Highland Economics LLC

Memo

To: Julie Davies O'Shea, FCA

From: Barbara Wyse, Highland Economics

cc: Stacy Lowery, FCA; Jerry Bryan, FCA; Les Perkins, Farmers Irrigation District

Date: May 11, 2016

Re: Benefits Analysis of Irrigation District Modernization: Farmers Irrigation District Case Study

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This memo describes findings and general methodology for quantifying some of the primary expected financial, economic, and environmental benefits of an irrigation system modernization program. The analysis is based on the experience of Farmers Irrigation District (FID) in Hood River, Oregon, which began modernizing in 1985 with installation of in-line hydropower production and piping to replace unlined irrigation canals. Piped conveyance systems were installed throughout the period 1987 to 2014, leading to increased hydropower production, reduced energy usage for water pumping, reduced district operation and maintenance (O&M) costs, increased water supply availability and reliability to FID growers, and increased in-stream water flows during critical summer months. Restoration efforts by FID were also undertaken, but the environmental and recreation benefits of these efforts (and of enhanced instream flow) are not analyzed here.[1]

The experience of districts who have already completed modernization may provide valuable insights for other irrigation districts considering modernization. This analysis quantifies and compares the level of benefits that districts, growers, and their communities may expect from slow implementation of modernization over a 30-year period (as implemented at FID between 1985 to 2014), and the level of *increased* benefits that may be expected from rapid modernization over a five-year period. While the analysis is a case study of FID, and is grounded in actual data from FID, the data has been adjusted in the following ways: costs of modernization related to fish screen development were omitted, and the value of hydropower generation is not the actual price received by FID, but rather a conservative price we expect Districts may receive in the future (based on the 2015 price received by FID). We conduct the analysis

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[1] Other potentially significant benefits realized from modernization that are not analyzed here include social and environmental benefits related to preservation of farmland, such as aesthetic benefits for both residents and tourists, community benefits of maintaining the rural way of life, and wildlife habitat and soil carbon sequestration benefits provided by agricultural lands (compared to urbanized lands). Finally, this analysis does not consider the local community jobs directly supported by modernization-related construction activities and indirectly through preserved or enhanced economic activity in the tourism, agriculture, and recreation sectors.

from the standpoint of a district or other entity contemplating investment today in irrigation modernization.

The analysis aims to isolate only those costs and benefits to the District, growers, and community that are directly related to irrigation modernization. The timeframe of the analysis is 1985 to 2035 (assuming a 50-year useful life of the initial hydropower generation infrastructure), with an additional analysis done from 1985 to 2015 to highlight benefits accrued to date at FID. Benefits are analyzed for two modernization scenarios: slow modernization completed over a 30-year period (compared to no modernization), and rapid modernization over a 5-year period (compared to no modernization). Benefits are higher in the rapid modernization scenario in which piping is completed rapidly. This is due to greater hydropower production, water and energy savings, O&M cost savings, and water supply reliability to District growers which maintains irrigated acreage in production—benefiting both growers and the District (through assessment fees and account charges). While not all of these types of benefits may be relevant to all districts, the framework and methodology established in this analysis may serve as a framework for future benefit analyses for other districts who have completed modernization or are considering undertaking a modernization program.

Findings are presented in **Table 1 and Table 2** for the period 1985 to 2035. **Tables 3 and 4** also provide a summary of data using the period from 1985 to 2016 (period to date). Interpretation of the metrics, as well as a summary of the methodology and data utilized are provided below the tables.

Table 1: Select Estimated Economic Benefits from Irrigation Modernization Over 50 Years

Economic Metric	Rapid Modernization	Slow Modernization	Additional Benefit of Rapid Modernization
Annual Average Simple Return on Investment (ROI) to District	2.64%	1.48%	1.16%
Net Present Value Benefit to District	$8,100,000	$1,700,000	$6,400,000
Present Value Capital Expenditures	*-$44,700,000*	*-$42,300,000*	*-$2,400,000*
Present Value Hydro Benefit	*$38,700,000*	*$34,900,000*	*$3,800,000*
Present Value O&M Cost Savings Benefit	*$9,700,000*	*$4,700,000*	*$5,100,000*
Present Value District Assessment/Account Fee Benefit (Maintaining Irrigable Land Base)	*$4,400,000*[1]	*$4,400,000*	*$0*
Present Value Agricultural Income[1]	$111,400,000	$109,400,000	$2,000,000
Present Value of Farm Profit	*$59,200,000*[2]	*$59,200,000*	*$0*[2]
Present Value of Farm Labor Income	*$48,400,000*	*$48,400,000*	*$0*
Present Value of Reduced Farm Pumping Cost	*$3,800,000*	*$1,800,000*	*$2,000,000*

1/This value will likely vary widely by region, but without modernization and increased water use efficiency, the potential for acreage to be taken out of production due to reduced water supply availability and reliability will likely be relevant to all irrigation districts.

2/Likely an underestimate for FID and other Districts as this only includes an estimate of acreage kept in production due to water savings from piping; rapid modernization resulted in increased water supply reliability (compared to slow modernization) that likely resulted in higher crop yields and net farm income in addition to the benefits associated with maintaining land in production.

Table 2: Select Energy and Environmental Benefit Estimates from Irrigation Modernization

Economic Metric	Unit	Rapid Modernization	Slow Modernization	Additional Benefit of Rapid Modernization	Interpretation Notes of Additional Benefit
Hydropower Generation, 1985-2035	MWh	1,184,300	1,100,000	84,300	
Annual Average MWh, 1987-2009[1]	MWh	23,410	19,740	3,670	Power for 335 homes[2]
Reduced Carbon Emissions, 1985-2035	Metric Tons	944,500	860,700	83,800	Carbon stored, on average, in 2,865 acres of Oregon forests[3]
Reduced Energy Usage		*53,300*	*32,900*	*20,400*	
MWh Produced[4]		*891,200*	*827,800*	*63,600*	
Value of Reduced Carbon Emissions	2015 $	$39,700,000	$36,200,000	$3,500,000	
Water Conserved / Summertime Instream Flow Enhanced, 1985-2035	Millions of Gallons	294,300	182,000	112,300	
Annual Water Conserved/Summertime Instream Flow Enhanced, 1988-2012	Millions of Gallons	5,960	1,730	4,230	128,800 people supplied with water annually[5]; equivalent to average flow of Columbia River at Dalles Dam for 54 minutes.[6]

1/ The period 1987 to 2009 is the period during which hydropower generation differed between the two scenarios, and so this is the time period used to estimate the annual average difference in hydropower production.

2/ Based on 10,932 kWh annual average electricity use by American residential utility customers in 2014 (Energy Information Administration).

3/ Based on US Forest Service estimate that forests in Oregon store on average 64,469 pounds of carbon per acre.

4/ Assumes replaces fossil fuel-based electricity generation.

5/ Based on USGS estimate of 90 gallons of individual water use at home daily.

6/ Based on 175,000 cubic feet per second average mean daily discharge at Dalles Dam between 1978 and 1998.

Table 3: Select Estimated Economic Benefits to Date from Irrigation Modernization: 1985 - 2016

Economic Metric	**Rapid Modernization**	**Slow Modernization**	**Additional Benefit of Rapid Modernization**
Annual Average Simple Return on Investment (ROI) to District	1.08%	-0.31%	1.39%
Net Present Value Benefit to District	-$5,600,000	-$6,100,000	$500,000
Present Value Capital Expenditures	*-$44,700,000*	*-$42,300,000*	*-$2,400,000*
Present Value Hydro Benefit	*$29,200,000*	*$25,400,000*	*3,800,000*
Present Value O&M Cost Savings Benefit	*$7,400,000*	*$2,300,000*	*$5,100,000*
Present Value District Assessment/Account Fee Benefit (Maintaining Irrigable Land Base)	*$2,100,000*	*$2,100,000*	*$0*
Present Value Agricultural Income[1]	*$55,200,000*	*$53,200,000*	*$2,000,000*
Present Value of Farm Profit	*$28,800,000*	*$28,800,000*	*$0*
Present Value of Farm Labor Income	*$23,500,000*	*$23,500,000*	*$0*
Present Value of Reduced Farm Pumping Cost	*$2,900,000*	*$900,000*	*$2,000,000*

1/This value will likely vary widely by region, but without modernization and increased water use efficiency, the potential for acreage to be taken out of production due to reduced water supply availability and reliability will likely be relevant to all irrigation districts.

2/Likely an underestimate for FID and other Districts as this only includes an estimate of acreage kept in production due to water savings from piping; rapid modernization resulted in increased water supply reliability (compared to slow modernization) that likely resulted in higher crop yields and net farm income in addition to the benefits associated with maintaining land in production.

Table 4: Select Energy and Environmental Benefit Estimates from Irrigation Modernization: 1985-2016

Economic Metric	Unit	Rapid Modernization	Slow Modernization	Additional Benefit of Rapid Modernization	Interpretation Notes of Additional Benefit
Hydropower Generation, 1985-2016	MWh	709,300	625,000	84,300	
Annual Average MWh, 1987-2009[1]	MWh	23,410	19,740	3,670	Power for 335 homes[2]
Reduced Carbon Emissions, 1985-2016	Metric Tons	566,300	482,500	83,800	Carbon stored, on average, in 2,865 acres of Oregon forests[3]
Reduced Energy Usage	Metric Tons	*32,500*	*12,200*	*20,300*	
MWh Produced[4]	Metric Tons	*533,800*	*470,300*	*63,500*	
Value of Reduced Carbon Emissions 1985-2016	2015 $	$23,800,000	$20,300,000	$3,500,000	
Water Conserved / Summertime Instream Flow Enhanced, 1985-2016	Millions of Gallons	179,800	67,400	112,400	
Annual Water Conserved/Summertime Instream Flow Enhanced, 1988-2012	Millions of Gallons	5,960	1,730	4,230	128,800 people supplied with water annually[5]; equivalent to average flow of Columbia River at Dalles Dam for 54 minutes.[6]

1/ The period 1987 to 2009 is the period during which hydropower generation differed between the two scenarios, and so this is the time period used to estimate the annual average difference in hydropower production.

2/ Based on 10,932 kWh annual average electricity use by American residential utility customers in 2014 (Energy Information Administration).

3/ Based on US Forest Service estimate that forests in Oregon store on average 64,469 pounds of carbon per acre.

4/ Assumes replaces fossil fuel-based electricity generation.

5/ Based on USGS estimate of 90 gallons of individual water use at home daily.

6/ Based on 175,000 cubic feet per second average mean daily discharge at Dalles Dam between 1978 and 1998.

The interpretation of the quantified benefit metrics, and their cost and benefit components, as presented in **Tables 1 and 2** are as follows:

1) Net present value to district represents the gain (benefits less costs), in today's dollars, of modernization benefits over a 50-year period. Future benefits (and costs) are discounted at an annual rate of 3 percent to account for society's preference for benefits to accrue sooner rather than later (time value of money).

   The estimate of net present value to the District includes the following values:

   a. Increased capital cost expenditures required for hydropower facilities and piping; nominal capital costs are lower in the rapid modernization scenario compared to slow modernization (by an estimated $5.75 million) due to reduced need for temporary piping and fish screen installations.[2]

   b. Hydropower revenues from in-line hydropower facilities. The benefits included in this analysis are related solely to price per kilowatt-hour (kWh) received; any sales of Renewable Energy Certificates (RECs) or revenue from demonstrated capacity payments would increase hydropower revenues. Furthermore, the analysis conservatively holds constant through time the real price received per kWh at the 2015 rate received by FID ($0.06852/kWh). See #4 below regarding estimation of megawatt hours (MWh) generated through time in each modernization scenario.

   c. District operation and maintenance (O&M) cost savings, including materials, contractors, and fixed and variable staff expenses (salary, benefits, and overtime). Reduced O&M costs, estimated to rise in the slow modernization case from $7,000 in 1988 to $428,000 by 2013, are related to increased efficiencies associated with piping that drastically decrease costs associated with floods, debris flows, and other events that damage diversions, hydropower systems, and canals. These cost savings increase over time in accordance with the level of capital investments made in piping over time (with the assumption that reduced O&M cost correlate proportionately with the mileage of conveyance system that is piped). Cost savings accrue earlier in the rapid modernization scenario: they rise from $7,000 in 1985 to $428,000 by 1990.

   d. District assessment and account fees maintained through provision of reliable water supplies. Through increased efficiency from modernization, FID can provide water to irrigate all agricultural acreage within its service area at a lower average diversion rate than allowed by its 3 acre-foot per acre duty. To reduce water diversions to this level without modernization, approximately 41 percent of lands, or approximately 2,380 acres and 700 accounts, on average could not have been serviced and would likely have been removed from the District service area, reducing district assessments and account fees ($110/acre and $200 per account, respectively).

[2] For the rapid modernization scenario, capital costs expended by FID between 1988 and 2013 for piping are allocated to the years 1985 to 1990. To account for construction costs differences between time periods, the capital costs are adjusted using the RS Means Construction Cost Index. Although nominal capital costs are lower in the rapid modernization scenario, the present value of capital costs in 2015$ is actually higher than they were with slow modernization because they are all borne early in the analysis period and as such are not as heavily discounted as costs borne later in the analysis period.

2) Average annual simple return on investment (ROI) provides information on the average annual level of net benefits provided relative to the investment costs. It is calculated as the ratio of total net benefits (benefits less costs) to total costs, divided by 50 (as there are 50 years in the analysis period). The ROI metric provides important information to help a district or other potential investor compare the net benefit of investing in an irrigation modernization project versus alternative investments. Unlike the net present value calculation, there is no discounting included in a simple ROI calculation.

3) Present value of agricultural income provides information on the benefit to agricultural growers and farm laborers of a reliable water supply and reduced pumping costs associated with piping. As noted above, water supply reliability is enhanced through piping because of 1) less frequent interruption of service and 2) increased availability of water resulting from increased efficiency.

   The estimate of agricultural income includes the following values:

   a. Preserved on-farm net income to farm operators working the approximately 2,380 acres maintained in productive agriculture. As described in the discussion of the benefits to District finances, increased availability of water at the farm due to FID piping is expected to have preserved FID irrigation service to approximately 2,380 acres of productive farmland. Without the water savings associated with modernization, due to water use reporting requirements at the state level, these lands would likely have gone out of production. This would have resulted in reduced farm profit, estimated at $2,300 per acre.[3]

      The affected acreage, and the associated benefit to on-farm net income of modernization, is assumed to increase over time in accordance with the level of capital investments made in piping over time (with the assumption that modernization rates and associated water savings were based on a collaborative partnership with state resource management agencies, and that without the water savings achieved through modernization, reduced water would have been available for diversion). As such, annual preserved farmland net income benefits are estimated to rise from $275,000 in 1990 to $5,500,000 in 2013 in both modernization scenarios.[4]

   b. Preserved income to farm laborers working on the approximately 2,380 acres maintained in productive agriculture. This farm laborer income is estimated at $1,880 per acre. Using the affected acreage values derived based on the level of capital investments made through time,

[3] These values are based on the following Oregon State University Enterprise Budgets for a representative, 70-acre Hood River Farm: AEB 0024 for medium density apples (2012), AEB 0025 for medium density pears (2012), AEB 0026 for fresh market pears (2012), AEB 0027 for winter pears (2012), and EM 8942 for wine grapes (2007). Average per acre net farm income and farm labor income from these budgets were weighted by acreage in each crop (as indicated by the representative farm identified in the budgets), taking into account the zero dollar per acre benefits for the 10 acres assumed to be orchard establishment. All values are adjusted to current dollars using the CPI (which produces very similar results to using a PPI inflator for orchard fruit commodities).

[4] Oregon Statute 537.099, passed in 1987, included a water use reporting requirement. OAR 690 Division 85 was published in 1988, and 1989 was the first water year requiring water use reporting. Even though water use reporting was required in 1989, and modernization had not achieved large-scale efficiency improvements yet, no FID lands were taken out of production in the slow modernization scenario. We conservatively assume that lands in both modernization scenarios would have gone out of production at the rate at which water efficiency gains were implemented in the slow modernization scenario. Depending on the driving factor affecting irrigation district use of water, changes in the availability of water may happen gradually (as modeled here in the no-modernization scenario) or rapidly. By assuming a slow reduction in the available water for agricultural diversion, this analysis likely understates the benefit of rapid modernization in terms of minimizing risk of water shortages to agriculture and associated land fallowing or yield reduction from deficit irrigation.

the preserved farm labor values are estimated to rise from $224,800 in 1990 to $4,500,000 in 2013 in both modernization scenarios.

c. On farm energy cost savings resulting from less pumping required due to the provision of reliable, pressurized water. This reduced energy use is expected to rise through time to 1,450 MWh (current level of energy savings estimated by FID), valued at $166,750 in terms of reduce energy costs.[5] The level of energy savings through time is proportionate to the cumulative level of investment in piping (i.e., 10 percent of piping investments to date would result in 145 MWh of energy conservation).

4) Green hydropower energy is generated only with modernization, and generation is enhanced with the increased availability of water for hydropower made possible by piping. Annual MWh generation in the slow modernization scenario is based on records of MWh sales, and rises from 11,980 MWh in 1985 to annual average maximum generation of 25,000,000 MWh by 2010. Annual MWh generation in the rapid modernization scenario is assumed to be maximized by 1990, and for comparison with actual hydropower generation in the slow modernization scenario (which varies by water year type), is estimated at 22,000,000 MWh for low water years, 25,000,000 for medium water years, and 28,000,000 for wet water years.[6]

5) Carbon dioxide emission reductions are the estimated decrease in global ambient carbon levels, and are measured in metric tons of carbon.

The estimate of carbon emission reductions includes the following values:

a. Reduced carbon emissions from reduced on-farm energy use. As described above, modernization reduces on-farm pumping, with associated energy savings. Each reduced MWh of on-farm energy use translates into an estimated reduction of 0.75251 metric tons of carbon emissions.[7]

b. Reduced carbon emissions from hydropower replacing fossil-fuel powered electricity generation. Each reduced MWh of increased hydropower production is estimated to translate into a reduction of 0.75251 metric tons of carbon emissions.

6) Value of avoided carbon emissions represents the incremental benefit to society of reduced climate change from FID modernization. The estimated benefit per ton of reduced carbon emissions is based on the social cost of carbon value used by federal agencies, which is approximately $42 per metric ton

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5 Based prices from the Hood River Electric Cooperative for agricultural irrigation pumping, energy costs are estimated using a price per kWh of $0.0775 and a $37.50 fixed cost per horsepower of each pump; we assumed FID pumps are 1.5 horsepower on average.

6 For the period between 1987 and 2011 for which FID provided Tucker Bridge gauge water flow data, we categorize 1/3 of water years as wet, 1/3 as dry, and 1/3 as average based on water flow volumes January through May and from October through December. Based on water year type, we then assign average MWh that would have been generated under rapid modernization (22,000,000 MWh for low water years; 25,000,000 for medium water years; and 28,000,000 for wet water years).

7 This assumes that marginal changes in energy demand are met with fossil fuel-based production (renewable energy is typically used first and then fossil fuel powered generation is then used), such that 100 percent of energy use reduction and green energy production results in reduced fossil fuel-powered generation. Furthermore, we base our estimate of 0.75251 metric tons of carbon emitted from one MWh of fossil fuel powered electricity generation on 1) the current proportion of fuel source - oil, natural gas, and coal – for fossil fuel-powered electrical power generation in the west, and 2) the associated metric tons of CO_2 produced per MWh powered by each fossil fuel source, as reported by the Energy Information Administration.

in current dollars. This value is estimated based on the expected incremental avoided economic damage from reduced climate change, based on such factors as agricultural productivity, human health, increased flood risk, and energy system costs.

7) Water conserved through increased agricultural efficiency enhances summertime instream flow. The total volume of water conserved currently, compared to no modernization, is estimated by FID at 18,500 acre-feet annually. The water conservation through time in both slow and rapid modernization scenarios is estimated to be proportionate to the level of district pipe infrastructure investments completed. For example, by 1999, FID had spent ten percent of total piping infrastructure costs incurred from 1987 to 2013, so we estimate that 10 percent of water savings, or 1,850 AF was achieved by 1999. In contrast, in the rapid modernization scenario, 100 percent of pipe infrastructure investment is assumed to be completed in 1990, resulting in the full 18,500 AF of water savings in that year.

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