WILD FLOOD TO GRADED BORDER IRRIGATION FOR WATER AND ENERGY CONSERVATION IN THE KLAMATH BASIN

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ABSTRACT

A large percentage of pasture in the Upper Klamath Basin is irrigated by “wild flood” surface irrigation methods. Efforts underway to improve irrigation efficiency in the basin using federal funds have included conversions to sprinkler irrigation systems and to higher efficiency graded border surface irrigation systems. With dramatic increases in power rates for agricultural users on the horizon, surface irrigation enhancements have significant promise to increase water use efficiency without substantially increasing production costs. While these projects generally do not solve the basin’s water supply problems, they do provide a significant enhancement to surface water quality by reducing sediment and nutrient containing surface return flows. In areas where groundwater levels are declining due to irrigation pumping, these projects can also reduce stresses on groundwater supplies. A project implemented near Sprague River is used as a case study to describe how the simple conversion from ditched to piped laterals, creation of new border ridges, and improvements to irrigation scheduling can dramatically increase irrigation application efficiency while at the same time reducing pumping costs and groundwater withdrawals without any increase to daily labor requirements.

INTRODUCTION

Competition for water supplies within the Upper Klamath Basin (south-central Oregon) was brought to a head in 2001, when the combination of drought and Endangered Species Act (ESA) water management decisions severely curtailed irrigation deliveries to more than 2,000 farms and ranches. Since that time, a significant amount of federal support has been provided to the region to support water conservation measures. As administered through the Natural Resources Conservation Service (NRCS), the Environmental Qualities Incentive Program (EQIP) is one vehicle that has been used to invest federal funds in improving the irrigation efficiency of operating farms while keeping them in operation and attempting to alleviate some of the stresses on water resources in the basin.

While much of the cost-share funding through EQIP has been focused on converting low efficiency flood irrigation systems to sprinkler systems, some funding has also been directed to convert low efficiency flood irrigation systems to higher efficiency flood irrigation systems. In both cases, the primary benefit of irrigation efficiency enhancements is water quality improvement, as total consumptive use is not normally reduced significantly. In fact, in some cases, the improved uniformity of irrigation application can increase consumptive use following

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conservation improvements. The largest direct benefit of these conservation measures is thus the reduction in tailwater return flows to surface water, because tailwater return flows carry nutrients and sediments that negatively impact sensitive receiving waters.

Within the Upper Klamath Basin, the Sprague River Sub-basin has been identified as having the greatest opportunity for irrigation water conservation measures providing significant benefit to basin water quality and reducing ESA constraints (USDA-NRCS, 2004). In this subbasin, irrigation is primarily used for irrigated pasture and grass hay over about 82,000 acres and is predominantly managed with low efficiency flood irrigation practices, locally termed “wild flood.” Approximately 35 percent of irrigation diversions are from groundwater with the remaining 65 percent from streams.

This paper uses a case study of a 100-acre wild flood irrigated pasture located in the Sprague River Sub-basin as an example of the projected water balance and economic impacts of converting a ditched delivery wild flood irrigation system to an engineered piped delivery graded border system. This EQIP funded project was initiated in late 2005 with a participating landowner. It was constructed following the end of the irrigation season in 2006 and commissioned at the start of the 2007 irrigation season.

IRRIGATION SYSTEM DESIGN

Methods for increasing surface irrigation application efficiency include land leveling or smoothing, breaking fields into shorter run lengths, piping or lining ditch delivery systems, decreasing set times, and increasing the level of irrigator management. For this particular project, the methods selected for increasing on-farm application efficiency included the following components:

- Converting the ditch delivery system to a piped delivery system by installing buried PVC piping with alfalfa riser valves on 50-ft spacing. This improvement eliminates the conveyance water loss from ditch seepage and allows greater user control over the locations of water delivery to the field.
- Constructing border ridges on 50-ft to 150-ft spacing with settled heights of at least 4 inches. This measure reduced the average field run length from 1,200-ft to 900-ft between head ditches/laterals and will enable more uniform coverage of the entire field.
- Installation of a pump timer to enable automatic pump shut down at the end of an irrigation set. This eliminates the reliance on an irrigator returning to the field to physically turn off the pump.
- Installation of a flow meter to allow the user to keep track of water application.
- Development of an irrigation water management plan to assist the user in managing irrigations to crop irrigation requirements.

The first step in the design process was a meeting with the landowner to discuss historic irrigation operations, labor limitations for post-project operations, and project goals and to gather necessary design basis information. During this same visit, topographic survey information was collected and a field flood irrigation test was conducted to provide design information (Figure 1). Following the field data collection, the SRFR model (Strelkoff et al., 1998) was used for evaluating pre- and post-project irrigation management to estimate application efficiency, field water balances, and effective set times, and unit flow rates. This step was used to refine the design and operational criteria prior to designing the physical system improvements.

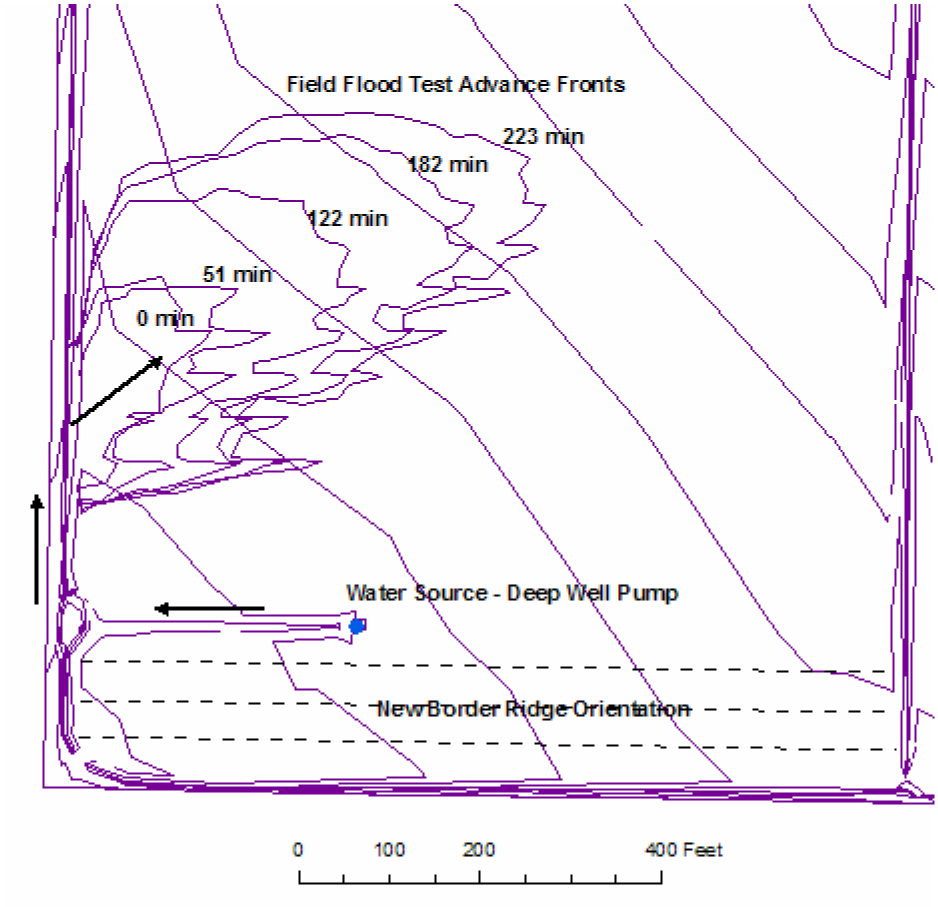

Figure 1. Map of a portion of the 100-acre field where the field flood irrigation test was conducted (contour lines are shown at 1-foot intervals).

During the field flood irrigation test, flood advance fronts were mapped at several intervals over an approximately 4 hour period (Figure 1). The advance fronts in Figure 1 illustrate the current direction of irrigation flows across one of the fields and the planned new border ridge orientation, which will decrease both the field run length and the surface slope along the flow path. Historic border ridges that have long since settled and been reduced to micro-topography from cattle traffic can also be seen in the advance front mapping.

Before running design scenarios, the SRFR model was first calibrated to the field performance data to enable better estimates of soil intake rates and surface roughness parameters. Using the measured flow rates during the test and the advance distances over time, the SCS intake family and Manning n values were adjusted in SRFR until the appropriate advance curve shape and slope were replicated (Figure 2). While this approach may not yield a unique solution to these two parameters (Clemmens et al, 2001), it does provide a reasonable design basis for evaluation of pre- and post-project operations given that the unit flow rates will not be varied significantly.

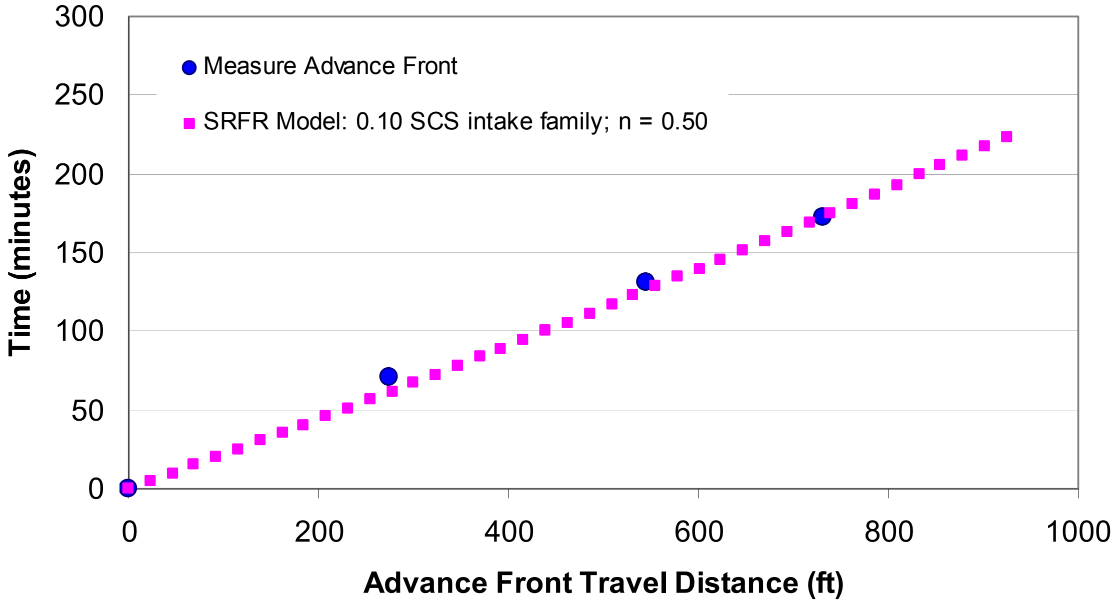

Figure 2. Correlation of field flood irrigation test results to calibrated SRFR model advance rate estimates.

Furthermore, the new irrigation delivery system was designed such that operational adjustments could easily be accomplished during commissioning to refine the irrigation water management plan. Because the advance fronts were not rectangular as assumed in SRFR, linear advance front travel distances were calculated by dividing the total wetted areas at each mapped time interval by an average inflow width after about 1 hour of flow when the source area had stabilized.

WATER CONSERVATION

In order to evaluate the potential water conservation benefits of this project, water balances were projected for pre- and post-project irrigation water management. Since the pre-project system did not have a flow meter, historic irrigation operations were reconstructed from an irrigator survey. However, the historic operations were very simple with two 12-hour sets per day for 24-hour-per-day operations over a 173-day irrigation season. Consequently, gross irrigation deliveries and total groundwater pumping could be reasonably estimated from this information. Post-project deliveries were based upon the design irrigation water management plan, and water budget distributions were based upon SRFR model results.

Pre-project operations of this wild flood irrigation system were dictated primarily by labor limitations and the lack of any automatic water control strategy or scheduling to match deliveries with crop needs. The even application of water throughout the irrigation season thus resulted in very low application efficiency in the spring and fall and increased efficiency levels in the peak summer months. Estimated application efficiencies ranged from 20 percent in May to 42 percent in July with an annual average of about 28 percent. On average, approximately 41 percent of applied water was estimated to run off as tailwater and 31 percent was estimated to be returned to groundwater as deep percolation.

The most significant improvement of the new water conservation measures for this site will be realized in following the defined irrigation water management plan, and, with a pump timer, having the ability to run shorter irrigation sets. For post-project operations, the landowner was reticent to commit to any greater than two irrigation sets per day as is currently practiced. Consequently, a rotation was developed such that the field could be irrigated with the same two visits to the field each day. During the peak summer months, 7.5-hour sets on an 8-day rotation will replace the 12-hour sets on a 20-day rotation. This will also translate into 15-hour-per-day operations as opposed to 24-hour-per-day irrigation. By lengthening the return interval for irrigations during the lower demand portions of the irrigation season, further savings will be realized. With the revised field layout and management, an application efficiency of approximately 57 percent is projected with 38 percent lost to tailwater runoff and an estimated 5 percent lost to deep percolation.

As shown in Figure 3, the water conservation measures implemented on this project are anticipated to significantly reduce total groundwater pumping, deep percolation return flow to groundwater, and tailwater return flows to surface water while maintaining approximately the same total consumptive use. Although the fraction of tailwater generation during an individual irrigation event is only expected to decrease a few percent, the total reduction in gross irrigation deliveries will substantially reduce the volume of surface water return flows over an irrigation season. The increased total application efficiency will be realized primarily in the reduction of excess infiltration and deep percolation losses. Due to the fine-textured soils at this site, head ditch seepage losses are estimated to be fairly minor in the range of 5 ac-ft per year or about 2 percent of the annual net irrigation requirements.

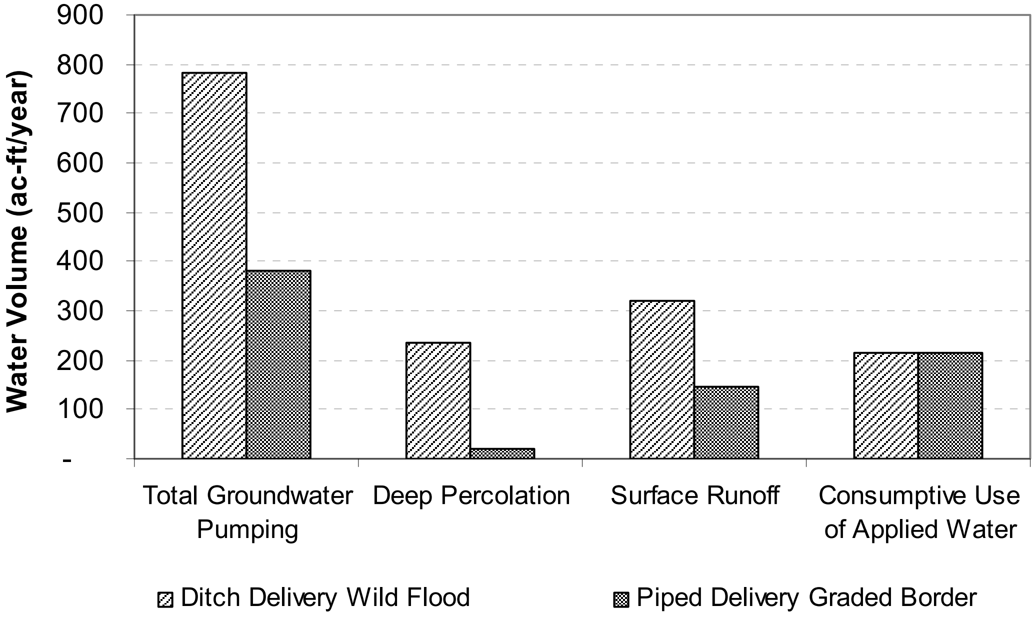

Figure 3. Estimated water balances for pre- and post-project irrigation management.

Long-term monitoring of groundwater wells on and around this project site have shown that groundwater levels have declined more than 40 feet over the last 50 years. Projecting the water conservation impacts of this project across the subbasin at almost 400 ac-ft/year of reduced pumping for every 100 irrigated acres could result in a significant positive impact to this aquifer system as an additional benefit.

ECONOMICS OF ENERGY CONSERVATION

With the scheduled phase out of preferred energy rates for agricultural use in the Upper Klamath Basin, irrigators are facing energy bills that will increase over 10 times from 0.6¢/kW-hr to approximately 5.7¢/kW-hr over a 6 to 7 year transition period that started in 2006 (Jaeger, 2004 and personal communication with Pacific Power, April 2007). Consequently, conversion of irrigation delivery methods from gravity systems to pressurized systems must be undertaken only with a complete understanding of the long-term operations cost implications. By implementing on-farm irrigation efficiency enhancements that reduce the total pumping energy demand without any increase in labor requirements, the capital cost of system improvements can be recouped within a reasonably short period of time and will reduce total operations costs in the long-term.

At fixed power rates that irrigators have enjoyed over the past 50 years, there has been little economic incentive to increase irrigation efficiency at the farm scale. Using the irrigation efficiency enhancements of this project as an example, the capital investment in system improvements at approximately $745 per acre would take 98 years to pay off at a 5 percent discount rate or 25 years accounting for a 75 percent cost-share incentive provided through the EQIP (Table 1). Such investments would hardly make economic sense when evaluated upon annual operating costs alone. However, this balance will change dramatically with the increased energy rates such that this project would have a 10 year payback period using the same assumptions and could be further reduced to less than a 3 year period with the EQIP incentive payments.

The additional economic incentives for energy conservation may become a vehicle for encouraging water conservation in the basin. However, most flood to sprinkler conversion projects will increase energy demands over pre-project usage and will not benefit from this economic incentive. A pumping cost comparison between wild flood, graded border, and sprinkler irrigation is presented in Table 2 and takes into consideration the differences in gross irrigation requirements and pumping power requirements for each alternative. Because of the additional pumping lift required for pressurized systems, water costs for this project would be increased from approximately $18/ac-ft to $38/ac-ft. Even though gross irrigation requirements are lower for the higher efficiency sprinkler irrigation (75% assumed efficiency), the increased unit pumping costs would cause the total annual pumping cost for sprinkler irrigation on this project to be approximately $4,200 per year greater than for graded border over the 100 acres.

Irrigators facing a ten times increase in current energy bills over the next six years will have to weigh irrigation system upgrade decisions carefully. This will be especially important for those who are irrigating low margin pasture where the capital investment in water conservation measures will be hardest to recover.

Table 1. Economics of energy conservation for 100-acre flood conversion project

Item	Value
Capital Expenditure for System Improvements	$74,500
EQIP Cost Share Funding	$55,875
Net Capital Expenditure	$10,995
Discount Rate	5%
Pre-project Annual Energy Cost at 5.696¢/kW-hr	$13,949
Annual Energy Cost Savings at 5.696¢/kW-hr	$7,188
Payback Period w/o Cost Share at 5.696¢/kW-hr	10 years
Payback Period w/ Cost Share at 5.696¢/kW-hr	3 years
Pre-project Annual Energy Cost at 0.6¢/kW-hr	$1,469
Annual Energy Cost Savings at 0.6¢/kW-hr	$804
Payback Period w/o Cost Share at 0.6¢/kW-hr	98 years
Payback Period w/ Cost Share at 0.6¢/kW-hr	25 years

Table 2. Pumping cost comparison between irrigation methods for 100-ac project

	Wild Flood Irrigation	Graded Border Irrigation	Sprinkler Irrigation
Application Efficiency	28%	57%	75%
Annual Gross Irrigation (ac-ft)	784	380	289
Unit Pumping Cost ($/ac-ft) [a]	$17.80	$17.80	$38.03 [b]
Annual Pumping Cost	$13,949	$6,761	$10,978

[a] Pumping cost projected at 5.696¢/kW-hr

[b] Additional 50-hp of pumping power required for sprinkler irrigation in excess of 44-hp required for flood irrigation

OPPORTUNITIES FOR INCREASED BENEFITS

While benefits can be attained on a field by field basis, far greater opportunities exist as the scale of the area involved is increased. Most wild flood pasture systems are operated in units ranging in size from 10 acres to 100 acres. However, tailwater generated on each field is often routed through down-gradient fields where it can be recaptured and reused. Wherever possible, improvements should be planned and implemented over a scale sufficient to encompass a complete hydrologic unit from the initial irrigation water source to the final discharge of any unused tailwater to main conveyance channels or surface water.

CONCLUSIONS

The water and energy conservation impacts of this project case study provide a good example of the potential benefits that can be realized by implementing flood irrigation efficiency enhancements. With relatively simple engineered enhancements to wild flood application systems, significant reductions can be realized in groundwater pumping, tailwater return flows to surface water, and energy consumption with minimal impacts to operations labor. While the EQIP support for these projects is targeted towards alleviating water supply and water quality stresses, a smart irrigator can take advantage of this program for the additional tangible benefits of energy conservation and reduced pumping bills. For example, the cost-share reimbursement provided through this project can reduce the period of return on capital investments from 10 years to 3 years. While irrigated pastures represent a significant demand on water resources in the basin, the marginal economics of these systems may be better suited to enhancing the efficiency of surface irrigation systems rather than conversion to sprinkler systems that are more costly to install and to operate.

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