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REPORT 81

IRRIGATION WATER USE EFFICIENCY DEMONSTRATION PROJECT PHASE II: CONSERVATION ASSESSMENT

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STATE OF WASHINGTON
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WASHINGTON STATE UNIVERSITY AND
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Phase 2: Conservation Assessment

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CHAPTER 1

INTRODUCTION

Background

Rising agricultural, municipal, industrial, and instream demands for water have made water use efficiency a key element in water resource management and planning in the State of Washington. In 1988, the Washington State Legislature established a Water Use Efficiency Committee to identify and evaluate means for improving water use efficiency in Washington (Substitute House Bill 1594). In 1989, the Legislature recognized the special complexities of improving water use efficiency in irrigated agriculture and passed Substitute House Bill 1397. This bill authorized a three-phase project to develop an irrigation water use efficiency demonstration plan for a selected irrigated area of Washington. The three phases of this project include:

1. A state-wide evaluation of irrigated areas and selection of an area for a voluntary demonstration project.

2. An assessment of the impacts, benefits, and costs of water use efficiency measures and practices for irrigated agriculture appropriate to the selected study area.

3. The formulation of a demonstration water use efficiency plan for the selected area.

Phase 1 was completed in December 1989 with the selection of the Walla Walla basin as the study area (James et al. 1989). The assessment phase (Phase 2) began in January 1990. This report describes the procedures, methodology, and results of an assessment of eight alternative measures for improving water use efficiency in the Walla Walla basin. Recommendations for using the methodology in other irrigated basins in Washington are also included.

Problem Statement

The total amount of water diverted and/or withdrawn for irrigation in Washington is over twice the water requirement of the crops being irrigated. Losses due to spillage, seepage, and evaporation from conveyance facilities; and evaporation, deep percolation (drainage from the root zone), and runoff during field application account for water withdrawals and diversions in excess of crop consumption. Significant reductions in these losses should be attainable since irrigation efficiencies in excess of 80 percent are theoretically possible. This should reduce diversions and withdrawals for irrigation, making more water available for other uses, instream flows, and/or additional irrigation.

The effects of higher efficiencies are not always desirable or their implementation economically feasible in all cases, however. Increased capital investment and/or higher labor costs are required of irrigators and/or irrigation districts or ditch companies to increase efficiencies. To be economically feasible, these increases must be at least offset by lower costs for pumping, water, and, in the case of irrigators, fertilizer. A detailed analysis of costs and benefits is therefore needed to determine the economic feasibility of alternate measures for improving water use efficiency for a particular irrigation system. Such an analysis must be conducted for each basin and at several locations within a basin because of differences in crops, soils, water sources, irrigation systems, management practices, production costs, and crop prices.

From a basin perspective, the hydrologic and economic effects of increasing irrigation water use efficiency are often extremely complex. Less spillage, seepage, deep percolation, and runoff losses from irrigation systems reduce the amount of water returning to surface and ground water in drainage channels and via various underground pathways. Changes in these flows, called return flows, along with reductions in surface water diversions and ground water withdrawals can drastically alter flow paths and travel times; points and rates of diversion and withdrawal; as well as water uses and values within the basin. This is especially critical when significant amounts of return flow are reused at other locations within the basin. Users of return flow may be harmed by higher water use efficiency unless enough of the "saved water" is delivered to them in a timely manner. It is therefore essential to evaluate the hydrologic and economic impact of each alternate measure for increasing water use efficiency being considered for a basin. Differences in climate, geology, and topography between basins necessitate a separate evaluation for each basin.

Increasing irrigation water use efficiency is an extremely complex matter. The vast array of possible efficiency improvement measures, large variations in economic feasibility of efficiency measures within and between basins, and significant differences in the hydrologic and economic response of basins to efficiency measures all contribute to this complexity. A methodology for estimating the economic affect on irrigators of a given efficiency measure and predicting its economic and hydrologic impact on a basin is needed. It is desirable that this methodology use readily available data and be transferable from one basin to another.

Objectives

The overall goal of this study was to assess the impacts, benefits, and costs of water use efficiency measures and practices for irrigated agriculture in the Walla Walla basin. The specific objectives were to:

1. Develop methodology for evaluating the affect of changes in crops, crop mix, water source, irrigation systems, irrigation system management, and water allocation policy on irrigators and the economic and hydrologic response of the Walla Walla Basin.

2. Use this methodology to evaluate several alternatives for increasing irrigation water use efficiency in the Walla Walla Basin.

3. Provide information that the local Conservation Plan Formulation Committee and the Department of Ecology can use to develop an irrigation water use efficiency demonstration plan for the Walla Walla Basin.

4. Make recommendations for using this methodology in other irrigated basins in Washington.

Scope

This study considers three general strategies for improving the efficiency of water use in the Washington portion of the Walla Walla Basin. These strategies are to (a) increase stream flow by improving irrigation water use efficiency, (b) identify water allocation policies that enhance water use efficiency, and (c) store winter runoff for release during low flow periods in late summer and early fall. The impacts of several alternatives for implementing these general strategies are estimated and reported. No attempt is made to assess the availability of water resources in the basin or to formulate or recommend a plan for achieving improved water use efficiency. The study provides objective "first generation" information that citizens living in the Washington portion of the Walla Walla Basin and the Department of Ecology can use to formulate such a plan.

Limited time and budget constrained the data and methodology used in the study. Most of the data were obtained from public and private sources including published reports, power companies, commodity groups, irrigation districts, and governmental agencies such as ASCS (Agricultural Stabilization and Conservation Service), the Department of Ecology, the City of Walla Walla, the Bureau of Reclamation, the Geological Survey, and the Corps of Engineers. Only a preliminary wetlands inventory, a canal seepage assessment, and irrigator surveys were completed as part of this study. In addition, only conditions and data for a near average water supply and demand year, 1989, were considered.

Study methodology and the reliability and resolution of study results were determined by data availability, quality, and resolution. Time and budget constraints necessitated using existing mathematical models for the most part and precluded the opportunity of field verification of model predictions. Instead, data and model predictions were frequently reviewed by study personnel and the Conservation Plan Formulation Committee established by the Department of Ecology.

Methodology and data used in the study allow identification of general economic and hydrologic responses only. Specific responses can not be quantified with confidence nor is it possible to analyze specific farms.

CHAPTER 2

APPROACH, PROCEDURES, AND METHODOLOGY

In February 1990, the Department of Ecology contracted the State of Washington Water Research Center located on the Washington State University (WSU) campus in Pullman to assess the hydrologic and economic impacts of improved irrigation water use efficiency in the Walla Walla Basin. A study team composed of WSU faculty and graduate students (the authors of this report) was assembled by the Water Research Center to carry out the assessment. During March 1990, a local Conservation Plan Formulation Committee was established by the Department of Ecology to assist the WSU study team. The Committee, which included 19 regular and four advisory members representing a cross section of local interests and agencies, provided the study team with input, acted as liaison with local groups, and provided "reality checks" (verified that study data and results were consistent with the Committee's experience and knowledge of the basin). Committee members and their affiliation are listed in Appendix A.

Approach

A series of mathematical models adapted to the Walla Walla Basin were the primary instruments of assessment. Study activities involved modifying and linking several existing models, assembling input and calibration data required by these models, and then calibrating them to the Walla Walla Basin. Once calibrated, the models were used to estimate the impacts, benefits, and costs of several general strategies for increasing water use efficiency in the Walla Walla Basin. These strategies were developed in consultation with the local Formulation Committee and Department of Ecology and from recommendations made by the Bureau of Reclamation for increasing the efficiency of off-farm irrigation water delivery systems (see Appendix F). Information provided by the models, which is summarized in Chapters 6 and 8 of this report, will be considered by the Formulation Committee and Department of Ecology during Phase 3 of the project as an irrigation water use efficiency demonstration plan for the Walla Walla Basin is developed.

Procedures

The major steps of this study were:

1. Establishing the Conservation Plan Formulation Committee.

2. Defining the Study Area

3. Assembling Baseline Information for the Basin.

4. Describing Future Trends in Water Use.

5. Identifying and Adapting Mathematical Models.

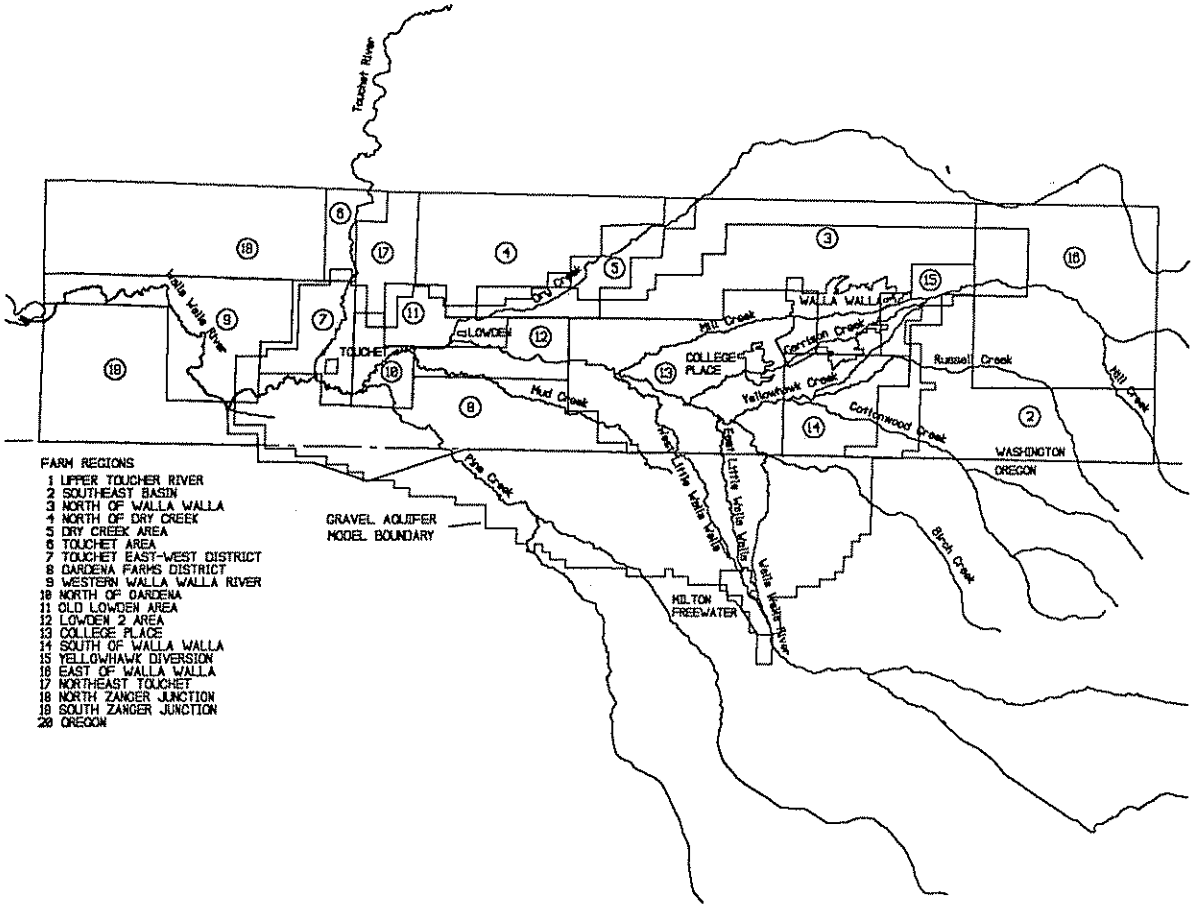


Figure 2.1 Farm regions in relation of the gravel aquifer boundary area used in the gravel aquifer.

6. Calibrating the Models.

7. Identifying Alternative Efficiency Measures.

8. Assessing and Comparing Alternative Efficiency Measures.

9. Reporting Study Results.

Methodology

The methodology used in each of the steps listed in the previous section is described in the following sections.

Conservation Plan Formulation Committee

The local Conservation Plan Formulation Committee established by the Department of Ecology in March 1990 was an especially important element of the assessment phase. They supplied the WSU study team with input and advice, acted as liaison with local groups, and provided "reality checks" (verified that study data and results were consistent with the Committee's experience and knowledge of the basin). These "reality checks" were an absolutely essential component of the study since field verification of data and model results were not practical (because of time and budget constraints).

The study team and committee interacted regularly during the study. There were six formal meetings and numerous contacts with individual committee members. In addition, the full committee was divided into subcommittees according to expertise and interest. Six subcommittees were formed to provide the study team with advice and assistance in the following areas: legal and institutional, water supply, off-farm irrigation, on-farm irrigation, education and information, and non-agriculture. Most committee members served on more than one subcommittee. The existence of the subcommittees enabled study team members to discuss problems and/or obtain guidance in the subcommittee's expertise area without convening the full Committee.

Study Area

The study area was defined to be the Washington portion of the Walla Walla Valley. This area, which is shown in Figure 2.1, contains 95 percent of the irrigated land in the Washington portion of the basin. Most of the remaining irrigated land is along the Touchet River, downstream of Dayton. Irrigation water use on these lands was held constant in the study.

The study area was subdivided into the 20 farming regions shown in Figure 2.1 to account for intra-basin differences in crops, climate, soils, water sources, water source characteristics, etc. The number of regions and their boundaries were chosen so that crops, water source(s), soils, and farming practices were generally similar within each region. The general characteristics of each region are summarized in Table 2.1. Detailed crop, water source, and irrigation information for each region and the criteria used to delineate the regions are available in Appendices B and C, respectively.

Table 2.1 General Characteristics of the 20 Farming Regions in the Study Area.

Farming Region		Irrigated Acres	Available Acres	Primary Water Source(s)
1	Upper Touchet River	N.A.[1]	N.A.[1]	Touchet River
2	Southeast Basin	584	21,120	Basalt System
3	North of Walla Walla	805	23,040	Basalt System Gravel Aquifer
4	North Dry Creek	113	12,800	Basalt System
5	Dry Creek	1,432	5,760	Dry Creek Basalt System
6	Touchet	564	2,560	Touchet River
7	Touchet East-West	2,836	5,120	East-West Canal
8	Gardena Farms	11,896	19,200	Gardena Canal Gravel Aquifer
9	Western Walla Walla River	4,352	11,520	Basalt System
10	North of Gardena	1,495	3,200	Gravel Aquifer
11	Old Lowden	1,859	3,840	Gravel Aquifer Old Lowden Canal Basalt System
12	Lowden # 2	1,648	4,480	Lowden #2 Canal Garden City Ditch Bergevin-Williams
13	College Place	5,785	23,680	Gravel Aquifer
14	South of Walla Walla	1,254	7,680	Gravel Aquifer
15	Yellowhawk Diversion	274	3,200	Yellowhawk Creek
16	East of Walla Walla	36	23,040	Mill Creek
17	Northeast Touchet	0	3,840	
18	North Zanger Junction	4,337	17,280	Columbia River Basalt System
19	South Zanger Junction	0	16,000	
20	Oregon	N.A.[1]	N.A.[1]	Irrigation Canals Gravel Aquifer
Total		34,937	276,480	

[1]N.A.: Data Not Available

Baseline Information

One of the first steps was to inventory existing, i.e., baseline conditions and practices in the basin. Most of these data were obtained from a variety of public and private sources. Only data for a preliminary wetlands survey, an assessment of irrigation canal seepage, and a survey of irrigator practices and costs were collected as part of this study. Table 2.2 lists the major categories of data used in this study as well as the source of these data. Baseline data are given in Chapter 3.

Future Trends in Water Use

A knowledge of future water use trends is essential to water resources planning and the formulation of an irrigation water use efficiency plan for the basin. Water use trends for the Walla Walla Basin were estimated from previous water use data and projections of future population growth, industrial development, and agricultural activity. Information was obtained from a variety of sources. Water use trends are discussed in Chapter 4.

Identifying and Adapting Models

The mathematical models used in this study were selected on the basis of their input data requirements and the output information they provided. Input data had to be limited to readily available/obtainable data for the basin because of time and budget constraints. The selected models also had to produce the type, quality, and resolution of information needed to assess the impacts of alternate water use efficiency and policy measures. Three models were chosen, one for each of the three major assessment tasks: one for determining on-farm economic costs and returns, another for assessing the hydrologic response of the basin, and a third for estimating the effects on the Mill Creek fishery.

The model chosen for the on-farm economic analysis is a profit maximizing model that estimates net farm returns above variable operating costs for crop production as a function of on-farm water use efficiency and water supply. Estimates for the twenty farming regions within the study area (Figure 2.1 and Table 2.1) were obtained for alternate water use efficiency measures and allocation policies using the farm economic model.

The farm economic model provides flexibility in assessing water use efficiency measures and allocation policies. It allows for deficit irrigation on grain and forage corps while automatically adjusting crop yield and farm input levels to the chosen amount of water application. It is also possible to change the supply and mix of water from surface and aquifer sources, adjust the seasonal distribution of water supply relative to crop requirements, change the acreage of irrigated crops by shifting to dryland agriculture or switching to less water intensive crops, and vary the value of farm product sales or the cost of farm inputs. A detailed description of the farm economic model is given in Appendix C.

The core of the hydrologic model was a steady-state ground water model developed by the US Geological Survey (Barker and MacNish 1976). This model predicts heads (water levels) and flow through the gravel aquifer that underlies the Walla Walla Valley. The model divides the 120,000-acre area above the gravel aquifer into 3,337 cells (see Figure 2.2). Information describing the type of irrigation system, crop water requirements, canal seepage, and irrigation water source (surface and/or ground water) in each cell is required to use the model. The ground water model provides estimates of ground water flow into or seepage from streams which is used in a volume-balance-type stream flow model to estimate flows at several locations along Washington streams A detailed description of the hydrologic model is given in Appendix D.

The fisheries model computes an index that describes a stream's suitability as a fish habitat. This index, called the weighted useable area (WUA), depends on fish species and life-stage and the stream's water depth, average velocity, discharge, and surface area. WUA values were computed with the model for several different flow rates in Mill Creek between its confluence with the Walla Walla River and Kooskooski. These values were used to estimate steelhead population and approximate value for each flow rate. A detailed description of the fisheries model is given in Appendix E.

Model Calibration

Model calibration, sometimes called parameter fitting, is the process of adjusting selected parameters used in a model until maximum agreement between model predictions and recorded data is achieved. Calibration results and a more detailed description of calibration procedures for the farm economics and hydrologic models are given in Appendices C and D, respectively.

Calibration of the hydrologic model was a two-step process. First, crop water use in ac-ft was computed for each irrigated section from metered electricity use and estimated pumping lifts and efficiencies. Next, this information was reconciled with water use estimates based on crop information obtained from the ASCS and commodity groups. This involved adjusting crop acreage within a section until maximum agreement between the two estimates of total water use in the section was obtained. In the second step, irrigation diversions and return flows were estimated from crop irrigation requirements computed from climatic data and the cropping patterns determined in the first step. Relationships for computing return flow in each irrigation district/ditch company were developed from this information. The previous calibration of the gravel aquifer model by the Geological Survey in 1976 was accepted without additional verification.

The farm economics model was calibrated with representative crop yield data for irrigated crops grown in the basin. These data were obtained from ASCS records, commodity groups, and interviews with irrigators. Relationships between water application and crop production, called production functions, developed for other locations were adjusted to the Walla Walla Basin using these data. The farm economics model also used the same cropping information data as the hydrologic model.

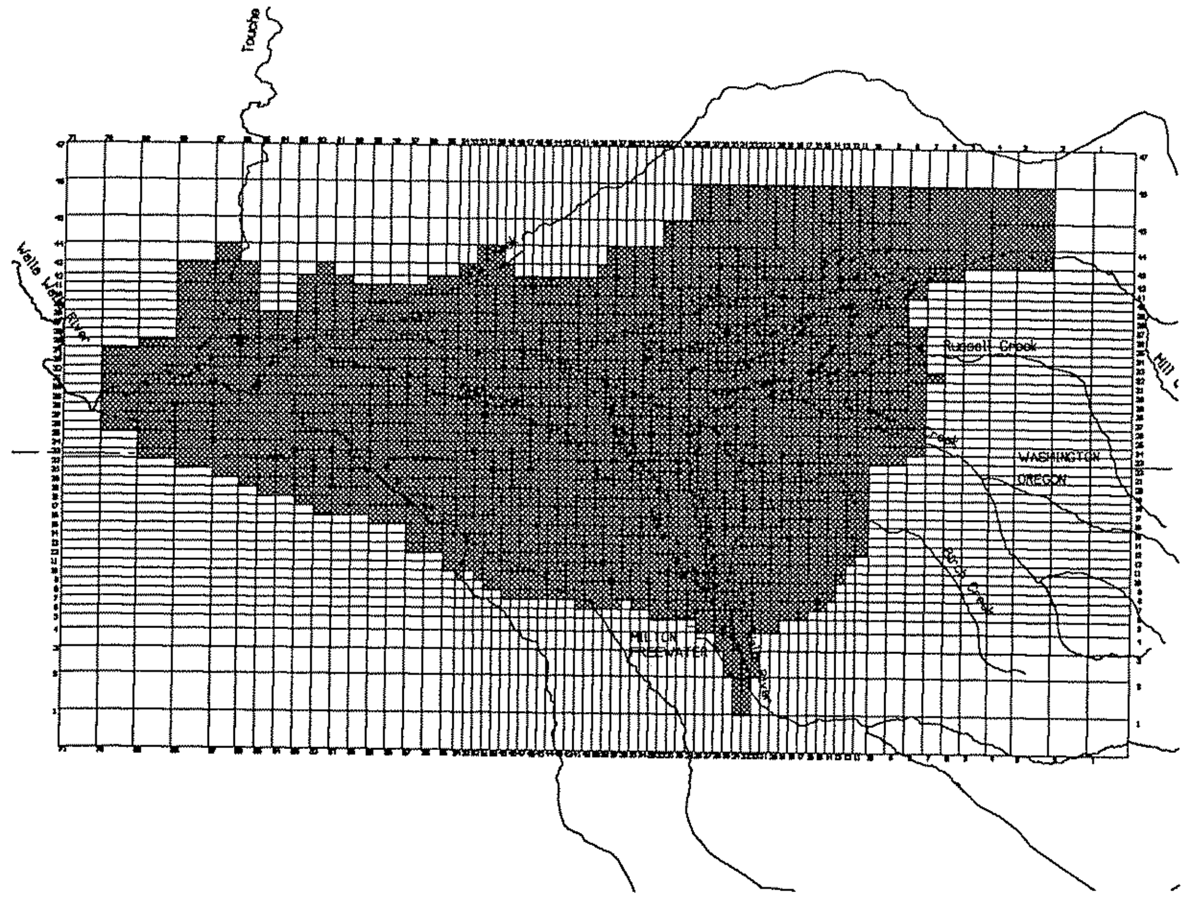


Figure 2.2 Grid cells used in Gravel Aquifer Model.

It was not possible to calibrate the fishery model to the Walla Walla Basin since the necessary data were not available. Information from other streams, primarily in the Pacific Northwest, was used in the fishery model.

Identifying Alternative Efficiency Measures

There are several structural, management, and institutional measures for improving irrigation water use efficiency. Examples of structural changes include lining canals, replacing open canals with pipelines, and converting from manual to automated on-farm application systems. Scientific on-farm irrigation scheduling and changing from a water delivery system where irrigators place water orders in advance to an on-demand system are examples of management changes. Institutional measures include the creation of water markets and consolidating irrigation districts. Table 2.2 lists the most common measures for improving irrigation water use efficiency. Butcher et al. (1988) provide a thorough review of irrigation water use efficiency theory, measures, and issues.

The WSU study team, the Department of Ecology, and the local Conservation Plan Formulation Committee worked closely to develop a range of efficiency measures appropriate to the Walla Walla Basin. The first step in this process was the study team developing an initial set of alternative measures based on a knowledge of the basin and the desires of the local Committee. This list was refined and expanded as a result of discussions with the Committee. The efficiency measures selected for analysis are described in Chapter 5.

Assessment and Comparison of Alternative Measures

The assessment of each efficiency measure was a three step process. First, the farm economic model was used to determine the net returns to irrigators of the efficiency measure being considered. Second, the effect of the efficiency measure on stream flow and ground water was estimated with the basin-wide hydrologic model. Finally, stream flow information from the hydrologic model was used in the fishery model to assess the efficiency measure's effect on the fishery of Mill Creek.

The results of each assessment are presented and compared in Chapter 6.

Reporting Results

A first draft of the final report was prepared by the study team and reviewed by the Conservation Plan Formulation Committee and the Department of Ecology. The study team also met with the Committee to discuss the draft. Comments and suggestions from the Committee and Ecology were used to prepare the final draft of the report.

Table 2.2. Baseline Data Categories and Sources.

Data Category	Source of Data
Irrigation Water Use	Irrigation Districts Ditch Companies Department of Ecology Estimated from Power Records
Municipal and Industrial Water Use	City of Walla Walla Economic and Engineering Services, Inc.
Crops and Crop Distribution	ASCS Commodity Groups Estimated from Power Records
On-Farm Irrigation Systems and Practices	ASCS Irrigator Interviews
Off-Farm Delivery Systems and Practices	Irrigation Districts Ditch Companies Bureau of Reclamation Walla Walla Community College
Wetlands	National Wetlands Inventory Maps Department of Ecology Bureau of Reclamation Walla Walla Community College
Climatic	NOAA WSU-PAWS
Surface and Ground Water	US Geological Survey Department of Ecology
Reservoir Storage	Bureau of Reclamation
Electricity Use for Irrigation Pumping	Pacific Power and Electric Columbia County PUD
Fishery	WA Department of Fisheries WA Department of Wildlife OR Department of Fish and Wildlife Confederated Tribes of the Umatilla Indian Reservation

Table 2.3. Measures for Improving Irrigation Water Use Efficiency and Their Potential for Conserving Water in Irrigated Agriculture (from Butcher et al. 1989).

Measure	Potential for Conserving Water		
	High	Medium	Low
Structural			
Diversion			
Flow Measurement			X
On/Off Control	X		
Flow Adjustment		X	
Repairing Leaks			X
Conveyance			
Lining Canals	X		
Control Vegetation		X	
Canal Replacement with Pipeline	X		
Canal Reservoirs	X		
Farm Reservoirs	X		
Repair Leaks			X
Automated Gates, Centralized Control, Computer-Assisted Control		X	
Application			
Change to a More Efficient System		Variable	
Sprinkle			
Change Sprinkler Type		X	
Change Sprinkler Mounting		X	
Install Basins	X		
Minimize Pressure Variation along Lateral		X	
Change Sprinkler/Lateral Spacing			X
Trickle			
Change Emission Device			X
Install Basins			X
Shade/Bury Laterals			X
Control System Clogging			X
Furrows			
Tailwater Recovery	X		
Cutback Irrigation		X	
Cablegation		X	
Surge-Flow		X	
Land Smoothing			X
Management (on-farm)			
Irrigation Scheduling	X		
Deficit Irrigation		X	
Management (off-farm)			
Modify Delivery Schedule		Variable	

CHAPTER 3

BASELINE DATA FOR THE BASIN

General Description

The Walla Walla Basin is located in southeast Washington and northeast Oregon. It straddles the Washington-Oregon border, lying in Walla Walla and Columbia Counties in Washington and Umatilla County in Oregon. The Cities of Walla Walla, WA and Milton-Freewater, OR are its principal urban areas. It is bounded by the Snake River Basin on the north, the Blue Mountains to the east and south, the Umatilla River Basin on the south, and the mainstream of the Columbia River to the west. The primary physiographic features of the basin are the Blue Mountains and the Walla Walla Valley.

The Blue Mountains, located on the southeastern border of the basin, are an extremely northern extension of the Blue Mountains of Oregon. The steep topography of the area is characterized by flat-topped ridges, steep-walled canyons, and mountain slopes. This area receives the highest annual amounts of precipitation in the basin and is the origin of most of the streams that drain the basin.

The Walla Walla Valley extends westward from the Blue Mountains through the central part of the basin to about eight miles east of the confluence of the Walla Walla and Columbia Rivers near Wallula. The valley is surrounded by upland areas of the basin to the north, west, and south and, like the rest of the basin, is underlain by Columbia River Basalt. The elevation of basalt bedrock within the valley is, however, much lower than the rest of the basin, is underlain by Columbia River Basalt. The elevation of basalt bedrock within the valley is, however, much lower than the rest of the basin. Bedrock elevation rises rapidly from the valley in all directions creating a "bedrock trough" beneath the valley. Large depths of lake and stream deposits have accumulated in this "trough". Most of the irrigated lands in the basin are located in the valley with dryland agriculture and livestock farming predominating in the upland areas surrounding the valley.

The total area of the basin is 1,758 square-miles (sq-mi) of which 73 percent (1,275 sq-mi) is in Washington. About 15 percent (273 sq-mi) of the basin is forest and 82 percent (1,488 sq-mi or 952,000 acres) is used in agriculture. It is estimated that about 96 percent of the basin is privately owned.

Surface Water

The primary streams in the Washington portion of the basin are the Touchet River, Mill Creek, and the Walla Walla River. As shown in Figure 3.1, these streams all originate in the Blue Mountains and flow generally westward toward the Columbia River. The Touchet River and Mill creek flow into the Walla Walla River west of the Cities of Touchet and Walla Walla, respectively.

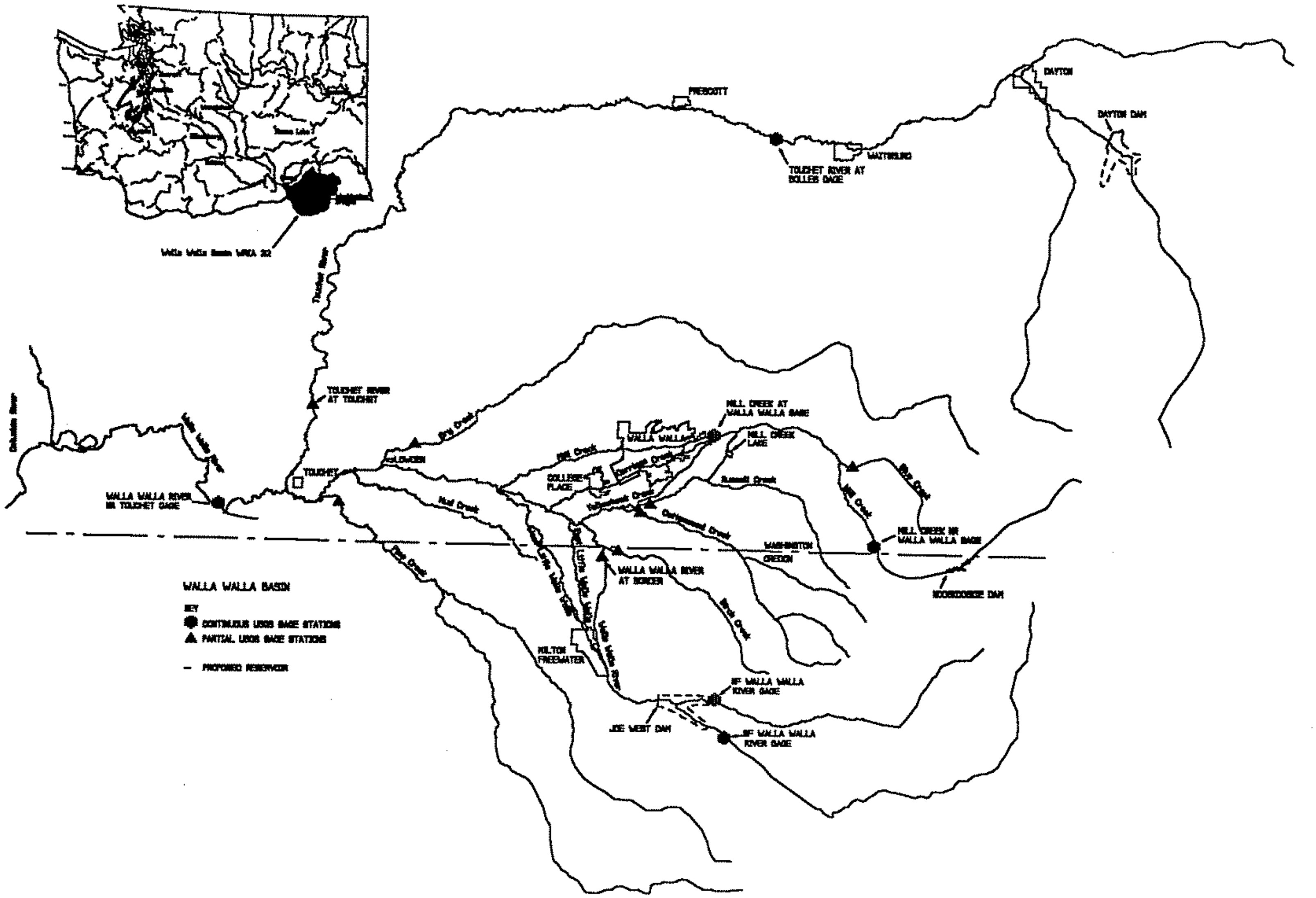


Figure 3.1 Streams and Gaging Stations in the Walla Walla Basin. The Location of Proposed Dams and Reservoirs are also Included.

The Touchet River drains about 740 sq-mi and is the Walla Walla River's largest tributary. It drains extensive upland areas on the northern and northwestern portions of the basin. The North and South Forks, which originate on the western slopes of the Blue Mountains in Columbia County, join and become the Touchet River a half mile southeast of Dayton, WA. The Touchet River flows about 30 miles westward from Dayton, WA. The Touchet River flows about 30 miles westward from Dayton before turning southward to join the Walla Walla River. The average annual discharge of the Touchet River at Bolles is 220 cfs.

Mill Creek originates in the Blue Mountains in southeastern Columbia County, WA. After dipping into Oregon it flows northward and then westward through the Cities of Walla Walla and College Place, WA to the Walla Walla River. Mill Creek and its tributary Blue Creek drain an area of approximately 100 sq-mi, with an average annual flow at Kooskooski of 91 cfs.

The Walla Walla River begins about 4 miles southeast of Milton-Freewater, OR at the confluence of its North and South Forks. From the confluence, the river flows through Milton-Freewater north into Washington and then westward to its confluence with the Columbia River. It drains approximately 160 sq-mi in Oregon and 771 sq-mi in Washington. The average annual discharge of the Walla Walla River near its mouth is 573 cfs. During the summer irrigation season, diversions in Oregon completely deplete flows into Washington. The major tributary drainages of the Walla Walla River in Washington, in addition to the Touchet River and Mill Creek, are Pine, Dry, Yellowhawk, and Cottonwood Creeks.

Stream Flow

The primary source of runoff in the Walla Walla Basin is rainfall and snow melt from the Blue Mountains. Precipitation in the basin ranges from about 7 inches near the basin's western edge at Wallula to over 40 inches in the Blue Mountains. Long term monthly average precipitation amounts for Dayton and Walla Walla are shown in Figure 3.2.

Maximum stream flows generally occur in the spring when snow melt combines with spring rains. Minimum flows and dry stream beds occur in the late summer due to low precipitation and high irrigation demands. Average long-term monthly flows for Mill Creek, the Touchet River, and the Walla Walla River are given in Figure 3.3. The location of stream gaging stations where these data were collected are identified in Figure 3.1.

There are no existing storage reservoirs along either the Walla Walla or Touchet Rivers. The Bureau of Reclamation did, however, in 1972 and 1976 develop preliminary plans for two multi-purpose dams: one, called Joe West Dam, to be located on the Walla Walla River about 3 miles upstream of Milton-Freewater, OR and another, named the Dayton Dam Reservoir would store 45,000 ac-ft. The Dayton Dam project has been, however, deauthorized due to citizen's objections.

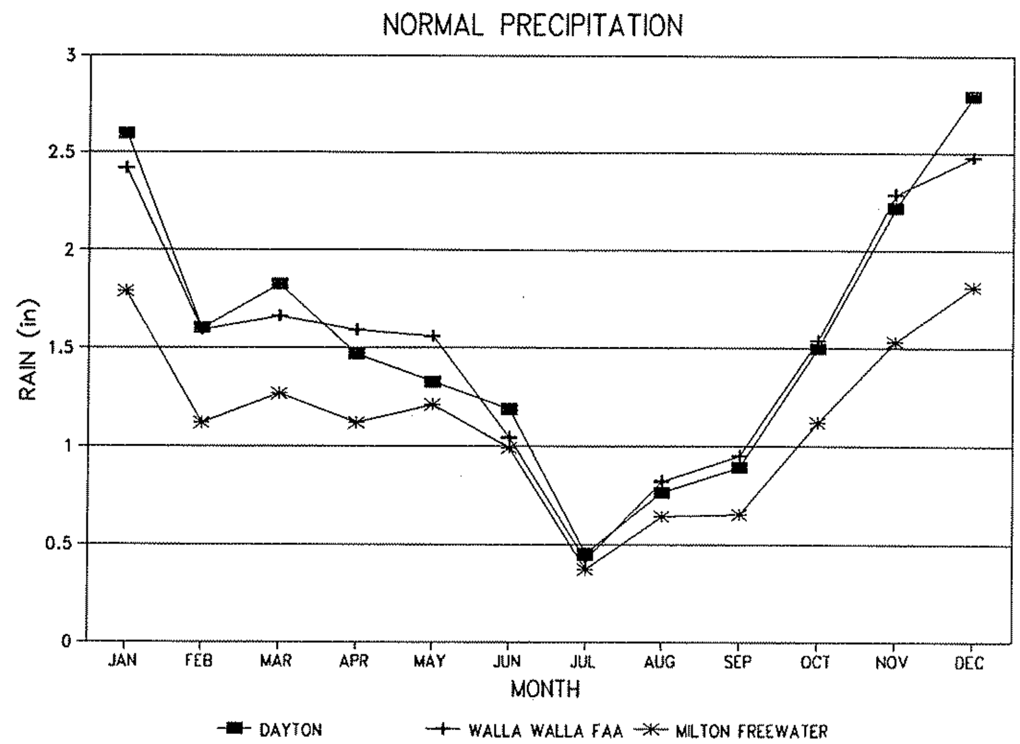


Figure 3.2 Average Monthly Precipitation for Three Weather Stations in the Walla Walla Basin.

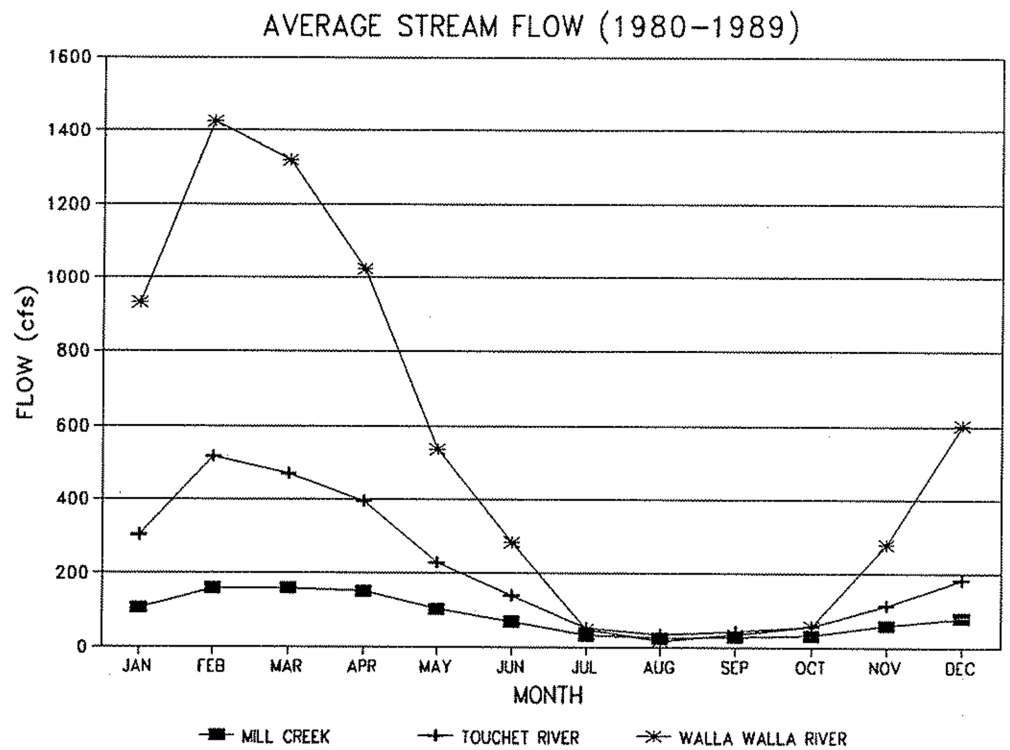


Figure 3.3 Average Monthly Stream Flow During the 10-Year Period 1980-89 for Mill Creek, the Touchet River, and the Walla Walla River.

Surface Water Diversions

Mill Creek is the primary source of water for the cities of Walla Walla and College Place during most of the year. Ground water is used during periods of turbid flow and during the summer when stream flow is low and demand is high. The city of Dayton obtained almost 80 percent of its water from the Touchet River during 1989. Most industrial users utilize municipal water.

Just under 40 percent of the water used for irrigation in the Washington portion of the basin is diverted from streams. Irrigation districts and ditch companies serve about 14,700 acres with diverted streamflow.

Stream Water Quality

Streams in the high elevation, timbered headwaters of the basin are generally cool, clear, low in pollutants, and high in dissolved oxygen. Stream water quality in the mid to lower regions of the basin is lower because essentially all of the agricultural, municipal, and industrial activity is located here. Heavy sediment loads during significant runoff events and high water temperatures and a concentrating of pollutants during low flow periods are characteristics of stream in the mid and lower portions of the basin.

Wetlands

Newcomb (1965) and Barker and MacNish (1976) describe five areas in the valley where water flowing in the gravel aquifer emerges as spring flow. Two of these areas are located in the Mill Creek drainage near Walla Walla, and three near the Walla Walla River where it crosses into Washington. The total discharge of these springs is estimated to be bout 56,000 ac-ft annually. There are also wetlands due to canal seepage were noted in a field survey of irrigation district and ditch company canals (see Figure 3.4).

Ground Water

There are two major aquifer systems beneath the Walla Walla Basin. One of these systems, called the basalt system, underlies the entire basin and is part of the layered Columbia River Basalt. This system is a series of interconnected lava flows that conduct water readily in the lateral (horizontal) direction. These conductive zones are sandwiched between dense zones of basalt with limited abilities to transmit water. Water in this system of interconnected confined aquifers flows slowly toward the Columbia and Snake Rivers to the northwest.

A gravel aquifer overlays the basalt system in the Walla Walla Valley. It is a triangular-shaped, 120,000 acre aquifer which extends from the Cities of Milton-Freewater and Walla Walla in the east to approximately two miles west of the confluence of the Touchet and Walla Walla Rivers in the lower valley (see Figure 3.5). This unconsolidated, unconfined aquifer consists primarily of gravel and sand, but varying amounts of silt and clay occur from place to place. A relatively impermeable, 200-ft thick clay layer separates the base of the gravel aquifer from the underlying basalt system.

The gravel aquifer has an average thickness of about 200 feet and a maximum thickness of approximately 500 feet. The aquifer is recharged by precipitation and irrigation as well as seepage from streams and irrigation canals. The basalt system is another minor source of recharge.

Agriculture, the cities of Walla Walla and College Place, and food processors are the primary users of ground water. The cities switch to ground water, primarily from the basalt system, when streamflow is turbid and during the low flow months when demand is high. About 60 percent of the water used for irrigation is pumped from the gravel aquifer. Figure 3.5 shows the general location of 142 wells in the primary basalt aquifer and 613 gravel aquifer wells.

Land Use

Hanson and Mitchell estimated that in 1977 about 63 percent of the Washington portion of the basin was dryland agriculture, 12 percent irrigated agriculture, 10 percent forest, and 11 percent rangeland. This distribution remains essentially the same. Most of the irrigated lands in the basin are located in the Walla Walla Valley and along the Touchet River between Dayton and the river's mouth near Touchet. Dryland agriculture and livestock farming predominates in the upland areas surrounding the valley.

Wheat, green peas, grass, barley, and dry peas are the primary dryland crops. There are more than twenty irrigated crops grown in the basin with alfalfa seed, wheat, and alfalfa hay having the largest acreages. Acreages for these and other irrigated crops grown in the Washington portion of the basin during 1989 are given in Table 3.1.

Table 3.1. Irrigated Crop Acreage in the Washington Portion of the Walla Walla Basin in 1989. These Estimates were Developed from Electricity Use for Pumping Data and Information Obtained from the ASCS and Commodity Groups.

Crop	Acres	Crop	Acres
Alfalfa Hay	5,950	Onion	1,300
Alfalfa Seed	11,405	Orchard/Spec	212
Asparagus	2,134	Pasture	1,816
Barley	316	Potato	611
Beans	1,047	Radish	6
Carrots	64	Soybeans	12
Corn	207	Squash	222
Dry Peas	80	Strawberry	58
Green Peas	205	Sweet Corn	21
Lettuce	1	Wheat	9,106
Oats	131	Other Crops	60
		Total	34,937

On-Farm Irrigation Systems

Excluding about 1,400 acres of flood irrigated pasture, most on-farm irrigation systems are either side-roll or handline sprinkle systems. The efficiency of these flood and sprinkle systems is about 45 and 65 percent, respectively.

About 60 percent of the water used for irrigation in the Washington portion of the basin is from ground water sources, with approximately two-thirds of this water coming from the gravel aquifer. Gravel aquifer wells typically yield about 200 to 300 gallons per minute (gpm), with some wells yielding 500 gpm or more. The lift from a gravel aquifer well is normally 50 to 100 feet. A typical pumpage rate from a gravel aquifer well is normally 50 to 100 feet. A typical pumpage rate from a basalt aquifer well is 400 to 500 gpm with a lift of 150 to 250 feet. Many farms that obtain water from irrigation districts and ditch companies divert water into off-stream ponds. It is then pumped from the pond into a sprinkle irrigation system.

On-farm water management practices vary with crop and surface water availability. Alfalfa seed growers, because of low summer stream flows, typically rely on irrigations during November, December, and March to fill the root zone and "carry" the crop through the growing season. Wheat growers normally irrigate prior to planting in the fall and again in the spring. During the growing season many of these irrigators supplementally irrigate from ground water sources because of limited surface water or water right restrictions. Vegetable and orchard crops are more likely to be fully irrigated. Very few irrigators practice scientific irrigation scheduling even though daily pan evaporation data has been published in the newspaper for years and WSU has established two PAWS weather stations in the valley.

Off-Farm Irrigation Conveyance Systems

The U.S. Bureau of Reclamation (Bureau) under their state planning assistance program and the Walla Walla Community College (WWCC) under contract with the Department of Ecology conducted a field investigation and assessment of off-farm irrigation water conveyance systems in the Washington portion of the basin. A report prepared by the Bureau that contains data collected by the WWCC students is included as Appendix F of this report. This information is summarized in the following paragraphs, table, and figure.

A total of 10 irrigation districts and ditch companies supply irrigation water to approximately 14,600 acres of land in the Washington portion of the basin. The location of these irrigation districts and ditch companies is shown in Figure 3.6. General data describing them is given in Table 3.2.

These systems divert water from the Walla Walla and Touchet Rivers via concrete or gravel diversion dams and distribute it to farms in earthlined, open canals. About 70 percent of the land served by these systems is sprinkle irrigated. All of the river diversion structures have a Cipolletti Weir to measure stream diversions, but only two of them have continuous automatic flow recorders. Irrigators are charged by the number of acres irrigated and total deliveries in ac-ft are not generally measured. Flow rate estimates are obtained via sprinkler counts and, where available, with weirs and flow meters.

Operation and maintenance of these systems varies according to the size of the district or ditch company. The larger districts employ ditch riders to operate the river diversion gates and set farm turnout gates according to water orders from individual irrigators. These ditch riders are also responsible for canal maintenance. The smaller districts and ditch companies have less structured operational procedures and significantly less stringent maintenance procedures and resources. In these systems, river diversion gate settings are adjusted by the farmers or local Watermaster (a State employee).

Fishery

Summer steelhead are the only native anadromous salmonid remaining in the basin. For run years 1977-78 through 1986-87, an estimated 1,000 to 1,800 native summer steelhead returned to the basin each year (Confederated Tribes of the Umatilla Indian Reservation 1989). Historical runs are believed to have contained 4,000 to 5,000 fish per year (ODFW 1987).

In recent years the Washington Department of Wildlife has released hatchery reared summer steelhead into the basin. There are currently no steelhead artificial production facilities in the Oregon portion of the basin.

Table 3.2. Description of Off-Farm Irrigation Water Conveyance Systems in the Washington Portion of the Walla Walla Basin.

Irrigation District or Ditch Company	Miles of Canal	Canal Lining	Diversion Type	Acres Irrigated	System Capacity cfs
Gardena Farms	23.6	Earth	Concrete	7,000	100
East Side-Touchet	5.1	Earth	Concrete	790	30
West Side-Touchet	4.1	Earth	Concrete	1,200	18
Lowden	5.4	Earth	Gravel	850	8*
Mud Creek	2.6	Earth	Gravel	500	
Garden City	4.8	Earth	Gravel	1,250	16
Old Lowden	3.2	Earth	Gravel	1,550	12
Bergevin-Williams	2.9	Earth	Gravel	1,040	5
Stiller Ditch	1.8	Earth	Gravel	130	5
Smith Ditch	0.6	Earth	Gravel	330	2
Totals	54.1			14,640	196

* Includes Mud Creek

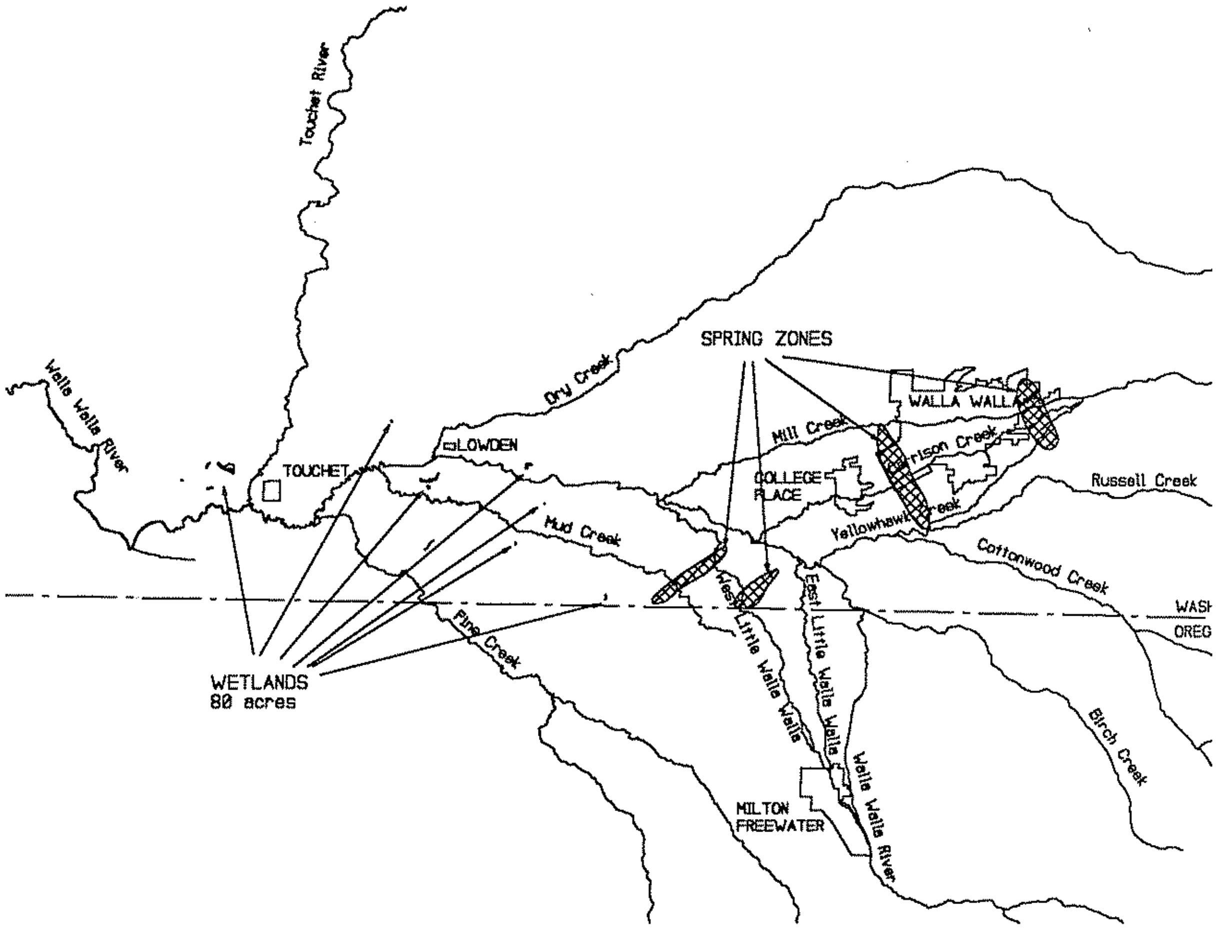


Figure 3.4 Location of Springs and Agricultural Wetlands in the Washington Portion of the Walla Walla Basin.

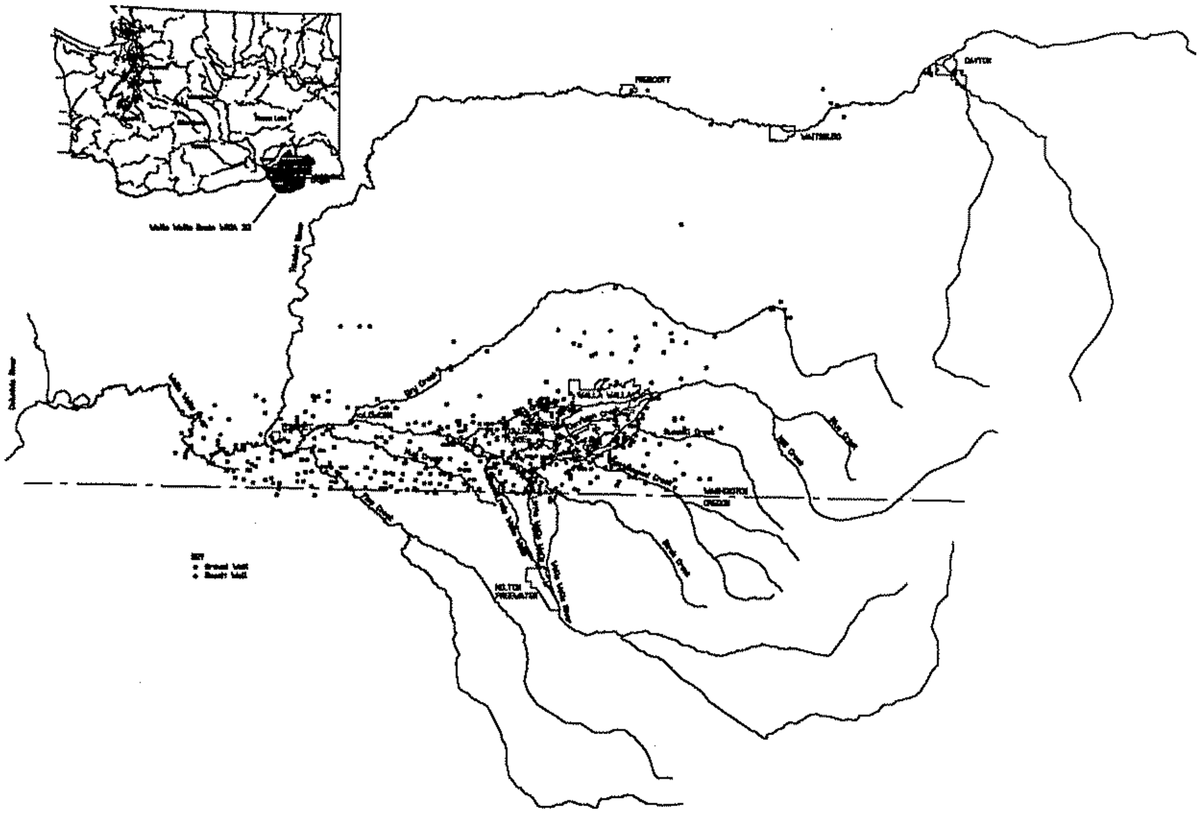


Figure 3.5 Location of the Gravel Aquifer and Wells in the Washington Portion of the Walla Walla Basin.

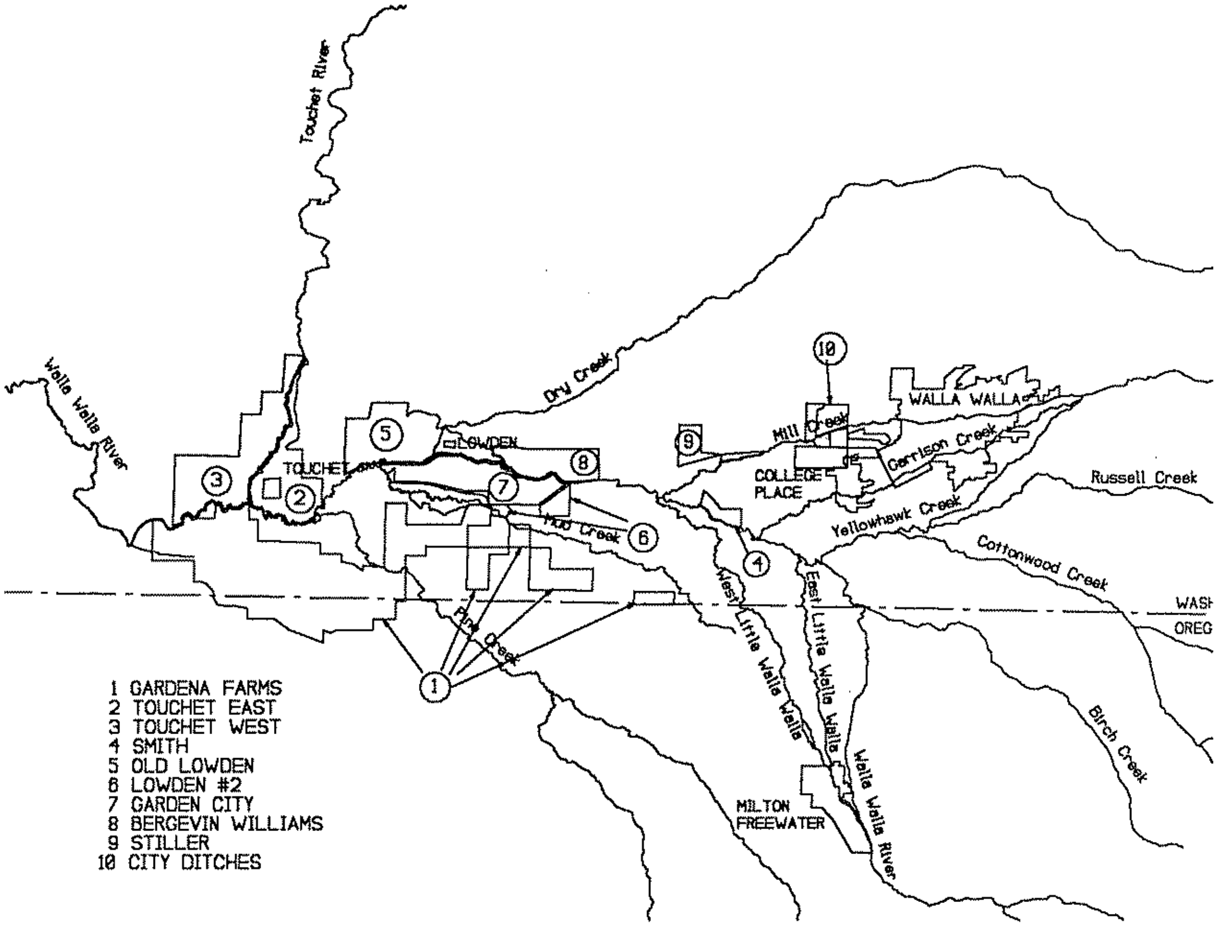


Figure 3.6 Location of Irrigation Districts and Ditch Companies in the Washington Portion of the Walla Walla Basin.

CHAPTER 4

FUTURE WATER USE TRENDS

Summary

Higher in-stream flows, slight increases in municipal and industrial water use, and little, if any, change in water use for irrigation are the expected water use trends in the Walla Walla Basin. Irrigated agriculture and municipalities will continue to be the primary users of water. Any increases in in-stream flows, or in municipal, industrial, and/or agricultural use can be expected to intensify existing water problems. These water use trends will be influenced by implementation of water use efficiency measures and/or water allocation policies.

Agriculture

Hanson and Mitchell in 1977 estimated that about 37,700 acres in the Washington portion of the basin were fully irrigated. They also estimated that there were approximately 38,000 acres with supplemental irrigation and an additional 57,800 acres that could be irrigated. There have been only minor shifts in irrigated crops and crop acreage since 1977. This trend is expected to continue. Thus, future levels of irrigation water use should be about the same as current levels.

Municipal

The basin's average annual rate of population growth has been about 0.4 percent since 1982. This rate is not expected to exceed 1 percent in the near future. Thus, a slight rise in municipal water use is anticipated. Implementation of water conservation measures by municipalities would reduce this rise in usage.

Industrial

Planners do not expect large industrial water users, such as food processors, to expand or move into the basin in the near future. Industrial water use should increase slowly at approximately the same rate as municipal use. Again, implementation of water conservation measures by industry would reduce the annual rate of increase.

In-Stream

Higher in-stream flows, particularly during the late summer and early fall, will be required to improve water quality and increase fish production in the basin. If this were to occur, it would be the most significant trend in future water use within the basin.

Ground Water

A slight increase in basalt system use, especially during periods of low or turbid streamflow, will probably be required to support any future population and industrial growth. Irrigators desiring a more stable and abundant water supply could also contribute to increasing use of the basalt system.

Use of the gravel aquifer should continue at about the same rate. Domestic water supplies and supplemental irrigation will remain the primary uses. If there is additional use, it will most likely be irrigators wishing to supplement surface supplies, particularly during the late summer when stream flows are lowest.

CHAPTER 5

ALTERNATIVE WATER USE EFFICIENCY MEASURES

Introduction

The lack of stream flow during the late summer and early fall has a profound effect on agricultural, municipal, industrial, and in-stream uses of water in the basin. Alfalfa seed and hay are major irrigated crops because irrigators can rely on water stored in the relatively large root zone of alfalfa during winter months to "carry" the crop through the growing season. Other irrigators must grow crops that tolerate water stress due to late season water shortages. Municipal and industrial users must switch from surface to ground water during periods of low stream flow. Fish habitats are damaged and fish production severely restricted by the lack of sufficient stream flow.

Three basic approaches to enhancing stream flows were examined. The first approach involved increasing stream flow through basin-wide improvements in irrigation water use efficiency. The second and third approaches were, respectively, to eliminate the use of surface water for irrigation wherever possible, and to expand water upstream storage to capture winter flows for release during low-flow periods. Three scenarios involving improved irrigation water use efficiency, two involving the elimination of surface water use for irrigation , and four expanded upstream storage alternatives are described in this chapter.

Improved Irrigation Efficiency

Three scenarios for improving irrigation water use efficiency were considered. Two of these involved a 10 percent increase in on-farm efficiency and the other, a 10 percent higher conveyance efficiency for off-farm delivery systems operated by irrigation districts and ditch companies.

On-Farm Efficiency

In these two scenarios, the efficiency of each on-farm irrigation system in the study area was increased by 10 percent. This efficiency improvement was achieved by increasing the level of management, i.e., labor was substituted for water. This scenario does not involve structural changes to the irrigation system or increases in irrigated crop acreage beyond the baseline level.

"Saved" water resulting from the efficiency increases was used in two ways. First, it could be used on-farm to either increase the amount of land irrigated and/or decrease ground water pumping or to reduce surface diversions, whichever provided the most on-farm economic benefit. In the second scenario, both surface diversions and ground water withdrawals were reduced by 10 percent.

Off-Farm Efficiency

After a preliminary assessment of systems in the Washington portion of the basin, the U.S. Bureau of Reclamation (Bureau), in Appendix F, recommended a comprehensive set of measures for improving the efficiency of off-farm delivery systems operated by irrigation districts and ditch companies. These measures included:

a. Installation of permanent flow measurement devices on all farm turnouts and canal wasteways.

b. Improved maintenance of all delivery systems.

c. Consolidation of small ditch companies.

d. Construction of new permanent diversion structures for those ditch companies which now use gravel diversions.

The Bureau, conservatively, estimated that implementation of these measures would improve conveyance efficiency of off-farm delivery systems in the study area by five percent.

The Bureau considered, but did not recommend, relining/replacement or automation of canals. Canal relining/replacement was not recommended since "water losses in the study area attributed to seepage from canals appear to be minor" (page 5 of the Bureau report in Appendix F). Canal automation was not included in the recommendations because most turnouts along larger canals are to pumped deliveries which don't require precise water level control. Thus, the potential water savings associated with canal automation were believed to be limited.

The effects of a 10 percent increase in the conveyance efficiency of off-farm delivery systems was evaluated in this study. The improvement was assumed to be the result of reduced canal seepage (even though seepage losses in the study area appear to be small). This scenario was examined rather than one based on the Bureau recommendations because of its more extreme effect on the gravel aquifer. The effect on stream flow of this scenario should be similar to the Bureau recommendations. On-farm efficiencies were held constant at baseline levels.

No Surface Diversions for Irrigation

In this approach to increasing stream flow, there are no surface diversions for irrigation. Ground water is allowed to substitute for surface water to the maximum degree possible wherever there is excess ground water capacity, but acreages are not allowed to increase above current levels. In areas where ground water is limited, irrigated acreages may be reduced.

This approach includes two scenarios. In the first one, water not diverted for irrigation is allowed to remain in-stream and flow through the basin. The primary benefits are associated with enhanced in-stream flows.

The second scenario involves a water market and is identical to the first scenario with one exception. Downstream surface water is now allowed to be diverted for agricultural use near the mouth of the basin after improving the fishery habitat. This allows examination of the economic value of additional surface water to irrigators in or near farming region 9 and their ability to compensate upstream agriculture for their "lost" water. In this scenario, the irrigated acreage constraint is made non-binding in region 9 so that the supply of monthly irrigation water becomes the sole factor limiting irrigated acreage. Ground water capacity throughout the basin is constrained to baseline levels to focus the analysis on the value of additional surface water to downstream agriculture.

Upstream Storage

Four upstream storage scenarios for increasing stream flow were considered. The first one assumes 6,000 ac-ft of storage are constructed on Mill Creek about four miles above Kooskooski. The stored water is assumed to be uniformly released in the critical months of July, August, September, and October. This additional storage has both an in-stream and on-farm value. The in-stream value is measured by, but not limited to, the benefit of additional surface water to fishery habitat. The additional stream flow can then be diverted by downstream irrigators in or near farming region 9 after improving upstream fishery habitat.

The three other storage scenarios focus on the on-farm value of rehabilitating Mill Creek Lake so that it can store 8,000 ac-ft for release into the lower third of Yellowhawk Creek via Russell Creek. This storage influences both in-stream and out-of-stream values by changing the timing of water availability. However, the location of this storage prohibits stored water from benefitting the Mill Creek Fishery. Hence, the benefit of this storage is limited to agriculture.

The agricultural value of additional surface water supplies can be measured in many ways. Three approaches are considered here. The first approach calculates the value of Mill Creek Lake as the reduction in energy costs associated with the substitution of surface water for more costly ground water while maintaining all other baseline conditions. The second approach releases the baseline constraint on total irrigated acreage so that additional acreage can make use of the upstream storage capacity while maintaining the baseline irrigated crop proportions and all other baseline conditions. The third alternative is similar to the second except that the baseline constraint on irrigated crop proportions is released. Thus, the third scenario assumes that a dependable source of surface water in the critical summer period allows irrigators to concentrate on higher value agriculture. The analysis assumes that surface water storage scenarios only affect agriculture in farming region 13. All other farming regions remained at baseline levels.

CHAPTER 6

TECHNICAL ASSESSMENT OF ALTERNATIVE WATER USE EFFICIENCY MEASURES

Introduction

This chapter presents and discusses the impacts, benefits, and costs of nine measures for improving water use efficiency in the Washington portion of the Walla Walla Basin. These measures, which are described in the previous chapter, were selected from a seemingly infinite number of options. It is unlikely that any of these nine measures will, in themselves, constitute a water use efficiency plan. Instead, they are a "first generation" set of measures that allow several general approaches for improving water use efficiency to be explored and the most productive ones identified. This information will be extremely useful to the local Committee and Department of Ecology developing the water use efficiency plan. They will provide this group with insights and quantitative data for refining and combining these nine measures as well as for proposing new ones. The plan they develop will probably emerge from these "second generation" measures.

Some of the nine measures are "extreme" and probably unrealistic. These measures were included to test the ability of the models described in Chapter 2 and Appendices C, D, and E to predict on-farm and basin responses. Because it is often easier to use one's experience and judgement to predict outcomes for "extreme" scenarios (than for more realistic ones), it is possible to test models by comparing their predictions for "extreme" scenarios to one's own expectations.

Only data for 1989 were considered in the study. Data in Figure 6.1 show that 1989 was a near "average" year for both water supply (as indicated by precipitation and stream flow) and water demand (as indicated by Irrigation requirements).

The on-farm economic effects of each alternative measure and policy are described first. Next, the hydrologic response of the basin and the impacts on the Mill Creek fishery are presented. The final section of this chapter summarizes these effects.

On-Farm Impacts

The on-farm impacts are analyzed for seven of the nine water policy scenarios in this section. The policies analyzed consist of two (of the three) on-farm efficiency scenarios, the two no surface diversion scenarios, and the three upstream storage scenarios involving the rehabilitation of Mill Creek Lake. (The upstream scenerio involving storage in upper Mill Creek was not analzyed.) For comparison purposes, the economic outcome associated with each measure is compared to current water use practices (i.e., baseline).

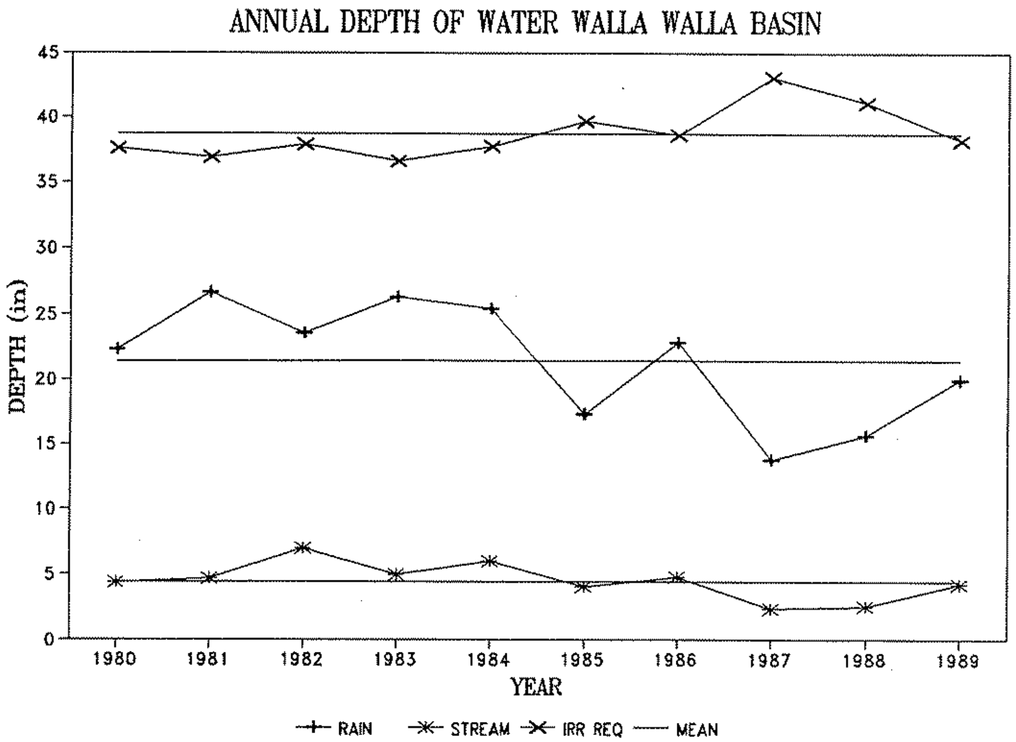


Figure 6.1 Annual Precipitation, Stream Flow, and Irrigation Requirements for the Walla Walla Basin for the 10-Year Period 1980-89.

On-Farm Irrigation Efficiency

Data in Table 6.1 indicate that increasing on-farm efficiency by 10 percent has minimal impact on basin income. No basin-wide income reduction is observed when surface water conserved through increased irrigation efficiency can be used on-farm. However, income is slightly reduced ($29,000) when the conserved surface water is left in-stream for fishery habitat. The two on-farm efficiency scenarios increase basin-wide irrigation efficiency from 59.8 percent to slightly over 69 percent.

Despite the fact that basin income is minimally effected by increased on-farm efficiency, the impact varies from region-to-region. Some regions experience an increase in net farm income, while others experience a reduction in net farm income. Region 10, for example, experiences a farm income increase under the scenario that allows conserved water to be used on-farm. This occurs since the energy savings more than offset the additional labor cost necessary to bring about the efficiency increase. Three factors are responsible for this outcome. First, increased irrigation efficiency reduces the quantity of relatively expensive ground water that is pumped. This efficiency benefit is especially valuable to regions heavily dependent on ground water diversions like region 10. Secondly, conserved surface water is substituted for more expensive ground water to the maximum degree possible. Thirdly, the irrigated crops in combination with the irrigation systems used in the region have a relatively low irrigation labor requirement. Thus, it is possible to increase irrigation efficiency at minimal labor cost. Collectively, these three factors increase net farm income in region 10, since the energy savings associated with the efficiency increase more than offset the additional irrigation labor costs. However, this is not always the case. Regions that are highly dependent on surface diversions and/or crops which have a high irrigation labor component experience a decrease in net farm income. This is the case for regions 13 and 14. Regional summaries similar to Table 6.1 are contained in Appendix I for each irrigated region. Detailed representative farm reports for region 8 are included in Appendix K (Tables K.3 through K.6).

No Surface Diversion for Irrigation

Eliminating stream diversions for irrigation and allowing "saved" water to remain in-stream and flow out of the basin reduces basin income by $493,000 dollars below the baseline level as nearly 2,000 irrigated acres are taken out of production and replaced by 1,183 acres of dryland production. The 783 acre reduction in total crop acreage results from idle land which was previously in irrigated pasture. All basin farm regions except for regions 3 and 4 experience an income decline. Regions 3 and 4 escape the impact of this policy since they are completely dependent on ground water for irrigation. Region 6 is the most adversely affected region as it has no ground water withdrawals and is forced into a dryland wheat-fallow rotation. Ground water use increased by 34,000 ac-ft over current irrigation practices. However, the ground water increase is inadequate to fully compensate for the 43,000 ac-ft of lost surface diversion.

Using the "saved" water for agriculture in or near farming region 9 increased basin-wide net farm income by 33 percent and irrigated acreage by almost 8,700 acres. Slightly more than half of the surface water which was left in-stream is utilized in or near region 9. Ground water use remains very close to its use level when water was left in-stream. This scenario suggests that it might be possible for irrigators in the eastern end of the basin to substitute ground water for surface water and then market their surface water to irrigators on the western (downstream) edge of the basin. The income generated in region 9 appears to be adequate to fully compensate upstream users for leaving their surface right in-stream. Appendix J contains a regional summary table for each region similar to Table 6.2.

Upstream Storage

Mill Creek Storage Above Kooskooski

The on-farm impacts of low-flow period releases into Mill Creek are minimal because of large seepage losses from lower Mill Creek (below the Yellowhawk diversion) and small irrigation diversions from Mill Creek. Values for the various on-farm parameters considered are essentially the same as for the baseline. The on-farm model was not run for this scenario.

Rehabilitation of Mill Creek Lake

The on-farm impacts of three measures involving the use of 8,000 ac-ft of water released from a rehabilitated Mill Creek Lake during the low-flow months are reported in Table 6.3. The modeling approach assumed the releases were utilized in region 13. Therefore, all other regions are unaffected and remain at their baseline values. Utilizing all stored water in region 13 is a modeling convenience, nothing prevents the stored water from being used in any region, or combination of regions, west of region 13. Table 6.4 presents the summary for region 13. The three on-farm economic values ranged from a low of $52,000 for the ground water substitution scenario to a high of 3.2 million dollars for the high-value crop approach. Groundwater pumping decreased by 8,000 ac-ft in the groundwater substitution scenario. Irrigated acreage increased by 2,747 acres in the high-value scenario relative to baseline. The high-value crop scenario suggests that the development and efficient management of additional storage capacity may generate a high return to basin farmers.

Hydrology

Average monthly flows in the Walla Walla River near its mouth and in Mill Creek at Walla Walla are shown in Figures 6.2 and 6.3. The entire annual hydrograph for each stream is given in Figures 6.2a and 6.3a for different measures for improving water use efficiency. The same data are included in Figures 6.2b and 6.3b except that the vertical axes have been expanded to show only flows up to 100 cfs. This allows flow differences during the 4-month, low-flow period of July through October to be more easily seen.

The baseline condition for the gravel aquifer and the effects of the nine water use efficiency measures on the gravel aquifer are summarized in Table 6.5. These data are annual totals and together constitute the gravel aquifer's annual water budget. Outflows from the gravel aquifer include pumpage for irrigation, evapotranspiration directly from the aquifer, and the discharge of springs. Inflows include recharge from precipitation and excess irrigation, seepage from streams and irrigation canals, leakage from the basalt system, and lateral subsurface flow into the aquifer. The change in gravel aquifer storage is the difference between the inflows and outflows. A positive storage indicates that inflows exceed outflows and that, in general, water levels in the gravel aquifer will rise.

It should be noted that in some areas of the basin water from the gravel aquifer enters streams while in other locations seepage from streams percolates to the gravel aquifer. The column entitled "Streams" in Table 6.5 is the algebraic sum of these values and is included with inflows since, basin-wide, seepage from streams normally exceeds the amount of gravel aquifer discharge to streams. This is also true for flows to and from the basalt system and lateral (subsurface) ground water flow to and from the gravel aquifer.

The following is a discussion of baseline conditions and changes from baseline conditions caused by each water use efficiency measure.

<u>Baseline</u>

During the four, low-flow months of July through October there is no flow in Mill Creek downstream of the Yellowhawk-Garrison Creek diversion and an average flow of about 21 cfs in the Walla Walla River near Touchet. Normally, there is flow in Mill Creek downstream of the diversion only when there is 35 cfs or more upstream of the diversion. Water is diverted from Figure 6.2

Table 6.1. Basin-Wide (Washington Portion) Summary of On-farm Impacts of a 10 Percent Improvement in Irrigation Efficiency. The Baseline Case is Included for Comparison Purposes.

Variable	Baseline	10% Increase in Irrigation Efficiency: On-Farm — Use "Saved" Water On-Farm	10% Increase in Irrigation Efficiency: On-Farm — Use "Saved" Water to Reduce Diversions	10% Increase in Irrigation Efficiency: Off-Farm — Use "Saved" Water to Reduce Diversions
Net Revenue Over Variable Costs (1,000 $)	$14,353	$14,353	$14,324	$14,353
Average Return Over Variable Costs ($/acre)	$413.30	$413.29	$412.94	$413.30
Irrigated Acres	34,729	34,729	34,668	34,729
Dry Land Acres	0	0	21	0
Total Acres	34,729	34,729	34,689	34,729
Surface Water Use (ac-ft)	42,527	42,199	38,220	42,527
Gravel Aquifer Use (ac-ft)	46,277	36,220	38,528	46,277
Basalt System Use (ac-ft)	21,275	17,069	17,834	21,275
Total Irrigation Water Applied (ac-ft)	110,079	95,487	94,581	110,079
Consumptive Use (ac-ft)	65,853	65,988	65,822	65,853
Irrigation Efficiency	59.8%	69.1%	69.6%	59.1%

Table 6.2. Basin-Wide (Washington Portion) Summary of On-Farm Impacts of Two Alternatives Involving No Surface Diversions for Irrigation. The Baseline Case is Included for Comparison Purposes.

		No surface Diversions for Irrigation	
Variable	Baseline	"Saved" Water Remains In-stream	"Saved" Water Used at Western End of Basin
Net Revenue Over Variable Costs (1,000 $)	$14,353	$13,860	$19,035
Average Return Over Variable Costs ($/acre)	$413.30	$408.30	$438.60
Irrigated Acres	34,729	32,763	42,215
Dry Land Acres	0	1,183	1,183
Total Acres	34,729	33,946	43,398
Surface Water Use (ac-ft)	42,527	0	24,518
Gravel Aquifer Use (ac-ft)	46,277	72,769	71,628
Basalt System Use (ac-ft)	21,275	28,838	24,588
Total Irrigation Water Applied (ac-ft)	110,079	101,608	120,734
Consumptive Use (ac-ft)	65,853	60,819	74,080
Irrigation Efficiency	59.8%	59.9%	61.4%

Table 6.3. Basin-Wide (Washington Portion) Summary of the On-Farm Impacts of Three Alternative Approaches Involving of an Additional 8,000 ac-ft of Storage Obtained by Rehabilitating Mill Creek Lake. Data for the Baseline Case are Included for Comparison Purposes.

Variable	Baseline	Increasing Upstream Storage by Rehabilitating Mill Creek Lake		
		Reduced GW Pumping	Irrigate Existing Crops	High-Value Crops
Net Revenue Over Variable Costs (1,000 $)	$14,353	$14,405	$15,870	$17,567
Average Return Over Variable Costs ($/acre)	$413.30	$414.80	$425.76	$468.76
Irrigated Acres	34,729	34,729	37,274	37,476
Dry Land Acres	0	0	0	0
Total Acres	34,729	34,729	37,274	37,476
Surface Water Use (ac-ft)	42,527	50,527	50,527	50,527
Gravel Aquifer Use (ac-ft)	46,277	38,078	45,470	45,864
Basalt System Use (ac-ft)	21,275	21,077	21,256	21,265
Total Irrigation Water Applied (ac-ft)	110,079	109,682	117,252	117,656
Consumptive Use (ac-ft)	65,853	65,853	70,778	71,018
Irrigation Efficiency	59.8%	60.0%	60.4%	60.4%

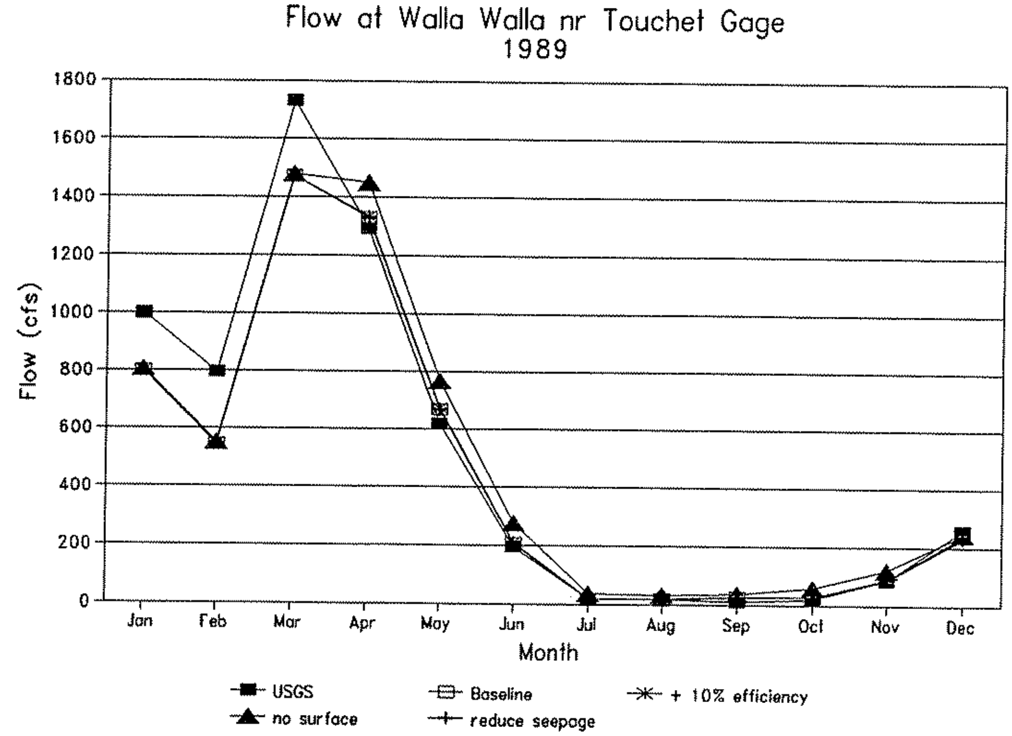
Table 6.4. Farming Region 13 Summary of the On-Farm Impacts of Three Alternative Approaches Involving of an Additional 8,000 ac-ft of Storage Obtained by Rehabilitating Mill Creek Lake. Data for the Baseline Case are Included for Comparison Purposes.

Variable	Baseline	Increasing Upstream Storage by Rehabilitating Mill Creek Lake		
		Reduced GW Pumping	Irrigate Existing Crops	High-Value Crops
Net Revenue Over Variable Costs (1,000 $)	$3,341	$3,392	$4,857	$6,554
Average Return Over Variable Costs ($/acre)	$577.56	$586.51	$583.09	$768.26
Irrigated Acres	5,784	5,784	8,329	8,532
Dry Land Acres	0	0	0	0
Total Acres	5,784	5,784	8,329	8,532
Surface Water Use (ac-ft)	2,507	10,507	10,507	10,507
Gravel Aquifer Use (ac-ft)	14,764	6,564	13,956	14,351
Basalt System Use (ac-ft)	357	159	338	347
Total Irrigation Water Applied (ac-ft)	17,628	17,230	24,801	25,205
Consumptive Use (ac-ft)	11,193	11,193	16,119	16,358
Irrigation Efficiency	63.5%	65.0%	65.0%	64.9%

Table 6.5. 1989 Gravel Aquifer Water Budget for Selected Water Use Efficiency Measures in the Walla Walla Basin (Oregon Portion Included).

Water Use Efficiency Measure	Outflows from Gravel Aquifer (ac-ft)			Inflows to Gravel Aquifer (ac-ft)					Change in Gravel Aquifer Storage
	Irrigation Pumpage	Evapo-trans-piration	Discharge of Springs	Irrigation, Precip Recharge	Canal Seepage	From Streams	GW Flow into Gravel Aquifer	From Basalt System	
Baseline	60,379	7,190	48,134	17,042	4,454	43,378	14,415	10,356	-26,076
Increase On-Farm Efficiency By 10 %									
a. Use "Saved" Water On-Farm	51,800	7,730	48,640	15,707	4,464	40,850	14,397	10,357	-22,162
b. Reduce Diversions/Withdrawals	53,683	7,696	48,574	15,506	4,454	42,540	14,349	10,357	-22,768
Increase Off-Farm Delivery System Efficiency by 10%	60,373	7,050	47,656	17,042	773	45,082	14,601	10,356	-27,243
Add 6,000 ac-ft Storage on Mill Creek Above Kooskooski	60,379	7,323	49,369	17,042	4,452	48,365	14,213	10,356	-22,662
Rehabilitate Mill Creek Lake to Obtain an Additional 8,000 ac-ft of Storage									
a. Use "Extra" Water Instead of Ground Water for Irrigation	53,056	7,468	48,914	16,958	4,454	39,976	14,414	10,360	-23,294
b. Use "Extra" Water to Irrigate Additional Acres of Existing Crops	59,524	7,164	48,197	16,956	4,457	44,076	14,413	10,363	-24,636
c. Use "Extra" Water to Irrigate Higher-Valued Crops	59,996	7,006	48,090	16,984	4,457	44,494	14,415	10,363	-24,397
No Surface Diversions for Irrigation									
a. "Saved" Water Remains Instream and Flows Through Basin	83,241	6,892	48,357	17,004	2,780	58,253	14,323	10,352	-35,805
b. "Saved" Water Remains Instream & Used to Irrigate High-Value Crops at Western End of Basin	83,241	6,892	48,357	17,004	2,780	58,253	14,323	10,352	-35,805

A



B

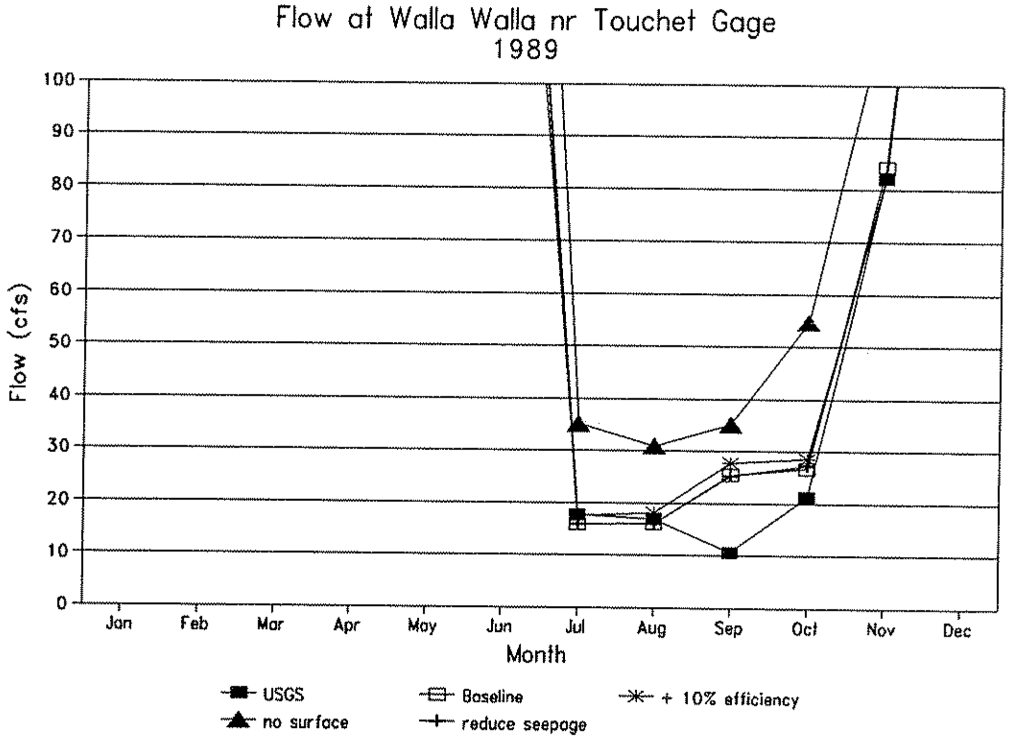
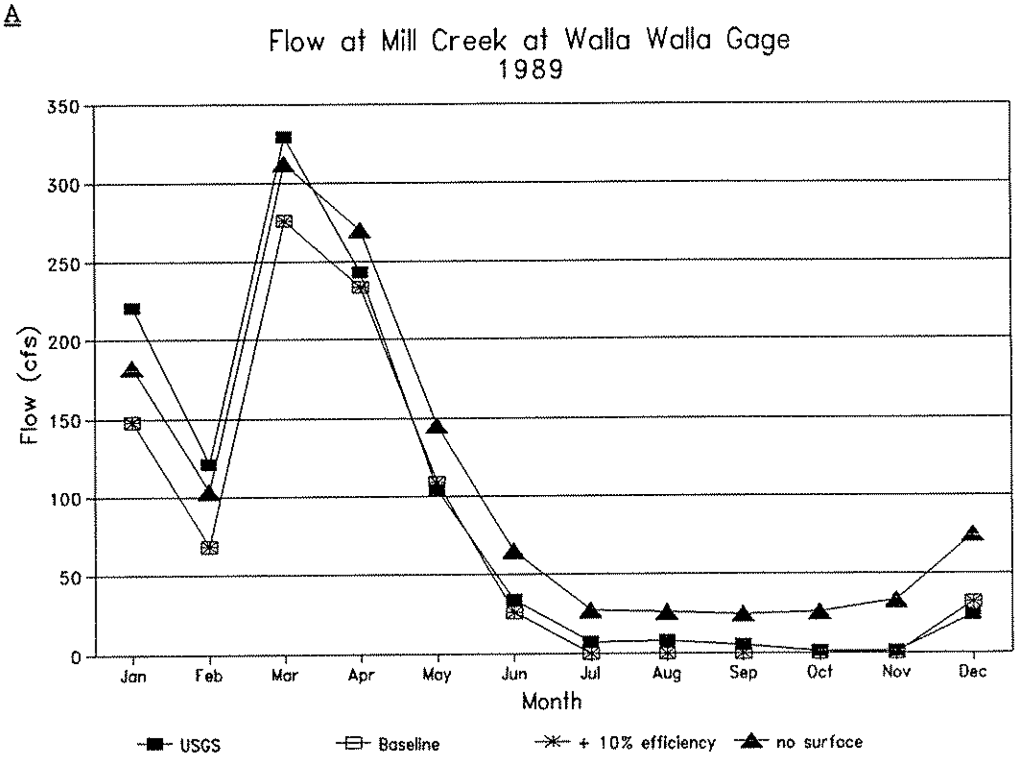
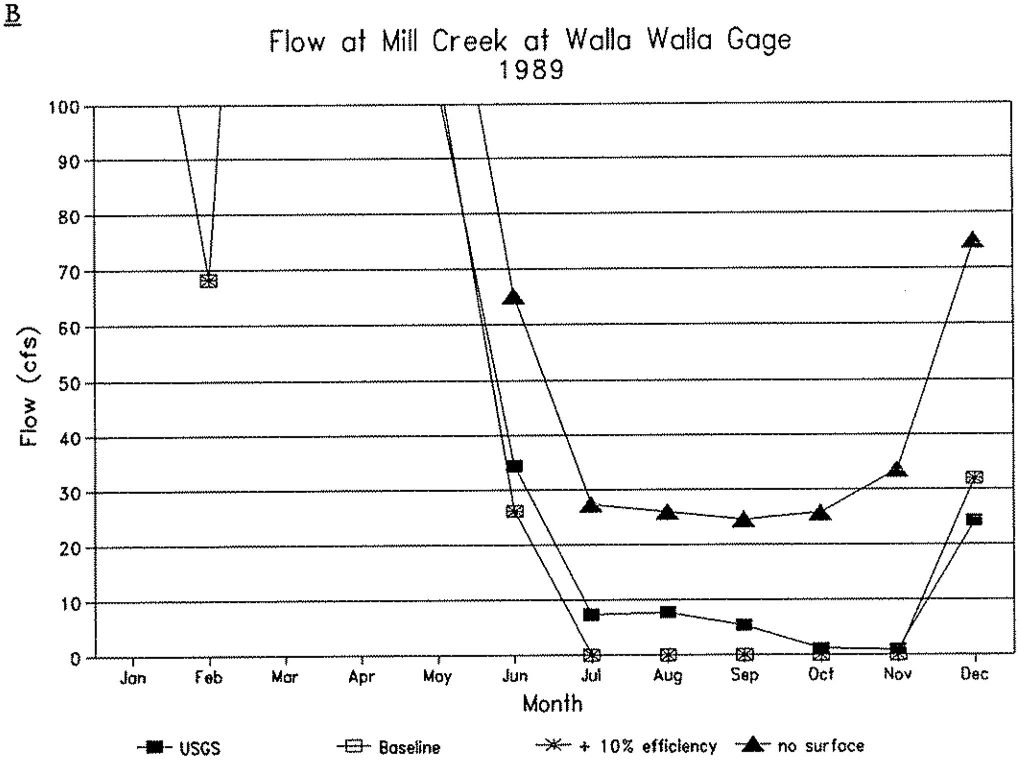


Figure 6.2 Predicted Flows in the Walla Walla River near Touchet for the Baseline Condition and Several Alternative Water Use Efficiency Measures.

A


Flow at Mill Creek at Walla Walla Gage
1989
Flow (cfs)
350
300
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
USGS
Baseline
+ 10% efficiency
no surface

B


Flow at Mill Creek at Walla Walla Gage
1989
Flow (cfs)
100
90
80
70
60
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
USGS
Baseline
+ 10% efficiency
no surface

Mill Creek into Yellowhawk Creek just upstream of the Walla Walla gage at an average rate of approximately 20 cfs during the low-flow period.

Water budget data in Table 6.5 indicate that irrigation pumpage and the discharge of springs are the primary outflows from the gravel aquifer and seepage from streams the primary inflow. These data also indicate that in 1989, aquifer outflows exceeded inflows by 26,076 ac-ft. This would result in an approximately 5-inch aquifer-wide average decline in the water table. This decline would probably be at least 2-inches less in a normal precipitation year as total precipitation during 1989 was about 1-inch less than average.

Improved Irrigation Efficiency

On-Farm Efficiency

Reducing surface diversions and ground water withdrawals through improved on-farm irrigation (application) efficiencies increased average flow in the Walla Walla River near Touchet by about 7 cfs during the 4-month, low-flow period (see Figure 6.2b). Similarly, average flow in Mill Creek at Walla Walla during the low-flow period was increased by approximately 2 cfs primarily because of increased flow in October. (This is when Gardena Farms begins to exercise their winter water right.)

These relatively small increases in stream flow are explained by the fact that irrigation in the Washington portion of the basin has evolved around plentiful winter and spring, and minimal summer flows. Almost 75 percent of the irrigated land in the Washington portion of the basin is alfalfa seed, alfalfa hay, and wheat (see Table 3.3) since these crops can normally be successfully grown with minimal summer irrigation. Most irrigators in the Gardena Irrigation District, which accounts for about half of the surface irrigated acreage, grow these crops because of water right restrictions between April and September. Thus, many of the potential water savings from improved irrigation efficiencies are limited by current water allocation policy. Improvements in irrigation efficiency therefore result in relatively small increases in stream flows during low-flow periods.

Increasing on-farm irrigation efficiency from 65 to 75 percent reduced withdrawals from the gravel aquifer by 14 percent (8,579 ac-ft) when "saved" water could be used on-farm and by 11 percent (6,696 ac-ft) when surface diversions were reduced (see Table 6.5). The most significant effects of reduced pumpage were to lower the depletion of aquifer storage and recharge from excess irrigation by over 1,300 ac-ft. There were also small decreases in seepage from streams and the discharge of springs.

Off-Farm Efficiency

In this scenario, canal seepage was reduced to simulate the effect of lining irrigation district and ditch company canals with concrete. Figure 6.2b indicates that this scenario has almost no effect on summer flows in the Walla Walla River near Touchet. Again this is the result of the largest district not diverting large amounts of water during low flow periods. There was no change in flow in Mill Creek at Walla Walla since all irrigation district/ditch company diversions are downstream of this location.

Data in Table 6.5 indicate that, in this scenario, canal seepage was 3,681 ac-ft less than for the baseline condition. This increased seepage from streams by 1,704 ac-ft and depletion of gravel aquifer storage by 1,167 ac-ft. There was little, if any, change in the other gravel aquifer parameters in Table 6.5.

No Surface Diversions for Irrigation

All stream diversions for irrigation were eliminated to determine the upper limit of available streamflows gained from irrigated agriculture. In these scenarios, flows in the Walla Walla River near Touchet increased by about 18 cfs during the 4-month, low-flow period. Flow in Mill Creek dropped to as low as 25 cfs (see Figure 6.3b) even though no water was diverted into Yellowhawk-Garrison Creek. The hydrologic model predicted that increasing irrigation pumping by 22,862 ac-ft would result in an additional 9,729 ac-ft depletion of the gravel aquifer storage (from the baseline). In addition, canal seepage would decrease by 1,674 ac-ft while stream seepage would increase by 14,875 ac-ft. There was little, if any, change in the other gravel aquifer water budget parameters. It should be noted that the model does not provide information for assessing the effect of increased pumping on individual wells.

Upstream Storage

Mill Creek Storage Above Kooskooski

Constructing a 6,000 ac-ft storage on Mill Creek upstream of Kooskooski will increase flow in the Walla Walla River near Touchet by only 1 cfs even though an average of 25 cfs of additional flow would be released into Mill Creek during the low-flow period of July through October. Large seepage losses along Mill Creek between the Walla Walla gage and the Creek's confluence with the Walla Walla River explain this small increase in flow in the Walla Walla River near Touchet. Upstream of the Yellowhawk-Garrison Creek diversion, there would be about 43 cfs in Mill Creek during the low-flow period. Of this, 20 cfs would continue to be diverted into Yellowhawk Creek for irrigation. The remaining 23 cfs would be left in Mill Creek to improve the fish habitat.

Data in Table 6.5 indicate that stream seepage in the basin would be increased by almost 5,000 ac-ft in this scenario. All of this would occur in lower Mill Creek. Thus, only about 1,000 ac-ft (4 cfs) of the 6,000 ac-ft (25 cfs) released would enter the Walla Walla River. The increased seepage would reduce depletion of gravel aquifer storage by 3,414 ac-ft. There would be only minor changes in the other water budget parameters in Table 6.5.

Rehabilitating Mill Creek Lake

Flow in Mill Creek at Walla Walla and in the Walla Walla River near Touchet remain unchanged from baseline values in the three scenarios involving the rehabilitation of Mill Creek Lake. This is because the additional 8,000 ac-ft (34 cfs) of flow is released downstream of the Walla Walla gage on Mill Creek and is completely used in region 13 before it reaches the gage near Touchet on the Walla Walla River. Flow rates in the lower half of Yellowhawk Creek where water released from Mill Creek Lake enters and the Touchet gage exceed baseline flow rates by as much as 34 cfs.

Using water released from Mill Creek Lake instead of ground water reduces irrigation pumpage from the gravel aquifer by 7,323 ac-ft (from the baseline condition). In addition, there is 677 ac-ft less pumpage from the basalt system. This lower pumpage rate from the gravel aquifer results in 3,402 ac-ft less stream seepage and 2,782 ac-ft less annual depletion of gravel aquifer storage. There are only minor, if any, changes in the other water budget parameters in Table 6.5.

The other two scenarios associated with rehabilitating Mill Creek Lake increase stream seepage and decrease the depletion of gravel aquifer storage only slightly. There were negligible changes in the other water budget parameters in Table 6.5.

Mill Creek Fishery

Only the fish habitat of Mill Creek between its confluence with the Walla Walla River and Kooskooski was evaluated in this study. Lack of channel geometry data, and time and budget constraints made it impossible to obtain the data needed to analyze other streams. If these data were available, the methodology used in this study (and described in Appendix E) could be utilized to evaluate the fish habitat of the other streams. Although the information developed for Mill Creek should not be extrapolated to other streams, it does provide some useful insights into the fishery potential of the basin.

Currently, there is negligible summer flow in the lower reach of Mill Creek. The fishery portion of this study examined the effects of increasing summer flows on the adult steelhead population and the associated benefits. Flows ranging from 10 to 30 cfs and the large seepage losses in Mill Creek downstream of the Yellowhawk Diversion were considered.

The suitability of reaches along Mill Creek as a habitat for a particular life-stage and fish species were evaluated using an index called the weighted usable area (WUA). Table 6.6 gives the WUA calculated for each flow and steelhead life stage. As flows reach 30 cfs, WUA increases drastically for all life stages except fry. Fry prefer lower flows than the other life stages. Therefore, if summer flows are raised much above 30 cfs, the effect could be detrimental to fry. Juvenile WUA increases as the flows increase, up until well above 75 cfs. Consequently, higher summer flows would improve the habitat suitability for juvenile. Spawning and adult steelhead are not present in Mill Creek during the summer months, but adult rainbow trout are present. These resident fish would also benefit from higher summer flows.

Table 6.7 relates Juvenile WUA to changes in the adult steelhead population in Mill Creek. The fish density factor was supplied by a study done by the Department of Wildlife (1981). The steelhead smolt-to-adult survival rate of 2.2 percent used in the Walla Walla Salmon and Steelhead Subbasin Plan (Salmon and Steelhead Plan 1989) was used in this study. These increases in the steelhead adult population assume that there is sufficient stocking and suitable habitat for spawning and rearing. Mill Creek's lower reach would be used mainly for rearing, although the lower four miles could be suitable for spawning. If the 6,000 acre feet reservoir were built on upper Mill Creek, prime steelhead spawning grounds could be destroyed. Therefore, benefits associated with increased flows could be offset by losses resulting from the lack of spawning habitat. Also, in many of the following scenarios, water is transferred from Yellowhawk Creek to Mill Creek. The gains made in Mill Creek's fishery could be offset by losses incurred by Yellowhawk's fishery. At the present time no fishery data exist for Yellowhawk Creek and potential losses can not be estimated.

In Table 6.8, the benefits associated with different summer flows are presented. The benefits range from $510 to $13,970, depending on the flow level and the marginal benefit assigned to the steelhead adults. These marginal benefits of $6.65, $23 and $103 were transferred from studies done in Oregon and Washington (Loomis 1988, Johnson and Adams 1989, and Sampler ad Bishop 1985). All three were included to give a range of possible values associated with each flow regime considered. Finally, it is important to note that these are user benefits, i.e., they are benefits derived by fishermen. Nonuser benefits should also be considered when determining the value of Mill Creek's fishery. Nonuser benefits are often equal to or greater than user benefits.

Table 6.6. Weighted Usable Area (WUA) in sq-ft Per 1000 ft for Four Flow Rates in the Lower Reach of Mill Creek.

Steelhead Life-Stage	Flow Rates			
	10 cfs	15 cfs	20 cfs	30 cfs
Fry	21,285	25,265	27,974	30,345
Spawning	622	622	622	1,260
Adult	278	278	278	778
Juvenile	4,921	5,175	5,430	8,504

Table 6.7. Estimation of Total Change in Adult Steelhead Population for the Four Different Flows for the Study Area.

Flow Rate cfs	Juvenile WUA sq-ft per 1000 ft	Density Factor[1]	Estimated No. of Juveniles per 1000 ft	Aggregated Total Change in Adult Steelhead[2]
0	0	0.0198	0	-
10	4,921	0.0198	97	77
15	5,175	0.0198	102	81
20	5,430	0.0198	108	86
30	8,504	0.0198	168	131

[1]The density factor is based on the assumption that Mill Creek's base summer fish population is approximately 10,780 fish (Department of Wildlife 1981). The density equation: Fish population per 1000 ft divided by WUA per 1000 ft = density factor.

[2]Steps in determining "Aggregated Total Change in Adult Steelhead Population": (a) Multiply "Estimated Number of Juvenile per 1000 ft" by 80 percent to determine percentage of Steelhead Juvenile; (b) Multiply Number of Steelhead Juvenile by 2.2 percent (the smolt-to-adult survival rate) to determine the Estimated Number of Adult Steelhead per 1000 feet; (c) Multiply Estimated Number of Adult Steelhead per 1000 feet by 45 (there are approximately 45 sections of 1000 feet in the study area) to determine the "Aggregated Total Change in Adult Steelhead Population."

Table 6.8. Total Benefits Associated with the Four Flow Rates.

Flow Rate cfs	Estimated No. of Adult Steelhead	Total User Benefits		
		$6.65/fish	$23/fish	$103/fish
10	77	$ 512[1]	$1,771[1]	$ 7,931[1]
15	81	539	1,863	8,343
20	86	572	1,978	8,858
30	131	871	3,013	13,493

[1]These revenues reflect changes from zero.

Baseline

Currently, there is negligible flow in the lower reach of Mill Creek during summer, therefore no fishery habitat exists. If some of the summer flow being diverted down Yellowhawk Creek were left in Mill Creek, the habitat would improve. For example, with 10 cfs left in Mill Creek, the estimated increase in adult steelhead would be 77 fish and the associated value would be $1.770. (All the values stated in this section assume a marginal value of $23 per fish.) This would be offset by some fish losses in Yellowhawk Creek due to the decreased diversion.

Improved Irrigation Efficiency

The 10 percent increase in irrigation efficiency would not affect fishery habitat in Mill Creek because this gain would occur in Yellowhawk Creek below its confluence with the Walla Walla River. Reducing surface diversions and leaving more water in-stream could positively affect the fishery habitat that exists in the lower Walla Walla River. Estimates obtained using the hydrologic model indicate that the increase in summer in-stream flows and benefits to fish habitat resulting from a 10% increase in irrigation efficiency would be small.

Improving on-farm irrigation efficiency and using the "saved" water on-farm would have a negligible impact on fish habitat.

No Surface Diversions for Irrigation

With no surface diversions, there would be approximately 30 cfs in the upper reach of Mill Creek during the summer. That means an additional 10 cfs of in-stream flows would be available. Four possible flows would involve leaving 10, 15, 20 or 30 cfs in Mill Creek's lower reach. If 10 cfs were left in the lower reach, the usual summer diversion of 20 cfs down Yellowhawk Creek would not be affected. In this case, the additional 10 cfs would be a net gain. It would yield approximately 77 adult steelhead and $1,770 in value. If 15 cfs remained in Mill Creek and 15 cfs were diverted down Yellowhawk Creek, the estimated change in steelhead adults would be 81 fish and the associated value would be $1,860. However, there could be a decrease in Yellowhawk Creek's fish population resulting from the decreased flows. If 20 cfs were left in Mill Creek and 10 cfs were diverted down Yellowhawk Creek, the estimated change in steelhead adults would be 86 fish and the associated value would be $1,970. Again, the decreased diversion down Yellowhawk Creek could adversely impact this fish population. Finally, if all 30 cfs were utilized in the lower reach of Mill Creek, Yellowhawk Creek would be dry. The estimated increase in the number of steelhead adults and value associated with a summer flow of 30 cfs in Mill Creek's lower reach would be 130 fish and $3,000, respectively. There are no available data regarding the impact this "no diversion" scenario would have on Yellowhawk Creek's fish population. The losses could possibly offset the gains made in Mill Creek, or they could be very small. This increased flow would also lead to more water entering the Walla Walla, whether it flowed down Mill Creek or Yellowhawk Creek. These increased flows, together with additional flows available below the mouth of Mill Creek could aid the fishery habitat in the lower Walla Walla River.

Upstream Storage

Mill Creek Storage Above Kooskooski

If a 6,000 ac-ft reservoir were built on upper Mill Creek, an additional 22 cfs could be released for four months during the late summer and early fall. The additional water would increase the in-stream flows to about 40 cfs (30 cfs after upstream irrigation diversions). Assuming the usual 20 cfs were diverted down Yellowhawk Creek, there would be approximately 20 cfs left in the lower reach of Mill Creek. This increased flow would increase the habitat suitability for fry and juvenile. The estimated change in steelhead adults and associated benefits would be 131 fish and $3,013. This increase in steelhead adults assumes that there is sufficient stocking, and spawning and rearing habitat to support the fish. The proposed reservoir site is on prime spawning grounds. Therefore, according to the Department of Wildlife, the reservoir's increased flows might not increase and may even decrease the number of steelhead adults in Mill Creek. The increased summer flows would most likely positively affect the resident trout in Mill Creek, the fishery in Yellowhawk Creek, and any fishery habitat that exists below the mouth of Mill Creek.

Rehabilitating Mill Creek Lake

Releasing 8,000 ac-ft of water from a rehabilitated Mill Creek Lake during the four low-flow months would not affect the Mill Creek Fishery since releases would be made into the lower third of Yellowhawk Creek. Releases would have a minor impact on the fish habitat of the lower Walla Walla River because all of the released water would be used for agriculture in farming region 13 (which is located just west of the City of Walla Walla). The Mill Creek fishery would benefit if releases were made into Mill Creek rather than Yellowhawk Creek.

Summary of Results

The impacts, benefits, and costs associated with the nine measures for improving water use efficiency described in Chapter 5 are summarized in Table 6.9. The following observations are based on this table.

a. On-farm benefits are greatest when additional water is made available for irrigation and it is used to irrigate additional land, especially lands with high-value crops.

b. In general, improving irrigation efficiency has only a small effect on on-farm net revenues over variable costs. In this study, only measures such as the use of scientific irrigation scheduling that substitute labor for water were considered. Thus, this observation is probably not valid for irrigation efficiency improvements which require capital expenditures.

c. Increasing on-farm irrigation efficiency and allowing the water to be used on-farm resulted in the lowest total amount of water use for irrigation. The total volume was 13 percent less than for the baseline.

d. Increasing on-farm irrigation efficiency reduced ground water depletion by about 13 percent and increased low-flow period stream flow 10 percent when "saved" water was used on-farm and 33 percent when diversions were reduced by the amount of "saved" water. These increases are expected to have a small effect on fish habitat in the lower Walla Walla River during the low-flow period since flow increased by only 2 and 7 cfs, respectively.

e. Increasing the efficiency of off-farm delivery systems had a negligible effect on stream flow, and hence fish habitat, during the four-month, low-flow period.

f. Eliminating the use of stream flow for irrigation had the largest impact on stream flow, increasing it from the baseline value of 21 cfs to 40 cfs during the low-flow period. This should provide the most improvement in fish habitat in the lower Walla Walla River of the water use efficiency measures considered.

g. Eliminating the use of stream flow for irrigation resulted in 37 percent (9,729 ac-ft) more depletion of gravel aquifer storage and increased pumpage from the basalt system by 36 percent (7,563 ac-ft) for case a and 16 percent (3,313 ac-ft) for case b (see Table 6.9).

h. Releasing 6,000 ac-ft of stored water into Mill Creek from a reservoir located upstream of Kooskooski during the four-month, low-flow period resulted in only a modest improvement in the number and value of fish in Mill Creek. It had minimal effect on the fishery of the Walla Walla River below the mouth of Mill Creek because of relatively large seepage losses from Mill Creek downstream of the Yellowhawk diversion. Routing these releases down Yellowhawk Creek to improve fish habitat in both Yellowhawk Creek and the lower Walla Walla River should be considered.

i. Rehabilitating Mill Creek Lake to store 8,000 ac-ft of water for release during July through October increases on-farm net revenues over variable costs, total irrigation water use, and irrigated acreage for cases b and c (in Table 6.9).

j. Releasing 8,000 ac-ft from a rehabilitated Mill Creek Lake during the low-flow period reduces the annual depletion of gravel aquifer storage by 6 to 12 percent (from the baseline) and has a negligible effect on pumpage from the basalt system.

k. Releasing 8,000 ac-ft from a rehabilitated Mill Creek Lake during the low-flow period has negligible effect on the fish habitat in Mill Creek (because water is released into the lower third of Yellowhawk Creek) and the Walla Walla River (since all of the released water is used in farming region 13, just west of Walla Walla).

Table 6.9. Summary of the Impacts of Measures for Improving Water Use Efficiency in the Washington Part of the Walla Walla Basin.

Water Use Efficiency Measure	Net Revenue Over Variable Costs $1000/acre	Total Irrigation Water Use ac-ft	Ac-Ft During Low-Flow Period in: Walla Walla R. nr Touchet	Ac-Ft During Low-Flow Period in: Mill Creek at Walla Walla	Pumpage from Basalt System ac-ft	Change in Gravel Aquifer Storage ac-ft	Number of Additional Steelhead in Mill Creek	Value of Additional Steelhead in Mill Creek	Relative Impact on Fishery in Other Streams
Baseline	$14,353	110,079	5,102	0	21,275	-26,076			
Increase On-Farm Efficiency By 10 %									
a. Use "Saved" Water On-Farm	$14,353	95,487	5,565	0	17,069	-22,162	0	0	Some
b. Reduce Diversions/Withdrawls	$14,324	94,581	6,734	486	17,834	-22,768	52	$1,196	Medium
Increase Off-Farm Delivery System Efficiency by 10%	$14,353	110,079	5,127	0	21,275	-27,243	52	$1,196	Some
Add 6,000 ac-ft Storage on Mill Creek Above Kooskooski	$14,353	110,079	5,153	5,411	21,275	-22,662	91	$2,093	Some
Rehabilitate Mill Creek Lake to Obtain an Additional 8,000 ac-ft of Storage									
a. Use "Extra" Water Instead of Ground Water for Irrigation	$14,405	109,682	5,102	0	21,077	-23,294	0	$0	Some
b. Use "Extra" Water to Irrigate Additional Acres of Existing Crops	$15,870	117,252	5,102	0	21,256	-24,636	0	$0	Some
c. Use "Extra" Water to Irrigate Higher-Valued Crops	$17,567	117,656	5,102	0	21,265	-24,397	0	$0	Some
No Surface Diversions for Irrigation									
a. "Saved" Water Remains Instream and Flows Through Basin	$13,860	101,608	9,492	6,297	28,838	-35,805	91	$2,093	Large
b. "Saved" Water Remains Instream & Used to Irrigate High-Value Crops at Western End of Basin	$19,035	120,734	9,492	6,297	24,588	-35,805	91	$2,093	Large

Note: All releases from Mill Creek Lake are used for agriculture in farming region 13.
Diversions to Yellowhawk Creek not included in Mill Creek at Walla Walla. About 20 cfs is diverted to Yellowhawk during the low-flow period.
Negative changes in gravel aquifer storage indicate an annual aquifer-wide decline in water table elevation .

CHAPTER 7

INSTITUTIONAL AND POLICY CONSIDERATIONS

Introduction

The major thrust of the analytical portion of this project has been to develop the baseline information and analytical models that can be used to predict consequences from various changes in water management and water allocation in the Walla Walla River Basin. The analytical "models" have been used to predict hydrologic and economic consequences from some illustrative scenarios of water use efficiency in the Walla Walla River Basin. Rather, they serve to illustrate how the models and data can be used by the local committee to move toward a plan for the Basin.

The process of moving to a plan is the primary business before the committee at this time. This will involve consideration of not only quantitative information coming from the analytical models but also the more qualitative issues of the planning process, the role of institutions in determining actual realization of the desired results.

There are four principal steps in the plan formulation process:

1. Determination of goals and objectives that are important for evaluating alternative components in a water conservation plan for the Walla Walla Basin, and selection of criteria that can be used to evaluate progress toward the goals.

2. Development of a workable process for the committee to use in evaluating different plan components and policy options and formulating a plan for water conservation in the Walla Walla River Basin. How can the committee work with the local community to bring about adoption and implementation of a better plan for the Basin.

3. Consideration of how existing institutions, regulations, and control of water rights will affect the possibility of actually achieving desired changes in efficiency and water management. Identification of impediments to voluntary cooperation with desired conservation programs.

4. Determination of changes to policies and institutions that are necessary or desirable to enhance the implementation of the preferred water conservation plan. Development of an agreed strategy for the committee to work toward the selected changes in policies, regulations, funding, attitudes, and individual behavior that will bring about acceptance and implementation of a desirable water plan for the Basin.

Deciding on Goals and Criteria

The charge to the committee from the legislature includes instructions to first decide upon goals and objectives that will be used to guide choices among water use and water allocation alternatives. It is a good idea to begin by considering basic or fundamental goals and then move on to choose more specific or direct objectives. Unanimous agreement about relative importance of goals is not likely, so discussion of goals should not be prolonged. However, jumping immediately to deliberations over specific conservation and water management actions is even less likely to lead to agreement unless some basic understanding of the goals of various parties has first been reached.

Basic or fundamental goals might be better understood as directions in which the community would like to move. Examples could be: economic productivity, protection of natural environments, equity and fairness, security of property rights, and freedom from conflict and turmoil. The next step after identifying goals is to devise criteria that can be used to evaluate alternative plans. Criteria are simply ways of measuring how far a particular plan moves the Basin in the direction of one of the fundamental goals.

One of the important goals for most communities and most individuals within them is economic productivity and economic well being. Economists talk about economic efficiency or productivity as the principal dimension of an economic goal for a society. The criterion for measuring a project or conservation action's economic achievements is the net economic benefits realized by the community or society as a whole. Does the total economic value produced exceed the total value of inputs required and costs incurred? If so, the project is judged to be economically beneficial. However, farmers and other businesses are constantly considering the options available to them in economic terms. How will their own profits be affected? One would expect that farmers and businesses would voluntarily adopt conservation measures that they believe would increase their profits. Conversely, if some measures have not been adopted by some individuals, it is perhaps because they are not expected to improve those individuals' economic well being.

In many cases water developments or conservation actions will improve the economic well being of some individuals but make others worse off. Those who are benefitted by the action will be very eager to see it carried out whereas those that lose will be opposed to it. Thus, the distributional effects of conservation actions must be taken into account before one can either predict how widely the plan will be accepted or pass judgement on whether conservation actions should be imposed on all water users in the community.

Some actions that could be undesirable or costly to directly affected parties can have positive economic benefits for the basin and community as a whole. For the community, economic progress and economic well being are determined by more than just the net benefits to directly affected parties from particular water development actions. Building the economic base of the community, stimulating growth of the trade and services sectors, and creating a community that is attractive to residents and visitors are all important to the community's economic welfare. Therefore, before one can specify criteria to use for measuring achievements in the direction of economic efficiency and productivity, one must address the issue of whether there are enough community economic gains to justify privately costly actions. Also, consideration must be given to whether individuals that are harmed, for the community's benefit will be compensated in some way for their losses.

One way of dealing with the fact of unequal effects is to simply rule out from consideration any projects or conservation actions that have adverse economic effects on anyone. Another approach is to simply pass judgement. Declare the action to be in the best interest of the community and require cooperation from all, including those who are individually made worse off. Such a declaration of public interest might be felt justified if, for example, widespread and substantial net benefits are realized while those who lose in economic terms are few and the losses are small. Another example might be a case in which benefits are not large but are realized by a particularly deserving group of individuals. Conversely, a project that has substantially more total benefits than costs may be judged undesirable from an equity point of view if the benefits are received by a small group of well-to-do individuals, whereas the costs are spread over a number of deserving families. Thus, it is important to give some thought, before selecting among components of a conservation plan, to how much potential gain in economic efficiency and productivity one is willing to forego to avoid undesirable equity effects or undesirable effects on overall community economic growth and employment.

The second fundamental objective that needs to be considered before the plan selection stage is that of protection and restoration of the environment and natural resources. Almost everyone would favor some protection and enhancement of environmental and resource conditions if there was no trade off or cost involved. But, in most river basins and in the Walla Walla Basin as well, water management affects anadromous and resident fisheries, water based recreation, scenic beauty, wildlife, and so forth. Some plans might enhance one aspect of the environment and make another less desirable. So, it is necessary to consider the relative importance of various aspects of the environment as well as the emphasis to be given to the general goal of protecting and enhancing environmental aspects of the basin.

In order to consider the environmental objective, it is necessary to consider how important the environment is relative to the achievement of economic productivity and equity. The link between environmental resources such as fish and the economy is somewhat indirect. Fish are usually what economists call a public good, enjoyed by everyone but owned by no one. Thus, there are no individual property owners to defend against damaging changes and to promote vigorously those actions that would benefit the fishery. The public's interests in fish often lose out to private interests in the use and management of water.

Planning Process

The process by which a plan is developed can have a significant effect not only upon the plan that finally emerges, but also on the likelihood that the plan will every become a reality. Any plan that is devised by this committee will be judged in part on the basis of how well the process conformed to what is considered within this community to be an acceptable way of deliberation and decision making. Communities often have strong preferences, virtually a goal, about the way in which policy deliberations are carried out and the kinds of actions that are taken to bring about individual cooperation with the preferred plan.

Some thought needs to be given at the start as to how important it is to the Walla Walla community to have widespread participation and representation of different interest groups in the irrigation water conservation planning process. To what extent is it acceptable in the Walla Walla community to advocate bold new ideas and departures from tradition? Will decisions be made within the committee by majority vote or consensus? Will the committee produce recommendations to a broader group of principal users of water or to the public in general, or will the committee attempt to move on to implementation as soon as the desired changes are identified? Are there strong feelings about the desirability of alternative policy instruments? How much economic or environmental gain would the community be willing to forego in exchange for avoiding a distasteful policy approach?

Institutional Considerations and the Policy Dimension

The analysis of water conservation alternatives in the Walla Walla River Basin has assumed, up to this point, "scenarios" in which water management and conservation actions occur precisely as designed. Hydrologic and economic effects have been predicted assuming that irrigators and other key parties to a water conservation plan respond exactly as called for in the scenario. In reality, the response will always be less than perfect. The process of moving toward a conservation plan for the Basin involves not only gaining the ability to predict hydrologic and economic consequences of various changes in water use efficiency and water allocation, but also an ability to predict how the many individual decision makers will respond to the plan and the policies that are put in place to bring about its implementation. Will more strict and compelling policies give enough gain in water conservation and saving in cost to justify the dissatisfaction with the policy approaches?

The economic cost and returns of conservation give information as to what might happen if water was made more of a marketable commodity or if costly actions were forced on water users. But various institutions (laws, regulations, water rights, governmental budgets, political power, etc.) also play an important role in determining water users' behavior. Even a well designed and strongly backed plan to improve water use efficiency or reallocate water from one use to another is likely to be simply another "paper plan" unless institutional aspects are given adequate consideration. A water conservation plan should not be considered complete unless it includes the institutional and policy changes that can be expected to lead to the desired changes in water use and water management.

Policy Measures

There are four principal types of policy interventions that might be used to lead to a desired or planned pattern of water use and management:

1. Regulations and standards, if strictly enforced, guarantee that prescribed practices will be followed. Regulations and standards have the appeal of commanding compliance by all and yielding exactly the results that are felt to be necessary or desirable for the plan. A rule that would require all irrigators to improve their water use efficiency by ten percent or forfeit their water rights is clear and precise and, if strictly enforced, would surely get the kind of improvement and efficiency that is desired. However, regulations are usually resisted by those being regulated because compliance is almost always, to some degree costly or inconvenient. Also, regulations and standards are usually uniform, in the interest of fairness and ease of enforcement, but the costs of compliance and the value of an ac-ft of water saved may differ widely among those conforming to the same standard.

2. Incentive payments provide a more flexible and "considerate" approach to gaining compliance. Cost sharing payments are a common devise for making compliance with regulations more acceptable. Incentive payments for saved water or water released for transfer can provide an even more flexible and less coercive approach. Price schedules that offer sizeable discounts to those who use water more efficiently can have much the same effect. No one need participate if they feel that the incentive offered is not greater than the costs and losses of compliance. Thus, diverse water users are able to respond and react in ways that make the best adaptation to achieve an improvement in water use efficiency. Thus, most economists, and many other people as well, prefer implementation plans that work with the incentives to the individual in order to bring about a change in behavior toward what is felt to be more desirable.

3. Water markets provide a means of creating the incentives for water users to improve efficiency and reduce the amount of water used. Those wanting more water can offer to buy from those with established rights, and water users with the best opportunities for reducing use at minimal cost will be most likely to sell. Thus, water will be provided to new purposes where needed, and the water will come from voluntary conservation carried out where it can be accomplished most efficiently.

4. Perhaps even more desirable are policies that attempt to change behavior through education and information. An education and information program provides people with information that they can adapt to their own circumstances and either accept or reject with no compulsion one way or the other. Information about conservation techniques can also be an inexpensive means to save water.

As with goals, there are also trade-offs among the different policy approaches and between policy approaches and other objectives. A policy of leaving actual decision entirely up to voluntary choice of individuals, influenced only by information that is supplied, may be most appealing as a policy process, but contribute very little to the goals of achieving environmental improvement and a more efficient allocation of resources.

The Process of Developing a Plan

Because of the conflicts and competition among the objectives, it is important in the overall process of developing a goals and objective statement to address the issue of trade-off among objectives and give some consideration to how the inevitable trade-off and competition among objectives will be considered in making decisions about particular plans.

With the hydrologic and economic models available and in place, goals and objectives stated and the trade-off among objectives considered, and consideration given to the effectiveness of different implementation strategies, the committee will have all parts in place for proceeding to develop a conservation plan. The process of working together as a committee and of providing for participation of individuals and expression of different points of view and value should be worked out in the early stages of the planning process. That process of working together can now be returned to the business of actually coming up with a conservation plan for the Basin.

The usual way of working toward a plan is to consider a scenario that involves certain conservation actions and interventions and then to evaluate the results that come out from that conservation "plan" in terms of the objectives and criteria that have been laid out before. One way in which that might be viewed is taking one of the scenarios that were used to illustrate the working of the models and carrying that through to evaluate what that would mean in terms of the goals and primary considerations from the community's point of view. Once the procedure is in place and some familiarity is gained with the working of the models and the process by which implementation policies lead to actual changes in conservation behavior, there would normally be an iterative procedure of changing certain features in the plans, evaluating them, making other changes, re-evaluating and slowly moving toward a more and more desirable plan. It is usually desirable to finish with not one single plan but with two or three options which give either alternative approaches to achieving conservation and other objectives or alternative weighing of different objectives. For example, one option might stress a higher level of improvement in environmental conditions within the Basin whereas another option might instead stress the advancement of economic development in the agricultural sector.

An alternative approach to developing the plan or alternative plans would be to put the emphasis on setting up criteria and incentives that would lead to more conservation or reallocation of water in all those cases in which it is desirable to have that take place. Under this strategy of developing a plan, there would not be a specification in terms of so many ac-ft of water conserved or a given level of improvement in water use efficiency. Rather, there would be an establishment of conditions that would lead to conservation whenever desirable. The result in terms of physical and economic changes would be accepted as is, regardless of its level, because of confidence that the basic criteria were being satisfied.

CHAPTER 8

SUMMARY AND RECOMMENDATIONS FOR FUTURE ASSESSMENTS

Summary

This was the second phase of a three-phase project to develop a demonstration water use efficiency plan for a selected irrigated area in Washington. The primary objective of this second phase was to assess the impacts, benefits, and costs of nine measures for improving water use efficiency in the Washington portion of the Walla Walla Basin.

The primary instruments of assessment were three mathematical (computer) models developed to estimate on-farm and basin responses to changes in water use efficiency. These models included one for estimating on-farm economic effects, another for predicting the basin's hydrologic response, and a third for evaluating fish habitat in Mill Creek between its confluence with the Walla Walla River and Kooskooski. The models were adapted (calibrated) to conditions in the basin using baseline data describing the basin's geology, climate, streams, stream flow, aquifers, ground water, fish habitat (only in Mill Creek), agriculture, on- and off-farm irrigation systems and management, municipal/industrial water use, and wetlands. Time and budget constraints limited field data collection and did not allow field verification of the models. Instead, the local Conservation Plan Formulation Committee (established by the Department of Ecology) reviewed study results for consistency with their experience and knowledge of the basin.

Nine "first-generation" measures for enhancing stream flow, especially during natural periods of low-flow in late summer and early fall, were considered in this study. These measures, which were chosen from a seemingly infinite array of options, enhanced in-stream flow by either, (a) increasing on- or off-farm irrigation efficiency, (b) storing additional surface water (for release during low-flow periods), or (c) changing water allocation policy.

The results of this study will be used in Phase 3 of this project by the local Conservation Plan Formulation Committee and Department of Ecology to develop "second-generation" measures. A plan for improving water use efficiency in the Washington portion of the basin should emerge from the second-generation measures.

Summary of Results

Only data for 1989, a near average year (in terms of both water supply and irrigation requirements), were considered in this study. Neither the long-term effects or the performance during more "extreme" years of the nine measures for improving water use efficiency were evaluated. The following paragraphs in this section describe the major effects during 1989 of enhancing stream flow during the four low-flow months by improving irrigation efficiency, providing additional upstream storage, and eliminating surface diversions for irrigation.

The largest impacts of improved irrigation efficiency were on irrigation water use and ground water pumpage. Irrigation water use was decreased by about 13 percent and pumpage from the gravel aquifer and basalt system were reduced by 13 percent (depending on how the "saved" water was used). The smaller amount of ground water pumpage reduced depletion of gravel aquifer storage by about 13 percent. Increasing on-farm application and off-farm delivery system efficiencies had a relatively small effect on on-farm returns over variable costs, in-stream flows, and fish habitat.

Providing upstream storage to capture high winter and spring stream flows for release during the four low-flow months of July through October had little effect on on-farm returns over variable costs unless "extra" water was used to irrigate additional land, especially lands with high-value crops. The benefit to fish habitat was modest primarily because of large seepage losses from Mill Creek downstream of the Yellowhawk diversion during the low-flow months and because water was used for agriculture in farming region 13 (located just west of the city of Walla Walla). This caused only small increases in flow and fish habitat in the lower Walla Walla River. Providing upstream storage had a negligible effect on ground water, except when "extra" water was used instead of ground water in farming region 13. This scenario reduced pumpage from the gravel aquifer by 8,200 ac-ft and from the basalt system by 198 ac-ft.

Eliminating stream diversions for irrigation in the Washington portion of the basin, although probably unrealistic, does define the effects of the present level of irrigation on ground water, stream flow, and fish habitat. Ground water pumpage for irrigation increased by 40 to 50 percent, depending on whether or not the "extra" water was used for irrigation in or near farming region 9. Average flow during the low-flow period increased by 26 cfs in Mill Creek at Walla Walla (assuming that no water is diverted down Yellowhawk Creek) and by 19 cfs in the Walla Walla River near Touchet. This provided the most improvement in fish habitat in the lower Walla Walla River of the measures studied. On-farm returns over variable costs were varied, ranging from the lowest (when the "extra" water passed through the basin) to second highest of the nine measures studied.

Recommendations for Future Assessments

1. A detailed study to measure the following data should be included in future assessments:

   a. Crops, crop acreage, and crop location.

   b. Irrigation pump locations, lifts, discharges, and efficiencies.

   c. On-farm irrigation systems, practices, and efficiencies.

   d. Continuous (analog) records of irrigation district/ditch company diversions, lateral and wasteway flows, and daily farm turnout flows.

e. Stream channel geometry and rating curve data for evaluating fish habitat, and present summer fish populations for all major streams.

f. One-year of continuous (analog) flow data for all major streams in the basin.

g. Spatial distribution of aquifer thickness and hydraulic conductivity.

The greatest challenge to completing this phase of the project was obtaining the necessary data. Land use, water use, and fishery data were especially difficult to obtain. A great deal of time and resources were expended in estimating these data since the quality of the assessment depended on it. The resolution and accuracy of these estimates and, hence, the assessment, were, however, considerably less than if data had been measured directly. The time required to complete the assessment was relatively small once the necessary data were available.

It is therefore recommended that measurement of the above data be a major part of future assessments and that ample time be provided to obtain the required quality and resolution of data.

2. The models developed and used in this study can, in general, be applied to other basins.

   Considerable time and effort will be required, however, to acquire all the data needed to run and calibrate the models. This is especially true for the groundwater model since aquifer data will probably not be as available in other basins as it was in the Walla Walla Basin.

3. The models should be field verified.

   Once calibrated, model predictions should be compared to measured data for at least one independent set (another year) of input data.

4. Several years of data should be used in the assessment (rather than only 1-year as was used in this study).

   Consideration of several years will allow the long-term effects of a water use efficiency measure to be evaluated. It will also make it possible to observe the performance of the measure in extreme as well as "average" years.

5. A local Conservation Plan Formulation Committee should be established early in the assessment and consulted frequently throughout the assessment.

This was done in this study and is highly recommended for future assessments since the local Committee was an absolutely essential element of this study. They supplied the WSU study team with input and advice, acted as a liaison with local groups, and provided "reality checks" (i.e., verified that study data and results were consistent with the Committee's experience and knowledge of the basin). A good relationship with the Committee also facilitates acceptance of assessment results.

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APPENDIX A

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APPENDIX A

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APPENDIX B

Detailed Crop Data for Farming Regions

Table B.1. 1989 Estimated Crop Acreage in Walla Walla Basin by Representative Farm Region.

	BASIN TOTAL	REGION 6	REGION 7	REGION 8	REGION 9	REGION 10
IRRIGATED CROP						
Alfalfa Hay	5,951	N.A.	0	0	17	662
Alfalfa Seed	11,405	N.A.	0	250	0	0
Asparagus	2,134	N.A.	157	180	36	230
Beans	1,572	N.A.	119	150	16	37
Onion	1,651	N.A.	101	0	20	5
Pasture	1,817	N.A.	40	0	0	0
Orchard/Spec.	185	N.A.	0	0	0	0
Potato	611	N.A.	0	0	0	0
Strawberry	58	N.A.	0	0	0	0
Wheat	9,553	N.A.	167	225	24	498
TOTAL	34,937	N.A.	584	805	113	1,432
% Region Irrig.	13%	N.A.	3%	3%	1%	25%
DRYLAND CROP						
ACR	4,669	N.A.	228	1,135	295	209
Barley	3,931	N.A.	336	1,327	283	173
CRP	14,839	N.A.	164	619	6,670	727
Dry Peas	2,875	N.A.	563	313	0	0
Fallow	17,151	N.A.	306	5,021	1,580	1,468
Green Peas	8,059	N.A.	2,693	1,038	99	0
Grass	4,650	N.A.	730	387	0	109
Oats	169	N.A.	0	0	0	0
Wheat	41,493	N.A.	5,190	8,534	2,780	1,593
Dryland Acres	97,836	N.A.	10,208	18,372	11,707	4,280
% Region Dryland	35%	N.A.	48%	80%	91%	74%
Sections Covered	432	N.A.	33	36	20	9
Available Acres	276,480	N.A.	21,120	23,040	12,800	5,760

Data Sources: 1989 Agricultural Crop and Stabilization Service records, Walla Walla District office. Soil Conservation Service, Walla Walla Office.

N.A.: Data Not Available.

NOTE: Region 18 irrigated acres not included in basin total since the irrigation water source is either the basalt aquifer or Columbia River.

Table B.1. (continued) 1989 Estimated Crop Acreage in Walla Walla Basin by Representative Farm Region.

	REGION 6	REGION 7	REGION 8	REGION 9	REGION 10
IRRIGATED CROP					
Alfalfa Hay	175	760	550	1,058	660
Alfalfa Seed	0	610	8,550	642	443
Asparagus	0	105	77	0	0
Beans	0	113	245	312	0
Onion	0	98	140	0	0
Pasture	75	175	225	330	96
Orchard/Spec.	0	0	0	0	0
Potato	0	0	0	611	0
Strawberry	0	0	0	0	0
Wheat	314	976	2.108	1.400	300
TOTAL	564	2,836	11,896	4,352	1,499
% Region Irrig.	22%	55%	62%	38%	47%
DRYLAND CROP					
ACR	81	79	130	85	8
Barley	202	22	143	40	70
CRP	0	143	0	677	0
Dry Peas	0	0	0	127	0
Fallow	772	201	287	470	25
Green Peas	0	0	0	0	0
Grass	40	30	133	96	72
Oats	0	0	0	0	0
Wheat	689	106	111	285	113
Dryland Acres	1,784	582	803	1,779	287
% Region Dryland	70%	11%	4%	15%	9%
Sections Covered	4	8	30	18	5
Available Acres	2,560	5,120	19,200	11,520	3,200

Data Sources: 1989 Agricultural Crop and Stabilization Service records, Walla Walla District office. Soil Conservation Service, Walla Walla Office.

N.A.: Data Not Available.

NOTE: Region 18 irrigated acres not included in basin total since the irrigation water source is either the basalt aquifer or Columbia River.

Table B.1. (continued) 1989 Estimated Crop Acreage in Walla Walla Basin by Representative Farm Region.

	REGION 11	REGION 12	REGION 13	REGION 14	REGION 15
IRRIGATED CROP					
Alfalfa Hay	598	190	996	285	0
Alfalfa Seed	306	108	496	0	0
Asparagus	113	144	856	229	0
Beans	0	53	306	183	36
Onion	30	39	902	316	0
Pasture	251	535	0	42	40
Orchard/Spec.	65	0	63	47	10
Potato	0	0	0	0	0
Strawberry	0	0	0	0	58
Wheat	497	577	2,165	153	130
TOTAL	1,859	1,648	5,785	1,254	274
% Region Irrig.	48%	37%	24%	16%	9%
DRYLAND CROP					
ACR	56	100	402	142	43
Barley	116	258	436	182	17
CRP	0	0	17	2	0
Dry Peas	0	0	0	107	53
Fallow	147	240	1,745	364	97
Green Peas	0	0	76	538	59
Grass	114	622	515	130	107
Oats	0	5	116	0	0
Wheat	465	357	4,227	1,191	399
Dryland Acres	898	1,581	7,533	2,656	774
% Region Dryland	23%	35%	32%	35	24%
Sections Covered	6	7	37	12	5
Available Acres	3,840	4,480	23,680	7,680	3,200

Data Sources: 1989 Agricultural Crop and Stabilization Service records, Walla Walla District office. Soil Conservation Service, Walla Walla Office.

N.A.: Data Not Available.

NOTE: Region 18 irrigated acres not included in basin total since the irrigation water source is either the basalt aquifer or Columbia River.

Table B.1. (continued) 1989 Estimated Crop Acreage in Walla Walla Basin by Representative Farm Region.

IRRIGATED CROP	REGION 16	REGION 17	REGION 18	REGION 19	REGION 20 (Oregon)
Alfalfa Hay	0	0	0	0	N.A.
Alfalfa Seed	0	0	0	0	N.A.
Asparagus	8	0	22	0	N.A.
Beans	0	0	2,256	0	N.A.
Onion	0	0	29	0	N.A.
Pasture	8	0	53	0	N.A.
Orchard/Spec.	0	0	0	0	N.A.
Potato	0	0	844	0	N.A.
Strawberry	0	0	0	0	N.A.
Wheat	20	0	1,133	0	N.A.
TOTAL	36	0	4,337	0	N.A.
% Region Irrig.	.16%	0%	25%	0%	N.A.
DRYLAND CROP					
ACR	846	167	519	26	N.A.
Barley	231	14	83	0	N.A.
CRP	114	0	4,127	1,579	N.A.
Dry Peas	1,104	0	318	0	N.A.
Fallow	750	1,049	2,091	0	N.A.
Green Peas	3,558	0	0	0	N.A.
Grass	895	25	376	184	N.A.
Oats	48	0	0	0	N.A.
Wheat	11,192	1,171	2,625	0	N.A.
Dryland Acres	18,739	2,426	10,138	1,790	N.A.
% Region Dryland	81%	63%	59%	11%	
Sections Covered	36	6	27	25	N.A.
Available Acres	23,040	3,840	17,280	16,000	N.A.

Data Sources: 1989 Agricultural Crop and Stabilization Service records, Walla Walla District office. Soil Conservation Service, Walla Walla Office.

N.A.: Data Not Available.

NOTE: Region 18 irrigated acres not included in basin total since the irrigation water source is either the basalt aquifer or Columbia River.

APPENDIX C

Description of On-Farm Economic Model

APPENDIX C

ECONOMIC MODEL SPECIFICATION AND DATA SOURCES

INTRODUCTION

A linear programming (LP) model was developed to measure the on-farm economic impacts resulting from potential water policy changes for the Walla Walla Basin. Examples of potential modifications to current water policy are changes in the quantity of water allocated to agriculture, reductions in surface diversions, increased on-farm efficiency, the substitution of ground water for surface water in months of low surface water supply, and the development of upstream storage. On-farm economic impacts are measured in terms of changes from the current condition of cropping patterns, water use, crop yields, irrigation systems, irrigation practices and economic returns over variable cost.

The LP model consists of a series of representative farm models for the 20 farming regions within the basin. Cropping pattern, irrigation system, and source of irrigation water were the primary characteristics utilized in identifying individual regions. Each region is represented by one or more farm models that reflect the general farming practices of the region. A broad overview of the modeling mechanics and structure is presented to give a context to the subsequent discussion of the specific modeling assumptions.

MODEL OVERVIEW

Figure C.1 presents a schematic of the data flow and solution procedure used to analyze the on-farm economic impacts resulting from a variety of water conservation policies. As seen in Figure C.1 the basic analytic model consists of four major components. These four components are: (1) a data input template; (2) a matrix generator; (3) an optimization model; and (4) a regional and basin-wide report writer.

Besides prompting the user for hydrologic, agronomic, and budgeting data, the data input template also requests information on irrigation system type and efficiency. Individual irrigation efficiencies may be specified for each crop. For each farm region, hydrologic data is provided for monthly surface diversion, monthly pumping capacity and average pump lift for both the gravel and basalt aquifers.

The required agronomic information consists of selecting up to five irrigated crops in any farm model and specifying their per acre yield. The user must specify the degree to which individual crops may be deficit irrigated, not meeting full ET requirements for a crop, and the per acre crop yield at the maximum moisture deficit. For example, research indicates that irrigating alfalfa to only 90 percent of its maximum consumptive seasonal need (e.g., a 10 percent deficit) reduces alfalfa yield by about 9 percent from its maximum level.

The appropriate monthly consumptive water use requirements for each crop are generated for each irrigated crop in the farm model. A dryland rotation, specified for each farm, is the default rotation when there is insufficient water to meet irrigated crop demands. The farm model also allows the user to specify upper and lower acreage bounds for each irrigated crop.
The following budget data is required by the on-farm model for each irrigated crop: revenue per unit of output and per acre variable production harvest and fertilizer

cost. All budget and revenue data used in this study are reported in Appendices G and H. Information is requested on hourly wage rate of irrigation labor and the kilowatt hour cost irrigation energy. Per acre revenue and variable cost data are also input for the dryland crop rotation.

Five irrigation systems are available to irrigate each crop. These systems are center pivot, solid set, sideroll, handline, and rill. The user is prompted to specify the system used for each irrigated crop and the system irrigation efficiency. The default values for irrigation pump efficiency and irrigation system pressure respectively are 55 percent and 50 pounds per square inch for all non-rill systems. Alternative values for pump efficiency and system pressure may be specified by the user.

A matrix generator provides the link between the input data and the optimization model. For each farm model the matrix generator produces an LP matrix consisting of 410 equations and 313 decision variables. The technical coefficients, resource limitations, and product and input prices determine the specific on-farm scenario to be addressed. The linear programming model determines optimal producer response for each production scenario through an objective function that maximizes net farm returns over variable cost.

A report writer comprising the fourth component of the basic analytic model has four major functions. First, the report writer summarizes the basic economic and hydrologic data generated by the optimization model for each representative farm. Summary reports for selected water policy scenarios and regions are included in Appendices I and J. Second, the report writer aggregates the representative farm output into a tabular format that allows a comparison of impacts of various water policies among farming regions. Third, the report writer totals the individual economic and hydrologic impacts resulting from alternative water policies into an aggregate basin-wide impact. The final function of the report writer is to provide the water use and irrigated acreage data required by the hydrology model. The data set generated for this purpose contains information on monthly applied water by source (stream, irrigation ditch, gravel aquifer, basalt aquifer), monthly irrigation water consumptively used, and irrigated acreage by crop.

REPRESENTATIVE FARM REGIONS

Hydrologic characteristics, irrigation practices, and irrigated crop acreages were used to stratify the basin into 20 relatively homogeneous farm regions. These 20 regions are identified in figure C.2. Lack of irrigated acreage data prevented analyzing the on-farm economic impacts associated with water policy changes for regions 1 and 20. Region 1 consists of land irrigated from the upper Touchet River north of township seven. Region 20 comprises all irrigated acreage on the Oregon side of the Walla Walla Basin, except for those Oregon acres which are part of the Gardena irrigation district. Even though the on-farm economic impacts are not modeled for regions 1 and 20, the water used in these regions is accounted for by the hydrology model and thus directly influences the quantity of irrigation water available for the remaining farm regions.

Irrigation Water

Areas of the basin that receive most surface water through canal delivery were identified as separate farming regions based upon the point of diversion from natural streams. The combination of having crop acreage reported on a section basis and limited time prevented disaggregating data below the sectional level, thus it was impossible to define representative farm regions that exactly follow irrigation district boundaries. These canal dependent farm regions are numbered 7, 8, 11, and 12 in Figure C.2. The East-West Irrigation district is contained in farm region 7. The Gardena Farms irrigation district accounts for nearly 90 percent of the farm acreage in region 8, while the Old Lowden Irrigation District comprises 75 percent of the acreage in farm region 11. Region 12 contains three small irrigation districts; (1) Lowden # 2, (2) the Garden City ditch; and (3) the Bergin-Williams ditch. These three districts contain 72 percent of the acreage in Region 12. It was assumed that a reduction in the allowable surface water diversion uniformly affects all farms within an irrigation district.

Groundwater sources comprise 100% of the irrigation water in regions 3 and 4, and 99% of the irrigation water in region 2. Region 6 is the polar case to regions 2, 3, and 4, being 100% dependent on surface water for irrigation. Regions 5, 9, 10, 13, 14, 15, and 16 have access to both surface and groundwater irrigation diversions. Regions 17 and 19 are 100% dryland. Region 18 has a considerable amount of irrigated agriculture but the source of irrigation water in this region is limited to the deep basalt aquifer and Columbia River. Since neither of these water sources affect, or are effected by surface water flow within the basin study area or gravel aquifer use, region 18 is unaffected by basin water policy and is treated as a dryland region in the analysis. Table C.1 presents a detailed regional breakdown of each source of irrigation water in the Walla Walla Basin.

Average irrigation pump lift and monthly well capacity for both the gravel and basalt aquifers is reported in Table C.2 for each region. Monthly well capacities were estimated from 1989 irrigation power records provided by the Pacific Power and Light Company, and the Columbia Rural Electric Association. For each aquifer in each region the maximum monthly pumping capacity equals the peak monthly usage multiplied by 1.25. The multiplication factor 1.25 accounts for excess pumping capacity in peak use months. The excess capacity was determined to exist after examining monthly power records back to 1985. The hydrology model suggests that both aquifers, especially the gravel aquifer, can sustain this pumpage rate.

Table C.1. 1989 Baseline Water Use by Farm Region and Water Source for the Walla Walla Basin.

	TOTAL STREAM DIVERSION			DITCH DIVERSION		GRAVEL WITHDRAWAL		BASALT WITHDRAWAL	
Region	Diversion	(AC/FT)	(%)	(AC/FT)	(%)	(AC/FT)	(%)	(AC/FT)	(%)
Region 1	4,377	3,666	83.75	0	0.00	0	0.00	711	16.25
Region 2	1,687	16	0.93	0	0.00	253	15.02	1,418	84.05
Region 3	1,988	0	0.00	0	0.00	970	48.80	1,018	51.20
Region 4	335	0	0.00	0	0.00	39	11.77	296	88.23
Region 5	4.835	3,382	49.26	0	0.00	103	2.14	2,350	48.60
Region 6	1,866	1,745	93.47	122	6.53	0	0.00	0	0.00
Region 7	9,210	157	1.70	4,757	51.65	2,029	22.03	2,267	24.62
Region 8	34,272	1,029	3.00	16,930	49.40	16,244	47.40	68	0.20
Region 9	14,484	3,461	23.89	350	2.41	2,260	15.60	8,414	58.09
Region 10	5,314	1,585	29.82	0	0.00	2,259	42.51	1,470	27.67
Region 11	6,906	88	1.28	2,245	32.51	2,743	39.72	1,830	26.50
Region 12	6,339	409	6.45	3,964	62.53	1,287	20.31	679	10.71
Region 13	17,628	1,835	10.41	672	3.81	14,764	83.75	357	2.03
Region 14	4,382	369	8.43	0	0.00	3,109	70.95	904	20.63
Region 15	750	372	49.58	0	0.00	189	25.21	189	25.21
Region 16	103	60	58.61	0	0.00	27	26.12	16	15.27
Region 17	0	0	0.00	0	0.00	0	0.00	0	0.00
Region 18	0	0	0.00	0	0.00	0	0.00	0	0.00
Region 19	0	0	0.00	0	0.00	0	0.00	0	0 00
Region 20	40,138	0	0.00	16,874	42.04	20,219	50.37	3,045	7.59
Basin Total	154,614	17,173	11.11	45,913	29.70	66,496	43.01	25,031	16.19
Study Area	110,099	13,507	12.27	29,039	26.38	46,277	42.03	21,275	10.32

Water use estimated from Pacific Power and Light, and Columbia Rural Electric Association monthly power records on agricultural pumps.

The on-farm study area excludes regions 1 and 20 when estimating economic impact of various water policies since crop acreage data by section was unavailable for these regions. However, the irrigation water used in these two regions is controlled for in both the economic and hydrology models.

Table C.2. Average Pump Lift and Monthly Well Capacity by Farm Region and Aquifer.[1,2]

Region	Gravel Aquifer Pump lift (ft)	Gravel Aquifer Capacity (ac/ft)	Basalt Aquifer Pump lift (ft)	Basalt Aquifer Capacity (ac/ft)
1	none	none	200	225
2	80	92	200	500
3	80	271	300	400
4	110	28	200	85
5	80	33	175	500
6	none	none	none	none
7	50	630	150	486
8	50	4200	280	58
9	50	680	150	2215
10	50	514	150	356
11	50	659	150	409
12	50	388	150	294
13	80	3176	200	101
14	80	910	210	195
15	100	48	300	104
16	75	10	150	6
17	none	none	none	none
18	none	none	none	none
19	none	none	none	none
20	80	4708	220	959

[1]Average regional pump lift calculated by authors from hydrology data and power record data on irrigation pump location.

[2]Regional gravel and basalt well monthly capacity calculated by authors from Pacific Power and Light, and Columbia Rural Electric power records. An average efficiency of 55% was used for all irrigation pumps.

Crop Acreage

According to 1989 Agricultural Stabilization and Conservation Service (ASCS) records, 22 crops are grown in the basin study area. The ASCS data provides crop acreage on a section basis. To make the modeling procedure manageable, these 22 crops were reduced to 10 representative crops. For example, wheat also represents barley and oats. Onion production is used as the proxy for high value vegetable production and beans is the representative crop for low value vegetable crops. Table B.3 contains both the 1989 irrigated acreage figures for the study area, and the proxy crop information. A complete regional breakdown for irrigated and dryland crop acreage is included in Appendix B.

CROP YIELD AND MONTHLY WATER REQUIREMENTS

Crop yield data for the 10 representative crops is reported in Table C.4. Yield information was collected in a series of farmer interviews and from published county statistics. Yields are assumed to be similar in all basin farm regions. However, region specific crop yields can easily be incorporated into the farm models as better data become available in the future.

The monthly net irrigation requirement for each representative crop is reported in Table C.5. Monthly net irrigation requirement is the monthly crop consumptive requirement less effective monthly rainfall. When there is insufficient irrigation water to meet all monthly net irrigation requirements each representative farm has four short-run options for dealing with the water shortage. These four options are: (1) converting the irrigated acreage to less water intensive crops; (2) adopting deficit irrigation practices where feasible; (3) increasing irrigation efficiency through better water management; and (4) converting some irrigated acreage to dryland production.

IRRIGATION SYSTEMS AND PRACTICES

The study area contains nearly 35,000 irrigated acres. Excluding 1,400 acres of flood irrigated pasture, most irrigation in the basin uses side-roll or handline systems. Sprinkler systems were assumed to have an irrigation efficiency of 65 percent and flood irrigation efficiency was judged 45 percent.

Table C.6 contains information on the number of irrigations and primary irrigation system for selected irrigated crops in the study area. The labor requirement for each handline move or rill irrigation is 0.57 hours per set. Each wheel line move requires 0.25 hours of irrigation labor per set.

TABLE C 3. Irrigated crop Acreage and Proxy Crops, Walla Walla Basin Study Area, 1989.

IRRIGATED CROP	ACRES	PROXY CROP	ACRES	PERCENT NON-PROXY
Alfalfa Hay	5,950	Alfalfa Hay	5,950	100.00%
Alfalfa Seed	11,405	Alfalfa Seed	11,401	100.00%
Asparagus	2,134	Asparagus	2,134	100.00%
Beans	1,047	Beans	1,572	66.64%
Dry Peas	80	Beans		
Green Peas	205	Beans		
Corn	207	Beans		
Soybean	12	Beans		
Sweet Corn	21	Beans		
Onion	1,300	Onion	1,651	78.73%
Carrots	64	Onion		
Lettuce	1	Onion		
Radish	6	Onion		
Squash	222	Onion		
Other Crop	60	Onion		
Pasture	1,816	Pasture	1,816	100.00%
Orchard/spec.	212	Apple Orchard	212	100.00%
Potato	611	Potato	611	100.00%
Strawberry	58	Strawberry	58	100.00%
Wheat	9,106	Wheat	9,553	95.32%
Barley	316	Wheat		
Oats	131	Wheat		
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Total Irri. Acres	34,937		34,937	

Data from 1989 ASCS records for the Walla Walla Basin study area.

Table C.4. Yields for Selected Crops in the Walla Walla Basin.

Crop	Unit	Normal Yield
Irrigated Crops:		
Alfalfa Hay	Pound	6.50
Alfalfa Seed	Cwt.	5.75
Apple	Pound	30,000.00
Asparagus	Pound	4,000.00
Dry Beans	Pound	2,200.00
Pasture	Aum	10.00
Potatoes	Cwt.	560.00
Strawberry	Pound	10,000.00
Sweet Onion	Pound	36,000.00
Wheat	Bushel	105.00
Dryland crops:		
Wheat	Bushel	70.00
Peas	Pound	2,200.00

TABLE C.5. Monthly Net Irrigation Requirement for Selected Crops in the Walla Walla Basin (Acre Inches Per Acre).

Month	Alfalfa Hay	Alfalfa Seed	Apple	Asparagus	Dry Beans	Pasture	Potatoes	Straw-berry	Sweet Onion	Winter Wheat
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49
Apr	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.04	0.68	3.68
May	3.50	3.50	4.43	1.10	0.00	4.24	0.71	1.18	4.89	6.01
Jun	6.29	6.29	8.18	2.30	1.49	7.04	3.24	2.86	7.23	6.32
Jul	9.67	4.05	13.01	5.05	9.81	10.35	10.67	2.77	10.75	1.53
Aug	7.39	2.25	10.28	5.46	9.69	8.12	9.53	2.65	7.13	0.58
Sep	4.58	2.25	6.28	3.74	1.54	5.15	5.04	1.48	0.25	0.00
Oct	0.50	0.50	0.91	0.00	0.00	0.99	0.39	0.00	0.00	0.00
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ANNUAL NET IRRIGATION REQUIREMENT	31.93	18.84	43.09	17.95	22.53	35.89	29.58	10.98	30.93	18.61

Source: Department of Agricultural Engineering, Washington State University, Pullman, Washington, 1991.

Table C.6. Number of Irrigations and Primary Irrigation System for Selected Irrigated Crops in the Walla Walla Basin.

Crop	Number Irrigations	Primary System
Alfalfa Hay	5	Sideroll
Alfalfa Seed	2	Handline
Apple[1]	10	Solid Set
Asparagus	4	Sideroll
Dry Beans[2]	10	Handline
Pasture[3]	5	Sideroll
	5	Rill
Potatoes[1]	Continuous	Center Pivot
Strawberry[1]	10	Solid Set
Sweet Onion[1]	13	Handline
Wheat[4]	4	Handline
	4	Sideroll

1 Deficit irrigation is not allowed on these crops because it would be harmful to product quality.

2 Most dry beans are irrigated with handline.

3 About 30% of non-rill irrigated pasture is handline. All model runs assume all sprinkle irrigated pasture is sideroll irrigated.

4 About 30% of all wheat is sideroll irrigated. Model results assume wheat is always under handline system.

Soil Based Water Storage

The lack of a summer surface water right has forced many irrigators in the western end of the basin to adopt the practice of recharging the soil profile in the late fall and winter when surface water is plentiful. This irrigation practice assumes that the soil can be used as a storage reservoir for excess water applied in late fall and winter. Surface water applied in October through April is stored for consumptive use in April through July. The farther into the future the water is transferred the smaller the percentage of recovered stored water. The default water transfer matrix used for the intertemporal water transfers is reported in Table C.7. The data input template allows alternative water transfer coefficients to be specified. The actual percentage of water consumptively used for a specific intertemporal transfer is equal to the transfer coefficient multiplied by irrigation system efficiency.

Table C.7. Intertemporal Surface Water Transfer Coefficients: Percent of Stored Soil Moisture Available For Crop Use.

Month	Month Surface Water Applied						
Used	Oct.	Nov.	Dec.	Jan.	Feb.	March	April
April	0.50	0.60	0.70	0.75	0.80	0.85	1.00
May	0.45	0.50	0.60	0.65	0.70	0.75	0.80
June	0.40	0.45	0.50	0.55	0.60	0.65	0.70
July	0.35	0.35	0.40	0.45	0.50	0.55	0.60

Deficit Irrigation

Deficit irrigation is the practice of not meeting full seasonal consumptive use requirement of crops wherein the crop will suffer some moisture stress and yield loss. The magnitude of the yield depression depends on both the timing and degree of stress imposed. In the LP model the maximum percentage deficit allowed for each crop as a function of full consumptive need is specified. A maximum deficit to 70% of full consumptive need implies the crop can be under irrigated by no more than 30% of consumptive requirement. Furthermore, any single monthly deficit can never exceed the specified maximum deficit even if the seasonal deficit is not exceeded. The LP model also requires the user to specify the percentage of maximum yield realized at the maximum allowable deficit. The maximum allowable irrigation deficit for each crop and associated default yield value are presented in Table C.8.

Table C.8. Maximum Allowable Level of Deficit Irrigation and Yield at the Maximum Allowable Deficit.

Crop	Normal Yield	Maximum Deficit Level % of Crop Requirement	Yield at Maximum % of Normal Yield
Alfalfa Hay (tons)	6.50	70.0%	70.0%
Alfalfa Seed (cwt)	5.75	80.0%	82.0%
Apple (lb)	30000.00	100.0%	100.0%
Asparagus (lb)	4000.00	95.0%	96.0%
Beans (lb)	2200.00	80.0%	82.0%
Pasture (aum)	10.00	70.0%	72.0%
Potatoes (cwt)	560.00	100.0%	100.0%
Strawberry (lb)	10000.00	100.0%	100.0%
Sweet Onion (lb)	36000.00	100.0%	100.0%
Wheat (bu)	105.00	70.0%	80.0%

Note: A maximum deficit of 100% of crop requirement implies no deficit is allowed. That is, crop is irrigated to full consumptive requirement. A maximum deficit of 70% of full crop requirement implies that the crop is under irrigated by 30%.

The default yield values for the deficit models were programmed utilizing information provided by the FAO Irrigation and Drainage Paper No. 33 (Doorenbos and Kassam, 1979). FAO 33 represents the most comprehensive and ambitious effort to quantify the relationship between crop stress and yield. This source is used to calculate crop yield when the deficit is between the maximum allowable deficit and full consumptive crop requirement.

Irrigation system operation and maintenance cost, energy cost, harvest cost, and fertilizer cost can all be less under a deficit irrigation practice. The savings associated with operation, maintenance, and energy costs are directly related to applied water and automatically realized as less irrigation water is applied. Harvest and fertilizer savings are proportionately related to the percentage reduction in yield. For example, if deficit irrigation reduces yield by 10% then harvest and fertilizer costs are reduced by 10%. The data input template allows the user to turn off the fertilizer and/or harvest savings features of the model.

Labor costs increase with the level of deficit irrigation since the farm manager is assumed to manage his scarce water supply by employing more labor. Increased irrigation frequency and shorter sets are utilized to more closely match consumptive requirements to water availability and increase irrigation efficiency. Table C.9 compares the higher efficiency level attained at the maximum allowable irrigation deficit to the baseline efficiency. Efficiency also increases because at deficit irrigation levels less water is lost to runoff and deep percolation.

DRYLAND ROTATION

Given that the various water policy scenarios affect either the cost and/or supply of irrigation water, a dryland rotation was substituted for current irrigated crop acreage when necessary to maximize farm returns over variable costs. For example, a policy which drastically reduces surface water supplies and forces irrigators to substitute groundwater, can increase production costs to the point where it is no longer profitable to produce beans. Thus, the profit maximizing farmer substitutes a profitable dryland rotation for the no longer profitable irrigated crop. A dryland rotation is also substituted for irrigated acreage in the event that a water policy reduces the supply of irrigation water to the point where it is impossible to irrigate all of the baseline acreage. The default dryland rotation is a wheat-pea rotation in the eastern half of the basin (Regions 2, 3, 13, 14, 15, and 16) and a wheat-fallow rotation in the western end of the basin (Regions 4, 5, 6, 7, 8, 9, 10, 11, and 12).

No dryland rotation is substituted for irrigated pasture when it becomes economically unprofitable to produce pasture. Instead, the land simply goes out of production. This modeling assumption is based on the fact that most irrigated pasture is grown on marginal, irregularly shaped fields with little potential to be profitably farmed as dryland acreage. The data input template allows the user to relax this assumption in future scenarios.

PRODUCTION COSTS AND REVENUES

The production cost and revenue data used in this study is contained in Appendices G and H. This analysis is a short-run analysis since the budget data focuses on returns over variable costs. All cost and revenue data are expressed in 1990 dollars. Walla Walla Basin farmers were instrumental in updating the Washington State University Extension budgets utilized in this study. A representative five year average crop price was determined for each crop after expressing 1985 through 1989 crop prices in 1990 dollar values.

MODEL CALIBRATION

Calibrating and interfacing the on-farm economic model with the hydrology model was a two stage process. The first stage consists of the independent development of the hydrology and on-farm economic model. Both models were developed using 1989 data. Monthly power records on agricultural pumps were used to estimate monthly water use for each representative farm region.

The second part of the model calibration process involves matching consumptive crop demand to monthly irrigation water supply for each farm region. Sprinkler systems were estimated to be 65% efficient on average, and rill irrigation 45% efficient on average. Furthermore, all baseline irrigated acreage is assumed to be fully irrigated. Utilizing the irrigation efficiency information and the full irrigation assumption, annual regional consumptive demand can be compared to regional water supply. The first comparison revealed that crop demands equaled water supply on an annual basis in each region. However, monthly supply and demand often were not equal. Monthly electric billing procedures were discovered to be the cause of this data inconsistency. Surface water use as estimated from the monthly power records was redistributed over time to achieve greater consistency with the few metered surface gages in the basin. The groundwater use estimates were also intertemporally shifted (normally a month) so that it is pumped in the month that it is consumptively required. In the redistribution process, the annual supply of each source of irrigation water (stream, ditch, gravel aquifer, basalt aquifer) within each region, remained equal to the stage one estimate.

After completing this two-stage process the independently estimated water supply values were in agreement with each regions consumptive requirement.

ADDITIONAL MODELING FEATURES

The flexibility of the data input format allows many alternative scenarios to be analyzed as additional data becomes available. For example, alternative irrigation efficiencies can be specified for each crop, crop yields can be varied for different basin regions, and irrigation labor requirements can be changed for individual crops. Crop revenue and cost figures can be changed. Specific crops can be forced into the programming solution. Both groundwater and surface water diversions can be controlled for individual farm regions. If more detail is required, additional representative farms can be utilized to further refine individual farm regions.

Table C.9. The Relationship Between Deficit Irrigation and Irrigation Efficiency for Crops in the Walla Walla Basin.

Crop	Irrigation System	Baseline Efficiency	Maximum Deficit Percent[1]	Efficiency at Maximum Deficit
Alfalfa Hay	Handline	65.0%	70.0%	75.0%
Alfalfa Seed	Sideroll	65.0%	80.0%	71.0%
Apple	Solid Set	65.0%	100.0%	65.0%
Asparagus	Sideroll	65.0%	95.0%	67.0%
Beans	Handline	65.0%	80.0%	70.0%
Pasture	Sideroll	65.0%	70.0%	75.0%
	Rill	45.0%	70.0%	58.0%
Potatoes	Center Pivot	65.0%	100.0%	65.0%
Strawberry	Solid Set	65.0%	100.0%	65.0%
Sweet Onion	Handline	65.0%	100.0%	65.0%
Wheat	Handline	65.0%	70.0%	75.0%
	Sideroll	65.0%	70.0%	75.0%

[1]This percentage is the minimum percent of full consumptive requirement which must be met in each month for each crop. ASCS records were consulted in the process of estimating irrigated acreage for each farm region.

APPENDIX D

Description of Hydrologic Model

APPENDIX D

Detailed Description of the Hydrologic Model and its Calibration

The hydrology of the Walla Walla River basin was simulated using two linked computer models: one which modeled the gravel aquifer and another which estimated flow in the streams above the gravel aquifer within the Washington portion of the basin. The gravel aquifer model was a modified version of the mathematical model developed by Barker and MacNish (1976) to estimate water elevations and fluxes within the gravel aquifer that underlies the Walla Walla Valley. The stream flow model was developed as part of this study to estimate flows in the Washington portion of the basin. The linkage and operation of these models will be explained in this chapter.

Gravel Aquifer Model

General Description

The flow of water in an unconfined aquifer with recharge and withdrawals can be predicted by applying the Dupuit assumptions and using the following two dimensional continuity equation:

$$T\left(\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2}\right) = S\,\frac{\partial h}{\partial t} + W(x,y,t) \qquad \text{(D.1)}$$

where
- h = hydraulic head (aquifer water level)
- S = Storage Coefficient
- T = Kh = Transmissivity
- K = hydraulic conductivity
- W = water flow in z direction

The storage coefficient, S, is a function of soil porosity and determines the unit volume of water released from storage in the aquifer for a unit decline of water level. Transmissivity is a function of the hydraulic conductivity, K, and the aquifer thickness. Transmissivity characterizes the capacity of the aquifer to transmit water.

The solution of equation (D.1) using a finite difference approximation written by Barker and MacNish (1976) in FORTRAN IV for the gravel aquifer was updated to a PC and modified slightly to fit the needs of this study. The finite difference solution requires the land over the aquifer to be divided into discrete areas called cells as shown in figure D.1. Cells are identified by their y,x coordinates. There are 47 cells in the y direction and 71 cells in the x direction. Different sized cells were used to save computation time and storage space. The cells were made smaller within the center of the basin where the fluctuations in the water levels are greatest. Cell sizes range from 0.25 sq-mi near the middle of the aquifer to the largest cell of 1 sq-mi at the edge of the aquifer.

The location of different hydrological areas were identified within the cells. The boundary of the gravel aquifer identified within the cells is the shaded area shown in figure D.1. The basin was divided into farm regions of similar hydrology and cropping patterns (see Appendix C). Figure D.2 shows these farm regions in relation to the aquifer cells. Cells which overlay streams were classified as streams. Cells with irrigation ditches in them were located and coded accordingly. This allows inputs and outputs for a particular category to be grouped.

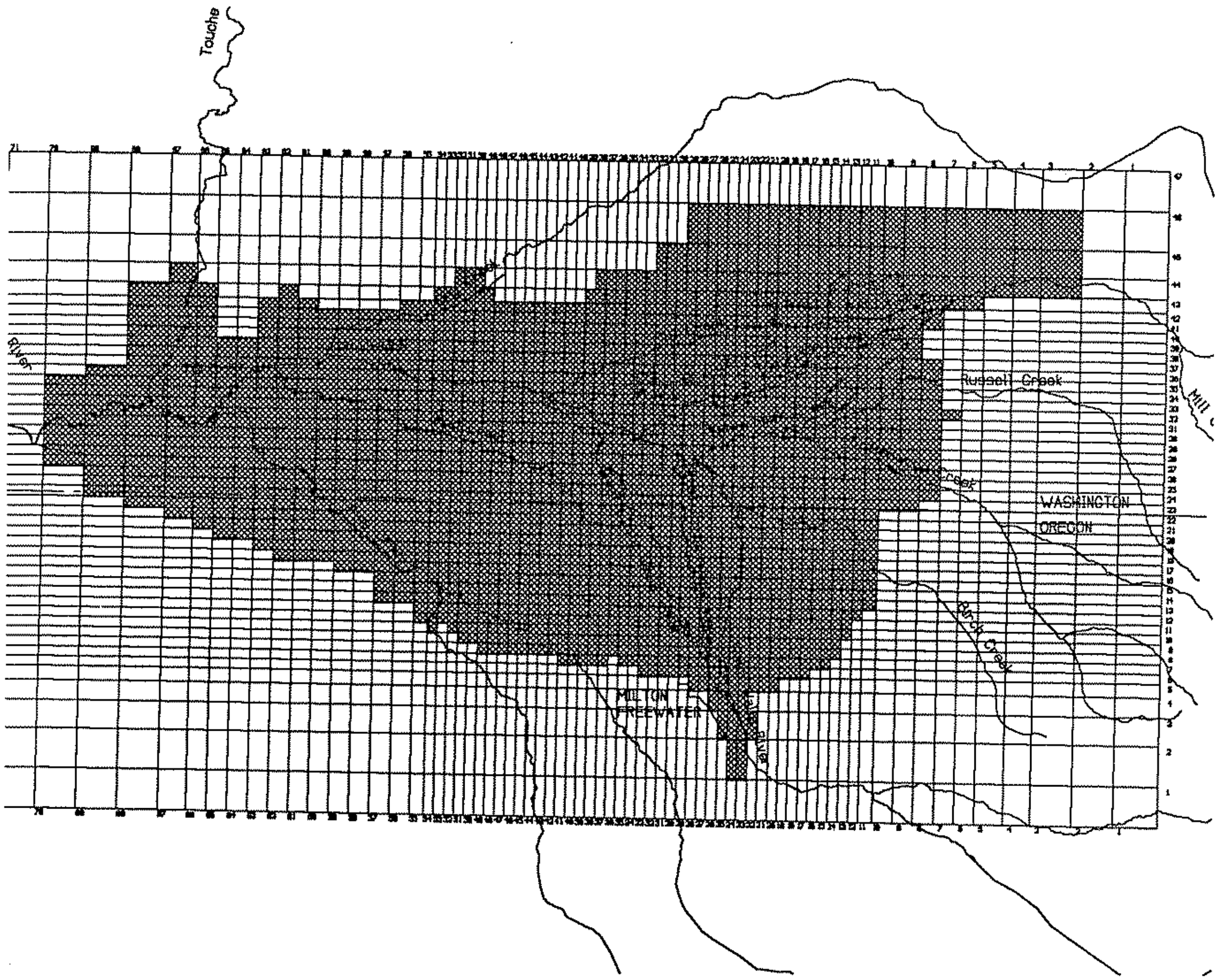

Figure D.1 Grid cells used in Gravel Aquifer Model.

Model Operation

The gravel aquifer model runs in yearly cycles, from one January to the next. The inherent assumption was that the seasonal conditions were exactly reproduced year after year. The year was broken into 119 time-steps. It is important to choose the "right" time-step. Small time-steps increase computer storage requirements and run times, while steps that are too large result in computational errors. Two-day time-steps were used during the months of May-September when the changes in water elevation are the greatest.

Time-steps of five days were used for the remaining months.

A constant head was assumed to exist around the perimeter of the aquifer. This assumption is fairly accurate because the hydraulic conductivity values near the boundary are low. Lower hydraulic conductivity values result in small water level fluctuations.

Estimates of initial water level, transmissivity, storage coefficient and vertical water flows are determined for each cell inside the aquifer boundary area. Monthly estimates of precipitation, irrigation, seepage from irrigation canals, springs, streams and basalt aquifer, pumpage, and consumptive use for each cell were determined as vertical flows to and from the aquifer.

The gravel aquifer model reads the beginning water levels, along with various initial input data about land surface elevation, streambed elevation, spring elevation, hydraulic conductivities, storage coefficients, cell widths, etc. The model then increments through the time-steps computing change in storage, vertical, and lateral flows using the current and the previous time-step water levels. Figure D.3 is a flow chart of the model.

The basic flow and assumptions of the original model were not changed when it was up dated. The input data format was changed to allow individual data for farming regions to be considered. Additional output information was added to accommodate the stream flow model.

The gravel aquifer pumpage was originally read as an annual value for each grid cell. These annual values were then scaled to monthly values by a monthly percentage. Given the monthly pumpage values calculated from power data, the model was changed so that actual monthly pumpage values could be read.

The original model had developed curves for applied irrigation, consumptive use, and ditch use for two areas. The model was changed to make use of such curves for each of the farming regions. These regions are defined in a matrix filled with each regions number. Curves then are read into the model by region number and each curve is used for the grid cell with the corresponding region number. In this way any one region's water use pattern can be changed individually.

The model was also modified to read in a new acreage data set for each cell. This allows acreage in a region to be changed and then to be reduced evenly in each cell. Previously the acreage data was imbedded in a data set with ditch area. The old data set is used for Oregon.

The final modification to the gravel aquifer model was to total and print out the monthly stream and spring fluxes, along with ditch seepage values for the main ditches in the basin. These values are used by the stream flow model.

The gravel aquifer model keeps monthly and running budget totals of the gains and losses to the aquifer. These are printed at the end of every month. At the end of a year the model computes the difference between the input water elevations and the final water elevations and outputs these differences.

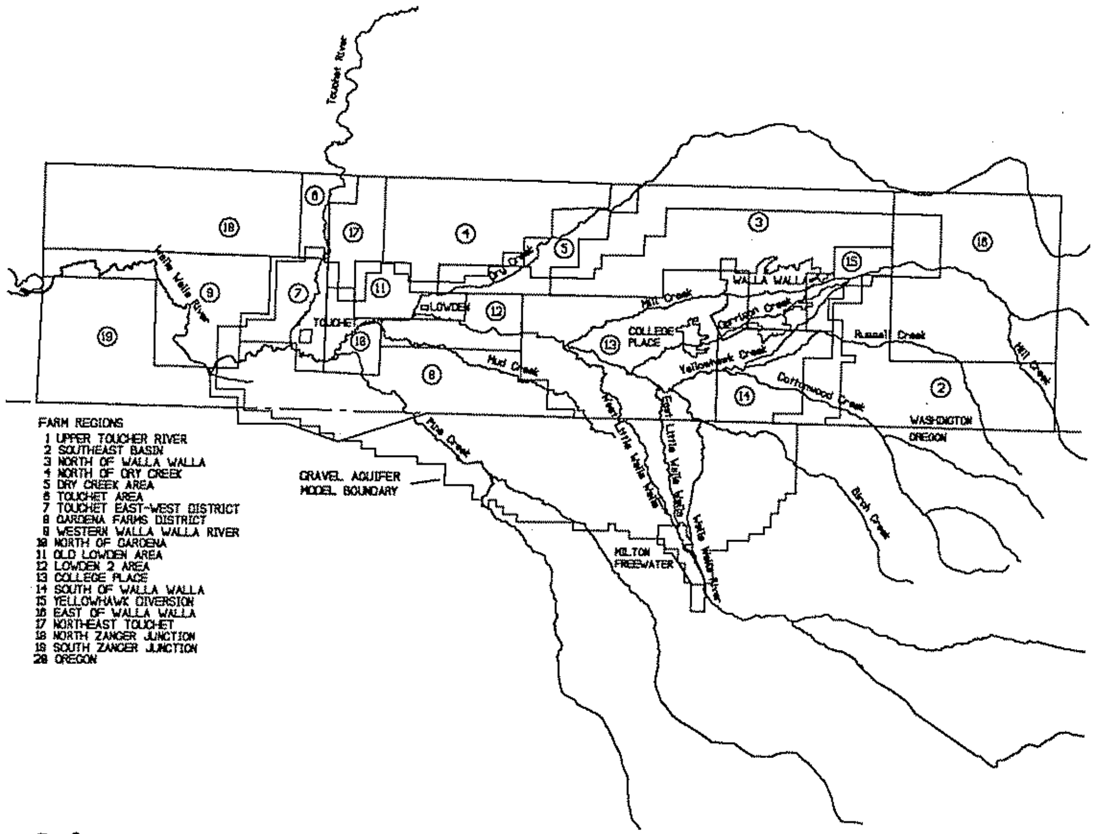

Figure D.2 Farm regions in relation of the gravel aquifer boundary area used in the gravel aquifer.

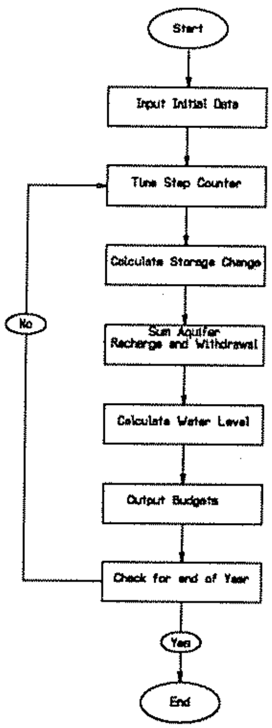

Figure D.3 Flow chart for gravel aquifer model.

Calibrated Input Data

Water Levels

Well logs obtained from the Department of Ecology, for wells drilled between 1987-1990, were used to verify the beginning elevation of the water table used in the model. The elevations of the ground water were determined from a given water depth from the well log, subtracted from the land elevation read from USGS 7½' quadrangle maps. The accuracy of this method is ±10 feet. The current elevations were plotted against the initial starting elevations used by the gravel aquifer model. No change in elevation was seen between the two, so the existing data were used in the model.

Hydraulic Conductivity and Storage Coefficient

The values of hydraulic conductivity and storage coefficient from Barker and MacNish (1976) were used without modification in this study. The values for hydraulic conductivity were originally obtained from well tests at various points and extrapolated to the remaining cells. The final calibrated values used in the model were obtained by trial-and-error testing to obtain the best results. Storage coefficients were taken from reported values of similar soil types as found in the gravel aquifer. A calibrated set of storage coefficients was determined from trial simulations.

Precipitation

The amount of precipitation in each cell is determined from an equation relating rainfall to elevation. Annual rainfall from measuring stations in and around the Walla Walla basin for 1989 were plotted against the elevation of the gage as shown in figure D.4. The monthly percent of rainfall for Walla Walla FAA is shown in figure D.5. Based on this data, the monthly average rainfall at any elevation is determined using the following equation:

$$R_m = (8.18 + (E-300)0.012304)P_m \qquad (D.2)$$

where
R_m = monthly rainfall (in)
E = average elevation (ft)
P_m = monthly percent of annual rainfall at Walla Walla FAA gage (see Figure D.5)

Irrigation

Estimates of the amount of water used for irrigation were determined from 1989 electricity used for irrigation pumping. Only one year of record was used due to the time required to enter the information into the computer. Power data was used to estimate water use because farm deliveries are not measured. In the basin, the number of ditch irrigated land was 1400 acres out of the total

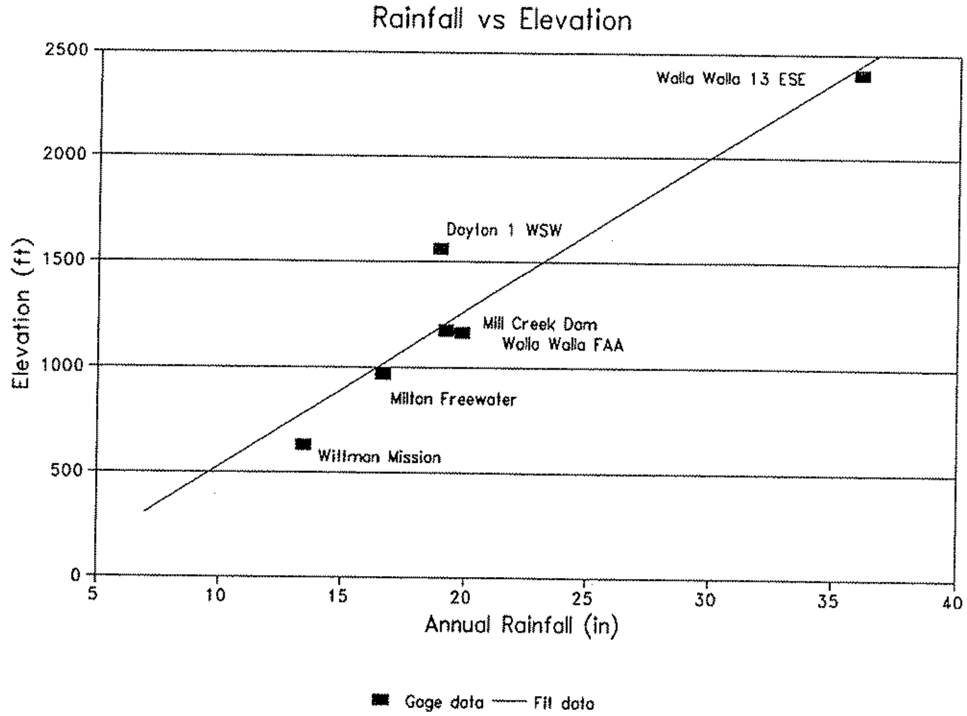

Figure D.4 Annual rainfall in the Walla Walla basin related to elevation, as estimated from gaged rain data for 1989.

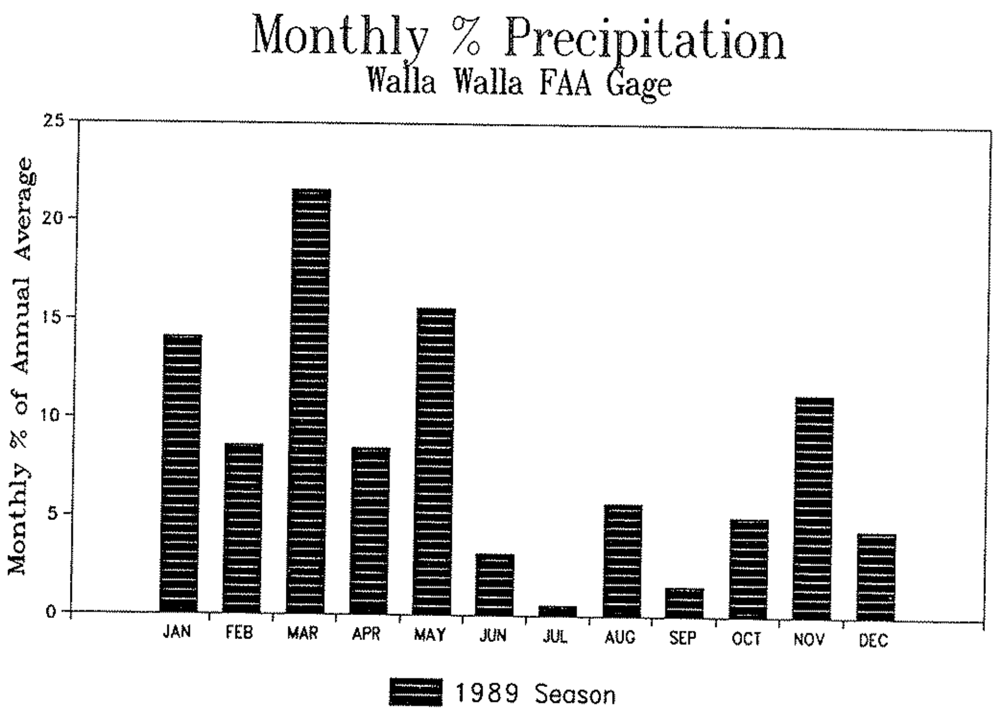

Figure D.5 Percent of total annual rainfall that occurs in each month. These percentages are based on the Walla Walla FAA gage for 1989.

34,836 acres, thus 96% of the irrigation land is under sprinklers. The monthly volume of water pumped is given as follows:

$$V = \frac{Ee_p}{kH_t} \qquad (D.3)$$

where V = monthly volume pumped (ac-ft)
E = monthly energy used (kw-hr)
e_p = average basin pumping efficiency(decimal)
k = conversion constant=1.022
H_t = total head= pump lift + operating pressure (ft)

Monthly pump energy use data were provided by two local power companies, with a total of 1759 pumps located in the Walla Walla River basin. This included pumps located in Oregon. Estimates of pump efficiency, pump lift, and operating pressure were made along with the source of water for each pump. These estimates of water use were not ground truthed due to time constraints on the project.

An estimate of basin wide pump efficiency was determined from pump test information collected by Henderson (1981). These included over 100 pump tests conducted throughout the Walla Walla basin during the early 1980's. Based on this information, figure D.6, relating input energy to output energy was developed. The slope of the regression line fit to the pump test data represents the average efficiency of pumps in the basin. An average pump efficiency was rounded to 60% and used through out the model for each pump.

Based on information provided by farmers in the basin an average irrigation system operating pressure of 50 psi was used in the model.

The least accurate and most difficult data to obtain or estimate for each pump was its source of water and its lift. There are four possible water sources: 1) stream; 2) ditch; 3) gravel aquifer; and 4) basalt aquifer. The process by which each pump's source of water was determined was first based on known sources and second by location and pump size. To show the location of each pump in the basin, the pump site locations were digitized using USGS 1:24000 scale maps according to the location provided by the power companies. The data set provided by Columbia REA included the location of pumps to the nearest quarter section. The larger data set provided by Pacific Power and Light (PPL) described the location of each pump to within a tenth of a section.

The data provided by the Columbia REA power company, which included 259 pumps, listed the water source, either ditch or well, for each pump. Those which were well-pumps were assumed to take water from the gravel aquifer if they were located over the gravel aquifer area. Those pumps outside of this area were assumed to take water from the basalt aquifer. The exception to this were pumps of 65 hp or greater. These pumps were assumed to take water from the basalt aquifer, unless otherwise known.

The data from PPL, which included most of the pumps, did not identify each pumps water source. The following methods were used to assign a water source to each pump. First, a listing provided by the USGS of the well pumps used in the 1970's gravel aquifer model was matched to the current data set. The matched pumps included an estimate of the pump lift during the 1970's. Second, an effort was made to match water rights, which identify source of water by stream or ground water, to the power data. A problem in using water rights to classify pumps is that the water right only describes the point of diversion, but this may not be the point at which the water is pumped. This is the case where water is diverted down a ditch from the point of diversion, and then is pumped from the ditch at a different location. The location of the pump does not correspond with the water right point of diversion in this case. It was assumed, however, that a pump would be located at or near the point of diversion for which the well right was granted. The ground water is not distinguished between gravel and basalt aquifer though. The remaining pumps were identified based on their location and the size of the pump. After the above steps had been performed, ditch riders of the two largest ditches, Touchet East-West ditch and Gardena Farms ditch, located the pumps which take water from their ditches. Other pumps near these ditches were then assumed to use ground water.

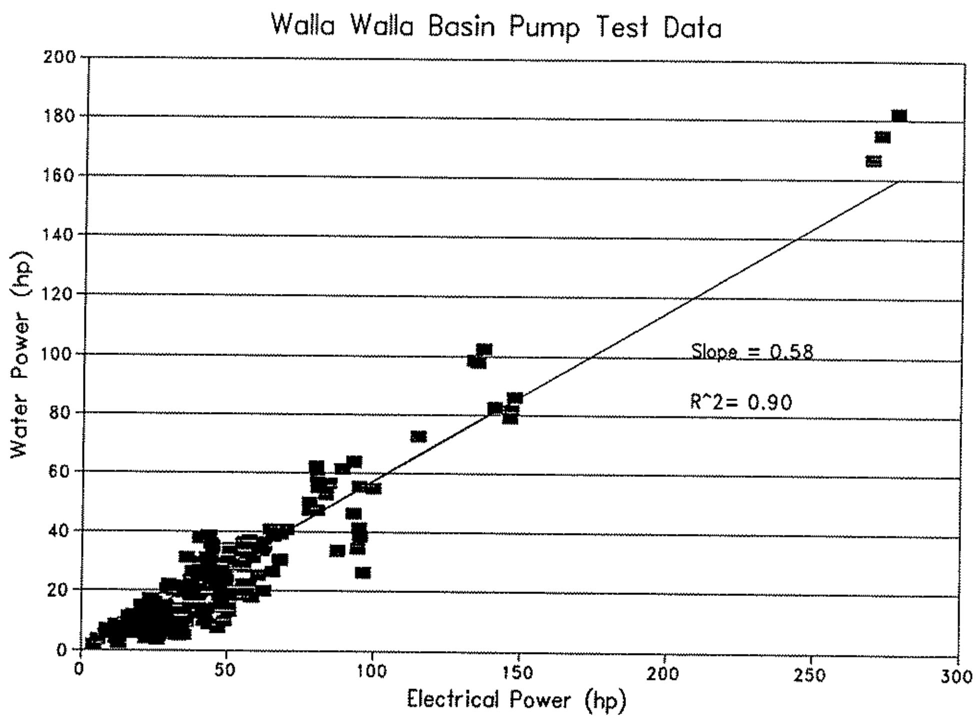

Figure D.6 Pump test data for the Walla Walla basin used to determine a basin average pump efficiency. An efficiency of 60% was used based on the slope of output power to input power.

The lift of pumps taking water from streams and ditches was assumed to be five feet. For those pumps which were within a half mile of a pump that was matched to a 1970's pump, the old pump lift was used or an average of the surrounding pumps when there was more than one. Lifts for other pumps were estimated from gravel aquifer thickness and bottom elevation in the cell where the pump was located. If a pump's source was from the gravel aquifer, a lift of 75% of the aquifer depth from the ground surface in that area was used. For a basalt pump, a lift equal to the depth to the bottom of the gravel aquifer from the land surface was used.

Table D.1 shows the calibrated data developed for each farm region.

The irrigation depth applied in each farm region was then determined from the monthly volume of water used per the number of acres served. The number of irrigated acres in each farm region are given in Appendix B. Table D.2 shows the irrigation depth and irrigated acres in each farm region. Acreage data was not available for farm regions 1 and 20.

Canal Seepage

The main ditches in the basin were mapped by Walla Walla Community College (1990). This data and information in the 1970 gravel aquifer model data set, indicated that the ditches currently used had not changed from the previous study. Thus data of ditch area from Barker and MacNish (1976) were used in this study.

TABLE D.1 Calibrated irrigation water applied in acre-feet by farm region, estimated from power data.

FARM REGION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1 Upper Touchet River	99	100	213	542	717	962	857	802	558	165	100	99	5212
2 Southeast	0	0	11	94	236	334	476	404	129	5	0	0	1687
3 North of Walla Walla	0	0	14	113	311	466	479	401	188	16	0	0	1988
4 North of Dry Creek	0	0	2	14	44	65	97	81	31	1	0	0	3865
5 Dry Creek Area	0	0	279	687	717	840	761	759	507	289	0	0	4835
6 Touchet Area	0	0	62	354	280	355	378	267	152	18	0	0	1866
7 Touchet East-West District	0	0	61	856	1500	1589	1656	1332	767	938	457	55	9211
8 Gardena Farms District	0	0	132	5105	4790	6546	5546	3954	3091	1693	2987	429	34272
9 Western Walla Walla River	0	0	679	483	1856	3114	3268	2749	1477	741	119	0	14485
10 North of Gardena	0	0	218	554	778	1008	934	875	579	339	30	0	5315
11 Old Lowden Area	1	0	193	517	1024	1387	1369	1182	753	231	209	22	6886
12 Lowden 2 Area	0	0	542	877	830	817	1184	987	600	317	184	0	16963
13 College Place Area	1	0	27	339	525	818	1150	1048	387	31	5	0	4329
14 South of Walla Walla	0	0	27	339	525	818	1150	1048	387	31	5	0	4329
15 Yellowhawk Diversion	4	2	60	13	154	191	162	143	74	15	0	0	818
16 East of Walla Walla	0	0	1	10	21	26	20	15	9	1	0	0	104
17 North East Touchet	0	0	0	0	0	0	0	0	0	0	0	0	0
18 North Zanger Junction	0	0	0	0	0	0	0	0	0	0	0	0	0
19 South Zanger Junction	0	0	0	0	0	0	0	0	0	0	0	0	0
20 Oregon	583	957	3265	5063	5438	6826	7176	4777	5297	3504	815	567	44268

To estimate the amount of seepage from ditches, the following equation was used:

$$Q_m = KAP_m \qquad (D.4)$$

where Q_m = monthly seepage rate (cfs)
K = ditch seepage rate(ft/sec)
A = ditch area (ft^2)
P_m = monthly percentage of maximum ditch usage (for month of maximum usage P_m=1)

Table D.2 Calibrated irrigation depth and acres irrigated by farm region.

FARM REGION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL ANNUAL	ACRES
1 Upper Touchet River	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2 Southeast Basin	0.0	0.0	0.2	1.7	4.6	6.9	7.1	6.0	2.8	0.2	0.0	0.0	29.5	809
3 North of Walla Walla	0.0	0.0	0.2	1.7	4.6	6.9	7.1	6.0	2.8	0.2	0.0	0.0	29.5	809
4 North of Dry Creek	0.0	0.0	0.2	1.5	4.7	6.9	10.3	8.6	3.3	0.1	0.0	0.0	35.6	113
5 Dry Creek Area	0.0	0.0	2.3	5.7	6.0	7.0	6.4	6.4	4.2	2.4	0.0	0.0	40.4	1436
6 Touchet Area	0.0	0.0	1.3	7.5	6.0	7.6	8.0	5.7	3.2	0.4	0.0	0.0	39.7	564
7 Touchet East-West District	0.0	0.0	0.3	3.8	6.6	7.0	7.3	5.8	3.4	4.1	2.0	0.2	40.5	2729
8 Gardena Farms District	0.0	0.0	0.1	5.1	4.8	6.6	5.6	4.0	3.1	1.7	3.0	0.4	34.4	11955
9 Western Walla River	0.0	0.0	1.9	1.3	5.1	8.6	9.0	7.6	4.1	2.0	0.3	0.0	39.9	4356
10 North of Gardena	0.0	0.0	1.7	4.4	6.2	8.1	7.5	7.0	4.6	2.7	0.2	0.0	42.4	1504
11 Old Lowden Area	0.0	0.0	1.3	3.4	6.7	0.1	9.0	7.8	5.0	1.5	1.4	0.1	45.3	1824
12 Lowden 2 Area	0.0	0.0	4.1	6.7	6.3	6.2	9.0	7.5	4.6	2.4	1.4	0.0	48.2	1578
13 College Place Area	0.0	0.0	0.3	4.9	5.8	7.3	7.5	6.2	2.8	0.2	0.0	0.0	41.3	1258
15 Yellowhawk Diversion	0.2	0.1	2.6	0.6	6.7	8.4	7.1	6.3	3.2	0.7	0.0	0.0	35.9	273
16 East of Walla Walla	0.0	0.0	0.4	3.3	7.0	8.7	6.6	5.1	3.1	0.4	0.0	0.0	34.6	36
17 Northeast Touchet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
18 North Zanger Junction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
19 South Zanger Junction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
20 Oregon	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Seepage rates are estimated to be a maximum of 1.55x10-5 ft/s, during spring flows before a layer of silt has sealed the ditch bottom. Tests conducted on ditches in Oregon produced an average seepage rate for ditches with a silt layer of 2.0x10-6 ft/s (Barker and MacNish 1976). This value was used in calibration runs of the model.

The monthly percentages of maximum ditch usage were determined from the power data estimates of ditch water use, by dividing each month by the maximum monthly water use. The monthly percentages of maximum ditch usage are shown in Table D.3 for farming regions with ditches.

Table D.3 Monthly percentages of maximum ditch usage based on power record data.

FARM REGION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
7 Touchet East-West District	0	0	0	0.6	0.8	0.5	0.5	0.4	0.6	1	0.5	0.1
8 Gardena Farms District	0	0	0	1	0.6	0.4	0.2	0.1	0.1	0.3	0.6	0.1
11 Old Lowden Area	0	0	0.4	1	0.7	0.7	0.7	0.3	0.3	0.5	0.5	0
12 Lowden 2 Area	0	0	0.5	1	1	0.6	0.6	0.4	0.3	0.3	0.2	0
13 College Place Area	0	0	0.2	0.4	1	0.7	0.7	0.6	0.5	0.4	0	0

Verifying the current status of ditch water use in Oregon was beyond the scope of this project. Therefore monthly percentages of maximum ditch use for the Oregon portion of the basin were unchanged from the original model.

Stream and Spring Seepage

The following form of Darcy's Law was used to estimate seepage from streams and springs:

$$Q_s = KA\frac{(h_s - h_a)}{m} \qquad (D.5)$$

where Q_s = stream or spring flow rate (cfs)
h_s = streambed or spring outlet elevation (ft)
h_a = aquifer elevation (ft)
m = thickness of streambed or spring (ft)
K = hydraulic conductivity of streambed or spring (ft/sec)
A = area of streambed or spring (ft2).

To estimate the amount of seepage from ditches, the following equation was used:

$$Q_m = KAP_m \qquad (D.4)$$

where Q_m = monthly seepage rate (cfs)
K = ditch seepage rate(ft/sec)
A = ditch area (ft^2)
P_m = monthly percentage of maximum ditch usage (for month of maximum usage P_m=1)

Stream Seepage

Recharge water from perennial streams was modeled using the following rules: 1) perennial stream reaches above an elevation of 850 feet lose water to the aquifer year round; 2) stream reaches below an elevation of 750 feet gain water from the aquifer year round; and 3) stream reaches between 750 and 850 may lose or gain water depending on the water table level below the streambed.

The elevation of stream reaches was estimated from quadrangle maps. The actual streambed elevation is not known, but the difference between water surface elevation and streambed elevation is generally one foot or less.

Streambed thickness was assumed to be one foot for all reaches.

A conductivity value of 1.55x10-5 ft/sec was used for all stream reaches. This is an average value of published data for streambed conductivities (Reid and Dreiss 1989).

The values of stream channel area were originally taken from aerial photos and topographic maps. Values were adjusted during calibration to reflect the observed water levels. The value of streambed conductivity most likely is not a constant for all reaches of the river. By changing the stream channel area parameter the effects of different streambed conductivities could be compensated for to match known water levels.

Spring Seepage

The amount of water discharged through springs in the basin is assumed to be the same as in the past at 50,000 to 60,000 ac-ft annually (Barker and MacNish 1976). No attempt in the current study was made to verify these numbers.

The value of the constant $\frac{KA}{m}$ for springs was derived by trial-and-error simulation.

Basalt Aquifer Seepage

The amount and distribution of the steady-state vertical seepage between the gravel and basalt aquifer systems were simulated by the digital model of the basalt aquifer (MacNish and Barker, 1976). The output from the basalt aquifer model was used as input to the gravel aquifer model.

Consumptive Use

Consumptive use was determined with the following Doorenbos and Pruitt Blaney-Criddle equation:

$$CU_m = K_c ET_o \qquad \text{(D.6)}$$

$$ET_o = \left[\frac{Na}{25.4} + \frac{bTp}{100}\right] \qquad \text{(D.7)}$$

where CU_m = monthly consumptive use (in)
K_c = crop coefficient
ET_o = Evapotranspiration
N = number of days in month
a,b = Factors which depend on long term average minimum relative humidities, daytime wind speeds, and ratios between actual measured sunshine hours and maximum possible sunshine hours.
T = average air temperature for month (°F)
p = percent of annual daytime hours during the month.

The values of K_c, a, b, p are taken from James et al (1982). The average air temperature was taken from measurements published by the National Weather Service for 1989. These values are shown in Table D.4.

Regional estimates of consumptive use were totaled based on the crop mix in the region. The farm region monthly and annual totals are shown in Table D.5.

Baseline Results

Using the data for vertical flow into and out of the aquifer, the model was used to determine the effects on water elevations and provide a budget of water flow for the gravel aquifer. Table D.6 shows the budget totals output, at the end of one year run, by the model using this baseline data.

Stream Flow Model

General Description

Flow in a small reach of a stream is expressed using the following continuity equation:

$$Q_o = Q_i - I \pm Sr + Sp + R \qquad (D.8)$$

where Q_o = Flow out of reach
Q_i = Flow into reach
I = Irrigation from reach
Sr = Stream seepage gain or loss in reach
Sp = Spring seepage gain to reach
R = return flow to reach.

Table D.4 Values used to estimate ET_o for 1989.

Month	a	b	N	p (%)	Temp (F)	ET_o (in)
JAN	-1.33	0.74	31.00	6.33	36.90	0.11
FEB	-1.49	0.90	28.00	6.50	24.10	0.00
MAR	-1.71	1.15	31.00	8.28	41.60	1.87
APR	-1.88	1.33	30.00	9.11	54.00	4.32
MAY	-1.92	1.36	31.00	10.38	57.80	5.82
JUNE	-1.98	1.40	30.00	10.53	68.10	7.70
JULY	-2.17	1.65	31.00	10.65	73.30	10.23
AUG	-2.12	1.56	31.00	9.79	71.20	8.29
SEPT	-2.01	1.45	30.00	8.43	66.20	5.72
OCT	-1.77	1.13	31.00	7.58	53.80	2.45
NOV	-1.41	0.77	30.00	6.37	45.30	0.56
DEC	-1.26	0.60	31.00	6.05	33.90	0.00
ANNUAL						47.06

Table D.5 Consumptive use requirement for each farm region based on the calibrated crop mix using Blaney Criddle method.

CONSUMPTIVE USE (in)

FARM REGION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1 Upper Touchet River	-	-	-	-	-	-	-	-	-	-	-	-	0
2 Southeast Basin	0	0	0.4	1.9	3.9	5.1	6.7	6	2.3	0.4	0	0	26.7
3 North of Walla Walla	0	0.1	0.6	1.7	3.7	5.1	4.9	4.4	2.3	0.6	0.1	0	23.5
4 North of Dry Creek	0	0	0.3	1.6	3.8	5.2	7	6.2	2.7	0.4	0	0	27.2
5 Dry Creek Area	0	0	0.5	1.8	4.8	6.2	6.4	4.9	3.3	0.9	0	0	28.8
6 Touchet Area	0	0	0.8	2.6	5.9	7.1	5.5	4.3	2.7	1.1	0	0	30
7 Touchet East-West District	0	0.1	0.6	1.9	5.1	6.6	5.7	4.3	2.6	0.9	0	0	27.8
8 Gardena Farms District	0	0.2	0.6	1.3	4.6	6.7	4.4	3	2.4	1	0.2	0	24.4
9 Western Walla Walla River	0	0	0.5	1.6	4.5	6.2	6.7	5.5	3.2	1	0	0	29.2
10 North of Gardena	0	0.1	0.4	1.1	4.9	6.9	6.7	5.1	3.5	1.1	0.1	0	29.9
11 Old Lowden Area	0	0	0.5	1.5	5	6.9	6.7	5.2	3.5	1.1	0	0	30.4
12 Lowden 2 Area	0	0	0.5	1.9	5.2	6.7	6.4	4.9	3.2	1.1	0	0	29.9
13 College Place Area	0	0	0.6	2.2	5	6.3	6	4.8	2.3	0.7	0	0	27.9
14 South of Walla Walla	0	0	0.2	1.2	4	5.9	8.6	7.2	3	0.5	0	0	30.6
15 Yellowhawk Diversion	0	0	0.7	2.5	4.8	5.9	4.9	4.3	2.1	0.7	0	0	25.9
16 East of Walla Walla	0	0	0.8	2.8	5.5	6.3	4.6	3.9	2.5	0.9	0	0	27.3
17 Northeast Touchet	0	0	0	0	0	0	0	0	0	0	0	0	0
18 North Zanger Junction	0	0	0	0	0	0	0	0	0	0	0	0	0
19 South Zanger Junction	0	0	0	0	0	0	0	0	0	0	0	0	0
20 Oregon	-	-	-	-	-	-	-	-	-	-	-	-	-

Table D.6 Baseline annual gravel aquifer water budget data.

Outflows from Gravel Aquifer (af-ft)			Inflows to Gravel Aquifer (ac-ft)					
Irrication Pumpage	Evapo-trans-piration	Discharge of springs	Irrigation Precip Recharge	Canal Seepage	GW Flow into Streams	From Gravel Aquifer	Basalt System	Change in Gravel Aquifer Storage
60379	7190	48134	17042	4453	43378	14416	10356	26076

There is assumed to be no storage in the stream reach.

A stream flow model was developed using equation (D8) for the Washington side of the Walla Walla River basin. Permanent streams were divided into reaches according to the gravel aquifer cell system. The permanent streams include the Walla Walla River, Touchet River, Mill Creek, Yellowhawk Creek, and Garrison Creek. Major ditch diversion points, irrigation pumps, inflow locations from non permanent streams, and return flow points were identified along these streams. The input stream flows are based on USGS continuous and partial gaging stations. The location of these points are shown in figure D.7. Stream and spring seepage were determined for the cells from the gravel aquifer model.

Model Operation

The flow chart in figure D.8 illustrates how the stream flow model operates. Input monthly average flows for the permanent and annual streams are read into the model. Then the model reads estimated water use for irrigation from each ditch for the baseline and the current scenario. Ditch diversions are estimated based on ditch irrigation flows, seepage losses and return flows. The difference between the baseline and scenario ditch diversion flows, called "saved" flows, are added back to the designated stream reach. In the case of

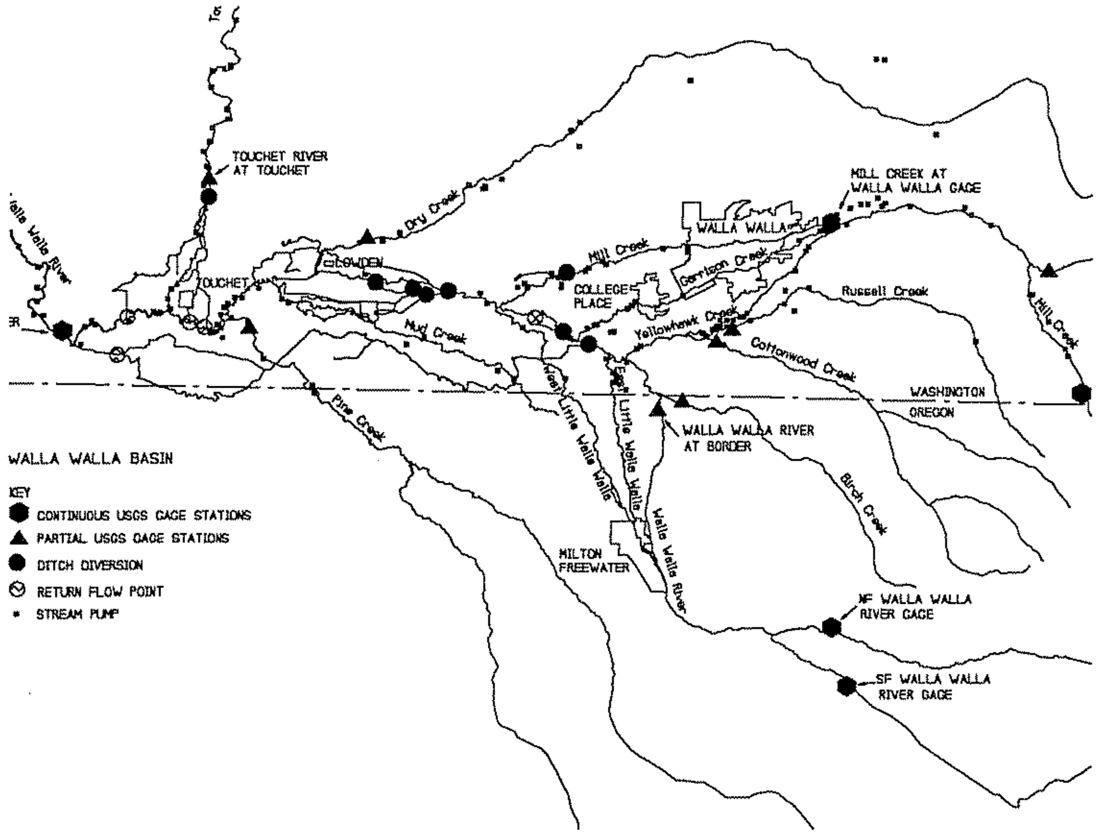

Figure D.7 Diversion, stream inflow, return flow, and stream pump locations.

Gardena Farms, this saved flow maybe subtracted from the Yellowhawk diversion, if it is less than 27 cfs, and left in Mill Creek.

The model then begins a monthly time-step, where it reads the stream flux, spring seepage, and stream pump diversions for each reach. Using the initial stream inflows, water is tracked along the following path:

- Mill Creek from Kooskooskie to diversion with Yellowhawk-Garrison Creek;
- Yellowhawk Creek from Mill Creek Diversion to Walla Walla River;
- Garrison Creek from Yellowhawk Diversion to Walla Walla River;
- Mill Creek from Yellowhawk-Garrison Creek Diversion to Walla Walla River;
- Walla Walla River from Oregon border to Touchet River;
- Touchet River from north of Touchet East-West Diversion to Walla Walla River;

- Walla Walla River from Touchet River to USGS Gage, Walla Walla near Touchet (this corresponds to western edge of gravel aquifer grid cells).

Hydrographs for various points are possible with the model. Currently the model outputs monthly flow data at two gage sites: Walla Walla River near Touchet and Mill Creek at Walla Walla. Data from USGS measurements and the estimated model monthly flows are both output for these gage sites.

<u>Calibrated Input Data</u>

Input Stream Flows

Input stream flows were based on USGS gaged stream data. Continuous gage site data for the calendar year 1989 were used for calibration, input flows and estimating 1989 flows for smaller streams.

Partial gage sites are places were a stream was measured once per day every third or fourth month out of the year. Flow data for these partial gage sites were plotted against the flow data, measured for the same day, from the continuous gage sites and relationships between them developed. These relationships were used to estimate the flow at the partial gage site for 1989 from 1989 continuous gage site data. The monthly average flows at these different locations are shown in Table D.7.

The amount of water that is diverted down Yellowhawk-Garrison Creeks is not accurately known. However, it is known that the maximum amount which can be diverted without negative effects is 35 cfs, of which 8 cfs is used in down

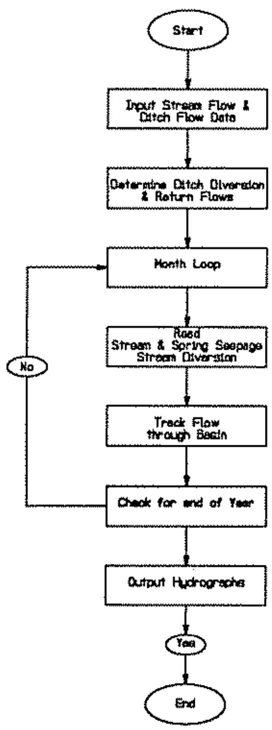

Figure D.8 Flow chart of stream flow model.

Table D.7 Stream flows used in the flow model.

CREEK	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Kooskooskie	139	82.5	241	220	128	65.2	31.4	30	28.9	30.5	37.8	77.3
Blue	49	25	74.9	54.3	20.9	4.2	0	0	0	0	0	1.8
Mill at Walla Walla	221	121	329	243	104	34.3	7.3	7.6	5.3	1	0.9	24.2
Northfork	50.3	34.9	120	162	93.6	32.5	8	6.4	4.9	5.7	10.1	14.5
Southfork	137	109	228	332	292	169	105	94.6	83.2	76.8	96.6	100
Tcht nr Tcht	368	288	595	461	239	122	30.8	25.6	25.4	36.3	57	120
W2Near	998	795	1729	1291	615	193	17.6	16.9	10.7	21.1	82.2	257
Russell	1.9	0.9	6.5	9.2	4.7	0.7	0	0	0	0	0	0
Birch	1.2	0.9	2.5	3.2	2	0.9	0.4	0.4	0.4	0.4	0.5	0.5
Cottonwood	15.3	9.5	41.4	57.2	31.5	8.6	0	0	0	0	0.2	1.9
W2Border	137.6	88.4	360.4	494.7	276	80.7	2.4	0	0	0	9.1	23.2
Dry	18.5	12.4	46.1	62.8	35.6	11.4	1.7	1.1	0.5	0.3	2.5	4.3
Pine	57.2	27.1	111.7	100.5	51.3	17.8	0	0	0	0	3.2	15.4
Yelgar	35	35	35	35	35	35	35	35	35	35	35	35

Yellowhawk and Garrison Creeks. Therefore the initial assumption was Garrison Creek. Also it is a general rule that all of Mill Creek is diverted that 35 cfs was diverted from Mill Creek, if the flows in Mill Creek were greater than 35 cfs, otherwise all the water in Mill Creek was diverted.

Ditch Diversions and Return Flows

The available ditch inflow weir measurements were used to calibrate estimated ditch diversions and return flows. Weir data obtained from the Ecology water master was used to develop average hydrographs for the smaller ditches; Smith, Bergevin-Williams, Old Lowden, Lowden 2, and Garden City. This data consisted of spot weir measurements from 1987-1990. The two larger ditches, Touchet East-West and Gardena Farms Districts, take frequent weir measurements. The Touchet East-West ditch has a chart recorder to measure elevation of water at its double weir measurement station. The Gardena Farms ditch has the intake weir measured twice daily by a ditch rider. The 1989 weir measurements for these two ditches were used for calibration.

Four ditches were determined to have significant return flow back to the river; Gardena Farms, Touchet East-West, Smith, and Bergevin-Williams ditch. No measurements of return flow are made for any of the ditches, so return flows had to be estimated by comparing the estimated irrigation water use plus ditch seepage, to weir inflow measurements. These return flow estimates were reduced in those cases were the flow was higher than what was known to be the upper limit based on information given by ditch riders and the water master. The monthly percentages used in the model to estimate ditch return flows are shown in table D.8.

Figures D.9 through D.15 show the relationship between estimated ditch diversion and measured flows at the intake weirs. The poorest agreement was for the Touchet East-West ditch (See Figure D.10). It is unknown at this time if there is more water being used for irrigation or if more water is being returned to the river. This ditch has many branches with three return points so it requires a large amount of waste water under the on-demand operation scheme. The largest diverter of water is Gardena Farms, which employs two full time ditch riders to keep water return flows to a minimum. The other ditches are quite small. The shortage of summer water has forced them to be efficient with water.

Table D.8 Monthly percents of total diversions that are return flow from each ditch.

GARDENA	0	0	0.1	0.1	0.3	0.3	0.3	0	0	0.1	0	0.2
TOUCHET EAST-WEST	0	0	0.5	0.25	0.4	0.4	0.4	0.4	0.4	0.25	0.3	0.3
SMITH	0	0	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
BERGEVIN-WILLIAMS	0	0	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4

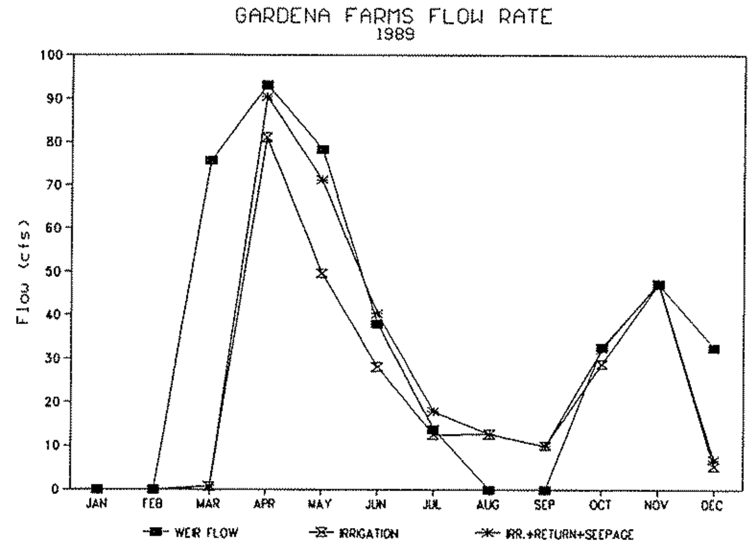

Figure D.9 Hydrograph for Gardena Farms ditch comparing: 1) weir inflow measurement; 2) estimated flow used for irrigation based on power data; and 3) irrigation estimate plus return flow and seepage.

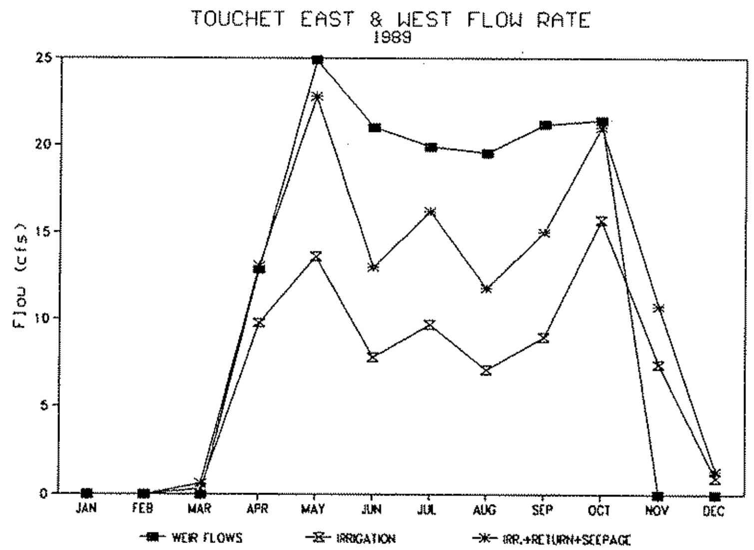

Figure D.10 Hydrograph for Touchet East-West ditch comparing: 1) weir inflow measurement; 2) estimated flow used for irrigation based on power data; 3) irrigation estimate plus return flow and seepage.

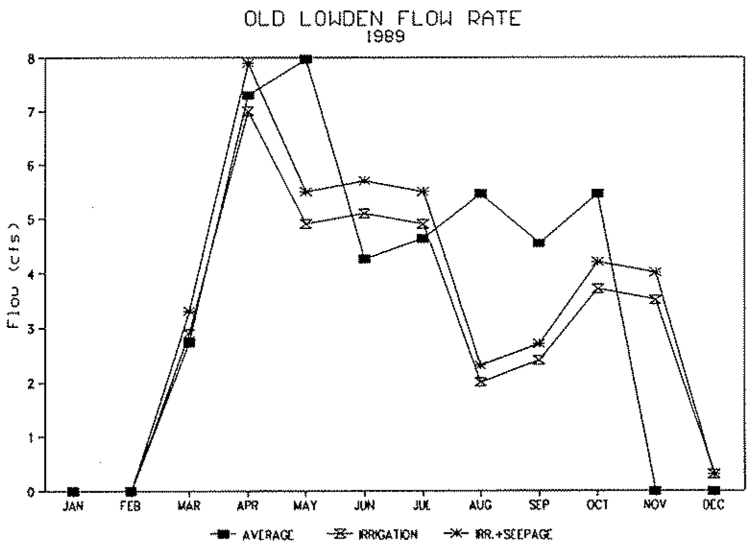

Figure D.11 Hydrograph for Old Lowden ditch comparing: 1) average inflow based on three years of DOE data; 2) estimated flow used for irrigation based on power data; and 3) irrigation estimate plus seepage.

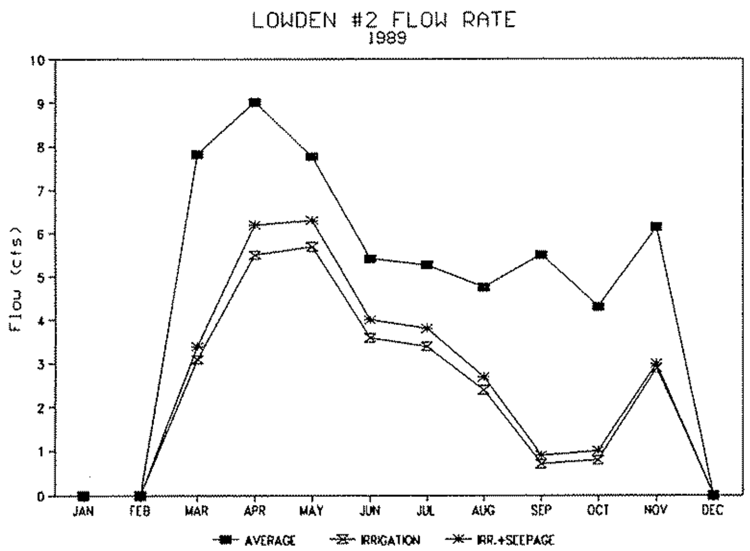

Figure D.12 Hydrograph for Lowden #2 ditch comparing: 1) average inflow based on three years of DOE data; 2) estimated flow used for irrigation based on power data; and 3) irrigation estimate plus seepage.

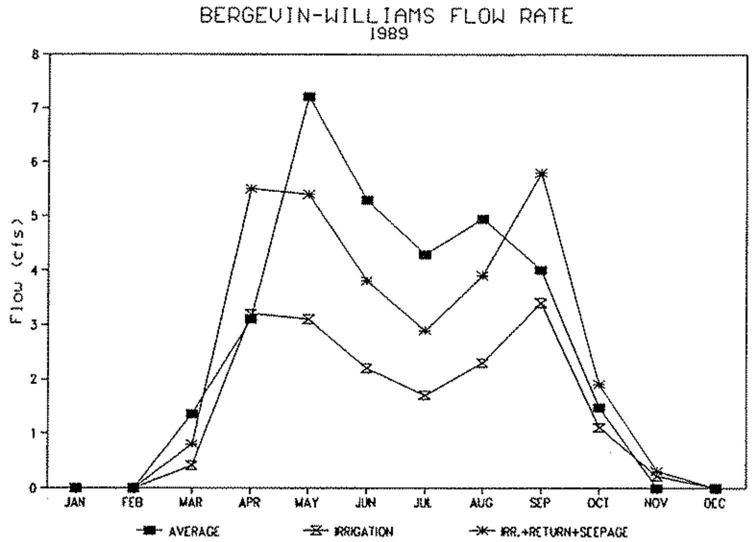

Figure D.13 Hydrograph for Bergevin-Williams ditch comparing: 1) average inflow based on three years of DOE data; 2) estimated flow used for irrigation based on power data; and 3) irrigation estimate plus return flow and seepage.

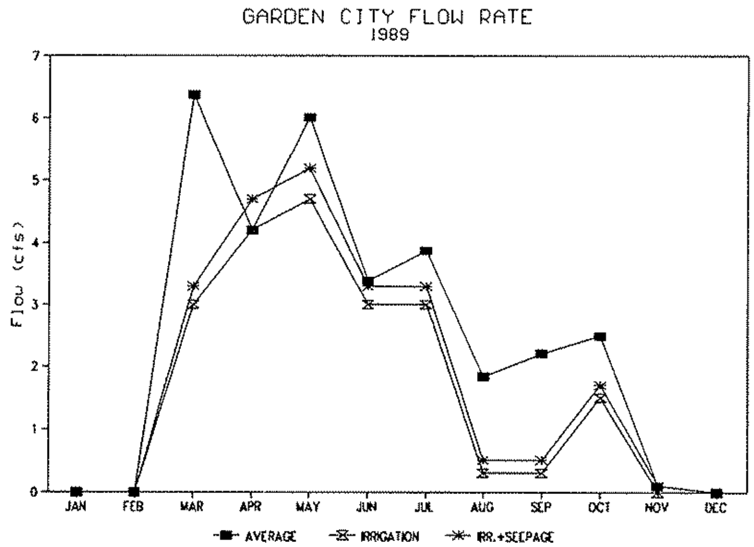

Figure D.14 Hydrograph for Garden City ditch comparing: 1) average inflow based on three years of DOE data; 2) estimated flow used for irrigation based on power data; and 3) irrigation estimate plus seepage.

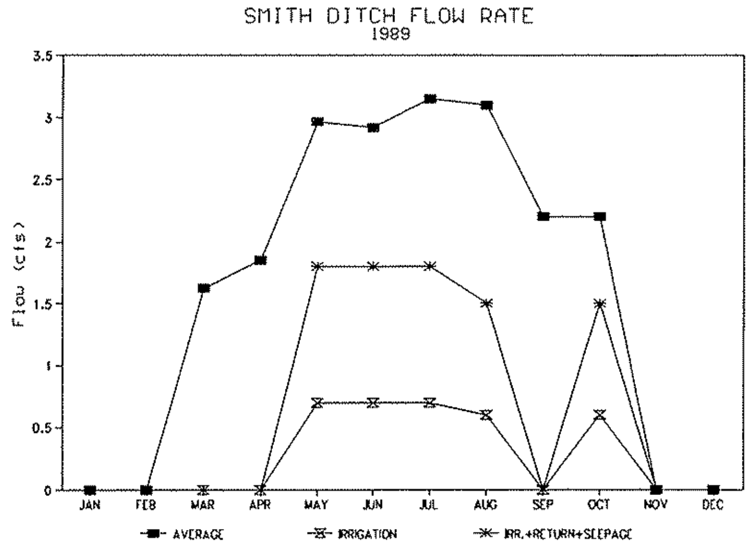

Figure D.15 Hydrograph for Smith Ditch comparing: 1) average inflow based on three years of DOE data; 2) estimated flow used for irrigation based on power data; and 3) irrigation estimate plus return flow and seepage.

Baseline Results

The monthly flows estimated by the model were compared to flow at two USGS gage stations. One is the flow below the diversion for Yellowhawk-Garrison Creek. The other is for the flow out of the basin in the Walla Walla River west of Touchet. These flows are shown in the hydrographs of figures D.16 & D.17.

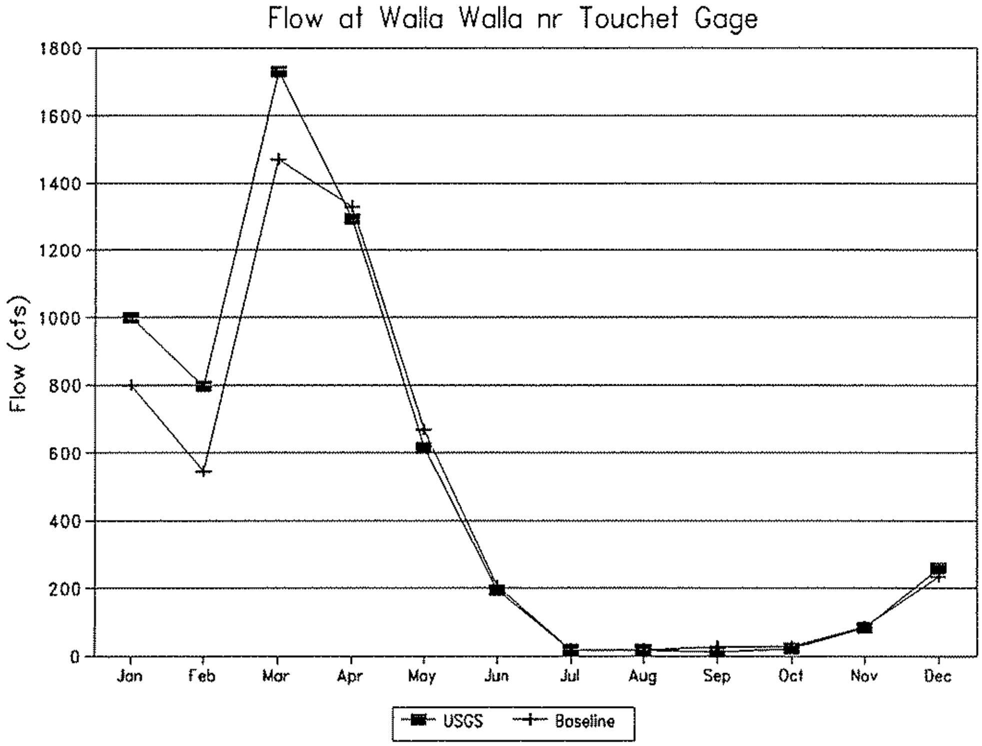

Figure D.16 Hydrograph for flow at Walla Walla near Touchet gage site.

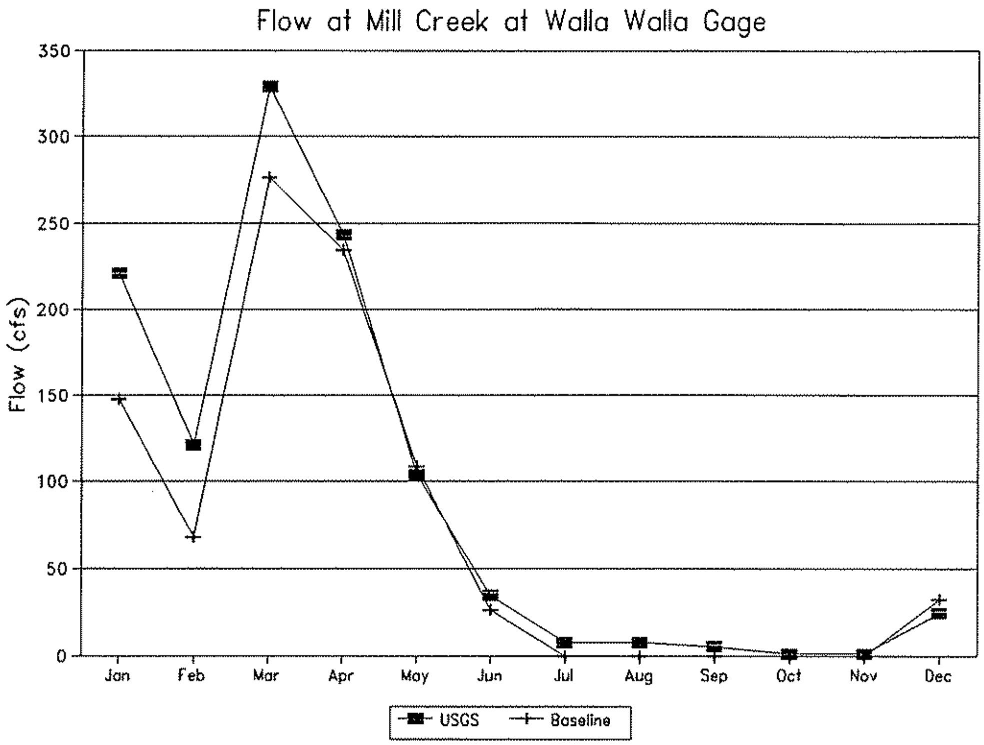

Figure D.17 Hydrograph for flow at Mill Creek at Walla Walla gage site.

APPENDIX E

Description of Fishery Model

APPENDIX E

DATA AND METHODS USED IN FISHERY MODEL

Methods

The methodology used to evaluate Mill Creek as a fish habitat is based upon the concept of weighted usable area, WUA. WUA is an index to the suitability of a stream reach as a habitat for a particular life stage and fish species. For a given subsegment of the stream, WUA is calculated with equation E1. A subsegment is a section of stream between two stations.

$$WUA = (SA)(F_D)(F_V) \qquad (E1)$$

where SA = water surface area of stream subsegment
F_D = preference factor for stream depth
F_V = preference factor for stream velocity

The stream width at the up- and downstream stations of a subsegment is needed to calculate its SA using equation E2.

$$SA = \left(\frac{W_u + W_d}{2}\right) L \qquad (E2)$$

where W_u = stream width at upstream station of subsegment (ft)
W_d = stream width at downstream station of subsegment (ft)
L = length of subsegment (ft)

Values of F_d and F_v for rainbow trout adults are obtained from relationships such as those in Figures E.1 and E.2, respectively, when the flow rate and velocity are known. The depth of flow can be computed by assuming a rectangular flow cross-section and using Equation E3.

$$V = \frac{V_u + V_d}{2} \qquad (E3)$$

$$D = \frac{Q}{V * W}$$

where, $Q = \frac{Q_u + Q_d}{2}$

$W = \frac{W_u + W_d}{2}$

Q_u, Q_d = stream flow at up- and downstream stations of subsegment (ft^3/s)
V_u, V_d = velocity at up- and downstream stations of subsegment (ft/s)

Total WUA (WUA for the entire study area) is found by summing the WUA values over all subsegments.

To calculate WUA for Mill Creek, it is necessary to know the preference curves for both the resident and anadromous fish, i.e., for the rainbow and steelhead trout. Preference is determined in terms of velocity and depth; the measure of it is given as a number in the interval between 0 and 1, where one indicates the highest preference and zero the lowest. For illustrative purposes, velocity and depth preference curves for adult rainbow trout are shown in Figure E.1 and E.2. At a velocity of 1 ft/sec, F_V is one. But a velocity between 0 and .5 ft/sec yields a F_V of only .4. The preferred depth for this life stage ranges between 2.5 and 3 feet. Each life stage has its own preference curves.

Data

The data for this study came from a number of sources. To compute the total WUA, subsegments along Mill Creek and the associated velocity, depth and flow rate information must be known. To generate subsegments, a map drawn for the Department of Conservation, Division of Water Resources, was used. The Mill Creek study area was divided into subsegments; each subsegment is assumed to approximate either a rectangular or trapezoidal surface area.

The division of the approximately 16.5 mile study area resulted in 201 stations. There is a concrete bottom for approximately two miles of the lower reach; this section was deleted from the study because it was assumed that increasing the flows in this area would not result in increased fish habitat. Therefore, 30 stations were removed (leaving 171 stations) and the study area dropped to approximately 14 miles in length.

Five of these stations were chosen as representative cross-sections (stations 1, 27, 37, 47 and 65). At each station, the width of the station plus the distance between that station and the next station was measured on the map. The data were then multiplied by the scaling factor of the map.

The flow rate, velocity and depth information for the two gages on Mill Creek: Kooskooskie and Walla Walla (considered stations 1 and 65, respectively). Another source was a consulting company that conducted a study on Mill Creek (Beck, 1987). From their data set, cross-sectional information for three more stations (27, 37 and 47) was obtained.

There are 171 stations and there was only detailed information for five of them. Therefore, assumptions were made regarding the other stations. For these sections, the variation in velocity and flow rate is assumed to be linear. For example, data exist for stations 47 and 65, but there are seventeen subsegments between them. By assuming a linear relationship between stations 47 and 65, it is possible to determine the velocity at each subsegment. If the velocity is .749 and .579 at stations 47 and 65, respectively, a line equation allows the program to calculate the velocity for all the subsegments between them:

Velocity = (.579-.749/distance between them) *
(distance from station 1 to the particular station -
distance from station 1 to station 47) + .749

From the Walla Walla gage to the junction of Mill Creek and the Walla Walla River, there are no available channel geometry data and rating curves. Therefore, it is as assumed that the velocity and flow decreased linearly in the downstream direction within this reach. It was further assumed that flow at the mouth of Mill creek was 1 cfs for the low-flow period flows considered in this study. This allowed the effects of seepage in lower Mill Creek to be included in the computation of WUA.

To find the suitability of velocity and depth for each subsegment, average velocity and depth is calculated by using equation E3 and the velocities and depths of the stations bounding that particular subsegment. For example, for the subsegment bounded by stations 65 and 64, the velocities are .549 and .552 (calculated using the above linear assumption). Therefore, .549 + .552/2 gives the average velocity for that subsegment. The average velocity is used with the preference curves to determine the subsegment's velocity suitability for each life stage.

The preference curves used for this study were obtained from a study done for the city of Walla Walla (Beck, 1987). The curves can be split into line segments.

With the aid of the above data and equation E1, it is possible to calculate each life stage's WUA for all subsegments along Mill Creek. As an illustration, suppose we are interested in calculating the steelhead adult WUA for the subsegment between stations 27 and 28. Suppose additionally that (1) this subsegment's surface area is calculated as 25,090 ft sq and (2) for the calculated average velocity and depth at this subsegment, the corresponding preference factors are .9 and .6, respectively. WUA equals 13,548 ft^2 ((25,090)*(.9)*(.6) = 13,548).

<u>The Simulation Program</u>

A computer simulation program was developed to calculate WUA for different life stages of steelhead and rainbow trout. The program consists of a main body, with no subroutines. It is written in BASIC and can be run with the GWBASIC interpreter environment on an AT compatible personal computer.

<u>Structure of the Simulation Program</u>

- The program opens an input file called "DATA", which consists of 171 lines of data. Each line has the distance, (1 in millimeters) between adjacent stations, starting from the first station (at Blue Creek) and the width (w in millimeters) at that station. Chronologically, the simulation program proceeds as follows.

- On-line information (i.e., velocity and flow rates) is input by the user as the answers to the questions directed by the program.

- Velocity is calculated at each station. Either the velocity is known (in the case of stations 1, 27, 37, 47 and 65) or estimated by assuming a linear relationship between the known stations' velocities. For example, as demonstrated earlier, the following equation allows the determination of velocity at each station between stations 47 and 65: Velocity = (velocity at station 65 - velocity at station 47)/distance between them) * (the distance from station 1 to the station in question - the distance from station 1 to station 47) + velocity at station 47.

- Flow rate is calculated at each station in the same manner as velocity.

- Depth is calculated at each station, using the velocity and flow rate calculated previously.

- The surface area of each subsegment is calculated based on whether it is rectangular or trapezoidal.

- Average velocity and depth at a given subsegment is calculated.

- Using the average velocity and depth at each subsegment, the suitability factor for velocity and depth is calculated from the preference curves for each life stage of both steelhead and rainbow trout.

- WUA for each subsegment is found by multiplying the surface area of each subsegment with its associated suitability factors for velocity and depth.

- The WUA for the entire length of interest is computed by summing up all the subsegment WUA values.

- The results are displayed on the screen as well as printed in files.

Relationship Between WUA and Fish Numbers

After various scenarios were run, the simulation program generated WUA numbers for the life stages of steelhead and rainbow trout. WUA is an index that is used by biologists to describe changes in a river's habitat suitability for different life stages of fish. For economists, the WUA numbers must be taken one step further.

To enable calculation of the economic benefits associated with increasing instream flows in the lower portion of Mill Creek, WUA must be translated into fish numbers. With that translation, an economic analysis regarding the revenues associated with various flows in Mill creek can be made.

Interpretation of WUA

There is not a consistent interpretation of WUA in the literature. Some biologists consider WUA to be uncorrelated to fish population (Mathur et al., 1985). On the other hand, Bovee (1978) describes WUA and standing crop as having a "one-to-one ratio" (p. 345). In another study, the authors discuss the assumed relationship between WUA and fish population: "There are direct relations between weighted usable area for spawning and the number of successful nests, weighted usable area for fry and number of fry produced, and weighted usable are for juvenile and their number or standing stock" (Orth and Maughan, 1982, p. 441). For purposes of this study, Orth and Maughan's interpretation is assumed to be appropriate.

The next necessary step is to determine the ultimate effect of various flow rates on the adult population in Mill Creek. The steelhead adult life stage is of major interest because the presence of more adults leads to increased fishing opportunities. Increased fishing opportunities could, in turn, generate higher benefits.

Survival Rates for Steelhead

Only the survival rates related to steelhead trout and will be discussed. First, there are no available survival rates for rainbow trout. Second, the public considers steelhead a more valuable fish than rainbow trout. Therefore, they are more likely to generate benefits. Only fry and juvenile survival rates are discussed because the adult and spawning WUA are not directly affected by increased summer flow rates. The survival rates allow us to determine how many of these additional fry and juvenile could potentially reach adulthood.

Fry Survival Rates

The first fry survival rate of interest is fry-to-smolt, which is approximately 19% according tot he John Day Subbasin Salmon and Steelhead Plan (1989). Fish are called smolts when they out-migrate.

To determine the number of smolts that survive to adulthood, a smolt-to-adult survival rate is necessary. It ranges between 2.2% (Walla Walla Subbasin Salmon and Steelhead Plan, 1989) and 3.8% (Umatilla River Subbasin Salmon dn Steelhead Plan, 1989). For this study, it is assumed that the lower number is more appropriate since it comes from the Walla Walla Subbasin Plan.

Juvenile Survival Rates

There were no survival rates for juvenile-to-adult mentioned in the above subbasin plans, therefore it is assumed that the above smolt-to-adult survival rate of 2.2% is applicable.

Combining changes in WUA for juvenile and fry steelhead with the above survival rates allows the estimation of the potential change in steelhead adult population for the different flow regimes. Once these potential changes in the adult steelhead population are calculated, it is possible to estimate the economic benefits associated with different flow regimes.

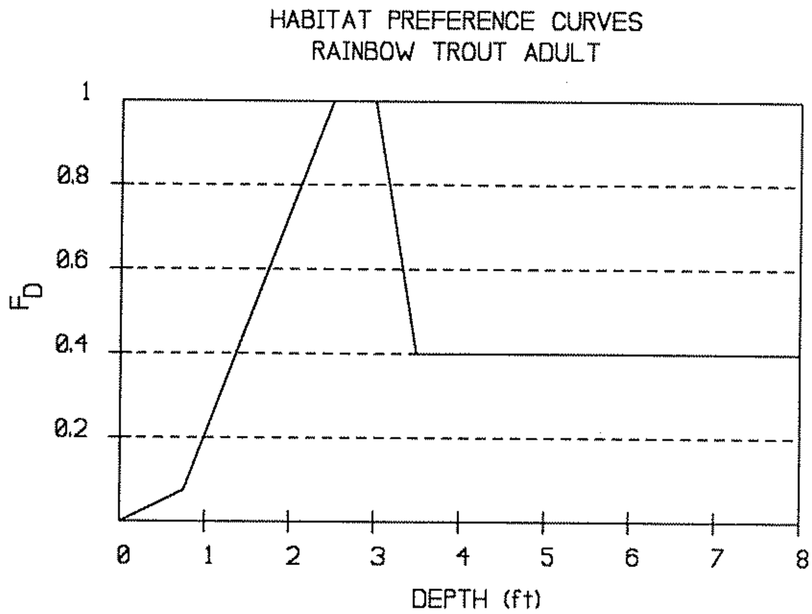

Figure E.1 Depth Preference Curves for Adult Rainbow Trout (Beck, 1987).

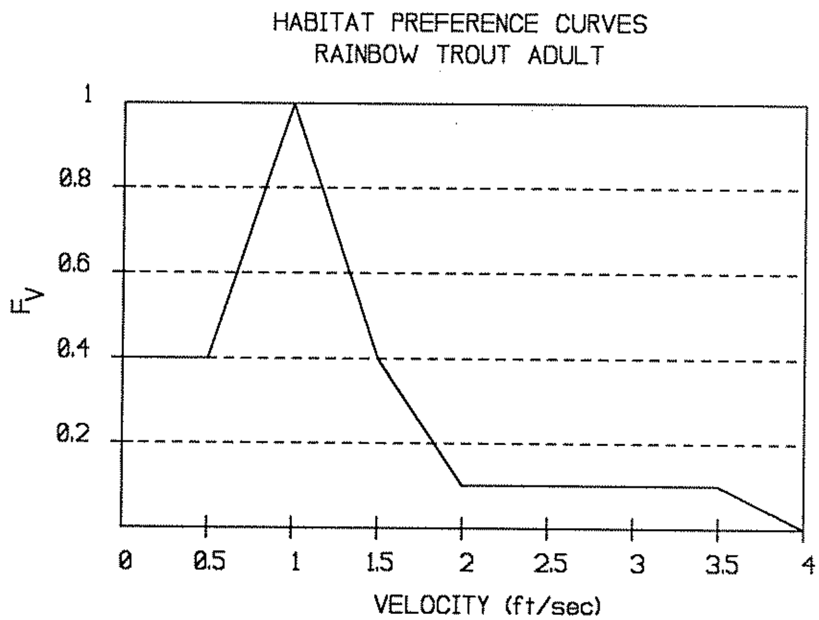

Figure E.2 Velocity Preference Curves for Adult Rainbow Trout (Beck, 1987).

APPENDIX F

Bureau of Reclamation Report on Off-Farm Delivery Systems

WALLA WALLA RIVER BASIN
IRRIGATION SYSTEM
WATER CONSERVATION ASSESSMENT

Walla Walla County, Washington

PRELIMINARY ASSESSMENT
REPORT

U.S. Bureau of Reclamation
Denver Office
Denver, Colorado

July 1990

FOREWORD

This report has been prepared by the Denver Office of the Bureau of Reclamation. Input from both the Assistant Commissioner Engineering and Research (ACER) and the Assistant Commissioner Resources Management (ACRM) organizations was used to prepare the report. This report has been written to provide technical input to the Washington State Department of Ecology's water conservation assessment study of the Walla Walla River Basin.

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INTRODUCTION:

On May 12, 1989, the Governor of the State of Washington signed Substitute House Bill 1397 which in part provides that the Washington State Department of Ecology (WDOE) shall (1) complete a state-wide assessment of irrigated agricultural areas, (2) select a demonstration project area and conduct a technical evaluation of present water use and identify and evaluate conservation opportunities, and (3) develop a conservation plan for the demonstration project area prioritizing potential water use efficiency initiatives based on cost-effectiveness, net water savings, and environmental benefits and impacts. The objective of this activity is to show what can be done to improve water use efficiency and what must be addressed to permit implementation. Substitute House Bill 1397 also provides that WDOE shall secure technical assistance from the Bureau of Reclamation to assist in this activity.

The state-wide assessment was completed at the end of 1989, and the Walla Walla River basin was selected as the demonstration project area. The Bureau of Reclamation was requested to participate in an assessment of the existing irrigation main conveyance and distribution systems and the identification and evaluation of potential opportunities for structural and nonstructural improvements which could result in reductions in irrigation diversions. This work is being conducted under Reclamation's Technical Assistance to State as a part of the General Investigation Program.

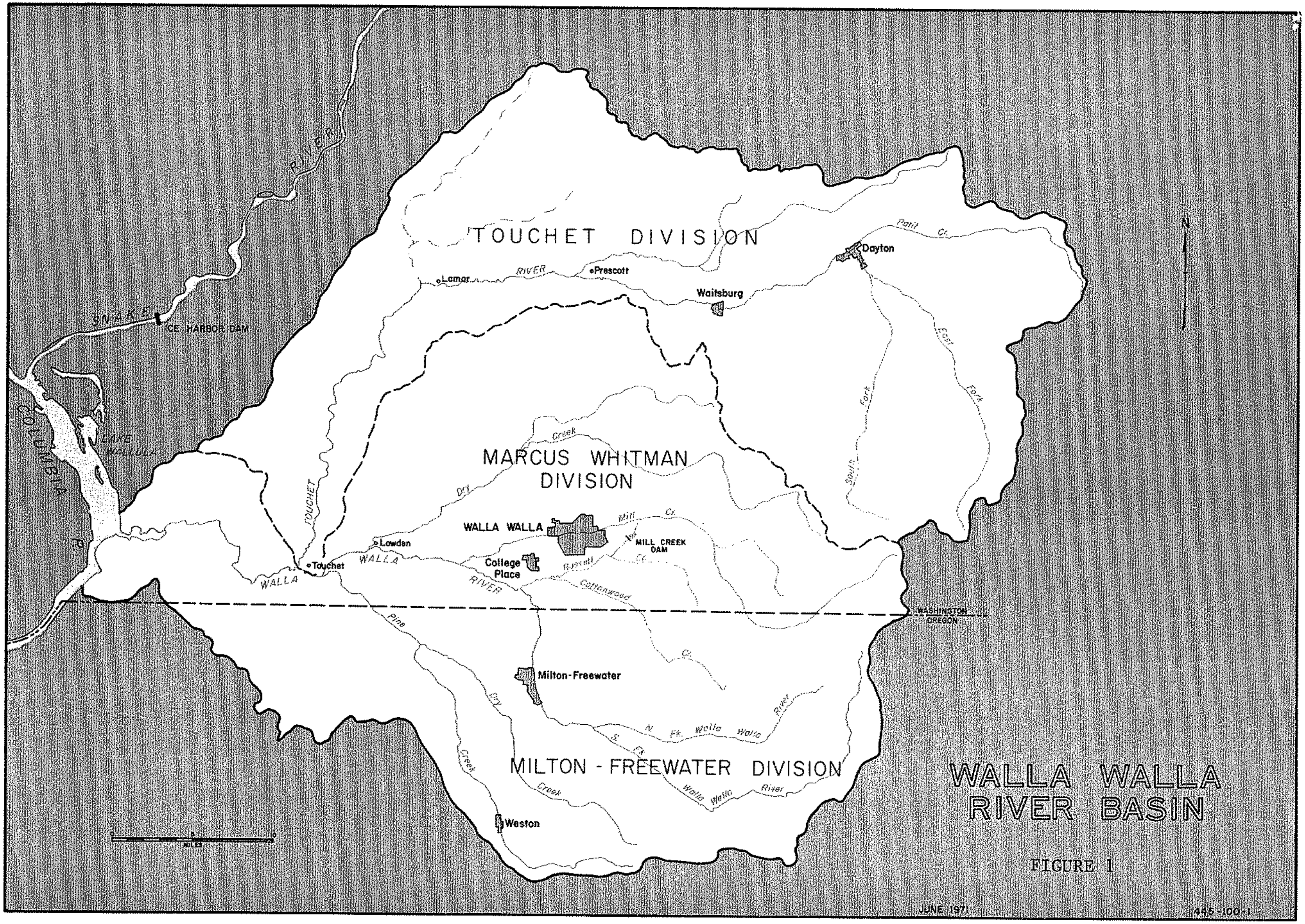
This report will be included in the full assessment report to be prepared by the WDOE as a technical appendix. Final evaluations of measures identified herein for conservation will be completed by the State in the full assessment report.

WALLA WALLA RIVER BASIN IRRIGATION PROJECT:

The Walla Walla River Basin Irrigation Project is located in southeast Washington and northeast Oregon. The Project is divided into three divisions, the Milton Freewater Division located in Oregon, the Marcus Whitman Division located mainly in Washington, and the Touchet Division located on the Touchet River Drainage in Washington (see figure 1 for details).

There is little or no storage capacity in the basin to store river flows for irrigation, except for a Corps of Engineers' flood control project on Mill Creek near Walla Walla, Washington. Due to the lack of storage reservoirs, irrigation within the basin is run-of-the-river. High spring flows pass through the basin largely unused while irrigation diversions in the upper reaches of the river drainages virtually dry up the rivers by the end of June in all but the wettest of years. This pattern is particularly evident on the upper Walla Walla River where late summer irrigation diversions near the river headwaters in Oregon deplete the riverflow before it enters Washington.

Due to this pattern of surface water availability, the farmers in much of the basin utilize ground water pumped from deep wells to supplement their irrigation demands in mid-to-late summer.


WALLA WALLA
RIVER BASIN
FIGURE 1
JUNE 1971
445-100-1
TOUCHET DIVISION
MARCUS WHITMAN
DIVISION
MILTON - FREEWATER DIVISION
WALLA WALLA
College
Place
Milton-Freewater
Weston
Dayton
Waitsburg
Prescott
Lamar
Lowden
Touchet
MILL CREEK
DAM
ICE HARBOR DAM
SNAKE RIVER
COLUMBIA R.
LAKE
WALLULA
WASHINGTON
OREGON
TOUCHET
RIVER
WALLA
WALLA
RIVER
Patit Cr.
East Fork
South Fork
Dry Creek
Mill Cr.
Russell Cr.
Cottonwood
Cr.
Pine
Dry Creek
N. Fk. Walla Walla River
S. Fk. Walla Walla River
Creek
N
MILES
0
5
10

Flow in the rivers returns again in late fall and many of the irrigation districts and ditch companies again divert flows to provide irrigation for fall plantings.

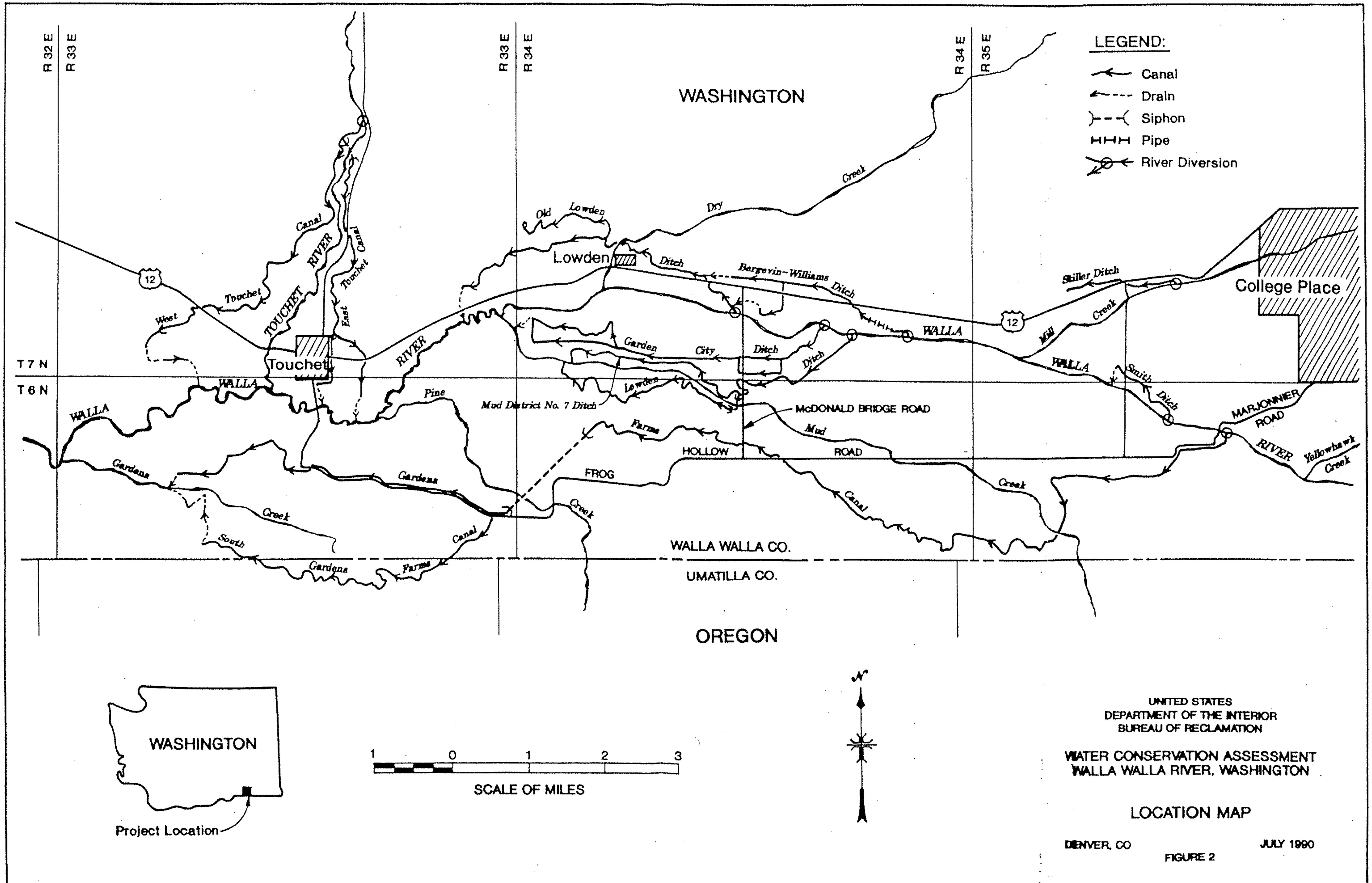
STUDY AREA DESCRIPTION:

The focus of this report will be on the area surrounding Walla Walla, Washington shown in Figure 2. A total of 10 canals or ditches are included in the study with a total irrigated area of approximately 14,000 acres. The irrigation districts and ditch companies studied include Gardena Farms Irrigation District, East Side Touchet Irrigation District, West Side Touchet Irrigation District, Lowden Irrigation District, Mud Creek Irrigation District, Garden City Ditch Company, Old Lowden Ditch Company, Bergevin-Williams Ditch Company, Stiller Ditch Company, and Smith Ditch Company. The canals in the study area vary in capacity from 2 ft^3/s (cubic feet per second) for the Smith Ditch to over 80 ft^3/s for the Gardena Farms canal (records show flows up to 100 ft^3/s in this canal for short durations) . Consequently, the degree of sophistication of the canal facilities also varies widely.

The Gardena and Touchet East and West districts have concrete diversion dams with headworks located on the Walla Walla and Touchet rivers, respectively. The Touchet districts share a common diversion structure and headworks with a division structure located further down the canal. The other canals and ditches in the study area have gravel diversions. There is a concrete division structure on Mill Creek (built by the Corps as part of a flood control project) which allows water from Mill Creek to be diverted to the Walla Walla River upstream of the Gardena Farms diversion via Yellowhawk Creek. This water would normally flow into the Walla Walla River downstream of the Gardena Farms diversion point.

Flows diverted to the canals are measured near the river diversions with Cipolletti weirs in all of the canals in the study area except the Stiller Ditch. While the flows are measured in most of the canals, only the Touchet canals have an continuous automated flow recorder. All of the canal diversions observed are supplied with fish screen and fish bypass facilities to return fish stopped by the screens to the river.

The canals studied consist mainly of earth lined canals or ditches with a few pipe siphons located across drainages. Original construction of many of the canals dates back to the late 1800's. The farm turnouts were originally designed for gravity flows to flood or row irrigate, however roughly seventy percent of the farm deliveries in the study area have since been converted to sprinkler irrigation with farmer-owned pumps being installed in sumps or holding ponds beside the canals. This is particularly true on the larger Gardena and Touchet canals where upwards of ninety percent of the turnouts now serve sprinkler irrigation. On the smaller ditches, most of the turnouts are still gravity which irrigate land ranging from field crops to pastures to small home gardens.



LEGEND:
Canal
Drain
Siphon
Pipe
River Diversion
WASHINGTON
OREGON
R 32 E
R 33 E
R 34 E
R 35 E
T 7 N
T 6 N
Touchet
Lowden
College Place
WALLA WALLA CO.
UMATILLA CO.
McDONALD BRIDGE ROAD
HOLLOW ROAD
FROG
MARJONNIER ROAD
Garden City Ditch
Bergevin-Williams Ditch
Lowden Ditch
Old Lowden
Dry Creek
Stiller Ditch
Mill Creek
Smith Ditch
Yellowhawk Creek
WALLA WALLA RIVER
TOUCHET RIVER
West Touchet Canal
East Touchet Canal
Pine Creek
Mud District No. 7 Ditch
Mud Creek
Gardena Creek
Gardena Farms Canal
South Gardena Farms Canal
Frog Hollow Canal
12
WASHINGTON
Project Location
SCALE OF MILES
1 0 1 2 3
N
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER CONSERVATION ASSESSMENT
WALLA WALLA RIVER, WASHINGTON
LOCATION MAP
DENVER, CO
JULY 1990
FIGURE 2

While flows into most of the canals are measured, farm turnout flows in the study area are not measured. Only the Touchet Districts provide their ditch rider with a portable weir to measure gravity deliveries and only the Gardena Farms District provides a portable flow meter for measurement of pumped deliveries. Farmers pay for irrigation by the acre of land irrigated not by the volume of water applied to their land via the canal or ditch systems.

Operation of the canals varies according to the size of the district. The Gardena and Touchet districts have ditch riders who operate the river diversion gates and set turnout gates to deliver water. Water flows in these canals are scheduled with individual farmers who indicate their flow requirements to the ditch rider in advance so he can adjust river diversion gates allowing travel time for the water in the canal. The Lowden No. 2 ditch also employs a ditch rider and schedules deliveries, although not to the degree of the larger canals.

The remaining ditch companies in the study area have less structured operational procedures. River diversion gate settings are adjusted by the farmers or the local Watermaster (a State employee). The Watermaster checks flows in all of the irrigation district and ditch company facilities. He often adjusts diversion gate settings to reduce operational wasting of water on the smaller ditches and works closely with the ditch riders on the larger systems.

Depending on the size of the irrigation districts or ditch companies, maintenance of the canal systems varies widely throughout the basin. The larger districts, such as Gardena and Touchet East and West districts, have full time ditch riders who handle canal maintenance for such things as weed control both on the canal banks and in the canal channel. The larger districts also own and operate equipment which is used to remove silt accumulations and to reshape the canal prisms in the off season. The smaller ditch companies have significantly less stringent maintenance procedures and resources.

Due largely to the river flow patterns described in the previous section, the area rivers are not currently maintained as a prime fishery. The concrete diversion dams are not equipped with fish ladders to allow upstream migration for spawning runs and the constant reworking of the gravel diversions often disrupt flows even when the river does have water.

ASSESSMENT FINDINGS:

Limited Storage - The lack of storage reservoirs in the basin has significantly affected the study area's ability to exercise its full water rights. The existing Corps of Engineers Mill Creek flood control reservoir may hold some promise for development of limited irrigation storage. A more complete description of existing storage facilities and a discussion of potential storage projects is included in Appendix A.

Seepage - Water losses in the study area attributed to seepage from the canals appear to be minor. Some isolated canal reaches have trees growing on the canal banks, but these areas are very limited and do not contribute significantly to losses in the study area. Virtually no wetlands were observed which could be traced to seepage from canals. The lack of storage reservoirs in the basin may have indirectly contributed to the relative tightness of the ditches in the area. Since irrigation diversions are most prevalent during the high riverflow periods and since no reservoirs are present on the rivers to capture silt, water diverted in the spring carries a significant silt load. Most of the canals were already constructed in fairly tight soils and after many years of operation, deposition of this silt in the canals and ditches has effectively sealed many of the canals in the area. A more thorough discussion of the estimated seepage in the study area is included in Appendix B.

Maintenance - Maintenance of the canals, ditches, and appurtenant structures in the study area varies widely. In general the larger irrigation districts adequately maintain the canal prisms and banks. However, the concrete diversion structures and canal structures for these districts appear to be in need of maintenance. As an example, the diversion structure for the Gardena Farms canal has silt and gravel buildup upstream of the dam and should be removed. The sluiceway provided for removal of this silt is not utilized. Major repairs and improvements on the larger canals, such as the Gardena Farms South Canal turnout, are made when warranted however.

The smaller ditch companies do not adequately maintain their ditches. Weed growth in the channels and on the ditch banks is unchecked in many areas and silt deposition has reduced the ditch cross sectional area in some locations. A more complete assessment of the maintenance requirements in the study area and an illustration of the impacts of channel maintenance is included in Appendix C. Estimated costs for maintenance programs are included in Appendix D.

Flow Measuring Devices - Installation of flow measuring devices at each turnout would allow the operators to set deliveries more accurately. This, combined with installation of weirs or flumes on existing mainline structures and on wasteways would provide information on flow within the canal which would allow more efficient operation. The Gardena Farms Canal would be especially suited to installation of weirs on existing mainline structures due to the number of such structures existing along the canal and the elevation drop available at most of these structures. Parshall and ramp flumes could be used to measure mainline flows where there is insufficient drop for weirs. Such a program would enhance operational efficiencies and reduce routine wasting of water at the end of the canals. The program would benefit all of the canals and ditches in the area but would be of particular benefit on the Gardena Farms Canal. Water diverted at the Gardena Farms Canal diversion which is wasted to the Walla Walla River, bypasses the diversions of six other ditch companies (Smith, Bergevin-Williams, Old Lowden, Lowden No. 2, Mud Creek No. 7, and Garden City). Any reduction in operational waste on the Gardena Farms system would therefore increase the supply to these ditch companies.

Several alternatives are available to measure farm turnout flows. Appendix D lists costs for three of these alternatives. Constant head orifice structures are included in the estimate. These structures allow precise control and measurement of flow, provided the canal water depth is held fairly constant. They have proved to be somewhat difficult to set on small installations, however. Propeller meters are also included in the estimate, installed in structures to measure flow between the canal and the farmers pump, and installed on the farmers pipe downstream of his pump. These meters are very easy to read and are recommended on nearly all new Reclamation projects of this type. The meters do, however, require annual maintenance. If the maintenance programs on the canals in the study area can not guarantee this maintenance will be done, propeller meters may not be the best option.

The costs listed in Appendix D for measuring gravity turnouts assume installation of small weir structures in the farmers' ditches. Installation of ramp flumes in the ditches would also be acceptable. Installation of V-notch weirs or ramp flumes on the pumped turnouts were considered, but due to the fluctuations in the canal water surfaces throughout the system, they were not considered to be appropriate for these turnouts.

In addition to providing operational information, installation of flow measuring devices on farm delivery turnouts and on canals will allow operators to isolate reaches of their canals to determine if excessive seepage is occurring. Once such reaches are identified, ponding tests could be performed to better define the seepage. With the amount of seepage quantified, a decision could then be made as to the economical viability of a variety of repair techniques. Relining of the canal with concrete or PVC linings will reduce seepage while replacing the canal with equivalent pipe systems will virtually eliminate seepage. One or both of these repair techniques may prove to be viable depending upon the circumstances. This particular advantage of installing measuring devices may prove to be more beneficial in other study areas due to the apparent minor seepage losses in this area, but it will provide valuable data for location of local seepage zones in this study area as well.

Approximate cost estimates for installation of the canal flow measurement devices on each canal and estimated costs for ponding tests, canal relining, and replacement of canals with pipe are included in Appendix D.

<u>Diversion Structures</u> - The diversion works of all the smaller irrigation companies consist of gravel bars which are constructed prior to irrigating each year and repaired after each major flood event. This construction and repair work involves entering the river with heavy equipment to shape the gravel in the river bed to allow diversion to an uncontrolled canal intake. These diversion dams do not adequately maintain the level of water for diversion to the canals since water flows out through the gravel matrix. The Old Lowden diversion is the least effective of these diversion as a short feeder canal has been excavated into a gravel zone to maintain diversions which must be pumped via a low lift pump station into the main canal. Gravel companies removing material from the river bed have lowered the grade necessitating the excavation of the feeder canal.

To reduce the amount of river bed construction, a number of small irrigation companies (Bergevin-Williams, Old Lowden, Lowden No. 2, Garden City, Mud Creek No. 7) could combine their separate diversions into a single permanent diversion at the current Bergevin-Williams diversion site. Headworks gates can be provided for each district on each side of the river to allow them to maintain control over their diversions. Another alternative would require Bergevin-Williams to be improved to convey Old Lowden flows in addition to their own, eliminating the pump station Old Lowden presently operates for diversions. Smith Ditch could use the north side of the Gardena Farms diversion structure for a permanent headworks structure. A canal less than a mile in length would be needed to convey water from this diversion to the existing Smith Ditch.

Cost estimates for improved concrete river diversions have been included in Appendix D. Estimating methods are provided for construction of individual concrete diversion structures as well as an estimated cost of combining the diversions for the ditch companies listed above.

Construction of permanent diversion structures would not only allow more efficient and predictable diversion of river water to the irrigation systems, it would also reduce the annual construction activity in the river channel which disrupt stream flows. The permanent diversion structures would establish a permanent streambed grade at the diversion point and avoid large fluctuations in the river bed elevation such as that which has occurred at the Old Lowden diversion. The structures would also regulate flow in the river more effectively which could be used to enhance the river fishery. Fish ladders could be provided and a portion of the structure cost could be furnished by fishery enhancement funds which may become available in the basin.

<u>Canal Automation Potential</u> - Canal automation has developed into a powerful operational tool in recent years. Older canals can often benefit from installation of an automated system of gates along the canal to control the distribution of water within the canal channel. Automated operation of gates along canals is primarily used to maintain preset water levels within specific reaches of the canal alignment (often referred to as pools). This control of water surface elevations between such gates is critical to deliver steady flow rates to gravity turnouts within each pool.

As described in the study area description section, most of the turnouts on the larger canal are to pumped deliveries. Therefore, the water levels along the canal alignments are not as critical as those in a canal system which has mostly gravity turnouts. In canals with concrete lining, maintaining steady water levels is important even with pumped deliveries. Rapidly varying water levels subject the lining to unbalanced uplift pressures which can cause structural damage. Therefore, if concrete lining is installed in the canals in this or other study areas, canal automation should be considered as a means to protect the lining.

Automated systems also work well to accommodate rapid fluctuations in flow requirements along the canal. The water deliveries along the larger canals in this study area are scheduled (or could be) so the canal flows are fairly steady and rapid fluctuations in delivery requirements along the canals are not encountered. Deliveries along the smaller ditches in the area could also be scheduled to provide a steadier canal flow as part of an overall improvement in ditch operations. This program is described in the conclusions section of this report.

Given these considerations, the potential water savings which could be derived from installation of an automated system of gates on the canals within this study area, appear limited.

While significant water savings were not directly linked to installation of a automated control system on the canals in this study area, automation should be considered as a viable option to improve water conservation on other irrigation systems studied throughout the State. Operation of many canal and pipe systems can be enhanced significantly by such installations and the resulting improvement in operational efficiencies can conserve significant amounts of water. The nature of the systems in this study area do not lend themselves to such an installation however.

Specific Observations - A list of specific observations and recommendations concerning individual ditches and canals is included in Appendix E. Many of these observations and recommendations are site specific and have not been included in the main body of this report.

COST ESTIMATES:

Cost estimates for a variety of structural improvements to the study area irrigation systems are included in Appendix D. All cost estimates included in Appendix D are appraisal level estimates of field construction costs only and do not include estimates for design or construction management costs.

The cost information included in Appendix D is not exclusive to the Walla Walla area. With minor variations, these costs should provide a basis for evaluation of structural improvements on projects in other parts of the state.

CONCLUSIONS:

General - Reductions in irrigation diversions within the Walla Walla study area would primarily result from more efficient operation of the canals within the area and through an improved system maintenance program.

In order to quantify the current system efficiencies, installation of flow measurement devices throughout the study area will be necessary. Without accurate information on what percentage of canal diversion flows is getting to the farmers through the existing system, estimates of potential reductions in canal diversions must be based largely on speculation.

Based on the best available information, seepage from the area canals does not appear to be a major problem in the Walla Walla basin. Although no quantitative data was collected in the study area concerning seepage rates, field observations and data collected in other areas of the Walla Walla basin do not indicate a program to reduce seepage on an area-wide basis would be cost effective.

A number of specific measures which will improve the operational efficiency of the canals in the study area are identified in the previous section and in appendices of this report. A summary of these measures is listed below along with benefits afforded by each and costs associated with construction or implementation (if available).

A summarized analysis of the costs and potential water diversion savings for the major items identified in this report are presented in Table 1 at the end of this section. The cost data included in the table are appraisal level estimates of field costs only and do not include design or construction management costs. The water savings listed in the table for seepage and improved operations should also be used as appraisal level estimates. They are not based on specific data collected in the study area and therefore may vary significantly from the actual values.

Flow Measurement - Installation of flow measurement devices on the entire system is recommended along with a system by which complete records of the system flow patterns are maintained. All farm turnouts and canal wasteways in the study area could be fitted with permanent measurement devices for approximately $600,000.

Such installation would allow more dependable operation of the canals by giving the ditch riders more precise information on flow demands. It would also allow a more accurate assessment of seepage along each of the canals. In order to derive the maximum benefits from the flow rate information, complete flow measurement records must be maintained. These records should include flow rates for the canal diversion, readings from weirs or flumes along the main canal, farm turnout flow rates, and wasteway flow rates. By studying these records, operational patterns can be identified and refined. Reaches of the canals having high water losses can then be isolated. Such records should be maintained by the local irrigation districts and ditch companies and should be provided to the local Watermaster.

Water savings associated with installation of flow measurement devices throughout the study area are discussed below in the operations section.

Maintenance Program - An improved maintenance program is recommended in most of the study area. Benefits from such a program include improved operational efficiencies as well as reduced miscellaneous losses from the canal. These benefits are of particular importance for junior water rights such as those served by the Gardena Farms canal. The estimated cost for implementing such a program is approximately $600 per year per mile. Based on this cost, a maintenance program would cost approximately $32,500 per year to cover the majority of the study area. Assuming a fifty year time frame for evaluation and an interest rate of eight percent, the present worth of this annual cost is approximately $398,000. The cost of initial clean-up of the more run-down ditches could approach $1,400 per mile. Assuming only the smaller companies would require this initial cleanup, approximately $37,000 would be required for the initial cleanup. Therefore, the total present worth cost of the improved maintenance program is approximately $435,000. Water savings associated with implementation of an upgraded maintenance program throughout the study area are discussed below in the operations section.

District Consolidation - Consolidation of several of the smaller ditch companies would have a number of benefits. A single permanent diversion structure could be constructed for up to five of the ditch companies to allow for more precise control of their diversions. Consolidation of these and perhaps other small ditch companies would allow pooling of resources for operations and maintenance; thus, allowing each ditch to be better maintained and allowing for more efficient operation. The costs associated with such a consolidation is minor. The potential water savings resulting from the consolidation is discussed in the operations section below.

Diversion Structures - Construction of new permanent diversion structures for those ditch companies who now use gravel diversions would provide better control over the canal diversions which would also lead to more consistent and efficient operation of the canals. A side benefit to the study area which could be derived from constructing permanent diversion structures would be the ability to improve the river fishery through more effective river regulation.

Costs for diversion structures will vary depending on the width of the river at each diversion. However, by combining several of the diversions, the six existing gravel diversions in the study could be replaced with two new concrete structures and an upgraded structure at Gardena Farms for a cost of approximately $2,700,000. Water savings resulting from this measure are discussed in the operation section below.

Operation - The combined effects of improved diversion structures, improved operational procedures resulting from installation of measurement devices, an improved maintenance program, and irrigation district consolidation must be evaluated together as part of a single package. By instituting a comprehensive program involving these elements, operational efficiencies of the canals in the area will improve. The degree to which the canals improve their efficiency is difficult to estimate however, since no data are available on the operating efficiencies of the existing system.

Presuming these measures are instituted, the operational efficiency of the main lines should approach that of a typical nonautomated Reclamation canal system without inline canal storage at ninety to ninety five percent. This assumes operational waste flows at the end of the canal ranging from five to ten percent of the diversion flows.

As a conservative estimate, an improvement in operational efficiency of five percent will be assumed as the benefit resulting from implementing these measures. From table B2-1 in Appendix B, the total estimated diversion in the system is approximately 55,600 acre-feet per year. Therefore, at the assumed five percent level of improvement, a reduction in water diversions of approximately 2700 acre-feet per year would be realized if the above improvements are made.

Until the flow measurement devices are installed in the study area however, a full assessment of the reduced diversions which may be realized by these measures can not be performed accurately.

Seepage Estimate - Using the best available information on the area, the seepage rates and volumes have been estimated in Appendix B. Estimates are provided in Appendix B based on the results of ponding tests in other areas of the basin and based on field observations. The seepage values used in Table 1 are based on the ponding tests from other areas in the basin and are computed in Appendix B. Based on these values, it does not appear that relining of the canals or replacement with pipe systems to reduce seepage losses is warranted. If local areas of seepage are discovered with further study, the price information in Appendix D may be used to evaluate which repair option is warranted.

Canal Relining/Replacement - Although the figures in Appendix D should be consulted for specific installations, some typical canal relining and pipe replacement costs can be developed for this study. Average costs of relining the existing canals in the study area vary from approximately $64,000 per mile to $105,000 per mile. The average cost of pipe replacement for the study area is approximately $570,000 per mile. Potential water savings resulting from relining or replacing the existing canals are listed in Table 1 below along with an estimated average cost per acre-foot of water saved. A fifty percent reduction in the predicted seepage rates is assumed for relining the canals while a one hundred percent reduction is assumed for replacing the canals with pipe.

Storage - The Walla Walla area and the State of Washington in general would benefit significantly from construction of storage facilities in the upper reaches of the river basin. By storing the high spring flows which currently pass through the basin, and releasing the water on demand, irrigation demands could be supplied throughout the summer. This would reduce the demands on the ground-water pumping which is now used heavily to supplement surface water irrigation supplies. Minimum stream flows could also be established for fishery enhancement if storage facilities were available. Investigation of smaller storage facilities such as shared use of the Corps' Mill Creek flood control reservoir should also be pursued.

Any development of new storage facilities or utilization of existing storage facilities must incorporate a basin wide water management program. By regulating releases from such facilities and coordinating these releases with scheduled canal diversion flows, water within the basin can be conserved by reducing the volume of unused water leaving the basin. It would also encourage more scheduled operations of the irrigation districts within the basin. Such operations would conserve water through more efficient canal operating procedures.

On a smaller scale, construction of permanent diversion structures to replace the temporary gravel diversion currently used would provide more reliable flows to the canals thus allowing for more precise control of the irrigation flows. Installation of these structures also benefits the river's potential for being developed as a fishery.

Costs have not been computed for enhancing storage in the basin as this was outside of the scope of this report. Quantifying the water savings which could be realized by development of storage in the area is also beyond the scope of this study, but the existing studies described in Appendix A should provide data on this issue.

<u>Study Issues for Other Areas</u> - This assessment identifies a number of structural and nonstructural alternatives for improving irrigation efficiency. Many of the issues will be applicable to other studies to be undertaken by the State of Washington under its irrigated agriculture water use efficiency studies. A list of items to check in these studies is as follows:

1. System operating procedures, including flow measurement.

2. Control automation potential.

3. Maintenance programs.

4. Seepage losses in system and evaluation of corrective action costs.

5. Consolidation of small irrigation districts to pool resources.

6. Storage use and potential (both on and off farm).

The general items listed above and the specific assessment conclusions for this study area should provide a starting point for future assessment studies throughout the State.

In general, the local, State, and district personnel operate the existing main conveyance and distribution systems in the Walla Walla River Basin very well. Given some additional tools, operation of the systems could be enhanced, however. This is likely to be the case in other areas of the State as well.

To be most effective, both structural and nonstructural improvements identified for this and other study areas throughout the State need to utilize the most up-to-date concepts in water conservation, but also need to reflect the unique nature of each system. Using the experience of the local operators to gain insight into the operation of these systems is vital to effectively identify improvements with high chances for successful implementation.

TABLE 1
ASSESSMENT CONCLUSIONS SUMMARY

MEASURE	ESTIMATED COST Capital Expenditure	ESTIMATED COST Annual* Cost	ESTIMATED WATER SAVINGS (Acre-Feet Per Year)	COST PER ACRE-FOOT Based On Capital Expenditure	COST PER ACRE-FOOT Based On Annual* Cost
Installation of Measurement Devices:	$600,000	$49,000/yr	___	___	___
Improved Maintenance Program:	$435,000**	$35,500/yr	___	___	___
Irrigation District Consolidation:	N.A.		___	___	___
Improved Diversion Structures:	$2,700,000***	$221,000/yr***	___	___	___
Combination of All Measures Above:	$3,735,000	$305,500/yr	2,700	$1,380	$115
Canal Relining -					
Concrete Lined -	54 miles at $105,000/mile $5,670,000	$463,500/yr	1,760	$3,220	$260
PVC Lined -	54 miles at $64,000/mile $3,456,000	$282,500/yr	1,760	$1,960	$160
Pipe replacement -	$32,493,000	$2,655,000/yr	3,525	$9,220	$750

* Annual costs are computed assuming 8% interest and a 50 year repayment term.
** Includes present worth of annual maintenance cost plus initial cleanup.
*** Cost sharing may be available for these features as part of a State fishery enhancement program.

APPENDIX A:

RIVER BASIN STORAGE

Section A1 - General: There are no storage reservoirs being used by the irrigators in the Walla Walla River basin. During years when the snowpack in the drainage basin is low or when warmer than normal temperatures cause an early runoff, storage facilities could capture river flows until needed for irrigation in the valley. Diversion dams, pump ponds, offstream storage, and regulating reservoirs allow potential for water storage in the Walla Walla River basin. At the concrete diversion dams in the study area, diversion pools which are partially filled with sediments and gravel could be excavated to the same elevation as the canal invert. The storage attained by such measures may be minimal but for canals with small flows, the storage volume may be adequate to allow more flexibility in operations. This is the case in most of the study area where canal flows are less than 50 ft^3/s for all irrigation companies except the Gardena Irrigation District. For irrigators who presently use sprinkler systems where pumps are used to increase the water pressure, some have pump ponds dug downstream of turnouts. Pump ponds should be constructed at all pump turnouts to rely more on the pump ponds and less on the canal levels.

Small regulating reservoirs, consisting of widened sections of canal or off canal storage ponds, could also be sized to meet irrigation demand in the event the river channels are too low for sufficient diversion.

Inline river storage facilities would benefit not only irrigation in the basin, but also would allow enhanced stream flows throughout the year. This would allow fisheries to be established in the rivers which now virtually dry up by mid-summer.

Section A2 - Area Storage Potential: Storage developed upstream of the city of Walla Walla on both the Walla River and Mill Creek would benefit all irrigators except the Touchet East and West Side Irrigation Districts. With a combined diversion allocation for all canals in the study area diverting upstream of the Touchet River confluence of approximately 125 ft^3/s, a reservoir (or series of reservoirs) with 20,000 acre-feet of storage would provide full flow for nearly 3 months.

There have been studies made by both Reclamation and the Corps investigating additional storage sites upstream of the study area on both Mill Creek and the Walla Walla River. The Reclamation study is documented in a 1971 report on the Walla Walla Basin. Studies made by the Corps should also be reviewed as part of the final assessment of storage in the basin.

At the Mill Creek Diversion Dam, a Corps facility at River Mile 11.5, the diversion pool is overgrown with tules which create channels for the main flow of water. Current wetlands policy could inhibit development of storage at this location. Some clearing near the diversion dam may be allowed if fishery enhancement is a portion of the justification. At Mill Creek Lake, storage within certain limitations may be permitted by the Corps, who owns and operates this offstream flood control reservoir. Mill Creek Lake Dam, which impounds Mill Creek Lake, is capable of storing approximately 8,300 acre-feet of floodwaters at the maximum pool elevation of 1257.5 feet mean sea level. At the conservation pool elevation of 1205.0 feet, Mill Creek Lake contains 866 acre-feet of storage. Should opportunities for flooding in the Mill Creek watershed be low in probability, outside the months of the standard project flood, a variance for storage may be granted to the irrigators of the valley provided this storage is vacated by the onset of the following flood season. Mill Creek Lake, has a foundation seepage problem which would need correction before any storage would be acceptable. Cost sharing to correct this problem with the Corps may be one method to achieve irrigation storage in Mill Creek Lake.

At the Gardena Diversion Dam, sediments and gravel have accumulated to the tops of some checkboards which is well above the ogee weir crest. Storage developed at this location would primarily benefit the Gardena Irrigation District as the river dries up during the summer months.

APPENDIX B:

SEEPAGE ESTIMATES

Section B1 - General: Conveyance losses and wastes vary throughout the season depending upon the acreage supplied and the current crop requirement, irrigation practices, and type of canal. Wastes and losses are heaviest during the spring months when needs and operating efficiencies are low and priming losses are high. Usually maximum demands come at the height of the irrigation season when crop requirements are high, the canal is in its best condition and there is little waste through inefficient operation. Canal capacity should, therefore, be based on such periods of maximum demand with the best possible estimate of losses and waste under such conditions. If possible, losses should be estimated from nearby operating canals of similar hydraulic properties and lengths, and type of earth or other material used for construction, including linings. If such information is not available it may be necessary to make estimates from less comparable systems and known experimental values or operating ranges based on experience further removed from the project. For purposes of project planning water supply studies, lateral losses are commonly stated as a percentage of deliveries from the main canal, and main canal losses as a percentage of the diversion into the main canal. Lateral losses range from less than 5 percent for lined systems in good condition to over 30 percent for untreated earth systems. Main canal losses may range from less than 5 percent to over 60 percent, depending upon the length of the canal and its character. In estimating water requirements, canal and lateral losses are usually combined with an allowance for operating waste in a single item. Evaporation is small in comparison to seepage and waste and is ordinarily ignored in design.

Canal seepage follows in general the laws of percolation. The loss per unit area of wetted surface varies directly with the head and permeability of the soil; inversely as the length of path. Percolation is fairly rapid when water is first turned into the canal, until the soil is fully saturated for some distance from the canal and it has expanded to fill cracks produced in drying. As the distance of movement increases, the ground-water gradient becomes the controlling measure of head rather than the depth of water in the canal. Both head and distance of travel approach a uniform condition and the permeability factor becomes a control in the measurement of seepage. For practical purposes, seepage is represented by depth of water lost per day over the wetted area. See Table B1-1 for values.

TABLE B1-1
TYPICAL SEEPAGE VALUES

Kind of Material	Loss per day in feet*	
	Reclamation Estimate**	Irrigation Engineering Estimate***
Lining Materials:		
3 to 4 inch Concrete (with good joint filler)	0.07	0.03
1 inch Shotcrete (reinforced)	--	0.18
Cement Mortar	--	0.31
Concrete Lining (unreinf. w/o joint filler)	0.33	--
Canals Excavated in the Following Materials w/o Linings:		
Cemented Gravel and Hardpan with Sandy Loam	0.34	--
Clay Soil	--	0.37
Clay and Clay Loam	0.41	0.46
Sandy Loam	0.66	0.77
Medium Loam	--	0.62
Volcanic Ash	0.68	--
Volcanic Ash with some Sand	0.98	--
Coarse Sandy Loam	--	0.92
Sand and Volcanic Ash or Sand and Clay	1.20	--
Fine Sand	--	1.23
Medium Sand	--	1.54
Sandy Soil with some Rock	1.68	--
Coarse Sand and Gravel	--	2.15
Sand and Gravelly Soil	2.20	--

* Values listed are for the C coefficient in the Moritz formula for estimating canal losses in second-feet per mile.
** Bureau of Reclamation, Vol. 4 Water Studies
*** Irrigation Engineering, Davis and Wilson

The loss for the entire canal, or for the design reaches, may be estimated from seepage data in terms of depth for the material involved and stated in convenient terms; acre-feet per acre irrigated per month, cubic-feet per second, or percent of total diversion. The Moritz formula for estimating canal loss in second-feet per mile is

$$S = 0.2\ C\ (Q/V)^{1/2}$$

where

S = Loss in second-feet per mile of canal
Q = discharge of canal in second-feet
V = mean velocity of flow in feet per second
C = depth of water in feet lost through the wetted areas in 24 hours (see table B1-1).

This formula is indicative of results in unchecked flow but is not representative under operating conditions that require checking up the level in the canal appreciably above normal depth in order to facilitate diversions into lateral or farm turnouts. Where diversions from the canal are more or less uniform along the canal, the required capacity may be made proportional to the remaining acreage to be served without direct consideration of seepage loss per foot. The loss in a relatively short reach is only a small percentage of the water carried.

Losses are sometimes stated in percent loss per mile of canal length; and while this terminology is not strictly applicable to canals varying greatly in length it may be acceptable as a guide, particularly if available data are in these terms. The following values are included for use in rough preliminary studies prior to selection of the canal section:

Capacity of canal or lateral ft^3/s	Loss in percent of flow per mile			
	Impervious soils-heavy clay loams	Medium pervious clay loam & silt	Pervious soils sandy loam	Concrete lining
10 or less	4.0 %	8.0 %	12.0 %	1.0 %
10 - 25	2.5 %	4.5 %	7.0 %	0.5 %
26 - 50	1.5 %	3.0 %	4.5 %	0.3 %
51 - 75	1.0 %	2.0 %	3.0 %	0.2 %
76 or more	0.75%	1.5 %	2.5 %	0.15%

Depending upon the cost of developing a water supply and providing for drainage of irrigated land, or upon scarcity of supply, it may be desirable to prepare both water supply studies and cost estimates using different types of systems such as earth, concrete lined, closed pipes, etc., taking into account differences in size of area to be served. Experience shows that some allowance should be made for leakage of concrete and other pavement type linings. Measuring structures should be provided in canals so that the operating personnel can locate seepage points and data can be collected on losses for future use.

Section B2 - Walla Walla Canals: Seepage tests in the Walla Walla, Washington irrigation area have not been performed. Seepage estimates were extrapolated for this area using a base seepage rate of 0.17 cubic feet per square foot of wetted area per day (0.17 $ft^3/ft^2/day$) calculated by ponding methods in the Walla Walla River irrigation area in Oregon State.

During a site visit to the irrigation districts, the Gardena Ditch was diverting about 55 ft^3/s (cubic feet per second). Deliveries at that time totaled about 35 ft^3/s with an estimated 8 ft^3/s overdelivered and wasted. The 12 ft^3/s remaining was assumed to be a combination of seepage, evaporation, and phreatophyte canal losses. Seepage losses for this district were estimated to be 10 ft^3/s which is about 0.27 $ft^3/ft^2/day$. Tables B2-1 and B2-2 show the estimated rates for the 10 districts based on 0.17 and 0.27 $ft^3/ft^2/day$, respectively, using an average canal cross section and a 6-month irrigation period.

The data based on ponding tests will be used for further evaluation in this report as it reflects more reliable measurement techniques. Using the seepage values from table B2-1 which are based on the ponding test data from other areas of the Walla Walla Basin, seepage totals can be computed for various reaches of the system canals. Breaking this data down into groups which are associated with the reaches of canal identified for relining in Table D4-1 of Appendix D, estimated annual seepage losses can be computed for each of these reaches. This will allow an assessment of the potential water savings which could be realized by relining various reaches of the canals.

For example, Gardena Farms - Reach 1 covers the portion of the canal with an 18 foot bottom width. From Table B2-1, the seepage volume in this reach for 6 months of operation is (360+400+850)/2 or 805 acre-feet. A summary of these estimated seepage volumes is shown in Table B2-3.

TABLE E2-1
SEEPAGE ESTIMATES BASED ON 0.17 ft3/ft2/day

	Depth feet	Side slope	Bottom width feet	Length feet miles	Constant ft3/ft2 day	Seepage CFD	Seepage AC-FT/D	Seepage AC-FT/T	Delivery 6 months ft3/s	Total Delivery Acre-Feet	Percent Loss
Gardena Ditch Main											
Sec 3, T 6, R 35, Reach 1	3.12	1.0	18.0	9.452	0.170	43.100	0.99	360			
Sec 9, T 6, R 35, Reach 2	4.17	1.0	18.0	9.400	0.170	47.610	1.09	400			
Reach 3	4.00	1.0	18.0	20,376	0.170	101,540	2.33	850			
Sec 4, T 6, R 34, Reach 4	4.00	1.0	8.0	12,222	0.170	40,130	0.92	340			
Sec 6, T 6, R 34, Reach 5	4.00	1.0	8.0	22,116	0.170	72,610	1.67	610			
Reach 6 P.						0	0.00	0			
Sec 12, T 6, R 33, Reach 7	4.00	1.0	8.0	24,794	0.170	81,410	1.87	680			
Sec 12, T 6, R 33, Reach 8	4.00	1.0	8.0	26,480	0.170	86,940	2.00	730			
Sec 12, T 6, R 33, Reach 9 P.						0	0.00	0			
				23.64		473,340	10.87	3,970			
Seepage for 1/2 year (3 mo. spring, 3 mo. fall)						236,670	5.44	1,985	75.0	26800	7.4%
Smith Ditch Main											
Sec. 4, T 6, R 35, Reach 1	1.00	1.0	4.0	3,388	0.170	3,930	0.09	30			
				0.64							
Seepage for 1/2 year (3 mo. spring, 3 mo. fall)						1,965	0.05	15	2.0	700	2.1%
Stiller Ditch Main											
Sec 28, T 7, R 35, Reach 1	2.00	1.0	6.0	9,615	0.170	19,050	0.44	160			
				1.82							
Seepage for 1/2 year (3 mo. spring, 3 mo. fall)						9,525	0.22	80	5.0	1800	4.4%
Garden City Main											
Sec 35, T 7, R 34, Reach 1	4.00	1.0	5.0	25,521	0.170	70,780	1.62	590			
				4.83							
Seepage for 1/2 year (3 mo. spring, 3 mo. fall)						35,390	0.81	295	16.0	5700	5.2%
Old Lowden Main											
Sec 38, T 7, R 34, Reach 1	3.00	1.0	15.0	11,975	0.170	47,810	1.10	400			
Sec 19 Reach 2	3.00	1.0	9.0	905	0.170	2,690	0.06	20			
Sec 19 Reach 3	3.00	1.0	9.0	3,610	0.170	10,730	0.25	90			
				3.12		61,230	1.41	510			
Seepage for 1/2 year (3 mo. spring, 3 mo. fall)						30,615	0.71	255	12.0	4300	5.9%
Mud District No. 7 Main											
Sec 4, T 6, R 34, Reach 1	3.00	1.0	3.0	13,968	0.170	27,270	0.63	230			
				2.65							
Seepage for 1/2 year (3 mo. spring, 3 mo. fall)						13,635	0.32	115	2.4	900	12.8%
Bergevin-Williams Main											
Sec 37, T 7, R 34, Reach 1	3.00	1.0	6.0	1,700	0.170	4,190	0.10	40			
Sec 35 Reach 2 P.				1,200		0	0.00	0			
Sec 35 Reach 3	2.00	1.0	3.0	12,200	0.170	17,950	0.41	150			
				2.86		22,140	0.51	190			
Seepage for 1/2 year (3 mo. spring, 3 mo. fall)						11,070	0.26	95	5.0	1800	5.3%
Lowden No. 2 Main											
Sec 35, T 7, R 34, Reach 1	3.00	1.0	6.0	28,432	0.170	70,010	1.61	590			
				5.38							
Seepage for 1/2 year (3 mo. spring, 3 mo. fall)						35,005	0.81	295	8.0	2900	10.2%
Touchet East Main											
Sec 15, T 7, R 33, Reach 1	1.50	1.0	7.0	15,467	0.170	29,560	0.68	250			
Sec 15 Reach 2	1.50	1.0	7.0	2,802	0.170	5,360	0.12	40			
Sec 34 Reach 3	1.50	1.0	6.0	8,538	0.170	14,870	0.34	120			
				5.08		49,790	1.14	410			
Seepage for 1/2 year (3 mo. spring, 3 mo. fall)						24,895	0.57	205	12.0	4300	4.8%
Touchet West Main											
Sec 15, T 7, R 33, Reach 1a	2.00	1.0	10.0	4,694	0.170	12,490	0.29	110			
Sec 15 Reach 1b C.	2.00	1.0	10.0	1,500	0.070	1,640	0.04	10			
Sec 22 Reach 2						0	0.00	0			
Sec 28 Reach 3	2.00	1.0	7.0	9,350	0.170	20,120	0.46	170			
Sec 32 Reach 4	2.00	1.0	4.0	5,953	0.170	9,770	0.22	80			
				4.07		44,020	1.01	370			
Seepage for 1/2 year (3 mo. spring, 3 mo. fall)						22,010	0.51	185	18.0	6400	2.9%
System Totals (1/2 year operation):				54.1				3,525.0		55,600.0	6.3%

P. = Pipe Reach
C. = Concrete Lined Reach
ft3/ft2/day = cubic feet per square foot per day

TABLE E2-2
SEEPAGE ESTIMATES BASED ON 0.27 ft3/ft2/day

	Depth feet	Side slope	Bottom width feet	Length feet miles	Constant ft3/ft2 day	Seepage CFD	Seepage AC-FT/D	Seepage AC-FT/T	Delivery 6 months ft3/s	Total Delivery Acre-Feet	Percent Loss
Gardena Ditch Main											
Sec 3, T 6, R 35, Reach 1	3.12	1.0	18.0	9,452	0.270	88,460	1.57	570			
Sec 9, T 6, R 35, Reach 2	4.17	1.0	18.0	9,400	0.270	75,620	1.74	640			
Reach 3	4.00	1.0	18.0	20,376	0.270	161,270	3.70	1,350			
Sec 4, T 6, R 34, Reach 4	4.00	1.0	8.0	12,222	0.270	63,730	1.46	530			
Sec 6, T 6, R 34, Reach 5	4.00	1.0	8.0	22,116	0.270	115,330	2.65	970			
Reach 6 P.						0	0.00	0			
Sec 12, T 6, R 33, Reach 7	4.00	1.0	8.0	24,794	0.270	129,290	2.97	1,080			
Sec 12, T 6, R 33, Reach 8	4.00	1.0	8.0	26,480	0.270	138,090	3.17	1,160			
Sec 12, T 6, R 33, Reach 9 P.						0	0.00	0			
				23.64		751,790	17.26	6,300			
Seepage for 1/2 year (3 mo. spring, 3 mo. fall)						375,895	8.63	3,150	75.0	26800	11.8%
Smith Ditch Main											
Sec. 4, T 6, R 35, Reach 1	1.00	1.0	4.0	3,388	0.270	6,250	0.14	50			
				0.64							
Seepage for 1/2 year (3 mo. spring, 3 mo. fall)						3,125	0.07	25	2.0	700	3.6%
Stiller Ditch Main											
Sec 28, T 7, R 35, Reach 1	2.00	1.0	6.0	9,615	0.270	30,260	0.69	250			
				1.82							
Seepage for 1/2 year (3 mo. spring, 3 mo. fall)						15,130	0.35	125	5.0	1800	6.9%
Garden City Main											
Sec 35, T 7, R 34, Reach 1	4.00	1.0	5.0	25,521	0.270	112,410	2.58	940			
				4.83							
Seepage for 1/2 year (3 mo. spring, 3 mo. fall)						56,205	1.29	470	16.0	5700	8.2%
Old Lowden Main											
Sec 36, T 7, R 34, Reach 1	3.00	1.0	15.0	11,975	0.270	75,930	1.74	640			
Sec 19 Reach 2	3.00	1.0	9.0	905	0.270	4,270	0.10	40			
Sec 19 Reach 3	3.00	1.0	9.0	3,610	0.270	17,040	0.39	140			
				3.12		97,240	2.23	820			
Seepage for 1/2 year (3 mo. spring, 3 mo. fall)						48,620	1.12	410	12.0	4300	9.5%
Hud District No. 7 Main											
Sec 4, T 6, R 34, Reach 1	3.00	1.0	3.0	13,968	0.270	43,320	0.99	360			
				2.65							
Seepage for 1/2 year (3 mo. spring, 3 mo. fall)						21,660	0.50	180	2.4	900	20.0%
Bergevin-Williams Main											
Sec 37, T 7, R 34, Reach 1	3.00	1.0	6.0	1,700	0.270	6,650	0.15	50			
Sec 35 Reach 2 P.				1,200		0	0.00	0			
Sec 35 Reach 3	2.00	1.0	3.0	12,200	0.270	28,520	0.65	240			
				2.86		35,170	0.80	290			
Seepage for 1/2 year (3 mo. spring, 3 mo. fall)						17,585	0.40	145	5.0	1800	8.1%
Lowden No. 2 Main											
Sec 35, T 7, R 34, Reach 1	3.00	1.0	6.0	28,432	0.270	111,200	2.55	930			
				5.38							
Seepage for 1/2 year (3 mo. spring, 3 mo. fall)						55,600	1.28	465	8.0	2900	16.0%
Touchet East Main											
Sec 15, T 7, R 33, Reach 1	1.50	1.0	7.0	15,467	0.270	46,950	1.08	390			
Sec 15 Reach 2	1.50	1.0	7.0	2,802	0.270	8,510	0.20	70			
Sec 34 Reach 3	1.50	1.0	6.0	8,538	0.270	23,610	0.54	200			
				5.08		79,070	1.82	660			
Seepage for 1/2 year (3 mo. spring, 3 mo. fall)						39,535	0.91	330	12.0	4300	7.7%
Touchet West Main											
Sec 15, T 7, R 33, Reach 1a	2.00	1.0	10.0	4,694	0.270	19,840	0.46	170			
Sec 15 Reach 1b C.	2.00	1.0	10.0	1,500	0.270	6,340	0.15	50			
Sec 22 Reach 2						0	0.00	0			
Sec 28 Reach 3	2.00	1.0	7.0	9,350	0.270	31,950	0.73	270			
Sec 32 Reach 4	2.00	1.0	4.0	5,953	0.270	15,520	0.36	130			
				4.07		73,650	1.70	620			
Seepage for 1/2 year (3 mo. spring, 3 mo. fall)						36,825	0.85	310	18.0	6400	4.8%
System Totals (1/2 year operation):				54.1				5,610.0		55,600.0	10.1%

P. = Pipe Reach
C. = Concrete Lined Reach
ft3/ft2/day = cubic feet per square foot per day

Table B2-3

ESTIMATED SEEPAGE VOLUMES*

FOR CANAL RELINING REACHES

CANAL/DITCH	Est. Length (Miles)	Est. Average Bottom Width (ft.)	Est. Annual Seepage Volume W/O Lining (Acre-Feet)	Estimated Seepage Volume For Six Month Operation W/O Lining (Acre-Feet)
Gardena Farms - Reach 1:	7.4	18	1,610	805
Reach 2:	16.2	8	2,360	1,180
Touchet East:	5.1	7	410	205
Touchet West - Reach 1:	1.2	10	120	60
Reach 2:	2.9	7	250	125
Garden City:	4.8	5	590	295
Old Lowden - Reach 1:	2.3	15	400	200
Reach 2:	0.9	9	110	55
Lowden No. 2:	5.4	6	590	295
Mud Creek No. 7:	2.6	3	230	115
Bergevin-Williams:	2.9	3	190	95
Stiller Ditch:	1.8	6	160	80
Smith Ditch:	.6	4	30	15
Total Seepage Volume:				3,525

* Volumes taken from Table B2-1

Section B3 - Conclusions and Recommendations: Based on the seepage rates used in this study, the amount of seepage from most of the canals in the study area would not seem to warrant lining the canals or installing pipe to carry the canal flow. The only canal which appears to have the potential for significant seepage losses is Mud Creek No. 7. It would be to the irrigation districts advantage to have seepage tests performed in their respective districts in order that a more exact seepage coefficient may be found. The first step in determining areas of potential seepage should be installation of temporary or permanent flow measuring devices along each canal and at each turnout. This will allow an accurate assessment of which reaches are experiencing losses. Once general reaches of canal are identified as having seepage potential, ponding tests can be performed to quantify the seepage rates. When the seepage rates are known, an informed decision can be made as to whether the costs involved in lining the canal or replacing it with pipe are warranted.

APPENDIX C:

OPERATION AND MAINTENANCE RECOMMENDATIONS

Section C1 - General: To reduce diversions and waste from the canal systems, water scheduling with some advance notice, generally 24 hours, is needed. Turnouts between check structures could then be regulated more efficiently with a predetermined water surface elevation. Pumps that presently pull water directly from the canal should receive their deliveries from a turnout structure, which could be more easily measured and have less impact on canal levels. The turnout gates could be locked to prevent landowners from turning on pumps at their leisure. Additional check structures may be needed in reaches where there is a greater water demand.

In all but the largest districts within the study area, control of weed and grass growth both in the canal channels and along the canal banks is a maintenance issue which appears to be neglected. Only the Gardena Farms Canal appeared to have an effective program for vegetative management. The impacts of the growth of such vegetation, include water losses to support the vegetation itself and a reduced canal channel efficiency. The reduction in channel efficiency is discussed in detail in Section C2 below.

All siphons and culvert crossings should be dewatered and examined to check for obstructions or sediment deposition in the pipes. Buried siphons should be dewatered during periods of low ground water to minimize the possibility of floating the pipe. Once the condition of the buried siphons are determined, continued inspections should not be required unless significant maintenance problems are discovered. Highway crossings may be presently examined by the responsible highway department, thus reducing some of this workload. The two major inverted siphons in the valley are the East Side Siphon which crosses under the Touchet River and the Gardena Siphon which crosses under Pine Creek. Lowden No. 2 contains a siphon at Mud Creek which consists of an exposed steel pipe. The steel pipe has no protective exterior coating that might extend its service life.

Major equipment can be shared, leased, or purchased through a cooperative effort between the smaller irrigation companies in the basin. Equipment use could be scheduled to avoid conflicts based upon the monies contributed toward the maintenance or purchase of such equipment. Once all the ditches and canals are adequately improved, conflicts in use of such equipment should be fewer with routine maintenance scheduled for the various reaches.

To ensure adequate water supplies for all diversions in the basin, each diverter should prepare a water conservation and management plan. The plan should establish goals such as more extensive water measurement, prioritize work activities having the most impact on conveyance efficiency including structural alternatives, and outline a schedule for implementation of programs. The plan should allow for funds to be set aside for studies and construction. Some of the alternatives presented in this assessment can serve as the basis for the plan.

Section C2- Impacts of Canal Lining Condition: For the canal conveyance systems, the Manning's roughness coefficient 'n', increases with constrictions to flow. The n-value for a concrete-lined canal is generally less than 0.020, and greater than 0.075 for the river courses in the study basin. The better reaches of the Gardena system had n-values near 0.029. Most canals in the study area had n-values of about 0.040, with some reaches approaching 0.060 where weeds have almost blocked the channel. Since a reduction in n-value results in increased flow, improved canal cleaning of surface and aquatic weeds in the smaller canal systems could allow as much as twice the present flow in the more severely constricted reaches of canal. The majority of the canals in the valley have good lining composed of a combination of silts and clays, forming a watertight matrix. During drought conditions, these linings would probably dry up and crack, opening seepage paths that would create problems once water service is restored.

Flexible canal liners, such as the reinforced bitumen material used by the Kennewick Irrigation District near Kennewick, Washington, could improve flow further, n-value of 0.016, since cover materials are not always required. The reinforced bitumen is washed down periodically and accumulated sediments removed by rubber tired vehicles. Other flexible canal liners which require earth cover would also improve water passage; but a greater canal width would be needed since sideslopes should be at least 2.5:1 to retain the cover material. Weed growth would need to be removed from the earth cover to prevent reductions in flow.

Concrete lining could improve the n-value to 0.015. Silts and other sediments would still need to be removed to prevent weed growth atop the lining. Flap valves would be required in portions of the alinement which have high water tables to avoid back pressure and uplift on the lining.

APPENDIX D:

COST ANALYSES

Section D1 - General: Costs estimates provided in this report are appraisal grade field costs. Appraisal estimates are for use in appraisal reports and not for recommending project authorization, funding, and implementation. Appraisal estimates may be prepared from cost curves, simple sketches, or rough general designs. Such estimates normally are used as an aid in selecting the most economical plan by comparing alternative features such as dam types, dam sites, canal or pipeline routes, powerplant or pumping plant capacities, etc.

Appraisal estimates may be used in appraisal reports for the purpose of determining whether more detailed investigations of a potential project are economically justified. This method of determining costs should be used only when it is desirable to obtain approximate costs in a short period of time where available data is inadequate for the preparation of feasibility estimates.

The allowance for unlisted items in appraisal estimates should be at least 10 percent of the listed items. This line item in the appraisal estimate may be considered as a contingency for design changes and also to eliminate itemizing the pay items in the estimate that will have little influence on the total cost.

The allowance for contingencies provides additional monies which may be required for changes in the scope or nature of the work which become apparent as final design proceeds.

All costs developed in this report include allowances for 10 percent unlisted items and 25 percent for contingencies. The costs presented in this report do not include monies for contract administration or for the development of designs and specifications.

Section D2 - Seepage Measurement Costs: Ponding tests provide the most economical and direct means of determining seepage rates. Costs vary based on the size of each canal. Costs can be expected to be in the $4,500 to $7,000 range for each test on the canals in this study. A recommendation concerning the number of tests for each canal should be reserved until flow measurements along the canal identify reaches of higher losses.

Section D3 - Canal Flow Measurement Costs: The estimated costs for installing permanent flow measuring devices on each canal in the study group is summarized in table D3-1. The estimated costs include installation of weir plates on existing main line structures such as check or drop structures and construction of weir structures at each wasteway to allow measurement of operational waste flows. Installation of Parshall or ramp flumes on the main canals and wasteways would also provide reliable flow measurement. Costs for these structures have not been included in this report however.

The costs computed for farm turnout measurement devices provide three options for measuring flow to sprinkler deliveries; 1) installation of a saddle type propeller flow meter on the farmer's discharge pipe, 2) construction of a meter structure between the canal and the farmer's pump sump (the meter structure would house a propeller flow meter in a newly installed section of low pressure pipe), and 3) construction of a constant head orifice structure at the canal turnout. Estimated costs for measurement of gravity turnouts assume installation of a small weir structure in each farmer's ditch. The combined costs of mainline measurement and farm turnout measurement are summarized for each of the three options for measuring pumped turnout flows in the far right hand columns.

Table 03-1

FLOW MEASUREMENT COST SUMMARY

CANAL/DITCH	Main Line Weir Costs	Farm Turnouts	Assumed % Gravity Turnouts	Turnout Measurement Costs Only			Total Measurement Costs For Canal System		
				With Flow Meter Only	With Meter Structure	With C.H.O.*	With Flow Meter Only	With Meter Structure	With C.H.O.*
Gardena Farms	$15,000	63	10%	$55,000	$223,000	$280,000	$70,000	$238,000	$295,000
Touchet East Side	$7,000	20	15%	$18,000	$68,000	$85,000	$25,000	$75,000	$92,000
Touchet West Side	$7,000	18	15%	$16,000	$60,000	$75,000	$23,000	$67,000	$82,000
Garden City	$2,000	14	75%	$14,000	$22,000	$25,000	$16,000	$24,000	$27,000
Old Lowden	$2,000	17	70%	$16,000	$31,000	$36,000	$18,000	$33,000	$38,000
Lowden No. 2**	$4,000	22	75%	$21,000	$36,000	$41,000	$25,000	$38,000	$43,000
Bergevin-Williams	$2,000	10	70%	$10,000	$18,000	$21,000	$12,000	$20,000	$23,000
Stiller	$0	4	0%	$3,500	$15,000	$19,000	$3,500	$15,000	$19,000
Smith	$2,000	4	0%	$3,500	$15,000	$19,000	$5,500	$17,000	$21,000
TOTALS		172					$198,000	$532,000	$646,000

* C.H.O. refers to Constant Head Orifice structures.

** Includes Mud Creek No. 7 ditch.

Section D4 - Canal Lining Costs: Canal lining costs estimates curves were developed for canals with bottom widths of 10 feet, and larger and canals with bottom widths of 8 feet and smaller. Lining of small canals was based on bottom width sizes of 4, 6, and 8 feet with unreinforced concrete lining 2 inches thick. Large canals were estimated based on bottom widths of 10, 12, and 14 feet with unreinforced concrete lining 4 inches thick.

Several canal alternatives may be suitable for the Walla Walla area irrigation districts. The cost curves presented represent four possible methods to correct the canal prisms. These methods are listed below:

Reshape and clean: This action would require some cut and fill material be moved and would also bring the canals back on and establish grade. The cost for this type of work would be about $7,500 per mile.

Concrete lined canals: For canals with a bottom width from 2 to 10 feet, unreinforced concrete 2 inches thick placed on a 1.5 to 1 sideslope is assumed. For canals with a bottom width from 10 to 18 feet, unreinforced concrete 4 inches thick placed on a 1.5 to 1 sideslope is assumed. Figure D4-1 shows the cost curve for the 2 inch thick lining alternative while Figure D4-2 shows the cost curve for the larger canals with 4 inch thick lining.

Reinforced concrete lined canals: This lining option is not included in the cost analysis listed in Table D4-1 or in the conclusions section of this report as it isn't expected to be required in this study area. The cost figures may however, prove useful if localized areas of high settlement are encountered in this study area or in others throughout the State. Figure D4-2 shows the cost curve for this alternative.

Flexible membrane lined canals: There are many different types of flexible lining materials, some require a 12- to 18-inch cover material, usually sand or gravel, to materials that have an ultraviolet protective additive which will not require a sand or gravel cover. Polyvinyl chloride (PVC) is used for estimating purposes in this report. One cost curve, figure D4-3, is presented for PVC material of various thicknesses. Normally the thickness of a PVC membrane used for canals is 40 mills or less. Reclamation experience has shown the final installed price of 20 mill membranes in canal linings to be approximately equal to the final installed price of canal linings with 10 mill membranes. This is due to the miscellaneous costs associated with installing the lining. Therefore, the minimum membrane thickness considered for installation should be 20 mills.

To determine a cost for this alternative, determine the number of square feet required to line the canal and add $7,500 per mile for canal reshaping and cleaning. For example, a 6-foot bottom width canal with 2.5 to 1 sideslopes, 3 feet deep with 1 foot freeboard (total canal depth = 4 feet), 1 mile long, using a 30 mill PVC membrane would cost about $62,500.

Use of the figures listed above will allow general assessment of a variety of canals both within this report study area and throughout the state. Table D4-1 summarizes the costs of relining the canals and ditches in the study area.

Table D4-1
CANAL RELINING COST SUMMARY

CANAL/DITCH	Est. Length (Miles)	Est. Average Bottom Width (ft.)	Concrete Lined Total Cost (Cost/Mile)	PVC Lined Total Cost (Cost/Mile)
Gardena Farms - Reach 1:	7.4	18	$1,124,800 ($152,000)	$622,000 ($84,000)
Reach 2:	16.2	8	$1,783,000 ($110,000)	$1,080,000 ($67,000)
Touchet East:	5.1	7	$508,000 ($100,000)	$250,000 ($50,000)
Touchet West Reach 1:	1.2	10	$132,000 ($110,000)	$70,000 ($58,000)
Reach 2:	2.9	7	$290,000 ($100,000)	$270,000 ($93,000)
Garden City:	4.8	5	$386,000 ($80,000)	$190,000 ($39,000)
Old Lowden Reach 1:	2.3	15	$340,400 ($148,000)	$185,000 ($80,500)
Reach 2:	0.9	9	$102,000 ($113,000)	$60,000 ($67,000)
Lowden No. 2:	5.4	6	$484,200 ($90,000)	$336,000 ($62,000)
Mud Creek No. 7:	2.6	3	$158,700 ($60,000)	$130,000 ($50,000)
Bergevin-Williams	2.9	3	$171,600 ($59,000)	$145,000 ($50,000)
Stiller Ditch	1.8	6	$163,800 ($91,000)	$85,000 ($47,000)
Smith Ditch	.6	4	$44,800 ($75,000)	$55,000 ($92,000)
Total Length:	54.1			
Average Cost per Mile:			($105,000)	($64,000)

UNREINFORCED CONCRETE CANAL 2" THICK

COST PER MILE JULY 1990 PRICE LEVEL
APPRAISAL GRADE

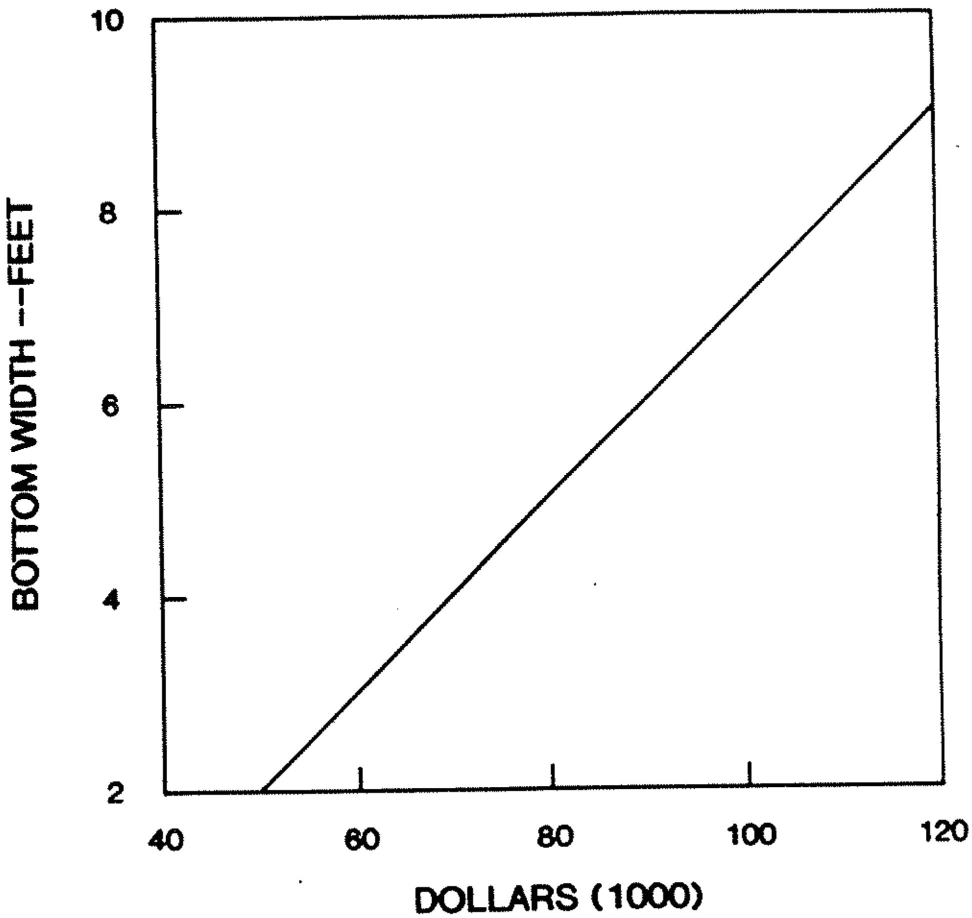


FIGURE D4-1

REINFORCED AND UNREINFORCED CONCRETE CANAL 4" THICK

COST PER MILE JULY 1990 PRICE LEVEL APPRAISAL GRADE

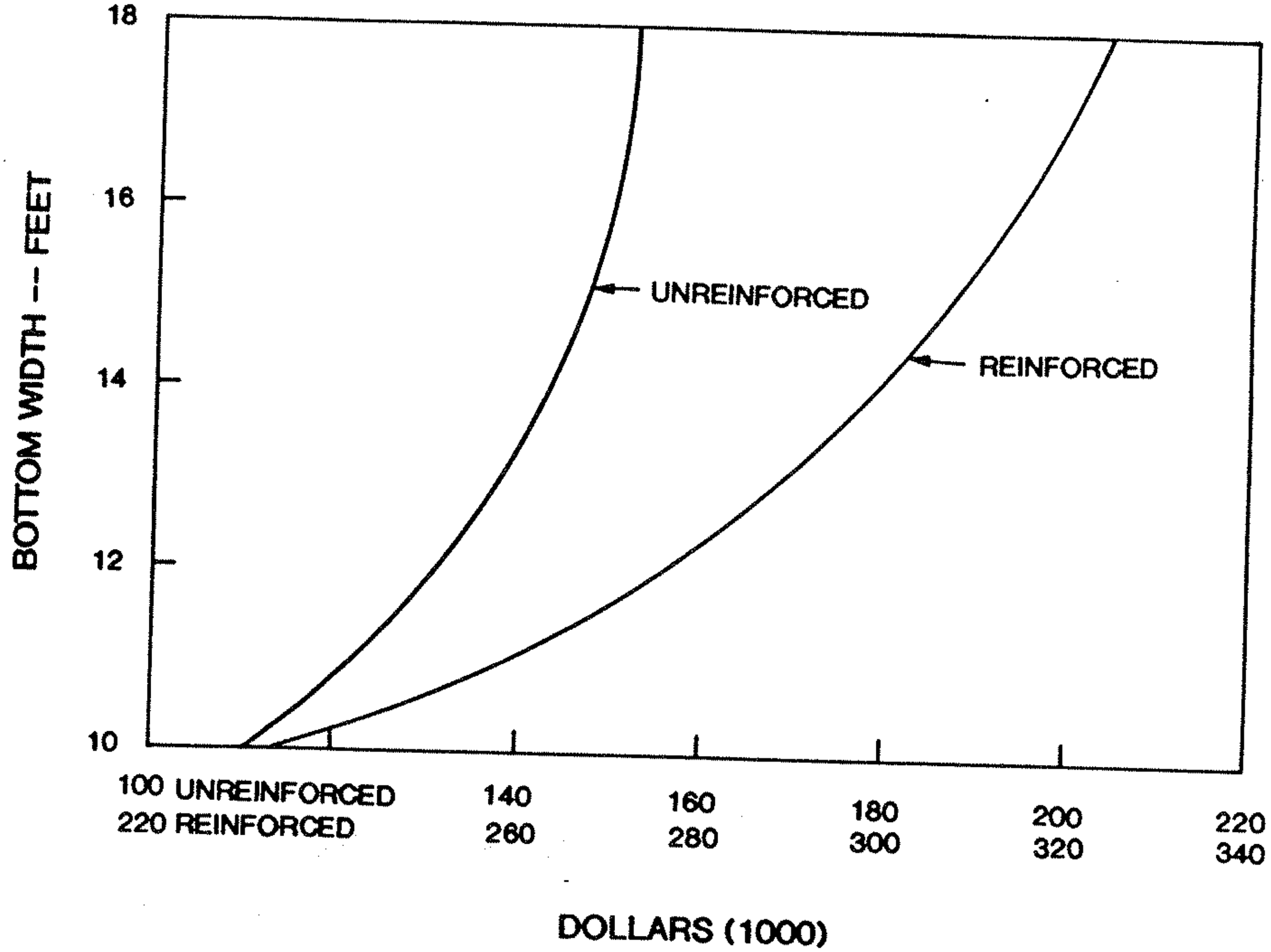


FIGURE D4-2

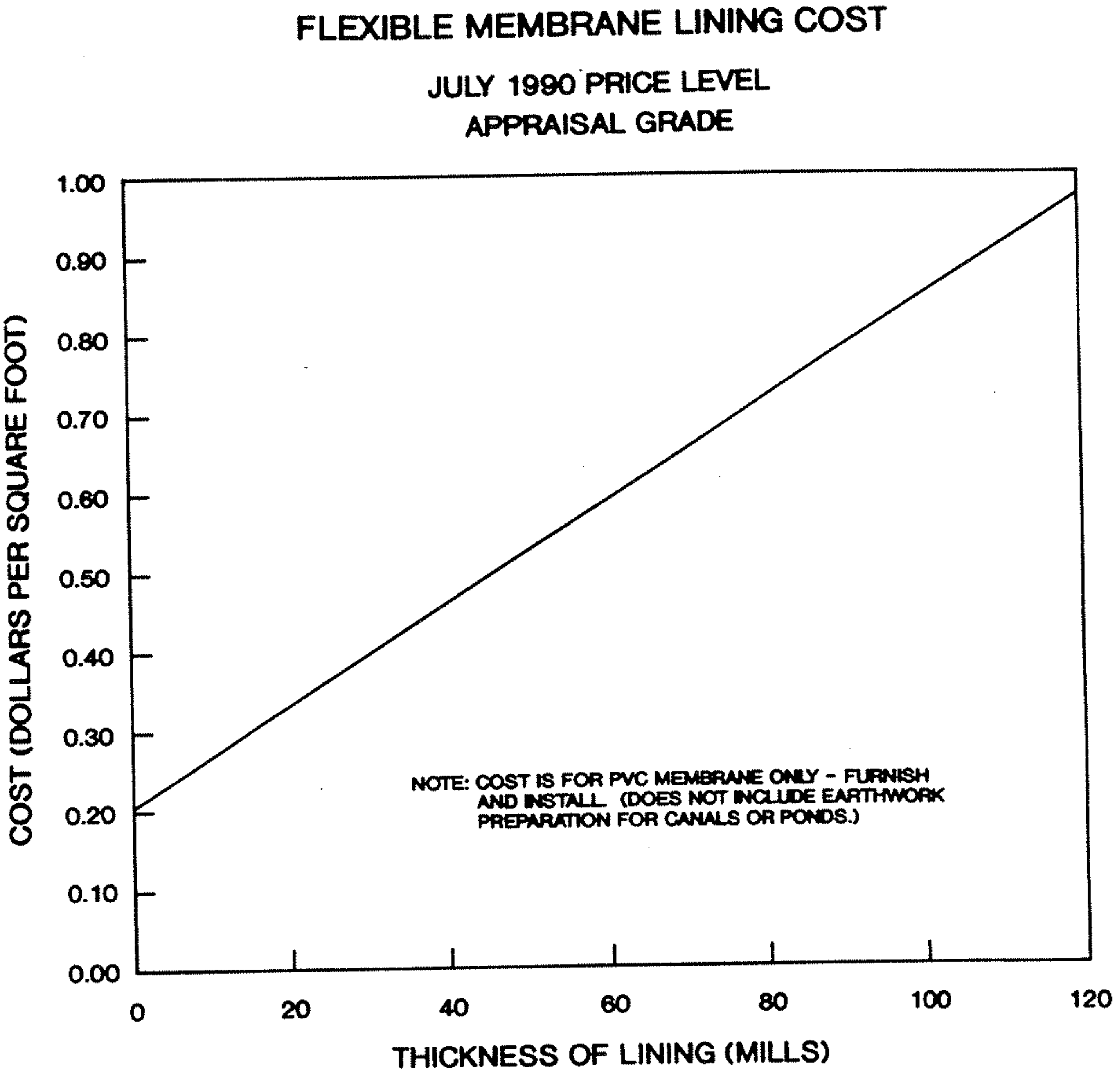

FLEXIBLE MEMBRANE LINING COST
JULY 1990 PRICE LEVEL
APPRAISAL GRADE
COST (DOLLARS PER SQUARE FOOT)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
20
40
60
80
100
120
THICKNESS OF LINING (MILLS)
NOTE: COST IS FOR PVC MEMBRANE ONLY - FURNISH AND INSTALL. (DOES NOT INCLUDE EARTHWORK PREPARATION FOR CANALS OR PONDS.)

FIGURE D4-3

Section D5 - Replacement of Canals with Pipe Systems: The cost of providing pipe systems to replace the existing canal systems has been summarized in table D5-1. The pipe systems are sized to allow delivery of current flow rates to the water surfaces currently served by the canal systems. The cost of replacing entire canals as well as average cost per mile have been included to allow comparison of pipe replacement and canal relining projects.

It should be noted that the pipe lengths used in this estimate assume the newly constructed pipelines would follow the existing canal alignments. The canal alignments are bound by gravity delivery of water and a replacement pipeline would not. Therefore, shorter more direct pipeline alignments could be used. This would reduce the cost of pipe replacement and make this option more competitive with canal relining as a method of reducing canal seepage.

Pipe replacement costs per mile in other areas of the State should be comparable to the figures developed in this report for canals of similar capacities.

Some of the canal lengths shown in table D5-1 below differ from those in table D4-1 in section 4 of this appendix which shows canal relining costs. The Gardena Farms canal length shown in table D4-1 includes approximately 2.9 miles of wasteway channel which would not be replaced by pipe. The lengths of the Touchet East, Garden City, Old Lowden, and Lowden No. 2 canals shown in table D4-1 do not include lateral delivery ditches. The lengths given in table D5-1 below, include these lateral ditches. Cost comparisons between the canal relining costs shown in table D4-1 and the pipe replacement costs shown in table D5-1 below are still valid however if the average cost per mile figures are used.

Table D5-1

PIPE REPLACEMENT
COST SUMMARY

CANAL/DITCH	Flow (ft^3/s)	Pipe Dia. Range (inches)	Cost for Total Pipe Replacement	Length (miles)	Average Cost Per Mile
Gardena Farms	80	30" - 57"	$20,500,000	20.5	$1,000,000
Touchet East	30	22" - 33"	$3,200,000	5.7	$560,000
Touchet West	18	21" - 30"	$1,650,000	4.1	$400,000
Garden City	16	15" - 27"	$2,400,000	7.3	$329,000
Old Lowden	12	12" - 27"	$1,850,000	5.9	$314,000
Lowden #2*	8	12" - 24"	$1,900,000	8.0	$238,000
Bergevin-Williams	5	12" - 16"	$550,000	2.9	$196,000
Stiller Ditch	5	10" - 18"	$370,000	1.8	$205,000
Smith Ditch	2	8" - 10"	$73,000	.6	$114,000
Total			$32,493,000	56.9	$572,000

*Includes Mud Creek No. 7 canal.

Section D6 - Diversion Structure Costs: Currently six irrigation districts take water from the Walla Walla River, and one district takes its water from Mill Creek. Two districts get their water from the Touchet River, and the remaining district has water delivered to it by way of the Lowden No. 2 main canal.

Diversion structures will be given in cost per foot of weir length based on drawings 1464-D-10 and 1464-D-11 and drawings 1464-D-61 through 1464-D-63 and a gated headwork and sluiceway also based on the same drawings. These drawings are included in Appendix F. The cost estimates for the diversion structures are based on similar structures built by Reclamation for the Valarde Project on the Rio Grande near the city of Espanola, New Mexico.

The Touchet and Gardena Irrigation districts have in place concrete diversion structures with headworks. Individual structures could be built to serve Smith, Lowden No. 2, Old Lowden, Bergevin-Williams, and Garden City Irrigation Districts on the Walla Walla River, and Stiller Irrigation District on Mill Creek. Each diversion would have a headwork and sluiceway similar to that shown on the drawings enclosed in Appendix F. This combination would cost about $260,000 each. To determine the cost for the weir see figure D6-1. Because each weir would vary in length, all the diversion structures would vary in total costs. Since exact dimensions for the potential diversion structures were not identified during this portion of the assessment study, costs for each diversion are not included in this report. Total estimated costs for each individual diversion structure can be computed by adding the weir costs (computed by using figure D6-1 and the length of the dam) to the $260,000 required per canal turnout.

DIVERSION STRUCTURE SHEET PILING WEIR

COST PER FOOT OF WEIR JULY 1990 PRICE LEVEL
APPRAISAL GRADE

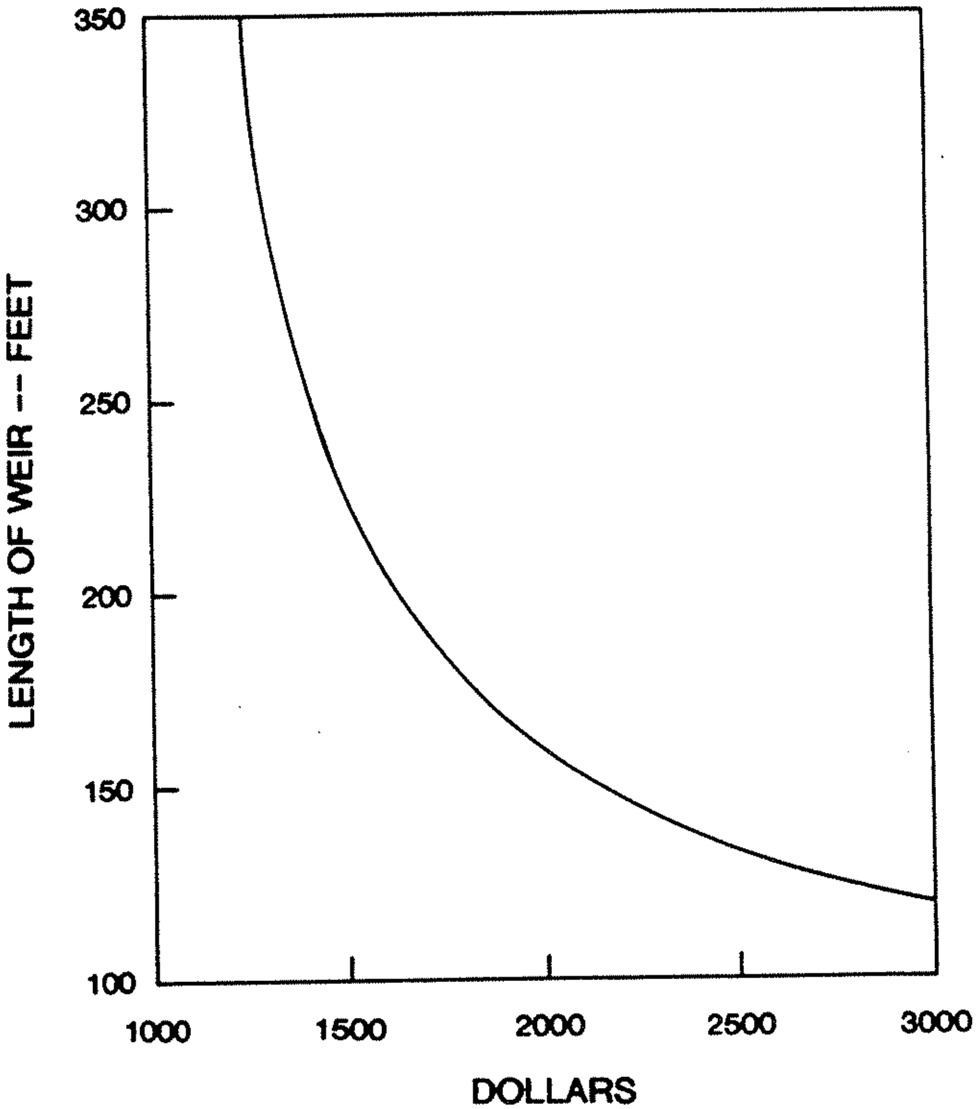


FIGURE D6-1

The possibility that four irrigation districts may be served from one diversion structure may be one way to save money and reduce the O&M costs of maintaining several structures. Bergevin-Williams and Old Lowden on the north side of the Walla Walla River could be served with one combined headworks, and Lowden No. 2 and Garden City on the south side of the river could also be served with one headworks. Both headworks would be installed on one diversion structure. The cost of this structure would be about $1,375,000 as shown below:

Headworks (2)	$ 520,000
Weir (assumed 200 feet)	330,000
Access canal to Garden City Ditch 2500'	150,000
	1,000,000
10% unlisted	100,000
	1,100,000
25% contingencies	275,000
Total Field Costs	$1,375,000

The cost of four individual dams, with 200 feet weir lengths, is about $3,250,000 as shown below:

Headworks (4)	$1,040,000
Weir (4)	1,320,000
	2,360,000
10% unlisted	240,000
	2,600,000
25% contingencies	650,000
Total Field Costs	$3,250,000

In addition to the $1,875,000 savings in initial construction costs of building a single diversion structure vs. building four separate structures, operations and maintenance costs would also be lower for a single structure. A combined structure would also allow for better control and delivery of irrigation flows to each canal by coordinating the operations of the five ditch companies served by the combined diversion.

The Smith Ditch could use the existing Gardena Farms diversion structure to divert flows. A new headworks and approximately .75 mile of new canal would need to be constructed to convey water from the Gardena Farms structure to the existing Smith Ditch. The estimated costs for such an installation are listed below:

Headworks (1) (On existing Gardena Farms Diversion Structure)	$ 260,000
Access canal to Smith Ditch 4000 ft.	100,000
	360,000
10% unlisted	36,000
	396,000
25% contingencies	99,000
Total Field Costs	$495,000

If these combined diversions were constructed, only one gravel diversion would remain in the study area (Stiller Ditch on Mud Creek). Assuming this structure would require a 200 foot weir length and one headworks, the estimated cost for replacing this diversion structure would be as shown below:

Headworks (1)	$ 260,000
Weir (assumed 200 feet)	330,000
	590,000
10% unlisted	60,000
	650,000
25% contingencies	162,500
Total Field Costs	$812,500

The total cost of replacing all gravel diversions in the study area would therefore be approximately $2,700,000 ($1,375,000 for the combined diversion plus $495,000 for the new Smith diversion features plus $812,500 for the Stiller diversion).

Section D7 - Operation and Maintenance Costs: Cost estimates for maintenance costs on canal systems are not well documented throughout the industry. The cost estimates presented here are based on a limited data base and should only be used for comparison purposes. The estimated maintenance costs shown in Table D7-1 assume an average annual maintenance cost of $0.0068 per square foot of canal wetted perimeter and is based on experience on a similar canal system. The average annual cost for maintenance in the study area using these assumptions is approximately $600 per mile per year. Actual maintenance costs may vary significantly from this assumed value and likely will be lower within this study area.

To obtain more reliable cost figures, a program to quantify maintenance costs currently being expended the Gardena Farms district. Taking these costs and adding twenty five percent for additional maintenance activities would provide a more reliable base cost for local conditions. The cost of improved maintenance programs for the smaller ditches in the study area could then be estimated by comparing the sizes of the ditches.

The reasons for the relatively high O&M costs for earth-lined canals include weed burning, pesticide use, and canal reshaping to remove sediments and sloughed canal banks. In the Walla Walla River Basin, the irrigation systems are constricted in places with weed growth, and other debris creating less than optimum conditions for water passage. To restore sections of these canal systems may necessitate expenditures approaching $1,400/mile.

Reclamation experience has determined that it is more cost effective to use pipe where a canal capacity is less than 50 ft^3/s. Sand traps or settling basins may be required where diverted water contains suspended sediments.

Table D7-1
Estimated Canal Maintenance Costs

	Depth feet	Side slope	Bottom width feet	Length feet (miles)	Wetted Area (sq ft)	Total Cost	Cost per mile
Gardena Ditch Main							
Sec 3, T 6, R 35, Reach 1	3.12	1.0	18.0	9,452	253,547	$1,724.29	$963.21
Sec 9, T 6, R 35, Reach 2	4.17	1.0	18.0	9,400	280,069	$1,904.65	$1,069.85
Reach 3	4.00	1.0	18.0	20,376	597,296	$4,062.01	$1,052.58
Sec 4, T 6, R 34, Reach 4	4.00	1.0	8.0	12,222	236,052	$1,605.31	$693.51
Sec 6, T 6, R 34, Reach 5	4.00	1.0	8.0	22,116	427,142	$2,904.85	$693.51
Reach 6 P.							
Sec 12, T 6, R 33, Reach 7	4.00	1.0	8.0	24,794	478,864	$3,256.60	$693.51
Sec 12, T 6, R 33, Reach 8	4.00	1.0	8.0	26,480	511,427	$3,478.05	$693.51
Sec 12, T 6, R 33, Reach 9 P.							
				23.64	2,784,397	$18,935.76	$800.87
Smith Ditch Main							
Sec. 4, T 6, R 35, Reach 1	1.00	1.0	4.0	3,388	23,135	$157.33	$245.19
				0.64	23,135	$157.33	$245.19
Stiller Ditch Main							
Sec 28, T 7, R 35, Reach 1	2.00	1.0	6.0	9,615	112,081	$762.22	$418.57
				1.82	112,081	$762.22	$418.57
Garden City Main							
Sec 35, T 7, R 34, Reach 1	4.00	1.0	5.0	25,521	416,342	$2,831.40	$585.78
				4.83	416,342	$2,831.40	$585.78
Old Lowden Main							
Sec 38, T 7, R 34, Reach 1	3.00	1.0	15.0	11,975	281,236	$1,912.59	$843.30
Sec 19 Reach 2	3.00	1.0	9.0	905	15,824	$107.61	$627.85
Sec 19 Reach 3	3.00	1.0	9.0	3,610	63,122	$429.27	$627.85
				3.12	360,182	$2,449.48	$784.31
Mud District No. 7 Main							
Sec 4, T 6, R 34, Reach 1	3.00	1.0	3.0	13,968	160,426	$1,091.01	$412.41
				2.65	160,426	$1,091.01	$412.41
Bergevin-Williams Main							
Sec 37, T 7, R 34, Reach 1	3.00	1.0	6.0	1,700	24,625	$167.47	$520.13
Sec 35 Reach 2 P.				1,200	0	$0.00	$0.00
Sec 35 Reach 3	2.00	1.0	3.0	12,200	105,614	$718.24	$310.85
				2.86	130,239	$885.71	$309.71
Lowden No. 2 Main							
Sec 35, T 7, R 34, Reach 1	3.00	1.0	6.0	28,432	411,846	$2,800.82	$520.13
				5.38	411,846	$2,800.82	$520.13
Touchet East Main							
Sec 15, T 7, R 33, Reach 1	1.50	1.0	7.0	15,467	173,890	$1,182.57	$403.70
Sec 15 Reach 2	1.50	1.0	7.0	2,802	31,502	$214.23	$403.70
Sec 34 Reach 3	1.50	1.0	6.0	8,538	87,452	$594.73	$367.79
				5.08	292,843	$1,991.53	$392.26
Touchet West Main							
Sec 15, T 7, R 33, Reach 1a	2.00	1.0	10.0	4,694	73,493	$499.80	$562.20
Sec 15 Reach 1b C.	2.00	1.0	10.0	1,500	23,485	$159.72	$562.20
Sec 22 Reach 2					0	$0.00	
Sec 28 Reach 3	2.00	1.0	7.0	9,350	118,342	$804.80	$454.48
Sec 32 Reach 4	2.00	1.0	4.0	5,953	57,487	$390.95	$346.75
				4.07	175,829	$1,195.75	$293.70
				54.10	4867320	$33,101.03	$611.83

APPENDIX E:

FIELD REVIEW OBSERVATIONS

During the field review of the study area, numerous observations were made by the review team concerning specific canals. These observations included maintenance procedures, structural facilities, and operational procedures. The following list summarizes these specific observations and recommendations by canal:

Gardena Farms Canal:

1. Canal is fairly well maintained.
2. No areas of observed seepage were noted along the canal. Siphon under Pine Creek should be inspected for silt deposition and leaks.
3. Water deliveries are scheduled along with ditch rider adjusting diversion gate and farm turnouts.
4. Canal banks between siphon inlet and the wasteway to Pine Creek should be raised so the wasteway could spill canal flows if the siphon inlet plugs.
5. Flow measurement is done at diversion only. Portable flow meters allow spot checking. Numerous existing structures could be used to install weir plates and should be installed on farm turnouts. Such installations would greatly reduced the effort ditch riders currently must use to adjust the system.
6. Users would benefit from storage development at Mill Creek project if it is done. On farm storage ponds could be developed to better regulate farm deliveries.

Touchet East and West Canals:

1. East and West Side canals share a common diversion. Flow is split at a division structure which houses Cipolletti weirs with flow recorders. Structure acts as a proportional division. Therefore, any increase in flow to one canal also adds flow to the other canal even if not needed. Wasteways near the upstream end of the canals are in place, which would allow this excess to be returned to river just downstream of the diversion, but they do not appear to be used. Recommend either improved use of wasteways or installation of gates to each canal.
2. Canal maintenance is quite good. Some weed growth in canal.
3. West side has an area of high seepage in a reach where the canal is constructed on a hillside. Material excavated from the hillside has been used to build up a bench for the canal. The district has lined the section with concrete and plastic liners and have installed some pipe in area to cut down seepage.
4. Water deliveries are scheduled with ditch rider and Watermaster.
5. No flow measurement is done along canal except at division structure. Ditch rider does have a portable weir to spot check gravity turnout flows. Installation of flowmeters at turnouts would allow more accurate operation of canals.
6. Use of on farm ponds for storage along canal would help regulate flows in the canal.

Lowden District No. 2:

1. Canal has a gravel diversion in river.
2. Existing weir is not well maintained and inaccurate.
3. Maintenance along canal appears to be poor. Cattle graze along and in canal in spots along alignment.
4. Tree growth along canal near diversion is heavy.
5. Canal also serves Mud Creek No. 7 ditch.
6. Some wetlands observed near downstream end of canal, possibly from canal seepage.
7. Wells pumping ground water are used widely to backup irrigation flows to fields.
8. Combining diversion with several other ditch companies seems viable.

Old Lowden Ditch:

1. Diversion must be pumped due to lowering of river bed resulting from gravel removal by sand and gravel company.
2. Channel from river to pump station is excavated in gravel formation. Seepage is probably high in this area.
3. Maintenance along canal appears to be poor with grass growth in channel common.
4. No on farm storage ponds are used. Storage potential along canal appears to be limited.
5. Flow measurement is not performed along canal.
6. Water scheduling is not done, excess water not used for irrigation is wasted back to river.

Bergevin-Williams Ditch:

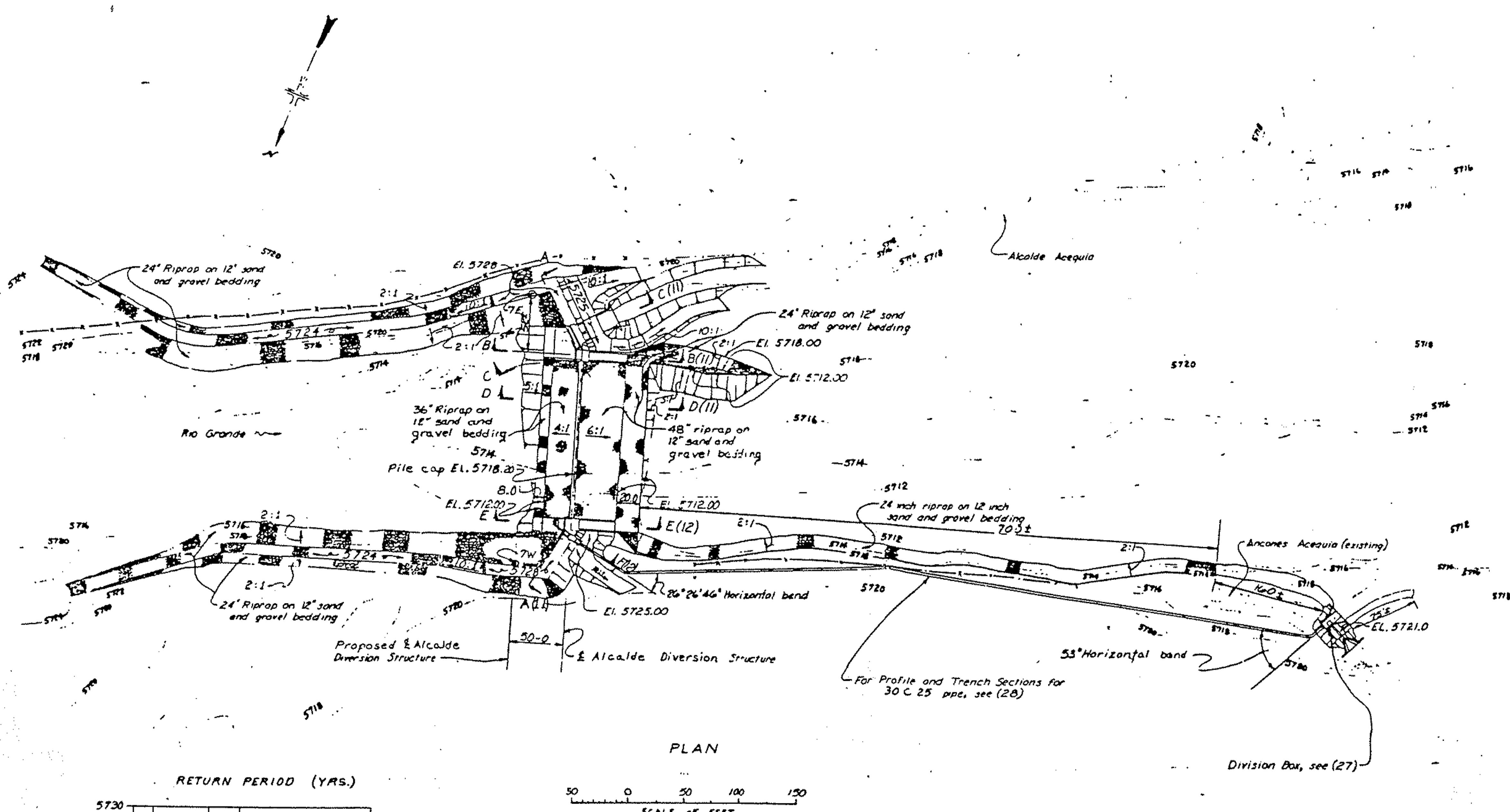
1. Gravel diversion in river.
2. Diversion is likely site for a combined diversion to serve Bergevin-Williams, Old Lowden, Lowden No. 2, Mud Creek No. 7, and Garden City ditches.
3. Ditch maintenance appears to be poor with grassy channels and weed growth along ditch banks.
4. No flow measurement is done along ditch.
5. Waste flows enter the Old Lowden ditch at two locations.

Mill Creek Storage Project:

1. Division structure diverts flow from Mill Creek to Walla Walla River upstream of Gardena Farms diversion through Yellowhawk Creek.
2. Storage reservoir is not in operation at this time due to excessive foundation seepage. Current Corps estimate to fix is $2,000,000. Status of repair is not known at this time.
3. Any use of reservoir for irrigation storage would need to be negotiated with the Corps to be coordinated with flood storage.

APPENDIX F:

INFORMATION DRAWINGS

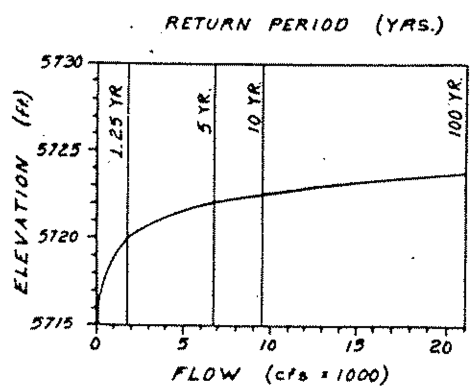


GENERAL NOTES

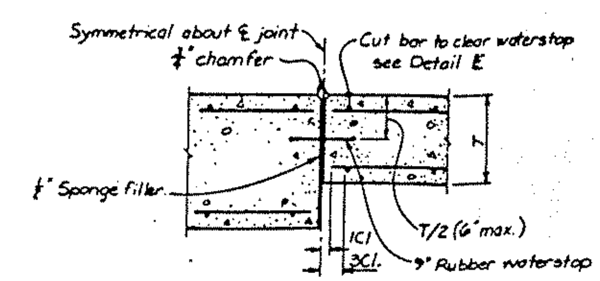
For general concrete outline notes, see 40-D-7006.
For reinforcement detailing requirements, see 40-D-6263 unless otherwise shown.
Structures to be placed on sound bedrock, undisturbed earth or thoroughly compacted fill.
All Cr. J (Contraction joints) to have 9 inch rubber waterstop (WSA) and ½ inch sponge rubber filler unless otherwise shown.
Fasten sponge rubber joint filler securely to one face of concrete.
Reinforcement shall be continuous through construction joints.
For details of rubber waterstop, see 40-D-2867.
For details of pipe handrail, see 40-D-6023. Splice No. 3 to be used when handrail crosses Cr. J.
Provide ¾ inch chamfer on all edges.
For Typical Cr. J., see (22).

DESIGN STRENGTHS

Concrete - f'_c = 4000 psi
Reinforcement - f_y = 60,000 psi



FLOOD FREQUENCY CURVE



TYPICAL Cr. J.
SECTION J-J (21)

INFORMATION ONLY

3-31-89	AS BUILT BY 504, LTR. 3-3-89
8-10-89	AS BUILT BY 400, LTR. 12-14-88
5-3-84	MINOR REVISIONS

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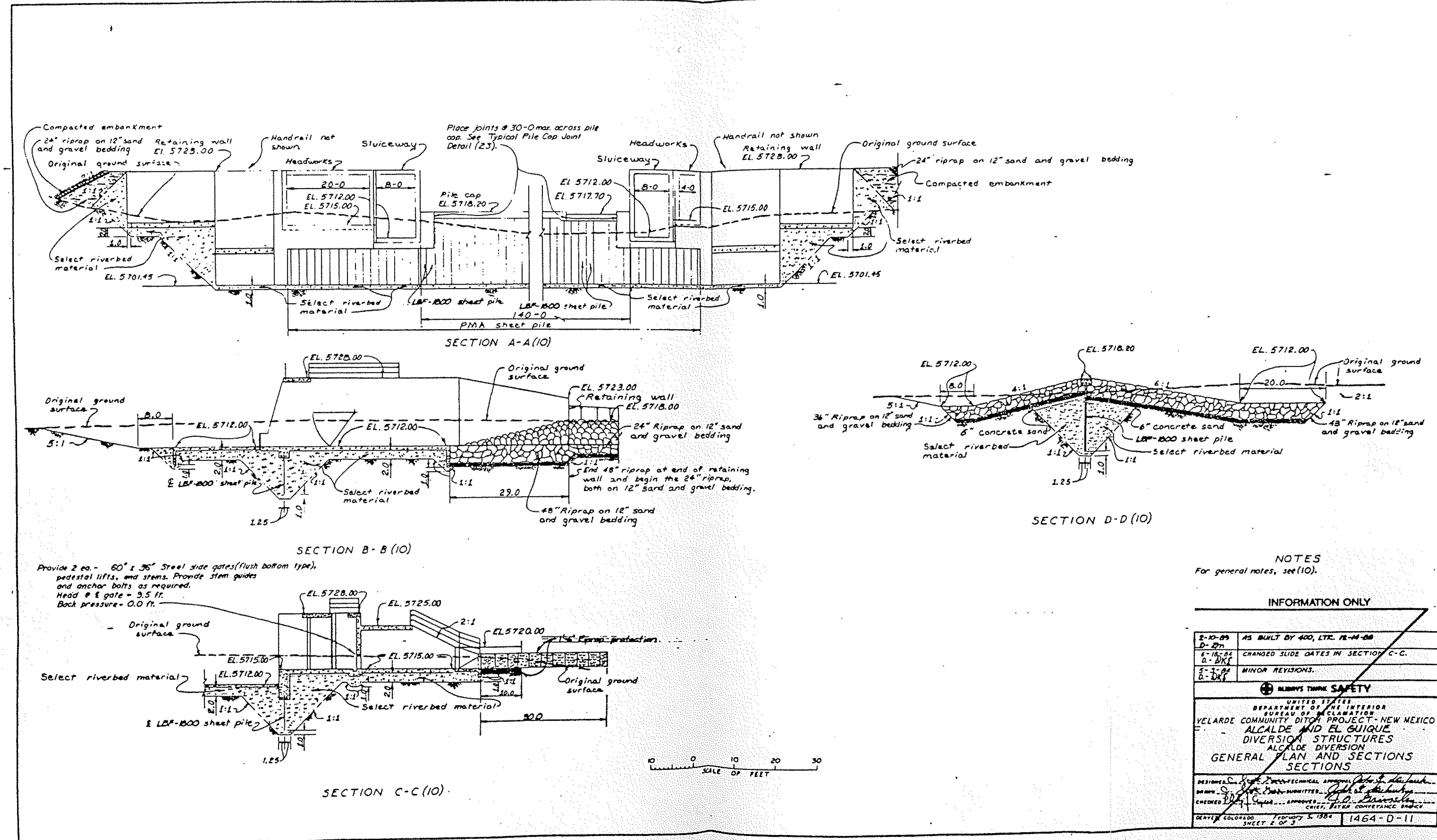
VELARDE COMMUNITY DITCH PROJECT - NEW MEXICO
GARCIA
DIVERSION STRUCTURE
GENERAL PLAN AND SECTIONS
PLAN

DENVER, COLORADO FEBRUARY 3, 1984 SHEET 1 OF 3 1464-D-10


SECTION A-A (10)
Compacted embankment
24" riprap on 12" sand and gravel bedding
Retaining wall El. 5723.00
Original ground surface
Handrail not shown
Headworks
Sluiceway
Place joints @ 30-0 max. across pile cap. See Typical Pile Cap Joint Detail (23).
Pile cap EL. 5718.20
EL. 5712.00
EL. 5715.00
EL. 5717.70
Select riverbed material
EL. 5701.45
LBF-1800 sheet pile
PMA sheet pile
140-0
SECTION B-B (10)
EL. 5728.00
EL. 5723.00
Retaining wall
EL. 5718.00
24" Riprap on 12" sand and gravel bedding
End 48" riprap at end of retaining wall and begin the 24" riprap, both on 12" sand and gravel bedding.
48" Riprap on 12" sand and gravel bedding
29.0
SECTION C-C (10)
Provide 2 ea. - 60" x 36" Steel slide gates (flush bottom type), pedestal lifts, and stems. Provide stem guides and anchor bolts as required.
Head @ ℄ gate = 9.5 ft.
Back pressure = 0.0 ft.
EL. 5725.00
EL 5720.00
Riprap protection
30.0
SECTION D-D (10)
EL. 5718.20
36" Riprap on 12" sand and gravel bedding
6" concrete sand
48" Riprap on 12" sand and gravel bedding
NOTES
For general notes, see (10).
SCALE OF FEET
INFORMATION ONLY
AS BUILT BY 400, LTR. 12-14-88
CHANGED SLIDE GATES IN SECTION C-C.
MINOR REVISIONS.
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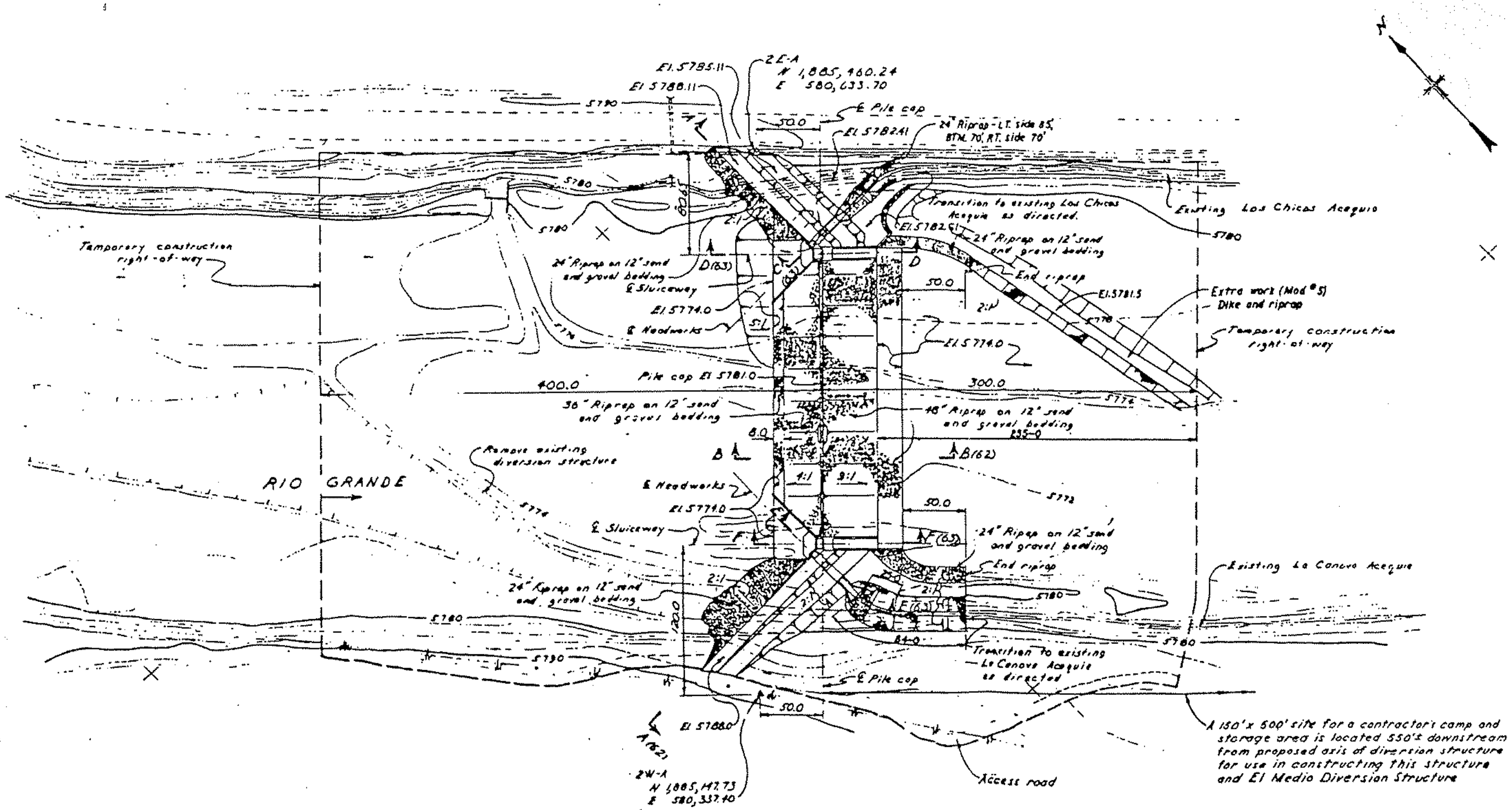
UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION
VELARDE COMMUNITY DITCH PROJECT - NEW MEXICO
ALCALDE AND EL GUIQUE DIVERSION STRUCTURES
ALCALDE DIVERSION
GENERAL PLAN AND SECTIONS
SECTIONS
DENVER, COLORADO February 3, 1984 SHEET 2 OF 3
1464-D-11



GENERAL PLAN

50 0 50 100 150
SCALE OF FEET

GENERAL NOTES

For general concrete outline notes, see 40-D-7038
For reinforcement detailing requirements, see 40-D-6263, unless otherwise shown.
Reinforcement shall be continuous through construction joints.
Provide ¾ inch chamfer on all exposed edges of concrete.
Fasten sponge rubber joint filler securely to one face of concrete.
For details of rubber waterstop, see 40-D-2867.
For details of pipe handrail, see 40-D-6023. Splice No. 3 to be used when handrail crosses expansion joints.

DESIGN STRENGTHS

Concrete at 28 days ---- f'c = 4,000 psi.
Reinforcement ----------- fy = 60,000 psi.

INFORMATION ONLY

7-13-89 9-HP	AS BUILT BY 304, LTR. 3-7-89.
4-30-86 D-	REVISED RIGHT-OF-WAY REQUIREMENTS.

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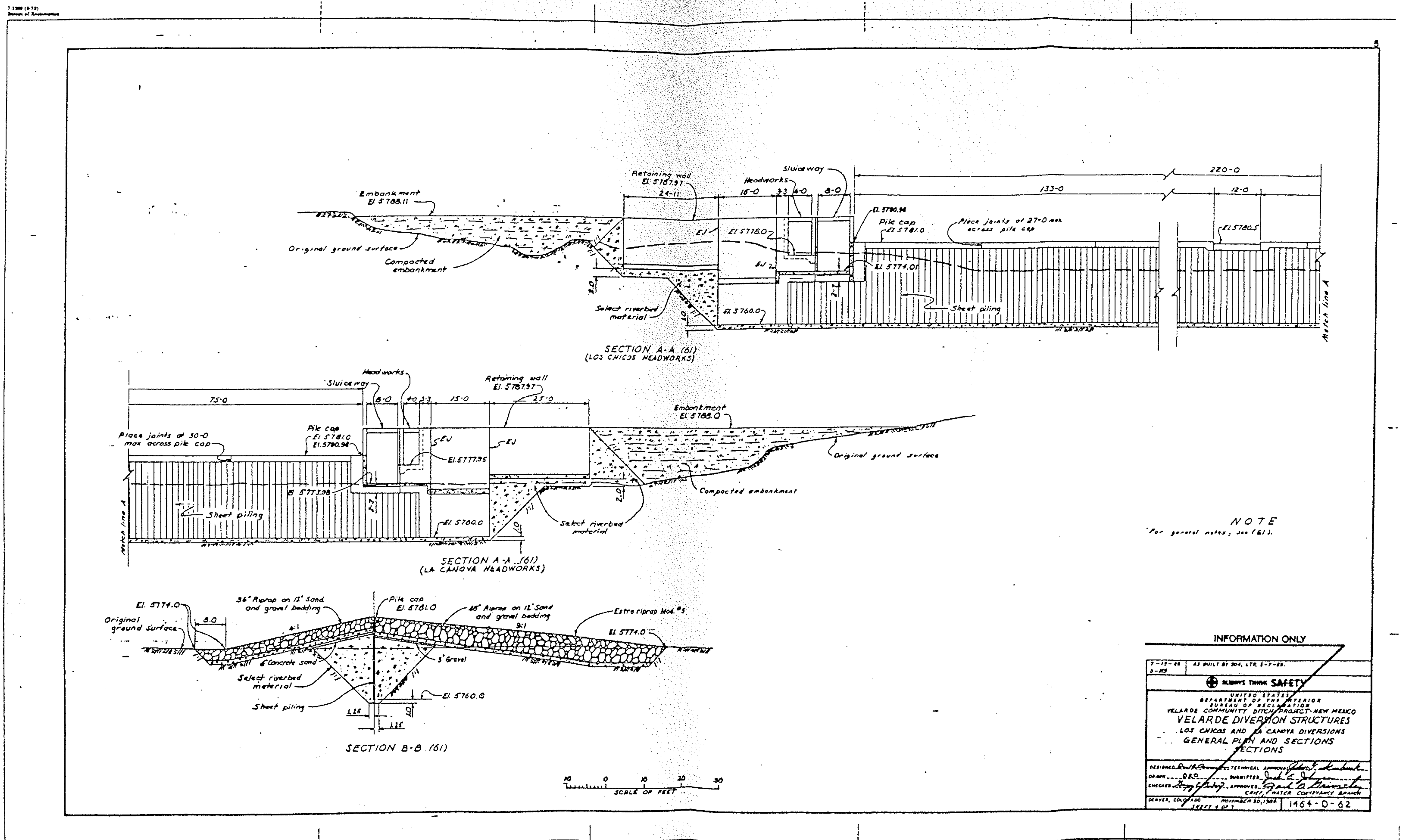
VELARDE DIVERSION STRUCTURES
LOS CHICOS AND LA CANOVA DIVERSIONS
GENERAL PLAN AND SECTIONS
GENERAL PLAN

DESIGNED ___ TECHNICAL APPROVAL ___
DRAWN ___ SUBMITTED ___
CHECKED ___ APPROVED ___
CHIEF, WATER CONVEYANCE BRANCH

DENVER, COLORADO JANUARY 17, 1984 SHEET 1 OF 7 | 1464-D-61


SECTION A-A (61)
(LOS CHICOS HEADWORKS)
SECTION A-A (61)
(LA CANOVA HEADWORKS)
SECTION B-B (61)
Retaining wall
El. 5787.97
Headworks
Sluiceway
Embankment
El. 5788.11
Original ground surface
Compacted embankment
Select riverbed material
Sheet piling
Pile cap
El. 5781.0
Place joints at 27-0 max across pile cap
Match line A
El. 5760.0
El. 5774.01
Place joints at 30-0 max across pile cap
El. 5777.95
El. 5773.98
Embankment
El. 5788.0
36" Riprap on 12" Sand and gravel bedding
45" Riprap on 12" Sand and gravel bedding
Extra riprap Mod. #5
6" Concrete sand
5" Gravel
El. 5774.0
El. 5781.0
SCALE OF FEET
NOTE
For general notes, see (61).
INFORMATION ONLY
AS BUILT BY 304, LTR. 3-7-69.
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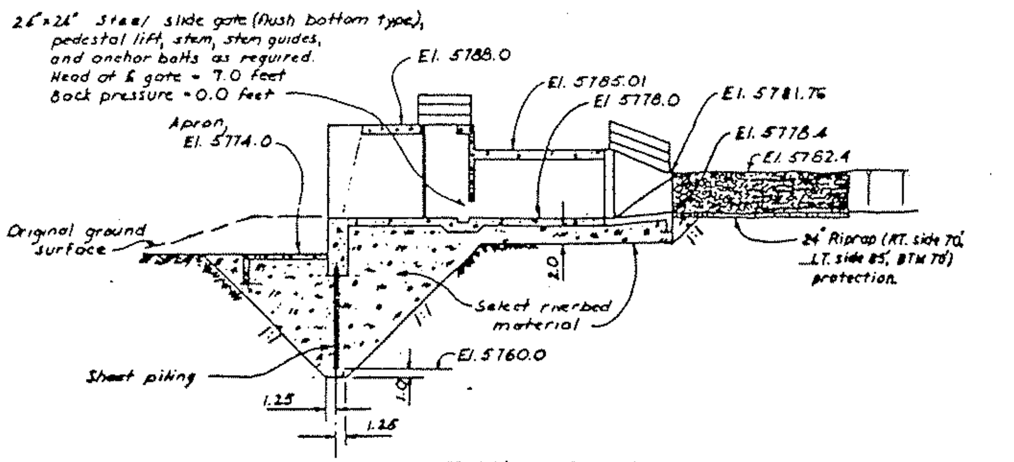
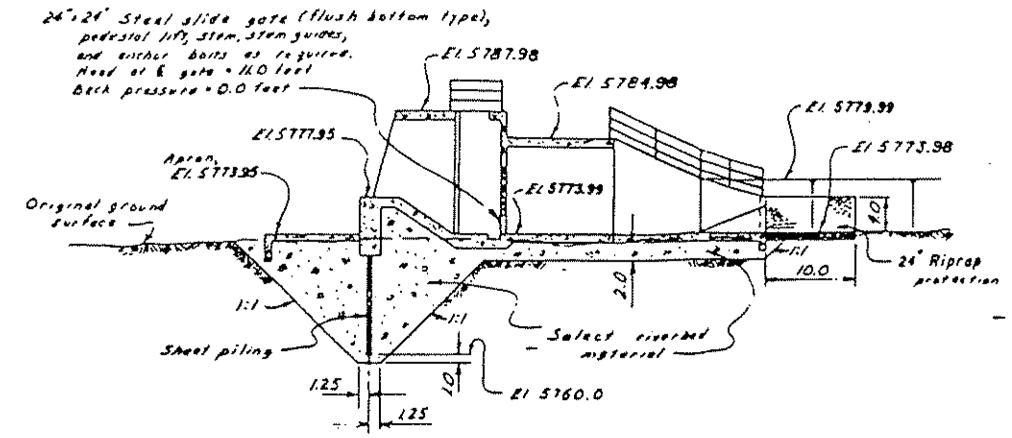
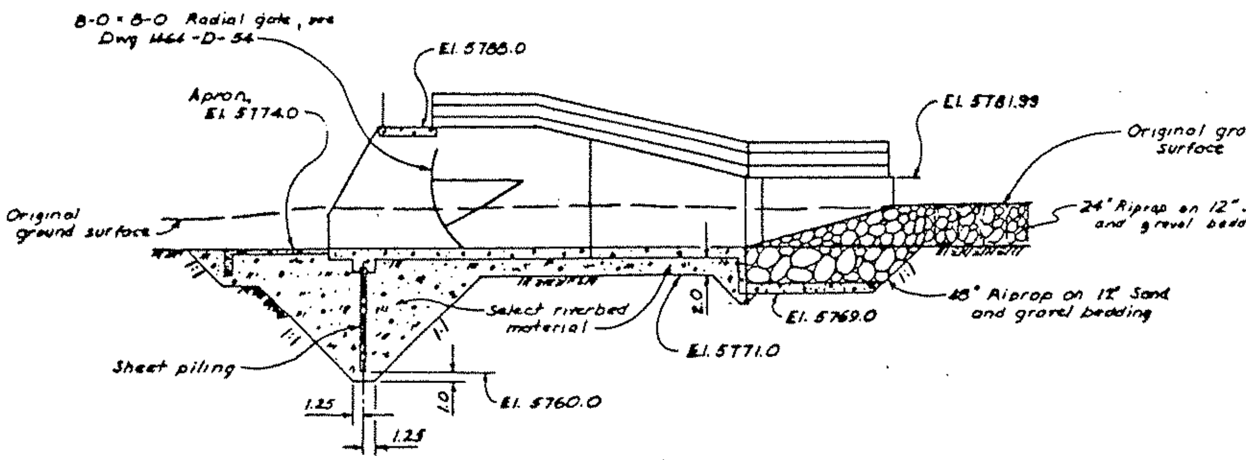
VELARDE DIVERSION STRUCTURES
LOS CHICOS AND LA CANOVA DIVERSIONS
GENERAL PLAN AND SECTIONS
SECTIONS
CHIEF, WATER CONVEYANCE BRANCH
DENVER, COLORADO
NOVEMBER 30, 1964
1464-D-62



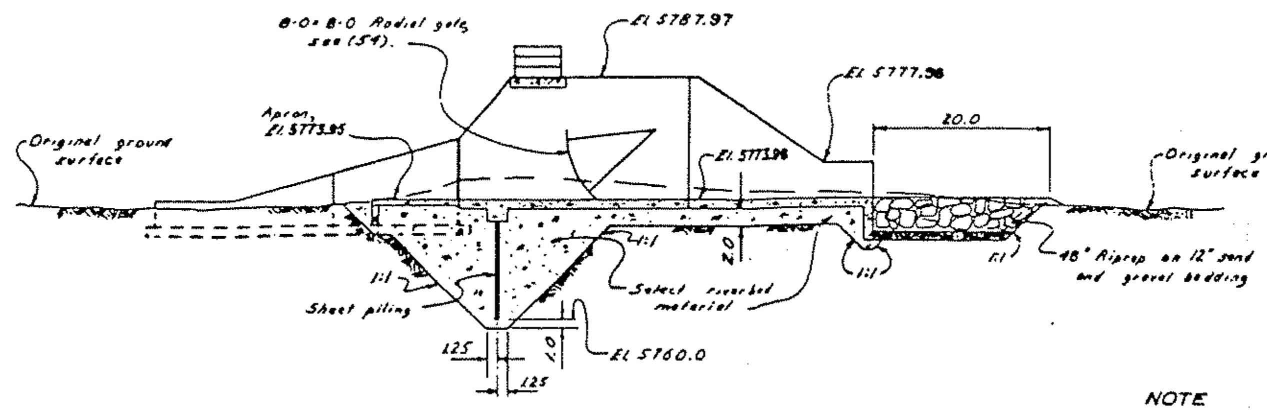
SECTION C-C (61)
(LOS CHICOS HEADWORKS)



SECTION E-E (61)
(LA CANOVA HEADWORKS)



SECTION D-D (61)
(LOS CHICOS SLUICEWAY)



SECTION F-F (61)
(LA CANOVA SLUICEWAY)

10 0 10 20 30
SCALE OF FEET

NOTE
For general notes, see (61).

INFORMATION ONLY

7-15-88 D-MS	AS BUILT BY 504, LTR. 3-7-88.

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VELARDE COMMUNITY DITCH PROJECT - NEW MEXICO
VELARDE DIVERSION STRUCTURES
LOS CHICOS AND LA CANOVA DIVERSIONS
GENERAL PLAN AND SECTIONS
SECTIONS

DESIGNED ... TECHNICAL APPROVAL ...
DRAWN ... SUBMITTED ...
CHECKED ... APPROVED ...
CHIEF, WATER CONVEYANCE BRANCH

DENVER, COLORADO — NOVEMBER 20, 1984 — SHEET 3 OF 7 — 1464-D-63

Table G.1 Summary of Variable Production Costs Per Acre For Alfalfa Seed Production, Walla Walla County, Washington, 1990 (Handline Irrigation System)(2 Irrigations).

Variable Costs	Unit	Cost/Unit	Quantity	Cost
Preharvest				
Sinbar	Lbs.	19.95	1.00	19.95
Paraquat	Pt.	5.63	1.00	5.63
Gopher Cont.	Lbs.	1.05	2.00	2.10
Hired Labor	Hour	7.00	1.02	7.14
Prowl	Qt.	7.50	2.00	15.00
Capture	Oz.	4.00	6.40	25.60
Pollinate Bees	Acre	25.71	1.00	25.71
Spur	Pt.	2.50	6.40	16.00
Dibrom	Pt.	7.50	2.00	15.00
Diquat	Pt.	8.75	2.00	17.50
Kicker	Pt.	2.50	2.00	5.00
Machinery Repair	Acre	3.08	1.00	3.08
Machinery Fuel	Acre	3.60	1.00	3.60
Machinery Lube	Acre	0.54	1.00	0.54
Irrig. Repair	Acre	1.44	1.00	1.44
Irrig. Elec.	Acre	20.77	1.00	20.77
Irrig. Charge	Acre	11.50	1.00	11.50
Labor (Mach.)	Hour	7.00	2.28	15.96
Labor (Irrig.)	Hour	7.00	1.14	7.98
Int. Op. Cap.	Dol.	0.12	87.81	10.54
Overhead Cost	Dol.	0.05	280.89	14.04
Establishment Cost	Acre	34.52	1.00	34.52
Subtotal Preharvest				**$278.60**
Harvest Costs				
Machinery Repair	Acre	6.69	1.00	6.69
Machinery Fuel	Acre	3.52	1.00	3.52
Machinery Lube	Acre	0.53	1.00	0.53
Labor (Machine)	Hour	7.00	0.80	5.60
Subtotal Harvest				**$16.34**
Total Variable Cost				**$294.94**

Irrigation electricity charge assumes all water is from a surface diversion. System pressure is assumed to be 50 PSI, pump efficiency is assumed to be 55%, and irrigation efficiency 65%. Ditch irrigation fee is only applicable to regions 7, 8, 11, and 12.

Table G.2 Summary of Variable Production Costs Per Acre For Alfalfa Hay Production, Walla Walla County, Washington, 1990 (Side-Roll Irrigation System)(5 Irrigations).

Variable Costs	Unit	Cost/Unit	Quantity	Cost
Preharvest				
Gopher Machine	Acre	0.35	1.00	0.35
Strychinine Oats	Lb.	1.28	0.50	0.64
Custom Fert.	Acre	5.00	1.00	5.00
Fertilzer	Acre	30.00	1.00	30.00
Custom Spray	Acre	6.00	1.00	6.00
Herbicide	Acre	11.50	1.00	11.50
Irrig. Elect.	Acre	35.20	1.00	35.20
Irr. Charge	Acre	11.50	1.00	11.50
Tractors	Acre	0.45	1.00	0.45
Machinery	Acre	11.06	1.00	11.06
Labor(Trac/Mach)	Hour	7.00	2.55	17.85
Irrigation Labor	Hour	7.00	1.25	8.75
Int. Op. Cap.	Dol.	0.12	118.13	14.18
Overhead Cost	Acre	0.05	304.01	15.20
Establishment Cost	Acre	61.38	1.00	61.38
Subtotal Preharvest				**$229.06**
Harvest Costs				
Custom Stack	Bale	0.30	136.50	40.95
Preservative	Lb.	1.00	4.00	4.00
Tractors	Acre	15.97	1.00	15.97
Machinery	Acre	9.02	1.00	9.02
Labor(Trac/Mach)	Acre	20.21	1.00	20.21
Subtotal Harvest				**$90.15**
Total Variable Cost				**$319.21**

Irrigation electricity charge assumes all water is from a surface diversion. System pressure is assumed to be 50 PSI, pump efficiency is assumed to be 55%, and irrigation efficiency 65%. Ditch irrigation fee is only applicable to regions 7, 8, 11, and 12.

Table G.3 Summary of Variable Production Costs Per Acre For Sweet Onions, Walla Walla County, Washington, 1990 (Handline Irrigation System)(13 Irrigations per Season).

Variable Costs	Unit	Cost/Unit	Quantity	Cost
Preharvest				
Seed	Lbs.	30.00	2.50	75.00
Dachtal	Lbs.	5.00	24.00	120.00
Fert. 16-20-0	Lbs.	0.30	120.00	36.00
Nitrogen 34%	Lbs.	0.26	150.00	39.00
Weed Killer	Acre	8.50	1.00	8.50
Fusilade	Pt.	8.00	1.50	12.00
Roundup	Oz.	0.56	12.00	6.72
Malathion	Qt.	7.50	2.00	15.00
Parathion	Pt.	4.23	1.00	4.23
Ridomil	Lbs.	8.70	4.00	34.80
Irrig. Elec.	Acre	34.09	1.00	34.09
Spin Fert Spray	Acre	0.50	2.00	1.00
Tractor Repair	Acre	25.19	1.00	25.19
Tractor Fuel/Lube	Acre	24.77	1.00	24.77
Machine Repair	Acre	59.84	1.00	59.84
Machine Fuel/Lube	Acre	8.73	1.00	8.73
Labor (Non-Irrig)	Acre	7.00	31.70	221.90
Labor (Irrig.)	Acre	7.00	7.41	51.87
Overhead Cost	Acre	0.05	3342.77	167.14
Int. Op. Cap.	Dol.	0.12	318.93	38.27
Subtotal Preharvest				**$984.05**
Harvest Costs				
Custom Picking	Bin	8.00	60.00	480.00
Processing	Bag	2.50	720.00	1800.00
Labor	Acre	7.00	19.65	137.55
Tractor Repair	Acre	23.49	1.00	23.49
Tractor Fuel/Lube	Acre	25.26	1.00	25.26
Machine Repair	Acre	47.26	1.00	47.26
Machine Fuel/Lube	Acre	12.30	1.00	12.30
Subtotal Harvest				**$2,525.86**
Total Variable Cost				**$3,509.91**

Irrigation electricity charge assumes all water is from a surface diversion. System pressure is assumed to be 50 PSI, pump efficiency is assumed to be 55%, and irrigation efficiency 65%. Ditch irrigation fee is only applicable to regions 7, 8, 11, and 12.

Table G.4 Summary of Variable Production Costs Per Acre For Asparagus Production, Walla Walla County, Washington, 1990 (Wheel Line Irrigation System)(4 Irrigations per Season).

Variable Costs	Unit	Cost/Unit	Quantity	Cost
Preharvest				
Aerial Spraying	Acre	5.25	1.00	5.25
Disyston	Gal.	57.89	0.13	7.53
Aerial Spraying	Acre	5.25	1.00	5.25
Disyston	Gal.	57.89	0.13	7.53
Treflan	Gal.	32.62	0.38	12.40
Roundup	Gal.	71.68	0.09	6.45
Custom Fert. App.	Acre	5.00	1.00	5.00
Nitrogen	Lbs.	0.20	120.00	24.00
Irrig. Water	Acre	11.50	1.00	11.50
Irrig. Electricity	Acre	19.79	1.00	19.79
Tractors	Acre	15.00	1.00	15.00
Machinery	Acre	10.54	1.00	10.54
Labor(Trac/Mach)	Acre	7.00	2.25	15.72
Labor(Irrig.)	Acre	7.00	1.00	7.00
Int. Op. Cap.	Dol.	0.12	193.26	23.19
Subtotal Preharvest				**$176.14**
Harvest Costs				
Custom Harvest	Acre	810.18	1.00	810.18
Sencor	Lbs.	24.15	0.63	15.21
Karmex	Lbs.	5.21	1.20	6.25
Tractors	Acre	4.06	1.00	4.06
Machinery	Acre	0.31	1.00	0.31
Labor(Trac/Mach)	Acre	7.00	2.72	19.04
Subtotal Harvest				**$855.06**
Post Harvest Costs				
Management Fee	Acre	126.03	1.00	126.03
Overhead	Acre	60.00	1.00	60.00
Tractors	Acre	3.16	1.00	3.16
Machinery	Acre	61.15	1.00	61.15
Labor(Trac/Mach)	Acre	30.25	1.00	30.25
Subtotal, Post-Harvest				**$280.59**
Total Variable Costs				**$1,311.79**

Irrigation electricity charge assumes all water is from a surface diversion. System pressure is assumed to be 50 PSI, pump efficiency is assumed to be 55%, and irrigation efficiency 65%. Ditch irrigation fee is only applicable to regions 7, 8, 11, and 12.

Table G.5 Summary of Variable Production Costs Per Acre For Irrigated Pasture in Walla Walla County, Washington, 1990 (Side-Roll Irrigation System)(4 Irrigations per Season).

Variable Costs	Unit	Cost/Unit	Quantity	Cost
Preharvest				
Nitrogen	Lb.	0.20	50.00	10.00
Phosphate	Lb.	0.27	40.00	10.80
Irrigation charge	Acre	11.50	1.00	11.50
Irrig. Elec.	Acre	39.56	1.00	39.56
Labor(Trac/Mach)	Hour	7.00	0.88	6.16
Labor(Irrig.)	Hour	7.00	1.00	7.00
Int. Op. Cap.	Dol.	0.12	60.30	7.24
Total Variable Cost				**$92.26**

Irrigation electricity charge assumes all water is from a surface diversion. Irrigation efficiency is assumed to be 45%. Ditch irrigation fee is only applicable to regions 7, 8, 11, and 12.

Table G.6 Summary of Variable Production Costs Per Acre For Irrigated Pasture, Walla Walla County, Washington, 1990 (Rill Irrigation System)(4 Irrigations per Season).

Variable Costs	Unit	Cost/Unit	Quantity	Cost
Preharvest				
Nitrogen	Lb.	0.20	50.00	10.00
Phosphate	Lb.	0.27	40.00	10.80
Irrigation charge	Acre	11.50	1.00	11.50
Labor(Trac/Mach)	Hour	7.00	0.88	6.16
Labor(Irrig.)	Hour	7.00	2.28	15.96
Int. Op. Cap.	Dol.	0.12	40.20	4.82
Total Variable Cost				**$59.24**

Irrigation electricity charge assumes all water is from a surface diversion. System pressure is assumed to be 50 PSI, pump efficiency is assumed to be 55%, and irrigation efficiency 65%. Ditch irrigation fee is only applicable to regions 7, 8, 11, and 12.

Table G.7 Summary of Variable Production Costs Per Acre For Dry Beans Walla Walla County, Washington, 1990 (Wheel Line Irrigation System)(10 Irrigations per Season).

Variable Costs	Unit	Cost/Unit	Quantity	Cost
Preharvest				
Dry Bean Seed	Lb.	0.30	70.00	21.00
Seed Treatment	Oz.	0.50	2.00	1.00
Nitrogen (Dry)	Lb.	0.20	80.00	16.00
Phosphate (Dry)	Lb.	0.27	50.00	13.50
Potash	Lb.	0.16	50.00	8.00
Zinc	Lb.	1.45	5.00	7.25
Sonalan	Pt.	3.50	2.00	7.00
Eptc	Gal.	26.00	0.50	13.00
Innoculant	Lb.	2.33	0.67	1.56
Cygon	Pt.	2.25	2.00	4.50
Foliar Nutrient	Acre	10.00	2.00	20.00
Custom Fert.	Acre	5.00	1.00	5.00
Custom Aerial	Acre	6.25	2.00	12.50
Irrig. Charge	Acre	11.50	1.00	11.50
Irrig. Elec.	Acre	24.83	1.00	24.83
Irrig. Repair	Acre	12.00	1.00	12.00
Tractors	Acre	34.13	1.00	34.13
Machinery	Acre	21.68	1.00	21.68
Labor(Trac/Mach)	Acre	7.00	1.00	7.00
Labor(Irrig.)	Hour	7.00	2.50	17.50
Int. on Capital	Dol.	0.12	120.40	14.45
Overhead	Dol.	0.05	330.88	16.54
Subtotal, Pre-Harvest				**$289.94**
Harvest				
Custom Window	Acre	9.00	1.00	9.00
Custom Cutting	Acre	18.00	1.00	18.00
Custom Combine	Acre	35.00	1.00	35.00
Custom Hauling	Ton	3.50	1.00	3.50
Subtotal, Harvest				**$65.50**
Total Variable Cost				**$355.44**

Irrigation electricity charge assumes all water is from a surface diversion. System pressure is assumed to be 50 PSI, pump efficiency is assumed to be 55%, and irrigation efficiency 65%. Ditch irrigation fee is only applicable to regions 7, 8, 11, and 12.

Table G.8 Summary of Variable Production Costs Per Acre For Dry Beans, Walla Walla County, Washington, 1990 (Hand Line Irrigation System)(10 Irrigations per Season).

Variable Costs	Unit	Cost/Unit	Quantity	Cost
Preharvest				
Dry Bean Seed	Lb.	0.30	70.00	21.00
Seed Treatment	Oz.	0.50	2.00	1.00
Nitrogen (Dry)	Lb.	0.20	80.00	16.00
Phosphate (Dry)	Lb.	0.27	50.00	13.50
Potash	Lb.	0.16	50.00	8.00
Zinc	Lb.	1.45	5.00	7.25
Sonalan	Pt.	3.50	2.00	7.00
Eptc	Gal.	26.00	0.50	13.00
Innoculant	Lb.	2.33	0.67	1.56
Cygon	Pt.	2.25	2.00	4.50
Foliar Nutrient	Acre	10.00	2.00	20.00
Custom Fert.	Acre	5.00	1.00	5.00
Custom Aerial	Acre	6.25	2.00	12.50
Irrig. Charge	Acre	11.50	1.00	11.50
Irrig. Elec.	Acre	24.83	1.00	24.83
Irrig. Repair	Acre	2.00	1.00	2.00
Tractors	Acre	34.13	1.00	34.13
Machinery	Acre	21.68	1.00	21.68
Labor(Trac/Mach)	Acre	7.00	1.00	7.00
Labor(Irrig.)	Hour	7.00	5.70	39.90
Int. on Capital	Dol.	0.12	105.00	12.60
Overhead	Dol.	0.05	349.45	17.47
Subtotal, Pre-Harvest				**$301.42**
Harvest				
Custom Window	Acre	9.00	1.00	9.00
Custom Cutting	Acre	18.00	1.00	18.00
Custom Combine	Acre	35.00	1.00	35.00
Custom Hauling	Ton	3.50	1.00	3.50
Subtotal, Harvest				**$65.50**
Total Variable Cost				**$366.92**

Irrigation electricity charge assumes all water is from a surface diversion. System pressure is assumed to be 50 PSI, pump efficiency is assumed to be 55%, and irrigation efficiency 65%. Ditch irrigation fee is only applicable to regions 7, 8, 11, and 12.

Table G.9 Summary of Variable Production Costs Per Acre For Winter Wheat, Walla Walla County, Washington, 1990(Wheel Line Irrigation System)(4 Irrigations per Season).

Variable Costs	Unit	Cost/Unit	Quantity	Cost
Preharvest				
Wheat Seed	Lb.	0.13	100.00	13.00
Nitrogen (Dry)	Lb.	0.20	120.00	24.00
Sulfur	Lb.	0.23	20.00	4.60
2-4-D	Gal.	10.00	0.13	1.30
Sticker	Qt.	2.50	0.50	1.25
Banvel	Oz.	0.53	2.00	1.06
Custom Fert.	Acre	5.00	1.00	5.00
Custom Spraying	Acre	4.50	1.00	4.50
Irrig. Charge	Acre	11.50	1.00	11.50
Irrig. Elec.	Acre	20.51	1.00	20.51
Irrig. Repair	Acre	9.00	1.00	9.00
Tractors	Acre	4.93	1.00	4.93
Machinery	Acre	7.78	1.00	7.78
Labor(Trac/Mach)	Hour	7.00	1.20	8.40
Labor (Irrig.)	Hour	7.00	1.00	7.00
Int. on Capital	Dol.	0.12	84.98	10.20
Overhead	Dol.	0.05	176.83	8.84
Subtotal, Pre-Harvest				**$142.87**
Harvest				
Custom Combine	Acre	30.00	1.00	30.00
Custom Hauling	Ton	4.00	3.15	12.60
Subtotal, Harvest				**$42.60**
Total Variable Cost				**$185.47**

Irrigation electricity charge assumes all water is from a surface diversion. System pressure is assumed to be 50 PSI, pump efficiency is assumed to be 55%, and irrigation efficiency 65%. Ditch irrigation fee is only applicable to regions 7, 8, 11, and 12.

Table G.12 Summary of Variable Production Costs Per Acre For Apple Orchards, Walla Walla County, Washington, 1990(Solid Set Irrigation System)(10 Irrigations per Season).

Variable Costs	Unit	Cost/Unit	Quantity	Cost
Preharvest				
Nitrogen	Lb.	0.20	110.00	22.00
Zinc Sulfate	Gal.	1.42	8.00	11.36
Superior Oil	Gal.	2.48	6.00	14.88
Parathion	Pt.	4.23	1.00	4.23
Solubor	Lb.	0.60	4.00	2.40
Promalin	Pt.	45.30	2.00	90.60
Regulaid	Qt.	5.54	1.00	5.54
Sorba-Spray MG	Qt.	3.20	1.20	4.80
Elgetol	Pt.	3.52	1.50	5.28
Amid-Thin	Lb.	12.68	1.25	15.85
Sevin	Lb.	2.30	4.25	9.77
Guthion	Lb.	4.50	4.00	18.00
Phosphamidon	Pt.	8.67	0.50	4.34
Foliar Nutrient	Lb.	1.00	4.00	4.00
Calcium Cloride	Lb.	0.27	16.00	4.32
Round-up	Gal.	71.68	0.17	12.19
2,4d	Qt.	3.73	0.33	1.23
Aerial	Acre	10.00	1.00	10.00
Irrig. Charge	Acre	11.50	1.00	11.50
Irrig. Elec.	Acre	47.50	1.00	47.50
Irrig. Repair	Acre	12.50	1.00	12.50
Tractors	Acre	16.31	1.00	16.31
Machinery	Acre	221.32	1.00	221.32
Labor(Trac/Mach)	Hour	7.00	153.38	1073.66
Labor (Irrig.)	Hour	7.00	2.50	17.50
Int. on Capital	Dol.	0.12	918.33	110.20
Overhead	Dol.	0.05	2392.94	119.65
Subtotal, Pre-Harvest				**$1,870.92**
Harvest				
Pickers	Bin	11.00	30.00	330.00
Custom Hauling	Bin	5.00	29.00	145.00
Tractors	Acre	15.12	1.00	15.12
Machinery	Acre	11.34	1.00	11.34
Labor(Trac/Mach)	Hour	7.00	3.90	27.30
Subtotal, Harvest				**$528.76**
Post Harvest				
Herbicide	Acre	29.78	1.00	29.78
Nitrogen	Lb.	0.20	110.00	22.00
Strychine Milo	Lb.	1.03	3.00	3.09
Z-P Pellets	Lb.	1.05	3.00	3.15
Labor	Acre	7.00	6.00	42.00
Tractors	Acre	9.46	1.00	9.46
Machinery	Acre	3.42	1.00	3.42
Subtotal, Post Harvest				**$112.90**
Total Variable Cost				**$2,512.58**

Irrigation electricity charge assumes all water is from a surface diversion. System pressure is assumed to be 50 PSI, pump efficiency is assumed to be 55%, and irrigation efficiency 65%. Ditch irrigation fee is only applicable to regions 7, 8, 11, and 12.

Table G.13 Summary of Variable Production Costs Per Acre For Potatoes, Walla Walla County, Washington, 1990 (Center Pivot Irrigation System).

Variable Costs	Unit	Cost/Unit	Quantity	Cost
Preharvest				
Potato Seed	Cwt.	10.71	21.00	224.91
Nitrogen (Dry)	Lb.	0.20	150.00	30.00
Nitrogen (Liq)	Lb.	0.27	210.00	56.70
Phosphate(Dry)	Lb.	0.17	275.00	46.75
Potash	Lb.	0.16	350.00	56.00
Zinc	Lb.	1.45	10.00	14.50
Boron	Lb.	2.50	1.00	2.50
Sulphur	Lb.	0.15	80.00	12.00
Methane Sodium	Gal.	4.60	50.00	230.00
Temik	Lb.	2.80	20.00	56.00
Metribuzin	Lb.	22.80	0.50	11.40
Mancozeb	Lb.	2.40	4.00	9.60
Bravo	Pt.	5.62	1.00	5.62
Monitor	Qt.	13.63	2.00	27.26
Custom Hauling	Ton	5.00	1.05	5.25
Custom Fert.	Acre	5.00	1.00	5.00
Custom Aerial	Acre	6.25	1.00	6.25
Consultant	Acre	8.00	1.00	8.00
Irrig. Elec.	Acre	32.61	1.00	32.61
Irrig. Repair	Acre	12.00	1.00	12.00
Tractors	Acre	31.81	1.00	31.81
Machinery	Acre	14.09	1.00	14.09
Labor(Trac/Mach)	Hour	7.00	3.90	27.30
Labor (Irrig.)	Hour	7.00	1.00	7.00
Int. on Capital	Dol.	0.12	505.98	60.72
Overhead	Dol.	0.05	1192.03	59.60
Subtotal, Pre-Harvest				**$1,052.87**
Harvest				
Custom Hauling	Ton	5.00	29.00	145.00
Tractors	Acre	15.12	1.00	15.12
Machinery	Acre	11.34	1.00	11.34
Labor(Trac/Mach)	Hour	7.00	3.90	27.30
Subtotal, Harvest				**$198.76**
Total Variable Cost				**$1,251.63**

Irrigation electricity charge assumes all water is from a surface diversion. System pressure is assumed to be 50 PSI, pump efficiency is assumed to be 55%, and irrigation efficiency 65%.

Table G.14 Summary of Variable Production Costs Per Acre For Dryland Winter Wheat Following Green Peas In Walla Walla County, Washington, 1990.

Variable Costs	Unit	Cost/Unit	Quantity	Cost
Nitrogen	Lb.	0.20	120.00	24.00
Sulfur	Lb.	0.23	15.00	3.45
Fargo Granular	Lb.	0.76	1.50	1.14
Bronate	Pt.	5.77	1.50	8.66
Banvel	Pt.	7.30	0.12	0.88
Mcpa Ester	Pt.	2.43	0.75	1.82
Benlate	Lb.	14.00	1.00	14.00
Disyston	Gal.	49.25	0.09	4.43
Cygon-400	Pt.	2.90	0.75	2.18
Wheat Seed	Lb.	0.12	100.00	12.00
Crop Insurance	Acre	5.94	1.00	5.94
Rent Applicator	Acre	1.50	2.00	3.00
Custom Aerial	Acre	4.50	3.00	13.50
Rent Applicator	Acre	1.50	0.10	0.15
Landmaster	Gal.	19.13	0.04	0.77
Overhead	Acre	0.05	142.62	7.13
Int. Oper. Cap.	Dol.	0.12	98.75	11.85
Tractor Repair	Acre	4.10	1.00	4.10
Tractor Fuel Lube	Acre	3.80	1.00	3.80
Machinery Repairs	Acre	13.74	1.00	13.74
Machine Fuel/Lube	Acre	3.21	1.00	3.21
Labor(Trac/Mach)	Hour	7.00	1.43	10.01
Total Variable Cost				**$149.75**

Table G.15 Summary of Variable Production Costs Per Acre For Green Peas Following Winter Wheat In Walla Walla County, Washington, 1990.

Variable Costs	Unit	Cost/Unit	Quantity	Cost
Nitrogen	Lb.	0.20	20.00	4.00
Sulfur	Lb.	0.23	10.00	2.30
Fargo Liquid	Qt.	10.52	1.00	10.52
Treflan	Pt.	3.44	1.00	3.44
Disyston (1/2)	Pt.	3.08	0.75	2.31
Parathion (1/2)	Pt.	1.31	1.00	1.31
Green Pea Seed	Lb.	0.20	200.00	40.00
Rent Aplicator	Acre	1.50	2.00	3.00
Custom Spraying	Acre	2.25	2.00	4.50
Crop Insurance	Acre	9.22	1.00	9.22
Overhead	Acre	0.05	127.25	6.36
Int. Op. Cap.	Dol.	0.12	70.67	8.48
Tractor Repair	Acre	9.14	1.00	9.14
Tractor Fuel/Lube	Acre	8.22	1.00	8.22
Machinery Repairs	Acre	8.13	1.00	8.13
Machine Fuel/Lube	Acre	0.99	1.00	0.99
Labor(Trac/Mach)	Hour	7.00	1.67	11.69
Total Variable Cost				**$133.61**

Table G.16 Summary of Variable Production Costs Per Acre For Dryland Winter Wheat Following Fallow In Walla Walla County, Washington, 1990.

Variable Costs	Unit	Cost/Unit	Quantity	Cost
Nitrogen	Lb.	0.20	120.00	24.00
Sulfur	Lb.	0.23	15.00	3.45
Fargo Granular	Lb.	0.76	1.50	1.14
Bronate	Pt.	5.77	1.50	8.66
Banvel	Pt.	7.30	0.12	0.88
Mcpa Ester	Pt.	2.43	0.75	1.82
Benlate	Lb.	14.00	1.00	14.00
Disyston	Gal.	49.25	0.09	4.43
Cygon-400	Pt.	2.90	0.75	2.18
Wheat Seed	Lb.	0.12	100.00	12.00
Crop Insurance	Acre	5.94	1.00	5.94
Rent Applicator	Acre	1.50	2.00	3.00
Custom Aerial	Acre	4.50	3.00	13.50
Overhead	Acre	0.05	141.66	7.08
Int. Oper. Cap.	Dol.	0.12	98.40	11.81
Tractor Repair	Acre	4.10	1.00	4.10
Tractor Fuel Lube	Acre	3.80	1.00	3.80
Machinery Repairs	Acre	13.74	1.00	13.74
Machine Fuel/Lube	Acre	3.21	1.00	3.21
Labor(Trac/Mach)	Hour	7.00	1.43	10.01
Total Variable Cost				**$148.74**

Table G.17 Summary of Variable Production Costs Per Acre For Summer Fallow Following Winter Wheat In Walla Walla County, Washington, 1990.

Variable Costs	Unit	Cost/Unit	Quantity	Cost
Tractor Repair	Acre	3.93	1.00	3.93
Tractor Fuel/Lube	Acre	4.77	1.00	4.77
Machinery Repairs	Acre	4.07	1.00	4.07
Machine Fuel/Lube	Acre	0.66	1.00	0.66
Labor(Trac/Mach)	Hour	7.00	1.10	7.70
Overhead	Acre	0.05	29.61	1.48
Int. Op. Cap.	Dol.	0.12	70.67	8.48
Total Variable Cost				**$31.09**

APPENDIX H

Net Returns over Variable Costs for Selected Study Area Crops

Table H.1 Summary of Per Acre Net Returns For Alfalfa Seed Production Over Variable Costs, Walla Walla County, Washington, 1990 (Handline Irrigation System)(2 Irrigations).

Item	Unit	Price or Cost/Unit	Quantity	Value Or Cost
Revenue	Cwt	126.701	5.75	$728.53
Variable Costs				
Fertilizer	Acre	0.00	1.00	0.00
Irrig. Charge	Acre	11.50	1.00	11.50
Irrig. Elec.	Acre	20.77	1.00	20.77
Irrig. Labor	Acre	7.98	1.00	7.98
Harvest	Acre	16.34	1.00	16.34
Other Variable Cost	Acre	238.35	1.00	238.35
Total Variable Cost				**$294.94**
Income After Variable Cost				**$433.59**

Ditch Irrigation charge is effective only for farm regions 7,8,11, and 12.

Irrigation electricity cost assumes all water is from a surface diversion. System pressure is assumed to be 50 PSI, pump efficiency is 55% and irrigation efficiency is 65%. Crop price is 1986-1990 average crop price. Yearly crop prices were converted to 1990 dollars before calculating average price.

Table H.2 Summary of Per Acre Net Returns For Alfalfa Hay Production Over Variable Costs, Walla Walla County, Washington, 1990 (Side-Roll Irrigation System)(5 Irrigations)

Item	Unit	Price or Cost/Unit	Quantity	Value Or Cost
Revenue	Ton	78.761	6.50	$511.95
Variable Costs				
Fertilizer	Acre	30.00	1.00	30.00
Irrig. Charge	Acre	11.50	1.00	11.50
Irrig. Elec.	Acre	35.20	1.00	35.20
Irrig. Labor	Acre	8.75	1.00	8.75
Harvest	Acre	90.15	1.00	90.15
Other Variable Cost	Acre	143.61	1.00	143.61
Total Variable Cost				**$319.21**
Income After Variable Cost				**$192.74**

Ditch Irrigation charge is effective only for farm regions 7,8,11, and 12.
Irrigation electricity cost assumes all water is from a surface diversion. System pressure is assumed to be 50 PSI, pump efficiency is 55% and irrigation efficiency is 65%. Crop price is 1986-1990 average crop price. Yearly crop prices were converted to 1990 dollars before calculating average price.

Table H.3 Summary of Per Acre Net Returns For Sweet Onion Production Over Variable Costs, Walla Walla County, Washington, 1990 (Handline Irrigation System)(13 Irrigations)

Item	Unit	Price or Cost/Unit	Quantity	Value Or Cost
Revenue	Lb	0.142	36000.00	$5,100.26
Variable Costs				
Fertilizer	Acre	75.00	1.00	75.00
Irrig. Charge	Acre	11.50	1.00	11.50
Irrig. Elec.	Acre	34.09	1.00	34.09
Irrig. Labor	Acre	51.87	1.00	51.87
Harvest	Acre	2525.86	1.00	2525.86
Other Variable Cost	Acre	811.59	1.00	811.59
Total Variable Cost				**$3,509.91**
Income After Variable Cost				**$1,590.35**

Ditch Irrigation charge is effective only for farm regions 7,8,11, and 12.
Irrigation electricity cost assumes all water is from a surface diversion. System pressure is assumed to be 50 PSI, pump efficiency is 55% and irrigation efficiency is 65%. Crop price is 1986-1990 average crop price. Yearly crop prices were converted to 1990 dollars before calculating average price.

Table H.4 Summary of Per Acre Net Returns For Asparagus Production Over Variable Costs, Walla Walla County, Washington, 1990 (Wheel Line Irrigation System)(4 Irrigations).

Item	Unit	Price or Cost/Unit	Quantity	Value Or Cost
Revenue	Lb	0.585	4000.00	$2,338.36
Variable Costs				
Fertilizer	Acre	24.00	1.00	24.00
Irrig. Charge	Acre	11.50	1.00	11.50
Irrig. Elec.	Acre	19.79	1.00	19.79
Irrig. Labor	Acre	7.00	1.00	7.00
Harvest	Acre	855.06	1.00	855.06
Other Variable Cost	Acre	394.44	1.00	394.44
Total Variable Cost				**$1,311.79**
Income After Variable Cost				**$1,026.58**

Ditch Irrigation charge is effective only for farm regions 7,8,11, and 12.
Irrigation electricity cost assumes all water is from a surface diversion. System pressure is assumed to be 50 PSI, pump efficiency is 55% and irrigation efficiency is 65%. Crop price is 1986-1990 average crop price. Yearly crop prices were converted to 1990 dollars before calculating average price.

Table H.5 Summary of Per Acre Net Returns For Irrigated Pasture Over Variable Costs, Walla Walla County, Washington, 1990 (Wheel Line Irrigation System)(4 Irrigations).

Item	Unit	Price or Cost/Unit	Quantity	Value Or Cost
Revenue	AUM	12.000	12.00	$144.00
Variable Costs				
Fertilizer	Acre	20.80	1.00	20.80
Irrig. Charge	Acre	11.50	1.00	11.50
Irrig. Elec.	Acre	39.56	1.00	39.56
Irrig. Labor	Acre	7.00	1.00	7.00
Harvest	Acre	0.00	1.00	0.00
Other Variable Cost	Acre	13.40	1.00	13.40
Total Variable Cost				**$92.26**
Income After Variable Cost				**$51.74**

Ditch Irrigation charge is effective only for farm regions 7,8,11, and 12.
Irrigation electricity cost assumes all water is from a surface diversion. System pressure is assumed to be 50 PSI, pump efficiency is 55% and irrigation efficiency is 65%. Crop price is 1986-1990 average crop price. Yearly crop prices were converted to 1990 dollars before calculating average price.

Table H.6 Summary of Per Acre Net Returns For Irrigated Pasture Over Variable Costs, Walla Walla County, Washington, 1990 (Rill Irrigation System)(4 Irrigations).

Item	Unit	Price or Cost/Unit	Quantity	Value Or Cost
Revenue	AUM	12.000	10.00	$120.00
Variable Costs				
Fertilizer	Acre	20.80	1.00	20.80
Irrig. Charge	Acre	11.50	1.00	11.50
Irrig. Elec.	Acre	0.00	1.00	0.00
Irrig. Labor	Acre	15.96	1.00	15.96
Harvest	Acre	0.00	1.00	0.00
Other Variable Cost	Acre	10.98	1.00	10.98
Total Variable Cost				**$59.24**
Income After Variable Cost				**$60.76**

Ditch Irrigation charge is effective only for farm regions 7,8,11, and 12.
Irrigation electricity cost assumes all water is from a surface diversion. Irrigation efficiency is assumed to be 45%. Crop price is 1986-1990 average crop price. Yearly crop prices were converted to 1990 dollars before calculating average price.

Table H.7 Summary of Per Acre Net Returns For Irrigated Dry Beans Over Variable Costs, Walla Walla County, Washington, 1990 (Wheel Line Irrigation System)(10 Irrigations).

Item	Unit	Price or Cost/Unit	Quantity	Value Or Cost
Revenue	Lb	0.255	2200.00	$560.25
Variable Costs				
Fertilizer	Acre	44.75	1.00	44.75
Irrig. Charge	Acre	11.50	1.00	11.50
Irrig. Elec.	Acre	24.83	1.00	24.83
Irrig. Labor	Acre	17.50	1.00	17.50
Harvest	Acre	65.50	1.00	65.50
Other Variable Cost	Acre	191.36	1.00	191.36
Total Variable Cost				**$355.44**
Income After Variable Cost				**$204.81**

Ditch Irrigation charge is effective only for farm regions 7,8,11, and 12.
Irrigation electricity cost assumes all water is from a surface diversion. System pressure is assumed to be 50 PSI, pump efficiency is 55% and irrigation efficiency is 65%. Crop price is 1986-1990 average crop price. Yearly crop prices were converted to 1990 dollars before calculating average price.

Table H.8 Summary of Per Acre Net Returns For Irrigated Dry Beans Over Variable Costs, Walla Walla County, Washington, 1990 (Hand Line Irrigation System)(10 Irrigations).

Item	Unit	Price or Cost/Unit	Quantity	Value Or Cost
Revenue	Lb	0.255	2200.00	$560.25
Variable Costs				
Fertilizer	Acre	44.75	1.00	44.75
Irrig. Charge	Acre	11.50	1.00	11.50
Irrig. Elec.	Acre	24.83	1.00	24.83
Irrig. Labor	Acre	39.90	1.00	39.90
Harvest	Acre	65.50	1.00	65.50
Other Variable Cost	Acre	180.44	1.00	180.44
Total Variable Cost				**$366.92**
Income After Variable Cost				**$193.32**

Ditch irrigation charge is effective only for farm regions 7,8,11, and 12.
Irrigation electricity cost assumes all water is from a surface diversion. System pressure is assumed to be 50 PSI, pump efficiency is 55% and irrigation efficiency is 65%. Crop price is 1986-1990 average crop price. Yearly crop prices were converted to 1990 dollars before calculating average price.

Table H.9 Summary of Per Acre Net Returns For Irrigated Winter Wheat Over Variable Costs, Walla Walla County, Washington, 1990 (Wheel Line Irrigation System)(4 Irrigations).

Item	Unit	Price or Cost/Unit	Quantity	Value Or Cost
Revenue	Bushel	4.000	105.00	$420.00
Variable Costs				
Fertilizer	Acre	28.60	1.00	28.60
Irrig. Charge	Acre	11.50	1.00	11.50
Irrig. Elec.	Acre	20.51	1.00	20.51
Irrig. Labor	Acre	7.00	1.00	7.00
Harvest	Acre	42.60	1.00	42.60
Other Variable Cost	Acre	75.26	1.00	75.26
Total Variable Cost				**$185.47**
Income After Variable Cost				**$234.53**

Ditch Irrigation charge is effective only for farm regions 7,8,11, and 12.
Irrigation electricity cost assumes all water is from a surface diversion. System pressure is assumed to be 50 PSI, pump efficiency is 55% and irrigation efficiency is 65%. Crop price is the 1990 target price since the adjusted five year average wheat price ($3.92 per bushel) was below the 1990 target price.

Table H.10 Summary of Per Acre Net Returns For Irrigated Winter Wheat Over Variable Costs, Walla Walla County, Washington, 1990 (Hand Line Irrigation System)(4 Irrigations).

Item	Unit	Price or Cost/Unit	Quantity	Value Or Cost
Revenue	Bushel	4.000	105.00	$420.00
Variable Costs				
Fertilizer	Acre	28.60	1.00	28.60
Irrig. Charge	Acre	11.50	1.00	11.50
Irrig. Elec.	Acre	20.51	1.00	20.51
Irrig. Labor	Acre	15.96	1.00	15.96
Harvest	Acre	42.60	1.00	42.60
Other Variable Cost	Acre	71.97	1.00	71.97
Total Variable Cost				**$191.14**
Income After Variable Cost				**$228.86**

Ditch Irrigation charge is effective only for farm regions 7,8,11, and 12.
Irrigation electricity cost assumes all water is from a surface diversion. System pressure is assumed to be 50 PSI, pump efficiency is 55% and irrigation efficiency is 65%. Crop price is the 1990 target price since the adjusted five year average wheat price ($3.92 per bushel) was below the 1990 target price.

Table H.11 Summary of Per Acre Net Returns For Strawberry Production Over Variable Costs, Walla Walla County, Washington, 1990 (Solid Set Irrigation System).

Item	Unit	Price or Cost/Unit	Quantity	Value Or Cost
Revenue	Lb.	0.520	10000.00	$5,200.00
Variable Costs				
Fertilizer	Acre	35.00	1.00	35.00
Irrig. Charge	Acre	0.00	1.00	0.00
Irrig. Elec.	Acre	12.10	1.00	12.10
Irrig. Labor	Acre	39.90	1.00	39.90
Harvest	Acre	2288.80	1.00	2288.80
Other Variable Cost	Acre	1194.32	1.00	1194.32
Total Variable Cost				**$3,570.12**
Income After Variable Cost				**$1,629.88**

Ditch Irrigation charge is effective only for farm regions 7,8,11, and 12.
Irrigation electricity cost assumes all water is from a surface diversion. System pressure is assumed to be 50 PSI, pump efficiency is 55% and irrigation efficiency is 65%. Crop price is 1986-1990 average crop price for the Walla Walla Basin. Yearly crop prices were converted to 1990 dollars before calculating average price.

Table H.12 Summary of Per Acre Net Returns For Apple Production Over Variable Costs, Walla Walla County, Washington, 1990 (Solid Set Irrigation System)(10 Irrigations).

Item	Unit	Price or Cost/Unit	Quantity	Value Or Cost
Revenue	Lb.	0.126	30000.00	$3,768.12
Variable Costs				
Fertilizer	Acre	71.87	1.00	71.87
Irrig. Charge	Acre	11.50	1.00	11.50
Irrig. Elec.	Acre	47.50	1.00	47.50
Irrig. Labor	Acre	17.50	1.00	17.50
Harvest	Acre	528.76	1.00	528.76
Other Variable Cost	Acre	1835.46	1.00	1835.46
Total Variable Cost				**$2,512.58**
Income After Variable Cost				**$1,255.53**

Ditch Irrigation charge is effective only for farm regions 7,8,11, and 12.
Irrigation electricity cost assumes all water is from a surface diversion. System pressure is assumed to be 50 PSI, pump efficiency is 55% and irrigation efficiency is 65%. Crop price is 1986-1990 average crop price. Yearly crop prices were converted to 1990 dollars before calculating average price.

Table H.13 Summary of Per Acre Net Returns For Potato Production Over Variable Costs, Walla Walla County, Washington, 1990 (Center Pivot Irrigation System).

Item	Unit	Price or Cost/Unit	Quantity	Value Or Cost
Revenue	Cwt	4.879	560.00	$2,732.41
Variable Costs				
Fertilizer	Acre	218.45	1.00	218.45
Irrig. Charge	Acre	0.00	1.00	0.00
Irrig. Elec.	Acre	32.61	1.00	32.61
Irrig. Labor	Acre	7.00	1.00	7.00
Harvest	Acre	198.76	1.00	198.76
Other Variable Cost	Acre	794.81	1.00	794.81
Total Variable Cost				**$1,251.63**
Income After Variable Cost				**$1,480.78**

Ditch Irrigation charge is effective only for farm regions 7,8,11, and 12.
Irrigation electricity cost assumes all water is from a surface diversion. System pressure is assumed to be 50 PSI, pump efficiency is 55% and irrigation efficiency is 65%. Crop price is 1986-1990 average crop price. Yearly crop prices were converted to 1990 dollars before calculating average price.

Table H.14 Summary of Variable Production Costs Per Acre For Dryland Winter Wheat-Green Pea Rotation, Walla Walla County, Washington, 1990.

Item	Unit	Price or Cost/Unit	Quantity	Value Or Cost
Revenue				
Winter Wheat	Bushel	4.000	70.00	$280.00
Green Pea	Lb	0.138	2200.00	$304.14
Rotation	Acre	292.071	1.00	$292.07
Variable Costs				
Winter Wheat	Acre	149.747	1.00	$149.75
Green Pea	Acre	133.613	1.00	$133.61
Rotation	Acre	141.680	1.00	$141.68
Income After Variable Cost				**$150.39**

Green Pea price is 1986-1990 average crop price. Yearly crop prices were converted to 1990 dollars before calculating average price.
Wheat price is the 1990 target price since the adjusted five year average wheat price ($3.92 per bushel) was below the 1990 target price.

Table H.15 Summary of Variable Production Costs Per Acre For Dryland Winter Wheat-Fallow Rotation, Walla Walla County, Washington, 1990.

Item	Unit	Price or Cost/Unit	Quantity	Value Or Cost
Revenue				
Winter Wheat	Bushel	4.000	70.00	$280.00
Fallow	N.A.	N.A.	N.A.	$0.00
Rotation	Acre	140.000	1.00	$140.00
Variable Costs				
Winter Wheat	Acre	148.742	1.00	$148.74
Fallow	Acre	31.091	1.00	$31.09
Rotation	Acre	89.916	1.00	$89.92
Income After Variable Cost				**$50.08**

Wheat price is the 1990 target price since the adjusted five year average wheat price ($3.92 per bushel) was below the 1990 target price.

APPENDIX I

On-Farm Economic Model Output Summaries for Irrigation Efficiency Scenarios

APPENDIX I

Table I.1. Region 2 Summary of On-farm Economic Effects for a 10 Percent Improvement In Irrigation Efficiency. The Baseline Case is Included for Comparison Purposes.

		Irrigation Scenario	
Variable:	Baseline	Use Conserved Water On-Farm	Leave Conserved Water In-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$635.59	$632.11	$676.75
NET REVENUE OVER VC:	$370,931	$368,899	$368,436
IRRIGATED ACRES:	584	584	544
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	584	584	544
SURFACE WATER USE (AC/FT):	16	16	14
GRAVEL AQUIFER USE (AC/FT):	253	219	196
BASALT AQUIFER USE (AC/FT):	1,418	1,227	1,096
TOTAL APPLIED WATER (AC/FT):	1,687	1,462	1,306
CONSUMPTIVELY USED WATER (AC/FT):	1,097	1,097	979
IRRIGATION EFFICIENCY:	65.00%	75.00%	75.00%

Table I.2. Region 3 Summary of On-farm Economic Effects for a 10 Percent Improvement In Irrigation Efficiency. The Baseline Case is Included for Comparison Purposes.

	Irrigation Scenario		
Variable:	Baseline	Use Conserved Water On-Farm	Leave Conserved Water In-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$440.78	$440.36	$440.36
NET REVENUE OVER VC:	$354,825	$354,490	$354,490
IRRIGATED ACRES:	805	805	805
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	805	805	805
SURFACE WATER USE (AC/FT):	0	0	0
GRAVEL AQUIFER USE (AC/FT):	970	841	841
BASALT AQUIFER USE (AC/FT):	1,018	882	882
TOTAL APPLIED WATER (AC/FT):	1,988	1,723	1,723
CONSUMPTIVELY USED WATER (AC/FT):	1,292	1,292	1,292
IRRIGATION EFFICIENCY:	65.00%	75.00%	75.00%

Table I.3. Region 4 Summary of On-farm Economic Effects for a 10 Percent Improvement In Irrigation Efficiency. The Baseline Case is Included for Comparison Purposes.

	----------Irrigation Scenario------------		
Variable:	Baseline	Use Conserved Water On-Farm	Leave Conserved Water In-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$685.88	$683.98	$683.98
NET REVENUE OVER VC:	$77,505	$77,289	$77,289
IRRIGATED ACRES:	113	113	113
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	113	113	113
SURFACE WATER USE (AC/FT):	0	0	0
GRAVEL AQUIFER USE (AC/FT):	39	34	34
BASALT AQUIFER USE (AC/FT):	296	256	256
TOTAL APPLIED WATER (AC/FT):	335	291	291
CONSUMPTIVELY USED WATER (AC/FT):	218	218	218
IRRIGATION EFFICIENCY:	65.00%	75.00%	75.00%

Table I.4. Region 5 Summary of On-farm Economic Effects for a 10 Percent Improvement In Irrigation Efficiency. The Baseline Case is Included for Comparison Purposes.

	----------Irrigation Scenario------------		
Variable:	Baseline	Use Conserved Water On-Farm	Leave Conserved Water In-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$329.31	$336.86	$334.05
NET REVENUE OVER VC:	$471,568	$482,390	$478,356
IRRIGATED ACRES:	1,432	1,432	1,411
DRYLAND ACRES:	0	0	21
TOTAL ACRES:	1,432	1,432	1,432
SURFACE WATER USE (AC/FT):	2,382	2,381	2,143
GRAVEL AQUIFER USE (AC/FT):	103	79	86
BASALT AQUIFER USE (AC/FT):	2,350	1,793	1,948
TOTAL APPLIED WATER (AC/FT):	4,835	4,253	4,177
CONSUMPTIVELY USED WATER (AC/FT):	2,902	2,960	2,921
IRRIGATION EFFICIENCY:	60.03%	69.60%	69.92%

Table I.5. Region 6 Summary of On-farm Economic Effects for a 10 Percent Improvement In Irrigation Efficiency. The Baseline Case is Included for Comparison Purposes.

	-----------Irrigation Scenario------------		
Variable:	Baseline	Use Conserved Water On-Farm	Leave Conserved Water In-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$205.48	$203.00	$202.94
NET REVENUE OVER VC:	$115,893	$114,490	$114,456
IRRIGATED ACRES:	564	564	564
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	564	564	564
SURFACE WATER USE (AC/FT):	1,866	1,592	1,626
GRAVEL AQUIFER USE (AC/FT):	0	0	0
BASALT AQUIFER USE (AC/FT):	0	0	0
TOTAL APPLIED WATER (AC/FT):	1,866	1,592	1,626
CONSUMPTIVELY USED WATER (AC/FT):	1,175	1,177	1,175
IRRIGATION EFFICIENCY:	62.95%	73.89%	72.27%

Table I.6. Region 7 Summary of On-farm Economic Effects for a 10 Percent Improvement In Irrigation Efficiency. The Baseline Case is Included for Comparison Purposes.

	----------Irrigation Scenario------------		
Variable:	Baseline	Use Conserved Water On-Farm	Leave Conserved Water In-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$325.59	$326.11	$324.99
NET REVENUE OVER VC:	$890,123	$891,559	$888,492
IRRIGATED ACRES:	2,734	2,734	2,734
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	2,734	2,734	2,734
SURFACE WATER USE (AC/FT):	4,914	4,896	4,423
GRAVEL AQUIFER USE (AC/FT):	2,029	1,480	1,669
BASALT AQUIFER USE (AC/FT):	2,267	1,654	1,865
TOTAL APPLIED WATER (AC/FT):	9,210	8,030	7,957
CONSUMPTIVELY USED WATER (AC/FT):	5,307	5,331	5,331
IRRIGATION EFFICIENCY:	57.62%	66.39%	67.00%

Table I.7. Region 8 Summary of On-farm Economic Effects for a 10 Percent Improvement In Irrigation Efficiency. The Baseline Case is Included for Comparison Purposes.

	Irrigation Scenario		
Variable:	Baseline	Use Conserved Water On-Farm	Leave Conserved Water In-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$378.85	$379.78	$378.85
NET REVENUE OVER VC:	$4,506,780	$4,517,751	$4,506,709
IRRIGATED ACRES:	11,896	11,896	11,896
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	11,896	11,896	11,896
SURFACE WATER USE (AC/FT):	17,960	17,960	16,164
GRAVEL AQUIFER USE (AC/FT):	16,244	11,906	13,267
BASALT AQUIFER USE (AC/FT):	68	50	56
TOTAL APPLIED WATER (AC/FT):	34,272	29,916	29,487
CONSUMPTIVELY USED WATER (AC/FT):	19,766	19,766	19,766
IRRIGATION EFFICIENCY:	57.68%	66.07%	67.03%

Table I.8. Region 9 Summary of On-farm Economic Effects for a 10 Percent Improvement In Irrigation Efficiency. The Baseline Case is Included for Comparison Purposes.

	----------Irrigation Scenario------------		
Variable:	Baseline	Use Conserved Water On-Farm	Leave Conserved Water In-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$398.05	$399.51	$398.81
NET REVENUE OVER VC:	$1,732,585	$1,738,932	$1,735,888
IRRIGATED ACRES:	4,353	4,353	4,353
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	4,353	4,353	4,353
SURFACE WATER USE (AC/FT):	3,811	3,811	3,430
GRAVEL AQUIFER USE (AC/FT):	2,260	1,858	1,925
BASALT AQUIFER USE (AC/FT):	8,414	6,916	7,166
TOTAL APPLIED WATER (AC/FT):	14,485	12,585	12,521
CONSUMPTIVELY USED WATER (AC/FT):	9,073	9,073	9,073
IRRIGATION EFFICIENCY:	62.64%	72.09%	72.46%

Table I.9. Region 10 Summary of On-farm Economic Effects for a 10 Percent Improvement In Irrigation Efficiency. The Baseline Case is Included for Comparison Purposes.

	Irrigation Scenario		
Variable:	Baseline	Use Conserved Water On-Farm	Leave Conserved Water In-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$256.99	$259.27	$258.66
NET REVENUE OVER VC:	$385,094	$388,517	$387,602
IRRIGATED ACRES:	1,499	1,499	1,499
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	1,499	1,499	1,499
SURFACE WATER USE (AC/FT):	1,585	1,585	1,426
GRAVEL AQUIFER USE (AC/FT):	2,259	1,790	1,873
BASALT AQUIFER USE (AC/FT):	1,470	1,165	1,219
TOTAL APPLIED WATER (AC/FT):	5,314	4,539	4,518
CONSUMPTIVELY USED WATER (AC/FT):	3,203	3,203	3,203
IRRIGATION EFFICIENCY:	60.28%	70.56%	70.89%

Table I.10. Region 11 Summary of On-farm Economic Effects for a 10 Percent Improvement In Irrigation Efficiency. The Baseline Case is Included for Comparison Purposes.

	Irrigation Scenario		
Variable:	Baseline	Use Conserved Water On-Farm	Leave Conserved Water In-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$323.67	$319.00	$318.25
NET REVENUE OVER VC:	$590,569	$592,793	$591,400
IRRIGATED ACRES:	1,825	1,858	1,858
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	1,825	1,858	1,858
SURFACE WATER USE (AC/FT):	2,313	2,313	2,082
GRAVEL AQUIFER USE (AC/FT):	2,743	2,251	2,375
BASALT AQUIFER USE (AC/FT):	1,830	1,502	1,585
TOTAL APPLIED WATER (AC/FT):	6,886	6,066	6,042
CONSUMPTIVELY USED WATER (AC/FT):	3,956	4,069	4,069
IRRIGATION EFFICIENCY:	57.45%	67.08%	67.34%

Table I.11. Region 12 Summary of On-farm Economic Effects for a 10 Percent Improvement In Irrigation Efficiency. The Baseline Case is Included for Comparison Purposes.

	-----------Irrigation Scenario------------		
Variable:	Baseline	Use Conserved Water On-Farm	Leave Conserved Water In-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$285.95	$271.66	$270.10
NET REVENUE OVER VC:	$451,111	$447,892	$445,315
IRRIGATED ACRES:	1,578	1,649	1,649
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	1,578	1,649	1,649
SURFACE WATER USE (AC/FT):	4,373	4,373	3,935
GRAVEL AQUIFER USE (AC/FT):	1,287	1,121	1,337
BASALT AQUIFER USE (AC/FT):	679	591	705
TOTAL APPLIED WATER (AC/FT):	6,339	6,085	5,977
CONSUMPTIVELY USED WATER (AC/FT):	3,338	3,554	3,537
IRRIGATION EFFICIENCY:	52.66%	58.41%	59.18%

Table I.12. Region 13 Summary of On-farm Economic Effects for a 10 Percent Improvement In Irrigation Efficiency. The Baseline Case is Included for Comparison Purposes.

	----------Irrigation Scenario------------		
Variable:	Baseline	Use Conserved Water On-Farm	Leave Conserved Water In-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$577.56	$574.01	$573.73
NET REVENUE OVER VC:	$3,340,644	$3,320,114	$3,318,509
IRRIGATED ACRES:	5,784	5,784	5,784
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	5,784	5,784	5,784
SURFACE WATER USE (AC/FT):	2,507	2,507	2,256
GRAVEL AQUIFER USE (AC/FT):	14,764	12,167	12,421
BASALT AQUIFER USE (AC/FT):	357	294	300
TOTAL APPLIED WATER (AC/FT):	17,628	14,969	14,978
CONSUMPTIVELY USED WATER (AC/FT):	11,193	11,193	11,193
IRRIGATION EFFICIENCY:	63.50%	74.78%	74.73%

Table I.13. Region 14 Summary of On-farm Economic Effects for a 10 Percent Improvement In Irrigation Efficiency. The Baseline Case is Included for Comparison Purposes.

	Irrigation Scenario		
Variable:	Baseline	Use Conserved Water On-Farm	Leave Conserved Water In-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$725.28	$720.89	$720.64
NET REVENUE OVER VC:	$909,289	$903,782	$903,473
IRRIGATED ACRES:	1,254	1,254	1,254
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	1,254	1,254	1,254
SURFACE WATER USE (AC/FT):	369	369	332
GRAVEL AQUIFER USE (AC/FT):	3,109	2,609	2,639
BASALT AQUIFER USE (AC/FT):	904	759	767
TOTAL APPLIED WATER (AC/FT):	4,382	3,737	3,738
CONSUMPTIVELY USED WATER (AC/FT):	2,788	2,788	2,788
IRRIGATION EFFICIENCY:	63.63%	74.60%	74.58%

Table I.14. Region 15 Summary of On-farm Economic Effects for a 10 Percent Improvement In Irrigation Efficiency. The Baseline Case is Included for Comparison Purposes.

	----------Irrigation Scenario------------		
Variable:	Baseline	Use Conserved Water On-Farm	Leave Conserved Water In-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$522.70	$519.60	$517.69
NET REVENUE OVER VC:	$143,273	$142,423	$141,898
IRRIGATED ACRES:	274	274	274
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	274	274	274
SURFACE WATER USE (AC/FT):	372	372	335
GRAVEL AQUIFER USE (AC/FT):	189	140	158
BASALT AQUIFER USE (AC/FT):	189	140	158
TOTAL APPLIED WATER (AC/FT):	750	652	651
CONSUMPTIVELY USED WATER (AC/FT):	478	478	478
IRRIGATION EFFICIENCY:	63.73%	73.24%	73.46%

Table I.15. Region 16 Summary of On-farm Economic Effects for a 10 Percent Improvement In Irrigation Efficiency. The Baseline Case is Included for Comparison Purposes.

	----------Irrigation Scenario------------		
Variable:	Baseline	Use Conserved Water On-Farm	Leave Conserved Water In-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$369.59	$368.79	$368.26
NET REVENUE OVER VC:	$13,305	$13,277	$13,257
IRRIGATED ACRES:	36	36	36
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	36	36	36
SURFACE WATER USE (AC/FT):	60	56	53
GRAVEL AQUIFER USE (AC/FT):	27	21	23
BASALT AQUIFER USE (AC/FT):	16	12	13
TOTAL APPLIED WATER (AC/FT):	103	89	89
CONSUMPTIVELY USED WATER (AC/FT):	67	67	67
IRRIGATION EFFICIENCY:	65.00%	75.00%	75.00%

APPENDIX J

On-Farm Economic Model Output Summaries for
No Surface Water for Irrigation Scenarios

Table J.1. Region 2 Summary of On-Farm Economic Effects for Two Alternative Surface Diversion Policies: Elimination of all Surface Diversions versus the Elimination of all Surface Diversions (Except in Region 9) for the Purpose of Enhancing Upstream Fishery Habitant Before Diverting the Conserved Water for Down-Stream Agricultural Use, West of the Gardena Irrigation District.

	-----------Irrigation Scenario------------		
Variable:	Baseline	Conserved Water Remains In-Stream	Conserved Water Used Down-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$635.59	$635.23	$635.23
NET REVENUE OVER VC:	$370,931	$370,719	$370,719
IRRIGATED ACRES:	584	584	584
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	584	584	584
SURFACE WATER USE (AC/FT):	16	0	0
GRAVEL AQUIFER USE (AC/FT):	253	256	256
BASALT AQUIFER USE (AC/FT):	1,418	1,431	1,431
TOTAL APPLIED WATER (AC/FT):	1,687	1,687	1,687
CONSUMPTIVELY USED WATER (AC/FT):	1,097	1,097	1,097
IRRIGATION EFFICIENCY:	65.00%	65.00%	65.00%

Table J.2. Region 3 Summary of On-Farm Economic Effects for Two Alternative Surface Diversion Policies: Elimination of all Surface Diversions versus the Elimination of all Surface Diversions (Except in Region 9) for the Purpose of Enhancing Upstream Fishery Habitant Before Diverting the Conserved Water for Down-Stream Agricultural Use, West of the Gardena Irrigation District.

Variable:	Irrigation Scenario: Baseline	Conserved Water Remains In-Stream	Conserved Water Used Down-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$440.78	$440.78	$440.78
NET REVENUE OVER VC:	$354,825	$354,825	$354,825
IRRIGATED ACRES:	805	805	805
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	805	805	805
SURFACE WATER USE (AC/FT):	0	0	0
GRAVEL AQUIFER USE (AC/FT):	970	970	970
BASALT AQUIFER USE (AC/FT):	1,018	1,018	1,018
TOTAL APPLIED WATER (AC/FT):	1,988	1,988	1,988
CONSUMPTIVELY USED WATER (AC/FT):	1,292	1,292	1,292
IRRIGATION EFFICIENCY:	65.00%	65.00%	65.00%

Table J.3. Region 4 Summary of On-Farm Economic Effects for Two Alternative Surface Diversion Policies: Elimination of all Surface Diversions versus the Elimination of all Surface Diversions (Except in Region 9) for the Purpose of Enhancing Upstream Fishery Habitant Before Diverting the Conserved Water for Down-Stream Agricultural Use, West of the Gardena Irrigation District.

	-----------Irrigation Scenario------------		
Variable:	Baseline	Conserved Water Remains In-Stream	Conserved Water Used Down-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$685.88	$685.88	$685.88
NET REVENUE OVER VC:	$77,505	$77,505	$77,505
IRRIGATED ACRES:	113	113	113
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	113	113	113
SURFACE WATER USE (AC/FT):	0	0	0
GRAVEL AQUIFER USE (AC/FT):	39	39	39
BASALT AQUIFER USE (AC/FT):	296	296	296
TOTAL APPLIED WATER (AC/FT):	335	335	335
CONSUMPTIVELY USED WATER (AC/FT):	218	218	218
IRRIGATION EFFICIENCY:	65.00%	65.00%	65.00%

Table J.4. Region 5 Summary of On-Farm Economic Effects for Two Alternative Surface Diversion Policies: Elimination of all Surface Diversions versus the Elimination of all Surface Diversions (Except in Region 9) for the Purpose of Enhancing Upstream Fishery Habitant Before Diverting the Conserved Water for Down-Stream Agricultural Use, West of the Gardena Irrigation District.

	----------Irrigation Scenario------------		
Variable:	Baseline	Conserved Water Remains In-Stream	Conserved Water Used Down-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$329.31	$299.34	$299.34
NET REVENUE OVER VC:	$471,568	$428,649	$428,649
IRRIGATED ACRES:	1,432	1,070	1,070
DRYLAND ACRES:	0	362	362
TOTAL ACRES:	1,432	1,432	1,432
SURFACE WATER USE (AC/FT):	2,382	0	0
GRAVEL AQUIFER USE (AC/FT):	103	137	137
BASALT AQUIFER USE (AC/FT):	2,350	3,115	3,115
TOTAL APPLIED WATER (AC/FT):	4,835	3,252	3,252
CONSUMPTIVELY USED WATER (AC/FT):	2,902	1,998	1,998
IRRIGATION EFFICIENCY:	60.03%	61.43%	61.43%

Table J.5. Region 6 Summary of On-Farm Economic Effects for Two Alternative Surface Diversion Policies: Elimination of all Surface Diversions versus the Elimination of all Surface Diversions (Except in Region 9) for the Purpose of Enhancing Upstream Fishery Habitant Before Diverting the Conserved Water for Down-Stream Agricultural Use, West of the Gardena Irrigation District.

	-----------Irrigation Scenario------------		
Variable:	Baseline	Conserved Water Remains In-Stream	Conserved Water Used Down-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$205.48	$95.04	$95.04
NET REVENUE OVER VC:	$115,893	$46,475	$46,475
IRRIGATED ACRES:	564	0	0
DRYLAND ACRES:	0	489	489
TOTAL ACRES:	564	489	489
SURFACE WATER USE (AC/FT):	1,866	0	0
GRAVEL AQUIFER USE (AC/FT):	0	0	0
BASALT AQUIFER USE (AC/FT):	0	0	0
TOTAL APPLIED WATER (AC/FT):	1,866	0	0
CONSUMPTIVELY USED WATER (AC/FT):	1,175	0	0
IRRIGATION EFFICIENCY:	62.95%	ERR	N.A.

Table J.6. Region 7 Summary of On-Farm Economic Effects for Two Alternative Surface Diversion Policies: Elimination of all Surface Diversions versus the Elimination of all Surface Diversions (Except in Region 9) for the Purpose of Enhancing Upstream Fishery Habitant Before Diverting the Conserved Water for Down-Stream Agricultural Use, West of the Gardena Irrigation District.

	-----------Irrigation Scenario------------		
Variable:	Baseline	Conserved Water Remains In-Stream	Conserved Water Used Down-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$325.59	$308.06	$308.06
NET REVENUE OVER VC:	$890,123	$819,945	$819,945
IRRIGATED ACRES:	2,734	2,336	2,336
DRYLAND ACRES:	0	325	325
TOTAL ACRES:	2,734	2,662	2,662
SURFACE WATER USE (AC/FT):	4,914	0	0
GRAVEL AQUIFER USE (AC/FT):	2,029	3,479	3,479
BASALT AQUIFER USE (AC/FT):	2,267	3,888	3,888
TOTAL APPLIED WATER (AC/FT):	9,210	7,367	7,367
CONSUMPTIVELY USED WATER (AC/FT):	5,307	4,309	4,309
IRRIGATION EFFICIENCY:	57.62%	58.49%	58.49%

Table J.7. Region 8 Summary of On-Farm Economic Effects for Two Alternative Surface Diversion Policies: Elimination of all Surface Diversions versus the Elimination of all Surface Diversions (Except in Region 9) for the Purpose of Enhancing Upstream Fishery Habitant Before Diverting the Conserved Water for Down-Stream Agricultural Use, West of the Gardena Irrigation District.

	----------Irrigation Scenario------------		
Variable:	Baseline	Conserved Water Remains In-Stream	Conserved Water Used Down-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$378.85	$369.90	$369.90
NET REVENUE OVER VC:	$4,506,780	$4,317,046	$4,317,046
IRRIGATED ACRES:	11,896	11,671	11,671
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	11,896	11,671	11,671
SURFACE WATER USE (AC/FT):	17,960	(0)	(0)
GRAVEL AQUIFER USE (AC/FT):	16,244	33,799	33,799
BASALT AQUIFER USE (AC/FT):	68	149	149
TOTAL APPLIED WATER (AC/FT):	34,272	33,947	33,947
CONSUMPTIVELY USED WATER (AC/FT):	19,766	19,094	19,094
IRRIGATION EFFICIENCY:	57.68%	56.24%	56.24%

Table J.8. Region 9 Summary of On-Farm Economic Effects for Two Alternative Surface Diversion Policies: Elimination of all Surface Diversions versus the Elimination of all Surface Diversions (Except in Region 9) for the Purpose of Enhancing Upstream Fishery Habitant Before Diverting the Conserved Water for Down-Stream Agricultural Use, West of the Gardena Irrigation District.

	Irrigation Scenario		
Variable:	Baseline	Conserved Water Remains In-Stream	Conserved Water Used Down-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$398.05	$389.94	$497.77
NET REVENUE OVER VC:	$1,732,585	$1,697,271	$6,871,531
IRRIGATED ACRES:	4,353	4,353	13,805
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	4,353	4,353	13,805
SURFACE WATER USE (AC/FT):	3,811	0	24,518
GRAVEL AQUIFER USE (AC/FT):	2,260	2,993	1,852
BASALT AQUIFER USE (AC/FT):	8,414	11,144	6,893
TOTAL APPLIED WATER (AC/FT):	14,485	14,137	33,263
CONSUMPTIVELY USED WATER (AC/FT):	9,073	8,986	22,247
IRRIGATION EFFICIENCY:	62.64%	63.56%	66.88%

Table J.9. Region 10 Summary of On-Farm Economic Effects for Two Alternative Surface Diversion Policies: Elimination of all Surface Diversions versus the Elimination of all Surface Diversions (Except in Region 9) for the Purpose of Enhancing Upstream Fishery Habitant Before Diverting the Conserved Water for Down-Stream Agricultural Use, West of the Gardena Irrigation District.

	-----------Irrigation Scenario-------------		
Variable:	Baseline	Conserved Water Remains In-Stream	Conserved Water Used Down-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$256.99	$250.04	$250.04
NET REVENUE OVER VC:	$385,094	$374,689	$374,689
IRRIGATED ACRES:	1,499	1,499	1,499
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	1,499	1,499	1,499
SURFACE WATER USE (AC/FT):	1,585	(0)	(0)
GRAVEL AQUIFER USE (AC/FT):	2,259	3,199	3,199
BASALT AQUIFER USE (AC/FT):	1,470	2,082	2,082
TOTAL APPLIED WATER (AC/FT):	5,314	5,281	5,281
CONSUMPTIVELY USED WATER (AC/FT):	3,203	3,200	3,200
IRRIGATION EFFICIENCY:	60.28%	60.59%	60.59%

Table J.10 Region 11 Summary of On-Farm Economic Effects for Two Alternative Surface Diversion Policies: Elimination of all Surface Diversions versus the Elimination of all Surface Diversions (Except in Region 9) for the Purpose of Enhancing Upstream Fishery Habitant Before Diverting the Conserved Water for Down-Stream Agricultural Use, West of the Gardena Irrigation District.

	Irrigation Scenario		
Variable:	Baseline	Conserved Water Remains In-Stream	Conserved Water Used Down-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$323.67	$331.53	$331.53
NET REVENUE OVER VC:	$590,569	$573,744	$573,744
IRRIGATED ACRES:	1,825	1,731	1,731
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	1,825	1,731	1,731
SURFACE WATER USE (AC/FT):	2,313	(0)	(0)
GRAVEL AQUIFER USE (AC/FT):	2,743	3,770	3,770
BASALT AQUIFER USE (AC/FT):	1,830	2,516	2,516
TOTAL APPLIED WATER (AC/FT):	6,886	6,286	6,286
CONSUMPTIVELY USED WATER (AC/FT):	3,956	3,687	3,687
IRRIGATION EFFICIENCY:	57.45%	58.66%	58.66%

Table J.11. Region 12 Summary of On-Farm Economic Effects for Two Alternative Surface Diversion Policies: Elimination of all Surface Diversions versus the Elimination of all Surface Diversions (Except in Region 9) for the Purpose of Enhancing Upstream Fishery Habitant Before Diverting the Conserved Water for Down-Stream Agricultural Use, West of the Gardena Irrigation District.

	------------Irrigation Scenario------------		
Variable:	Baseline	Conserved Water Remains In-Stream	Conserved Water Used Down-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$285.95	$330.85	$330.85
NET REVENUE OVER VC:	$451,111	$420,437	$420,437
IRRIGATED ACRES:	1,578	1,271	1,271
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	1,578	1,271	1,271
SURFACE WATER USE (AC/FT):	4,373	0	0
GRAVEL AQUIFER USE (AC/FT):	1,287	2,660	2,660
BASALT AQUIFER USE (AC/FT):	679	1,403	1,403
TOTAL APPLIED WATER (AC/FT):	6,339	4,063	4,063
CONSUMPTIVELY USED WATER (AC/FT):	3,338	2,460	2,460
IRRIGATION EFFICIENCY:	52.66%	60.53%	60.53%

Table J.12. Region 13 Summary of On-Farm Economic Effects for Two Alternative Surface Diversion Policies: Elimination of all Surface Diversions versus the Elimination of all Surface Diversions (Except in Region 9) for the Purpose of Enhancing Upstream Fishery Habitant Before Diverting the Conserved Water for Down-Stream Agricultural Use, West of the Gardena Irrigation District.

	----------Irrigation Scenario------------		
Variable:	Baseline	Conserved Water Remains In-Stream	Conserved Water Used Down-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$577.56	$574.39	$574.39
NET REVENUE OVER VC:	$3,340,644	$3,322,328	$3,322,328
IRRIGATED ACRES:	5,784	5,784	5,784
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	5,784	5,784	5,784
SURFACE WATER USE (AC/FT):	2,507	0	0
GRAVEL AQUIFER USE (AC/FT):	14,764	17,664	17,664
BASALT AQUIFER USE (AC/FT):	357	427	427
TOTAL APPLIED WATER (AC/FT):	17,628	18,091	18,091
CONSUMPTIVELY USED WATER (AC/FT):	11,193	11,193	11,193
IRRIGATION EFFICIENCY:	63.50%	61.87%	61.87%

Table J.13. Region 14 Summary of On-Farm Economic Effects for Two Alternative Surface Diversion Policies: Elimination of all Surface Diversions versus the Elimination of all Surface Diversions (Except in Region 9) for the Purpose of Enhancing Upstream Fishery Habitant Before Diverting the Conserved Water for Down-Stream Agricultural Use, West of the Gardena Irrigation District.

	Irrigation Scenario		
Variable:	Baseline	Conserved Water Remains In-Stream	Conserved Water Used Down-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$725.28	$722.61	$722.61
NET REVENUE OVER VC:	$909,289	$905,938	$905,938
IRRIGATED ACRES:	1,254	1,246	1,246
DRYLAND ACRES:	0	7	7
TOTAL ACRES:	1,254	1,254	1,254
SURFACE WATER USE (AC/FT):	369	(0)	(0)
GRAVEL AQUIFER USE (AC/FT):	3,109	3,390	3,390
BASALT AQUIFER USE (AC/FT):	904	985	985
TOTAL APPLIED WATER (AC/FT):	4,382	4,375	4,375
CONSUMPTIVELY USED WATER (AC/FT):	2,788	2,768	2,768
IRRIGATION EFFICIENCY:	63.63%	63.27%	63.27%

Table J.14. Region 15 Summary of On-Farm Economic Effects for Two Alternative Surface Diversion Policies: Elimination of all Surface Diversions versus the Elimination of all Surface Diversions (Except in Region 9) for the Purpose of Enhancing Upstream Fishery Habitant Before Diverting the Conserved Water for Down-Stream Agricultural Use, West of the Gardena Irrigation District.

	-----------Irrigation Scenario------------		
Variable:	Baseline	Conserved Water Remains In-Stream	Conserved Water Used Down-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$522.70	$520.33	$520.33
NET REVENUE OVER VC:	$143,273	$137,949	$137,949
IRRIGATED ACRES:	274	265	265
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	274	265	265
SURFACE WATER USE (AC/FT):	372	0	0
GRAVEL AQUIFER USE (AC/FT):	189	347	347
BASALT AQUIFER USE (AC/FT):	189	347	347
TOTAL APPLIED WATER (AC/FT):	750	694	694
CONSUMPTIVELY USED WATER (AC/FT):	478	451	451
IRRIGATION EFFICIENCY:	63.73%	65.00%	65.00%

Table J.15. Region 16 Summary of On-Farm Economic Effects for Two Alternative Surface Diversion Policies: Elimination of all Surface Diversions versus the Elimination of all Surface Diversions (Except in Region 9) for the Purpose of Enhancing Upstream Fishery Habitant Before Diverting the Conserved Water for Down-Stream Agricultural Use, West of the Gardena Irrigation District.

	-----------Irrigation Scenario------------		
Variable:	Baseline	Conserved Water Remains In-Stream	Conserved Water Used Down-Stream
AVE. RETURN OVER VC ($'S/ACRE):	$369.59	$356.78	$356.78
NET REVENUE OVER VC:	$13,305	$12,844	$12,844
IRRIGATED ACRES:	36	36	36
DRYLAND ACRES:	0	0	0
TOTAL ACRES:	36	36	36
SURFACE WATER USE (AC/FT):	60	0	0
GRAVEL AQUIFER USE (AC/FT):	27	65	65
BASALT AQUIFER USE (AC/FT):	16	38	38
TOTAL APPLIED WATER (AC/FT):	103	103	103
CONSUMPTIVELY USED WATER (AC/FT):	67	67	67
IRRIGATION EFFICIENCY:	65.00%	65.00%	65.00%

APPENDIX K

Example of Complete On-Farm Economic Model Output

APPENDIX K

Detailed information on Region 8 (Gardena area) irrigation practices, irrigated crops, and water use for the baseline situation and three alternative water policy scenarios is presented in this appendix. Given the size and diversity of Region 8, two representatve farms were required to effectively model each policy scenario for the region. Odd numbered appendix tables correspond to Farm A, and even numbered tables to Farm B.

Regional monthly water supply was divided between the two regions such that each farm's crop consumptive demand is met in the baseline scenario. Ground water capacity was allocated to each representatve farm as the percentage of each farm's consumptive demand to total regional consumptive demand under the baseline condition. The top half of each appendix table contains the critical assumptions for each farm policy. The bottom half or each appendix table reports selected economic and hydrologic variable values for each linear programming solution.

Regional water use, irrigated acreage, income over variable cost, and selected irrigation dependent costs are computed by summing the output information on Farms A and B for each policy scenario. As discussed in Appendix C, the selected irrigation dependent costs consist of fertilizer, harvest, irrigation labor, system maintenance, system energy, and well energy costs. Total irrigation dependent variable costs for each farm in the region are reported in each appendix table. These total costs are reported on both a representative farm and a per acre basis (the per acre cost is computed as total irrigation dependent costs divided by each farm's irrigated acreage).

Appendix Tables K.1 and K.2 contain the information on baseline farm returns and irrigation practices. Tables K.3 through K.6 summarize the two policies dealing with a 10 percent improvement in on-farm irrigation efficiency. Tables K.3 and K.4 corrrespond to the scenario that allows the conserved water to be used on-farm, while tables K.5 and K.6 are associated with the policy that leaves the conserved water in-stream for fish habitat. Appendix tables K.7 and K.8 report the economic and hydrologic impact a no surface diversion water policy has on Region 8. Since the remaining water polices analyzed do not affect current practices in Region 8, these eight appendix tables are sufficient to measure the economic and hydrologic impact of all policies examined on Region 8.

Appendix Table K.1. Baseline Summary Information for Farm A in Region 8.

	--------------IRRIGATED CROPS-------------					DRYLAND
CROP:	PAST	ASPR	ALSD	ONON	WHT	DWHFA
UNITS:	AUM	POUND	CWT	POUNDS	BUSHEL	BUSHEL
NORMAL YIELD:	10	4000	5.75	36000	105	70
MIN ACRES:	0.0	0.0	0.0	0.0	0.0	0.0
MAX ACRES(L1):	0.0	77.4	4275.0	140.1	1054.0	5000.0
MAX ACRES(L2):	112.5	0.0	0.0	0.0	0.0	0.0
TOTAL ACRES:	5659		FALLOW WITH DRYLAND ==>			YES
MAX IRR. DEF.	30.00%	5.00%	20.00%	0.00%	30.00%	N.A.
DEFICIT YIELD	7.20	3840.00	4.72	36000.00	84.00	<= FULL
% NORMAL YIELD	72.00%	96.00%	82.00%	100.00%	80.00%	<= DEFICI
IRRIG SYSTEM:	RILL	SIDEROLL	HANDLINE	HANDLINE	HANDLINE	DEFICIT
BASE EFFIC:	45.00%	65.00%	65.00%	65.00%	65.00%	<= NONE
DEFICIT EFFIC:	45.00%	67.00%	71.00%	65.00%	75.00%	<= FULL
GRAVEL AQUIFER	YES	WELL CAPACITY (AC/FT/MONTH)			2,157	LIFT
			PUMP EFFICIENCY		55.00%	130
BASALT AQUIFER	YES	WELL CAPACITY (AC/FT/MONTH)			28	LIFT
			PUMP EFFICIENCY		55.00%	280

MAX. SURFACE	JANUARY	0	MAY	1415	SEPTEMBER	309
DIVERSION	FEBUARY	0	JUNE	894	OCTOBER	791
(AC/FT/MONTH)	MARCH	50	JULY	404	NOVEMBER	1395
	APRIL	2384	AUGUST	546	DECEMBER	200

***********LINEAR PROGRAMMING SOLUTION FOR THIS SCENARIO**************

GROSS RETURNS OVER VARIABLE COSTS: 2334365 PER ACRE: $412.50

CROP:	PAST	ASPR	ALSD	ONON	WHT	DWHFA
ACRES PLANTED:	112.5	77.4	4275.0	140.1	1054.0	0.0
TOTAL PROD.:	1125	309600	24581	5043600	110670	0
PER ACRE YD.:	10.00	4000.00	5.75	36000.00	105.00	0.00
	SELECTED IRRIGATION DEPENDENT VARIABLE COSTS:					TOTAL
FERTILIZER:	$2,340	$1,858	$0	$10,508	$30,144	$44,849
HARVEST:	$0	$66,182	$69,854	$353,873	$44,900	534809
IRR. LABOR:	$1,796	$542	$34,115	$7,267	$16,822	60541
SYS. MAINT.:	$561	$314	$7,744	$417	$1,886	10922
SYS. ENERGY:	$0	$1,532	$88,783	$4,777	$21,622	116714
WELL ENERGY:						$72,989
TOTAL SEL. VC:	4696	70426	200496	376841	115375	840823
SEL VC PER AC:	41.74	909.90	46.90	2689.80	109.46	148.58

	CONSUMPTIVE	ACRE FEET APPLIED WATER BY SOURCE				REGIONAL
MONTH:	ACRE FEET	TOTAL	SURFACE	GRAVEL	BASALT	EFFICIENCY
JANUARY:	0.00	0.00	0.00	0.00	0.00	N.A.
FEBUARY:	0.00	0.00	0.00	0.00	0.00	N.A.
MARCH:	43.04	66.21	50.35	15.86	0.00	65.00%
APRIL:	333.10	2384.45	2384.45	0.00	0.00	13.97%
MAY:	1878.69	2369.51	1414.75	954.76	0.00	79.29%
JUNE:	2961.16	3054.09	893.70	2157.00	3.39	96.96%
JULY:	1832.31	2589.28	404.28	2157.00	28.00	70.77%
AUGUST:	1047.09	1662.97	546.27	1116.70	0.00	62.97%
SEPTEMBER:	876.89	1382.08	308.99	1073.09	0.00	63.45%
OCTOBER:	187.41	790.94	790.94	0.00	0.00	23.69%
NOVEMBER:	0.00	1395.04	1395.04	0.00	0.00	0.00%
DECEMBER:	0.00	200.15	200.15	0.00	0.00	0.00%
TOTAL:	9159.68	15894.72	8388.92	7474.41	31.39	57.63%

Appendix Table K.2. Baseline Summary Information for Farm B in Region 8.

	--------------IRRIGATED CROPS-------------					DRYLAND
CROP:	ALSD	ALHY	PAST	BEAN	WHT	DWHFA
UNITS:	CWT	TON	AUM	POUNDS	BUSHEL	BUSHEL
NORMAL YIELD:	5.75	6.5	10	2200	105	70
MIN ACRES:	0.0	0.0	0.0	0.0	0.0	0.0
MAX ACRES(L1):	4275.0	550.0	0.0	245.3	1054.0	5000.0
MAX ACRES(L2):	0.0	0.0	112.5	0.0	0.0	0.0
TOTAL ACRES:	6236.8		FALLOW WITH DRYLAND ==>			YES
MAX IRR. DEF.	20.00%	30.00%	30.00%	20.00%	30.00%	N.A.
DEFICIT YIELD	4.72	4.68	7.20	1804.00	84.00	<= FULL
% NORMAL YIELD	82.00%	72.00%	72.00%	82.00%	80.00%	<= DEFICI
IRRIG SYSTEM:	HANDLINE	SIDEROLL	RILL	HANDLINE	HANDLINE	DEFICIT
BASE EFFIC:	65.00%	65.00%	45.00%	65.00%	65.00%	<= NONE
DEFICIT EFFIC:	71.00%	75.00%	45.00%	70.00%	75.00%	<= FULL
GRAVEL AQUIFER	YES	WELL CAPACITY (AC/FT/MONTH)			2,465	LIFT
				PUMP EFFICIENCY	55.00%	130
BASALT AQUIFER	YES	WELL CAPACITY (AC/FT/MONTH)			30	LIFT
				PUMP EFFICIENCY	55.00%	280

MAX. SURFACE DIVERSION (AC/FT/MONTH)						
	JANUARY	0	MAY	1614	SEPTEMBER	353
	FEBUARY	0	JUNE	1020	OCTOBER	902
	MARCH	57	JULY	461	NOVEMBER	1592
	APRIL	2720	AUGUST	623	DECEMBER	228

***********LINEAR PROGRAMMING SOLUTION FOR THIS SCENARIO**************

GROSS RETURNS OVER VARIABLE COSTS:				2172415	PER ACRE:	$348.32
CROP:	ALSD	ALHY	PAST	BEAN	WHT	DWHFA
ACRES PLANTED:	4275.0	550.0	112.5	245.3	1054.0	0.0
TOTAL PROD.:	24581	3575	1125	539660	110670	0
PER ACRE YD.:	5.75	6.50	10.00	2200.00	105.00	0.00
SELECTED IRRIGATION DEPENDENT VARIABLE COSTS:						TOTAL
FERTILIZER:	$0	$16,500	$2,340	$10,977	$30,144	$59,962
HARVEST:	$69,854	$49,582	$0	$16,067	$44,900	180404
IRR. LABOR:	$34,115	$4,812	$1,796	$9,787	$16,822	67332
SYS. MAINT.:	$7,744	$3,966	$561	$531	$1,886	14689
SYS. ENERGY:	$88,783	$19,359	$0	$6,092	$21,622	135857
WELL ENERGY:						$85,637
TOTAL SEL. VC:	200496	94220	4696	43455	115375	543880
SEL VC PER AC:	46.90	171.31	41.74	177.15	109.46	87.20

	CONSUMPTIVE	ACRE FEET APPLIED WATER BY SOURCE				REGIONAL
MONTH:	ACRE FEET	TOTAL	SURFACE	GRAVEL	BASALT	EFFICIENCY
JANUARY:	0.00	0.00	0.00	0.00	0.00	N.A.
FEBUARY:	0.00	0.00	0.00	0.00	0.00	N.A.
MARCH:	43.04	66.21	57.45	8.76	0.00	65.00%
APRIL:	323.23	2720.35	2720.35	0.00	0.00	11.88%
MAY:	1974.92	2420.74	1614.05	806.69	0.00	81.58%
JUNE:	3180.67	3491.43	1019.60	2465.00	6.83	91.10%
JULY:	2317.97	2956.21	461.21	2465.00	30.00	78.41%
AUGUST:	1465.42	2290.61	623.23	1667.38	0.00	63.98%
SEPTEMBER:	1091.24	1709.32	352.51	1356.81	0.00	63.84%
OCTOBER:	210.32	902.36	902.36	0.00	0.00	23.31%
NOVEMBER:	0.00	1591.56	1591.56	0.00	0.00	0.00%
DECEMBER:	0.00	228.35	228.35	0.00	0.00	0.00%
TOTAL:	10606.81	18377.14	9570.67	8769.64	36.83	57.72%

Appendix Table K.3. Region 8 Summary Information for a 10 Percent Increase in On-Farm Irrigation Efficiency with the Conserved Water Used On-Farm: Farm A.

	-------------IRRIGATED CROPS------------					DRYLAND
CROP:	PAST	ASPR	ALSD	ONON	WHT	DWHFA
UNITS:	AUM	POUND	CWT	POUND	BUSHEL	BUSHEL
NORMAL YIELD:	10	4000	5.75	36000	105	70
MIN ACRES:	0.0	0.0	0.0	0.0	0.0	0.0
MAX ACRES(L1):	0.0	77.4	4275.0	140.1	1054.0	5000.0
MAX ACRES(L2):	112.5	0.0	0.0	0.0	0.0	0.0
TOTAL ACRES:	5659		FALLOW WITH DRYLAND ==>			YES
MAX IRR. DEF.	30.00%	5.00%	20.00%	0.00%	30.00%	N.A.
DEFICIT YIELD	7.20	3840.00	4.72	36000.00	84.00	<= FULL
% NORMAL YIELD	72.00%	96.00%	82.00%	100.00%	80.00%	<= DEFICI
IRRIG SYSTEM:	RILL	SIDEROLL	HANDLINE	HANDLINE	HANDLINE	DEFICIT
BASE EFFIC:	55.00%	75.00%	75.00%	75.00%	75.00%	<= NONE
DEFICIT EFFIC:	55.00%	75.00%	75.00%	75.00%	75.00%	<= FULL
GRAVEL AQUIFER	YES	WELL CAPACITY (AC/FT/MONTH)			2,157	LIFT
				PUMP EFFICIENCY	55.00%	130
BASALT AQUIFER	YES	WELL CAPACITY (AC/FT/MONTH)			28	LIFT
				PUMP EFFICIENCY	55.00%	280

MAX. SURFACE	JANUARY	0	MAY	1415	SEPTEMBER	309
DIVERSION	FEBUARY	0	JUNE	894	OCTOBER	791
(AC/FT/MONTH)	MARCH	50	JULY	404	NOVEMBER	1395
	APRIL	2384	AUGUST	546	DECEMBER	200

***********LINEAR PROGRAMMING SOLUTION FOR THIS SCENARIO*************

GROSS RETURNS OVER VARIABLE COSTS: 2339587 PER ACRE: $413.43

CROP:	PAST	ASPR	ALSD	ONON	WHT	DWHFA
ACRES PLANTED:	112.5	77.4	4275.0	140.1	1054.0	0.0
TOTAL PROD.:	1125	309600	24581	5043600	110670	0
PER ACRE YD.:	10.00	4000.00	5.75	36000.00	105.00	0.00
SELECTED IRRIGATION DEPENDENT VARIABLE COSTS:						TOTAL
FERTILIZER:	$2,340	$1,858	$0	$10,508	$30,144	$44,849
HARVEST:	$0	$66,182	$69,854	$353,873	$44,900	534809
IRR. LABOR:	$2,693	$813	$51,172	$10,900	$25,233	90811
SYS. MAINT.:	$459	$272	$6,712	$361	$1,635	9438
SYS. ENERGY:	$0	$1,327	$76,946	$4,140	$18,739	101152
WELL ENERGY:						$53,056
TOTAL SEL. VC:	5492	70451	204683	379782	120651	834116
SEL VC PER AC:	48.82	910.22	47.88	2710.79	114.47	147.40

MONTH:	CONSUMPTIVE ACRE FEET	ACRE FEET APPLIED WATER BY SOURCE TOTAL	SURFACE	GRAVEL	BASALT	REGIONAL EFFICIENCY
JANUARY:	0.00	0.00	0.00	0.00	0.00	N.A.
FEBUARY:	0.00	0.00	0.00	0.00	0.00	N.A.
MARCH:	43.04	57.38	50.35	7.03	0.00	75.00%
APRIL:	333.10	2384.45	2384.45	0.00	0.00	13.97%
MAY:	1878.69	1414.75	1414.75	0.00	0.00	132.79%
JUNE:	2961.16	2486.48	893.70	1592.78	0.00	119.09%
JULY:	1832.31	2490.12	404.28	2085.84	0.00	73.58%
AUGUST:	1047.09	1433.03	546.27	863.94	22.82	73.07%
SEPTEMBER:	876.89	1192.59	308.99	883.60	0.00	73.53%
OCTOBER:	187.41	790.94	790.94	0.00	0.00	23.69%
NOVEMBER:	0.00	1395.04	1395.04	0.00	0.00	0.00%
DECEMBER:	0.00	200.15	200.15	0.00	0.00	0.00%
TOTAL:	9159.68	13844.94	8388.92	5433.20	22.82	66.16%

Appendix Table K.4. Region 8 Summary Information for a 10 Percent Increase in On-Farm Irrigation Efficiency with the Conserved Water Used On-Farm: Farm B.

	IRRIGATED CROPS					DRYLAND
CROP:	ALSD	ALHY	PAST	BEAN	WHT	DWHFA
UNITS:	CWT	TON	AUM	POUND	BUSHEL	BUSHEL
NORMAL YIELD:	5.75	6.5	10	2200	105	70
MIN ACRES:	0.0	0.0	0.0	0.0	0.0	0.0
MAX ACRES(L1):	4275.0	550.0	0.0	245.3	1054.0	5000.0
MAX ACRES(L2):	0.0	0.0	112.5	0.0	0.0	0.0
TOTAL ACRES:	6236.8		FALLOW WITH DRYLAND ==>			YES
MAX IRR. DEF.	20.00%	30.00%	30.00%	20.00%	30.00%	N.A.
DEFICIT YIELD	4.72	4.68	7.20	1804.00	84.00	<= FULL
% NORMAL YIELD	82.00%	72.00%	72.00%	82.00%	80.00%	<= DEFICI
IRRIG SYSTEM:	HANDLINE	SIDEROLL	RILL	HANDLINE	HANDLINE	DEFICIT
BASE EFFIC:	75.00%	75.00%	55.00%	75.00%	75.00%	<= NONE
DEFICIT EFFIC:	75.00%	75.00%	55.00%	75.00%	75.00%	<= FULL
GRAVEL AQUIFER	YES	WELL CAPACITY (AC/FT/MONTH)			2,465	LIFT
			PUMP EFFICIENCY		55.00%	130
BASALT AQUIFER	YES	WELL CAPACITY (AC/FT/MONTH)			30	LIFT
			PUMP EFFICIENCY		55.00%	280

MAX. SURFACE DIVERSION (AC/FT/MONTH)						
	JANUARY	0	MAY	1614	SEPTEMBER	353
	FEBUARY	0	JUNE	1020	OCTOBER	902
	MARCH	57	JULY	461	NOVEMBER	1592
	APRIL	2720	AUGUST	623	DECEMBER	228

***********LINEAR PROGRAMMING SOLUTION FOR THIS SCENARIO**************

GROSS RETURNS OVER VARIABLE COSTS: 2178164 PER ACRE: $349.24

CROP:	ALSD	ALHY	PAST	BEAN	WHT	DWHFA
ACRES PLANTED:	4275.0	550.0	112.5	245.3	1054.0	0.0
TOTAL PROD.:	24581	3575	1125	539660	110670	0
PER ACRE YD.:	5.75	6.50	10.00	2200.00	105.00	0.00
SELECTED IRRIGATION DEPENDENT VARIABLE COSTS:						TOTAL
FERTILIZER:	$0	$16,500	$2,340	$10,977	$30,144	$59,962
HARVEST:	$69,854	$49,582	$0	$16,067	$44,900	180404
IRR. LABOR:	$51,172	$7,219	$2,693	$14,681	$25,233	100998
SYS. MAINT.:	$6,712	$3,437	$459	$461	$1,635	12703
SYS. ENERGY:	$76,946	$16,778	$0	$5,280	$18,739	117742
WELL ENERGY:						$63,210
TOTAL SEL. VC:	204683	93516	5492	47466	120651	535018
SEL VC PER AC:	47.88	170.03	48.82	193.50	114.47	85.78

MONTH:	CONSUMPTIVE ACRE FEET	ACRE FEET APPLIED WATER BY SOURCE TOTAL	SURFACE	GRAVEL	BASALT	REGIONAL EFFICIENCY
JANUARY:	0.00	0.00	0.00	0.00	0.00	N.A.
FEBUARY:	0.00	0.00	0.00	0.00	0.00	N.A.
MARCH:	43.04	57.45	57.45	0.00	0.00	74.91%
APRIL:	323.23	2720.35	2720.35	0.00	0.00	11.88%
MAY:	1974.92	1614.05	1614.05	0.00	0.00	122.36%
JUNE:	3180.67	2534.13	1019.60	1514.53	0.00	125.51%
JULY:	2317.97	2953.39	461.21	2465.00	27.18	78.48%
AUGUST:	1465.42	1990.80	623.23	1367.57	0.00	73.61%
SEPTEMBER:	1091.24	1478.40	352.51	1125.89	0.00	73.81%
OCTOBER:	210.32	902.36	902.36	0.00	0.00	23.31%
NOVEMBER:	0.00	1591.56	1591.56	0.00	0.00	0.00%
DECEMBER:	0.00	228.35	228.35	0.00	0.00	0.00%
TOTAL:	10606.81	16070.84	9570.67	6472.98	27.18	66.00%

Appendix Table K.5. Region 8 Summary Information for a 10 Percent Increase in On-Farm Irrigation Efficiency with the Conserved Water Left In-Stream for Fishery Habitat: Farm A.

	-------------IRRIGATED CROPS------------					DRYLAND
CROP:	PAST	ASPR	ALSD	ONON	WHT	DWHFA
UNITS:	AUM	POUND	CWT	POUND	BUSHEL	BUSHEL
NORMAL YIELD:	10	4000	5.75	36000	105	70
MIN ACRES:	0.0	0.0	0.0	0.0	0.0	0.0
MAX ACRES(L1):	0.0	77.4	4275.0	140.1	1054.0	5000.0
MAX ACRES(L2):	112.5	0.0	0.0	0.0	0.0	0.0
TOTAL ACRES:	5659		FALLOW WITH DRYLAND ==>			YES
MAX IRR. DEF.	30.00%	5.00%	20.00%	0.00%	30.00%	N.A.
DEFICIT YIELD	7.20	3840.00	4.72	36000.00	84.00	<= FULL
% NORMAL YIELD	72.00%	96.00%	82.00%	100.00%	80.00%	<= DEFICI
IRRIG SYSTEM:	RILL	SIDEROLL	HANDLINE	HANDLINE	HANDLINE	DEFICIT
BASE EFFIC:	55.00%	75.00%	75.00%	75.00%	75.00%	<= NONE
DEFICIT EFFIC:	55.00%	75.00%	75.00%	75.00%	75.00%	<= FULL
GRAVEL AQUIFER	YES	WELL CAPACITY (AC/FT/MONTH)			2,157	LIFT
				PUMP EFFICIENCY	55.00%	130
BASALT AQUIFER	YES	WELL CAPACITY (AC/FT/MONTH)			28	LIFT
				PUMP EFFICIENCY	55.00%	280

MAX. SURFACE DIVERSION (AC/FT/MONTH)						
JANUARY	0	MAY	1273	SEPTEMBER	278
FEBUARY	0	JUNE	804	OCTOBER	712
MARCH	45	JULY	364	NOVEMBER	1256
APRIL	2146	AUGUST	492	DECEMBER	180

***********LINEAR PROGRAMMING SOLUTION FOR THIS SCENARIO**************

GROSS RETURNS OVER VARIABLE COSTS: 2334421 PER ACRE: $412.51

CROP:	PAST	ASPR	ALSD	ONON	WHT	DWHFA
ACRES PLANTED:	112.5	77.4	4275.0	140.1	1054.0	0.0
TOTAL PROD.:	1125	309600	24581	5043600	110670	0
PER ACRE YD.:	10.00	4000.00	5.75	36000.00	105.00	0.00
SELECTED IRRIGATION DEPENDENT VARIABLE COSTS:						TOTAL
FERTILIZER:	$2,340	$1,858	$0	$10,508	$30,144	$44,849
HARVEST:	$0	$66,182	$69,854	$353,873	$44,900	534809
IRR. LABOR:	$2,693	$813	$51,172	$10,900	$25,233	90811
SYS. MAINT.:	$459	$272	$6,712	$361	$1,635	9438
SYS. ENERGY:	$0	$1,327	$76,946	$4,140	$18,739	101152
WELL ENERGY:						$59,348
TOTAL SEL. VC:	5492	70451	204683	379782	120651	840407
SEL VC PER AC:	48.82	910.22	47.88	2710.79	114.47	148.51

	CONSUMPTIVE	ACRE FEET APPLIED WATER BY SOURCE				REGIONAL
MONTH:	ACRE FEET	TOTAL	SURFACE	GRAVEL	BASALT	EFFICIENCY
JANUARY:	0.00	0.43	0.43	0.00	0.00	0.00%
FEBUARY:	0.00	0.00	0.00	0.00	0.00	N.A.
MARCH:	43.04	57.38	45.32	0.00	12.07	75.00%
APRIL:	333.10	2146.01	2146.01	0.00	0.00	15.52%
MAY:	1878.69	1273.28	1273.28	0.00	0.00	147.55%
JUNE:	2961.16	2913.14	804.33	2108.81	0.00	101.65%
JULY:	1832.31	2490.12	363.85	2112.82	13.45	73.58%
AUGUST:	1047.09	1433.03	491.64	941.39	0.00	73.07%
SEPTEMBER:	876.89	1192.59	278.09	914.50	0.00	73.53%
OCTOBER:	187.41	711.85	711.85	0.00	0.00	26.33%
NOVEMBER:	0.00	1255.54	1255.54	0.00	0.00	0.00%
DECEMBER:	0.00	180.14	180.14	0.00	0.00	0.00%
TOTAL:	9159.68	13653.49	7550.46	6077.51	25.52	67.09%

Appendix Table K.6. Region 8 Summary Information for a 10 Percent Increase in On-Farm Irrigation Efficiency with the Conserved Water Left In-Stream for Fishery Habitat: Farm B.

	IRRIGATED CROPS					DRYLAND
CROP:	ALSD	ALHY	PAST	BEAN	WHT	DWHFA
UNITS:	CWT	TON	AUM	POUNDS	BUSHEL	BUSHEL
NORMAL YIELD:	5.75	6.5	10	2200	105	70
MIN ACRES:	0.0	0.0	0.0	0.0	0.0	0.0
MAX ACRES(L1):	4275.0	550.0	0.0	245.3	1054.0	5000.0
MAX ACRES(L2):	0.0	0.0	112.5	0.0	0.0	0.0
TOTAL ACRES:	6236.8		FALLOW WITH DRYLAND ==>			YES
MAX IRR. DEF.	20.00%	30.00%	30.00%	20.00%	30.00%	N.A.
DEFICIT YIELD	4.72	4.68	7.20	1804.00	84.00	<= FULL
% NORMAL YIELD	82.00%	72.00%	72.00%	82.00%	80.00%	<= DEFICI
IRRIG SYSTEM:	HANDLINE	SIDEROLL	RILL	HANDLINE	HANDLINE	DEFICIT
BASE EFFIC:	75.00%	75.00%	55.00%	75.00%	75.00%	<= NONE
DEFICIT EFFIC:	75.00%	75.00%	55.00%	75.00%	75.00%	<= FULL
GRAVEL AQUIFER	YES	WELL CAPACITY (AC/FT/MONTH)			2,465	LIFT
			PUMP EFFICIENCY		55.00%	130
BASALT AQUIFER	YES	WELL CAPACITY (AC/FT/MONTH)			30	LIFT
			PUMP EFFICIENCY		55.00%	280

MAX. SURFACE	JANUARY	0	MAY	1453	SEPTEMBER	317
DIVERSION	FEBUARY	0	JUNE	918	OCTOBER	812
(AC/FT/MONTH)	MARCH	52	JULY	415	NOVEMBER	1432
	APRIL	2448	AUGUST	561	DECEMBER	206

***********LINEAR PROGRAMMING SOLUTION FOR THIS SCENARIO**************

GROSS RETURNS OVER VARIABLE COSTS: 2172288 PER ACRE: $348.30

CROP:	ALSD	ALHY	PAST	BEAN	WHT	DWHFA
ACRES PLANTED:	4275.0	550.0	112.5	245.3	1054.0	0.0
TOTAL PROD.:	24581	3575	1125	539660	110670	0
PER ACRE YD.:	5.75	6.50	10.00	2200.00	105.00	0.00
SELECTED IRRIGATION DEPENDENT VARIABLE COSTS:						TOTAL
FERTILIZER:	$0	$16,500	$2,340	$10,977	$30,144	$59,962
HARVEST:	$69,854	$49,582	$0	$16,067	$44,900	180404
IRR. LABOR:	$51,172	$7,219	$2,693	$14,681	$25,233	100998
SYS. MAINT.:	$6,712	$3,437	$459	$461	$1,635	12703
SYS. ENERGY:	$76,946	$16,778	$0	$5,280	$18,739	117742
WELL ENERGY:						$70,211
TOTAL SEL. VC:	204683	93516	5492	47466	120651	542019
SEL VC PER AC:	47.88	170.03	48.82	193.50	114.47	86.91

	CONSUMPTIVE	ACRE FEET APPLIED WATER BY SOURCE				REGIONAL
MONTH:	ACRE FEET	TOTAL	SURFACE	GRAVEL	BASALT	EFFICIENCY
JANUARY:	0.00	0.00	0.00	0.00	0.00	N.A.
FEBUARY:	0.00	0.00	0.00	0.00	0.00	N.A.
MARCH:	43.04	57.38	51.71	5.68	0.00	75.00%
APRIL:	323.23	2448.32	2448.32	0.00	0.00	13.20%
MAY:	1974.92	1452.64	1452.64	0.00	0.00	135.95%
JUNE:	3180.67	3046.03	917.64	2128.20	0.20	104.42%
JULY:	2317.97	2910.09	415.09	2465.00	30.00	79.65%
AUGUST:	1465.42	1990.80	560.91	1429.89	0.00	73.61%
SEPTEMBER:	1091.24	1478.40	317.26	1161.14	0.00	73.81%
OCTOBER:	210.32	812.12	812.12	0.00	0.00	25.90%
NOVEMBER:	0.00	1432.40	1432.40	0.00	0.00	0.00%
DECEMBER:	0.00	205.52	205.52	0.00	0.00	0.00%
TOTAL:	10606.81	15833.71	8613.60	7189.91	30.20	66.99%

Appendix Table K.7. Region 8 Summary of On-Farm Economic Effects of a No Surface Diversion Water Policy: Farm A.

	IRRIGATED CROPS					DRYLAND
CROP:	PAST	ASPR	ALSD	ONON	WHT	DWHFA
UNITS:	AUM	POUND	CWT	POUNDS	BUSHEL	BUSHEL
NORMAL YIELD:	10	4000	5.75	36000	105	70
MIN ACRES:	0.0	0.0	0.0	0.0	0.0	0.0
MAX ACRES(L1):	0.0	77.4	4275.0	140.1	1054.0	5000.0
MAX ACRES(L2):	112.5	0.0	0.0	0.0	0.0	0.0
TOTAL ACRES:	5659		FALLOW WITH DRYLAND ==>			YES
MAX IRR. DEF.	30.00%	5.00%	20.00%	0.00%	30.00%	N.A.
DEFICIT YIELD	7.20	3840.00	4.72	36000.00	84.00	<= FULL
% NORMAL YIELD	72.00%	96.00%	82.00%	100.00%	80.00%	<= DEFICI

IRRIG SYSTEM:	RILL	SIDEROLL	HANDLINE	HANDLINE	HANDLINE	DEFICIT
BASE EFFIC:	45.00%	65.00%	65.00%	65.00%	65.00%	<= NONE
DEFICIT EFFIC:	45.00%	67.00%	71.00%	65.00%	75.00%	<= FULL
GRAVEL AQUIFER	YES	WELL CAPACITY (AC/FT/MONTH)			2,157	LIFT
			PUMP EFFICIENCY		55.00%	130
BASALT AQUIFER	YES	WELL CAPACITY (AC/FT/MONTH)			28	LIFT
			PUMP EFFICIENCY		55.00%	280

MAX. SURFACE	JANUARY	0	MAY	0	SEPTEMBER	0
DIVERSION	FEBUARY	0	JUNE	0	OCTOBER	0
(AC/FT/MONTH)	MARCH	0	JULY	0	NOVEMBER	0
	APRIL	0	AUGUST	0	DECEMBER	0

***********LINEAR PROGRAMMING SOLUTION FOR THIS SCENARIO**************

GROSS RETURNS OVER VARIABLE COSTS: 2245276 PER ACRE: $404.81

CROP:	PAST	ASPR	ALSD	ONON	WHT	DWHFA
ACRES PLANTED:	0.0	77.4	4275.0	140.1	1054.0	0.0
TOTAL PROD.:	0	309600	24581	5043600	110670	0
PER ACRE YD.:	0.00	4000.00	5.75	36000.00	105.00	0.00
SELECTED IRRIGATION DEPENDENT VARIABLE COSTS:						TOTAL
FERTILIZER:	$0	$1,858	$0	$10,508	$30,144	$42,509
HARVEST:	$0	$66,182	$69,854	$353,873	$44,900	534809
IRR. LABOR:	$0	$542	$34,115	$7,267	$16,822	58745
SYS. MAINT.:	$0	$314	$7,744	$417	$1,886	10361
SYS. ENERGY:	$0	$1,532	$88,783	$4,777	$21,622	116714
WELL ENERGY:						$153,555
TOTAL SEL. VC:	0	70426	200496	376841	115375	916693
SEL VC PER AC:	0.00	909.90	46.90	2689.80	109.46	165.27

	CONSUMPTIVE	ACRE FEET APPLIED WATER BY SOURCE				REGIONAL
MONTH:	ACRE FEET	TOTAL	SURFACE	GRAVEL	BASALT	EFFICIENCY
JANUARY:	0.00	0.00	0.00	0.00	0.00	N.A.
FEBUARY:	0.00	0.00	0.00	0.00	0.00	N.A.
MARCH:	43.04	2157.00	0.00	2157.00	0.00	2.00%
APRIL:	333.10	2157.00	-0.00	2157.00	0.00	15.44%
MAY:	1838.94	2173.60	-0.00	2157.00	16.60	84.60%
JUNE:	2895.16	2185.00	0.00	2157.00	28.00	132.50%
JULY:	1735.28	2185.00	-0.00	2157.00	28.00	79.42%
AUGUST:	970.97	1493.80	0.00	1493.80	0.00	65.00%
SEPTEMBER:	828.60	1274.79	0.00	1274.79	0.00	65.00%
OCTOBER:	178.13	2157.00	0.00	2157.00	0.00	8.26%
NOVEMBER:	0.00	0.00	0.00	0.00	0.00	N.A.
DECEMBER:	0.00	0.00	0.00	0.00	0.00	N.A.
TOTAL:	8823.21	15783.19	-0.00	15710.59	72.60	55.90%

Appendix Table K.8. Region 8 Summary of On-Farm Economic Effects of a No Surface Diversion Water Policy: Farm B.

	--------------IRRIGATED CROPS-------------					DRYLAND
CROP:	ALSD	ALHY	PAST	BEAN	WHT	DWHFA
UNITS:	CWT	TON	AUM	POUNDS	BUSHEL	BUSHEL
NORMAL YIELD:	5.75	6.5	10	2200	105	70
MIN ACRES:	0.0	0.0	0.0	0.0	0.0	0.0
MAX ACRES(L1):	4275.0	550.0	0.0	245.3	1054.0	5000.0
MAX ACRES(L2):	0.0	0.0	112.5	0.0	0.0	0.0
TOTAL ACRES:	6236.8		FALLOW WITH DRYLAND ==>			YES
MAX IRR. DEF.	20.00%	30.00%	30.00%	20.00%	30.00%	N.A.
DEFICIT YIELD	4.72	4.68	7.20	1804.00	84.00	<= FULL
% NORMAL YIELD	82.00%	72.00%	72.00%	82.00%	80.00%	<= DEFICI
IRRIG SYSTEM:	HANDLINE	SIDEROLL	RILL	HANDLINE	HANDLINE	DEFICIT
BASE EFFIC:	65.00%	65.00%	45.00%	65.00%	65.00%	<= NONE
DEFICIT EFFIC:	71.00%	75.00%	45.00%	70.00%	75.00%	<= FULL
GRAVEL AQUIFER	YES	WELL CAPACITY (AC/FT/MONTH)			2,465	LIFT
			PUMP EFFICIENCY		55.00%	130
BASALT AQUIFER	YES	WELL CAPACITY (AC/FT/MONTH)			30	LIFT
			PUMP EFFICIENCY		55.00%	280

MAX. SURFACE	JANUARY	0	MAY	0	SEPTEMBER	0
DIVERSION	FEBUARY	0	JUNE	0	OCTOBER	0
(AC/FT/MONTH)	MARCH	0	JULY	0	NOVEMBER	0
	APRIL	0	AUGUST	0	DECEMBER	0

***********LINEAR PROGRAMMING SOLUTION FOR THIS SCENARIO*************

GROSS RETURNS OVER VARIABLE COSTS: 2071770 PER ACRE: $338.29

CROP:	ALSD	ALHY	PAST	BEAN	WHT	DWHFA
ACRES PLANTED:	4275.0	550.0	0.0	245.3	1054.0	0.0
TOTAL PROD.:	24581	3575	0	539660	110670	0
PER ACRE YD.:	5.75	6.50	0.00	2200.00	105.00	0.00
SELECTED IRRIGATION DEPENDENT VARIABLE COSTS:						TOTAL
FERTILIZER:	$0	$16,500	$0	$10,977	$30,144	$57,622
HARVEST:	$69,854	$49,582	$0	$16,067	$44,900	180404
IRR. LABOR:	$34,115	$4,812	$0	$9,787	$16,822	65536
SYS. MAINT.:	$7,744	$3,966	$0	$531	$1,886	14128
SYS. ENERGY:	$88,783	$19,359	$0	$6,092	$21,622	135857
WELL ENERGY:						$176,634
TOTAL SEL. VC:	200496	94220	0	43455	115375	630180
SEL VC PER AC:	46.90	171.31	0.00	177.15	109.46	102.90

	CONSUMPTIVE	ACRE FEET APPLIED WATER BY SOURCE				REGIONAL
MONTH:	ACRE FEET	TOTAL	SURFACE	GRAVEL	BASALT	EFFICIENCY
JANUARY:	0.00	0.00	0.00	0.00	0.00	N.A.
FEBUARY:	0.00	0.00	0.00	0.00	0.00	N.A.
MARCH:	43.04	2465.00	0.00	2465.00	0.00	1.75%
APRIL:	323.23	2465.00	-0.00	2465.00	0.00	13.11%
MAY:	1935.17	2480.96	0.00	2465.00	15.96	78.00%
JUNE:	3114.67	2495.00	-0.00	2465.00	30.00	124.84%
JULY:	2220.94	2495.00	-0.00	2465.00	30.00	89.02%
AUGUST:	1389.29	2121.44	0.00	2121.44	0.00	65.49%
SEPTEMBER:	1042.96	1602.03	0.00	1602.03	0.00	65.10%
OCTOBER:	201.04	2039.67	0.00	2039.67	0.00	9.86%
NOVEMBER:	0.00	0.00	0.00	0.00	0.00	N.A.
DECEMBER:	0.00	0.00	0.00	0.00	0.00	N.A.
TOTAL:	10270.34	18164.10	-0.00	18088.13	75.96	56.54%

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