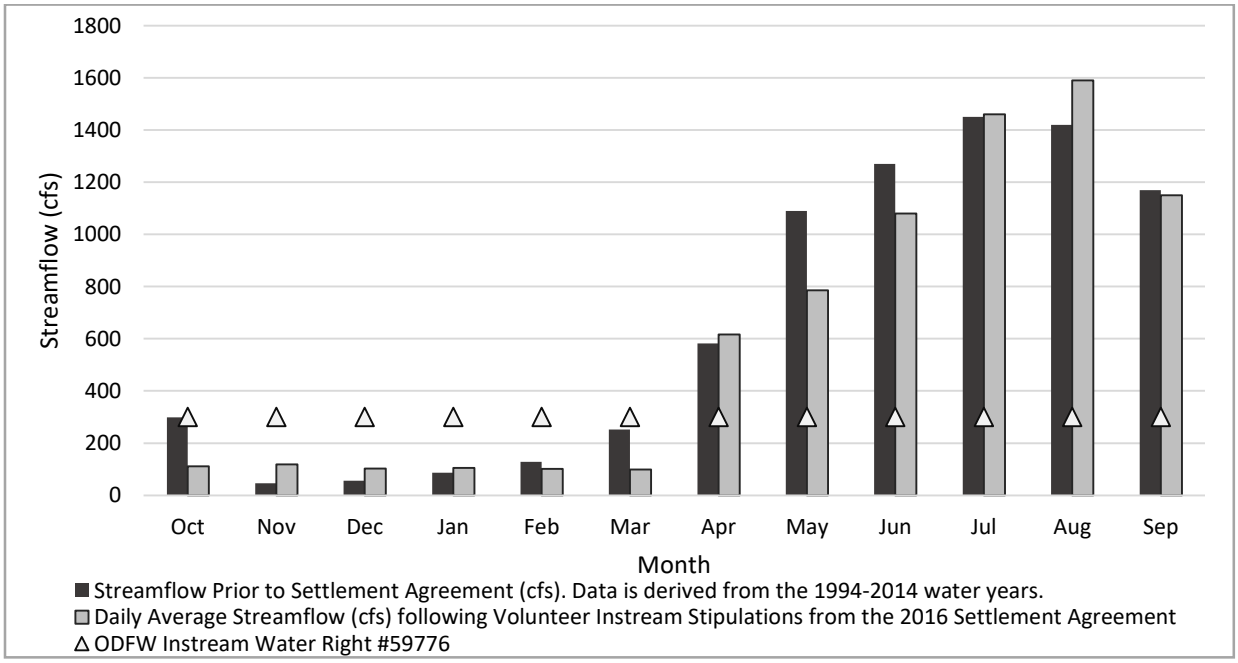
Source: Central Oregon Irrigation District

Figure 5-3. Deschutes River seasonal flow management.



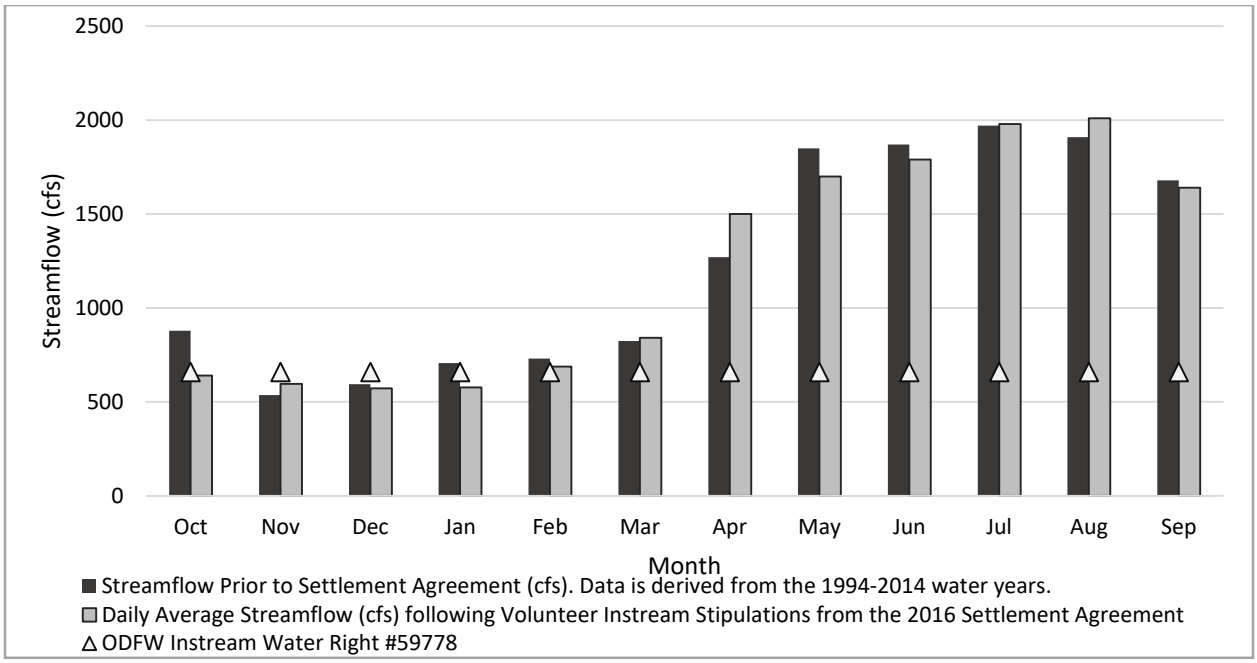
Source: OWRD 2018

Figure 5-4. Daily average streamflow in the Deschutes River downstream from Crane Prairie Reservoir at OWRD Gauge No. 14054000.



Source: OWRD 2017a

Figure 5-5. Daily average streamflow pre- and post- Stipulated Settlement Agreement in the Deschutes River downstream from Wickiup Reservoir at OWRD Gauge No. 14056500.



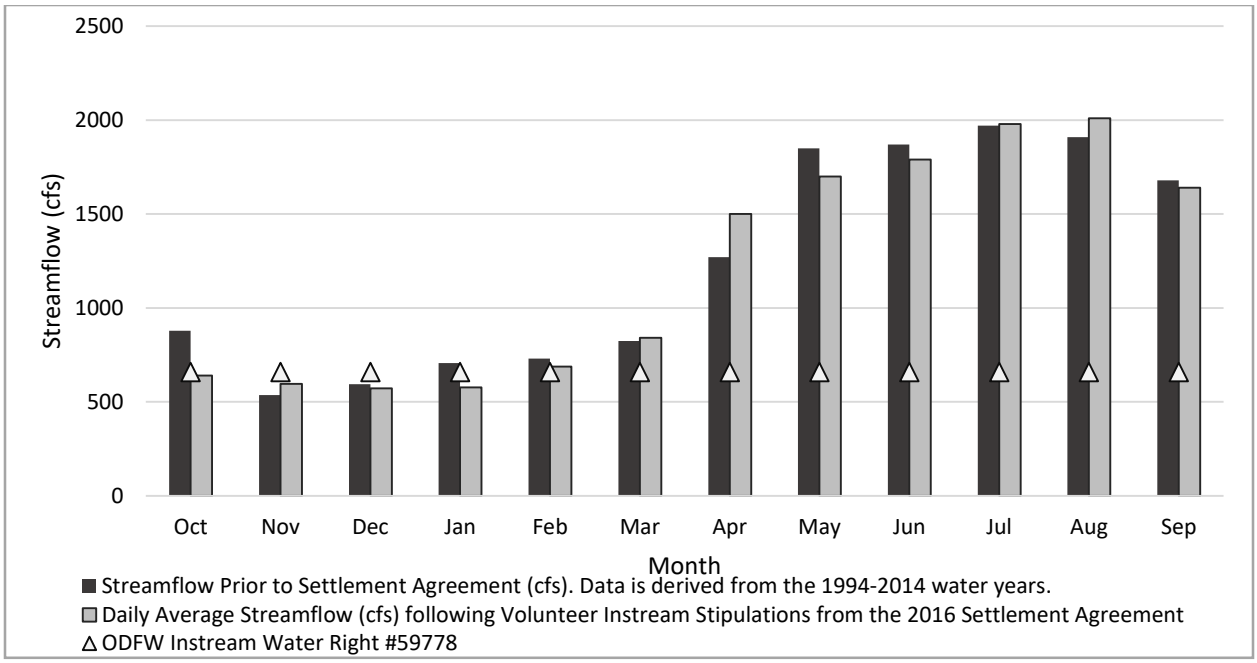
Source: OWRD 2017b

Figure 5-6. Daily average streamflow pre- and post- Stipulated Settlement Agreement in the Deschutes River at Benham Falls at OWRD Gauge No. 14064500.

5.14.2.2 *Deschutes River, North Canal Dam (RM 164.8) to Lake Billy Chinook (RM 120)*

Five irrigation districts in addition to AID divert water from the Deschutes River at or near the North Canal Dam, influencing streamflow patterns in the Deschutes River downstream to Lake Billy Chinook. Historically, under a voluntary agreement, these irrigation districts maintained a minimum of 30 cfs instream in this reach during the irrigation season. Extensive conservation efforts by the irrigation districts and their partners, starting in the 2000s, have enhanced streamflow during the irrigation season (April to October) increasing the average flows to 70 cfs. Following the Stipulated Settlement Agreement in 2016, the irrigation districts have maintained an average of 125 cfs downstream from their diversions during the summer irrigation season (Figure 5-7).

ODFW has a pending water right requesting a year-round flow of 250 cfs in this reach. This pending water right provides a preliminary streamflow target, needed for fish, wildlife, their habitat quality, or recreation between the North Canal Dam and Round Butte Reservoir (RM 119.5).



Source: OWRD 2017c

Figure 5-7. Daily average streamflow in the Deschutes River downstream from the North Canal Dam at OWRD Gauge No. 14070500.

5.14.3 Water Quality

The ODEQ maintains a list of all surface waters in the state that are considered impaired because they do not meet water quality standards under Section 303(d) of the CWA (33 U.S.C. 1251 et seq.). This list is referred to as the 2012 303(d) list. The waterbodies associated with District operations are included on Oregon's 303(d) list for not meeting water quality standards for one or more of the following impairments: aquatic weeds or algae, temperature, dissolved oxygen, pH, sedimentation, turbidity, and chlorophyll a (Table 5-6).

Water management in the Deschutes Basin has altered seasonal streamflow patterns, increasing streamflow above historical levels in some reaches and decreasing streamflow below historical levels in other reaches. Low flows affect water quality in the Deschutes River by exacerbating temperature and dissolved oxygen problems. In addition, water quality often dictates the spread and extent of invasive aquatic species, and these problems interact to degrade wildlife habitat within and around the Deschutes River. The following sections describe existing 303(d)-listed impairments in the waterbodies associated with District operations. ODEQ is required to develop total maximum daily loads for rivers and streams in the upper Deschutes Basin.

Table 5-6. Impaired Waterbodies Associated with District Operations

Name	Reach	Parameters Included on Oregon's 303(d) List
Crane Prairie Reservoir	N/A	Aquatic Weeds or Algae

Name	Reach	Parameters Included on Oregon's 303(d) List
Upper Deschutes River	Crane Prairie Reservoir (RM 238.5) to Wickiup Reservoir (RM 226.8)	Temperature
Wickiup Reservoir	N/A	Aquatic Weeds or Algae
Upper Deschutes River	Wickiup Reservoir Dam (RM 226.8) to North Canal Dam (RM 164.8)[1]	Temperature Dissolved oxygen pH Sedimentation Turbidity Chlorophyll a
Middle Deschutes River	North Canal Dam (RM 164.8) to Lake Billy Chinook (RM 120)	Temperature Dissolved oxygen

Source: ODEQ 2012b
Notes: 1. The Arnold Diversion is located at RM 174.6 in the Upper Deschutes River.

5.14.3.1 Temperature

The Deschutes River does not meet stream temperature criteria throughout the year. The temperature criterion that applies throughout the area is 18 °C, which is designed to protect salmon and trout rearing and migration. Elevated stream temperatures affect aquatic species, including native fish, by exacerbating conditions that cause stress and disease, raising their metabolism, and reducing growth rates. Low streamflow downstream of North Canal Dam, reduced streamside vegetation, and widened channels can all contribute to elevated stream temperatures.

5.14.3.2 Dissolved Oxygen

ODEQ's dissolved oxygen standards vary depending on the spawning season of steelhead, salmon, or trout. The dissolved oxygen levels in the Deschutes River reach of RM 120 to RM 222.2, which is affected by District operations, are not high enough to meet Oregon's standard during trout spawning season from January 1 to May 15. The upper Deschutes River reach from RM 171.7 to 223.3 does not meet Oregon's standard year round (ODEQ 2012). Low dissolved oxygen levels can affect aquatic life by reducing habitat quality and quantity, changing behavior, or reducing growth rates. Excess nutrient inputs, associated algae growth and die-off, and elevated stream temperatures can all contribute to lower dissolved oxygen levels.

5.14.3.3 pH

pH is a measure of the acidity or alkalinity of a waterbody. The Deschutes River exceeds Oregon's pH standard with higher, or more alkaline, values all-year round from RM 126.4 to RM 162.6, and during the summer from RM 162.6 to RM 168.2 (ODEQ 2012). Higher pH, caused by increased photosynthetic activity, can affect aquatic life by changing the solubility or biological availability of chemicals in the water (ODEQ 2012a).

5.14.3.4 Sedimentation

Sedimentation refers to deposits of silt, sand, or other small particles in a river. The upper Deschutes River from RM 168.2 to RM 222.2 does not meet Oregon's standard for sedimentation

(ODEQ 2012). The ODEQ set this standard to protect resident fish and aquatic life and salmonid fish spawning and rearing in the river. In the Deschutes River, lower winter flows and higher summer flows have contributed to increased bank erosion. Increased bank erosion contributes to increased sediment in the river. The river carries this sediment downstream and deposits it along the riverbed. Deposited sediment can affect fish and aquatic life by reducing the quantity and quality of available habitat.

5.14.3.5 Turbidity

Turbidity is a measure of water cloudiness. The upper Deschutes River from RM 168.2 to RM 222.2 does not meet Oregon's standard during the spring and summer (ODEQ 2012). This standard is set to protect aesthetics, resident fish and aquatic life, and water supply in the river. Suspended sediment, algae, and other suspended or dissolved materials contribute to increased turbidity.

5.14.3.6 Chlorophyll a

Chlorophyll a is a specific type of chlorophyll that is measured to evaluate the amount of algae in a waterbody. Monitoring chlorophyll levels is a direct way of tracking algal growth; surface waters that have high chlorophyll conditions are typically correlated with high levels of nutrients, commonly phosphorus and nitrogen. The Deschutes River from RM 168.2 to RM 189.4 does not meet Oregon's standard during the summer (ODEQ 2012). The ODEQ set this standard to protect multiple uses in the river, including resident fish and aquatic life. High chlorophyll a indicates excess algal growth in the river. Excess algae often contribute to low dissolved oxygen concentrations. Excess algae grown can be caused by both natural influences and nutrient inputs (from sources such as fertilizer or leaking septic tanks) into the waterbody.

5.14.3.7 Aquatic Weeds or Algae

The aquatic weeds and algae parameter on the 303(d) list indicates that a waterbody has received health advisories for algal blooms. Crane Prairie Reservoir and Wickiup Reservoir have been issued health advisories for exceeding toxicity levels (ODEQ 2012). The ODEQ set this standard to protect multiple uses in the waterbodies. Algal blooms can produce toxic substances, which pose danger to people and animals that drink or come into contact with affected waters.

5.14.4 Groundwater

Groundwater plays an important role in the hydrograph of the entire Deschutes watershed; groundwater in the upper watershed provides more than three quarters of the total streamflow for the entire watershed.

Due to the porous geology of the area, groundwater levels and stream discharge are tied to the frequent movement of water between surface and groundwater sytems. Irrigation canals in the Upper Deschutes watershed, and AID's service area in particular, often show seepage losses indicative of the area's permeable geology. An assessment study in 2016 measured up to 45.1 cfs of peak-season loss in AID's canals due to seepage (AID 2017). After a review of Gannet and Lites (2001) groundwater flow model, it is probable that this seepage water enters the region's groundwater system and discharges into streams and rivers in the middle Deschutes and near the confulence of the Metolious, Deschutes, and Crooked Rivers (Gannet et al. 2001).

5.14.5 Wild and Scenic Rivers

Two federally designated Wild and Scenic Rivers (Public Law 90-542; 16 U.S.C. 1271 et seq.) are associated with District operations.

- The Deschutes River, from Wickiup Reservoir (RM 226.8) to the Bend UGB at the southwest corner of Section 13, T18S, R11E (approximately RM 172), is classified as both "Scenic" and "Recreation" with Outstandingly Remarkable Values including Cultural, Fish, Geologic, Historic, Recreation, Scenery, Wildlife, and Botany.
- The Deschutes River, from Odin Falls (RM 139.9) to the upper end of Lake Billy Chinook (RM 120), is classified as "Scenic" with its Outstandingly Remarkable Values including Cultural, Fish, Geologic, Recreation, Scenery, Wildlife, Hydrology, Botanical/Ecological, and Wilderness.

In addition to federally designated Wild and Scenic Rivers, several waterways associated with District operations are designated as Oregon Scenic River Waterways (ORS 390.826). These locations, with specific exclusions and classifications, are detailed in Table 5-7.

Table 5-7. Designated Oregon Scenic River Waterways Associated with District Operations

River	Reach	Classification [1,2,3,4]
Upper Deschutes River	From RM 224.5 to RM 204, with the exception of Pringle Falls (RM 217.5 to RM 216.5)	Scenic River Area
Upper Deschutes River	From the Deschutes National Forest boundary in Section 20, T19S, R11E (approximately RM 184.8) to the Bend UGB(approximately RM 172)	Scenic River Area
Upper Deschutes River	From RM 226.4 to approximately RM 224.5; from RM 217.5 to RM 216.8; from RM 204 to about RM 199; and from RM 172 to RM 171	River Community Area
Upper Deschutes River	From RM 190.6 to approximately RM 184.8	Recreational River Area
Middle Deschutes River	From Deschutes Market Road (approximately RM 157) to the south boundary of the Wilderness Study Area (approximately RM 131), with the exception of the Clines Falls Dam and powerhouse between State Highway 126 Bridge (RM 144.9) and RM 144 and the Crooked River Ranch River Community Area (RM 129.9 to RM 131.5)	Scenic River Area
Middle Deschutes River	From RM 164 to approximately RM 161; from RM 129.9 to RM 131.5; and from RM 124.3 to RM 125.25	River Community Area
Middle Deschutes River	From the northern Bend UGB (RM 161) to Tumalo State Park (RM 158)	Recreational River Area

River	Reach	Classification [1,2,3,4]
Middle Deschutes River	From the south boundary of the Wilderness Study Area as approximately RM 131 to Lake Billy Chinook (RM 120), with the exception of RM 129.9 to RM 131.5.	Natural River Area

Notes:

1. Those designated scenic waterways or segments with related adjacent lands and shorelines still largely primitive and largely undeveloped, except for agriculture and grazing, but accessible in places by roads. These classified areas will be administered to maintain or enhance their high scenic quality, recreational value, and fishery and wildlife habitat while preserving their largely undeveloped character and allowing continuing agricultural uses.
2. Those designated areas of a scenic waterway where density of structures or other developments already exist and provide for precludes application of a more restrictive classification.
3. Those designated scenic waterways that are readily accessible by road or railroad, that allow a wide range of compatible river-oriented public outdoor recreation opportunities, to the extent that these do not impair substantially the natural beauty of the scenic waterway or diminish its esthetic, fish and wildlife, scientific and recreational values.
4. Those designated scenic waterways that are generally inaccessible except by trail or the river, with related adjacent lands and shorelines essentially primitive. These classified scenic waterways will be administered to preserve their natural, wild, and primitive condition, essentially unaltered by the effects of man, while allowing compatible recreational uses, other compatible existing uses, and protection of fish and wildlife.

5.15 Wetlands and Riparian Areas

Wetlands perform a number of valuable functions including water storage, water filtration, and biological productivity. They can also support complex food chains that provide sources of nutrients to plants and animals and specialized habitat for a wide variety of aquatic and terrestrial species. Wetlands in the area associated with the project may be subject to federal or state regulations depending on their characteristics. Within the State of Oregon, wetlands are managed under two regulations, Section 404 of the CWA, and Oregon Removal-Fill Law.

The USACE administers Section 404 of the CWA with the oversight of the U.S. Environmental Protection Agency. This law regulates the dredge or fill of wetlands over which the USACE has jurisdiction (or "jurisdictional wetlands"). Section 404 of the CWA defines wetlands as "those areas inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (USACE 1986).

Language provided in the 1986 Final Rule for Regulatory Programs of the Corps of Engineers (1986 Final Rule) identified that irrigation ditches are generally not considered Waters of the United States for the purpose of determining CWA Section 404(f)(1)(C) applicability. However, EPA reserved the "right to determine on a case-by-case basis if any of these waters are "Waters of the United States…" including, "…irrigation ditches excavated on dry land…" (USACE 1986). In 2006, a "significant nexus" jurisdiction standard from Rapanos v. United States (547 U.S. 715 2006) was established, which has been used to determine if identified waters are Waters of the United States.

In 2015, the Clean Water Rule: Definition of "Waters of the United States" (2015 Final Rule) (USEPA 2015) was published and provided clear exclusions for certain types of ditches. However, the U.S. Court of Appeals for the Sixth Circuit stayed the 2015 Final Rule nationwide pending

further action of the court. This reinstated the "significant nexus" jurisdiction standard from Rapanos v. United States.

The ODSL implements the Oregon Removal-Fill Law (ORS 196.800-990), which regulates the removal or fill of material in wetlands or waterways, requiring any person who plans to "remove or fill" material within "waters of the state" to obtain a permit from ODSL.

Per the Oregon Removal-Fill law OR 141-085-0515(9), an irrigation ditch is not jurisdictional for Oregon Removal-Fill permitting purposes if it meets both of the following (ODSL 2013):

- The ditch is operated and maintained for the primary purpose of irrigation; and
- The ditch is dewatered[3] outside of the irrigation season except for isolated puddles in low areas.

Water typically flows through the canals and laterals in the project area during the irrigation season, between April 1 and October 31. Water may also occasionally flow through these canals outside of the irrigation season for stock water deliveries or be present as standing water following rain or snow events. Although some canals and laterals may have hydrology and vegetation indicative of a wetland, they only contain water during the irrigation season, do not meet functional criteria of wetlands, and are not regulated as wetlands by ODSL or USACE. These canals and laterals meet exemptions under the Oregon Removal-Fill Law for specific agricultural activities in wetlands and other waters of the state.

National Wetland Inventory geographic information systems data (USFWS 2016) identifies areas that may be wetland resources at a national scale. The National Wetland Inventory does not describe wetland resources within the project area. Wetlands, including riverine and palustrine types, may occur within and sporadically adjacent to the 106.8 miles of the Deschutes River associated with District operations.

Riparian areas are transition zones between waterbodies and adjacent upland areas that support hydrophytic vegetation that is dependent upon the hydrology of the waterbody. Riparian areas as defined by Section 404 of the CWA are "areas next to or substantially influenced by water. These may include areas adjacent to rivers, lakes, or estuaries" (USEPA 2015).

Riparian areas of varying size and quality occur adjacent to natural waterbodies associated with District operations. Low streamflow in late fall, winter, and early spring associated with upstream reservoir storage limits riparian vegetation along the Deschutes River, as does irrigation withdrawals downstream of AID's diversion (RDG 2005). Because streamflow is strongly correlated with critical physical and biological characteristics of the river, it influences the functions of associated riparian areas (National Research Council 2002). In general, restablishing a more natural hydrologic regime

[3] "Dewatered" means that the source of the irrigation water is turned off or diverted from the irrigation ditch. A ditch that is dewatered outside of the irrigation season may be used for temporary flows associated with stormwater collection, stock water runs, or fire suppression.

reaches would allow the river channel to supply water to riparian areas via infiltration through channel banks, thus enhancing riparian function by facilitating processes such as hyporheic exchange, physical and chemical transformations, and supporting riparian plant communities and aquatic habitat (National Research Council 2002).

5.16 Wildlife

Generally, wildlife present in AID's project area and lands served by the District consists of habitat generalists or edge species with the ability to adapt to or exploit the urban environment. These species are tolerant to fragmentation, disturbance, and urbanization, and include species such as deer, coyote, skunk, grey squirrel, raccoon, and red-tailed hawk (Blair 1996; Ditchkoff et al. 2006; McKinney 2002; Shochat et al. 2006).

Wildlife within the project area may use the canal and lateral system as a water source and dispersal corridor. Additionally, where not cleared, vegetation along canals and laterals can provide food, cover, and breeding sites for many wildlife species throughout the year. Consultation with a USFWS biologist regarding Migratory Bird Treaty Act (MBTA)/ Bald and Golden Eagle Protection Act (BGEPA), federally listed, and state-listed species will occur during the development of the Watershed Plan-EA.

5.16.1 MBTA/BGEPA Species

There are multiple bird species with the potential to occur within the project area, some of which are protected under the MBTA or the BGEPA. Although migratory birds are known to occur in the project area and its vicinity, limited habitat is provided within the project area due to maintenance activities that remove vegetation on an annual basis.

5.16.2 Federally Listed Species

A review of available USFWS and Oregon Biodiversity Information Center's data showed no federal threatened or endangered wildlife species or designated critical habitat within the project area. Lewis's woodpecker (*Melanerpes lewis*), a federal species of concern, was shown to have the potential to occur in the project area.

5.16.3 State-Listed Species

The ODFW maintains a list of native wildlife species in Oregon that have been determined to be either threatened or endangered according to criteria set forth by rule (OAR 635-100-0105) (ODFW 2017). In addition, a "sensitive" species classification was created under Oregon's Sensitive Species Rule (OAR 635-100-0040), which focuses fish and wildlife conservation, management, and research and monitoring activities on species that need conservation attention. Information from the Oregon Biodiversity Information Center shows the potential for Lewis's woodpecker and Townsend's big-eared bat (*Corynorhinus townsendii*), both of which are listed as "sensitive", to be present within the District. There are no state-listed terrestrial species known to occur within project area.

5.17 Ecosystem Services

Ecosystem services are defined as the benefits people obtain from ecosystems, and can be categorized as supporting, provisioning, regulating, and cultural services (Millennium Ecosystem Assessment 2005). Examples include such benefits and services as food, water, pollination, medicinal resources, waste decomposition, nutrient recycling, water purification, soil formation, as well as recreation, spiritual, and educational experiences. Modernizing AID's irrigation infrastructure through piping and pressurizing open canals has the potential to strengthen ecosystem services by restoring streamflow, improving water quality, reducing carbon emissions, and improving habitat conditions for threatened fish species.

6 Technical Evaluations

A number of studies and technical evaluations pertaining to the modernization of AID were used to provide technical background for this PIR, and will be further utilized as a Watershed Plan-EA is developed for the District. Relevant technical evaluations are as follows:

- **Arnold Irrigation District System Improvement Plan.** Completed by Black Rock Consulting and Farmers Conservation Alliance in June 2017, this document describes the specific infrastructure requirements for modernization of AID's distribution system. This document is integral to the formulation of the project and is attached to this PIR as an appendix.
- **Upper Deschutes Basin Study.** A collaborative effort between Reclamation and the Deschutes Basin Study Work Group to develop a comprehensive analysis of water supply and demand for current and future conditions in the Upper Deschutes Basin. This work is currently underway and is expected to be finished in 2018.
- **Deschutes Basin Multi-Species Habitat Conservation Plan.** The USFWS is currently working to complete a Habitat Conservation Plan regarding potential effects of current water management and operations in the upper Deschutes on bull trout, middle Columbia River steelhead, Oregon spotted frog, sockeye salmon, and Chinook salmon in Crook, Deschutes, Jefferson, Klamath, Sherman, and Wasco counties, Oregon.

7 Alternatives

7.1 Formulation Process

In order to determine the most viable alternatives to meet the project's purpose and need, NRCS and AID are considering the needs of the water users, goals for conservation and restoration, resources and funding available for both the District and the water users, and the current status of the District's previous improvements. Alternatives considered during project development but proposed for elimination from detailed study were evaluated based on the criteria in USDA's Guidance for Conducting Analysis Under the Principles, Requirements, and Guidelines for Water and Land Related Resources Implementation Studies and Federal Water and Resource Investments (USDA 2017). Pursuant to this guidance, alternatives that become "unreasonable due to cost, logistics, existing technology, social, or environmental reasons," or general inability to address the

purpose and need for action, may be removed from consideration. Final analyses will be included in the Watershed Plan-EA to support full disclosure and transparency in the decision-making process; each alternative plan, strategy, or action is formulated to consider the following four criteria: completeness, effectiveness, efficiency, and acceptability (USDA 2017). Alternatives considered by AID during project development, but proposed for elimination, are discussed in Section 7.3. The No Action Alternative is described in Section 7.2.1 and the Piping and Pressurization Alternative is described in Section 7.2.2.

7.2 Description of Alternatives Considered

7.2.1 No Action Alternative (Future without Project)

Under the No Action Alternative, the District would continue to operate and maintain its existing canal, lateral, and pipe system in its current condition. This alternative assumes that modernization of the District's system, to meet the purposes and needs of the project, would not be reasonably certain to occur, as funding at the large scale necessary to modernize the District's infrastructure is not anticipated from other sources.

The No Action Alternative is a continuation of the District's standard O&M. Streamflow provided by the District for instream uses would remain the same. Individual on-farm pumps would continue to require an estimated 3.5 million kilowatt hours per year. Irrigated agriculture in AID would continue to be susceptible to inconsistent water supply and increased operational costs over time.

The No Action Alternative does not contribute to the purpose and need as follows:

- Improve water conservation: This alternative would maintain the existing water loss in the District's system of 45.1 cfs, or about 14,607 acre-feet per year, from canal seepage and evaporation would continue.
- Increase water delivery reliability to farms: This alternative would maintain existing operations and infrastructure and would not improve irrigation water delivery reliability.
- Reduce O&M costs: This alternative would maintain existing energy use and associated costs for farmers. The use of individual pumps requires an energy use of 3.5 million kilowatt hours per year across the District, at a cost of approximately $331,000 per year. District canal and maintenance costs would remain the same as District personnel would have to continue system maintenance that includes the removal of debris and foreign material that hinders system operation and performing repairs to the banks and slopes of the open canal and lateral system. This alternative would maintain existing O&M costs for the District.
- Enhance streamflow and habitat conditions for fish and aquatic species: This alternative would not affect existing streamflow and habitat conditions.
- Improve public safety: This alternative would not reduce the drowning risks associated with open canals.

7.2.2 High-Density Polyethylene Piping Alternative

This Alternative is AID's desired alternative. The District has determined through engineering analyses described in the District's SIP that this alternative is feasible and addresses the project's purpose and need. Under the HDPE Alternative, AID would pipe 31.5 miles of canal and laterals, 13 miles of aerial flume and open Arnold Canal and 18.5 miles of open laterals, with gravity-pressurized, buried high-density polyethylene (HDPE) pipe (Figure 7-1). Pipe diameters would range from 63 inches in the Arnold Canal down to 4 inches on smaller laterals.

The main construction tasks associated with this alternative include excavating trenches, pipe welding and placement, and backfill of the trenches. A full description including detailed pipe sizing, pipe materials, project alignment, a water loss assessment, and hydraulic modeling of the system can be found in the AID's SIP (AID 2017).

This alternative would contribute to the project's objectives as follows:

- Improve water conservation: This alternative would reduce water loss from canal seepage and evaporation by up to 45.1 cfs, or about 14,607 acre-feet per year, through installing pressurized HDPE pipe for all earthen canals and laterals.

- Increase water delivery reliability to patrons: Modernizing the system would improve irrigation water delivery reliability for 4,384 irrigated acres. Of the water saved by the project, 25 percent (up to 3,601 acre feet[4]) would remain on the District's certificate to improve water supply reliability issues caused by climate variability, water availability, and regulatory requirements. This alternative would improve operational efficiencies to ensure that patrons receive the water they need at the time that they need it. Additionally, a piped and pressurized system greatly increases conveyance efficiency.

- Reduce O&M costs: A fully piped system would eliminate the need to inspect, repair, and remove obstructions from open canals and laterals. Buried pipe requires extremely little maintenance and does not allow for obstructions such as tree limbs, leaves, garbage, or other types of debris from entering and clogging the District's system. A fully piped system would greatly reduce the need for staff to manually adjust diversion amounts at the District's main diversion on the Deschutes River and at the hundreds of individual delivery gates throughout the system. When patrons increase or decrease the amount of water they take from a fully piped and pressurized system, diversions into that system would adjust accordingly. Additionally, a pressurized pipeline would decrease the amount of energy used for pumping and in many cases eliminate the need for pumps. This combined would reduce patron energy use by approximately 926,000 kilowatt hours per year and $89,000 per year. The elimination of pumps would also decrease costs incurred by patron pump O&M.

[4] The final volume that the District will keep for themselves and that which goes instream will be determined by OWRD during the Conserved Water Allocation process. The number represented as saved water was based on single seepage loss conducted in 2017 which was the best available information at the time of writing this document.

- Enhance streamflow and habitat conditions for fish and aquatic species: This alternative would enhance streamflow and habitat conditions for fish and aquatic species by permanently allocating an estimated 11,005 acre-feet (75 percent of water saved through the project) instream. The District would allocate the saved water instream incrementally following the completion of each project group and verification of operational stability. Streamflow and habitat conditions along the Deschutes River would therefore also benefit incrementally.

- Improve public safety: Converting open canals and laterals to buried pipe would eliminate the risk of drowning.

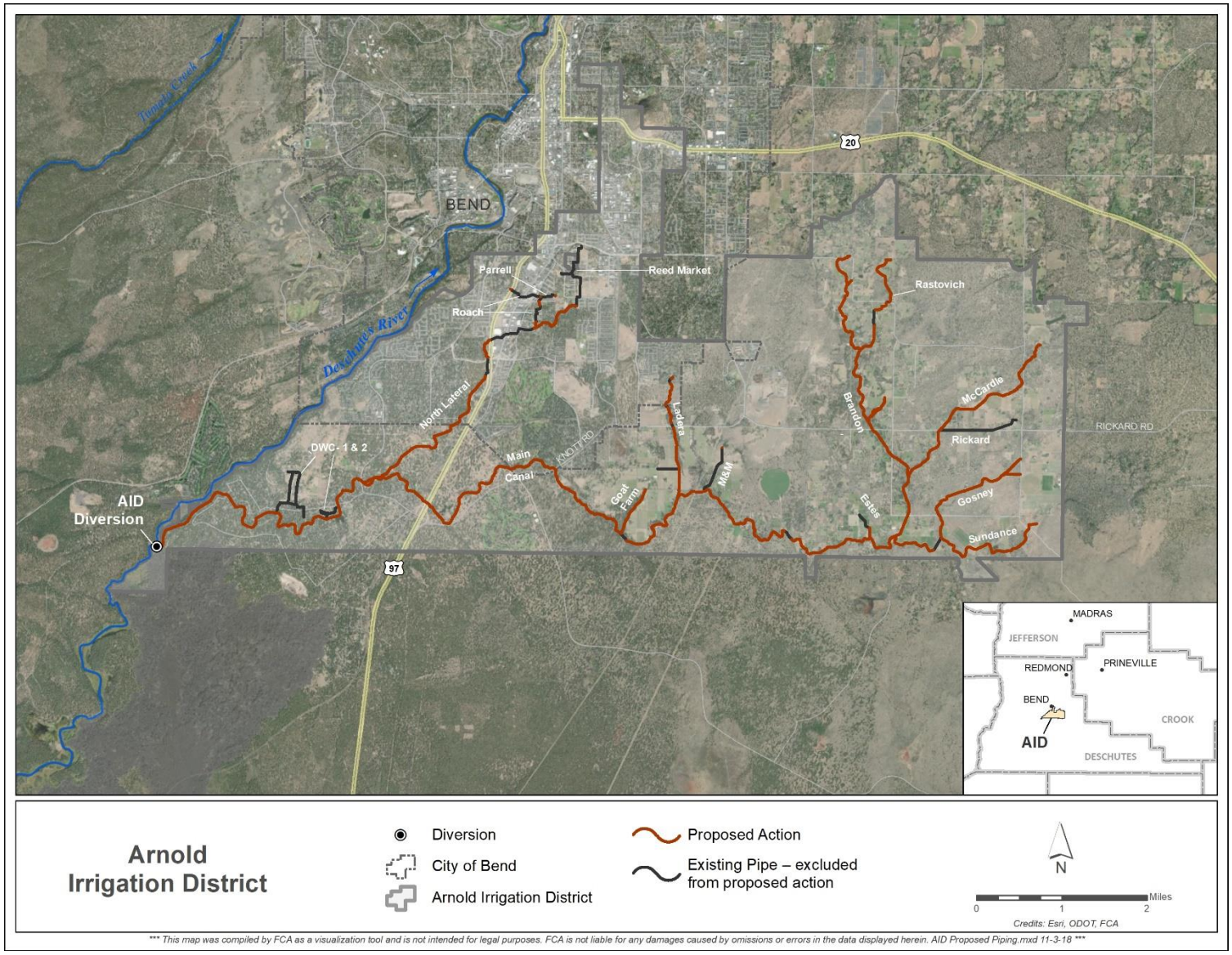


Figure 7-1. Arnold Irrigation District proposed piping.

7.3 Alternatives Proposed for Elimination from Detailed Study

The following alternatives are proposed for elimination from the analysis due to not meeting all aspects of the project's purpose and need.

7.3.1 Pipeline Realignment

The pipeline realignment alternative would involve the District converting their existing system to pipes, and, in some cases, the pipes would be laid in a new alignment (or path across the landscape). New alignments would be selected to serve all patrons, but, where possible, take a more direct route to decrease the length of piping needed. Depending on the most direct path and engineering requirements, the pipeline realignment alternative could require acquiring new easements or a ROW across lands within the District, the majority of which are private.

New easements could potentially disrupt prime farmland and residential areas, and would likely be a contentious and divisive issue within the community. Pipeline realignment outside the existing ROW and easements would require AID to pay market price for the new easements and negotiate with many landowners, which would be a complex, expensive, and time-consuming process. The pipeline realignment alternative would meet the sponsors' objectives; however, this alternative is proposed for elimination due to legal costs, logistical complexity, and social effects to adjacent landowners.

7.3.2 Dryland Farming

Under the dryland farming alternative, District patrons would no longer rely on irrigation water delivered by the District. Instead, crop growth would be dependent on precipitation as its water supply. The lack of rainfall throughout the growing season (approximately 11 inches per year) coupled with hot temperatures, desiccating winds, and generally shallow and well- to excessively drained soils with low storage potential, makes dryland farming infeasible within the District (Daly et al. 1994; Gannett et al. 2001). In the District, agricultural production would substantially decrease if dryland farming were implemented. With decreased production and income, farmers could potentially sell their land due to the development pressure Deschutes County is experiencing. Dryland farming would be inconsistent with ensuring agricultural production is maintained in an area undergoing rapid urbanization.

7.3.3 Fallowing of Farm Fields

The fallowing of farm fields alternative would include permanently or temporarily transferring water rights off of irrigated lands or not using water rights appurtenant to irrigated lands. Fallowing of farm fields would allow for less use of irrigation water and would therefore allow more water to remain instream for habitat uses. Fallowing of farm fields is proposed to be eliminated because it would not improve water delivery reliability or public safety for District-owned canal and lateral infrastructure, and it would be contrary to public policy supporting and maintaining existing agricultural land uses.

7.3.4 On-Farm Efficiency Upgrades

Under the on-farm efficiency upgrades alternative, the District's laterals and canal would remain in their current state and patrons would upgrade their on-farm irrigation methods and management

practices to use newer irrigation technologies that provide better and more uniform application of water and have greater efficiencies. Unlike District canals and laterals, on-farm infrastructure is owned and operated by patrons. Once delivered by the District and arriving on-farm, water is generally stored in a holding pond for sprinkler-irrigation systems. Each irrigation system has a different application efficiency (i.e., its ability to deliver the irrigation water to the crop root system across the full field being irrigated). Under the on-farm efficiency alternative, patrons would upgrade their current systems to irrigation systems with higher efficiencies.

This alternative would meet the objective of conserving water; however, this alternative is proposed for elimination because it would not improve water delivery reliability, and public safety for District-owned canal and lateral infrastructure. Although this alternative is proposed to be eliminated for PL-566 funding, it is viewed as a complementary activity that the District could pursue under other funding opportunities.

7.3.5 Exclusive or Partial Use of Groundwater for Irrigation

Exclusive or partial use of groundwater for irrigation has been considered in order to leave more surface water available in streams and rivers. The exclusive or partial use of groundwater would involve forgoing 1905 surface water rights and pumping groundwater to meet irrigation needs in the District. This alternative would require multiple wells that would each need a pump to draw water from the ground, incurring high electricity and installation costs. The exclusive or partial use of a conversion from surface water to groundwater for irrigation is proposed to be eliminated from consideration due to the exorbitant annual costs of installing and operating individual wells and pumps, and the logistical and legal constraints associated with obtaining associated groundwater rights.

7.3.6 Canal Lining

Under the canal lining alternative, the bottom and sides of the currently open canal and laterals would be covered with a geotextile liner and shotcrete to prevent water from seeping into the underlying soils and rock. This alternative would require sub-grade preparation, installation of a geotextile liner, and application of a layer of shotcrete to protect the geotextile liner across the District's 31.5 miles of open canal and laterals.

Lining would increase water velocity in the canal and laterals because the shotcrete cover is a smoother surface than the existing underlying rock. This makes the sides of the canal and laterals slippery and more difficult for people in the water to grasp onto and climb out. Fences would be installed along the length of the canal and laterals to prevent public access to the channel in order to increase public safety and reduce District liability. These fences would be chosen to prevent the public from nearing the edge or entering the channel and would be standard chain link with a 3-wire barbed wire cap per NRCS guidelines. In channels deeper than 2 feet, safety ladders would be installed every 750 feet to provide the opportunity for human and animal escape.

Canal lining reduces water loss due to seepage and would meet the objective of conserving water. Water loss in an open, lined system is estimated to be 10 percent based on studies of canal lining (Reclamation 2002). Lined canals are vulnerable to tears or cracks in the lining, and when torn or

cracked, seepage from lined canals is similar to that from unlined canals. In addition, canal lining would not provide pressurization of on-farm deliveries or a subsequent decrease in energy use.

Canal lining has a varying lifespan and can require extensive maintenance to continue operating at high efficiency (Reclamation 2002). Canal lining may be less expensive than HDPE piping to implement in its first installation cycle; however, the increased annual maintenance costs and replacement costs cause canal lining to exceed the cost of piping over a 100-year period for other districts in the Deschutes Basin.

This alternative was proposed for elimination because it does not meet all of the project's objectives, and the alternative would likely have higher annual costs over its lifetime due to maintenance and replacement.

7.3.7 Piping Material Alternatives

Under the piping material alternatives, AID would pipe their system with either polyvinyl chloride (PVC) or steel. Using a different piping material would meet the sponsors' objectives. However, using steel or PVC was proposed for elimination because of substantially higher costs that would be incurred across the project's lifetime.

7.4 Economics

A National Economic Efficiency analysis will be completed for the project during the Watershed Plan-EA process.

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9 Appendix A and B

Appendices are provided in a separate document.

Appendix A. System Improvement Plan
Appendix B. Supporting Information