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MODERNIZING IRRIGATION CONDUITS WITH HYDROPOWER POTENTIAL

Irrigation canals in the Western United States present an opportunity to conserve water and generate renewable energy

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I. Abstract

Modernizing irrigation systems is a win-win opportunity to jumpstart the United States' water conservation efforts and generate consistent renewable energy. Improving irrigation conduits can enhance efficiency and reliability of water supply to Americas farms, produce renewable energy with in-conduit hydropower turbines, and create resilient rural electrical grids.

Information in this report was collected through review of public documents from United States federal agencies including the Department of Energy and Department of Agriculture and interviews with irrigation district managers and experts in irrigation modernization research, planning, and engineering. The findings show that additional investment in modernizing irrigation systems can strengthen agricultural resilience to the effects of climate change, while generating revenue from hydropower to reinvest in the watershed.

The biggest barrier to expansive irrigation infrastructure overhaul is a recent, sharp decline in the power purchase rate for renewable energy. Irrigation districts historically financed some costs of modernization with revenue generated by hydropower production; now, the price per kilowatt hour (kWh) for hydropower has fallen too low to provide meaningful contribution toward satisfying modernization costs. However, when aggregated along thousands of miles of irrigation canals, the benefits from irrigation modernization can have critical importance to sustaining agricultural productivity.

II. Irrigation Conduits in the West

A majority of the irrigation infrastructure in the Western United States was constructed as a result of the 1902 Reclamation Act. Under the Reclamation Act, Congress authorized the construction of water projects to irrigate arid Western lands. These construction projects were federally financed and provide water for irrigation and flood control, and for domestic, industrial, and municipal use.[1] Many dams, reservoirs, and irrigation canals that were built as a result of this federal financing are still operational today. A majority of these projects were constructed between 1902-1940. Reclamation alone maintains 1,600 miles of main canal lines and 37,500 miles of canal laterals.[2] These, with state and locally owned canals, provide water for agricultural operations and carry over 80% of the total water used in the Western United States.[3]

Irrigation canals and pipes have the potential to generate a significant amount of electrical power. It is estimated that many of these thousands of miles of canals have enough elevation drop within their systems to generate kinetic energy which is converted to mechanical energy using in-conduit turbines. This energy is then converted to electrical energy using generators. Water diversions were constructed in rivers and streams at high elevation points in watersheds and then gravity forces water down to lower elevations through open canals.[4]

III. Conduit Hydropower

Conduits are "any tunnel, canal, pipeline, aqueduct, flume, ditch, or similar man-made conveyance structure used for the distribution of water for agricultural, municipal, or industrial consumption and not primarily for the generation of electricity".[5] Conduit hydropower uses existing conduits to generate hydroelectric power without the need to construct new dams or diversions. Water is moved through conduits by gravity and pressurized pipes. Sometimes water travels great distances through a combination of different conduits.

As water moves, excess energy builds up within irrigation conduits and can damage the infrastructure. Water that flows at a high velocity through canals erodes the canal walls. Pressurized piped systems have high static heads which can lead to higher pressure levels than

[1] The Bureau of Reclamation: A Very Brief History (U.S. Bureau of Reclamation: Reclamation History, 2018).
[2] Jay Swihart, Improved Water Delivery through Modern Canal Materials (U.S. Bureau of Reclamation: Research and Development Office, 2020).
[3] Irrigation & Water Use (U.S. Department of Agriculture: Economic Research Service,2019).
[4] Pumped Storage and Potential Hydropower from Conduits: Report to Congress (U.S. Department of Energy, 2015), 15.
[5] Pumped Storage and Potential Hydropower from Conduits: Report to Congress (U.S. Department of Energy, 2015), 14.

the system requires. Pressure-reducing valves (PRVs) are built into the system to dissipate this extra energy. Hydroelectric stations can be constructed where these PRVs are located and serve as PRVs for the conduit without disrupting pressure downstream for delivery to irrigators.

Conduit hydropower can also be generated within irrigation canals without pressurized pipes. Hydropower generators are built on top of a conduit with a turbine placed in the water which is turned by the natural flow’s velocity. This form of hydropower generation is less expensive because it requires little civil engineering work and permitting. Districts can purchase generators and place them 100-200 feet apart from one another and, when aggregated, they will create a large amount of renewable energy.[6]

Energy generated from conduits can be used in a community near the conduit and inside the water distribution system itself. The result is consistent renewable energy production, and increased energy efficiency within the water system. Hydraulic head at the location of the generator and the discharge past that point determines the amount of electrical generation that is possible from a pressurized system.[7]

Hydraulic head has four components that determine the energy potential:[8]

1. Velocity head – the bulk movement of the water
2. Static head – a drop in water surface elevation
3. Pressure head – pressure differentials across a system
4. Resistance head – friction losses within the water system.

Development of new hydropower within conduits must complete the following steps: planning, permitting, method of development, financing and power purchase agreement, interconnection and transmission, construction, start-up, and operation and maintenance.[9]

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[6] Morris, E. (March 9, 2021). Personal interview.
[7] Pumped Storage and Potential Hydropower from Conduits: Report to Congress (U.S. Department of Energy, 2015), 15.
[8] Pumped Storage and Potential Hydropower from Conduits: Report to Congress (U.S. Department of Energy, 2015), 15.
[9] Pumped Storage and Potential Hydropower from Conduits: Report to Congress (U.S. Department of Energy, 2015), 15.

IV. Irrigation Modernization

Fully modernizing an irrigation system requires installing a pressurized pipe system within irrigation conduits. Pressurized pipes replace irrigation canals and offer benefits of reduced water loss from seepage and evaporation, increased water delivery efficiency, and the opportunity for hydropower generation, among others. The process to complete an irrigation modernization project includes pre-engineering design, permitting, and financing, construction, and operation and maintenance. This section will describe the engineering, permitting, and financing phases of an irrigation modernization project.

Engineering

Irrigation districts range in size, topography, and uses.[10] Modernizing an irrigation district requires careful planning to develop a design specifically tailored to a district's unique qualities. To modernize an irrigation system, a district first must undertake a full analysis of its watershed and existing conduit flow. This pre-engineering design phase takes between 1 month to 2 years, depending on the size of the irrigation district. The pre-engineering design phase begins with using Geographic Information Systems mapping (GIS) technology to develop data for water conveyances and users of water in the irrigation district. This data includes measuring the amount of water each irrigator is using, the lengths of conveyances, and changes in elevation. Finding water use data can be challenging because some irrigation districts do not maintain an active database of individual water use. In these cases, irrigation districts rely on historical water rights to allocate resources.

Next, engineers and hydrologists conduct a water loss assessment of the existing conduits by conducting a field study to estimate how much water is lost from seepage and evaporation. The water loss assessment will estimate losses by taking the difference between upstream and downstream discharge measurements and removing contributions from natural inflows and diversions. Irrigation districts can lose up to 30% of canal water to seepage and evaporation.[11] Although, many irrigation districts do not monitor their own water loss. The quantity and quality of data that an irrigation district collects largely depends on how much scrutiny they get from state and federal regulators. Some irrigation districts do not own their conduits; instead, they are

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[10] All engineering information in this section comes from an interview with Mattie Bossler, Water Resources Engineer for Farmers Conservation Alliance from March 2, 2021.

[11] Dale Lancaster, Measurement of Seepage Losses from Irrigation Canals (ASCE: Bureau of Reclamation, 1952), 1.

contracted by the Bureau of Reclamation to operate and maintain irrigation canals under a high level of scrutiny. Even these districts can only indicate the locations where water is lost but not, typically, how much.

Using GIS data and a water loss assessment, engineers develop a hydraulic model of a piped and pressurized system for the water demanded at points along the system. EPANET,[12] a free product offered from the Environmental Protection Agency, uses hydraulic assumptions to estimate flow, pressure, and velocity through a system. Then, the model assigns demand based on irrigated acreage. The engineers generate multiple iterations of the hydraulic model to refine and determine the optimally sized pipe to install.

The hydraulic model identifies potential locations for hydropower generation. Traditionally, irrigation districts placed PRVs in these spots to maintain the system pressure below 100 psi. However, instead of PRVs, they can install hydropower turbines to serve the same pressure reducing function while generating renewable energy. It is challenging to maintain the correct pressure throughout a long system with constant elevation changes, as exists in the Western United States. Hydropower generators must not reduce the pressure too much and risk losing pressure for downstream patrons while also maintaining pressure below 100 psi to avoid overloading the system. A pressurized system has the benefit of reducing pump costs for irrigators by using pressure from the system itself to pump water. This saves irrigators money that is traditionally spent on diesel pumps.[13]

To estimate power capacity, the hydraulic model assumes irrigators are demanding water at the same time. Power capacity is estimated as follows:

1. Account for actual demand based on historical diversion data
2. Compare actual demand to the hydraulic model flows and to historical flows and reduce demands proportionally based on those ratios
3. Reduce the flow further by capacity generation factor for optimal hydropower generation
4. Re-run hydraulic model at the reduced flow to obtain the head-loss across PRVs
5. Use the reduced flow and the head loss across the PRV to estimate the power capacity.

[12] Environmental Protection Agency, EPANET.
[13] Jorgenson, J. Farmers Conservation Alliance. (February 19, 2021). Personal interview.

This process uses a general assumption by engineers to scale down the system, so it is more reflective of diversion data. Its then scaled down again for optimal hydropower generation with turbines. This is a complex process and is specific to each irrigation district.

Permitting and Compliance

Permits and compliances must be submitted and approved before construction on irrigation modernization projects can begin. The number and kind of permits required for a project depends on ownership of the land where the project is located, the owner of the irrigation infrastructure, and the source of the project's funding. Different federal, state, and local agencies have jurisdiction over lands and may each require different permits. Construction on federal land requires the most comprehensive permitting and compliance. Among the federal agencies that control public land are the Bureau of Land Management, U.S. Forest Service, National Park Service, and Fish and Wildlife Service. When a project runs through any federal land or nexus, the National Environmental Protection Act (NEPA) requirements apply. For NEPA, the federal agency that controls the land must complete an Environmental Impact Statement (EIS) and Environmental Assessment (EA). An EA determines whether the environmental impact of a project will be significant. If the environmental impact is deemed significant, an EIS is prepared. The intent of the NEPA process is to prevent environmentally destructive projects from taking place on federal land.

To receive funding for a piping project from NRCS PL 83-566 (Watershed and Flood Operation Protection program), irrigation districts must create a comprehensive Watershed Plans Environmental Assessment (WPEA). The WPEA must show the impact of a proposed project on the watershed's environmental, socioeconomic, and economic resources.[14]

Appendix A provides a comprehensive list of local, state, and federal permits and compliances that are necessary to begin construction. This information comes from the WPEA written by Central Oregon Irrigation District[15] for its ongoing irrigation modernization project. State and local information applies specifically to this project, located in Deschutes County, Oregon, but other localities have similar permits.

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[14] Bushnell, R. Farmers Conservation Alliance. (March 3, 2021). Personal interview.
[15] Central Oregon Irrigation District Smith Rock-King Way Infrastructure Modernization Project: Final Watershed Plan-Environmental Assessment (Oregon Watershed Plans, 2020) 106-109.

Financing

The current primary source of funding for irrigation modernization is from the Watershed and Flood Prevention Operations program (WFPO, PL83-566) from NRCS.[16] The WFPO was created in 1954 to provide funding for projects constructed by local sponsors with cooperation from the federal government to "protect and restore watersheds up to 250,000 acres".[17] To be eligible, a project must have public sponsorship, impact area up to 250,000 acres, and provide benefits directly related to agriculture (includes rural communities) which are at least 20% of the project's total benefits.[18] Projects are eligible for up to $25 million in funding through WFPO.[19] The WFPO program only requires a 25% match of federal funding rather than a 50/50 split which is typically required by government programs.[20]

NRCS also offers the Regional Conservation Partnership Program for smaller projects. This program will pay up to a 50% match in funding.[21] Other programs that offer small amounts of financing are offered by state and private organizations.

V. Benefits

Hydropower generation

Irrigation modernization offers an opportunity to generate renewable energy within existing infrastructure. Hydropower turbines are installed inside pressurized pipes instead of PRVs to generate small amounts of energy at a consistent rate throughout the irrigation season (April-October). In rare cases, districts have longer irrigation seasons, known as "winter water", which allows them to run hydropower year-round. The energy generated from irrigation systems can be sold to utility companies, used in the local community, or used offset existing energy use within the system (net metering). Farmers can connect to the energy generated by hydropower and use it to pump water. This will replace expensive diesel pumps and save irrigators money. Irrigation districts can use revenue from energy generation to reinvest in continued modernization efforts. The Farmers Irrigation District case study below describes how a district

[16] Jorgenson, J. Farmers Conservation Alliance. (February 19, 2021). Personal interview.
[17] Watershed and Flood Prevention Operations Program (U.S. Dept. of Agriculture: Natural Resources Conservation Service).
[18] Watershed and Flood Prevention Operations Program (U.S. Dept. of Agriculture: Natural Resources Conservation Service).
[19] Watershed and Flood Prevention Operations Program (U.S. Dept. of Agriculture: Natural Resources Conservation Service).
[20] Jorgenson, J. Farmers Conservation Alliance. (February 19, 2021). Personal interview.
[21] Jorgenson, J. Farmers Conservation Alliance. (February 19, 2021). Personal interview.

can pay off loans with energy revenue while piping more miles of canal or installing supply and flow monitors along the system.

Water Conservation

Modernized irrigations infrastructure can save water that is lost to seepage and evaporation. Some irrigation districts lose up to 30% of their water supply each year.[22] Seepage is the slow loss of water that escapes through the porous walls of irrigation canals. Evaporation is liquid water naturally turned into vapor. The water saved by piping creates a more reliable water supply and the excess is back into streams and rivers, restoring downstream flow and water quality for migratory fish passage.[23]

Agriculture

A modernized irrigation system is valuable to agricultural operations. Farmers in the west face increasingly inconsistent rainfall and prolonged periods of drought.[24] Piping and pressurizing open canals will increase an irrigation system's water supply reliability.[25] With water security, farms can grow higher value crops and generate more consistent revenue. Reliable and resilient water systems will give farmers a tool to weather prolonged drought and other extreme natural events.

Rural grid resilience

Energy generated by irrigation conduits can play an important role in creating a resilient electrical grid. The energy produced from conduits can be used to back up the main electrical grid during power failures. The occurrence of extreme weather events such as deep freeze, drought, and forest fires are increasing as a result of climate change.[26] Power from irrigation conduits will be a reliable source of energy when natural disasters and high demand disable the main electrical grid.

Irrigation modernization projects offer the opportunity for broader rural grid development as well. When piping, districts have the ability to install broadband internet connection and fiber

[22] Dale Lancaster, Measurement of Seepage Losses from Irrigation Canals (ASCE: Bureau of Reclamation, 1952), 1.
[23] Paul Menser, National Labs Lend Expertise to Overhaul Circulatory System of the American West (Idaho National Laboratory, 2020).
[24] Brian Palmer, Climate Change is Drying Out the American West (National Resource Conservation Service, 2020).
[25] Mosier, T. Idaho National Laboratory. (February 15, 2021). Personal interview.
[26] Leopoldina, European Academies' Science Advisory Council. (2018, March 21).

optic cables for a much lower cost than constructing separate, new infrastructure.[27] This advancement of rural infrastructure can provide communities with reliable access to the internet and communications systems.

Rural jobs

Irrigation modernization projects often take decades to complete. Piping infrastructure projects offer well-paying jobs in rural communities. These construction projects can provide rural work forces employment for years

Strengthening irrigation systems protects the vulnerable agriculture industry against impacts of climate change. Agriculture employs one of the largest rural workforces and should remain a viable, strong industry in rural communities. Without increasing the reliability of the agricultural water supply, farms in parts of the West will go bankrupt from of the effects of extreme and unpredictable weather. A healthy agriculture industry in the future is crucial to maintain a strong rural economy.

VI. Costs

Financing

Project financing is available from the Watershed and Flood Prevention Operations program from the NRCS. Through this program, districts can receive up to $25 million for irrigation piping projects.[28] NRCS also offers the Regional Conservation Partnership Program which can be used for smaller projects.[29] This program distributes a pool of $300 million annually with up to $10 million for each project that passes the application process. Eligible projects must demonstrate innovative improvements to watershed and resource concerns.[30]

Project financing is challenging because the programs weigh the net benefits from a project against its cost. Only certain benefits can be quantified. For example, there is no value associated with habitat improvement, so it is not accounted as a benefit. Presently, the fees from power purchase agreements are too low, causing the cost of hydropower generation to drag down a project's net benefit.[31]

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[27] Jorgenson, J. Farmers Conservation Alliance. (February 19, 2021). Personal interview.
[28] Watershed and Flood Prevention Operations Program (U.S. Dept. of Agriculture: Natural Resources Conservation Service).
[29] Jorgenson, J. Farmers Conservation Alliance. (February 19, 2021). Personal interview.
[30] Regional Conservation Partnership Program (U.S. Dept. of Agriculture: Natural Resources Conservation Service).
[31] Jorgenson, J. Farmers Conservation Alliance. (February 19, 2021). Personal interview.

Planning

Project identification and pre-engineering design phases can cost hundreds of thousands of dollars depending on the size of an irrigation district.[32] The process requires hiring outside consultants to conduct the analysis. The full cost and length of the planning process presents a barrier to project efficiency and the quantity of projects that can be completed

To combat the costs of the project identification process, Idaho National Laboratory, in conjunction with Farmers Conservation Alliance, is developing IrrigationViz, an irrigation modernization decision support and visualization tool. This program will allow irrigation districts to input their existing data and infrastructure design to generate estimates of water loss, cost to pipe segments, power generation potential, and revenue potential.[33] Managers can then modify specific segments of their systems in the program. The program also shows the groundwater effects, benefits from constructing a wetland, and consolidated analytics such as capital costs, financial metrics, water use, and water returned to streams for fish.[34] The IrrigationViz program will give irrigation district managers a tool to begin moving forward with their own projects without the expensive initial investment.

Permitting and compliance

The permitting and compliance process associated with piping projects is time consuming. Permitting can take 1 month to 3 years to complete.[35] For projects solely through private land, only county compatibility rules apply. For projects that run through federal land or use irrigation infrastructure that is federally owned, districts must work with the federal authorities which own the land/infrastructure and comply with its agencies' rules and requirements. Permitting can be a barrier for projects moving forward because of its complexity.

Purchase power agreements

Whether or not a hydropower project can help an irrigation district modernize is determined by its power purchase rate and the cost to connect it to the electrical grid. In the last decade, power prices have declined dramatically. In 1985, Farmer's Irrigation District negotiated

[32] Mosier, T. Idaho National Laboratory. (February 15, 2021). Personal interview.
[33] Mosier, T. Idaho National Laboratory. (February 15, 2021). Personal interview.
[34] Mosier, T. Idaho National Laboratory. (February 15, 2021). Personal interview.
[35] Bushnell, R. Farmers Conservation Alliance. (March 3, 2021). Personal interview

at 14¢ per kWh contract with the local utility company.[36] At this price, Farmers Irrigation District was able to generate enough revenue to pay debts to continue its modernization efforts for the entire district. Now, power rates range between 2-3¢ per kWh which is crippling modernization efforts.[37]

The rise of solar, wind, and natural gas caused the price for renewables and energy overall to decrease. Hydropower is caught in this industry-wide price collapse and has struggled to differentiate itself from other energy sources. Hydropower projects are priced like solar and wind but offer a wider range of benefits to electric grids such as consistency and the ability to generate power on demand.[38] Hydropower from irrigation conduits is localized and offers very different benefits than large-scale energy plants, but some utility companies resist purchasing power from outside sources.

VII. Case Study

<u>Farmers Irrigation District</u>

District Description

Farmers Irrigation District (FID) serves the west side of the lower Hood River Valley in Oregon. FID provides water to 5,888.25 acres totaling 1,851 accounts.[39] FID agricultural production includes pears, apples, and cherries, some of the highest value crops grown in the United States.

In 1965, the private irrigation firm which owned the district sold the property to the new Farmers Irrigation District. Deteriorating infrastructure prompted the sale which allowed the new public district to receive more reliable funding and access to government resources.[40] The infrastructure purchased by the new irrigation district consisted of open canals and wooden flumes. It continually failed to deliver water due to floods, landslides, and earthquakes. In some years, farms at higher elevations of the district were without water for over half the growing season.[41]

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[36] Perkins, L. Farmers Irrigation District, Manager. (March 2, 2021). Personal interview.
[37] Jorgenson, J. Farmers Conservation Alliance. (February 19, 2021). Personal interview.
[38] Benefits of Hydropower (USDE, Office of Energy Efficiency and Reliability).
[39] Les Perkins, Cumulative Watershed Impacts of Small-Scale Hydroelectric Projects in Irrigation Delivery Systems: A Case Study (Farmers Conservation Alliance, 2013), 8.
[40] Les Perkins, Cumulative Watershed Impacts of Small-Scale Hydroelectric Projects in Irrigation Delivery Systems: A Case Study (Farmers Conservation Alliance, 2013), 8.
[41] Les Perkins, Cumulative Watershed Impacts of Small-Scale Hydroelectric Projects in Irrigation Delivery Systems: A Case Study (Farmers Conservation Alliance, 2013), 8.

Project Description

FID began its modernization efforts in 1985 and completed the project in 2015. The improvements include a fully piped 63.4-mile irrigation system, hydropower generation capability, improved diversions and fish screens at every diversion to achieve a higher environmental sustainability standard than are even required by Oregon's strict code. From 1985 to 2013, FID's audited capital improvements were $45,484,713.[42]

Energy

Electricity generation is a secondary benefit to projects that improve an irrigation system's efficiency in conveying water and management of the system. Over the last 28 years, FID has increased its total annual power generation within the system by 2,255,000 kWH from piping and conserving more water to be run through their generators. FID's total annual energy generation is ~25,000,000 kWh. Using the electricity generated by the system, FID has installed a centralized pumping facility, eliminating outdated pumps on individual farms. This led to power savings and higher efficiency water application for farmers.

Below is a partial list of energy related accomplishments at FID.[43]

- 1,450 individual pumps eliminated
- ~25,000,000 renewable Low Impact Hydropower annual kWh production
- 2,000 homes supplied with low-impact hydropower, based on average annual household consumption in Oregon (11,892 kWh/year).

Water

As a result of pipe installation within the formerly open irrigation system, the amount of water used since 1995 has greatly decreased. In 1995, the water use was over 27,000-acre feet per year. Now, the system delivers under 13,000-acre feet per year and meets all FID irrigator needs, a 51% decrease.[44] Combined with keeping the 30% of water that is lost to seepage and evaporation within the system, districts can conserve up to 80% of water that is wasted by using old infrastructure.

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[42] Farmers Irrigation district, "Sustainability Plan", 2012 v.16
[43] Farmers Irrigation district, "Sustainability Plan", 2012 v.16
[44] Les Perkins, Cumulative Watershed Impacts of Small-Scale Hydroelectric Projects in Irrigation Delivery Systems: A Case Study (Farmers Conservation Alliance, 2013), 19.

Below is a partial list of water conveyance and conservation projects completed by FID since hydropower systems were installed.[45]

- 63.4 miles of canal enclosed in pipe
- 2,500 acre-feet of spray water conserved annually
- 15,000 acre-feet of irrigation water conserved annually
- 300% average annual reduction in residential irrigation use
- Flow measurement weirs installed (measures flow, improves efficiency and ensures compliance with regulations)
- Flow regulators and low head gauge holes installed (restricts flow to end users, ensuring water rights are not exceeded)
- Flow meters and piezometers installed (ensures delivery of the proper amount of water to irrigators and maximizes application efficiency).

Economy

FID modernization projects have benefited the Hood River Basin through significant investment in infrastructure improvement and watershed restoration. They have created high quality jobs including employees of the irrigation district and construction and watershed restoration workers.[46] The greatest impact on the local economy is an improved water delivery system for the agricultural industry. FID has generated almost $45 million in revenue from hydropower projects in the past 28 years.[47] All of this money is reinvested in the local community, either through paying debt for new infrastructure or directly to wages and project implementation.

Summary

Farmers Irrigation district is one of the most progressive irrigation districts in the country as a result of the hydropower projects it has undertaken in the last 30 years. The district is a leader in efficient water use, application and invention of new efficient technology, and stewardship of its watershed and patron farmers. Without revenue generated by hydropower, the

[45] Farmers Irrigation district, "Sustainability Plan", 2012 v.16
[46] Les Perkins, Cumulative Watershed Impacts of Small-Scale Hydroelectric Projects in Irrigation Delivery Systems: A Case Study (Farmers Conservation Alliance, 2013), 21.
[47] Les Perkins, Cumulative Watershed Impacts of Small-Scale Hydroelectric Projects in Irrigation Delivery Systems: A Case Study (Farmers Conservation Alliance, 2013), 21.

district would not have been able to make such impactful infrastructure improvements. By owning and operating hydropower plants, FID has become more engaged in the community, more politically active, and more economically sophisticated. FID is willing to collaborate with other irrigation districts interested in modernizing themselves.[48]

Middle Fork Irrigation District

District Description

Middle Fork Irrigation District (MFID) is located in the Upper Hood River Valley in Oregon. MFID delivers water for 6,676 acres to 403 users and operates 35 miles of irrigation infrastructure.[49] Located on the north slope of Mt. Hood, MFID must remove glacial sediment which is regularly dispenses into the Hood River and then into irrigation water. Sediment acts as sandpaper to pumps and other mechanical equipment, reducing its lifespan drastically.[50] This required the district to move early to a piped irrigation system to ensure better filtration and reduce maintenance costs in the future. MIFID produces some of the highest value crops in Oregon including winter pears.[51]

Project Description

In 1962, MFID implemented its first modernization plan to build a reservoir, sediment trapping facility, and 23 miles of pressurized distribution pipe.[52] By the 1980s this infrastructure was deteriorating, and the district explored options to make improvements. MFID identified hydropower as an alternative revenue source to fund the improvements. After permitting, MFID replaced its three pressure reducing vaults with three powerhouses with turbines. Two powerhouses use Pelton turbines, and one uses a Francis Turbine.[53] The project was put into service in 1986 and cost $7,500,000 and now generates 25,000,000 kWh annually.[54]

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[48] Les Perkins, Cumulative Watershed Impacts of Small-Scale Hydroelectric Projects in Irrigation Delivery Systems: A Case Study (Farmers Conservation Alliance, 2013), 23.
[49] Les Perkins, Cumulative Watershed Impacts of Small-Scale Hydroelectric Projects in Irrigation Delivery Systems: A Case Study (Farmers Conservation Alliance, 2013), 24.
[50] Middle Fork Irrigation District, “Water Management/Conservation Plan,” April 2011.
[51] Middle Fork Irrigation District, “Water Management/Conservation Plan,” April 2011.
[52] Les Perkins, Cumulative Watershed Impacts of Small-Scale Hydroelectric Projects in Irrigation Delivery Systems: A Case Study (Farmers Conservation Alliance, 2013), 25.
[53] Middle Fork Irrigation District, “Water Management/Conservation Plan,” April 2011.
[54] Les Perkins, Cumulative Watershed Impacts of Small-Scale Hydroelectric Projects in Irrigation Delivery Systems: A Case Study (Farmers Conservation Alliance, 2013), 27.

Energy

The MFID has been producing hydropower for 27 years. The power contributes to the stability of the district electrical grid and complements intermittent renewables such as solar and wind. Below is a partial list of energy impacts from MFID hydropower facilities:[55]

- 25,000,000 kWh produced per year
- 2,100 homes potentially supplied with power, based on average per household usage rate.

Water

In the last 27 years, MFID has piped smaller lateral ditches, eliminating loss from seepage and evaporation. By installing pressure reducing valves, MFID has reduced the pressure of water coming out of sprinklers. These valves have lead to a 30% reduction in flow coming out of sprinkler heads.[56] Below is a partial list of water conveyance and conservation projects completed by MFID since 1962:[57]

- 33.68 miles of pipe installed
- 100% spill and operational overflow elimination
- 24 pressure reducing valves installed.

Economy

Since hydropower plants were installed in 1986, the MFID has generated over $44 million in revenue. All of this revenue remains in the local economy and is used for equipment, salaries, infrastructure and watershed improvements and the engineering and construction jobs associated therewith.[58] Revenue from hydropower has allowed MFID to grow its support for agriculture, the main sector in the local economy. The projects that the district has undertaken with this revenue ensure that water is delivered to farms efficiently and reliably.

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[55] Les Perkins, Cumulative Watershed Impacts of Small-Scale Hydroelectric Projects in Irrigation Delivery Systems: A Case Study (Farmers Conservation Alliance, 2013), 33.

[56] Les Perkins, Cumulative Watershed Impacts of Small-Scale Hydroelectric Projects in Irrigation Delivery Systems: A Case Study (Farmers Conservation Alliance, 2013), 33.

[57] Middle Fork Irrigation District, “Middle fork Irrigation District’s Cooperative Conservation Efforts,” 2012.

[58] Les Perkins, Cumulative Watershed Impacts of Small-Scale Hydroelectric Projects in Irrigation Delivery Systems: A Case Study (Farmers Conservation Alliance, 2013), 34.

Summary

Over the past 27 years, MFID has taken steps to improve its infrastructure to combat present dangers such as negative sediment and debris impacts and to mitigate damages from predicted climate change. These improvements would not have been possible without revenue generated from hydropower. The hydropower plants increase water delivery efficiency and protection for natural resources. Because of its hydropower projects, MFID has provided a net benefit to the health of the Hood River Watershed.

VIII. Conclusion

Hydropower from irrigation conduits generates renewable energy, improves efficiency and reliability of the agricultural water supply, and revitalizes watersheds. The benefits from irrigation modernization with hydropower include revenue from hydropower generation, increased efficiency and reliability of water for agricultural use, rural grid resilience, and water conservation. When aggregated, these benefits greatly outweigh the cost of failing to modernize an irrigation system. At the present time, however, there are not enough financing options for many irrigation districts to undertake an expensive infrastructure project.

Farmers Irrigation District's first power purchase agreement in 1985 was 14¢ per kWh. At this rate, FID was able to use revenue from hydropower to modernize its entire system over 30 years with a fully piped system, flow regulators, weirs, and piezometers. These improvements save water and provide a more reliable supply to the district's patrons. Current power purchase rates offered by utility companies range between 2-3¢ per kWh. At this low-rate, irrigation districts will not generate enough revenue to offset up-front costs to build on their modernization efforts. To pursue a large number of irrigation modernization projects in the future, the full range of benefits from modernization projects must be priced into PPAs.

To understand the full scope and importance of modernizing our irrigation system, we must conceptualize the aggregation of renewable energy generation and water conservation along thousands of miles of conduits throughout the Western United States. The energy grid of the future is a distributed network of smaller power transported over shorter distances. This creates a more resilient electrical grid that can swiftly react to extreme weather events and other sudden demand changes. The Western United States' irrigation system must be modernized, and hydropower is the way to accomplish it.

IX. Appendices

Appendix A:

Local and County

- **County Planning:** A Land Use Compatibility Statement must be submitted for county approval prior to construction.

State

- **Department of Environmental Quality (DEQ):** The National Pollutant Discharge Elimination System program requires a permit for construction activities including clearing, grading, excavation, materials or equipment staging and stockpiling that would disturb one or more acres of land and have the potential to discharge into a public waterbody.
- **Water Resources Department (WRD):** To change the place of use, character of use, and/or point of diversion/appropriation of a water right, a water right transfer application must be approved by WRD.
- **Department of State Lands (DSL):** Prior to project implementation, consultation with DSL must occur to perform wetland determination for sites throughout the project area and determine exemption applicability to canals and laterals in the district. Oregon's Removal Fill Law requires any person who plans to remove or fill material within waters of the state to obtain a permit from the DSL.
- **Department of Fish and Wildlife (DFW):** The owner or operator of an artificial obstruction located in waters in which native migratory fish are currently or were historically present must address fish passage requirements prior to certain trigger events, such as the construction, installation, replacement, extension, or repair of culverts, roads, or other hydraulic facilities.

Federal

- **National Historic Preservation Act Section 106 (NHPA):** Pursuant to 36 CFR Part 800 of the NHPA, and the regulations of the Advisory Council on Historic Preservation implementing Section 106 of the NHPA, federal agencies must take into account the potential effect of an undertaking on "historic properties," which refers to cultural resources listed in, or eligible for listing in the National Register of Historic Places. Consultation with State Historic Preservation Offices (SHPO), National Resource

Conservation Service (NRCS), Tribal Historic Preservation Office (THPO), and other consulting parties including affiliated tribes to fulfill Section 106 obligations must be completed for the project prior to implementation.

- **Clean Water Act (CWA):** In 33 CFR 323.4(a)(6) and 40 CFR 232.3(c)(6), there must be assurance that flow and circulation patterns and chemical and biological characteristics of Waters of the United States are not impaired, that the reach of the Waters of the United States is not reduced, and that any adverse effect on the aquatic environment would be otherwise minimized. Prior to construction activities, coordination and consultation with U.S. Army Corps of Engineers (USACE), would occur and measures taken as required to identify and mitigate impacts to potential jurisdictional wetlands and Waters of the United States.
    - Irrigation modernization would include construction activities in the Waters of the United States. A Section 404 permit is required from the USACE when a project require fill or other modification of Waters of the United States. A request for a USACE permit to affect the Waters of the United States involved other resource and regulatory agencies as part of the interagency review process and applications for a Section 404 permit would be prepared and submitted prior to construction activities.
- **Farmland Protection Policy Act (FPPA):** Identify and quantify adverse impacts of federal programs on farmlands. The Act’s purpose is to minimize the number of federal programs that contribute to the unnecessary and irreversible conversion of agricultural land to nonagricultural uses. Irrigation modernization takes place within existing and new easement agreements and right-of-way. Irrigation modernization projects support agricultural productivity and the intention of the Act.
- **Endangered Species Act (ESA):** The ESA establishes a national program for the conservation of threatened and endangered species and the preservation of the ecosystems on which they depend. The ESA is administered by the U.S. Fish and Wildlife Service (USFWS) for wildlife and freshwater species. The ESA specifies prohibited actions and exceptions. Section 7 of the Act, called “Interagency Cooperation,” is the mechanism by which federal agencies ensure the actions they take, including those they fund or authorize, do not jeopardize the existence of any listed

species. Under Section 7, federal agencies must consult with USFWS when any action the agency carries out, funds, or authorizes *may affect* a listed endangered or threatened species.

- **Magnuson Stevens Act:** Established the requirements for including Essential Fish Habitat (EFH) descriptions in federal fishery management plans and requires federal agencies to consult with National Marine Fisheries Service (NMFS) on activities that may adversely affect EFH. EFH include all streams, lakes, ponds, wetlands, and other viable waterbodies, and most of the habitat historically accessible to salmon necessary for spawning, breeding, feeding or growth to maturity.
- **Safe Drinking Water Act (SDWA):** Established to protect the quality of drinking water in the U.S. Authorizes EPA to establish minimum standards to protect tap water and requires all owners or operators of public water systems to comply with primary, health-related standards.
- **Migratory Bird Treaty Act (MBTA):** Enacts treaties between the United States and other nations, such as Canada and Mexico, for protection of migratory birds. The Act states that taking, killing, or possessing migratory birds, or taking, destroying, or possessing their eggs or nests, is unlawful. The Act clarifies most species of birds as migratory, except for upland and nonnative birds such as pheasant, chukar, gray partridge, house sparrow, European starling, and rock dove.
- **Bald and Gold Eagle Protection Act (BGEPA):** The BGEPA prohibits the taking or possessing of, and commerce in, bald and golden eagles, with limited exceptions. The Act only covers international acts in “wanton disregard” of the safety of bald or golden eagles.

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