Yakima River Basin Study

Water Needs for Out-of-Stream Uses Technical Memorandum

U.S. Bureau of Reclamation
Contract No. 08CA10677A ID/IQ, Task 2.1

Prepared by

HDR Engineering, Inc
Anchor QEA

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region
Columbia-Cascades Area Office

State of Washington
Department of Ecology
Office of Columbia River

June 2011

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1.0 Introduction

This technical memorandum provides information on current and future water needs in the Yakima River Basin to help in evaluating a range of possible water resource management actions. It addresses "out-of-stream" uses. This includes any uses that require water to be diverted from surface water or pumped from groundwater. Out-of-stream uses are distinguished from "instream uses," which include ecosystem functions such as maintenance of fish habitat.

This water needs assessment is part of the Yakima River Basin Study (Subtask 2.1), which is jointly funded by the United States Bureau of Reclamation (Reclamation) and Washington State Department of Ecology (Ecology) under Reclamation's WaterSMART Program. It represents Phase III of a long-term Reclamation program called the Yakima River Basin Water Enhancement Project (YRBWEP). Findings of the Study will be used to develop a Final Integrated Water Resources Management Plan (Integrated Plan) to improve water supply reliability, instream flows and fish habitat in the Yakima River Basin.

A Workgroup comprised of irrigation district representatives, fish and wildlife agency representatives, Yakama Nation representatives, local governments and stakeholders was formed in June 2009. The Workgroup issued a preliminary Integrated Plan in December 2009, recommending a number of water supply and management projects for further characterization and analysis.

The Yakima River Basin Study is intended to provide additional information requested by the Workgroup for those projects. It examines how basin-wide water resource issues can potentially be resolved with changes to the operation of water supply systems; modifications to existing facilities; development of new facilities; or non-structural changes. The study draws from the latest science, engineering technology, climate models and innovation. The desired outcomes are collaboratively developed solutions that will help meet water demands and foster sustainable development.

This technical memorandum was prepared by HDR Engineering and Anchor QEA, with input from the Out-of-Stream Water Needs Subcommittee of the YRBWEP Workgroup.

1.1 Background

Water resource conditions in the Yakima River Basin have been studied extensively over the past several decades. A partial listing of recent reports addressing water needs and water management includes:

- Yakima River Basin Water Enhancement Project, Final Environmental Impact Statement, 1999, Reclamation
- Yakima River Basin Watershed Management Plan, 2003, Yakima River Basin Watershed Planning Unit and Tri-County Water Resources Agency

- Yakima River Basin Water Storage Feasibility Study Final Planning Report/EIS, 2008, Reclamation

- Yakima River Basin Integrated Water Resource Management Alternative, Final Environmental Impact Statement, 2009, Ecology

The largest use of water in the Basin is for irrigated agriculture. The primary source of water for this purpose is the Yakima Irrigation Project (Yakima Project), operated by Reclamation. The Yakima Project includes six irrigation divisions, plus a storage division (further details are provided in Section 1.2). Smaller quantities of water for agricultural irrigation are also supplied from non-Federal diversions of surface water and wells that extract groundwater from local or regional aquifers.

Land served by the Yakima Project is fixed under Federal law. Water supply available for irrigation of land outside the Federal project is highly constrained. Therefore, one assumption of the Integrated Plan is that acreage available for irrigated agriculture in the basin will not expand in the future. The Integrated Plan is intended to improve reliability of supplies, but not to serve expansion of irrigated acreage.

Water rights or entitlements served by the Yakima Project are divided into two classes: proratable and non-proratable. In each of the droughts occurring in recent decades, Reclamation has been able to fully supply non-proratable water rights. Proratable water rights receive reduced (prorated) supplies under drought conditions, sometimes as low as 37% of normal supply. A primary objective of the Integrated Plan is to improve reliability of supplies for irrigation users with proratable water rights. Therefore, the analysis of water needs distinguishes between these two categories, with a particular focus on the proratable category. The terms "water rights" and "entitlements" are both used in this document and are interchangeable.

Other uses of water in the basin include municipal, domestic wells, fruit-processing, stock watering, frost protection and gravel mining, as well as other uses. These uses are mostly supplied by non-Federal wells and diversions, with some exceptions. These uses are relatively small compared with water used for irrigated agriculture in the Basin.

Municipal and domestic uses are expected to grow with continued population growth in the Basin. Since water supply is constrained by available resources, assessing the needs of increased water supply for municipal and domestic use is another important focus of this study.

1.2 Study Area

The Study Area for this water needs assessment includes portions of Kittitas, Yakima and Benton Counties that draw water from the Yakima River, its tributaries, and aquifers having significant continuity with surface water. This includes virtually all of the populated areas of Kittitas and Yakima counties. In Benton County, the major municipal systems in the Tri-Cities area draw their drinking water supplies from the Columbia River and associated aquifers and are therefore excluded from this assessment. However, irrigation needs in the lower part of the Yakima River Basin within Benton County are served by the Yakima Project irrigation system, and those needs are included.

The Yakima Project is composed of seven divisions: six irrigation divisions (Kittitas, Roza, Tieton, Wapato, Sunnyside, and Kennewick) and a storage division. Within each irrigation division is an organization that operates the division. These are:

- Kittitas Reclamation District (KRD)
- Roza Irrigation District (Roza)
- Yakima-Tieton Irrigation District (YTID)
- Wapato Irrigation Project (WIP)
- Kennewick Irrigation District (KID)
- Sunnyside Valley Irrigation District (SVID)

Irrigation Divisions of the Yakima Project, major cities and other features of the Yakima River Basin are shown in Figure 1. Of the six irrigation divisions, all except the Kennewick division divert surface water above the Parker gage, the major control point of the Yakima Project (this streamflow monitoring gage is located on the Yakima River just downstream of Sunnyside Dam).

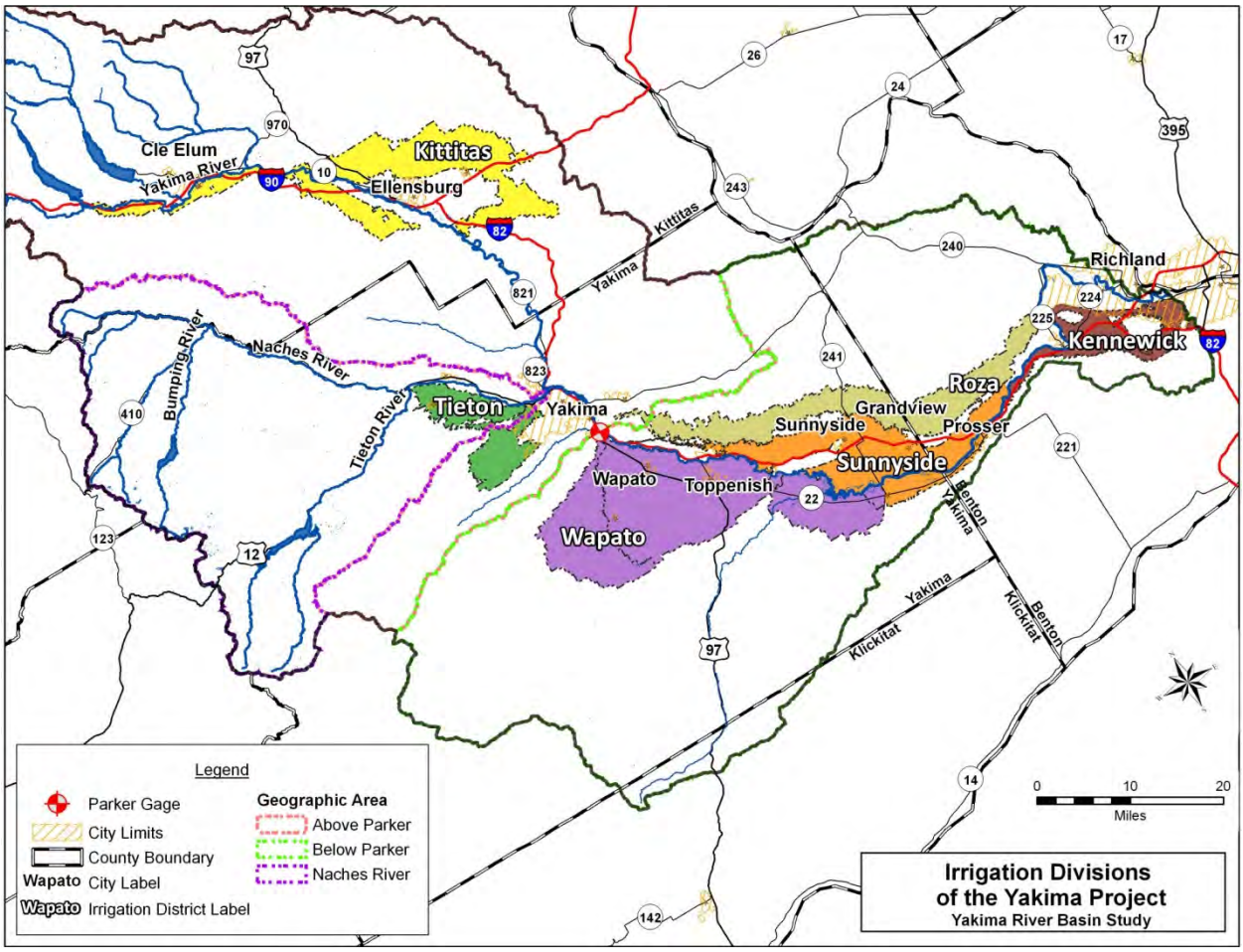

Figure 1. Irrigation Divisions of the Yakima Project

1.3 Terminology

For purposes of this assessment, the following terms are defined:

- *Acre-foot*: A measure of water volume. One acre-foot is the quantity of water that will cover an acre of land to a depth of one foot. This is approximately 326,000 gallons.

- *Consumptive use*: The portion of water diverted or pumped that does not return to the Yakima River or to groundwater aquifers of the Yakima River Basin.

- *Non-consumptive use:* The portion of water diverted or pumped that does return to the Yakima River or aquifers. Waters can return to the Yakima River or groundwater through many pathways including seepage, irrigation drains, groundwater inflow, wastewater treatment plants or septic systems.

- *Water need, or out-of-stream water need (also water use or water demand)*: The total quantity of water diverted or pumped to irrigate existing irrigated acreage under normal

water supply conditions; to supply municipal and domestic uses; and to supply other uses in the Basin. Water need is defined based on normal water supply conditions (not drought conditions). Out-of-stream needs are distinguished from "instream" needs, which include stream flow to support ecosystem functions such as fish habitat and habitat-forming stream processes.

- *Water supply deficiency*: This is the difference between water need and available supply. Water supply deficiency may be expressed as an average quantity for all conditions; or as a different quantity in wet, dry and average supply years.

1.4 Objectives of the Water Needs Assessment

The water needs assessment is intended first to identify and quantify current water needs, focusing on uses that have experienced recurring water supply deficiencies. Supply deficiencies occur during droughts in the Basin, such as those in 1992-1994; 2001 and 2005. The highest priority for water supply in the Integrated Plan is to address existing supply deficiencies.

The assessment also characterizes how water needs and supply deficiencies may change over a 50-year period from 2010 to 2060. Some needs for water may decline over this period, while others may increase. Since the Integrated Plan will include infrastructure improvements that are long-lived, it is important to assess long-term needs. A 50-year planning horizon was selected by a Subcommittee of the YRBWEP Workgroup as a reasonable time period to allow consideration of future conditions, without engaging in undue speculation about long-term future conditions.

Ultimately the purpose of the water needs assessment is to contribute information for evaluating the benefits of a range of different combinations of water resource management actions to be considered in the Integrated Plan.

The Yakima River Basin Study must comply with requirements of Reclamation's Basin Study program. Those requirements are outlined in the "Basin Study Framework, Water for America Initiative" (Reclamation, 2008a). Aspects of the Basin Study Framework that guide the out-of-stream water needs assessment are contained in Sections 4.4.5, 4.4.6, 5.4.1 and 5.4.2 of the framework document (Note: those sections also address other study elements that are not the subject of this peer review).

Section 4.4.6 of the Framework indicates that "the level of analysis will be similar to an appraisal study…[and] will not rise to the level of a feasibility study." The HDR team interprets this statement to mean that water needs shall be assessed at a general planning level on a regional (basin-wide) scale.

It is also important to match the scale of analysis to major control features of the water supply system within the Yakima River Basin. These include the Parker gage, described above, as well as the Project's storage reservoirs on the Yakima River, Kachess River, Cle Elum River and in the Naches River subbasin. Therefore the major sub-areas for this water needs assessment are the Upper Basin above the Parker gage, the Lower Basin below the Parker gage; and the Naches River Subbasin.

2.0 Summary of Findings

Water use categories covered in this assessment include Federally-supplied agricultural irrigation; agricultural irrigation supplied by other sources; municipal and domestic uses; and other uses. Water needs for each category are summarized as follows.

Federally-Supplied Agricultural Irrigation: Diversions for the Yakima Project above the Parker gage averaged approximately 1.7 million acre-feet from 1990 to 2009, not counting drought years. An additional 0.1 million acre-feet was diverted below the Parker gage by the Kennewick division. A declining trend in total diversions was noted over the past 60 years, most likely caused by conservation practices, cropping and land use factors, and changes in operations of the Yakima Project to improve instream flow. However, there are approximately 28,000 acres of idle land in the Wapato Irrigation Project. One study (NRCE, 2002) estimated that approximately 16,400 acres could be put into production. For the current study the HDR team estimated the consumptive use for that additional acreage to be 45,600 acre-feet.

During drought years, water supply is not adequate to serve all Yakima Project entitlements (water rights) above Parker gage, so deliveries to districts with proratable entitlements are reduced. Sunnyside Valley Irrigation District (SVID) and Yakima-Tieton Irrigation District (YTID) have some proratable entitlements, but have stated they do not need additional water under the Integrated Plan. Roza Irrigation District, Wapato Irrigation Project (WIP), and Kittitas Reclamation District (KRD) are severely affected by prorationing during droughts. Excluding SVID and YTID, these three districts have 96 percent of Yakima Project proratable water rights above the Parker gage. Therefore, consideration of drought year shortfalls focuses on these three districts. Kennewick Irrigation District (KID), although having proratable entitlements, has not been impacted to the same level as Roza Irrigation District, WIP and KRD because KID is located downstream of the Parker gage near the downstream end of the Yakima River Basin. Some of their water supply is derived from return flow from upstream irrigation districts which improves the reliability of their supply.

In prior Yakima River Basin water planning processes, the irrigation community has consistently identified a prorationing level of 70% as a volume that meets minimal supply needs and prevents severe economic losses to farmers. During the 2001 drought, prorationed supplies were only 38% of entitlements. The difference in diversions between 70% and 38% prorationed supply for Roza, WIP and KRD combined is approximately 355,000 acre feet. However, since KRD returns approximately one-half of its diversion back to the Yakima River as return flow during the irrigation season, the supply shortfall is estimated to be approximately 299,000 acre feet.

The potential effects of climate change on water needs was analyzed using an approach of comparing evapotranspiration needs of plants under current and future conditions. The estimated increase in consumptive use for Yakima Project irrigation districts is in the range of 8-10 percent. That totals approximately 95,000 acre-feet per year. That estimate assumes current cropping patterns will continue in the future and therefore does not account for potential responses to climate change by farmers who may plant different crops. The estimate also assumes a full water supply is available for all currently irrigated crops; in drought years less water would be available and the increase in consumptive use would be less. (The estimate was

reviewed by researchers associated with the University of Washington's Climate Impact Group; and their opinion was the increase in consumptive use would be on the order of 3-5 percent. This lower estimate accounts for reduced water demands from greater CO_2 concentrations and a shorter growing season [Stockle, 2010 personal communication]. A five percent increase in consumptive use would be approximately 53,000 acre-feet.)

Agricultural Irrigation Supplied by Other Sources: Total water uses for agriculture outside federally-supplied land are estimated to be 590,000 acre feet in non-drought years. Approximately two-thirds of this use comes from surface-water supplies; and one-third from groundwater. A lower overall quantity is used in drought years as surface-water supplies are reduced (however, ground water pumping increases). The water needs assessment does not estimate the drought-year supply deficiency in this category, because the Integrated Plan is not intended to provide additional supplies for this category of water use.

Municipal and Domestic Uses: Water needs in this category are estimated to be 91,000 acre-feet in 2010. This includes 42,000 acre-feet for large public water systems serving the six largest cities of the Basin; 15,000 acre feet for smaller public water systems; and 34,000 acre feet for owners of domestic wells. The municipal uses include both surface and groundwater (including urban irrigation as well as potable uses); while the domestic wells are entirely groundwater. Approximately 60% of the water use in this category is non-consumptive, meaning that water pumped or diverted returns to the Yakima River or groundwater aquifers.

Water needs for municipal and domestic uses are expected to grow over time, due to ongoing population growth in the Yakima River Basin. Based on the medium population growth forecast, and without adjusting for other factors, water use is projected to increase by 72,000 acre feet in the 50 years from 2010 to 2060. Adjusting for existing trends in water conservation, and offsets from conversion of crop land to urban uses, the net increase is reduced to 49,000 acre feet. When return flows are also accounted for, the net change in consumptive use is projected to be 20,000 acre feet from year 2010 to year 2060.

Other Uses: There are a number of other types of water uses in the Yakima River Basin, including fish and wildlife propagation, commercial/industrial uses separate from municipal systems; livestock use; and non-community public water systems. These water uses are estimated to be on the order of 26,000 acre feet. This quantity is relatively small, and detailed analysis of these uses does not appear necessary in order for the YRBWEP Workgroup to develop the Integrated Plan.

3.0 Current Agricultural Needs – Federally Supplied

The assessment of current needs for irrigated agriculture receiving Federal water supplies is based on Reclamation data for water diversions over a 20-year period. Diversions since 1990 are reported for all users (typically irrigation districts). Water supply deficiencies experienced by proratable users in recent droughts (1992-94; 2001, 2005) are documented in terms of percent reductions and water volume in acre-feet. Drought year diversions are compared with legal entitlements; and with average diversions during non-drought years. Deficiencies can then be

calculated in relation to alternative standards; such as full entitlements; percentages of full entitlements; and normal-year diversions.

In order to provide a more complete picture of water used for irrigation and to provide information for assessing future changes in water needs, a breakdown was developed of water used for crop requirements in the fields, losses from conveyance in canal systems, losses from irrigation application, and other considerations. This breakdown relies on review of available data on crop acreage, crop types and crop irrigation requirements (see discussion of non-federally supplied land for additional information on these data).

3.1 Yakima Project Entitlements and Diversions

Section 1.2 described how the Yakima Project includes six irrigation divisions (Kittitas, Roza, Tieton, Wapato, Sunnyside, and Kennewick – See Figure 1). Of the six irrigation divisions, all except the Kennewick division divert surface water above Parker gage, the major control point of the Yakima Project. Instream flow targets are established for the Parker gage and downstream at the Prosser Diversion dam. Below Parker gage, irrigation demands are met by return flows, flows passing Parker gage, and tributary inflows below Parker.

Entitlements above Parker Gage

Surface-water entitlements are divided into non-proratable, proratable and post-1905 water rights. Non-proratable water rights are those rights that have a priority date prior to May 10, 1905. These rights are served first from the Total Water Supply Available (TWSA), which is defined each year by Reclamation based on reservoir storage, runoff forecast and return flow estimates (Reclamation, 2002). There has always been enough water to meet all non-proratable water rights in every year.

Proratable water rights have a priority date of May 10, 1905. When the TWSA is not sufficient to serve all users, the users with proratable water rights share the water remaining after the non-proratable water rights are met (Reclamation, 2002).

Post-1905 water rights have a priority date later than May 10, 1905. For these rights, water supply is curtailed when the TWSA is not sufficient to serve all users. These water rights have a small effect on the overall status of the basin (less than 0.3 percent) and will not be discussed further (Ecology, 2010).

Table 1 summarizes entitlements above Parker gage on the Yakima, Tieton, and Naches Rivers for major claimants in the adjudication process. Table 1 does not include groundwater or tributary entitlements, nor does it include entitlements downstream of Parker gage. The table does include water rights for purposes other than Yakima Project irrigation, such as municipal, flood water, and stock water use. The table also includes water rights outside of the major irrigation season (April-October).

Five Yakima Project divisions have 81 percent of the total entitlements in the Yakima, Tieton and Naches Rivers above the Parker gage (1,938,300 acre-feet). Thus, the majority of out-of-stream needs are supplied by the Federal irrigation project.

Table 1. Major Claimant Surface-water Entitlements above Parker Gage on Yakima, Tieton and Naches Rivers (in acre-feet)

Entity	Proratable (and Post-1905) Entitlements	Non-Proratable Entitlements	Total Entitlements
Wapato Irrigation Project[1]	350,000	305,613	655,613
Sunnyside Division[1]	157,776	289,646	447,422
Roza Irrigation District[1]	393,000	0	393,000
Kittitas Reclamation District[1]	336,000	0	336,000
Yakima-Tieton Irrigation District[1]	30,425	75,865	106,290
Naches-Selah Irrigation District	4,486	46,254	50,740
Cascade Irrigation District	0	50,075	50,075
Selah-Moxee Irrigation District	6,348	37,742	44,089
Ellensburg Water Company	0	44,040	44,040
West Side Irrigating Company	8,200	25,768	33,968
United States of America	214[2]	27,507	27,721
City of Yakima	9,497[3]	13,790	23,287
Yakima Valley Canal Company	5,400	17,220	22,620
Union Gap Irrigation District	5,842	9,953	15,795
Naches-Cowiche Canal Company	0	10,484	10,484
New Schanno Ditch Company	0	8,673	8,673
Fowler Ditch Association	0	7,605	7,605
Old Union Irrigation Company	0	6,670	6,670
City of Ellensburg	6,000	0	6,000
Fruitvale-Schanno Irr. Co., Inc.	0	3,027	3,027
City of Prosser	260[4]	0	260
Subtotal	**1,313,448**	**979,931**	**2,293,379**
Non-Major Claimants	2,169[5]	111,369	113,538
Total	**1,315,617**	**1,091,300**	**2,406,917**

[1] This entity is a Yakima Project division

[2] United States of America has 53 AF of post-1905 entitlements

[3] City of Yakima has 4,414 AF of post-1905 entitlements

[4] City of Prosser has 260 AF of post-1905 entitlements

[5] Non-major claimants have 815 AF of post-1905 entitlements

Source: Ecology Yakima River Basin Water Rights Adjudication Database (2010)

Annual Surface-water Diversions for Irrigation

Daily surface-water diversions for the Yakima Project were obtained from gage records from Reclamation's Hydromet ARCHIVE data. For this analysis, a 20-year period (1990-2009) was used. This period includes a 3-year drought period (1992-1994) and two single-year droughts (2001 and 2005). Drought years are defined as any year where the TWSA is not sufficient to meet the 70 percent proration level, causing Reclamation and irrigation districts to significantly change their operations.

Table 2 summarizes annual diversions for the Yakima Project. The total average diversion volume for the Yakima Project from 1990 to 2009 is approximately 1.8 million acre-feet, not counting drought years. During drought years diversions by districts with proratable entitlements are substantially reduced. For the calculation of average non-drought diversions in Table 2, the drought years not included are 1992-1994, 2001 and 2005.

Table 2. Yakima Project Annual Surface-water Diversions Under Drought and Non-Drought Conditions (acre-feet)

	Diversion above Parker gage					Diversion below Parker gage	Total
	KRD	Roza	WIP	SVID	YTID	KID	
Entitlements	336,000	393,000	655,613	447,422	106,290	102,674	**2,040,999**
Peak Year Diversion (1990-2009)	323,158	385,914	666,474	460,892	88,097	109,616	**N/A**
Average Non-Drought Diversions (1990-2009)	285,983	319,670	560,081	429,122	79,029	99,519	**1,773,403**
Drought Year 2001 Diversions	122,997	170,325	405,360	347,116	75,474	84,773	**1,206,045**
Drought Year 2005 Diversions	144,918	196,771	428,837	332,660	75,304	75,153	**1,253,642**

Sources: Ecology Yakima River Basin Water Rights Adjudication Database (2010); Reclamation Hydromet ARCHIVE data (2010)

Diversions above the Parker Gage

Figure 2 shows the annual diversions for the Yakima Project above the Parker gage from 1950 to 2009. The total diversion in the past 20 years has ranged from a low of 1,121,300 acre-feet in 2001, a drought year, to a high of 1,889,300 acre-feet in 1990. In the past five non-drought years, diversions have averaged 1,595,800 acre-feet. Figure 2 shows a declining trend in total diversions, most likely due to conservation practices, cropping patterns, land use factors, and changes in operations of the Yakima Project to improve instream flow. The reduction in average non-drought diversions from the early 1990's is approximately 290,000 acre-feet.

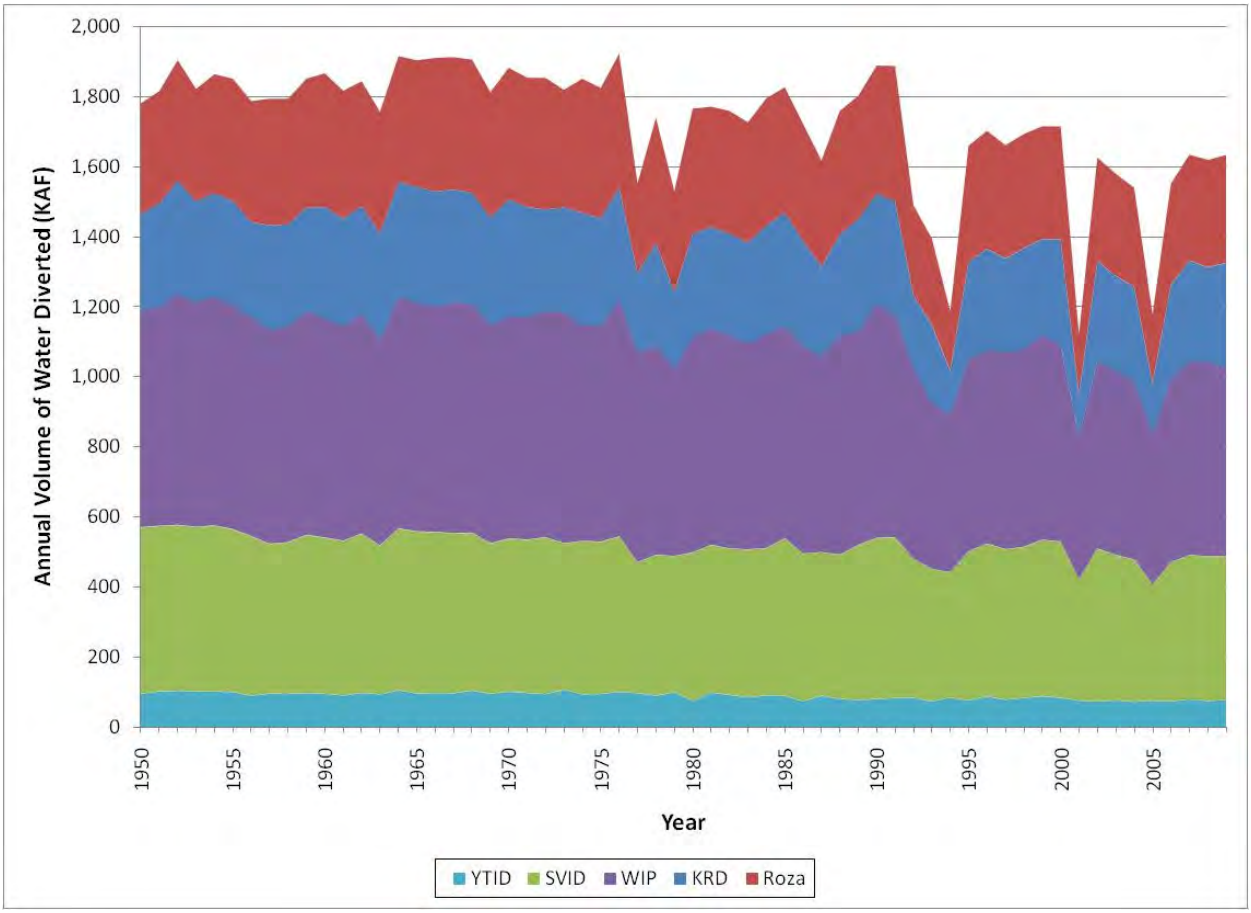

Figure 2. Annual Yakima Project Diversions above Parker Gage – 1950 to 2009
(in thousand acre-feet)

3.2 Return Flow

Some of the water diverted from the Yakima River returns to the river downstream, through seepage, irrigation drains, and other pathways. This "return flow" is recycled and contributes to TWSA. The portion of return flow that can be reused in the system depends on the timing and location of the return flow. Reclamation's *Interim Comprehensive Operating Plan* (Reclamation, 2002) states that return flows vary from year to year, but the portion of return flow usable above Parker gage is fairly uniform due to fairly stable diversions in the upper portions of the basin. It is estimated that the return flow available for reuse is 350,000 acre-feet from April to September during low runoff years, 375,000 acre-feet for average runoff years, and 400,000 acre-feet for high runoff years (Reclamation, 2002).

A rough estimate of daily return flow available for reuse above Parker gage is determined by adding YTID, KRD, and small irrigation diversions above Parker and dividing by 2. This estimate is only an indicator and not an absolute value (Reclamation, 2002).

Because KRD is a fully profitable district, drought years that significantly reduce their diversion will also significantly reduce the amount of return flow available. Reclamation's estimate for the

2001 return flow available was 290,000 acre-feet from April to September (Kreuter, pers. comm).

3.3 Irrigated Acreage in the Yakima Project

Total Irrigated Acreage

The Washington State Department of Agriculture (WSDA) provided a field-level survey of irrigated acreage in the Yakima River Basin, including the Yakima Project. The data contained crop type and type of on-farm irrigation practiced (rill, sprinkler, drip, etc). Those data were obtained from a GIS database and analyzed by irrigation district in the Yakima Project. The database contained surveys from 2002 to 2008. To check the WSDA data, the crop areas were totaled for each district and compared to irrigated acreage provided by the irrigation districts in 2010. Table 3 shows this comparison, including the year for which each irrigation district provided data. If recent crop area data were not provided by a district during the time frame for this study, data from Water Conservation Plans published in the 1990s were used.

A significant amount of irrigated acreage was not picked up in the WSDA survey. The WSDA data were overlain on color aerial photos and it was confirmed that irrigated land was missed in the WSDA survey. This is partly because the initial survey work by WSDA did not include irrigated pasture land. Because of this, it was determined that district records of acreage served would be more accurate and should be used to represent the total irrigated acreage. Based on district records, the total irrigated acreage in the Yakima Project is approximately 383,000 acres.

Table 3. Comparison of Irrigated Acreage Data from WSDA and Irrigation Districts

District (Year of Most Recent Data Received)	KRD (1993)[1]	Roza (2010)[2]	WIP (2006)[3]	SVID (2006)[4]	YTID (2010)[5]	KID (1998)[6]
Irrigated Acreage - District Data	55,516	72,491	109,115	99,243	27,900	18,441
Irrigated Acreage - WSDA Data	38,545	60,036	94,727	51,270	16,984	8,669
Difference	-16,971	-12,455	-14,388	-47,973	-10,916	-9,772
% Difference	-30.6%	-17.2%	-13.2%	-48.3%	-39.1%	-53.0%

Sources of District data:

[1] CH2M-Hill (1999)

[2] Pers. comm, Van Gundy (2010)

[3] WIP Crop Report (2006)

[4] Pers. comm, Trull (2010)

[5] Pers. comm, Dieker (2010)

[6] SCM (1999)

Crop Distribution

Crop data were obtained from WSDA and directly from the districts and analyzed to determine acreages of crops. The WSDA crop data for each district are available in Tables A-1 to A-6 in Appendix A. Table 4 summarizes the acreage of crop groups for each district as collected from WSDA data, and Table 5 summarizes the acreage of crop groups collected from Yakima Project district surveys. Several districts did not respond before publication of this memorandum and their acreage is left blank.

The largest differences in cropping data between the two data sources are in hay/silage, non-crop and cereal grain groups. From discussions with WSDA regarding the limitations of the data they collected and a comparison of their mapping to aerial photos our team believes those crops comprise most of the acreage missing from the WSDA survey.

Table 4. Yakima Project Crop Acreage by District – WSDA Data

Crop Group	KRD	Roza	WIP	SVID	YTID	KID
Orchard	527	26,034	11,535	8,120	15,248	1,998
Hay/Silage	24,661	3,739	14,421	8,618	900	1,502
Cereal Grain	2,413	3,749	32,372	11,864	16	1,168
Vineyard	9	18,865	4,167	11,397	7	1,973
Hops	0	2,789	12,839	5,452	0	0
Non-Crop	9,320	224	1,821	587	220	686
Vegetable	976	906	5,886	1,612	0	840
Mint	0	108	7,862	887	0	0
Other	639	3,622	3,824	2,733	592	502
Total	**38,545**	**60,036**	**94,727**	**51,270**	**16,984**	**8,669**

Survey data: 2002-2008
Non-crop uses include irrigated pasture, developed, and land within the federal Conservation Reserve Program (CRP)

Table 5. Yakima Project Crop Acreage – District Survey Data

Crop Group	KRD	Roza[1]	WIP[2]	SVID[3]	YTID	KID
Orchard	ND	26,622	11,287	10,321	ND	ND
Hay/Silage	ND	4,261	23,333	21,257	ND	ND
Cereal Grain	ND	5,606	15,543	1,215	ND	ND
Vineyard	ND	18,734	4,425	12,469	ND	ND
Hops	ND	7,619	8,982	6,323	ND	ND
Non-Crop	ND	7,760	9,575	44,166	ND	ND
Vegetable	ND	465	11,609	2,012	ND	ND
Mint	ND	315	7,494	1,480	ND	ND
Other	ND	1,108	17,025	0	ND	ND
Total	ND	**72,491**	**109,115**	**99,243**	ND	ND

ND: No data received from district.
[1] Data from 2010 survey (Pers. comm, Van Gundy, 2010)
[2] Data from 2006 crop report (Bureau of Indian Affairs, 2006)
[3] Data from 2006 survey (Pers. comm, Trull, 2010)
Non-crop uses include irrigated pasture, developed, and CRP land

Irrigation Type

On-farm irrigation data were obtained from WSDA and the districts, but the district data had less detail and was not linked to specific crop types. The data were analyzed to determine irrigation types for each district. The WSDA irrigation type data for each district are available in Tables A-1 to A-6 in Appendix A. Table 6 summarizes the irrigation types for each district as collected from WSDA data, and Table 7 summarizes the irrigation types collected from Yakima Project district surveys. Terminology is slightly different in these two sources: districts include wheel

and center-pivot equipment in the "sprinklers" category. Several districts did not respond, and their irrigation type is left blank.

The WSDA data shows rill irrigation is used in 67% of KRD, 39% in WIP and 33% in SVID. Less than 8 percent use rill irrigation in Roza, YTID, and KID. Sprinkler irrigation is used in the majority of Yakima Project divisions except KRD. The irrigation data from received District surveys show similar results.

Table 6. Yakima Project Irrigation Techniques by District– WSDA Data (in acres)

Irrigation Type	KRD	Roza	WIP	SVID	YTID	KID
Rill	25,817 (67.0%)	4,280 (7.1%)	37,212 (39.3%)	16,960 (33.1%)	205 (1.2%)	179 (2.1%)
Sprinkler	885 (2.3%)	34,104 (56.8%)	13,865 (14.6%)	15,929 (31.1%)	15,587 (91.8%)	2,740 (31.6%)
Drip	183 (0.5%)	13,697 (22.8%)	13,193 (13.9%)	5,328 (10.4%)	354 (2.1%)	2,098 (24.2%)
Wheel Line	3,172 (8.2%)	2,889 (4.8%)	17,841 (18.8%)	6,533 (12.7%)	456 (2.7%)	319 (3.7%)
Center Pivot	4,034 (10.5%)	3,597 (6.0%)	10,332 (10.9%)	5,482 (10.7%)	0 (0.0%)	2,828 (32.6%)
Other	4,453 (11.6%)	1,469 (2.4%)	2,283 (2.4%)	1,038 (2.0%)	382 (2.2%)	506 (5.8%)

Table 7. Yakima Project Irrigation Techniques – District Survey Data (in acres)

Irrigation Type	KRD	Roza[1]	WIP	SVID[2]	YTID	KID
Rill	ND	2,983 (4.1%)	ND	31,758 (32.0%)	ND	ND
Sprinkler	ND	50,545 (69.7%)	ND	64,509 (65.0%)	ND	ND
Drip	ND	18,963 (26.2%)	ND	2,977 (3.0%)	ND	ND

ND = No data received from districts

[1] Data from 2010 survey (Pers. comm, Van Gundy, 2010)

[2] Data from 2006 survey (Pers. comm, Trull, 2010)

3.4 On-Farm Water Needs

Crop Irrigation Requirements

The crop irrigation requirement (CIR) is the amount of water, in addition to rainfall, that must be applied to meet a crop's evapotranspiration need without a significant loss in crop yield. To estimate the total crop irrigation requirement for the Yakima Project, the acreage of individual crops in each district was multiplied by a CIR that is representative of that crop for the geographical area of the district. Each district was assigned a "station" from the Washington Irrigation Guide (WIG, NRCS, 1985). CIRs vary across the basin from station to station due to differences in temperature, humidity, and precipitation. Crops for each district were assigned CIRs based on the station and crop type. The CIRs in WIG are averaged using historic climate data. Table 8 presents the station from the WIG used for each district (see Figure 1 for locations).

Table 8. Crop Irrigation Requirement Stations for Yakima Project

District	KRD	Roza	WIP	SVID	YTID	KID
Station Used	Ellensburg	Sunnyside	Wapato	Sunnyside	(Yakima) x (0.75)[1]	Richland

[1] The Yakima Station is the closest station in the WIG; however, the station was not representative of the CIR for Yakima-Tieton due to the higher elevation of the district compared to the Yakima station. To account for this discrepancy, the reference evapotranspiration (ET) rates for Cowiche and Ahtanum stations were averaged and compared to the reference ET for Parker from WSU's AgWeatherNet for 2006-2007, recent average years. This ratio (0.75) was applied to the Yakima station CIRs from the WIG.

For crop types that did not have a specific entry in WIG, the CIR from a similar crop type was used. For example, there is no CIR listed for oat or rye. These crops are classified as cereal grains, so the "spring grain" entry in WIG was used instead. If no similar crop types were available, CIRs from Reclamation's Agrimet station at Harrah were used and multiplied by a ratio comparing the CIR for a reference crop (alfalfa) at Harrah to alfalfa at the other station. CIRs for pasture, asparagus, and watermelon crops were determined using this method. Crop types that still did not have a CIR from either WIG or Agrimet were assumed to have a CIR equal to the weighted average of all crops within the district. Just 1.4 percent of the crops in the districts fall into this final category. Details for CIRs used for each crop and station are found in Table A-7 in Appendix A.

The total crop irrigation requirement for each district was estimated by using the weighted average of CIRs for all crops within that district, with crop acreage used as the weighting factor. WSDA data were used to determine the crop distribution for each district. Although the WSDA dataset has missing acreage, data are available for all districts from one source. Crops having an irrigation type of "None" and crops that have no CIR (such as developed, idle, and CRP land) were not included in the weighted average. Data used to determine the weighted average CIR for each district are located in Tables A-8 to A-13 in Appendix A. The irrigation requirements estimated using WSDA crop distributions were compared to crop irrigation requirements using recent crop data obtained directly from the districts. Table 9 compares the estimated CIR from WSDA data to that from crop data provided by the districts (some districts did not supply crop or irrigation type data and a comparison was not made). The differences between the two estimates are minor (a few percent). Since the estimates of average CIR using the WSDA data are based upon a more detailed breakdown of crop type and irrigation type, that average CIR was used to determine the total on-farm water needs.

Table 9. Average Crop Irrigation Requirements by District (acre-feet per acre)

District (Year of Most Recent Data Received)	KRD	Roza (2010)	WIP (2006)	SVID (2006)	YTID	KID
Using WSDA Data	2.50	2.97	2.78	2.72	2.61	2.96
Using District Data	ND	2.92	2.85	2.63	ND	ND
Difference	ND	0.05	-0.07	0.09	ND	ND
% Difference	ND	1.7%	-2.5%	3.4%	ND	ND

ND = No data received from district.

On-Farm Application and Evaporation Losses

To estimate on-farm irrigation losses, each irrigation type in the Yakima Project was assigned field application efficiency values, based on "Determining Irrigation Efficiency and Consumptive Use" (Ecology, 2005a). Actual efficiency values will vary under different conditions. For example, the percent evaporated is strongly controlled by climate. Return flow depends on soil conditions. However for gross-level analysis at the Basin scale, these differences do not need to be analyzed in detail. Table 10 summarizes the values assumed for each irrigation type for the purposes of this technical memorandum. These efficiency values were applied to the distribution of crop type and irrigation type from WSDA data to derive an estimate of on-farm efficiency for each district. Data used to determine the efficiency values for each district are located in Tables A-14 to A-31 in Appendix A. Table 11 summarizes the results of this analysis.

Table 10. Efficiencies of Different Irrigation Techniques

Irrigation Type	% Application Efficiency	% Total Evaporated	% Total Consumed	% Return Flow
Rill[1]	65	5	70	30
Sprinkler[2]	75	10	85	15
Drip	88	5	93	7
Wheel Line	75	10	85	15
Center Pivot[3]	85	12	97	3
Flood	50	5	55	45
Big Gun	65	10	75	25
Hand[4]	75	10	85	15

Note: Percentages are based upon total volume of water delivered to farms

[1] Graded furrow

[2] Periodic move (handline), solid-set (undertree), pop-up impact

[3] Average of impact heads w/end gun and spray heads w/o end gun

[4] Only used in small nurseries, assumed same efficiency as sprinkler

Table 11. Estimated Average On-Farm Irrigation Efficiency

District	KRD	Roza	WIP	SVID	YTID	KID
% Application Efficiency	66.5%	77.0%	73.2%	73.5%	75.1%	80.5%
% Total Evaporated	6.1%	8.9%	7.5%	8.0%	9.8%	9.4%
% Total Consumed	72.6%	85.9%	80.7%	81.5%	84.9%	89.9%
% Return Flow	27.4%	14.1%	19.3%	18.5%	15.1%	10.1%

The estimated on-farm efficiencies in Table 11 were applied to the crop irrigation requirements in Table 9 using the following equations:

On-farm delivery needs = (CIR) / (Application efficiency)

Application loss = (On-farm delivery) x (Return flow)

Evaporation loss = (On-farm delivery) x (Total evaporated)

Table 12 summarizes the estimated on-farm water needs for each district on average for each acre irrigated.

Table 12. Estimated On-Farm Water Needs (in acre-feet per acre)

District	KRD	Roza	WIP	SVID	YTID	KID
Crop Irrigation Requirement	2.50	2.97	2.78	2.72	2.61	2.96
Application Loss	1.03	0.55	0.73	0.68	0.52	0.37
Evaporation Loss	0.23	0.34	0.29	0.30	0.35	0.34
Total On-Farm Delivery Needs	3.77	3.86	3.80	3.70	3.48	3.68

Total Estimated On-Farm Water Needs by District

Total on-farm water needs were estimated by multiplying the values in Table 12 by the estimated irrigated acreage for each district (Table 3, District Data). Table 13 summarizes each district's estimated on-farm water requirements in acre-feet.

Table 13. Estimated On-Farm Water Delivery Needs by District (in acre-feet)

District	KRD	Roza	WIP	SVID	YTID	KID
Estimated Crop Irrigation Requirement	138,977	215,340	303,790	269,910	72,819	54,550
Estimated On-Farm Application Loss	57,377	39,548	79,878	67,764	14,508	6,874
Estimated On-Farm Evaporation Loss	12,735	24,748	31,249	29,510	9,765	6,355
Estimated Total On-Farm Delivery Needs	**209,089**	**279,635**	**414,917**	**367,184**	**97,092**	**67,779**

3.5 Conveyance Losses

Water diverted from the river but not delivered to farms is typically called "conveyance losses." There are two major types of conveyance losses; operational spill and seepage and evaporation losses. Operational spills result from flow diverted from the river but not delivered to farms due to fluctuating demand. All canals operate with operational spills because canal operations cannot be matched exactly to demand patterns.

Seepage and evaporation losses depend on the type of conveyance system. Piped systems generally have little to no seepage or evaporation loss. Lined canal systems typically have less seepage loss than unlined canal systems but still experience seepage losses. Irrigation districts have a combination of lined and unlined canal systems.

Table 14 summarizes estimates of conveyance losses for each of the Yakima Project districts. Sources of these estimates are listed in the table.

Table 14. Yakima Project Conveyance Loss Estimates by District

	KRD	Roza	WIP	SVID	YTID	KID
Estimated Seepage/Evaporation Loss (% of diversion)	27.5%	24.3%	20.0%	ND	0.0%	14.5%
Estimated Operational Spills (% of diversion)	5.5%	10.6%	8.0%	ND	5.0%	26.3%
Total Conveyance Losses (% of diversion)	33.0%	34.9%	28.0%	11.5%	5.0%	40.8%
Notes	Based on most recent Water Conserva-tion Plan (CH2M Hill, 1999)	Based on 2006-2009 Monthly Water Distributions (Pers. comm, Van Gundy, 2010)	Based on most recent Water Conserva-tion Plan (NRCE, 1999)	Stated in District Survey (Pers. comm, Trull, 2010)	Based on most recent Water Conserva-tion Plan (MWG, 2000)	Based on most recent Water Conserva-tion Plan (SCM, 1999)

The total conveyance losses are estimated by multiplying the efficiencies in Table 14 by the diversions shown in Table 2. Table 15 presents estimated conveyance losses by district.

Table 15. Yakima Project Estimated Conveyance Losses (in acre-feet)

District	KRD	Roza	WIP	SVID	YTID	KID
Average Non-Drought Diversions (1990-2009)	285,983	319,670	560,081	429,122	79,029	99,519
Estimated Conveyance Losses	94,374	111,565	156,823	49,349	3,951	40,604
Estimated Deliveries to Farms	191,609	208,105	403,258	379,773	75,077	58,915

3.6 Preliminary Water Balance for Yakima Project Divisions

Tables 16 and 17 present a preliminary water balance by comparing diversions to the sum of estimated on-farm water needs and conveyance losses for the Yakima Project divisions. This section was included for informational purposes to show, in approximate terms, where the water that is diverted goes. KRD, WIP, SVID, and KID values are presented in Table 16, which compares the estimated deliveries to farms from Table 15 with the estimated on-farm water needs from Table 13. The preliminary water balance calculations show reasonable agreement between average diversions and the sum of on-farm irrigation requirements and conveyance losses for those districts.

The difference between diversions and estimated CIR plus losses as reported in Table 16 was calculated by taking the average non-drought diversions and subtracting the sum of conveyance losses, on-farm application and evaporation losses, and crop irrigation requirement. The percent difference is equal to the difference calculated divided by the average non-drought diversions.

The water balance calculations showed larger differences between average diversions and the sum of estimated irrigation requirements and estimated conveyance losses for Roza and YTID. Therefore a different approach was taken for those districts to attempt to better describe where the water diverted goes. For those districts, the deliveries to farms were estimated by subtracting conveyance losses from average diversions (Table 15). On-farm irrigation requirements and losses were estimated by proportioning the estimated deliveries by the percentages contained in Table 11. The estimated water balance for Roza and YTID is shown in Table 17.

Many errors can be attributed to these values, which decrease the accuracy. Conveyance losses may be different than reported due to system improvements made since the conveyance loss values were estimated. Actual irrigated acreage may be different than reported. Actual crop patterns and irrigation type may be different due to the missing data from the WSDA dataset.

Table 16. Yakima Project Preliminary Water Balance – KRD, WIP, SVID, KID (in acre-feet)

District	KRD	WIP	SVID	KID
Average Non-Drought Diversions (1990-2009)	**285,983**	**560,081**	**429,122**	**99,519**
Estimated Conveyance Losses	94,374	156,823	49,349	40,604
Estimated Deliveries to Farms	**191,609**	**403,258**	**379,773**	**58,915**
Estimated Crop Irrigation Requirement	138,977	303,790	269,910	54,550
Estimated On-Farm Application Loss	57,377	79,878	67,764	6,874
Estimated On-Farm Evaporation Loss	12,735	31,249	29,510	6,355
Estimated Total On-Farm Delivery Needs	**209,089**	**414,917**	**367,184**	**67,779**
Difference between Diversions and Estimated CIR+Losses (acre-feet)	*-17,480*	*-11,659*	*12,589*	*-8,864*
Difference in Diversions and Estimated CIR+Losses (%)	-6.1%	-2.1%	2.9%	-8.9%

Table 17. Yakima Project Preliminary Water Balance – Roza, YTID (in acre-feet)

District	Roza	YTID
Average Non-Drought Diversions (1990-2009)	**319,670**	**79,029**
Estimated Conveyance Losses	111,565	3,951
Estimated Deliveries to Farms	**208,105**	**75,077**
Estimated Crop Irrigation Requirement	160,256	56,379
Estimated On-Farm Application Loss	29,431	11,315
Estimated On-Farm Evaporation Loss	18,417	7,383

3.7 Water Needs in Drought Years

During drought years, an insufficient volume of water is available to serve all entitlements above the Parker gage, and deliveries to districts with proratable entitlements are reduced. Districts with a high percentage of proratable entitlements (Roza, WIP, and KRD) experience larger deficiencies during drought years compared to districts with lower percentages of proratable entitlements (SVID and YTID). SVID and YTID have stated that they do not need additional

water during drought periods even though they also have proratable entitlements. Table 18 compares the proratable water rights for the three districts with the rest of the Yakima Project entitlements above the Parker gage.

Table 18. Proratable Water Rights above Parker Gage

Irrigation Districts	Proratable Entitlements (acre-feet)	% of Total Proratable Entitlements	% of Total Proratable Entitlements Not Including SVID and YTID
Roza	393,000	30%	35%
WIP	350,000	27%	31%
KRD	336,000	26%	30%
Subtotal	***1,079,000***	***82%***	***96%***
SVID	157,776	12%	0
YTID	30,425	2%	0
Subtotal	***1,267,201***	***97%***	***96%***
Non-Division Entitlements	42,874	3%	***4%***
Total	**1,310,075**	**100%**	**100%**

From Table 18, the three districts (KRD, Roza, and WIP) in need of additional water hold 82 percent of the proratable water rights above the Parker gage. Excluding SVID and YTID, the three districts hold 96 percent of the proratable water rights above the Parker gage. Because KRD, Roza, and WIP hold a high percentage of the water rights that are reduced during drought years, it is appropriate to focus further analysis on these districts when determining additional water needs.

Kennewick Irrigation District (KID), although having proratable entitlements, has not been impacted to the same level as Roza Irrigation District, WIP and KRD during droughts because they are located downstream of the Parker gage near the downstream end of the Yakima River Basin. Some of their water supply is derived from return flow from upstream irrigation districts which improves the reliability of their supply. Although this memorandum does not focus on KID water needs, the effect on their water supply from the Integrated Plan will be assessed in the hydrologic modeling performed for the Yakima River Basin Study.

Storage Control/Proration Date

The storage control date and proration date are important terms to understand in considering water deficiencies for the Yakima Project. The storage control date occurs when target flows at Parker gage and irrigation demands can no longer be met by unregulated streamflow, and flows must be supplemented by releases from Yakima Project reservoirs. The median non-drought (1990-2009) storage control date is July 1.

The proration date is set either on or before the storage control date during drought years. This is the date when proration goes into effect. After that date each district is assigned an amount of water or "bucket" that they can use for the rest of the irrigation season. The bucket is based on the total remaining non-proratable entitlements and a percentage of the total remaining proratable entitlement.

Drought Year Diversions and Coping Strategies

Irrigation districts control how they use their bucket using strategies that vary among districts during drought years. Figures 3 to 5 show the daily diversion records for KRD, Roza, and WIP during drought year 2001 compared to average non-drought diversions. In addition to the measures described below, all of the districts with proratable entitlements practice rotation of deliveries during droughts.

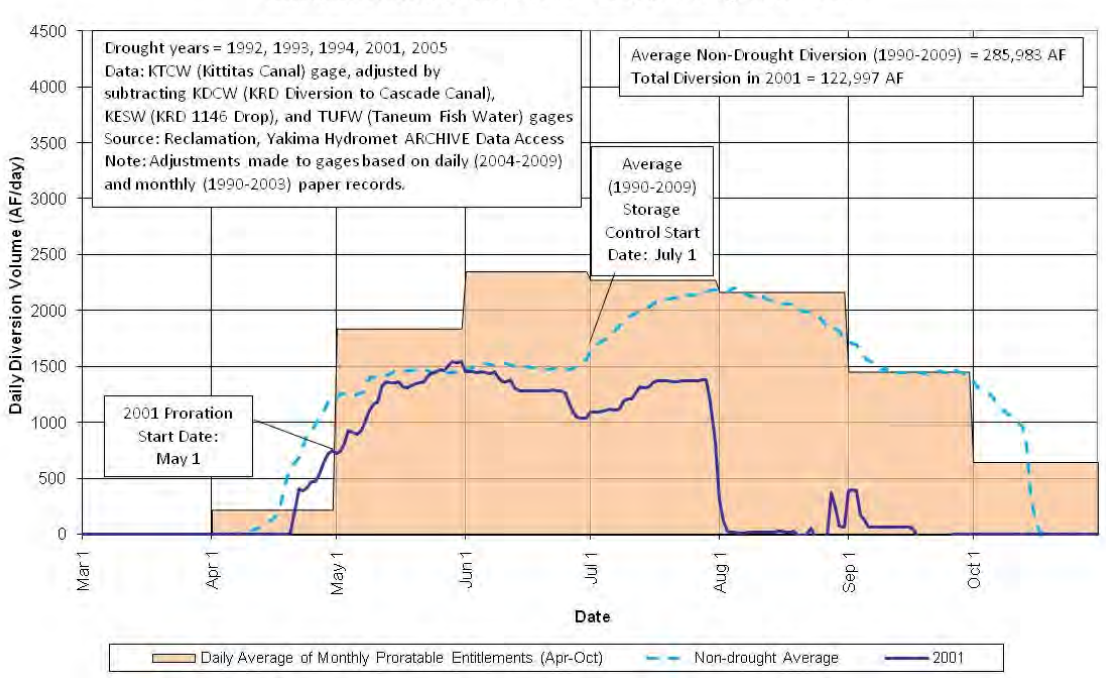

Figure 3. KRD Diversion Comparison
Average Non-Drought Years (1990-2009) vs. Drought Year (2001)

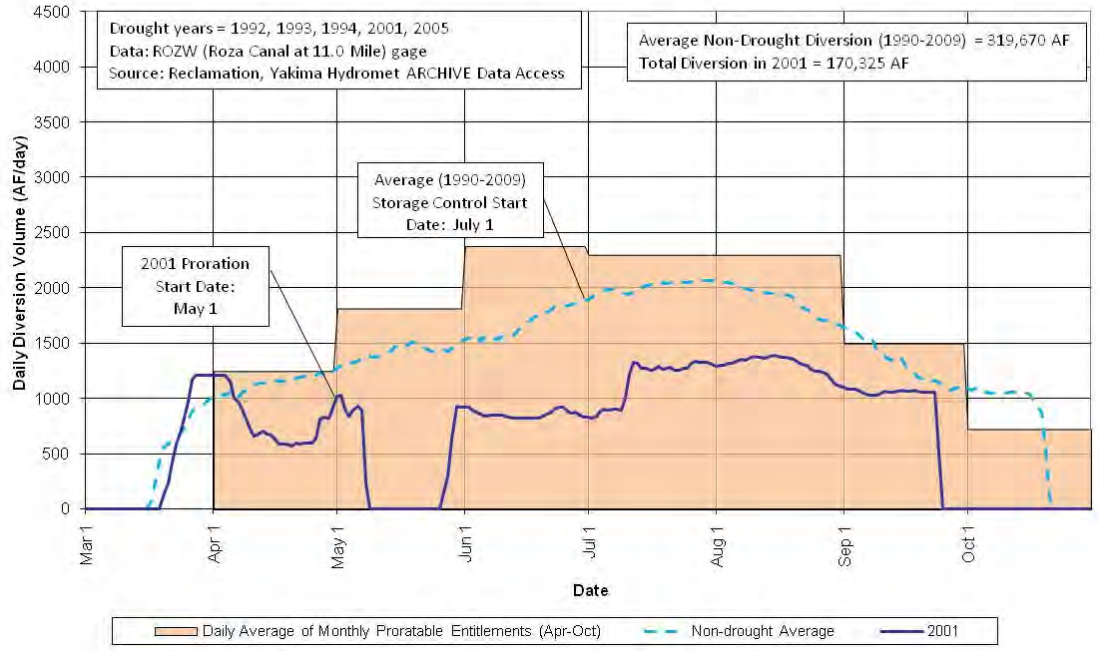

Figure 4. Roza Irrigation District Diversion Comparison Average Non-Drought Years (1990 – 2009) vs. Drought Year 2001

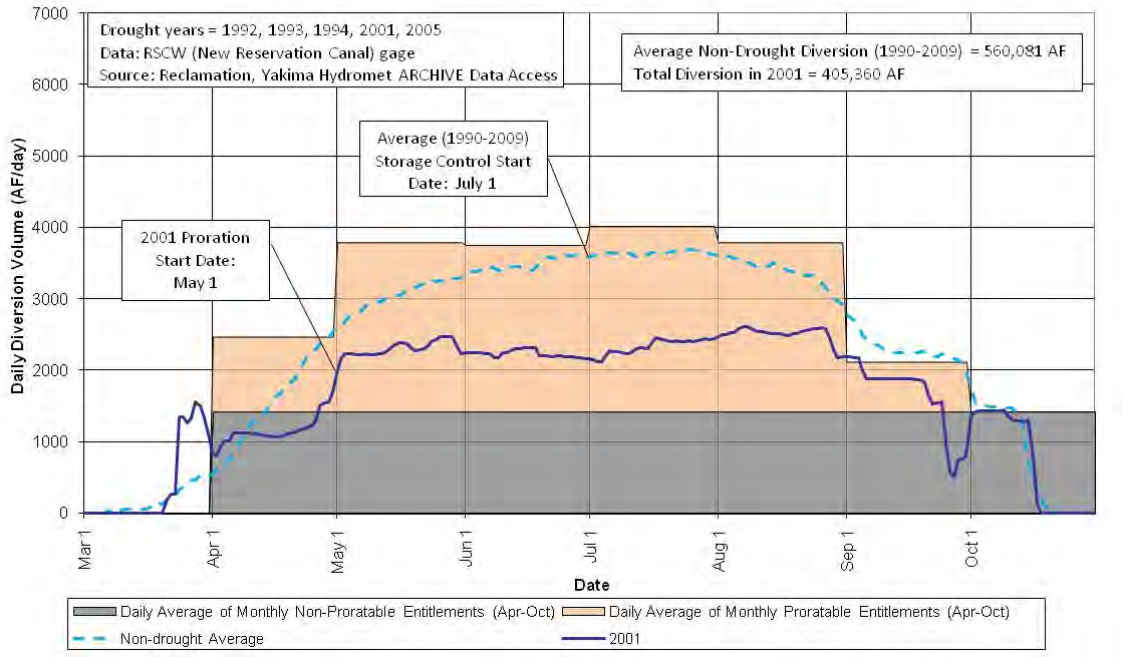

Figure 5. WIP Diversion Comparison Average Non-Drought Years (1990 – 2009) vs. Drought Year 2001

KRD tends to divert close to their average diversion until they run out of water in August. The district's primary crops are hay and alfalfa and their decision is to provide water for at least one cutting of hay. KRD farmers usually fallow some land and water the best fields to ensure they can get one cutting of hay. KRD leased 85 acre-feet of water during the 2001 drought (Westwater Research, 2003) and 800 acre-feet of water during the 2005 drought (Ecology, *2005b Drought Year Water Transfer Summary).*

Roza reduces diversions but also temporarily shuts down diversions early in the season to try and extend their supply as far into the irrigation season as possible. Some Roza farmers pump groundwater using drought-relief wells to supplement their supply. Others use small ponds to get by when the system is shut down. Roza also leases water from other districts in drought years: 16,818 acre-feet of water were leased in 2001 and 28,381 acre-feet of water were leased in 2005 (Monroe, pers. comm. 2010). The leased water is part of the diversions shown in Figures 3 and 4.

WIP reduces diversions for the entire irrigation season and delivers a smaller quantity of water to all farms even though they have a mixture of proratable and non-proratable entitlements. WIP also pumps water into their canals from wells during droughts. WIP is unable to deliver water to parts of its service area during droughts, creating unequal hardship among water users.

Methods to Determine Drought Year Shortfalls

Different methods can be used to determine drought year shortfalls for KRD, Roza and WIP. Results of two alternate methods are presented below.

Comparison of Drought Year Diversions with Average Year Diversions

Table 19 shows the results of one method, which compares drought year diversions (2001, 2005) to average non-drought diversions for the three districts. The shortfall is calculated for the time period that occurs after the proration date during that drought year. The volume of water leased by KRD and Roza is a component of the shortfalls shown in Table 19.

Table 19. Comparison of Drought Year Diversions to Average Non-Drought Diversions (in acre-feet)

	KRD	Roza	WIP
Shortfall between Drought Year 2001 and Average Non-Drought Diversions (1990-2009) Measured after Proration Date of May 1, 2001	156,542	155,721	149,007
Shortfall between Drought Year 2005 and Average Non-Drought Diversions (1990-2009) Measured after Proration Date of April 6, 2005	141,865	154,064	133,764

Figures 6 through 8 show the monthly shortfalls between drought year 2001 and average non-drought diversions for KRD, Roza, and WIP. The shortfall in these figures is the light blue area, which is the difference between the 2001 and average non-drought diversions.

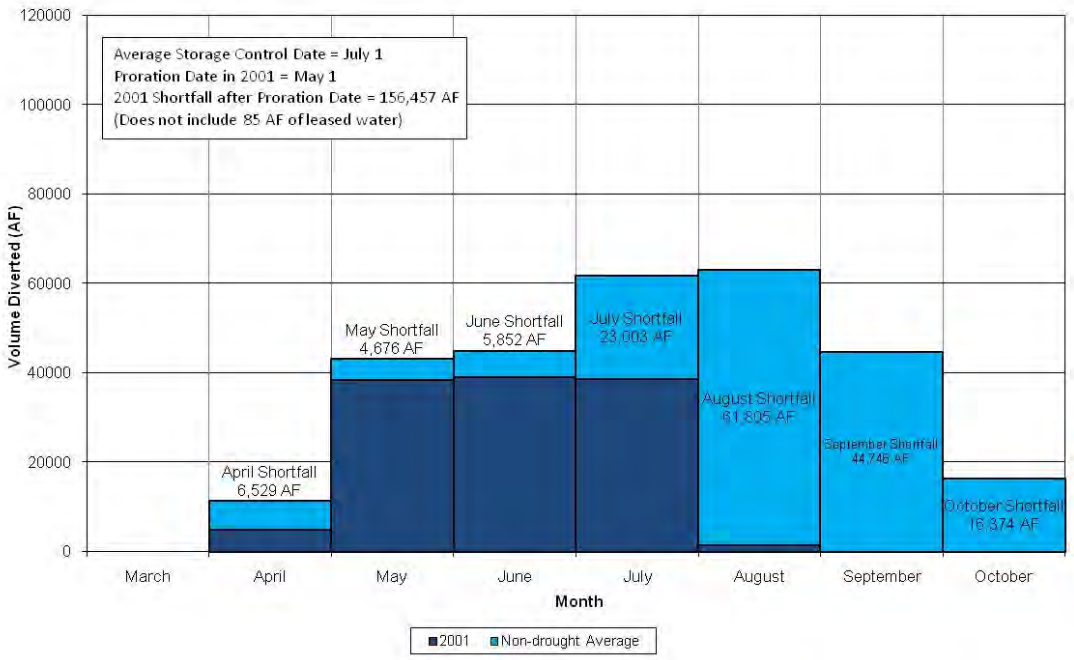

Figure 6. KRD Monthly Diversion Shortfall Comparison
Average Non-Drought Years (1990 – 2009) vs. Drought Year 2001

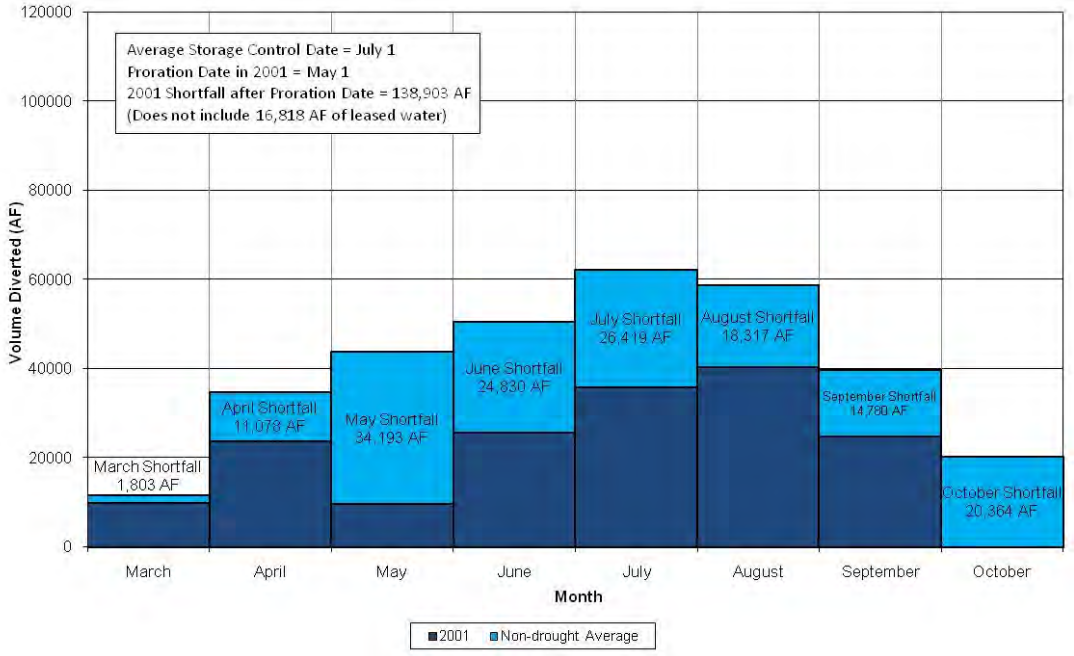

Figure 7. Roza Irrigation District Monthly Diversion Shortfall Comparison
Average Non-Drought Years (1990 – 2009) vs. Drought Year 2001

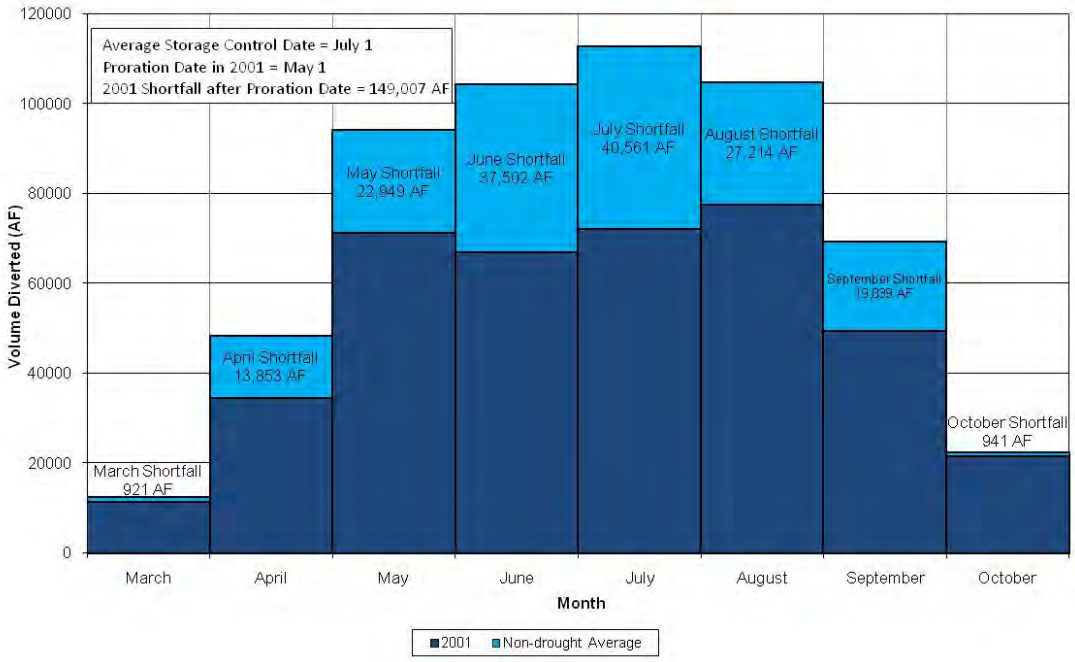

Figure 8. WIP Monthly Diversion Shortfall Comparison
Average Non-Drought Years (1990 – 2009) vs. Drought Year 2001

Comparison of Drought Year Diversions with 70 Percent of Proratable Entitlements

A second method of determining drought year shortfalls is to compare diversions during drought years with water right entitlements. In previous studies, a 70 percent reliability was expressed by the proratable irrigation districts as a level that would allow the districts and farmers to operate without major economic losses. Polls of irrigation district managers were performed to confirm that desired level of water supply reliability in the 20/20 Vision Report (Yakima Watershed Council 1998), the Yakima River Watershed Plan (Tri-County Water Resource Agency, 2003), and the Yakima River Water Storage Feasibility Study (Reclamation, 2008b).

Water Needs Expressed by Irrigation Districts

KRD, Roza and WIP were asked to confirm the calculations performed for this study and how much additional water they need during drought periods.

KRD expressed interest in receiving 70 percent water supply during a drought year. During dry years, farmers usually fallow some land and concentrate water to the best fields to get a first cutting of timothy hay in late June. A second cutting is not always possible during drought years because the system is shut down too early. A 70 percent water supply would allow for the second cutting to take place (Reclamation, Meeting Report, 2007).

WIP said they are able to deliver an acceptable water supply to all areas of the irrigation project if they receive 70 to 75 percent of their proratable entitlement. This is done by using increased

water management techniques and rotation of irrigation deliveries. WIP estimated they would need 115,500 acre-feet of additional supply during drought years (Crane, 2009).

Roza Irrigation District also expressed interest in receiving 70 percent water supply during a drought year.

The 70 percent reliability goal was characterized by the proratable districts as a volume that meets minimal water supply needs and prevents severe economic losses to farmers.

The volume of water that 70 percent reliability would require for each district for drought years 2001 and 2005 was calculated. The calculation was performed for entitlements that fall after the proration date for those two drought years. Table 20 presents that comparison. Water leased during those two years was accounted for in the table.

Table 20. Comparison of Drought Year Diversions to 70 Percent Reliability Target for KRD, Roza and WIP (in acre-feet)

	KRD	Roza	WIP
Shortfall between Drought Year 2001 and 70 Percent Reliability (Measured after Proration Date of May 1, 200)	112,582	116,338	126,492
Shortfall between Drought Year 2005 and 70 Percent Reliability (Measured after Proration Date of April 6, 2005)	90,298	107,720	122,009

Figures 9 to 11 show the monthly shortfalls between drought year 2001 diversions and 70% of proratable entitlements for KRD, Roza, and WIP. The shortfall in these figures is the brown area, which is the difference between the 2001 diversions and 70 percent reliability.

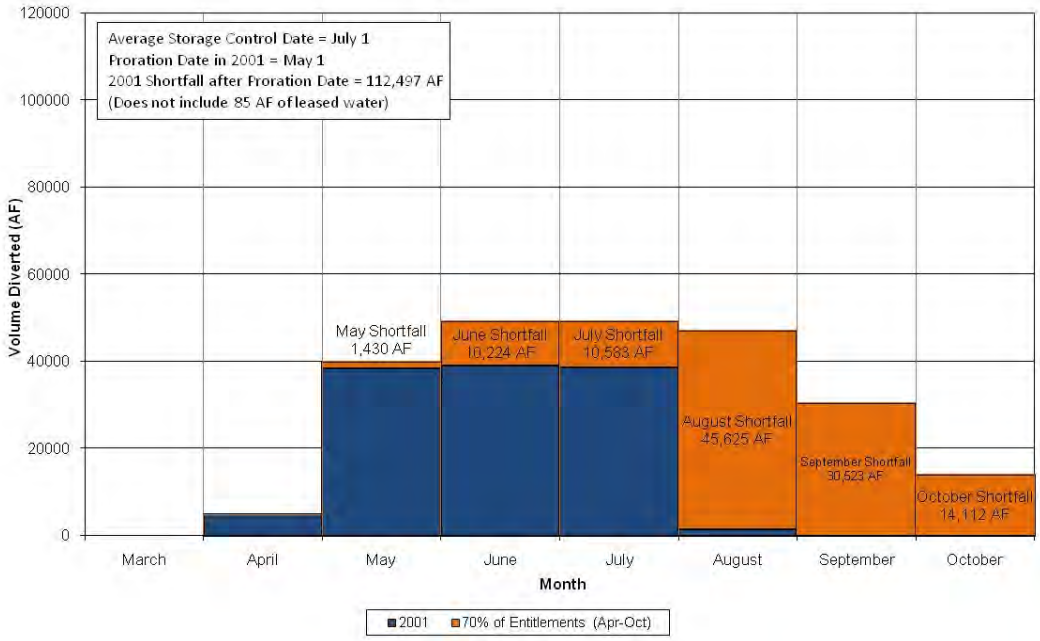

Figure 9. KRD Monthly Diversion Shortfall Comparison
70 Percent Reliability vs. Drought Year 2001

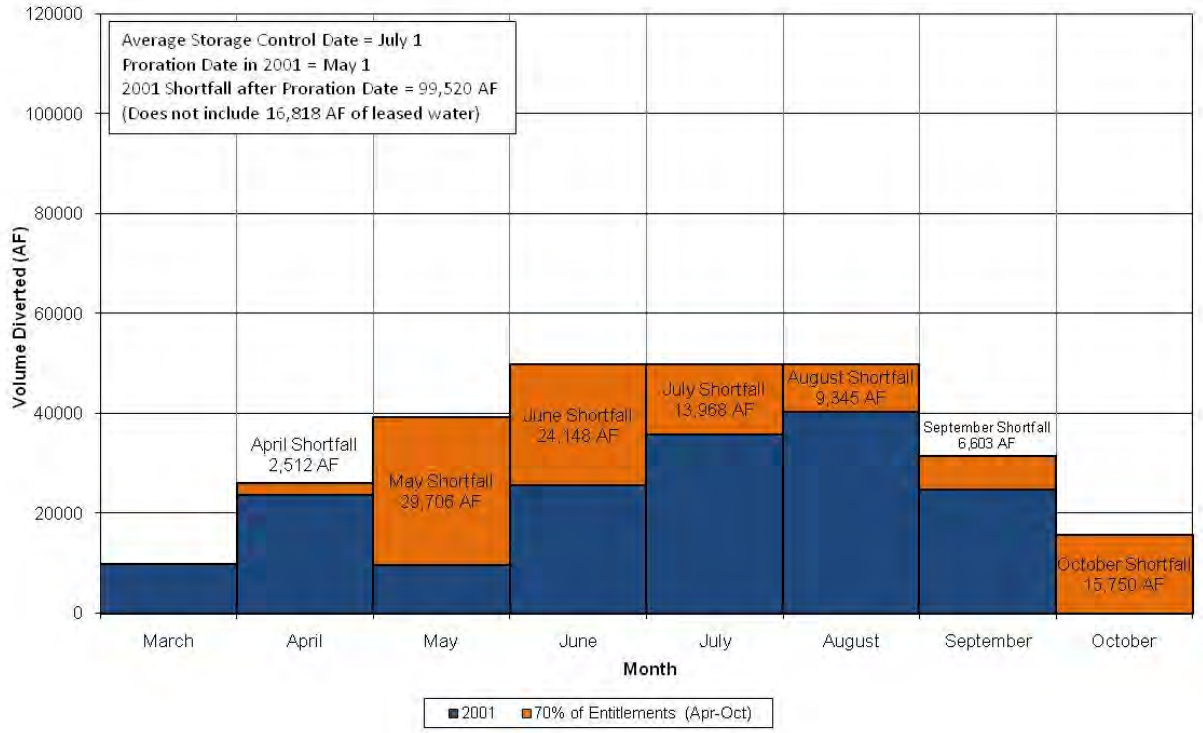

Figure 10. Roza Irrigation District Monthly Diversion Shortfall Comparison
70 Percent Reliability vs. Drought Year 2001

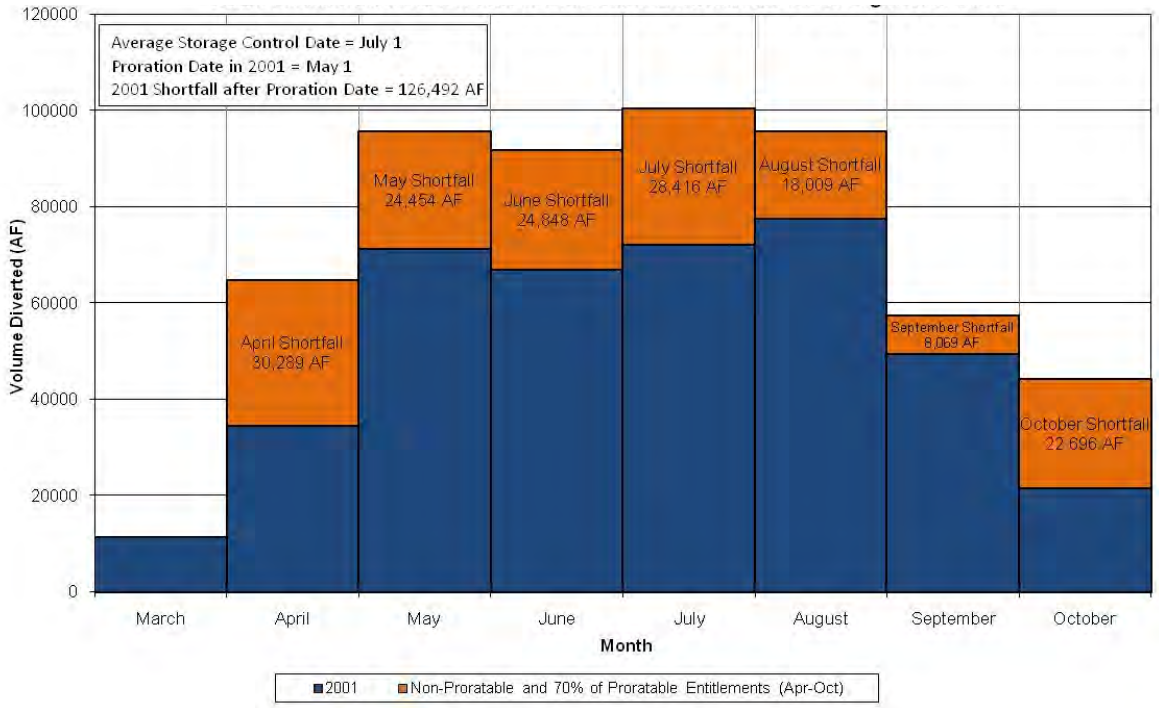

Figure 11. WIP Monthly Diversion Shortfall Comparison
70 Percent Reliability vs. Drought Year 2001

Volume of Water Supply with Lesser Reliability than 70 Percent

Members of the Water Needs subcommittee of the YRBWEP Workgroup expressed their desire to see the volume of water that would comprise 50 percent and 60 percent reliability to KRD, Roza and WIP and compare those to 70 percent reliability. Table 21 provides those calculations for the 2001 drought year.

Table 21. Water Shortfalls at Different Levels of Reliability (acre-feet)

	KRD	Roza	WIP
Shortfall between Drought Year 2001 and 50% Reliability	46,726	48,838	62,792
Shortfall between Drought Year 2001 and 60% Reliability	79,654	82,588	94,642
Shortfall between Drought Year 2001 and 70% Reliability	112,582	116,338	126,492

The volumes presented in Table 21 are for informational purposes and do not represent the water supply needs or goals expressed by the irrigation districts.

Summary of Yakima Project Water Needs in Drought Years

Two methods were used to estimate the total water volume needed in drought years, informed by conversations with irrigation districts. The first method, taking the difference between drought year diversions and average diversions leads to a shortfall of 461,300 acre-feet in the 2001 drought year not accounting for return flows. The second method, computing the difference between drought year diversions and 70% of proratable entitlements leads to a shortfall of 355,400 acre-feet in the 2001 drought not accounting for return flow.

The role of return flows in providing water supply to the Yakima Project is described in Section 3.2. Based on preliminary water balance calculations, an estimated 53% of the water diverted by KRD is lost to seepage or on-farm losses, most of which returns to the Yakima River during the irrigation season. Adjusting the estimated shortfall by 50% return flow from the KRD shortfall, the total shortfall would be reduced to approximately 299,100 acre-feet in the 2001 drought year using the second method described above. The effect of return flows on water supplies will be more accurately determined using the RiverWare hydrologic model. A multi-year drought (1992-94) will also be examined. That analysis has not yet been performed.

The preliminary water balance for each district shows the distribution among crop irrigation requirements, on-farm losses and conveyance losses. The water need described above would be reduced with reductions in on-farm and conveyance losses. However cropping changes may increase the crop irrigation requirement and resulting water need. Section 5 discusses the role that water conservation and changes in cropping patterns have on water demands.

4.0 Current Agricultural Needs – Not Federally Supplied

Water needs were estimated for land that does not receive water from the Federal Yakima Project. This includes land that is irrigated with private surface-water diversions as well as land having primary groundwater rights.

Comprehensive diversion and pumping records for irrigated agriculture served by non-Federal water supplies are not readily available. Therefore estimates of current need in this category were developed using data on crop acreage, crop types and crop irrigation requirements. These estimates are intended to support a comprehensive understanding of water needs within the Yakima River Basin. However, since the Integrated Plan is not intended to enhance supplies for this land, the analysis is general and relies on assumptions and standard factors rather than hard water-use data. For the same reason, drought-year deficiencies have not been estimated.

4.1 Method for Estimating Non-Federally Supplied Agricultural Use

The following estimation procedure was used for current needs of non-Federally supplied land:

1. Estimate acreage in the Yakima River Basin used for growing each irrigated crop type based on data from the Washington State Department of Agriculture 2008 Crop Geodatabase. Only areas outside Federally supplied irrigation districts were considered based on irrigation district boundaries available from Reclamation (GIS shape files).
2. Multiply acres of each crop type by the average irrigation requirement for that crop type (from Washington Irrigation Guide, NRCS, 1985). This provides estimated consumptive use for each crop type. Crop irrigation requirements were broken out geographically for major subareas within the Basin, using five agricultural stations: Ellensburg, Yakima, Sunnyside, Richland and Wapato.
3. Estimate losses from irrigation practices and water conveyance using estimated irrigation efficiency for different irrigation practices, and estimated conveyance efficiency for surface-water delivery systems.

   Expressed as an equation, this procedure is:

   - $D_c = [(A \times I) \div E_i] \div E_c$

   Where:

   - D_c represents total demand for the crop type
   - A = irrigated acreage in that crop type
   - I = crop irrigation requirement for that crop type, expressed in inches or acre-feet
   - E_i = irrigation application efficiency for that crop type (the fraction of water applied to a field that is actually consumed by the crop, which depends in part on the irrigation technology used.)

- E_c = conveyance efficiency (the fraction of water diverted or pumped that actually reaches the field).

E_i was obtained from the Ecology document *Determining Irrigation Efficiency and Consumptive Use* (1985).

E_c was estimated using data on conveyance efficiency for small irrigation water users from the Yakima River Basin Watershed Assessment (TCWRA, 2001), together with information on irrigation equipment used locally from the WSDA 2008 Crop Geodatabase. This information was used to develop a standard E_c of 65% for land irrigated with surface water. For land where groundwater is the primary supply, conveyance efficiency was assumed to be 100%, because there is typically minimal conveyance distance from the wellhead to the field, and water pumped is typically contained within pressurized pipes rather than open ditches.

This procedure provides an estimate of total water diverted or pumped. The results were subdivided geographically into areas above and below the Parker gage (control point for the Yakima Irrigation Project) and in the Naches Subbasin.

4.2 Results for Non-Federally Supplied Agricultural Use

Table 22 summarizes the results from this procedure. This information is provided for descriptive purposes, to allow for a more complete picture of water uses in the Yakima River Basin. Additional information on the assessment of current needs for non-federally supplied agricultural land is provided in Appendix B.

Table 22. Estimated Non-Federal Agricultural Irrigation

Geographic Area	Acres Irrigated [1, 2]			Estimated Annual Diversions		
	Surface Water	Groundwater - Primary	Total	Surface Water	Ground-water - Primary	Total
	Acres	Acres	Acres	Acre-Feet	Acre-Feet	Acre-Feet
Non-Federal District						
Above Parker	18,492	0	18,492	125,454	0	125,454
Below Parker	2,534	0	2,534	15,823	0	15,823
Naches River	4,903	0	4,903	33,665	0	33,665
Subtotal Non-Federal District	*25,930*	*0*	*25,930*	*174,942*	*0*	*174,942*
Outside District						
Above Parker	18,450	21,221	39,671	127,582	81,854	209,436
Below Parker	8,114	16,703	24,817	46,060	65,947	112,007
Naches River	0	3,086	3,086	0	13,302	13,302
Subtotal Outside Districts	*26,564*	*41,010*	*67,574*	*173,642*	*161,102*	*334,745*
Total Non-Federal (land from WSDA)	**52,494**	**41,010**	**93,503**	**348,584**	**161,102**	**509,687**
Total Non-Federal (Adjusted for Missing Land) [3]	**60,368**	**47,161**	**107,529**	**400,872**	**185,268**	**586,140**

[1] Excludes All Acreage Inside of the Federally-supplied Yakima Project irrigation districts

[2] Excludes fields with irrigation types of "None" and "N/A".

[3] Based on comparison of WSDA land in GIS with aerial imagery, an estimated 15% of irrigated agricultural land was not captured in the WSDA irrigated cropland geodatabase. A 15% adjustment is made here.

5.0 Future Changes in Agricultural Needs

Future agricultural water needs will be dependent on many factors that may increase or decrease the total water demand for irrigated agriculture. These factors are:

- Conversion of land from agricultural use to urban use
- Reduced diversions due to water conservation projects in the agricultural sector
- Changes in acreage when idle agricultural land is brought back into production
- Potential changes in crops grown, in response to market forces
- Potential changes in crop requirements due to changes in precipitation and temperature resulting from climate change

This section provides information on these factors. The discussion focuses primarily on land irrigated by water from the federal Yakima Project. Some information is also provided on land irrigated by non-federal supplies.

5.1 Effects of Land Conversion from Agricultural to Urban Uses

Section 6.5 of this Technical Memorandum discusses how continued population growth and development in the Yakima River Basin is expected to cause continued conversion of agricultural land to urban uses, within Urban Growth Areas. Changes in the quantity and seasonal timing of water use will accompany this conversion. For more information on the quantity of land involved and the expected change in water use, see Section 6.5.

5.2 Agricultural Conservation

Irrigation districts have carried out various water conservation projects that improve facilities and operations to reduce diversions and improve service and reliability as part of the YRBWEP program. Most irrigation districts served by the Federal water system have developed water conservation plans. Conservation projects from these plans have been reviewed and prioritized by a Conservation Advisory Group appointed to assist Reclamation direct funding to projects that best meet YRBWEP purposes. Implementation of water conservation projects has contributed to the overall reduced diversions that have occurred over the past several decades as shown in Figure 2.

Additional agricultural water conservation measures will be implemented in the future for irrigation water delivery systems (canals and laterals) and on-farm systems. Potential water conservation measures include lining or piping existing canals or laterals, constructing reregulation reservoirs on irrigation canals, installing gates and automation on irrigation canals, improving water measurement and accounting systems, installing higher efficiency sprinkler systems, and implementing irrigation water management practices and other measures to reduce seepage, evaporation and operational spills. These water conservation measures will not change the crop irrigation requirements but will reduce water losses between the point of diversion and the farm turnout and the amount of water lost to seepage and evaporation on farms.

Water conservation measures yield the largest water savings in years with at least average water supply. During droughts, water conservation measures yield lower water savings than in average water supply years, because less water is conveyed through canals and applied to farms, so seepage losses are smaller. The reduced seepage reduces return flows, which are a source of water supply to other irrigation districts.

For on-farm irrigation practices, upgrades to higher efficiency sprinkler systems have been occurring for several reasons including cropping changes (to vineyards or new orchards), reducing energy use, better control of fertilizer and chemical application, a need to reduce sediment runoff and improve water quality, to improve instream flow in tributaries and to improve the reliability of available water supplies.

Tables 6 and 7 provide estimates of irrigation type by district in the Yakima Project. Roza farmers are estimated to have approximately 90% of the total acreage in sprinkler or drip systems. Although SVID has a smaller percentage of acreage sprinkler or drip irrigated (68%), they are currently installing new piped lateral systems which will deliver pressurized water to much of their acreage. That will facilitate conversion to higher efficiency irrigation systems. In the YTID, over 90% of the acreage is estimated to be sprinkler irrigated, which corresponds to the percentage of acreage in orchards which typically use higher efficiency irrigation systems. In WIP, approximately 55% of the acreage is sprinkler or drip irrigated. However additional water conserved on-farm in WIP may not result in corresponding reduction in diversion requirements because return flow provides supply to other WIP farmers. This issue was reviewed in Priority Irrigation Water Conservation and Management Measures Plan for the Wapato Irrigation Project (NRCE 2002) and it was estimated that a diversion reduction of only 0.2 acre-feet per acre improved (11,375 ac-ft for 55,750 acres improved) would result. During drought years, the water savings would be reduced because less water is applied to fields.

In KRD, only 20% of the acreage is irrigated with sprinkler or drip systems. However return flow from KRD farms flows back to the Yakima River and is a source of supply for water users downstream of the Kittitas Valley. Therefore a reduction in seepage on KRD farms would not improve water supply conditions in the basin.

Outside of the Yakima Project, it is estimated that 75% of irrigated acreage is sprinkler or drip irrigated. Approximately 95% of the gravity (rill) irrigated acreage outside of the Yakima Project is located in Kittitas County and return flow from that acreage is a source of supply for water users downstream of the Kittitas Valley. A reduction of seepage on those farms would not improve water supply conditions in the basin, because the return flow from seepage returns to the Yakima River and flows downstream to provide supply to other users. However in the Kittitas Valley, on-farm water conservation improvements could have large benefits to stream flow in various creeks that flow into the Yakima River.

5.3 Idle Acreage

The Yakima River Basin Study assumes there will be no increase in acreage authorized for irrigation, either in federally or non-federally-supplied areas. New acreage is not likely to occur because current supplies are not sufficient to serve current acreage during drought years.

However, some land that is currently idle within irrigation divisions of the Yakima Project may potentially be irrigated in the future.

There are approximately 28,000 acres of idle land in the Wapato Irrigation Project. They are currently idle for a variety of reasons listed in the *Priority Irrigation Water Conservation and Management Measures Plan for the Wapato Irrigation Project* (Natural Resources Consulting Engineers [NRCE], 2002). These reasons include limited or no access to parcels and/or irrigation facilities, irregular field sizes and layouts, prohibitive land and irrigation system development costs, and unfavorable topography for irrigation and crop production. In the report, NRCE estimated that approximately 16,400 acres can be put into production if conveyance and distribution systems are improved and an on-farm water conservation program and water leasing plan are implemented. This acreage would cause an additional consumptive use of 45,600 acre-feet in non-drought years, using WIP's current average CIR. Additional flow is needed for conveyance and on-farm losses, but an undetermined amount of the water lost would return to other irrigated areas in WIP.

Other Districts did not report significant idle acreage. It is expected that some acreage will be idle or fallow every year because of crop rotations or a decision to not plant a crop for various reasons. Other new acreage is not likely to occur because current entitlements are not sufficient to serve current acreage during drought years.

5.4 Potential Variability in Cropping Patterns

Water needs for irrigated agriculture are influenced by the specific crops grown. A robust agricultural economy includes the ability to respond dynamically to commodity prices; newly developed crop varieties; and technological innovation. Therefore the water needs assessment includes consideration of potential future changes in crop mixes within the Yakima River Basin. A review of past cropping patterns and crop irrigation requirements was performed to estimate the magnitude of change in water needs from this factor.

Cropping patterns affect future water needs because different crops have different irrigation requirements. For example orchards and hay have higher crop irrigation requirements than vineyards and vegetables. Cropping patterns change over time to meet market demands.

Table 23 shows past cropping patterns obtained from districts' Water Conservation Plans.

Table 23. Past Cropping Patterns for Yakima Project Districts

District (Year of Cropping Data)	KRD (1993)	Roza (1985-1990)	WIP (1990)	SVID (1990)	YTID (1994)	KID (1992)
Orchard	1.5%	42.0%	10.5%	13.2%	88.0%	34.4%
Hay/Silage	86.5%	---	12.2%	29.2%	11.5%	58.3%
Cereal Grain	6.1%	---	18.8%	4.5%	---	---
Vineyard	---	17.0%	3.0%	9.4%	---	---
Hops	---	12.0%	7.8%	10.6%	---	---
Non-Crop	---	---	10.0%	21.7%	0.5%	---
Vegetable	1.0%	---	16.6%	8.2%	---	---
Mint	---	---	11.8%	3.1%	---	---
Other	4.9%	29.0%	9.3%	0.1%	---	7.2%

Note: Values in table are percentages of total acreage within each individual district
Blank slots mean the crop group was not included in district data;
"Other" encompasses all slots not listed by a district
"Non-crop" uses include irrigated pasture, developed, and CRP land

Data supplied from districts were used to estimate current cropping patterns. Table 24 presents the current cropping patterns for Roza, WIP and SVID, the districts that supplied recent cropping patterns.

Table 24. Current Cropping Patterns for Yakima Project Districts

District (Year of Cropping Data)	Roza (2010)	WIP (2006)	SVID (2006)
Orchard	36.7%	10.3%	10.4%
Hay/Silage	5.9%	21.4%	21.4%
Cereal Grain	7.7%	14.2%	1.2%
Vineyard	25.8%	4.0%	12.6%
Hops	10.5%	8.2%	6.4%
Non-Crop	10.7%	8.8%	44.5%
Vegetable	0.6%	10.6%	2.0%
Mint	0.4%	6.9%	1.5%
Other	1.4%	15.6%	0.0%

Note: Values in table are percentages of total acreage within each individual district
"Non-crop" uses include irrigated pasture, developed, and CRP land

Table 25 presents estimated average crop irrigation requirements for Yakima Project districts calculated using estimated current cropping patterns from Table 24 and past cropping patterns described in Table 23. For those districts that did not supply current cropping patterns, the crop irrigation requirement estimated using WSDA data (in Table 9) was used.

Table 25. Estimated Past and Present Average Crop Irrigation Requirements by District (acre-feet per acre)

District	KRD	Roza	WIP	SVID	YTID	KID
Average CIR (Past)	2.72	3.11	2.73	2.69	2.58	3.50
Average CIR (Current)	2.50	2.97	2.78	2.72	2.61	2.96
Year(s) of Past Data	1993	1985-1990	1990	1990	1994	1992

Changes in cropping patterns have caused overall average crop irrigation requirements in Yakima Project irrigation districts to decrease or only slightly increase. Where cropping patterns have changed from orchards to vineyards, such as in Roza Irrigation District, overall average crop irrigation requirements are smaller than in past years. In Kennewick Irrigation District, a similar shift from orchard to vineyard has occurred along with a shift to other crop types and land use with lower crop irrigation requirements. In KRD it appears more pasture is present than in past years which has a lower crop irrigation requirement than hay crops.

The past and present estimated crop irrigation requirements were multiplied by the irrigated acreage to estimate the consumptive use. Table 26 presents the estimated change in consumptive use for the Yakima Project irrigation districts.

Table 26. Estimated Past and Present Consumptive Use by District

District	KRD	Roza	WIP	SVID	YTID	KID
Estimated Consumptive Use by Crops (Past)	151,000	225,000	298,000	256,000	72,000	65,000
Estimated Consumptive Use by Crops (Current)	139,000	212,000	311,000	261,000	73,000	55,000
Estimated Change in Consumptive Use	-12,000	-13,000	13,000	5,000	1,000	-10,000

Note: All values in acre-feet

The estimated consumptive use by crops for the Yakima Project irrigation districts has decreased by approximately 16,000 acre-feet since the mid-1980s and early 1990s due to changes in cropping patterns. Additional water was used to convey and apply the water to crops. That volume was not estimated for past cropping patterns as data on conveyance losses and on-farm losses were not available for that time period.

A wide variety of crops can be grown in the Yakima River Basin, and different crops have different water needs. Irrigation equipment also differs among the different crops grown. A vibrant agricultural economy must have the flexibility to respond to market conditions, and this includes choices from year to year and decade to decade regarding the mix of crops grown.

5.5 Climate Change Effects on Agricultural Water Needs

Climate change has been predicted for the Pacific Northwest, and the University of Washington (UW) Climate Impacts Group (CIG) has modeled potential effects on temperature and precipitation for a range of global climate change scenarios. Under a separate task of the Yakima River Basin Study, effects of climate change on snowpack and runoff are being assessed. Reclamation's RiverWare model of the Yakima River and irrigation system are being used in that assessment.

Climate change can also be expected to influence water needs on the demand side. Effects on demand have not been studied in prior research to the same extent as effects on supply. One study performed by UW researchers was reviewed, but was deemed not suitable for this purpose as the study appeared to predict large decreases in irrigation demand for apples and cherries with climate change. Members of the Water Needs subcommittee, which reviewed this memorandum, thought their study was not complete as other crops were addressed and they also did not agree with their conclusions of reduced water demands for apples and cherries. They

asked the HDR team to derive new calculations. Therefore, for purposes of this technical memorandum, rough estimates were developed of how changes in temperature and precipitation may affect crop irrigation needs. The analysis is described in Appendix C.

Table 27 summarizes the results for each district in the Yakima Project. Detailed spreadsheet calculations are provided in Appendix C attachments for both current and future CIRs. The increases range from 7.8% for KID to 9.8% for KRD. These CIRs represent only the consumptive use of crops district-wide, and do not include seepage and evaporation losses that occur on-farm and district wide.

Table 27. Summary of Weighted Current and Future CIR

District	Current CIR (ft)	Future CIR (ft)	Percent Increase
KRD	2.51	2.75	9.8%
Roza	2.97	3.24	9.0%
WIP	2.78	3.03	8.7%
SVID	2.72	2.97	9.2%
YTID	2.61	2.84	8.9%
KID	2.96	3.19	7.8%

The percentage increases listed in Table 27 will be used to adjust consumptive use estimates for each irrigation district in the RiverWare model. Using the estimates in Table 27 and district acreage data, the estimated increase in consumptive use is presented in Table 28.

Table 28. Estimated Increase in Yakima Project Consumptive Use Under Climate Change Conditions

District	Current CIR (ft)	Future CIR (ft)	Increase in CIR (ft)	Irrigated Land (ac)	Increase (ac-ft)
KRD	2.51	2.75	0.24	55,516	13,000
Roza	2.97	3.24	0.27	72,491	20,000
WIP	2.78	3.03	0.25	109,115	27,000
SVID	2.72	2.97	0.25	99,243	25,000
YTID	2.61	2.84	0.23	27,900	6,000
KID	2.96	3.19	0.23	18,441	4,000
				Totals	95,000

The total estimated increase in consumptive use for Yakima Project irrigation districts is approximately 95,000 acre-feet per year. That estimate assumes current cropping patterns will continue in the future and therefore does not account for potential responses to climate change and additional water shortfalls by Yakima River basin water users. The estimate also assumes a full water supply is available for all currently irrigated crops; in drought years less water would be available and the increase in consumptive use would be less.

The estimates of future water use, adjusted for climate change, will be used in the RiverWare model to test the effectiveness of the Integrated Water Resource Management Plan in meeting the challenges of changing runoff patterns and water demands. We understand that a much more comprehensive analysis of future water needs will be performed by Washington State University

(WSU) as part of their contract with Washington State Department of Ecology (Ecology) for the Columbia River Water Supply Investment Plan.

A draft of the climate change analysis in Appendix C was forwarded to researchers associated with the UW Climate Impacts Group for review since there was disagreement on UW's findings of irrigation demand decreasing for apples and cherries with climate change.

Researchers responded (Stockle, pers. comm.) that there was an error in reporting their findings of impacts to irrigation demands with climate change. The reduction in irrigation demand shown in their report actually represents the shortfall in irrigation supply and does not represent the impact on net irrigation requirements. They also stated that it is correct to assume that potential evapotranspiration (PET), as an engineering calculation, will increase with climate change. However there are other factors such as response to CO_2 concentrations and a shorter growing season that will increase water demand less than the HDR team projected using standard PET calculations. They estimated the increase would be perhaps on the order of 3 to 5 percent. (An additional demand of 5 percent would result in an increase in consumptive use of 53,000 acre-feet, using the same methodology shown in Table 28.)

For the purposes of hydrologic modeling of climate change effects, the increases in consumptive use shown in Table 28 will be used. That will result in conservative estimates of the effect of climate change on irrigation demands in the Yakima River Basin.

6.0 Municipal and Domestic Water Needs

Estimates of current needs for municipal water systems were developed based on data from eight of the largest water systems in the basin. These data were used to extrapolate usage by smaller systems not examined individually. The eight systems are:

- City of Ellensburg
- City of Grandview
- City of Prosser
- City of Sunnyside
- City of Toppenish
- City of Yakima
- Nob Hill Water Association (west Yakima area)
- Yakima County - Terrace Heights (east Yakima area)

6.1 Method for Assessing Current Municipal and Domestic Needs

The following estimation procedure was used for current municipal and domestic needs:

1. For the eight systems examined individually, water system data were acquired to document current water usage (potable water supply was distinguished from irrigation supply).
2. For the eight systems examined individually, total per-capita (per person) water use was estimated (including potable water use and landscape irrigation combined). This was

then used as a surrogate value for all smaller municipal systems (that were not examined individually).

3. There are hundreds of smaller water systems, ranging from subdivisions with only a few homes to small towns and cities in the Basin. For the smaller systems, Department of Health records of the number of municipal system "connections" (customers) were used to estimate the number of households served by municipal systems. In smaller systems, connections equate roughly to households, since there is little multifamily housing or commercial or industrial activity. The number of households was converted to an estimated number of people based on county planning department estimates of persons per household.

4. Water use by smaller systems was estimated by multiplying estimated population served by per-capita water usage estimated as described above.

5. Total municipal uses were calculated by adding up the use by the eight large systems and use by the smaller public water systems.

6. A similar procedure was applied to estimate water use by individual domestic wells. The per-capita water use value was multiplied by an estimate of the number of people in the Study Area who rely on domestic wells. The population using domestic wells was estimated based on total population for each county, minus the population served by public water systems.

It could be argued that per-capita usage derived from municipal systems typically exceeds per-capita water usage of domestic well owners, because municipal data include commercial and industrial usage, in addition to residential usage. However, rural stakeholders in the Yakima River Basin typically respond that rural homes sit on larger acreages and tend to include gardens, pasture or small orchards that require more irrigation than urban homes. Therefore, for the broad purposes served by this assessment, the same per-capita water use was applied to rural domestic wells as urban water uses.

The number of people relying on domestic wells was estimated by subtracting the number of people served by municipal systems (see prior subsection) from the total population in each County. County population was obtained from comprehensive plan documents prepared by Benton, Kittitas and Yakima counties. As discussed in Section 1.2, the population considered for Benton County is limited to those living within the Study Area.

6.2 Current and Projected Population

This subsection presents results of the population growth analysis for municipal water systems and domestic wells.

Current population estimates and future forecasts were obtained from county comprehensive plans prepared by Benton, Kittitas and Yakima counties. County information is based in turn on data and forecasts from the Washington State Office of Financial Management (OFM). OFM is charged with providing forecasts used in land use planning under the state's Growth Management Act (GMA).

Table 29 shows the estimated population served by the eight large public water systems that deliver water to the six largest cities in the Yakima River Basin. Table 30 shows population served by smaller public water systems and domestic wells in each county. Figure 12 summarizes the estimated population served by large and small systems and domestic wells.

Table 29. Estimated Population Served by Large Public Water Systems

System	Population Served
Yakima Area:	
Yakima Water & Irrigation	65,000
Nob Hill Water	26,400
Terrace Heights (Yak. Co.)	3,900
Yakima Area Subtotal:	*95,300*
Ellensburg Water Dept	17,200
City of Sunnyside	15,300
City of Toppenish	9,400
City of Grandview	9,200
City of Prosser	5,100
Total:	**151,500**

Source: 2009 Water Facilities Inventory forms submitted to Washington State Department of Health

Table 30. Estimated Population Served, by County and Service Category

County/Category	Population Served
Benton County (w/in Basin)	
Large Public Systems	5,100
Small Systems	8,400
Domestic Wells	13,000
Benton Co. Total	*26,500*
Kittitas County	
Large Public Systems	17,200
Small Systems	7,900
Domestic Wells	19,000
Kittitas Co. Total	*44,100*
Yakima County	
Large Public Systems	129,200
Small Systems	37,100
Domestic Wells	89,000
Yakima Co. Total	*255,300*
Subtotals by Category	
Large Systems	**151,500**
Small Systems	**53,400**
Domestic Wells	**121,000**
Total Basin Population	**325,900**

Source: Large Systems from Water Facilities Inventory forms submitted to DOH (2009). Small systems from DOH Database. Domestic wells estimated by subtracting other categories from total county populations.

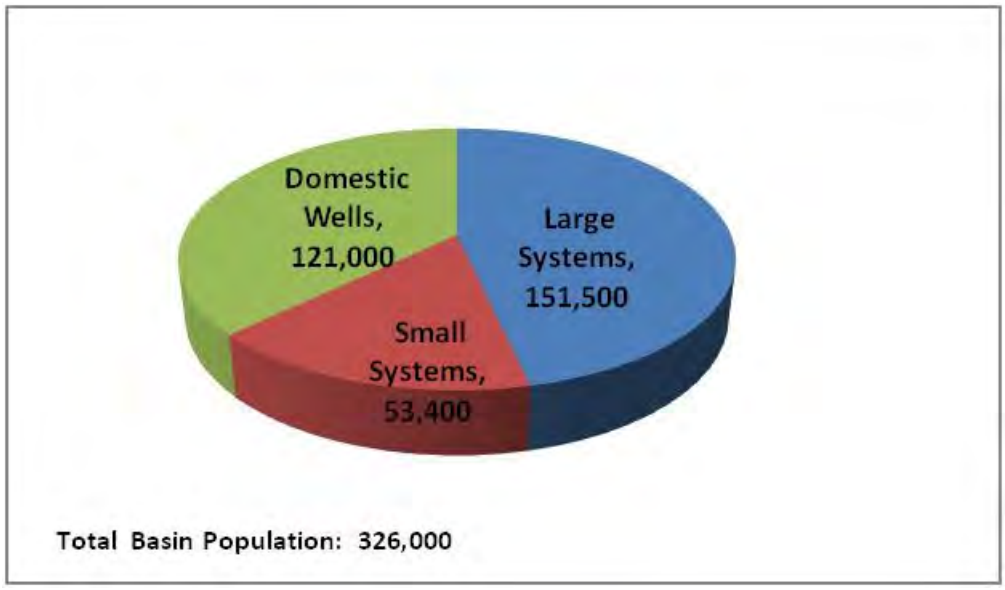

Figure 12. Yakima River Basin Population by Type of Water Service

Table 31 shows population projections acquired from the three county comprehensive plans. The total Basin population is forecast to grow by 27% during that 15-year time span, rising from approximately 326,000 people in 2010 to 415,000 in 2025.

The Benton County planning department estimated the portion of the County population residing within the Yakima River Basin (S. Walker, personal communication, 2010). Irrigation supplies for Kennewick, Richland and West Richland are drawn largely from the Yakima River, while potable water supplies for those systems come from a combination of the Columbia River and groundwater. Therefore those three systems were excluded from the analysis. (Irrigation supply for those three cities is included in the diversion data compiled under the agricultural irrigation analysis.)

Table 31. County Population Projections

	2010	2025
Benton County [1]		
Cities	9,447	11,700
Unincorporated	16,852	24,400
Total	26,299	36,100
Kittitas County [2]		
Cities	31,389	37,758
Unincorporated	12,512	15,052
Total	43,901	52,810
Yakima County [3]		
Cities	156,600	202,260
Unincorporated	98,989	123,994
Total	255,589	326,254
Basin Total	**326,000**	**415,000**

[1] Benton County Comprehensive Plan, 2006. Chapter 4 Appendix: Item 4. In-Basin population from email received from Benton County planning department, June 9, 2010.

[2] Kittitas County Community Development Services. Frequently asked questions from May/June Open House, 2006. 2025 Projections

[3] Yakima County Plan 2015, 1997- Updated in 2007. Chapter V: Table V-4.

While the three counties project population to 2025, forecasts for this assessment were needed for a 50-year period to 2060. Growth rates used by the counties for years 2010 to 2025 average approximately 1.5 percent per year, but decline over that 15-year period. Therefore HDR adopted an annual growth rate of 1 percent per year for the medium-level forecast from 2025 to 2060. To provide a range around this forecast, it was also bracketed by growth curves using growth rates of 0.5% and 1.5% for this time period. Population growth could fall anywhere within this range. Planning department staff in each of the three counties and the City of Yakima concurred that this range of growth rates is consistent with growth trends and reasonable for long-range planning purposes.

Using this approach, the range of population forecasts are shown in Table 32 and displayed graphically in Figure 13.

The medium forecast for 2060 shows a population of 590,000 in the Basin, an increase of 81% from the current population of 326,000. The low and high forecasts for 2060 are 500,000 to 700,000 (50-year growth ranging from 52% to 115% of the 2010 population). The growth estimates assume no constraints based on water availability. This is appropriate because one purpose of the Integrated Plan is to provide water for growth and development within the Basin, and the purpose of this Technical Memorandum is to assess how much water would be needed to support the growth and development that is expected to occur.

Table 32. Population Forecasts to 2060 for the Study Area (Low, Medium and High)

	2010	2025	2030	2040	2050	2060
Low	Not calculated	Not calculated	428,000	450,000	473,000	497,000
Medium	326,000	415,000	438,000	484,000	535,000	590,000
High	Not calculated	Not calculated	448,000	520,000	603,000	700,000

Growth rates were applied by HDR for years after 2025.

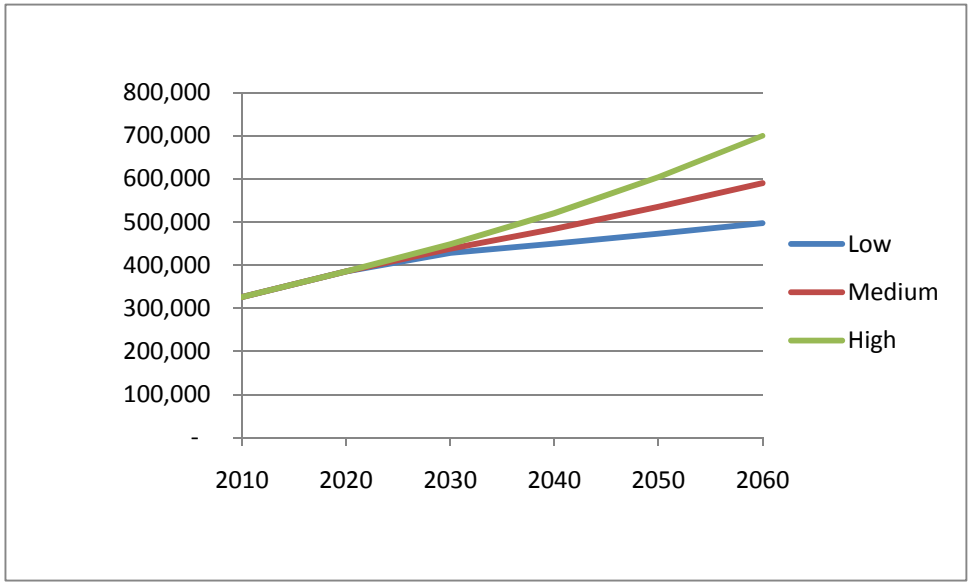

Figure 13. Population Forecasts to 2060 for the Study Area (Low, Medium and High)

6.3 Current Water Use Estimates – Municipal Systems and Individual Domestic Wells

Water Use in Largest Cities

Water use data were gathered from the eight public water systems that serve the six largest cities in the Basin. These data were used to estimate per-capita water use for municipal and domestic purposes. The per-capita use estimates and population data discussed above were then combined to estimate water use for smaller public water systems and for residents using domestic wells. Table 33 shows municipal use for the Basin's eight large water systems in 2008, which includes all domestic, irrigation, commercial, industrial and government uses.

Table 33. 2008 Municipal Use – Eight Large Water Systems

Municipal- Eight Large Water Systems - Potable [1]	Million Gallons per Year	Acre-Feet per Year
City of Yakima Water Division	4,649	14,269
Ellensburg	1,545	4,742
Nob Hill Water Association	1,388	4,261
Sunnyside	889	2,728
Prosser	842	2,586
Grandview	623	1,912
Toppenish	607	1,863
Yakima County- Terrace Heights	296	909
Subtotal	**10,840**	**33,269**
Municipal- City of Yakima Irrigation Systems [2]		
City of Yakima- General Irrigation System	1,458	4,475
Fruitvale Irrigation System (50% used by City residents)	1,490	4,571
Subtotal	**2,948**	**9,046**
Total	**13,787**	**42,315**

[1] 2008 numbers from annual water use reports submitted to DOH and/or responses to HDR survey.

[2] Data reported by City of Yakima Water and Irrigation Department, in response to HDR survey.

Irrigation water use in the City of Yakima is largely accounted for by including the City's General Irrigation and Fruitvale Irrigation systems (some smaller systems are not accounted for directly). The City of Ellensburg serves irrigation needs within its service area with potable water, which is included in the calculations. Some residents in the remaining cities listed in Table 33 receive outdoor irrigation water from irrigation districts, which is not included in this table but in the diversion data compiled for irrigation districts in the discussion of agricultural water needs above.

Per-capita Water Use

Figure 14 shows average daily per-capita (per person) water use for Yakima River Basin municipal and domestic uses. These estimates are based on data from communities where the total quantity of indoor and outdoor (irrigation) use could be estimated. These estimates were then compared with estimates for the Yakima River Basin from two other studies: the 2001 Yakima River Basin Watershed Assessment (TCWRA, 2001) and the USGS Groundwater Study, report on estimated groundwater pumpage (USGS, 2009).

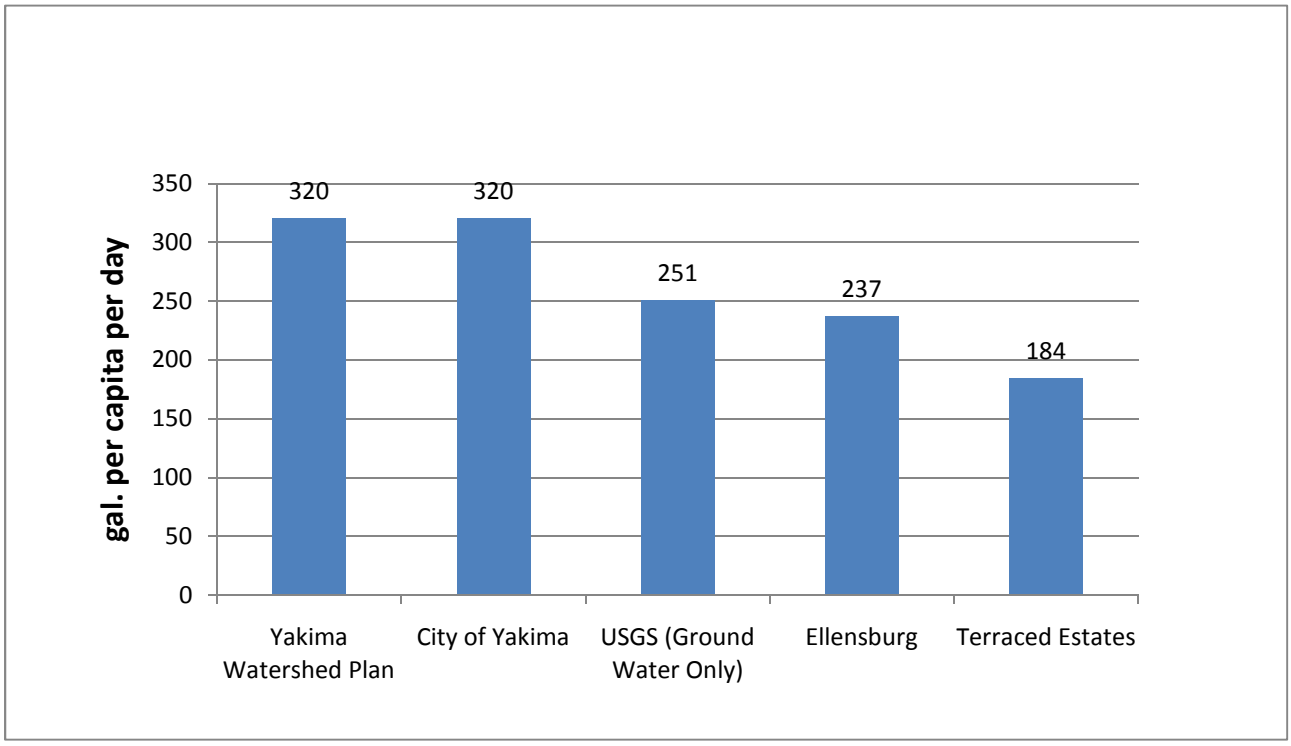

Figure 14. Estimates of Average, Daily Per-capita Water Use for Yakima River Basin Municipal and Domestic Supplies

For comparison, Table 34 shows representative estimates of average, daily per-capita water use from other communities in the inland Northwest and from California.

Table 34. Estimates of Average, Daily Per-capita Water Use from Other Locations

Northwest[1]		California[2]	
Moscow	159	Los Angeles	142
Cheney	206	San Diego	157
Bend	267	Bakersfield	279
Spokane	271	Sacramento	279
Walla Walla	300	Fresno	354

Values in gallons per capita per day.

[1] Sources: Moscow, Cheney and Bend water master plans; and data reported to DOH for Spokane and Walla Walla.

[2] Source: California Water Plan, Update 2009 (California DWR Bulletin 160-09).

Based on the estimates of per-capita water use shown here, the HDR Team selected a value of 250 gallons per capita per day (gpcd) for estimating water uses of smaller water systems and domestic wells in the Yakima River Basin. This value is intended to represent all municipal and domestic uses, including both indoor uses and outdoor irrigation by residents and businesses.

Further discussion on application of this estimate is provided in Section 6.1 of this Technical Memorandum.

The water usage rate of 250 gpcd includes all water diverted or pumped to serve municipal and domestic uses. This value is affected by the type of water delivery systems existing in the Yakima River Basin. Many residents in the middle and lower part of the basin receive water from irrigation districts for their outdoor landscape irrigation. In these areas the delivery system often includes open canals, which are inherently less efficient than piped systems. For example this can be seen in Figure 14 by comparing the water use in the City of Yakima (where open canal systems serve a large area of the city) compared with the City of Ellensburg (where all municipal use is served by a piped system). Since the water use rate includes the total water diverted, it includes water that leaks from canal beds and returns to the Yakima River, and water that returns to the river through canals or irrigation system drains. In addition, many residents living within irrigation districts have multi-acre properties that include small pastures, small orchards, livestock, or other quasi-agricultural uses. These factors cause higher water usage per person in the Yakima River Basin, compared with cities where land uses are purely urban and all water is delivered through closed pipe systems.

Section 6.4 of this technical memorandum includes a projection of consumptive use in the Yakima River Basin by year 2060. Calculations in that section account for ongoing trends in technology and Washington State conservation requirements for municipal water systems. Water use in 2010 is based on an estimate of 250 gpcd. Water use by 2060 is reduced to 234 gpcd due to these factors. Additional water conservation actions are under consideration under the municipal water conservation element of the Integrated Plan, and these would further reduce per-capita water use.

Water Use by Smaller Water Systems and Domestic Wells

Table 35 shows water use estimates for smaller public water systems (other than the eight large systems discussed previously) and domestic wells in the Yakima River Basin. These estimates were developed by combining the per-capita use estimate with population estimates discussed in Section 6.2.

Table 35. Water Use Estimates – Small Systems and Domestic Wells

	Million Gallons per Year	Acre-Feet per Year
Smaller Municipal Systems [1]	4,873	14,955
Domestic Wells [2]	11,041	33,887

[1] Population from DOH records times Basin-wide estimate of per-capita water use.

[2] Estimated population times Basin-wide estimate of per-capita water use.

Total Basin-wide Municipal and Domestic Water Use

Figure 15 shows total current water use for municipal and domestic purposes, estimated to be 91,000 AFY. Although the usage data largely reflect conditions in 2008, this is used as the estimate for 2010 because there has been relatively little growth in the basin from 2008 to 2010.

Based on monthly production records provided by the larger systems contacted for this study, approximately 70 percent of municipal water use occurs during the irrigation season (April through September). It is assumed this percentage can be applied to domestic water use also. This assumption seems reasonable since a large percentage of residential use is for outdoor landscape irrigation. Using this percentage, it is estimated that 64,000 acre-feet are currently used during the irrigation season; and 27,000 acre feet during the non-irrigation season.

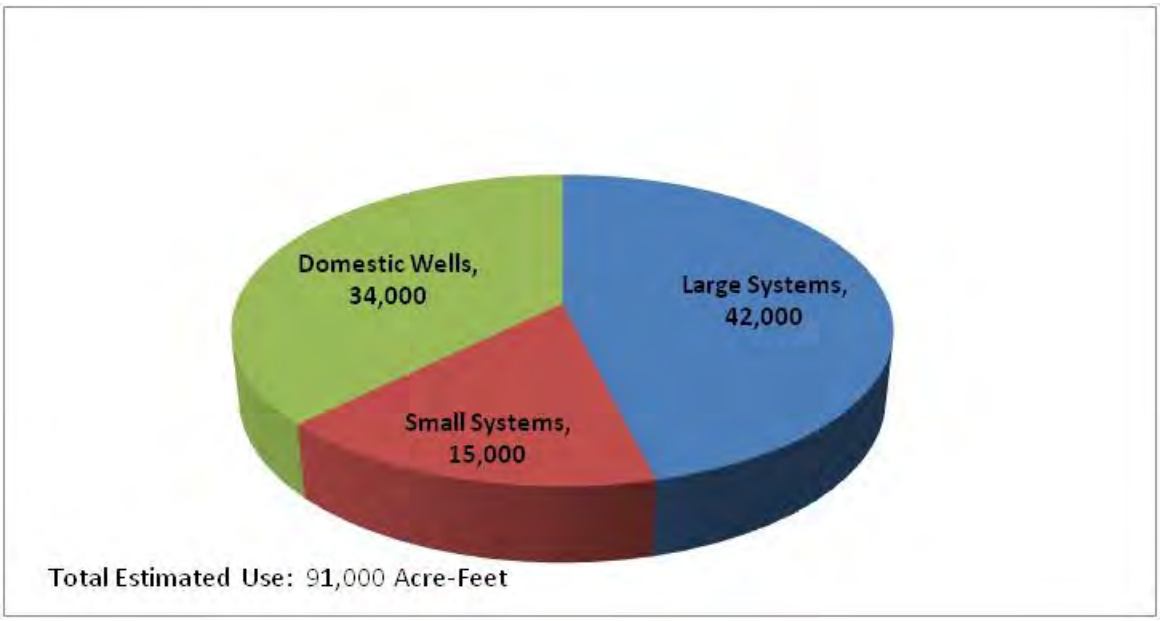

Figure 15. Estimate of Current Municipal and Domestic Water Uses in Yakima River Basin

The estimate of 91,000 acre-feet per year represents municipal and domestic water uses that are currently active in the Basin and use existing water supply sources. For the City of Yakima and much of the outdoor irrigation use in the Basin, these needs are met largely with surface water drawn from the Yakima River and its tributaries. Other public water systems and domestic well owners rely on groundwater to meet their needs.

Comments received from the Water Needs Subcommittee of the YRBWEP Workgroup indicate that water uses relying on post-1905 water rights may be at risk during severe droughts or if climate change reduces supplies in the Yakima River Basin. During the 2005 drought, water rights of domestic well owners were indeed challenged by entities having senior rights to surface-water supplies in the Basin. This issue is not examined in detail as part of this water

needs assessment but is identified here as a point for Workgroup consideration as the Integrated Plan is developed.

6.4 Future Water Need Forecast – Municipal and Individual Domestic Wells

Population growth is typically the primary driver of future change in municipal water needs in Washington State. This applies to the Yakima River Basin, as population has grown steadily for the past 40 years, including the past decade. All three counties in the study area forecast continued growth in their comprehensive plans.

Population growth may affect water needs differently, depending on characteristics such as the presence or absence of businesses and industries, household income levels, lot sizes and distribution system characteristics. However, this assessment of water needs is designed to apply to the Yakima River Basin as a whole, and localized differences have not been assessed.

Method for Forecasting Future Municipal and Domestic Needs

The following procedure was used to estimate future change in municipal water needs:

1. Start with estimates of current population and current water use per capita in the municipal sector, based on the estimate of current needs described in Section 6.3.
2. Obtain forecasts of population growth from the three counties (these extend to 2025 or 2030, depending on the county). The team contacted county planning departments to identify reasonable growth rates for extrapolation to 2060.
3. Project future water usage by applying the same percentage growth rates as indicated by the population forecasts.
4. Adjust future water usage for 2030 and 2060 based on:
    - Expected water conservation savings. A model of municipal water conservation potential developed by HDR was used to estimate the potential range of water savings from conservation, plumbing code requirements and broad trends in water-use efficiency. Water savings were estimated under a separate task of the Basin Study, and methods and results are documented in a separate Technical Memorandum, *Potential Water Savings from Municipal and Domestic Conservation* (Draft), July 6, 2010. These savings are expected from existing trends and state law, and do not include additional water savings under consideration as part of the municipal water conservation element of the Integrated Plan.
    - Effect of urban conversion. Land that is irrigated for agriculture typically uses more water per acre than urban land. Therefore, as population growth occurs and land is converted from agricultural use to urban use, water use can be reduced. The size of this effect is estimated, and it is applied as an adjustment to the projected increase in municipal and domestic water use.
    - Effect of climate change. Climate change is expected to increase temperature and change precipitation patterns in the Yakima River Basin. The effect of climate

change on outdoor, consumptive use is estimated, and will be used in the RiverWare modeling conducted for the Basin Study. Consistent with other aspects of the modeling, this effect is estimated for the 2040's.

Forecasts prepared independently by the Basin's eight large municipal water systems were also reviewed during this process (see Section 6.1). Assumptions, definitions and forecasting methods differ substantially from one municipal system to another. Therefore HDR used a consistent methodology basin-wide to allows key data and assumptions to be readily identified and discussed at the basin-wide scale.

The methodology applied to forecasting changes in use by individual domestic wells was the same as for municipal needs small water systems. A standard factor for water use per capita was multiplied by the number of new people expected to be served as growth occurs. The resulting quantity of water use estimated solely based on population growth was then adjusted for water conservation and climate change effects.

Forecast Results for Municipal and Domestic Needs

Table 36 and Figure 16 show the projected long-term increase in water needs for municipal uses and domestic wells in the Yakima River Basin, based on growth rates from the population analysis. The forecasts are based on projecting current per-capita water use into the future, which provides a "baseline" for considering future needs. The forecasts include all water pumped and diverted for municipal and domestic purposes (i.e. consumptive and non-consumptive use combined). It is important to recognize that much of this water returns to the Yakima River through wastewater systems, septic systems, and irrigation return flow.

Table 36. Growth-Adjusted Increase in Municipal and Domestic Needs - 2010 to 2060 (acre-feet per year)

	2010	2020	2030	2040	2050	2060	Increase from 2010 to 2060
Low	90,000	104,000	118,000	124,000	130,000	137,000	46,000
Medium	91,000	106,000	121,000	134,000	148,000	163,000	72,000
High	90,000	107,000	124,000	144,000	167,000	193,000	102,000

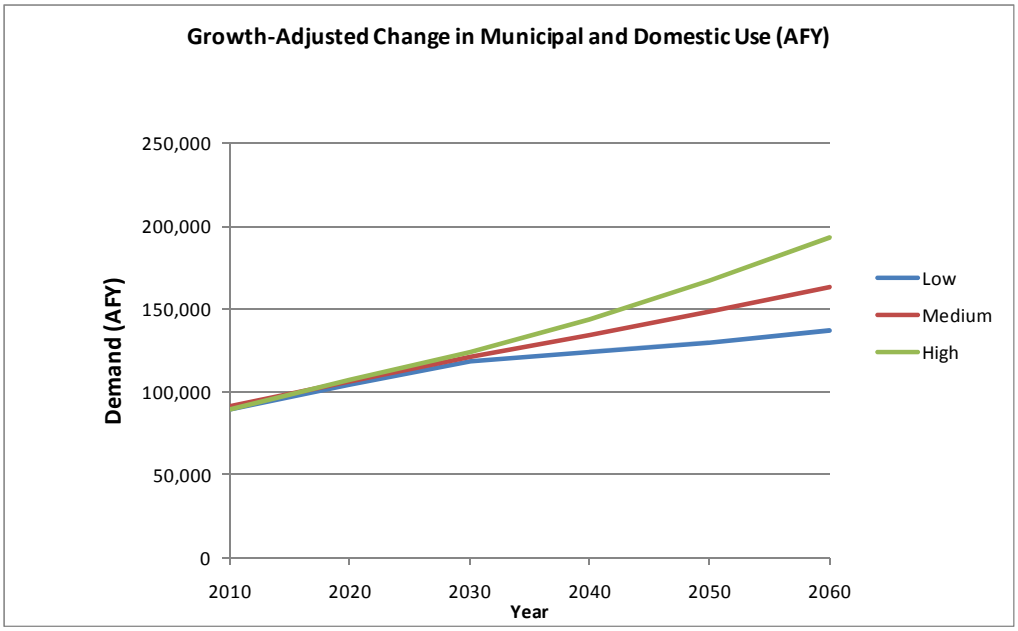

Figure 16. Growth-Adjusted Increase in Municipal and Domestic Needs – 2010 to 2060 (acre-feet per year)

Table 37 shows the medium forecast broken down by category of use.

Table 37. Medium Forecast of Municipal and Domestic Needs by Category of Use – 2010 to 2060 (acre-feet per year)

	2010	2030	2060	Increase from 2010 to 2060
Large Systems	42,000	56,000	76,000	34,000
Small Systems	15,000	20,000	27,000	12,000
Domestic Wells	34,000	45,000	60,000	26,000
Total	91,000	121,000	163,000	**72,000**

Based on growth rates only. Does not consider water conservation, offsets due to agricultural land conversion, climate change or other factors.

Using the medium forecast of future water needs, Table 38 identifies additional considerations that come into play in determining how much additional water supply may be needed. The net consumptive use of 19,560 acre-feet per year is used as a key result in the Integrated Plan.

Table 38. Consumptive Use Breakdown of Municipal and Domestic Needs – Using Medium Forecast (acre-feet per year)

	2010	2030	2060	Increase from 2010 to 2060
Growth-Based Demand	91,000	121,000	163,000	72,000
Less Conservation Trends (No-Action)[1]	0	4,000	8,200	
Less Land Conversion Effect [2]	0	7,500	14,900	
Adjusted Demand	**91,000**	**109,500**	**139,900**	**48,900**
Less Return Flow (estimated)[3]	54,600	65,700	83,940	
Net Consumptive Use	**36,400**	**43,800**	**55,960**	**19,560**
Less Off-Season Consumptive Use [4]	10,920	13,140	16,788	
Irrigation Season Consumptive use	**25,480**	**30,660**	**39,172**	**13,692**
Quantity Below Parker [5]				4,016
Quantity Above Parker [5]				9,676
(Irrigation season consumptive use can be reduced further with conservation actions)				

[1] From municipal/domestic conservation analysis (Task 4.11). This step accounts for current trends and existing state law, but does not include expanded water conservation actions that could be incorporated in the Integrated Plan.

[2] See assessment of land conversion from agricultural use to urban use.

[3] Return flow estimated at 60% based on a standard engineering handbook: *Wastewater Engineering, 4th Ed.*, Metcalf & Eddy, 2003. They report a range from 60% to 90%, with the lower end of the range applicable to hot, arid areas of the southwestern United States.

[4] Calculated from monthly production records provided by Yakima, Ellensburg, Nob Hill, Prosser and Toppenish.

[5] Based on current water use estimates broken down by county and by water system (assumed 1/3 of the Yakima Co. population served by small systems and domestic wells is below Parker; and 2/3 above Parker, based roughly on the distribution of urban centers).

Factors considered in Table 38 include:

- Conservation trends. Task 4.11 of the Yakima River Basin Study analyzes potential water savings from conservation in the municipal and domestic sectors. Even without action under the Integrated Plan, municipal water suppliers are required to adopt water conservation goals and implement programs to meet those goals. Water-using equipment such as washing machines, toilets and showers have become more efficient in recent years, and it is expected that more consumers will acquire efficient equipment between now and 2060. An estimate of water conservation savings under the "No-Action" scenario is included in Table 38 to account for these trends. This adjustment reduces water use per capita from 250 gpcd in 2010 to 234 gpcd by 2060.
- Land conversion. Growth in the municipal and domestic sectors will occur, in part, on land that is currently used for irrigated agriculture. As land is converted from irrigated agriculture to urban use, demand decreases. This topic is discussed further in Section 6.5 of this Technical Memorandum.
- Return flow. Much of the water used for urban and residential purposes is quickly returned to the Yakima River or shallow groundwater systems via septic systems, wastewater treatment plants, runoff and seepage. In the Yakima River Basin these return flows typically occur close to where water was diverted or pumped.
- Seasonality. Water uses in the Yakima River Basin are highly constrained in the irrigation season, but much less so during the non-irrigation season. It is important to

understand the seasonal difference in demand. Based on monthly production records obtained from the large public water systems, approximately 70% of water use occurs during the irrigation season (April through September). For year 2060, this means 114,000 AF would be used during the irrigation season, and 49,000 AF during the non-irrigation season.

- Location. Because of the way the Yakima Project is managed, the Parker gage is a key control point. Much of the return flow from uses above Parker is available for use below Parker. Therefore in Table 38 the consumptive use during the irrigation season is broken down further by location.

One other factor is not shown in Table 38: the amount of developed supply or water rights that public water systems have available now, to meet growing needs. Several of the large systems contacted for this study indicated they have sufficient production capacity or water rights to meet their needs for the next 10 to 20 years. Members of the YRBWEP Workgroup have pointed out that those supplies may not be fully secure from legal challenges, and even if they are, they represent additional depletion of surface or groundwater that has not been accounted for elsewhere. Therefore no adjustment is made in Table 38 for this factor.

6.5 Land Conversion

The growth in municipal and domestic water usage is driven primarily by population growth in the Basin. As growth occurs, some land that is irrigated for agricultural purposes today will be developed for urban or residential purposes which change water demand patterns. Appendix D provides results of an analysis of land conversion.

Washington State's Growth Management Act provides a framework for directing growth to "Urban Growth Areas" (UGAs). Counties and cities in the Yakima River Basin have worked together since the 1990's to define UGAs, which are located primarily around incorporated cities. While not all growth will occur within UGAs, much of it will.

A total of 21,000 acres of irrigated farmland is currently located within urban growth boundaries (UGB's) in the Basin, including both the current city land areas and the UGAs where cities will expand. This acreage was identified using the WSDA cropland geodatabase. Based on a comparison of available land within UGB's and the population growth forecasts presented in this report, it is unlikely that all of this land will actually be developed within the 50-year planning period. It was assumed that one-third of the land would be developed by 2030 and two-thirds by 2060. This assumption is very coarse, but substantial investigation would be needed to refine how the pace of development will occur specifically on irrigated farmland.

Two methods were used to assess water use per acre after land is converted to urban use. One method assumed all of this land would be converted to residential housing at an average density of four homes per acre. This density is based on communication with several cities and towns within the Yakima River Basin, with reference to their comprehensive land use plans. The other method used water use per acre in urban areas, estimated by dividing total water use in the water service areas of the cities of Yakima and Ellensburg, by total acreage currently served by those systems. These two methods yielded a range of estimates for water use per acre of 1.65 to 3.15 acre-feet per acre. Current water use for agricultural purposes on the same land was calculated

to be 4.0 acre-feet per acre on average for the 21,000 acres. Thus the reduction in water use, based on these two methods, ranges from 0.85 to 2.35 acre feet per acre.

Several irrigation district managers were contacted regarding how changes in land use affect water usage from irrigation supplies. They reported based on operational experience in delivering water that in areas where residential development is at lower densities (e.g. 0.2 to 0.5 homes per acre), homeowners often use at least as much water as adjacent farmland in the same irrigation district. In other words, the change due to land conversion in those areas may be zero (Van Gundy, Dieker, Trull, personal communications 2010).

In order to reconcile these different results, the following procedure was applied. It was assumed that one third of the land converting would be at low densities and would experience no change in water usage. For the remaining land it was assumed that conversion from farm land to urban use would reduce water usage from a current average of 4 acre-feet per acre down to a new amount of 2.4 acre feet per acre. This is based on the average reduction from the two methods described above.

Table 39 summarizes the estimated effect of land conversion on water needs. It is estimated that water needed on the 21,000 acres inside urban growth boundaries will be reduced by 7,500 acre-feet per year by 2030; and by 14,900 acre-feet per year by 2060. This will partially offset the increased water needed for growth in municipal and domestic uses.

The numbers presented in Table 39 are subject to considerable uncertainty. Estimated acreage of irrigated farm land inside the UGBs came from Washington State Department of Agriculture Database that required adjustments by the analyst to address certain missing land (15% adjustment). Estimates of how much land will be converted by 2030 and 2060 are essentially educated guesses, developed by comparing available land at planned densities with the rate of population growth. The change in water use is also an estimate and the wide range provides an indication of uncertainty in this value. More extensive analysis beyond the scope of this study would be required to address these sources of uncertainty.

Table 39. Estimated Effect of Land Conversion on Water Needs

	Farm Land Inside Urban Growth Boundaries (acres)	Land Converted for Urban Uses (acres)	Water Used for Farm Irrigation [3] (acre-feet per year)	Water Used for New Developments at 4 AF/ac [4] (acre-feet per year)	Water Used for New Developments at 2.4 AF/ac [5] (acre-feet per year)	Total Water Need on This Land (acre-feet per year)
Current Usage	21,000	0	84,000	0	0	**84,000**
2030 Forecast Usage [1]	14,000	7,000	56,000	9,300	11,200	**76,500**
Reduction from 2010 to 2030						7,500
2060 Conditions [2]	7,000	14,000	28,000	18,700	22,400	**69,100**
Reduction from 2010 to 2060						14,900

[1] Assumed one-third of acreage is converted by 2030.

[2] Assumes two thirds of acreage is converted by 2060.

[3] Using 4.0 acre-feet per acre, from analysis of agricultural land.

[4] Using 4.0 acre feet per acre, assuming one-third of converted land experiences no change in water use.

[5] Using 2.4 acre-feet per acre, based on average results from two separate methods documented in text. This is applied to two-thirds of the converted land.

6.6 Climate Change Effects

Section 5.5 of this technical memorandum summarized how climate change effects on water needs were estimated for agricultural irrigation. The method and results are presented in Appendix C. Results from that analysis were also applied to municipal and domestic uses. It was assumed that climate change would affect only outdoor irrigation usage and that this is approximately represented by the consumptive use from Table 38.

Table 38 provides an estimate of consumptive use at different forecast periods. Interpolating between years 2030 and 2060 gives a value of approximately 48,000 acre feet in consumptive use at year 2040. Based on results presented in Section 5.5, it was estimated that consumptive use for the short grass reference crop would increase by five percent due to climate change by year 2040. Applying a five percent increase to the municipal and domestic consumptive use at 2040 yields approximately 2,400 acre feet in increased need due to climate change.

This increase will be input to the RiverWare model climate change runs, to evaluate how the Integrated Plan performs with climate change.

7.0 Other Water Uses

Table 40 shows estimates of other water uses in the Yakima River Basin that are relatively small compared with total water use in the Basin. There is some potential for growth in these uses; however the Water Needs Subcommittee of the YRBWEP Workgroup determined detailed

information on trends in these uses was not needed to make sound recommendations for water management actions in the Basin.

Table 40. Other Uses of Water in the Yakima River Basin

Use	Estimated Quantity (AFY)
Fish & Wildlife (groundwater) [1]	9,000
Commercial/Industrial (groundwater) [1]	7,000
Livestock (groundwater) [1]	7,000
Non-Community Public Water Systems [2]	3,000
Livestock (surface water)	Unknown

GW = Groundwater; SW = Surface Water

[1] Source: Estimates of Ground-Water Pumpage from the Yakima River Basin Aquifer System, Washington, 1960-2000 (USGS SIR 2005-5205, April 2009).

[2] Source: DOH records analyzed in Watershed Assessment, Yakima River Basin, Table 4-3 (Yakima River Basin Watershed Planning Unit and TCWRA, January 2001).

These uses are relatively small in the context of total water needs for the Yakima River Basin. While any of these needs could experience growth in future decades, detailed examination of trends does not appear warranted in order to permit sound recommendations for the water management actions under consideration by the YRBWEP Workgroup.

Water is also used in the Yakima River Basin for gravel mining adjacent to the Yakima River, fish and wildlife propagation, and hydropower incidental to irrigation canal systems. These uses are relatively small and have a very high proportion of return flow. Therefore they are not estimated separately.

8.0 Use of Assessment in Integrated Plan

This water needs assessment has been developed to provide basic information for use by the YRBWEP Workgroup as it reviews a range of water-resource management actions identified for consideration. This memorandum does not identify a specific "target" quantity of water for the Integrated Plan, pending further discussion by the Workgroup. However it does help identify the quantities of water needed in the Yakima River Basin for different purposes, both now and in the future.

9.0 References

1. Benton County, 2006, *Comprehensive Plan.*
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Appendix A

Yakima Project Irrigation Data

Appendix A

Yakima Project Irrigation Data

Appendix A provides additional details used for analyses completed in Sections 3.3 (Irrigated Acreage in the Yakima Project) and 3.4 (On-Farm Water Needs). A brief description of the additional tables follows.

Tables A-1 to A-6 contain crop acreage data from Washington State Department of Agriculture (WSDA) for each individual Yakima Project district sorted by crop type and irrigation type. These tables were used to populate Tables 4 and 6 in the main report.

Table A-7 lists the crop irrigation requirements (CIRs) for each crop and station used to determine the weighted average CIR for each district.

Tables A-8 to A-13 contain the CIRs (in acre-feet) for each district sorted by crop type and irrigation type. These tables were used to estimate the average CIR for each district which is reported in Table 9 in the main report.

Tables A-14 to A-19 contain the total on-farm water needs (in acre-feet) for each district sorted by crop type and irrigation type. These tables were used to estimate the application efficiency percentage for each district which is reported in Table 11 in the main report.

Tables A-20 to A-25 contain the return flow (in acre-feet) for each district sorted by crop type and irrigation type. These tables were used to estimate the return flow percentage for each district which is reported in Table 11 in the main report.

Tables A-26 to A-31 contain the estimated evaporation losses (in acre-feet) for each district sorted by crop type and irrigation type. These tables were used to determine the evaporation loss percentage for each district and reported in Table 11 in the main report.

Table A-1

Crop Acreage by Irrigation Type - KRD

Crop Type	Crop Group	Rill	Center Pivot	Wheel Line	Flood	None	Sprinkler	Drip	Big Gun	Unknown	Blank	Total
Timothy	Hay/Silage	15,303.4	2,047.0	1,814.9	24.7	517.5	183.5		8.4	8.9		19,908.4
Pasture	Non-Crop	4,572.4	463.0	399.5	2,967.3	34.5	186.4		10.3			8,633.3
Grass, Hay	Hay/Silage	1,727.9	264.0	324.0		306.8	9.8		37.0			2,669.5
Alfalfa, Hay	Hay/Silage	712.9	252.9	198.0			1.0					1,164.6
Wheat	Cereal Grain	821.0	183.4	115.5		3.4						1,123.3
Oat	Cereal Grain	767.0	182.1	120.9		2.0	40.2					1,112.2
Corn, Sweet	Vegetable	491.1	404.9			18.0						914.0
Sudangrass	Hay/Silage	552.3	66.2	55.9								674.5
Fallow	Other	211.2	169.4	56.2		98.1	4.0	6.0		41.6		586.5
Developed	Non-Crop	312.5		20.5		187.7	9.2				5.3	535.2
Apple	Orchard						265.2	93.7				358.9
Alfalfa/Grass, Hay	Hay/Silage	141.0		41.6		26.3	35.2					244.2
Barley	Cereal Grain	142.3		25.5		1.5	8.0					177.3
Pear	Orchard	1.3					34.8	76.9				113.0
Wildlife Feed	Non-Crop					92.1						92.1
CRP	Non-Crop					59.2						59.2
Potato	Vegetable	58.3										58.3
Cherry	Orchard						55.2					55.2
Golf Course	Other						50.6					50.6
Grape, Wine	Vineyard					2.7	0.9	5.8				9.3
Market Crops	Vegetable	2.7										2.7
Sunflower, Seed	Other		1.4									1.4
Onion	Vegetable						1.0					1.0
Blueberry	Other							0.5				0.5
Total		25,817.3	4,034.3	3,172.4	2,992.0	1,349.8	885.0	182.9	55.7	50.5	5.3	38,545.2

Note: Data from WSDA

Table A-2

Crop Acreage by Irrigation Type - Roza

Crop Type	Crop Group	Sprinkler	Drip	Rill	Center Pivot	Wheel Line	None	Unknown	Big Gun	Total
Apple	Orchard	17,289.3	1,440.9	146.1			133.7	9.3		19,019.3
Grape, Wine	Vineyard	1,743.2	7,690.7	19.1			1.3			9,454.4
Grape, Concord	Vineyard	6,118.5	972.3	2,295.8			24.0			9,410.5
Cherry	Orchard	4,011.7	110.4	19.1						4,141.3
Hops	Hops		2,700.8	88.6						2,789.5
Fallow	Other	1,028.2	28.6	275.8	397.3	224.9	145.2	215.2		2,315.3
Alfalfa, Hay	Hay/Silage	441.8		49.9	100.6	1,675.2				2,267.5
Pear	Orchard	1,943.5	24.6				30.4			1,998.6
Corn, Field	Cereal Grain			528.5	1,143.6	100.5				1,772.6
Wheat	Cereal Grain	113.1		98.2	502.6	271.1	178.8	65.3		1,229.1
Sorghum	Hay/Silage	18.3		3.7	781.7	127.6		8.7	191.4	1,131.5
Nectarine/Peach	Orchard	567.1	5.3				16.8			589.2
Triticale	Cereal Grain				487.2	93.6			2.7	583.5
Asparagus	Vegetable	211.8		288.7						500.5
Research Station	Other		285.8			28.1	8.3			322.2
Apricot	Orchard	163.7	36.5	6.9			35.5			242.5
Alfalfa/Grass, Hay	Hay/Silage	105.0			36.3	101.2				242.4
Green Manure	Other	22.4		45.5		18.1		137.8		223.7
Caneberry	Other		185.0							185.0
Nursery, Orchard/Vineyard	Other	83.2		50.6		8.0				141.8
Corn, Sweet	Vegetable			136.0						136.0
Rye	Cereal Grain				37.2	96.4				133.6
CRP	Non-Crop						116.2			116.2
Unknown	Other							110.3		110.3
Mint	Mint			43.6		64.5				108.1
Squash	Vegetable		91.3							91.3
Grass, Hay	Hay/Silage	9.8				63.9		12.5		86.2
Nursery, Ornamental	Other	82.2								82.2
Corn, Seed	Other			4.3	70.1					74.4
Currant	Other			69.1						69.1
Pumpkin	Vegetable		67.9							67.9
Developed	Non-Crop	44.6					14.7			59.2
Blueberry	Other	1.0	56.6							57.7
Potato	Vegetable			56.9						56.9
Pasture	Non-Crop	32.4				16.2				48.5
Tomato	Vegetable			46.5						46.5
Plum	Orchard	42.9								42.9
Herb, Medicinal	Other				40.4					40.4
Barley	Cereal Grain	30.4								30.4
Hay/Silage, Unknown	Hay/Silage							11.0		11.0
Market Crops	Vegetable			7.2						7.2
Total		34,103.9	13,696.7	4,280.0	3,597.2	2,889.2	705.0	569.9	194.1	60,036.0

Note: Data from WSDA

Table A-3

Crop Acreage by Irrigation Type - WIP

Crop Type	Crop Group	Rill	Wheel Line	Sprinkler	Drip	Center Pivot	None	Unknown	Big Gun	Total
Corn, Field	Cereal Grain	14,795.8	235.6	103.0		3,666.9	133.0		80.1	19,014.3
Wheat	Cereal Grain	6,209.0	4,412.0	214.3		2,196.7	195.0			13,227.0
Hops	Hops	1,593.6	73.3	41.4	11,060.4		32.8	37.4		12,838.9
Alfalfa, Hay	Hay/Silage	902.9	6,143.7	287.7		3,460.7	21.0			10,816.0
Apple	Orchard	461.1	36.9	8,056.7	23.6	124.9	141.9	10.6		8,855.7
Mint	Mint	4,984.2	2,529.2	206.0		115.4		27.5		7,862.3
Grape, Concord	Vineyard	2,997.8		847.2	264.3		24.7	23.2		4,157.2
Fallow	Other	547.6	340.5	549.7	117.1	29.2	832.2	61.7		2,478.1
Alfalfa/Grass, Hay	Hay/Silage	298.7	969.4	184.7		45.0	142.6	20.1		1,660.5
Pasture	Non-Crop	609.3	520.2	409.0		91.5			5.2	1,635.1
Asparagus	Vegetable	1,207.1	117.5			202.8				1,527.5
Grass, Hay	Hay/Silage	237.5	645.2	191.1		82.0	261.0			1,416.7
Nectarine/Peach	Orchard			1,000.5						1,000.5
Potato	Vegetable	832.8	97.5		37.8					968.2
Pear	Orchard	145.9		773.6						919.6
Corn, Sweet	Vegetable	345.9	146.3		268.3					760.4
Onion	Vegetable	58.2	89.9		536.3					684.4
Market Crops	Vegetable	183.9	202.9	6.3	222.5		28.8			644.4
Cherry	Orchard	15.2		602.9	1.9					620.0
Bean, Dry	Vegetable	124.5	279.7			131.5				535.7
Sorghum	Hay/Silage	37.0	370.6	14.7						422.3
Pepper	Vegetable	34.9	17.1	1.1	276.8					329.8
Unknown	Other					113.4	51.0	112.9		277.3
Nursery, Orchard/Vineyard	Other	103.8			111.7					215.5
Developed	Non-Crop	22.4	35.9	86.3			40.4			185.0
Squash	Vegetable	55.8	33.7		85.5					175.0
Corn, Seed	Other	173.2								173.2
Dill	Other		140.7							140.7
Oat	Cereal Grain	39.2	91.3							130.5
Nursery, Ornamental	Other			77.0	38.2					115.2
Timothy	Hay/Silage		105.5							105.5
Golf Course	Other			88.7						88.7
Bluegrass, Seed	Other		75.4							75.4
Plum	Orchard	31.5		41.4						72.9
Apricot	Orchard			66.6						66.6
Cucumber	Vegetable		23.6		36.6					60.2
Carrot, Seed	Other	26.5	32.2							58.7
Clover, Seed	Other		57.7							57.7
Tomato	Vegetable	2.8			53.5					56.3
Cabbage	Vegetable	40.2	4.0							44.2
Pumpkin	Vegetable	16.4			27.0					43.3
Canola	Other					36.1				36.1
Broccoli, Seed	Other					35.8				35.8
Vegetable, Unknown	Vegetable	32.5								32.5
Bean, Green	Vegetable	12.2	12.3							24.6
Watermelon	Other				22.2					22.2
Sunflower, Seed	Other	21.7								21.7
Blueberry	Other			13.0						13.0
Sage	Other	10.9								10.9
Grape, Wine	Vineyard				9.7					9.7
Driving Range	Other			2.5						2.5
Alfalfa, Seed	Other		0.9							0.9
CRP	Non-Crop						0.5			0.5
Total		37,212.0	17,840.7	13,865.2	13,193.4	10,331.9	1,904.8	293.4	85.2	94,726.8

Note: Data from WSDA

Table A-4

Crop Acreage by Irrigation Type - SVID

Crop Type	Crop Group	Rill	Sprinkler	Wheel Line	Center Pivot	Drip	Unknown	None	Big Gun	Hand	Total
Grape, Concord	Vineyard	5,412.1	4,585.7			324.0	22.4	44.6			10,388.7
Corn, Field	Cereal Grain	5,964.2	147.2	98.9	2,880.3		73.9	141.0	92.8		9,398.5
Alfalfa, Hay	Hay/Silage	764.8	1,262.4	2,965.2	1,084.5		4.4				6,081.3
Hops	Hops	1,495.8	20.3			3,936.1					5,452.2
Cherry	Orchard	61.4	3,725.3			96.2		3.4			3,886.3
Apple	Orchard	25.1	3,261.8			57.4		3.2			3,347.5
Fallow	Other	302.0	464.9	298.4	150.8		357.9	22.9			1,596.8
Wheat	Cereal Grain	281.1	19.9	656.0	429.1		53.1				1,439.1
Asparagus	Vegetable	1,188.7	66.6	58.2			9.1	1.4			1,323.9
Alfalfa/Grass, Hay	Hay/Silage	24.5	180.4	823.3	158.1						1,186.4
Grape, Wine	Vineyard	1.0	314.4			676.3		16.9			1,008.5
Mint	Mint	550.4	68.4	243.0			19.3	6.1			887.2
Sorghum	Hay/Silage	18.4	3.8	380.8	283.3						686.3
Triticale	Cereal Grain	197.8	29.3	205.9	210.5		11.9	24.6			679.9
Grass, Hay	Hay/Silage	61.5	245.2	335.9			21.6		0.0		664.3
Pear	Orchard	51.5	571.3								622.9
Pasture	Non-Crop	22.0	112.3	252.0	181.6						568.0
Nursery, Ornamental	Other	83.9	172.3			85.0	14.4			4.0	359.5
Squash	Vegetable	177.0									177.0
Oat	Cereal Grain	17.8		78.5	66.2						162.4
Research Station	Other		147.9								147.9
Plum	Orchard	17.9	114.2			1.6		13.4			147.0
Golf Course	Other		126.0								126.0
Barley	Cereal Grain	20.8	49.3	31.0							101.1
Corn, Seed	Other	98.1	2.2								100.2
Rye	Cereal Grain		6.3	38.9	37.1			0.9			83.1
Nectarine/Peach	Orchard	12.1	69.6								81.7
Watermelon	Other					75.4					75.4
Market Crops	Vegetable	46.8	13.5				3.9	7.5			71.6
Canola	Other			67.5							67.5
Caneberry	Other					65.4					65.4
Poplar, Hybrid	Other					5.7	43.4				49.0
Green Manure	Other		29.3								29.3
Bulb, Iris	Other	21.8	4.7								26.5
Nursery, Silvaculture	Other		20.4			5.5					25.9
Apricot	Orchard		22.2								22.2
Nursery, Orchard/Vineyard	Other		20.6								20.6
Pumpkin	Vegetable	18.6	1.3								19.9
Corn, Sweet	Vegetable	5.0	5.3				8.8				19.2
Developed	Non-Crop		12.2				6.3				18.6
Carrot, Seed	Other	13.2									13.2
Walnut	Orchard		11.0								11.0
Currant	Other		8.6								8.6
Christmas Tree	Other		5.1								5.1
Bulb, Allium	Other	4.4									4.4
Driving Range	Other		4.3								4.3
Sunflower, Seed	Other		3.9								3.9
Unknown	Other						3.6				3.6
Orchard, Unknown	Orchard						1.4				1.4
Total		16,959.5	15,929.1	6,533.3	5,481.6	5,328.5	655.3	285.8	92.9	4.0	51,270.1

Note: Data from WSDA

Table A-5

Crop Acreage by Irrigation Type - YTID

Crop Type	Crop Group	Sprinkler	Wheel Line	Drip	None	Rill	Unknown	Total
Apple	Orchard	12,481.4	20.7	323.1		199.4	142.9	13,167.5
Pear	Orchard	1,277.1				6.0	10.3	1,293.4
Cherry	Orchard	767.9						767.9
Alfalfa/Grass, Hay	Hay/Silage	281.0	351.0					632.0
Fallow	Other	324.0						324.0
Developed	Non-Crop				220.4			220.4
Grass, Hay	Hay/Silage	139.6	34.4					174.0
Golf Course	Other	152.8						152.8
Alfalfa, Hay	Hay/Silage	44.4	49.8					94.2
Sod Farm	Other	69.9						69.9
Caneberry	Other	16.9		24.3				41.3
Barley	Cereal Grain	16.0						16.0
Nectarine/Peach	Orchard	8.8						8.8
Orchard, Unknown	Orchard						8.1	8.1
Grape, Wine	Vineyard	0.6		6.2				6.8
Walnut	Orchard	2.8						2.8
Christmas Tree	Other	2.2						2.2
Blueberry	Other	1.5						1.5
Nursery, Lavender	Other			0.6				0.6
Total		15,587.1	455.8	354.1	220.4	205.4	161.3	16,984.1

Note: Data from WSDA

Table A-6

Crop Acreage by Irrigation Type - KID

Crop Type	Crop Group	Center Pivot	Sprinkler	Drip	None	Wheel Line	Rill	Unknown	Hand	Total
Grape, Wine	Vineyard		4.7	1,968.0						1,972.7
Apple	Orchard		1,074.0	110.8	124.4					1,309.2
Alfalfa, Hay	Hay/Silage	635.7	254.2			172.9	120.8			1,183.6
Wheat	Cereal Grain	675.8	87.1			77.3	58.3			898.6
Cherry	Orchard		589.3	19.0						608.2
Developed	Non-Crop	27.3	208.3		142.0			92.2		469.9
Fallow	Other	67.4	203.6		21.4	14.5		59.2		366.1
Asparagus	Vegetable	281.2								281.2
Alfalfa/Grass, Hay	Hay/Silage	169.0	69.5			33.0				271.6
Corn, Field	Cereal Grain	269.9								269.9
Potato	Vegetable	215.7								215.7
Corn, Sweet	Vegetable	199.0								199.0
Pasture	Non-Crop	142.5	8.6							151.0
Pumpkin	Vegetable	144.0								144.0
Golf Course	Other		134.1							134.1
CRP	Non-Crop				65.2					65.2
Pear	Orchard		64.8							64.8
Grass, Hay	Hay/Silage		25.7			21.2				46.9
Plum	Orchard		7.9							7.9
Nectarine/Peach	Orchard		6.1							6.1
Nursery, Ornamental	Other								1.9	1.9
Walnut	Orchard		1.7							1.7
Total		2,827.5	2,739.7	2,097.8	353.0	319.0	179.1	151.4	1.9	8,669.4

Note: Data from WSDA

Table A-7
Crop Irrigation Requirements for Crops and Stations

Crop Type	Crop Irrigation Requirement (ft)					WIG Crop Assumed
	Ellensburg	Sunnyside	Wapato	Yakima	Richland	
Blueberry						None
Caneberry	3.18	3.58	3.71	3.42	3.82	Raspberry
Currant	3.18	3.58	3.71	3.42	3.82	Raspberry
Barley	2.29	2.05	2.11	1.92	2.17	Spring Grain
Corn, Field	2.00	2.44	2.53	2.35	2.61	Field Corn
Oat	2.29	2.05	2.11	1.92	2.17	Spring Grain
Rye	2.29	2.05	2.11	1.92	2.17	Spring Grain
Triticale	2.29	2.05	2.11	1.92	2.17	Spring Grain
Wheat	2.19	2.03	2.09	1.89	2.16	Winter Wheat
Christmas Tree						None
Poplar, Hybrid						None
Bulb, Allium						None
Bulb, Iris						None
Green Manure	2.29	2.05	2.11	1.92	2.17	Spring Grain
Alfalfa, Hay	2.48	3.09	3.20	2.94	3.30	Alfalfa
Alfalfa/Grass, Hay	2.48	3.09	3.20	2.94	3.30	Alfalfa
Clover, Hay	2.76	3.43	3.56	3.27	3.66	Clover
Grass, Hay	2.76	3.43	3.56	3.27	3.66	Clover
Hay/Silage, Unknown	2.76	3.43	3.56	3.27	3.66	Clover
Sorghum	1.63	2.09	2.17	2.01	2.24	Sorghum
Sudangrass	2.76	3.43	3.56	3.27	3.66	Clover
Timothy	2.76	3.43	3.56	3.27	3.66	Clover
Herb, Medicinal						None
Sage						None
Hops	2.28	2.56	2.66	2.46	2.73	Hops
Watermelon	1.02	1.26	1.31	1.21	1.35	Estimated from Agrimet
Mint	2.54	3.00	3.11	2.86	3.21	Mint
Pasture	1.97	2.46	2.55	2.34	2.63	Estimated from Agrimet
Wildlife Feed	2.00	2.44	2.53	2.35	2.61	Field Corn
Nursery, Lavender						None
Nursery, Orchard/Vineyard						None
Nursery, Ornamental						None
Nursery, Silvaculture						None
Canola						None
Dill						None
Apple	3.18	3.70	3.84	3.54	3.95	Apple w/cover
Apricot	3.09	3.50	3.63	3.34	3.75	Apricot w/cover
Cherry	3.31	3.74	3.89	3.58	4.00	Cherry w/cover
Chestnut						None
Nectarine/Peach	3.06	3.48	3.61	3.32	3.72	Peach w/cover
Orchard, Unknown	3.18	3.70	3.84	3.54	3.95	Apple w/cover
Pear	3.00	3.42	3.56	3.27	3.66	Pear & Plum w/cover
Plum	3.00	3.42	3.56	3.27	3.66	Pear & Plum w/cover
Walnut						None
Research Station						None
Alfalfa, Seed						None
Bluegrass, Seed						None
Broccoli, Seed						None
Carrot, Seed						None
Clover, Seed						None
Corn, Seed						None
Sunflower, Seed						None
Driving Range	2.62	3.26	3.38	3.11	3.48	Turf
Golf Course	2.62	3.26	3.38	3.11	3.48	Turf
Sod Farm	2.62	3.26	3.38	3.11	3.48	Turf
Asparagus	2.01	2.50	2.59	2.38	2.67	Estimated from Agrimet
Bean, Dry	1.65	1.89	1.96	1.81	2.01	Dry Bean
Bean, Green	1.32	1.55	1.60	1.49	1.65	Green Bean
Cabbage						None
Corn, Sweet	1.67	1.75	1.82	1.69	1.86	Sweet Corn
Cucumber	1.39	1.83	1.89	1.75	1.96	Cucumber
Market Crops	1.84	2.29	2.38	2.21	2.45	Tomato
Onion	2.57	2.77	2.87	2.65	2.94	Dry Onion
Pepper						None
Potato	2.05	2.40	2.49	2.31	2.56	Potato
Pumpkin	1.25	1.49	1.54	1.44	1.59	Squash
Squash	1.25	1.49	1.54	1.44	1.59	Squash
Tomato	1.84	2.29	2.38	2.21	2.45	Tomato
Vegetable, Unknown	1.84	2.29	2.38	2.21	2.45	Tomato
Grape, Concord	1.92	2.28	2.37	2.18	2.44	Grapes
Grape, Wine	1.92	2.28	2.37	2.18	2.44	Grapes

Table A-8

Crop Irrigation Requirement - KRD (acre-feet)

Crop Type	Crop CIR	Rill	Center Pivot	Wheel Line	Flood	Sprinkler	Drip	Big Gun	Unknown	Total
Timothy	2.76	42,237.5	5,649.8	5,009.2	68.1	506.5	0.0	23.3	24.6	53,519.0
Pasture	1.97	9,007.7	912.1	787.0	5,845.6	367.3	0.0	20.2	0.0	16,939.8
Grass, Hay	2.76	4,768.9	728.7	894.2	0.0	27.0	0.0	102.1	0.0	6,521.1
Alfalfa, Hay	2.48	1,767.9	627.1	491.0	0.0	2.4	0.0	0.0	0.0	2,888.3
Wheat	2.19	1,797.9	401.6	253.0	0.0	0.0	0.0	0.0	0.0	2,452.5
Oat	2.29	1,756.4	417.0	276.9	0.0	92.2	0.0	0.0	0.0	2,542.4
Corn, Sweet	1.67	820.1	676.2	0.0	0.0	0.0	0.0	0.0	0.0	1,496.3
Sudangrass	2.76	1,524.4	182.8	154.4	0.0	0.0	0.0	0.0	0.0	1,861.6
Apple	3.18	0.0	0.0	0.0	0.0	843.4	297.8	0.0	0.0	1,141.2
Alfalfa/Grass, Hay	2.48	349.8	0.0	103.1	0.0	87.4	0.0	0.0	0.0	540.2
Barley	2.29	325.9	0.0	58.3	0.0	18.3	0.0	0.0	0.0	402.5
Pear	3.00	3.8	0.0	0.0	0.0	104.3	230.8	0.0	0.0	338.9
Potato	2.05	119.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	119.5
Cherry	3.31	0.0	0.0	0.0	0.0	182.6	0.0	0.0	0.0	182.6
Golf Course	2.62	0.0	0.0	0.0	0.0	132.6	0.0	0.0	0.0	132.6
Grape, Wine	1.92	0.0	0.0	0.0	0.0	1.6	11.1	0.0	0.0	12.7
Market Crops	1.84	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0
Sunflower, Seed	*2.50*	0.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	3.5
Onion	2.57	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	2.5
Blueberry	*2.50*	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	1.3
Total		64,484.7	9,598.8	8,027.1	5,913.7	2,368.2	541.0	145.6	24.6	91,103.6

Weighted Average CIR = 2.50 acre-feet/acre

Table A-9

Average Crop Irrigation Requirement - Roza (acre-feet)

Crop Type	Crop CIR	Sprinkler	Drip	Rill	Center Pivot	Wheel Line	Unknown	Big Gun	Total
Apple	3.70	63,970.5	5,331.2	540.6	0.0	0.0	34.3	0.0	69,876.7
Grape, Wine	2.28	3,974.4	17,534.9	43.6	0.0	0.0	0.0	0.0	21,553.0
Grape, Concord	2.28	13,950.1	2,216.8	5,234.3	0.0	0.0	0.0	0.0	21,401.3
Cherry	3.74	15,003.9	412.8	71.5	0.0	0.0	0.0	0.0	15,488.3
Hops	2.56	0.0	6,914.2	226.9	0.0	0.0	0.0	0.0	7,141.1
Alfalfa, Hay	3.09	1,365.1	0.0	154.1	311.0	5,176.4	0.0	0.0	7,006.7
Pear	3.42	6,646.7	84.3	0.0	0.0	0.0	0.0	0.0	6,730.9
Corn, Field	2.44	0.0	0.0	1,289.4	2,790.4	245.3	0.0	0.0	4,325.2
Wheat	2.03	229.6	0.0	199.3	1,020.4	550.3	132.5	0.0	2,132.0
Sorghum	2.09	38.3	0.0	7.7	1,633.9	266.7	18.2	400.1	2,364.8
Nectarine/Peach	3.48	1,973.5	18.3	0.0	0.0	0.0	0.0	0.0	1,991.8
Triticale	2.05	0.0	0.0	0.0	998.8	191.8	0.0	5.6	1,196.3
Asparagus	2.50	529.4	0.0	721.8	0.0	0.0	0.0	0.0	1,251.2
Research Station	*2.97*	0.0	848.7	0.0	0.0	83.4	0.0	0.0	932.1
Apricot	3.50	572.8	127.7	24.0	0.0	0.0	0.0	0.0	724.5
Alfalfa/Grass, Hay	3.09	324.3	0.0	0.0	112.1	312.7	0.0	0.0	749.1
Green Manure	2.05	45.9	0.0	93.2	0.0	37.0	282.4	0.0	458.5
Caneberry	3.58	0.0	662.2	0.0	0.0	0.0	0.0	0.0	662.2
Nursery, Orchard/Vineyard	*2.97*	247.0	0.0	150.4	0.0	23.7	0.0	0.0	421.1
Corn, Sweet	1.75	0.0	0.0	237.9	0.0	0.0	0.0	0.0	237.9
Rye	2.05	0.0	0.0	0.0	76.3	197.6	0.0	0.0	273.8
Unknown	*2.97*	0.0	0.0	0.0	0.0	0.0	327.4	0.0	327.4
Mint	3.00	0.0	0.0	130.8	0.0	193.5	0.0	0.0	324.4
Squash	1.49	0.0	136.1	0.0	0.0	0.0	0.0	0.0	136.1
Grass, Hay	3.43	33.7	0.0	0.0	0.0	219.3	42.8	0.0	295.7
Nursery, Ornamental	*2.97*	244.0	0.0	0.0	0.0	0.0	0.0	0.0	244.0
Corn, Seed	*2.97*	0.0	0.0	12.8	208.2	0.0	0.0	0.0	220.9
Currant	*2.97*	0.0	0.0	205.3	0.0	0.0	0.0	0.0	205.3
Pumpkin	1.49	0.0	101.1	0.0	0.0	0.0	0.0	0.0	101.1
Blueberry	*2.97*	3.1	168.2	0.0	0.0	0.0	0.0	0.0	171.3
Potato	2.40	0.0	0.0	136.6	0.0	0.0	0.0	0.0	136.6
Pasture	2.46	79.6	0.0	0.0	0.0	39.7	0.0	0.0	119.4
Tomato	2.29	0.0	0.0	106.4	0.0	0.0	0.0	0.0	106.4
Plum	3.42	146.6	0.0	0.0	0.0	0.0	0.0	0.0	146.6
Herb, Medicinal	*2.97*	0.0	0.0	0.0	120.1	0.0	0.0	0.0	120.1
Barley	2.05	62.2	0.0	0.0	0.0	0.0	0.0	0.0	62.2
Hay/Silage, Unknown	3.43	0.0	0.0	0.0	0.0	0.0	37.7	0.0	37.7
Market Crops	2.29	0.0	0.0	16.4	0.0	0.0	0.0	0.0	16.4
Total		109,440.8	34,556.6	9,603.3	7,271.2	7,537.4	875.3	405.7	169,690.3

Weighted Average CIR = 2.97 acre-feet/acre

Table A-10

Average Crop Irrigation Requirement - WIP (acre-feet)

Crop Type	Crop CIR	Rill	Wheel Line	Sprinkler	Drip	Center Pivot	Unknown	Big Gun	Total
Corn, Field	2.53	37,433.4	596.0	260.6	0.0	9,277.2	0.0	202.5	47,769.7
Wheat	2.09	12,976.9	9,221.1	448.0	0.0	4,591.1	0.0	0.0	27,237.0
Hops	2.66	4,239.0	195.0	110.1	29,420.5	0.0	99.6	0.0	34,064.2
Alfalfa, Hay	3.20	2,889.4	19,659.8	920.6	0.0	11,074.3	0.0	0.0	34,543.9
Apple	3.84	1,770.4	141.7	30,937.7	90.6	479.6	40.7	0.0	33,460.7
Mint	3.11	15,500.7	7,865.9	640.7	0.0	359.0	85.4	0.0	24,451.7
Grape, Concord	2.37	7,104.8	0.0	2,007.9	626.4	0.0	55.0	0.0	9,794.2
Alfalfa/Grass, Hay	3.20	955.8	3,102.1	591.0	0.0	144.0	64.4	0.0	4,857.3
Pasture	2.55	1,553.6	1,326.4	1,043.0	0.0	233.3	0.0	13.2	4,169.4
Asparagus	2.59	3,126.4	304.4	0.0	0.0	525.4	0.0	0.0	3,956.2
Grass, Hay	3.56	845.4	2,297.0	680.2	0.0	291.9	0.0	0.0	4,114.4
Nectarine/Peach	3.61	0.0	0.0	3,611.7	0.0	0.0	0.0	0.0	3,611.7
Potato	2.49	2,073.8	242.9	0.0	94.1	0.0	0.0	0.0	2,410.8
Pear	3.56	519.5	0.0	2,754.1	0.0	0.0	0.0	0.0	3,273.6
Corn, Sweet	1.82	629.5	266.2	0.0	488.3	0.0	0.0	0.0	1,384.0
Onion	2.87	167.0	257.9	0.0	1,539.2	0.0	0.0	0.0	1,964.1
Market Crops	2.38	437.6	482.9	14.9	529.6	0.0	0.0	0.0	1,465.1
Cherry	3.89	59.2	0.0	2,345.1	7.5	0.0	0.0	0.0	2,411.8
Bean, Dry	1.96	244.0	548.1	0.0	0.0	257.8	0.0	0.0	1,050.0
Sorghum	2.17	80.2	804.1	32.0	0.0	0.0	0.0	0.0	916.3
Pepper	*2.78*	96.9	47.5	2.9	769.6	0.0	0.0	0.0	916.9
Unknown	*2.78*	0.0	0.0	0.0	0.0	315.3	313.8	0.0	629.1
Nursery, Orchard/Vineyard	*2.78*	288.6	0.0	0.0	310.4	0.0	0.0	0.0	599.1
Squash	1.54	86.0	51.8	0.0	131.6	0.0	0.0	0.0	269.4
Corn, Seed	*2.78*	481.6	0.0	0.0	0.0	0.0	0.0	0.0	481.6
Dill	*2.78*	0.0	391.2	0.0	0.0	0.0	0.0	0.0	391.2
Oat	2.11	82.7	192.7	0.0	0.0	0.0	0.0	0.0	275.4
Nursery, Ornamental	*2.78*	0.0	0.0	214.0	106.2	0.0	0.0	0.0	320.2
Timothy	3.56	0.0	375.6	0.0	0.0	0.0	0.0	0.0	375.6
Golf Course	3.38	0.0	0.0	299.9	0.0	0.0	0.0	0.0	299.9
Bluegrass, Seed	*2.78*	0.0	209.6	0.0	0.0	0.0	0.0	0.0	209.6
Plum	3.56	112.1	0.0	147.5	0.0	0.0	0.0	0.0	259.6
Apricot	3.63	0.0	0.0	241.8	0.0	0.0	0.0	0.0	241.8
Cucumber	1.89	0.0	44.6	0.0	69.2	0.0	0.0	0.0	113.8
Carrot, Seed	*2.78*	73.6	89.6	0.0	0.0	0.0	0.0	0.0	163.3
Clover, Seed	*2.78*	0.0	160.3	0.0	0.0	0.0	0.0	0.0	160.3
Tomato	2.38	6.6	0.0	0.0	127.4	0.0	0.0	0.0	134.0
Cabbage	*2.78*	111.8	11.2	0.0	0.0	0.0	0.0	0.0	123.0
Pumpkin	1.54	25.2	0.0	0.0	41.5	0.0	0.0	0.0	66.7
Canola	*2.78*	0.0	0.0	0.0	0.0	100.2	0.0	0.0	100.2
Broccoli, Seed	*2.78*	0.0	0.0	0.0	0.0	99.6	0.0	0.0	99.6
Vegetable, Unknown	2.38	77.3	0.0	0.0	0.0	0.0	0.0	0.0	77.3
Bean, Green	1.60	19.6	19.7	0.0	0.0	0.0	0.0	0.0	39.3
Watermelon	1.31	0.0	0.0	0.0	29.0	0.0	0.0	0.0	29.0
Sunflower, Seed	*2.78*	60.4	0.0	0.0	0.0	0.0	0.0	0.0	60.4
Blueberry	*2.78*	0.0	0.0	36.0	0.0	0.0	0.0	0.0	36.0
Sage	*2.78*	30.4	0.0	0.0	0.0	0.0	0.0	0.0	30.4
Grape, Wine	2.37	0.0	0.0	0.0	23.1	0.0	0.0	0.0	23.1
Driving Range	3.38	0.0	0.0	8.4	0.0	0.0	0.0	0.0	8.4
Alfalfa, Seed	*2.78*	0.0	2.5	0.0	0.0	0.0	0.0	0.0	2.5
Total		94,159.7	48,908.0	47,347.9	34,404.4	27,748.5	658.9	215.7	253,443.1

Weighted Average CIR = 2.78 acre-feet/acre

Table A-11

Average Crop Irrigation Requirement - SVID (acre-feet)

Crop Type	Crop CIR	Rill	Sprinkler	Wheel Line	Center Pivot	Drip	Unknown	Big Gun	Hand	Total
Grape, Concord	2.28	12,339.6	10,455.3	0.0	0.0	738.7	51.1	0.0	0.0	23,584.7
Corn, Field	2.44	14,552.7	359.2	241.3	7,028.0	0.0	180.4	226.6	0.0	22,588.1
Alfalfa, Hay	3.09	2,363.4	3,900.7	9,162.4	3,351.2	0.0	13.5	0.0	0.0	18,791.3
Hops	2.56	3,829.2	51.9	0.0	0.0	10,076.4	0.0	0.0	0.0	13,957.6
Cherry	3.74	229.5	13,932.7	0.0	0.0	359.6	0.0	0.0	0.0	14,521.8
Apple	3.70	92.8	12,068.7	0.0	0.0	212.6	0.0	0.0	0.0	12,374.0
Wheat	2.03	570.5	40.3	1,331.6	871.1	0.0	107.8	0.0	0.0	2,921.3
Asparagus	2.50	2,971.7	166.4	145.5	0.0	0.0	22.7	0.0	0.0	3,306.3
Alfalfa/Grass, Hay	3.09	75.7	557.5	2,544.1	488.6	0.0	0.0	0.0	0.0	3,665.9
Grape, Wine	2.28	2.3	716.7	0.0	0.0	1,541.9	0.0	0.0	0.0	2,260.9
Mint	3.00	1,651.1	205.2	729.0	0.0	0.0	58.0	0.0	0.0	2,643.3
Sorghum	2.09	38.5	7.9	795.8	592.2	0.0	0.0	0.0	0.0	1,434.3
Triticale	2.05	405.6	60.0	422.0	431.6	0.0	24.4	0.0	0.0	1,343.5
Grass, Hay	3.43	211.0	841.1	1,152.2	0.0	0.0	74.0	0.1	0.0	2,278.4
Pear	3.42	176.2	1,954.0	0.0	0.0	0.0	0.0	0.0	0.0	2,130.2
Pasture	2.46	54.2	276.3	620.0	446.7	0.0	0.0	0.0	0.0	1,397.3
Nursery, Ornamental	*2.72*	228.2	468.6	0.0	0.0	231.2	39.0	0.0	10.9	977.9
Squash	1.49	263.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	263.7
Oat	2.05	36.5	0.0	160.8	135.6	0.0	0.0	0.0	0.0	333.0
Research Station	*2.72*	0.0	402.3	0.0	0.0	0.0	0.0	0.0	0.0	402.3
Plum	3.42	61.2	390.4	0.0	0.0	5.4	0.0	0.0	0.0	457.0
Golf Course	3.26	0.0	410.8	0.0	0.0	0.0	0.0	0.0	0.0	410.8
Barley	2.05	42.6	101.0	63.6	0.0	0.0	0.0	0.0	0.0	207.2
Corn, Seed	*2.72*	266.7	5.9	0.0	0.0	0.0	0.0	0.0	0.0	272.6
Rye	2.05	0.0	12.8	79.7	76.1	0.0	0.0	0.0	0.0	168.6
Nectarine/Peach	3.48	42.1	242.2	0.0	0.0	0.0	0.0	0.0	0.0	284.3
Watermelon	1.26	0.0	0.0	0.0	0.0	95.0	0.0	0.0	0.0	95.0
Market Crops	2.29	107.1	31.0	0.0	0.0	0.0	8.8	0.0	0.0	146.9
Canola	*2.72*	0.0	0.0	183.5	0.0	0.0	0.0	0.0	0.0	183.5
Caneberry	3.58	0.0	0.0	0.0	0.0	234.0	0.0	0.0	0.0	234.0
Poplar, Hybrid	*2.72*	0.0	0.0	0.0	0.0	15.4	118.0	0.0	0.0	133.4
Green Manure	2.05	0.0	60.1	0.0	0.0	0.0	0.0	0.0	0.0	60.1
Bulb, Iris	*2.72*	59.2	12.9	0.0	0.0	0.0	0.0	0.0	0.0	72.1
Nursery, Silvaculture	*2.72*	0.0	55.5	0.0	0.0	15.0	0.0	0.0	0.0	70.5
Apricot	3.50	0.0	77.6	0.0	0.0	0.0	0.0	0.0	0.0	77.6
Nursery, Orchard/Vineyard	*2.72*	0.0	56.0	0.0	0.0	0.0	0.0	0.0	0.0	56.0
Pumpkin	1.49	27.7	1.9	0.0	0.0	0.0	0.0	0.0	0.0	29.6
Corn, Sweet	1.75	8.7	9.4	0.0	0.0	0.0	15.5	0.0	0.0	33.6
Carrot, Seed	*2.72*	35.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.9
Walnut	*2.72*	0.0	29.9	0.0	0.0	0.0	0.0	0.0	0.0	29.9
Currant	3.58	0.0	30.6	0.0	0.0	0.0	0.0	0.0	0.0	30.6
Christmas Tree	*2.72*	0.0	13.8	0.0	0.0	0.0	0.0	0.0	0.0	13.8
Bulb, Allium	*2.72*	11.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.9
Driving Range	3.26	0.0	14.1	0.0	0.0	0.0	0.0	0.0	0.0	14.1
Sunflower, Seed	*2.72*	0.0	10.5	0.0	0.0	0.0	0.0	0.0	0.0	10.5
Unknown	*2.72*	0.0	0.0	0.0	0.0	0.0	9.7	0.0	0.0	9.7
Orchard, Unknown	3.70	0.0	0.0	0.0	0.0	0.0	5.3	0.0	0.0	5.3
Total		40,755.5	48,031.3	17,631.6	13,421.1	13,525.2	728.1	226.6	10.9	134,330.5

Weighted Average CIR = 2.72 acre-feet/acre

Table A-12

Average Crop Irrigation Requirement - YTID (acre-feet)

Crop Type	Crop CIR	Sprinkler	Wheel Line	Drip	Rill	Unknown	Total
Apple	2.66	33,138.1	54.9	857.9	529.5	379.3	34,959.8
Pear	2.45	3,132.2	0.0	0.0	14.7	25.3	3,172.2
Cherry	2.69	2,061.8	0.0	0.0	0.0	0.0	2,061.8
Alfalfa/Grass, Hay	2.21	619.7	773.9	0.0	0.0	0.0	1,393.5
Grass, Hay	2.45	342.5	84.4	0.0	0.0	0.0	426.8
Golf Course	2.33	356.4	0.0	0.0	0.0	0.0	356.4
Alfalfa, Hay	2.21	98.0	109.8	0.0	0.0	0.0	207.8
Sod Farm	2.33	163.1	0.0	0.0	0.0	0.0	163.1
Caneberry	2.57	43.5	0.0	62.3	0.0	0.0	105.8
Barley	1.44	23.0	0.0	0.0	0.0	0.0	23.0
Nectarine/Peach	2.49	21.8	0.0	0.0	0.0	0.0	21.8
Orchard, Unknown	2.66	0.0	0.0	0.0	0.0	21.4	21.4
Grape, Wine	1.64	1.0	0.0	10.1	0.0	0.0	11.1
Walnut	*2.61*	7.3	0.0	0.0	0.0	0.0	7.3
Christmas Tree	*2.61*	5.8	0.0	0.0	0.0	0.0	5.8
Blueberry	*2.61*	3.9	0.0	0.0	0.0	0.0	3.9
Nursery, Lavender	*2.61*	0.0	0.0	1.4	0.0	0.0	1.4
Total		40,017.9	1,022.9	931.8	544.2	426.1	42,942.8

Weighted Average CIR = 2.61 acre-feet/acre

Table A-13

Average Crop Irrigation Requirement - KID (acre-feet)

Crop Type	Crop CIR	Center Pivot	Sprinkler	Drip	Wheel Line	Rill	Hand	Total
Grape, Wine	2.44	0.0	11.4	4,801.9	0.0	0.0	0.0	4,813.3
Apple	3.95	0.0	4,242.4	437.6	0.0	0.0	0.0	4,680.0
Alfalfa, Hay	3.30	2,097.8	839.0	0.0	570.4	398.6	0.0	3,905.9
Wheat	2.16	1,459.8	188.2	0.0	167.1	126.0	0.0	1,941.0
Cherry	4.00	0.0	2,357.0	75.9	0.0	0.0	0.0	2,433.0
Asparagus	2.67	750.8	0.0	0.0	0.0	0.0	0.0	750.8
Alfalfa/Grass, Hay	3.30	557.9	229.4	0.0	109.0	0.0	0.0	896.3
Corn, Field	2.61	704.4	0.0	0.0	0.0	0.0	0.0	704.4
Potato	2.56	552.1	0.0	0.0	0.0	0.0	0.0	552.1
Corn, Sweet	1.86	370.2	0.0	0.0	0.0	0.0	0.0	370.2
Pasture	2.63	374.7	22.5	0.0	0.0	0.0	0.0	397.2
Pumpkin	1.59	229.0	0.0	0.0	0.0	0.0	0.0	229.0
Golf Course	3.48	0.0	466.8	0.0	0.0	0.0	0.0	466.8
Pear	3.66	0.0	237.3	0.0	0.0	0.0	0.0	237.3
Grass, Hay	3.66	0.0	94.0	0.0	77.6	0.0	0.0	171.6
Plum	3.66	0.0	28.8	0.0	0.0	0.0	0.0	28.8
Nectarine/Peach	3.72	0.0	22.7	0.0	0.0	0.0	0.0	22.7
Nursery, Ornamental	*2.96*	0.0	0.0	0.0	0.0	0.0	5.6	5.6
Walnut	*2.96*	0.0	5.1	0.0	0.0	0.0	0.0	5.1
Total		7,096.7	8,744.7	5,315.4	924.1	524.6	5.6	22,611.2

Weighted Average CIR = 2.96 acre-feet/acre

Table A-14

Total On-Farm Water Needs - KRD (acre-feet)

Application Efficiency	65%	85%	75%	50%	75%	88%	65%	65%	**66.5%**
Crop Type	Rill	Center Pivot	Wheel Line	Flood	Sprinkler	Drip	Big Gun	Unknown	Total
Timothy	64,980.8	6,646.8	6,678.9	136.2	675.4	0.0	35.8	37.8	79,191.7
Pasture	13,858.0	1,073.0	1,049.3	11,691.1	489.7	0.0	31.1	0.0	28,192.2
Grass, Hay	7,336.8	857.3	1,192.3	0.0	36.0	0.0	157.1	0.0	9,579.6
Alfalfa, Hay	2,719.8	737.8	654.6	0.0	3.2	0.0	0.0	0.0	4,115.4
Wheat	2,766.0	472.4	337.3	0.0	0.0	0.0	0.0	0.0	3,575.8
Oat	2,702.1	490.6	369.2	0.0	122.9	0.0	0.0	0.0	3,684.7
Corn, Sweet	1,261.7	795.6	0.0	0.0	0.0	0.0	0.0	0.0	2,057.3
Sudangrass	2,345.2	215.1	205.8	0.0	0.0	0.0	0.0	0.0	2,766.1
Apple	0.0	0.0	0.0	0.0	1,124.6	338.4	0.0	0.0	1,463.0
Alfalfa/Grass, Hay	538.1	0.0	137.4	0.0	116.5	0.0	0.0	0.0	792.1
Barley	501.3	0.0	77.8	0.0	24.4	0.0	0.0	0.0	603.6
Pear	5.8	0.0	0.0	0.0	139.0	262.3	0.0	0.0	407.1
Potato	183.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	183.9
Cherry	0.0	0.0	0.0	0.0	243.5	0.0	0.0	0.0	243.5
Golf Course	0.0	0.0	0.0	0.0	176.8	0.0	0.0	0.0	176.8
Grape, Wine	0.0	0.0	0.0	0.0	2.2	12.6	0.0	0.0	14.8
Market Crops	7.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7
Sunflower, Seed	0.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	4.2
Onion	0.0	0.0	0.0	0.0	3.4	0.0	0.0	0.0	3.4
Blueberry	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	1.5
Total	99,207.3	11,292.7	10,702.8	11,827.3	3,157.5	614.8	224.0	37.8	137,064.2

Estimated Average Application Efficiency = 66.5%

Table A-15

Total On-Farm Water Needs - Roza (acre-feet)

Application Efficiency	75%	88%	65%	85%	75%	75%	65%	**77.0%**
Crop Type	Sprinkler	Drip	Rill	Center Pivot	Wheel Line	Unknown	Big Gun	Total
Apple	85,294.1	6,058.2	831.7	0.0	0.0	45.7	0.0	92,229.8
Grape, Wine	5,299.2	19,926.0	67.1	0.0	0.0	0.0	0.0	25,292.4
Grape, Concord	18,600.1	2,519.1	8,052.8	0.0	0.0	0.0	0.0	29,172.1
Cherry	20,005.2	469.1	110.1	0.0	0.0	0.0	0.0	20,584.4
Hops	0.0	7,857.0	349.1	0.0	0.0	0.0	0.0	8,206.1
Alfalfa, Hay	1,820.2	0.0	237.1	365.9	6,901.9	0.0	0.0	9,325.0
Pear	8,862.2	95.8	0.0	0.0	0.0	0.0	0.0	8,958.0
Corn, Field	0.0	0.0	1,983.8	3,282.9	327.1	0.0	0.0	5,593.7
Wheat	306.1	0.0	306.5	1,200.4	733.7	176.7	0.0	2,723.5
Sorghum	51.1	0.0	11.8	1,922.2	355.6	24.3	615.5	2,980.5
Nectarine/Peach	2,631.3	20.8	0.0	0.0	0.0	0.0	0.0	2,652.1
Triticale	0.0	0.0	0.0	1,175.1	255.8	0.0	8.6	1,439.5
Asparagus	705.9	0.0	1,110.5	0.0	0.0	0.0	0.0	1,816.4
Research Station	0.0	964.5	0.0	0.0	111.2	0.0	0.0	1,075.6
Apricot	763.7	145.1	37.0	0.0	0.0	0.0	0.0	945.8
Alfalfa/Grass, Hay	432.4	0.0	0.0	131.9	416.9	0.0	0.0	981.3
Green Manure	61.2	0.0	143.3	0.0	49.4	376.5	0.0	630.5
Caneberry	0.0	752.4	0.0	0.0	0.0	0.0	0.0	752.4
Nursery, Orchard/Vineyard	329.3	0.0	231.4	0.0	31.6	0.0	0.0	592.3
Corn, Sweet	0.0	0.0	366.0	0.0	0.0	0.0	0.0	366.0
Rye	0.0	0.0	0.0	89.7	263.4	0.0	0.0	353.2
Unknown	0.0	0.0	0.0	0.0	0.0	436.6	0.0	436.6
Mint	0.0	0.0	201.3	0.0	258.1	0.0	0.0	459.3
Squash	0.0	154.6	0.0	0.0	0.0	0.0	0.0	154.6
Grass, Hay	44.9	0.0	0.0	0.0	292.4	57.0	0.0	394.3
Nursery, Ornamental	325.4	0.0	0.0	0.0	0.0	0.0	0.0	325.4
Corn, Seed	0.0	0.0	19.6	244.9	0.0	0.0	0.0	264.5
Currant	0.0	0.0	315.8	0.0	0.0	0.0	0.0	315.8
Pumpkin	0.0	114.9	0.0	0.0	0.0	0.0	0.0	114.9
Blueberry	4.1	191.2	0.0	0.0	0.0	0.0	0.0	195.3
Potato	0.0	0.0	210.2	0.0	0.0	0.0	0.0	210.2
Pasture	106.2	0.0	0.0	0.0	53.0	0.0	0.0	159.2
Tomato	0.0	0.0	163.7	0.0	0.0	0.0	0.0	163.7
Plum	195.5	0.0	0.0	0.0	0.0	0.0	0.0	195.5
Herb, Medicinal	0.0	0.0	0.0	141.3	0.0	0.0	0.0	141.3
Barley	83.0	0.0	0.0	0.0	0.0	0.0	0.0	83.0
Hay/Silage, Unknown	0.0	0.0	0.0	0.0	0.0	50.2	0.0	50.2
Market Crops	0.0	0.0	25.2	0.0	0.0	0.0	0.0	25.2
Total	145,921.1	39,268.8	14,774.3	8,554.3	10,049.9	1,167.1	624.1	220,359.6

Estimated Average Application Efficiency = 77.0%

Table A-16

Total On-Farm Water Needs - WIP (acre-feet)

Application Efficiency	65%	75%	75%	88%	85%	75%	65%	**73.2%**
Crop Type	Rill	Wheel Line	Sprinkler	Drip	Center Pivot	Unknown	Big Gun	Total
Corn, Field	57,589.9	794.6	347.5	0.0	10,914.4	0.0	311.6	69,957.9
Wheat	19,964.5	12,294.7	597.3	0.0	5,401.2	0.0	0.0	38,257.8
Hops	6,521.5	260.1	146.7	33,432.4	0.0	132.8	0.0	40,493.5
Alfalfa, Hay	4,445.2	26,213.0	1,227.4	0.0	13,028.5	0.0	0.0	44,914.1
Apple	2,723.8	188.9	41,250.3	102.9	564.2	54.2	0.0	44,884.3
Mint	23,847.3	10,487.9	854.2	0.0	422.3	113.9	0.0	35,725.6
Grape, Concord	10,930.5	0.0	2,677.2	711.9	0.0	73.3	0.0	14,392.9
Alfalfa/Grass, Hay	1,470.4	4,136.2	788.0	0.0	169.4	85.8	0.0	6,649.9
Pasture	2,390.2	1,768.5	1,390.6	0.0	274.4	0.0	20.3	5,844.1
Asparagus	4,809.8	405.9	0.0	0.0	618.1	0.0	0.0	5,833.9
Grass, Hay	1,300.7	3,062.6	906.9	0.0	343.4	0.0	0.0	5,613.6
Nectarine/Peach	0.0	0.0	4,815.5	0.0	0.0	0.0	0.0	4,815.5
Potato	3,190.5	323.8	0.0	106.9	0.0	0.0	0.0	3,621.2
Pear	799.3	0.0	3,672.1	0.0	0.0	0.0	0.0	4,471.4
Corn, Sweet	968.4	355.0	0.0	554.9	0.0	0.0	0.0	1,878.3
Onion	257.0	343.8	0.0	1,749.1	0.0	0.0	0.0	2,349.9
Market Crops	673.3	643.8	19.9	601.9	0.0	0.0	0.0	1,938.9
Cherry	91.1	0.0	3,126.8	8.5	0.0	0.0	0.0	3,226.5
Bean, Dry	375.5	730.9	0.0	0.0	303.3	0.0	0.0	1,409.6
Sorghum	123.4	1,072.2	42.7	0.0	0.0	0.0	0.0	1,238.2
Pepper	149.1	63.3	3.9	874.6	0.0	0.0	0.0	1,090.9
Unknown	0.0	0.0	0.0	0.0	370.9	418.4	0.0	789.4
Nursery, Orchard/Vineyard	444.0	0.0	0.0	352.8	0.0	0.0	0.0	796.8
Squash	132.3	69.1	0.0	149.6	0.0	0.0	0.0	351.0
Corn, Seed	740.9	0.0	0.0	0.0	0.0	0.0	0.0	740.9
Dill	0.0	521.6	0.0	0.0	0.0	0.0	0.0	521.6
Oat	127.3	256.9	0.0	0.0	0.0	0.0	0.0	384.2
Nursery, Ornamental	0.0	0.0	285.3	120.7	0.0	0.0	0.0	406.0
Timothy	0.0	500.8	0.0	0.0	0.0	0.0	0.0	500.8
Golf Course	0.0	0.0	399.8	0.0	0.0	0.0	0.0	399.8
Bluegrass, Seed	0.0	279.5	0.0	0.0	0.0	0.0	0.0	279.5
Plum	172.4	0.0	196.7	0.0	0.0	0.0	0.0	369.1
Apricot	0.0	0.0	322.4	0.0	0.0	0.0	0.0	322.4
Cucumber	0.0	59.4	0.0	78.6	0.0	0.0	0.0	138.1
Carrot, Seed	113.2	119.5	0.0	0.0	0.0	0.0	0.0	232.8
Clover, Seed	0.0	213.8	0.0	0.0	0.0	0.0	0.0	213.8
Tomato	10.1	0.0	0.0	144.8	0.0	0.0	0.0	154.9
Cabbage	172.0	14.9	0.0	0.0	0.0	0.0	0.0	186.9
Pumpkin	38.7	0.0	0.0	47.2	0.0	0.0	0.0	85.9
Canola	0.0	0.0	0.0	0.0	117.9	0.0	0.0	117.9
Broccoli, Seed	0.0	0.0	0.0	0.0	117.2	0.0	0.0	117.2
Vegetable, Unknown	119.0	0.0	0.0	0.0	0.0	0.0	0.0	119.0
Bean, Green	30.1	26.3	0.0	0.0	0.0	0.0	0.0	56.4
Watermelon	0.0	0.0	0.0	33.0	0.0	0.0	0.0	33.0
Sunflower, Seed	92.9	0.0	0.0	0.0	0.0	0.0	0.0	92.9
Blueberry	0.0	0.0	48.0	0.0	0.0	0.0	0.0	48.0
Sage	46.8	0.0	0.0	0.0	0.0	0.0	0.0	46.8
Grape, Wine	0.0	0.0	0.0	26.2	0.0	0.0	0.0	26.2
Driving Range	0.0	0.0	11.2	0.0	0.0	0.0	0.0	11.2
Alfalfa, Seed	0.0	3.3	0.0	0.0	0.0	0.0	0.0	3.3
Total	144,861.0	65,210.6	63,130.5	39,095.9	32,645.3	878.5	331.9	346,153.8

Estimated Average Application Efficiency = 73.2%

Table A-17

Total On-Farm Water Needs - SVID (acre-feet)

Application Efficiency	65%	75%	75%	85%	88%	75%	65%	75%	**73.5%**
Crop Type	Rill	Sprinkler	Wheel Line	Center Pivot	Drip	Unknown	Big Gun	Hand	Total
Grape, Concord	18,984.0	13,940.4	0.0	0.0	839.4	68.1	0.0	0.0	33,831.9
Corn, Field	22,388.8	478.9	321.8	8,268.2	0.0	240.5	348.5	0.0	32,046.7
Alfalfa, Hay	3,636.0	5,201.0	12,216.5	3,942.6	0.0	18.0	0.0	0.0	25,014.1
Hops	5,891.1	69.2	0.0	0.0	11,450.5	0.0	0.0	0.0	17,410.9
Cherry	353.0	18,577.0	0.0	0.0	408.7	0.0	0.0	0.0	19,338.7
Apple	142.8	16,091.6	0.0	0.0	241.5	0.0	0.0	0.0	16,475.9
Wheat	877.8	53.8	1,775.5	1,024.8	0.0	143.7	0.0	0.0	3,875.5
Asparagus	4,571.8	221.9	194.1	0.0	0.0	30.2	0.0	0.0	5,018.0
Alfalfa/Grass, Hay	116.4	743.4	3,392.2	574.9	0.0	0.0	0.0	0.0	4,826.8
Grape, Wine	3.5	955.7	0.0	0.0	1,752.1	0.0	0.0	0.0	2,711.3
Mint	2,540.2	273.6	971.9	0.0	0.0	77.3	0.0	0.0	3,863.0
Sorghum	59.2	10.5	1,061.0	696.7	0.0	0.0	0.0	0.0	1,827.4
Triticale	624.0	80.0	562.7	507.8	0.0	32.5	0.0	0.0	1,806.9
Grass, Hay	324.6	1,121.5	1,536.3	0.0	0.0	98.7	0.1	0.0	3,081.2
Pear	271.1	2,605.3	0.0	0.0	0.0	0.0	0.0	0.0	2,876.4
Pasture	83.4	368.4	826.7	525.6	0.0	0.0	0.0	0.0	1,804.1
Nursery, Ornamental	351.1	624.7	0.0	0.0	262.7	52.1	0.0	14.5	1,305.2
Squash	405.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	405.7
Oat	56.2	0.0	214.4	159.6	0.0	0.0	0.0	0.0	430.2
Research Station	0.0	536.5	0.0	0.0	0.0	0.0	0.0	0.0	536.5
Plum	94.2	520.5	0.0	0.0	6.1	0.0	0.0	0.0	620.8
Golf Course	0.0	547.8	0.0	0.0	0.0	0.0	0.0	0.0	547.8
Barley	65.5	134.7	84.9	0.0	0.0	0.0	0.0	0.0	285.0
Corn, Seed	410.4	7.9	0.0	0.0	0.0	0.0	0.0	0.0	418.2
Rye	0.0	17.1	106.3	89.5	0.0	0.0	0.0	0.0	212.9
Nectarine/Peach	64.8	323.0	0.0	0.0	0.0	0.0	0.0	0.0	387.7
Watermelon	0.0	0.0	0.0	0.0	108.0	0.0	0.0	0.0	108.0
Market Crops	164.8	41.3	0.0	0.0	0.0	11.8	0.0	0.0	217.9
Canola	0.0	0.0	244.7	0.0	0.0	0.0	0.0	0.0	244.7
Caneberry	0.0	0.0	0.0	0.0	265.9	0.0	0.0	0.0	265.9
Poplar, Hybrid	0.0	0.0	0.0	0.0	17.5	157.3	0.0	0.0	174.8
Green Manure	0.0	80.1	0.0	0.0	0.0	0.0	0.0	0.0	80.1
Bulb, Iris	91.1	17.1	0.0	0.0	0.0	0.0	0.0	0.0	108.3
Nursery, Silvaculture	0.0	74.0	0.0	0.0	17.0	0.0	0.0	0.0	91.0
Apricot	0.0	103.4	0.0	0.0	0.0	0.0	0.0	0.0	103.4
Nursery, Orchard/Vineyard	0.0	74.7	0.0	0.0	0.0	0.0	0.0	0.0	74.7
Pumpkin	42.7	2.5	0.0	0.0	0.0	0.0	0.0	0.0	45.2
Corn, Sweet	13.4	12.5	0.0	0.0	0.0	20.6	0.0	0.0	46.6
Carrot, Seed	55.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	55.2
Walnut	0.0	39.9	0.0	0.0	0.0	0.0	0.0	0.0	39.9
Currant	0.0	40.8	0.0	0.0	0.0	0.0	0.0	0.0	40.8
Christmas Tree	0.0	18.4	0.0	0.0	0.0	0.0	0.0	0.0	18.4
Bulb, Allium	18.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.2
Driving Range	0.0	18.9	0.0	0.0	0.0	0.0	0.0	0.0	18.9
Sunflower, Seed	0.0	14.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0
Unknown	0.0	0.0	0.0	0.0	0.0	12.9	0.0	0.0	12.9
Orchard, Unknown	0.0	0.0	0.0	0.0	0.0	7.1	0.0	0.0	7.1
Total	62,700.8	64,041.8	23,508.8	15,789.5	15,369.6	970.9	348.7	14.5	182,744.6

Estimated Average Application Efficiency = 73.5%

Table A-18

Total On-Farm Water Needs - YTID (acre-feet)

Application Efficiency	75%	75%	88%	65%	75%	**75.1%**
Crop Type	Sprinkler	Wheel Line	Drip	Rill	Unknown	Total
Apple	44,184.2	73.2	974.9	814.7	505.8	46,552.7
Pear	4,176.3	0.0	0.0	22.6	33.7	4,232.6
Cherry	2,749.0	0.0	0.0	0.0	0.0	2,749.0
Alfalfa/Grass, Hay	826.2	1,031.8	0.0	0.0	0.0	1,858.0
Grass, Hay	456.6	112.5	0.0	0.0	0.0	569.1
Golf Course	475.2	0.0	0.0	0.0	0.0	475.2
Alfalfa, Hay	130.7	146.4	0.0	0.0	0.0	277.0
Sod Farm	217.4	0.0	0.0	0.0	0.0	217.4
Caneberry	58.0	0.0	70.8	0.0	0.0	128.8
Barley	30.7	0.0	0.0	0.0	0.0	30.7
Nectarine/Peach	29.1	0.0	0.0	0.0	0.0	29.1
Orchard, Unknown	0.0	0.0	0.0	0.0	28.5	28.5
Grape, Wine	1.3	0.0	11.4	0.0	0.0	12.8
Walnut	9.7	0.0	0.0	0.0	0.0	9.7
Christmas Tree	7.7	0.0	0.0	0.0	0.0	7.7
Blueberry	5.2	0.0	0.0	0.0	0.0	5.2
Nursery, Lavender	0.0	0.0	1.6	0.0	0.0	1.6
Total	53,357.2	1,363.9	1,058.8	837.2	568.1	57,185.2

Estimated Average Application Efficiency = 75.1%

Table A-19

Total On-Farm Water Needs - KID (acre-feet)

Application Efficiency	85%	75%	88%	75%	65%	75%	**80.5%**
Crop Type	Center Pivot	Sprinkler	Drip	Wheel Line	Rill	Hand	Total
Grape, Wine	0.0	15.2	5,456.7	0.0	0.0	0.0	5,471.9
Apple	0.0	5,656.5	497.3	0.0	0.0	0.0	6,153.8
Alfalfa, Hay	2,468.1	1,118.7	0.0	760.6	613.3	0.0	4,960.6
Wheat	1,717.4	250.9	0.0	222.8	193.8	0.0	2,384.9
Cherry	0.0	3,142.7	86.3	0.0	0.0	0.0	3,229.0
Asparagus	883.3	0.0	0.0	0.0	0.0	0.0	883.3
Alfalfa/Grass, Hay	656.3	305.9	0.0	145.4	0.0	0.0	1,107.5
Corn, Field	828.7	0.0	0.0	0.0	0.0	0.0	828.7
Potato	649.5	0.0	0.0	0.0	0.0	0.0	649.5
Corn, Sweet	435.5	0.0	0.0	0.0	0.0	0.0	435.5
Pasture	440.9	30.0	0.0	0.0	0.0	0.0	470.9
Pumpkin	269.4	0.0	0.0	0.0	0.0	0.0	269.4
Golf Course	0.0	622.4	0.0	0.0	0.0	0.0	622.4
Pear	0.0	316.5	0.0	0.0	0.0	0.0	316.5
Grass, Hay	0.0	125.4	0.0	103.5	0.0	0.0	228.9
Plum	0.0	38.4	0.0	0.0	0.0	0.0	38.4
Nectarine/Peach	0.0	30.3	0.0	0.0	0.0	0.0	30.3
Nursery, Ornamental	0.0	0.0	0.0	0.0	0.0	7.5	7.5
Walnut	0.0	6.8	0.0	0.0	0.0	0.0	6.8
Total	8,349.0	11,659.6	6,040.3	1,232.2	807.1	7.5	28,095.7

Estimated Average Application Efficiency = 80.5%

Table A-20

Return Flow - KRD (acre-feet)

Return Flow	30%	3%	15%	45%	15%	7%	25%	30%	**27.4%**
Crop Type	Rill	Center Pivot	Wheel Line	Flood	Sprinkler	Drip	Big Gun	Unknown	Total
Timothy	19,494.2	199.4	1,001.8	61.3	101.3	0.0	8.9	11.4	20,878.4
Pasture	4,157.4	32.2	157.4	5,261.0	73.5	0.0	7.8	0.0	9,689.2
Grass, Hay	2,201.0	25.7	178.8	0.0	5.4	0.0	39.3	0.0	2,450.3
Alfalfa, Hay	815.9	22.1	98.2	0.0	0.5	0.0	0.0	0.0	936.7
Wheat	829.8	14.2	50.6	0.0	0.0	0.0	0.0	0.0	894.6
Oat	810.6	14.7	55.4	0.0	18.4	0.0	0.0	0.0	899.2
Corn, Sweet	378.5	23.9	0.0	0.0	0.0	0.0	0.0	0.0	402.4
Sudangrass	703.6	6.5	30.9	0.0	0.0	0.0	0.0	0.0	740.9
Apple	0.0	0.0	0.0	0.0	168.7	23.7	0.0	0.0	192.4
Alfalfa/Grass, Hay	161.4	0.0	20.6	0.0	17.5	0.0	0.0	0.0	199.5
Barley	150.4	0.0	11.7	0.0	3.7	0.0	0.0	0.0	165.7
Pear	1.7	0.0	0.0	0.0	20.9	18.4	0.0	0.0	41.0
Potato	55.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	55.2
Cherry	0.0	0.0	0.0	0.0	36.5	0.0	0.0	0.0	36.5
Golf Course	0.0	0.0	0.0	0.0	26.5	0.0	0.0	0.0	26.5
Grape, Wine	0.0	0.0	0.0	0.0	0.3	0.9	0.0	0.0	1.2
Market Crops	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3
Sunflower, Seed	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Onion	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.5
Blueberry	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1
Total	29,762.2	338.8	1,605.4	5,322.3	473.6	43.0	56.0	11.4	37,612.7

Estimated Return Flow as Percent of Water Applied = 27.4%

Table A-21

Return Flow - Roza (acre-feet)

Return Flow	15%	7%	30%	3%	15%	15%	25%	**14.1%**
Crop Type	Sprinkler	Drip	Rill	Center Pivot	Wheel Line	Unknown	Big Gun	Total
Apple	12,794.1	424.1	249.5	0.0	0.0	6.9	0.0	13,474.6
Grape, Wine	794.9	1,394.8	20.1	0.0	0.0	0.0	0.0	2,209.8
Grape, Concord	2,790.0	176.3	2,415.9	0.0	0.0	0.0	0.0	5,382.2
Cherry	3,000.8	32.8	33.0	0.0	0.0	0.0	0.0	3,066.6
Hops	0.0	550.0	104.7	0.0	0.0	0.0	0.0	654.7
Alfalfa, Hay	273.0	0.0	71.1	11.0	1,035.3	0.0	0.0	1,390.4
Pear	1,329.3	6.7	0.0	0.0	0.0	0.0	0.0	1,336.0
Corn, Field	0.0	0.0	595.1	98.5	49.1	0.0	0.0	742.7
Wheat	45.9	0.0	92.0	36.0	110.1	26.5	0.0	310.5
Sorghum	7.7	0.0	3.5	57.7	53.3	3.6	153.9	279.7
Nectarine/Peach	394.7	1.5	0.0	0.0	0.0	0.0	0.0	396.1
Triticale	0.0	0.0	0.0	35.3	38.4	0.0	2.2	75.8
Asparagus	105.9	0.0	333.1	0.0	0.0	0.0	0.0	439.0
Research Station	0.0	67.5	0.0	0.0	16.7	0.0	0.0	84.2
Apricot	114.6	10.2	11.1	0.0	0.0	0.0	0.0	135.8
Alfalfa/Grass, Hay	64.9	0.0	0.0	4.0	62.5	0.0	0.0	131.4
Green Manure	9.2	0.0	43.0	0.0	7.4	56.5	0.0	116.1
Caneberry	0.0	52.7	0.0	0.0	0.0	0.0	0.0	52.7
Nursery, Orchard/Vineyard	49.4	0.0	69.4	0.0	4.7	0.0	0.0	123.6
Corn, Sweet	0.0	0.0	109.8	0.0	0.0	0.0	0.0	109.8
Rye	0.0	0.0	0.0	2.7	39.5	0.0	0.0	42.2
Unknown	0.0	0.0	0.0	0.0	0.0	65.5	0.0	65.5
Mint	0.0	0.0	60.4	0.0	38.7	0.0	0.0	99.1
Squash	0.0	10.8	0.0	0.0	0.0	0.0	0.0	10.8
Grass, Hay	6.7	0.0	0.0	0.0	43.9	8.6	0.0	59.1
Nursery, Ornamental	48.8	0.0	0.0	0.0	0.0	0.0	0.0	48.8
Corn, Seed	0.0	0.0	5.9	7.3	0.0	0.0	0.0	13.2
Currant	0.0	0.0	94.7	0.0	0.0	0.0	0.0	94.7
Pumpkin	0.0	8.0	0.0	0.0	0.0	0.0	0.0	8.0
Blueberry	0.6	13.4	0.0	0.0	0.0	0.0	0.0	14.0
Potato	0.0	0.0	63.1	0.0	0.0	0.0	0.0	63.1
Pasture	15.9	0.0	0.0	0.0	7.9	0.0	0.0	23.9
Tomato	0.0	0.0	49.1	0.0	0.0	0.0	0.0	49.1
Plum	29.3	0.0	0.0	0.0	0.0	0.0	0.0	29.3
Herb, Medicinal	0.0	0.0	0.0	4.2	0.0	0.0	0.0	4.2
Barley	12.4	0.0	0.0	0.0	0.0	0.0	0.0	12.4
Hay/Silage, Unknown	0.0	0.0	0.0	0.0	0.0	7.5	0.0	7.5
Market Crops	0.0	0.0	7.6	0.0	0.0	0.0	0.0	7.6
Total	21,888.2	2,748.8	4,432.3	256.6	1,507.5	175.1	156.0	31,164.5

Estimated Return Flow as Percent of Water Applied = 14.1%

Table A-22

Return Flow - WIP (acre-feet)

Return Flow	30%	15%	15%	7%	3%	15%	25%	**19.3%**
Crop Type	Rill	Wheel Line	Sprinkler	Drip	Center Pivot	Unknown	Big Gun	Total
Corn, Field	17,277.0	119.2	52.1	0.0	327.4	0.0	77.9	17,853.6
Wheat	5,989.3	1,844.2	89.6	0.0	162.0	0.0	0.0	8,085.2
Hops	1,956.4	39.0	22.0	2,340.3	0.0	19.9	0.0	4,377.7
Alfalfa, Hay	1,333.5	3,932.0	184.1	0.0	390.9	0.0	0.0	5,840.5
Apple	817.1	28.3	6,187.5	7.2	16.9	8.1	0.0	7,065.3
Mint	7,154.2	1,573.2	128.1	0.0	12.7	17.1	0.0	8,885.3
Grape, Concord	3,279.2	0.0	401.6	49.8	0.0	11.0	0.0	3,741.6
Alfalfa/Grass, Hay	441.1	620.4	118.2	0.0	5.1	12.9	0.0	1,197.7
Pasture	717.1	265.3	208.6	0.0	8.2	0.0	5.1	1,204.2
Asparagus	1,443.0	60.9	0.0	0.0	18.5	0.0	0.0	1,522.4
Grass, Hay	390.2	459.4	136.0	0.0	10.3	0.0	0.0	995.9
Nectarine/Peach	0.0	0.0	722.3	0.0	0.0	0.0	0.0	722.3
Potato	957.1	48.6	0.0	7.5	0.0	0.0	0.0	1,013.2
Pear	239.8	0.0	550.8	0.0	0.0	0.0	0.0	790.6
Corn, Sweet	290.5	53.2	0.0	38.8	0.0	0.0	0.0	382.6
Onion	77.1	51.6	0.0	122.4	0.0	0.0	0.0	251.1
Market Crops	202.0	96.6	3.0	42.1	0.0	0.0	0.0	343.7
Cherry	27.3	0.0	469.0	0.6	0.0	0.0	0.0	497.0
Bean, Dry	112.6	109.6	0.0	0.0	9.1	0.0	0.0	231.4
Sorghum	37.0	160.8	6.4	0.0	0.0	0.0	0.0	204.2
Pepper	44.7	9.5	0.6	61.2	0.0	0.0	0.0	116.0
Unknown	0.0	0.0	0.0	0.0	11.1	62.8	0.0	73.9
Nursery, Orchard/Vineyard	133.2	0.0	0.0	24.7	0.0	0.0	0.0	157.9
Squash	39.7	10.4	0.0	10.5	0.0	0.0	0.0	60.5
Corn, Seed	222.3	0.0	0.0	0.0	0.0	0.0	0.0	222.3
Dill	0.0	78.2	0.0	0.0	0.0	0.0	0.0	78.2
Oat	38.2	38.5	0.0	0.0	0.0	0.0	0.0	76.7
Nursery, Ornamental	0.0	0.0	42.8	8.4	0.0	0.0	0.0	51.2
Timothy	0.0	75.1	0.0	0.0	0.0	0.0	0.0	75.1
Golf Course	0.0	0.0	60.0	0.0	0.0	0.0	0.0	60.0
Bluegrass, Seed	0.0	41.9	0.0	0.0	0.0	0.0	0.0	41.9
Plum	51.7	0.0	29.5	0.0	0.0	0.0	0.0	81.2
Apricot	0.0	0.0	48.4	0.0	0.0	0.0	0.0	48.4
Cucumber	0.0	8.9	0.0	5.5	0.0	0.0	0.0	14.4
Carrot, Seed	34.0	17.9	0.0	0.0	0.0	0.0	0.0	51.9
Clover, Seed	0.0	32.1	0.0	0.0	0.0	0.0	0.0	32.1
Tomato	3.0	0.0	0.0	10.1	0.0	0.0	0.0	13.2
Cabbage	51.6	2.2	0.0	0.0	0.0	0.0	0.0	53.8
Pumpkin	11.6	0.0	0.0	3.3	0.0	0.0	0.0	14.9
Canola	0.0	0.0	0.0	0.0	3.5	0.0	0.0	3.5
Broccoli, Seed	0.0	0.0	0.0	0.0	3.5	0.0	0.0	3.5
Vegetable, Unknown	35.7	0.0	0.0	0.0	0.0	0.0	0.0	35.7
Bean, Green	9.0	3.9	0.0	0.0	0.0	0.0	0.0	13.0
Watermelon	0.0	0.0	0.0	2.3	0.0	0.0	0.0	2.3
Sunflower, Seed	27.9	0.0	0.0	0.0	0.0	0.0	0.0	27.9
Blueberry	0.0	0.0	7.2	0.0	0.0	0.0	0.0	7.2
Sage	14.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0
Grape, Wine	0.0	0.0	0.0	1.8	0.0	0.0	0.0	1.8
Driving Range	0.0	0.0	1.7	0.0	0.0	0.0	0.0	1.7
Alfalfa, Seed	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.5
Total	43,458.3	9,781.6	9,469.6	2,736.7	979.4	131.8	83.0	66,640.3

Estimated Return Flow as Percent of Water Applied = 19.3%

Table A-23

Return Flow - SVID (acre-feet)

Return Flow	30%	15%	15%	3%	7%	15%	25%	15%	**18.5%**
Crop Type	Rill	Sprinkler	Wheel Line	Center Pivot	Drip	Unknown	Big Gun	Hand	Total
Grape, Concord	5,695.2	2,091.1	0.0	0.0	58.8	10.2	0.0	0.0	7,855.2
Corn, Field	6,716.6	71.8	48.3	248.0	0.0	36.1	87.1	0.0	7,208.0
Alfalfa, Hay	1,090.8	780.1	1,832.5	118.3	0.0	2.7	0.0	0.0	3,824.4
Hops	1,767.3	10.4	0.0	0.0	801.5	0.0	0.0	0.0	2,579.3
Cherry	105.9	2,786.5	0.0	0.0	28.6	0.0	0.0	0.0	2,921.1
Apple	42.8	2,413.7	0.0	0.0	16.9	0.0	0.0	0.0	2,473.5
Wheat	263.3	8.1	266.3	30.7	0.0	21.6	0.0	0.0	590.0
Asparagus	1,371.5	33.3	29.1	0.0	0.0	4.5	0.0	0.0	1,438.5
Alfalfa/Grass, Hay	34.9	111.5	508.8	17.2	0.0	0.0	0.0	0.0	672.5
Grape, Wine	1.1	143.3	0.0	0.0	122.6	0.0	0.0	0.0	267.1
Mint	762.1	41.0	145.8	0.0	0.0	11.6	0.0	0.0	960.5
Sorghum	17.8	1.6	159.2	20.9	0.0	0.0	0.0	0.0	199.4
Triticale	187.2	12.0	84.4	15.2	0.0	4.9	0.0	0.0	303.7
Grass, Hay	97.4	168.2	230.4	0.0	0.0	14.8	0.0	0.0	510.9
Pear	81.3	390.8	0.0	0.0	0.0	0.0	0.0	0.0	472.1
Pasture	25.0	55.3	124.0	15.8	0.0	0.0	0.0	0.0	220.1
Nursery, Ornamental	105.3	93.7	0.0	0.0	18.4	7.8	0.0	2.2	227.4
Squash	121.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	121.7
Oat	16.9	0.0	32.2	4.8	0.0	0.0	0.0	0.0	53.8
Research Station	0.0	80.5	0.0	0.0	0.0	0.0	0.0	0.0	80.5
Plum	28.3	78.1	0.0	0.0	0.4	0.0	0.0	0.0	106.8
Golf Course	0.0	82.2	0.0	0.0	0.0	0.0	0.0	0.0	82.2
Barley	19.6	20.2	12.7	0.0	0.0	0.0	0.0	0.0	52.6
Corn, Seed	123.1	1.2	0.0	0.0	0.0	0.0	0.0	0.0	124.3
Rye	0.0	2.6	15.9	2.7	0.0	0.0	0.0	0.0	21.2
Nectarine/Peach	19.4	48.4	0.0	0.0	0.0	0.0	0.0	0.0	67.9
Watermelon	0.0	0.0	0.0	0.0	7.6	0.0	0.0	0.0	7.6
Market Crops	49.4	6.2	0.0	0.0	0.0	1.8	0.0	0.0	57.4
Canola	0.0	0.0	36.7	0.0	0.0	0.0	0.0	0.0	36.7
Caneberry	0.0	0.0	0.0	0.0	18.6	0.0	0.0	0.0	18.6
Poplar, Hybrid	0.0	0.0	0.0	0.0	1.2	23.6	0.0	0.0	24.8
Green Manure	0.0	12.0	0.0	0.0	0.0	0.0	0.0	0.0	12.0
Bulb, Iris	27.3	2.6	0.0	0.0	0.0	0.0	0.0	0.0	29.9
Nursery, Silvaculture	0.0	11.1	0.0	0.0	1.2	0.0	0.0	0.0	12.3
Apricot	0.0	15.5	0.0	0.0	0.0	0.0	0.0	0.0	15.5
Nursery, Orchard/Vineyard	0.0	11.2	0.0	0.0	0.0	0.0	0.0	0.0	11.2
Pumpkin	12.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0	13.2
Corn, Sweet	4.0	1.9	0.0	0.0	0.0	3.1	0.0	0.0	9.0
Carrot, Seed	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.6
Walnut	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0
Currant	0.0	6.1	0.0	0.0	0.0	0.0	0.0	0.0	6.1
Christmas Tree	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	2.8
Bulb, Allium	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5
Driving Range	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	2.8
Sunflower, Seed	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	2.1
Unknown	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	1.9
Orchard, Unknown	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	1.1
Total	18,810.3	9,606.3	3,526.3	473.7	1,075.9	145.6	87.2	2.2	33,727.4

Estimated Return Flow as Percent of Water Applied = 18.5%

Table A-24

Return Flow - YTID (acre-feet)

Return Flow	15%	15%	7%	30%	15%	**15.1%**
Crop Type	Sprinkler	Wheel Line	Drip	Rill	Unknown	Total
Apple	6,627.6	11.0	68.2	244.4	75.9	7,027.1
Pear	626.4	0.0	0.0	6.8	5.1	638.3
Cherry	412.4	0.0	0.0	0.0	0.0	412.4
Alfalfa/Grass, Hay	123.9	154.8	0.0	0.0	0.0	278.7
Grass, Hay	68.5	16.9	0.0	0.0	0.0	85.4
Golf Course	71.3	0.0	0.0	0.0	0.0	71.3
Alfalfa, Hay	19.6	22.0	0.0	0.0	0.0	41.6
Sod Farm	32.6	0.0	0.0	0.0	0.0	32.6
Caneberry	8.7	0.0	5.0	0.0	0.0	13.7
Barley	4.6	0.0	0.0	0.0	0.0	4.6
Nectarine/Peach	4.4	0.0	0.0	0.0	0.0	4.4
Orchard, Unknown	0.0	0.0	0.0	0.0	4.3	4.3
Grape, Wine	0.2	0.0	0.8	0.0	0.0	1.0
Walnut	1.5	0.0	0.0	0.0	0.0	1.5
Christmas Tree	1.2	0.0	0.0	0.0	0.0	1.2
Blueberry	0.8	0.0	0.0	0.0	0.0	0.8
Nursery, Lavender	0.0	0.0	0.1	0.0	0.0	0.1
Total	8,003.6	204.6	74.1	251.2	85.2	8,618.7

Estimated Return Flow as Percent of Water Applied = 15.1%

Table A-25

Return Flow - KID (acre-feet)

Return Flow	3%	15%	7%	15%	30%	15%	**10.1%**
Crop Type	Center Pivot	Sprinkler	Drip	Wheel Line	Rill	Hand	Total
Grape, Wine	0.0	2.3	382.0	0.0	0.0	0.0	384.3
Apple	0.0	848.5	34.8	0.0	0.0	0.0	883.3
Alfalfa, Hay	74.0	167.8	0.0	114.1	184.0	0.0	539.9
Wheat	51.5	37.6	0.0	33.4	58.1	0.0	180.7
Cherry	0.0	471.4	6.0	0.0	0.0	0.0	477.4
Asparagus	26.5	0.0	0.0	0.0	0.0	0.0	26.5
Alfalfa/Grass, Hay	19.7	45.9	0.0	21.8	0.0	0.0	87.4
Corn, Field	24.9	0.0	0.0	0.0	0.0	0.0	24.9
Potato	19.5	0.0	0.0	0.0	0.0	0.0	19.5
Corn, Sweet	13.1	0.0	0.0	0.0	0.0	0.0	13.1
Pasture	13.2	4.5	0.0	0.0	0.0	0.0	17.7
Pumpkin	8.1	0.0	0.0	0.0	0.0	0.0	8.1
Golf Course	0.0	93.4	0.0	0.0	0.0	0.0	93.4
Pear	0.0	47.5	0.0	0.0	0.0	0.0	47.5
Grass, Hay	0.0	18.8	0.0	15.5	0.0	0.0	34.3
Plum	0.0	5.8	0.0	0.0	0.0	0.0	5.8
Nectarine/Peach	0.0	4.5	0.0	0.0	0.0	0.0	4.5
Nursery, Ornamental	0.0	0.0	0.0	0.0	0.0	1.1	1.1
Walnut	0.0	1.0	0.0	0.0	0.0	0.0	1.0
Total	250.5	1,748.9	422.8	184.8	242.1	1.1	2,850.3

Estimated Return Flow as Percent of Water Applied = 10.1%

Table A-26

Evaporation Losses - KRD (acre-feet)

Evaporation Losses	5%	12%	10%	5%	10%	5%	10%	5%	**6.1%**
Crop Type	Rill	Center Pivot	Wheel Line	Flood	Sprinkler	Drip	Big Gun	Unknown	Total
Timothy	3,249.0	797.6	667.9	6.8	67.5	0.0	3.6	1.9	4,794.4
Pasture	692.9	128.8	104.9	584.6	49.0	0.0	3.1	0.0	1,563.2
Grass, Hay	366.8	102.9	119.2	0.0	3.6	0.0	15.7	0.0	608.3
Alfalfa, Hay	136.0	88.5	65.5	0.0	0.3	0.0	0.0	0.0	290.3
Wheat	138.3	56.7	33.7	0.0	0.0	0.0	0.0	0.0	228.7
Oat	135.1	58.9	36.9	0.0	12.3	0.0	0.0	0.0	243.2
Corn, Sweet	63.1	95.5	0.0	0.0	0.0	0.0	0.0	0.0	158.6
Sudangrass	117.3	25.8	20.6	0.0	0.0	0.0	0.0	0.0	163.7
Apple	0.0	0.0	0.0	0.0	112.5	16.9	0.0	0.0	129.4
Alfalfa/Grass, Hay	26.9	0.0	13.7	0.0	11.7	0.0	0.0	0.0	52.3
Barley	25.1	0.0	7.8	0.0	2.4	0.0	0.0	0.0	35.3
Pear	0.3	0.0	0.0	0.0	13.9	13.1	0.0	0.0	27.3
Potato	9.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.2
Cherry	0.0	0.0	0.0	0.0	24.3	0.0	0.0	0.0	24.3
Golf Course	0.0	0.0	0.0	0.0	17.7	0.0	0.0	0.0	17.7
Grape, Wine	0.0	0.0	0.0	0.0	0.2	0.6	0.0	0.0	0.8
Market Crops	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Sunflower, Seed	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Onion	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.3
Blueberry	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1
Total	4,960.4	1,355.1	1,070.3	591.4	315.8	30.7	22.4	1.9	8,347.9

Estimated Evaporation Loss as Percent of Water Applied = 6.1%

Table A-27

Evaporation Losses - Roza (acre-feet)

Evaporation Losses	10%	5%	5%	12%	10%	10%	10%	**8.9%**
Crop Type	Sprinkler	Drip	Rill	Center Pivot	Wheel Line	Unknown	Big Gun	Total
Apple	8,529.4	302.9	41.6	0.0	0.0	4.6	0.0	8,878.5
Grape, Wine	529.9	996.3	3.4	0.0	0.0	0.0	0.0	1,529.6
Grape, Concord	1,860.0	126.0	402.6	0.0	0.0	0.0	0.0	2,388.6
Cherry	2,000.5	23.5	5.5	0.0	0.0	0.0	0.0	2,029.5
Hops	0.0	392.9	17.5	0.0	0.0	0.0	0.0	410.3
Alfalfa, Hay	182.0	0.0	11.9	43.9	690.2	0.0	0.0	928.0
Pear	886.2	4.8	0.0	0.0	0.0	0.0	0.0	891.0
Corn, Field	0.0	0.0	99.2	393.9	32.7	0.0	0.0	525.8
Wheat	30.6	0.0	15.3	144.0	73.4	17.7	0.0	281.0
Sorghum	5.1	0.0	0.6	230.7	35.6	2.4	61.5	335.9
Nectarine/Peach	263.1	1.0	0.0	0.0	0.0	0.0	0.0	264.2
Triticale	0.0	0.0	0.0	141.0	25.6	0.0	0.9	167.5
Asparagus	70.6	0.0	55.5	0.0	0.0	0.0	0.0	126.1
Research Station	0.0	48.2	0.0	0.0	11.1	0.0	0.0	59.3
Apricot	76.4	7.3	1.8	0.0	0.0	0.0	0.0	85.5
Alfalfa/Grass, Hay	43.2	0.0	0.0	15.8	41.7	0.0	0.0	100.8
Green Manure	6.1	0.0	7.2	0.0	4.9	37.7	0.0	55.9
Caneberry	0.0	37.6	0.0	0.0	0.0	0.0	0.0	37.6
Nursery, Orchard/Vineyard	32.9	0.0	11.6	0.0	3.2	0.0	0.0	47.7
Corn, Sweet	0.0	0.0	18.3	0.0	0.0	0.0	0.0	18.3
Rye	0.0	0.0	0.0	10.8	26.3	0.0	0.0	37.1
Unknown	0.0	0.0	0.0	0.0	0.0	43.7	0.0	43.7
Mint	0.0	0.0	10.1	0.0	25.8	0.0	0.0	35.9
Squash	0.0	7.7	0.0	0.0	0.0	0.0	0.0	7.7
Grass, Hay	4.5	0.0	0.0	0.0	29.2	5.7	0.0	39.4
Nursery, Ornamental	32.5	0.0	0.0	0.0	0.0	0.0	0.0	32.5
Corn, Seed	0.0	0.0	1.0	29.4	0.0	0.0	0.0	30.4
Currant	0.0	0.0	15.8	0.0	0.0	0.0	0.0	15.8
Pumpkin	0.0	5.7	0.0	0.0	0.0	0.0	0.0	5.7
Blueberry	0.4	9.6	0.0	0.0	0.0	0.0	0.0	10.0
Potato	0.0	0.0	10.5	0.0	0.0	0.0	0.0	10.5
Pasture	10.6	0.0	0.0	0.0	5.3	0.0	0.0	15.9
Tomato	0.0	0.0	8.2	0.0	0.0	0.0	0.0	8.2
Plum	19.5	0.0	0.0	0.0	0.0	0.0	0.0	19.5
Herb, Medicinal	0.0	0.0	0.0	17.0	0.0	0.0	0.0	17.0
Barley	8.3	0.0	0.0	0.0	0.0	0.0	0.0	8.3
Hay/Silage, Unknown	0.0	0.0	0.0	0.0	0.0	5.0	0.0	5.0
Market Crops	0.0	0.0	1.3	0.0	0.0	0.0	0.0	1.3
Total	14,592.1	1,963.4	738.7	1,026.5	1,005.0	116.7	62.4	19,504.9

Estimated Evaporation Loss as Percent of Water Applied = 8.9%

Table A-28

Evaporation Losses - WIP (acre-feet)

Evaporation Losses	5%	10%	10%	5%	12%	10%	10%	**7.5%**
Crop Type	Rill	Wheel Line	Sprinkler	Drip	Center Pivot	Unknown	Big Gun	Total
Corn, Field	2,879.5	79.5	34.7	0.0	1,309.7	0.0	31.2	4,334.6
Wheat	998.2	1,229.5	59.7	0.0	648.1	0.0	0.0	2,935.6
Hops	326.1	26.0	14.7	1,671.6	0.0	13.3	0.0	2,051.7
Alfalfa, Hay	222.3	2,621.3	122.7	0.0	1,563.4	0.0	0.0	4,529.7
Apple	136.2	18.9	4,125.0	5.1	67.7	5.4	0.0	4,358.4
Mint	1,192.4	1,048.8	85.4	0.0	50.7	11.4	0.0	2,388.6
Grape, Concord	546.5	0.0	267.7	35.6	0.0	7.3	0.0	857.2
Alfalfa/Grass, Hay	73.5	413.6	78.8	0.0	20.3	8.6	0.0	594.9
Pasture	119.5	176.9	139.1	0.0	32.9	0.0	2.0	470.4
Asparagus	240.5	40.6	0.0	0.0	74.2	0.0	0.0	355.3
Grass, Hay	65.0	306.3	90.7	0.0	41.2	0.0	0.0	503.2
Nectarine/Peach	0.0	0.0	481.6	0.0	0.0	0.0	0.0	481.6
Potato	159.5	32.4	0.0	5.3	0.0	0.0	0.0	197.3
Pear	40.0	0.0	367.2	0.0	0.0	0.0	0.0	407.2
Corn, Sweet	48.4	35.5	0.0	27.7	0.0	0.0	0.0	111.7
Onion	12.8	34.4	0.0	87.5	0.0	0.0	0.0	134.7
Market Crops	33.7	64.4	2.0	30.1	0.0	0.0	0.0	130.1
Cherry	4.6	0.0	312.7	0.4	0.0	0.0	0.0	317.7
Bean, Dry	18.8	73.1	0.0	0.0	36.4	0.0	0.0	128.3
Sorghum	6.2	107.2	4.3	0.0	0.0	0.0	0.0	117.7
Pepper	7.5	6.3	0.4	43.7	0.0	0.0	0.0	57.9
Unknown	0.0	0.0	0.0	0.0	44.5	41.8	0.0	86.4
Nursery, Orchard/Vineyard	22.2	0.0	0.0	17.6	0.0	0.0	0.0	39.8
Squash	6.6	6.9	0.0	7.5	0.0	0.0	0.0	21.0
Corn, Seed	37.0	0.0	0.0	0.0	0.0	0.0	0.0	37.0
Dill	0.0	52.2	0.0	0.0	0.0	0.0	0.0	52.2
Oat	6.4	25.7	0.0	0.0	0.0	0.0	0.0	32.1
Nursery, Ornamental	0.0	0.0	28.5	6.0	0.0	0.0	0.0	34.6
Timothy	0.0	50.1	0.0	0.0	0.0	0.0	0.0	50.1
Golf Course	0.0	0.0	40.0	0.0	0.0	0.0	0.0	40.0
Bluegrass, Seed	0.0	27.9	0.0	0.0	0.0	0.0	0.0	27.9
Plum	8.6	0.0	19.7	0.0	0.0	0.0	0.0	28.3
Apricot	0.0	0.0	32.2	0.0	0.0	0.0	0.0	32.2
Cucumber	0.0	5.9	0.0	3.9	0.0	0.0	0.0	9.9
Carrot, Seed	5.7	12.0	0.0	0.0	0.0	0.0	0.0	17.6
Clover, Seed	0.0	21.4	0.0	0.0	0.0	0.0	0.0	21.4
Tomato	0.5	0.0	0.0	7.2	0.0	0.0	0.0	7.7
Cabbage	8.6	1.5	0.0	0.0	0.0	0.0	0.0	10.1
Pumpkin	1.9	0.0	0.0	2.4	0.0	0.0	0.0	4.3
Canola	0.0	0.0	0.0	0.0	14.2	0.0	0.0	14.2
Broccoli, Seed	0.0	0.0	0.0	0.0	14.1	0.0	0.0	14.1
Vegetable, Unknown	5.9	0.0	0.0	0.0	0.0	0.0	0.0	5.9
Bean, Green	1.5	2.6	0.0	0.0	0.0	0.0	0.0	4.1
Watermelon	0.0	0.0	0.0	1.7	0.0	0.0	0.0	1.7
Sunflower, Seed	4.6	0.0	0.0	0.0	0.0	0.0	0.0	4.6
Blueberry	0.0	0.0	4.8	0.0	0.0	0.0	0.0	4.8
Sage	2.3	0.0	0.0	0.0	0.0	0.0	0.0	2.3
Grape, Wine	0.0	0.0	0.0	1.3	0.0	0.0	0.0	1.3
Driving Range	0.0	0.0	1.1	0.0	0.0	0.0	0.0	1.1
Alfalfa, Seed	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.3
Total	7,243.1	6,521.1	6,313.1	1,954.8	3,917.4	87.8	33.2	26,070.4

Estimated Evaporation Loss as Percent of Water Applied = 7.5%

Table A-29

Evaporation Losses - SVID (acre-feet)

Evaporation Losses	5%	10%	10%	12%	5%	10%	10%	10%	**8.0%**
Crop Type	Rill	Sprinkler	Wheel Line	Center Pivot	Drip	Unknown	Big Gun	Hand	Total
Grape, Concord	949.2	1,394.0	0.0	0.0	42.0	6.8	0.0	0.0	2,392.0
Corn, Field	1,119.4	47.9	32.2	992.2	0.0	24.0	34.9	0.0	2,250.6
Alfalfa, Hay	181.8	520.1	1,221.7	473.1	0.0	1.8	0.0	0.0	2,398.5
Hops	294.6	6.9	0.0	0.0	572.5	0.0	0.0	0.0	874.0
Cherry	17.7	1,857.7	0.0	0.0	20.4	0.0	0.0	0.0	1,895.8
Apple	7.1	1,609.2	0.0	0.0	12.1	0.0	0.0	0.0	1,628.4
Wheat	43.9	5.4	177.5	123.0	0.0	14.4	0.0	0.0	364.2
Asparagus	228.6	22.2	19.4	0.0	0.0	3.0	0.0	0.0	273.2
Alfalfa/Grass, Hay	5.8	74.3	339.2	69.0	0.0	0.0	0.0	0.0	488.4
Grape, Wine	0.2	95.6	0.0	0.0	87.6	0.0	0.0	0.0	183.3
Mint	127.0	27.4	97.2	0.0	0.0	7.7	0.0	0.0	259.3
Sorghum	3.0	1.1	106.1	83.6	0.0	0.0	0.0	0.0	193.7
Triticale	31.2	8.0	56.3	60.9	0.0	3.2	0.0	0.0	159.6
Grass, Hay	16.2	112.1	153.6	0.0	0.0	9.9	0.0	0.0	291.9
Pear	13.6	260.5	0.0	0.0	0.0	0.0	0.0	0.0	274.1
Pasture	4.2	36.8	82.7	63.1	0.0	0.0	0.0	0.0	186.7
Nursery, Ornamental	17.6	62.5	0.0	0.0	13.1	5.2	0.0	1.5	99.8
Squash	20.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.3
Oat	2.8	0.0	21.4	19.1	0.0	0.0	0.0	0.0	43.4
Research Station	0.0	53.6	0.0	0.0	0.0	0.0	0.0	0.0	53.6
Plum	4.7	52.1	0.0	0.0	0.3	0.0	0.0	0.0	57.1
Golf Course	0.0	54.8	0.0	0.0	0.0	0.0	0.0	0.0	54.8
Barley	3.3	13.5	8.5	0.0	0.0	0.0	0.0	0.0	25.2
Corn, Seed	20.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	21.3
Rye	0.0	1.7	10.6	10.7	0.0	0.0	0.0	0.0	23.1
Nectarine/Peach	3.2	32.3	0.0	0.0	0.0	0.0	0.0	0.0	35.5
Watermelon	0.0	0.0	0.0	0.0	5.4	0.0	0.0	0.0	5.4
Market Crops	8.2	4.1	0.0	0.0	0.0	1.2	0.0	0.0	13.6
Canola	0.0	0.0	24.5	0.0	0.0	0.0	0.0	0.0	24.5
Caneberry	0.0	0.0	0.0	0.0	13.3	0.0	0.0	0.0	13.3
Poplar, Hybrid	0.0	0.0	0.0	0.0	0.9	15.7	0.0	0.0	16.6
Green Manure	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0
Bulb, Iris	4.6	1.7	0.0	0.0	0.0	0.0	0.0	0.0	6.3
Nursery, Silvaculture	0.0	7.4	0.0	0.0	0.8	0.0	0.0	0.0	8.2
Apricot	0.0	10.3	0.0	0.0	0.0	0.0	0.0	0.0	10.3
Nursery, Orchard/Vineyard	0.0	7.5	0.0	0.0	0.0	0.0	0.0	0.0	7.5
Pumpkin	2.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	2.4
Corn, Sweet	0.7	1.2	0.0	0.0	0.0	2.1	0.0	0.0	4.0
Carrot, Seed	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8
Walnut	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0
Currant	0.0	4.1	0.0	0.0	0.0	0.0	0.0	0.0	4.1
Christmas Tree	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	1.8
Bulb, Allium	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Driving Range	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	1.9
Sunflower, Seed	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	1.4
Unknown	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	1.3
Orchard, Unknown	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.7
Total	3,135.0	6,404.2	2,350.9	1,894.7	768.5	97.1	34.9	1.5	14,686.7

Estimated Evaporation Loss as Percent of Water Applied = 8.0%

Table A-30

Evaporation Losses - YTID (acre-feet)

Evaporation Losses	10%	10%	5%	5%	10%	**9.8%**
Crop Type	Sprinkler	Wheel Line	Drip	Rill	Unknown	Total
Apple	4,418.4	7.3	48.7	40.7	50.6	4,565.8
Pear	417.6	0.0	0.0	1.1	3.4	422.1
Cherry	274.9	0.0	0.0	0.0	0.0	274.9
Alfalfa/Grass, Hay	82.6	103.2	0.0	0.0	0.0	185.8
Grass, Hay	45.7	11.2	0.0	0.0	0.0	56.9
Golf Course	47.5	0.0	0.0	0.0	0.0	47.5
Alfalfa, Hay	13.1	14.6	0.0	0.0	0.0	27.7
Sod Farm	21.7	0.0	0.0	0.0	0.0	21.7
Caneberry	5.8	0.0	3.5	0.0	0.0	9.3
Barley	3.1	0.0	0.0	0.0	0.0	3.1
Nectarine/Peach	2.9	0.0	0.0	0.0	0.0	2.9
Orchard, Unknown	0.0	0.0	0.0	0.0	2.9	2.9
Grape, Wine	0.1	0.0	0.6	0.0	0.0	0.7
Walnut	1.0	0.0	0.0	0.0	0.0	1.0
Christmas Tree	0.8	0.0	0.0	0.0	0.0	0.8
Blueberry	0.5	0.0	0.0	0.0	0.0	0.5
Nursery, Lavender	0.0	0.0	0.1	0.0	0.0	0.1
Total	5,335.7	136.4	52.9	41.9	56.8	5,623.7

Estimated Evaporation Loss as Percent of Water Applied = 9.8%

Table A-31

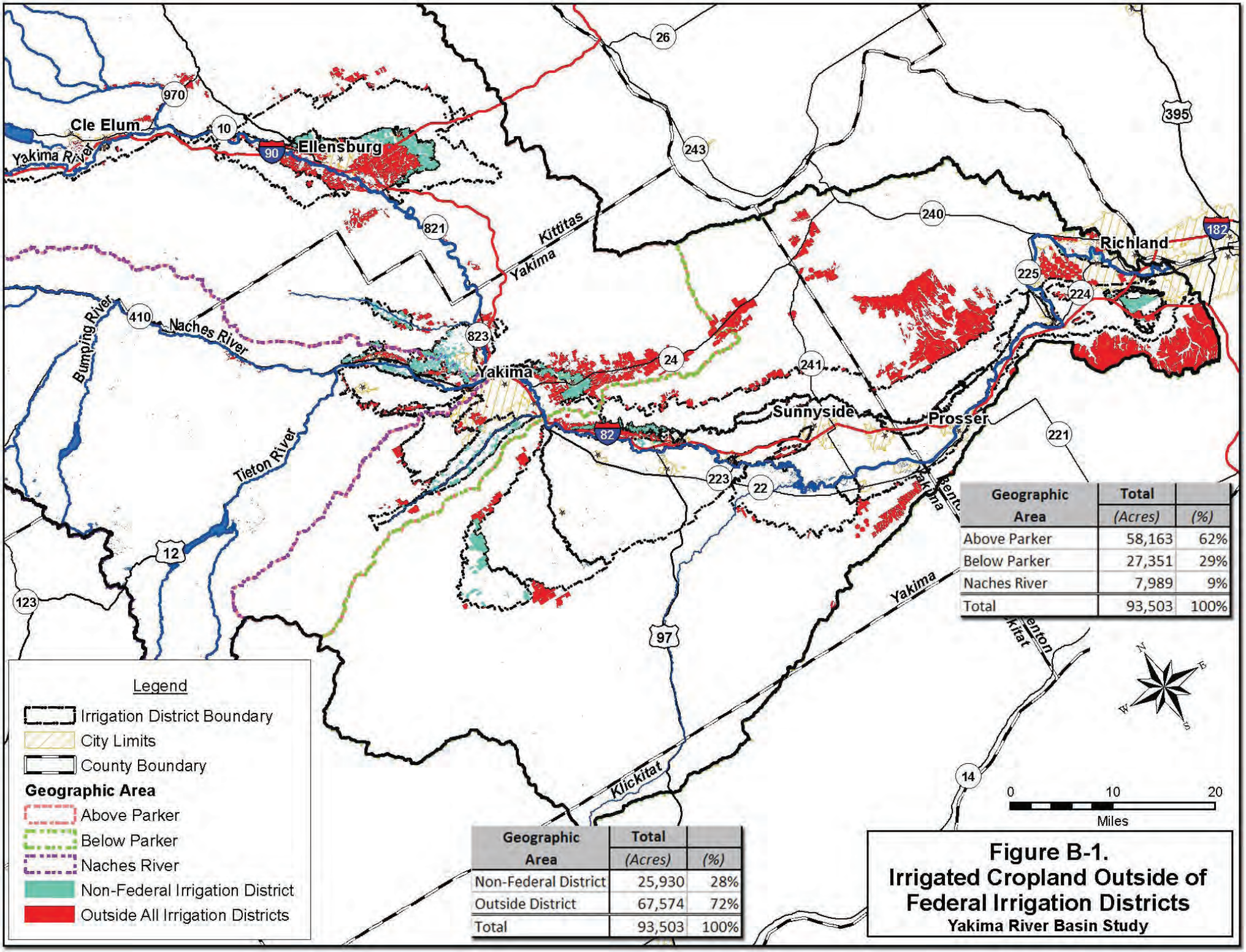
Evaporation Losses - KID (acre-feet)

Evaporation Losses	12%	10%	5%	10%	5%	10%	**9.4%**
Crop Type	Center Pivot	Sprinkler	Drip	Wheel Line	Rill	Hand	Total
Grape, Wine	0.0	1.5	272.8	0.0	0.0	0.0	274.4
Apple	0.0	565.6	24.9	0.0	0.0	0.0	590.5
Alfalfa, Hay	296.2	111.9	0.0	76.1	30.7	0.0	514.8
Wheat	206.1	25.1	0.0	22.3	9.7	0.0	263.1
Cherry	0.0	314.3	4.3	0.0	0.0	0.0	318.6
Asparagus	106.0	0.0	0.0	0.0	0.0	0.0	106.0
Alfalfa/Grass, Hay	78.8	30.6	0.0	14.5	0.0	0.0	123.9
Corn, Field	99.4	0.0	0.0	0.0	0.0	0.0	99.4
Potato	77.9	0.0	0.0	0.0	0.0	0.0	77.9
Corn, Sweet	52.3	0.0	0.0	0.0	0.0	0.0	52.3
Pasture	52.9	3.0	0.0	0.0	0.0	0.0	55.9
Pumpkin	32.3	0.0	0.0	0.0	0.0	0.0	32.3
Golf Course	0.0	62.2	0.0	0.0	0.0	0.0	62.2
Pear	0.0	31.6	0.0	0.0	0.0	0.0	31.6
Grass, Hay	0.0	12.5	0.0	10.3	0.0	0.0	22.9
Plum	0.0	3.8	0.0	0.0	0.0	0.0	3.8
Nectarine/Peach	0.0	3.0	0.0	0.0	0.0	0.0	3.0
Nursery, Ornamental	0.0	0.0	0.0	0.0	0.0	0.8	0.8
Walnut	0.0	0.7	0.0	0.0	0.0	0.0	0.7
Total	1,001.9	1,166.0	302.0	123.2	40.4	0.8	2,634.2

Estimated Evaporation Loss as Percent of Water Applied = 9.4%

Appendix B

Agricultural Uses Supplied by Non-Federal Sources



Geographic Area	Total (Acres)	(%)
Above Parker	58,163	62%
Below Parker	27,351	29%
Naches River	7,989	9%
Total	93,503	100%

Geographic Area	Total (Acres)	(%)
Non-Federal District	25,930	28%
Outside District	67,574	72%
Total	93,503	100%

Figure B-1.
Irrigated Cropland Outside of Federal Irrigation Districts
Yakima River Basin Study

Federal and Non-federal Acreage

Tables B-1 and B-2 provide a summary of the crop acreage identified in the Yakima basin by location within federally-supplied districts, other districts, or outside all districts.

Table B-1 presents the acreage with irrigation type "none" (e.g., not irrigated in 2008); irrigated acreage, and the total acreage. The yellow highlight in the center columns of Table B-1 indicates the acreage that was included in the analysis of non-federal irrigation demand (a different approach was used to estimate federal project demand as described elsewhere in this report).

Table B-2 presents a summary of the irrigated acreage (yellow highlighted columns from Table B-1) by number and percentage.

Table B-1. Estimated Acreage by Irrigation District & Federal Project Location

Geographic Area	Acres with Irrigation Type = "None" or "#N/A"			Acres with Specified Irrigation Type			Total Acres		
	Surface Water	Ground Water - Primary	Total	Surface Water	Ground Water - Primary	Total	Surface Water	Ground Water - Primary	Total
	(Acres)	*(Acres)*	*(Acres)*	*(Acres)*	*(Acres)*	*(Acres)*	*(Acres)*	*(Acres)*	*(Acres)*
Non-Federal District	1,463	0	1,463	25,930	0	25,930	27,393	0	27,393
Federal District	4,824	0	4,824	265,408	0	265,408	270,232	0	270,232
Outside District	44,115	26,713	70,828	26,564	41,010	67,574	70,679	67,723	138,401
Total	50,402	26,713	77,115	317,901	41,010	358,911	368,303	67,723	436,026

Table B-2. Non-Federal Acreage by Project/District Location (Excluding NONE)

Geographic Area	Total	
	(Acres)	*(%)*
Federal District	265,408	74%
Non-Federal District	25,930	7%
Outside District	67,574	19%
Total	358,911	100%

Acreage Irrigated by Non-Federal Sources

Tables B-3 and B-4 provide a summary of the non-federally supplied crop acreage by diversion sources above and below Parker and in the Naches River Basin.

Table B-3 presents the acreage with irrigation type "none" (e.g., not irrigated in 2008); irrigated acreage, and the total acreage. The yellow highlight in the center columns of Table B-3 indicates the acreage that was included in the characterization of non-federal irrigation demand.

Table B-4 presents a summary of the yellow highlighted columns from Table B-3 by number and percentage.

Table B-3. Estimated Acreage by Diversion Source (Excluding Federal Project)

Geographic Area	Acres with Irrigation Type = "None"			Acres with Specified Irrigation Type			Total Acres		
	Surface Water (Acres)	Ground Water - Primary (Acres)	Total (Acres)	Surface Water (Acres)	Ground Water - Primary (Acres)	Total (Acres)	Surface Water (Acres)	Ground Water - Primary (Acres)	Total (Acres)
Above Parker	4,182	2,143	6,325	36,942	21,221	58,163	41,124	23,364	64,488
Below Parker	40,820	24,302	65,122	10,649	16,703	27,351	51,468	41,005	92,473
Naches River	577	268	844	4,903	3,086	7,989	5,480	3,354	8,833
Total	45,578	26,713	72,291	52,494	41,010	93,503	98,072	67,723	165,794

Note: Excludes All Acreage Inside of the Federal Project.

Table B-4. Non-Federal Acreage by Diversion Source (Excluding NONE)

Geographic Area	Total	
	(Acres)	(%)
Above Parker	58,163	62%
Below Parker	27,351	29%
Naches River	7,989	9%
Total	93,503	100%

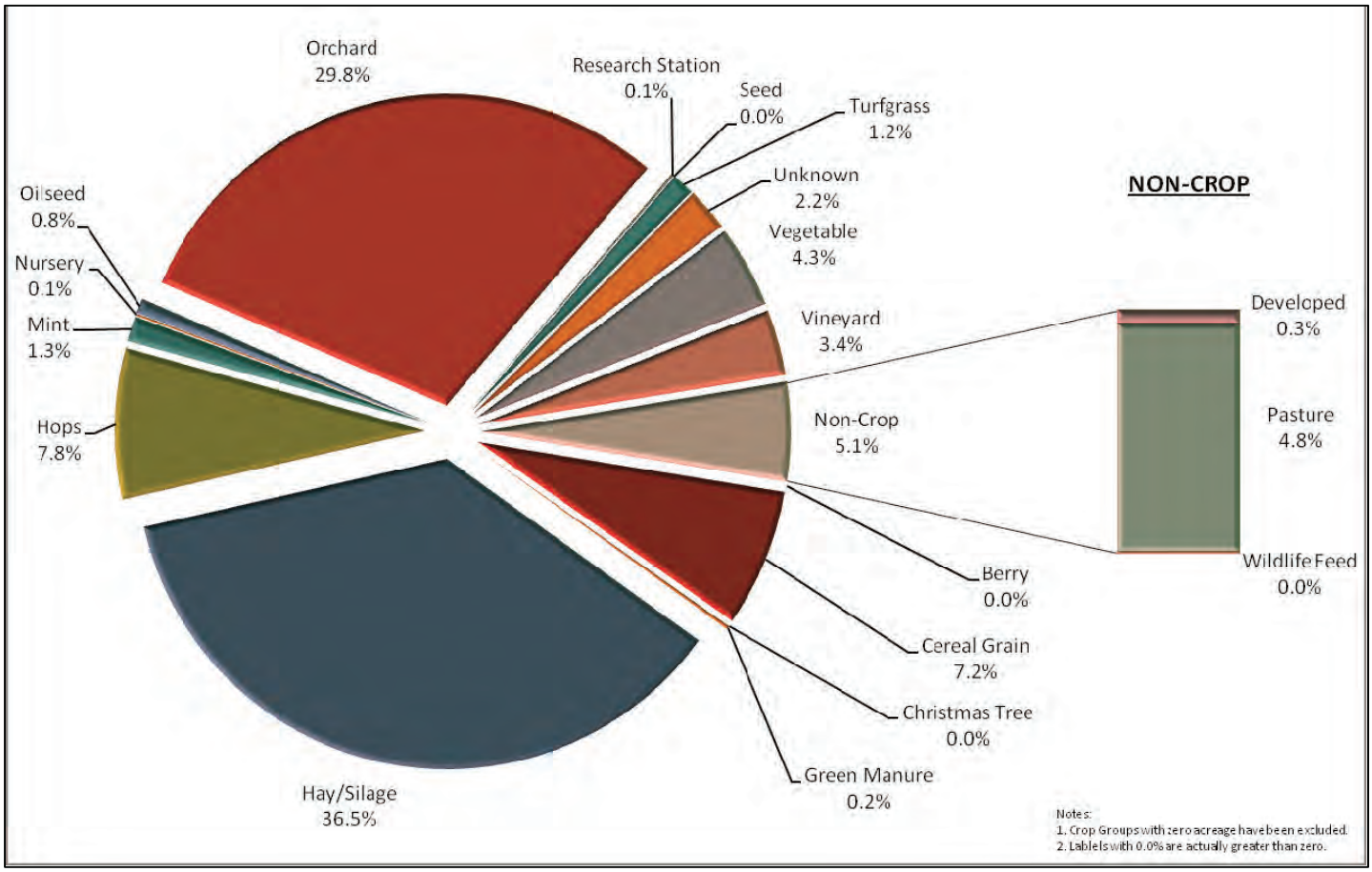
Notes: Excludes All Acreage Inside of the Federal Project.

Excludes Acreage with Irrigation Method of "NONE".

Crop Types

Figure B-2 presents a summary of the crop types found in the non-federally supplied irrigated acreage.

Figure B-2. Non-Federal Irrigated Acreage



Non-federal Irrigation Demand – Annual

Table B-5 summarizes the estimated annual irrigation demand for non-federal irrigated acreage, including acreage within districts that do not receive federal supplies and acreage outside all districts. The demands for each location are then shown by diversion source (above and below Parker and Naches River basin).

Table B-5. Non-Federal Acreage, Requirements, Losses, and Diversions

Geographic Area	Acres Irrigated			Annual Irrigation Requirement			Annual Irrigation Efficiency Loss			Annual Conveyance Efficiency Loss			Estimated Annual Diversions		
	Surface Water (Acres)	Groundwater - Primary (Acres)	Total (Acres)	Surface Water (Acre-Feet)	Groundwater - Primary (Acre-Feet)	Total (Acre-Feet)	Surface Water (Acre-Feet)	Groundwater - Primary (Acre-Feet)	Total (Acre-Feet)	Surface Water (Acre-Feet)	Groundwater - Primary (Acre-Feet)	Total (Acre-Feet)	Surface Water (Acre-Feet)	Groundwater - Primary (Acre-Feet)	Total (Acre-Feet)
Non-Federal District															
Above Parker	18,492	0	18,492	52,293	0	52,293	29,252	0	29,252	43,909	0	43,909	125,454	0	125,454
Below Parker	2,534	0	2,534	8,117	0	8,117	2,168	0	2,168	5,538	0	5,538	15,823	0	15,823
Naches River	4,903	0	4,903	16,510	0	16,510	5,372	0	5,372	11,783	0	11,783	33,665	0	33,665
Subtotal Non-Federal District	25,930	0	25,930	76,920	0	76,920	36,792	0	36,792	61,230	0	61,230	174,942	0	174,942
Outside District															
Above Parker	18,450	21,221	39,671	45,772	61,581	107,353	37,156	20,273	57,429	44,654	0	44,654	127,582	81,854	209,436
Below Parker	8,114	16,703	24,817	23,878	50,769	74,647	6,061	15,178	21,239	16,121	0	16,121	46,060	65,947	112,007
Naches River	0	3,086	3,086	0	9,955	9,955	0	3,347	3,347	0	0	0	0	13,302	13,302
Subtotal Outside District	26,564	41,010	67,574	69,651	122,304	191,955	43,217	38,798	82,015	60,775	0	60,775	173,642	161,102	334,745
Total Non-Federal	52,494	41,010	93,503	146,571	122,304	268,875	80,009	38,798	118,808	122,005	0	122,005	348,584	161,102	509,687

Notes: 1. Excludes All Acreage Inside of the Federal Project.

2. Excludes fields with Irrigation types of "None" and "N/A".

Non-federal Irrigation Demand - monthly

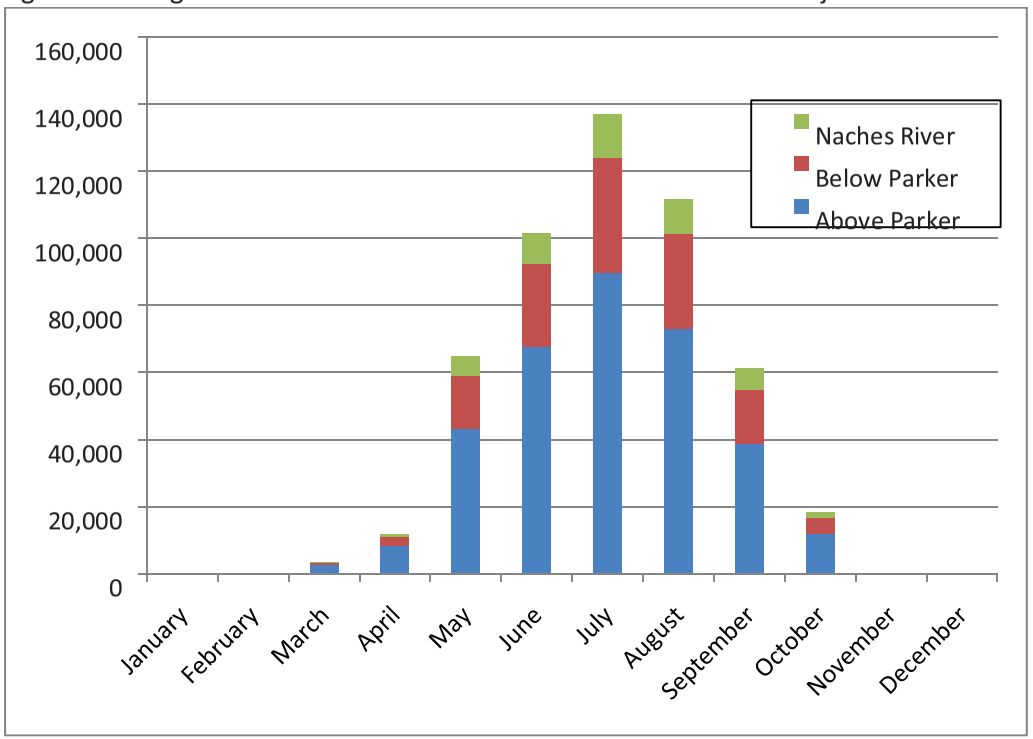
Table B-6 and Figure B-3 summarize the estimated monthly non-federal irrigation demand by diversion source (above and below Parker and Naches River basin).

Table B-6. Estimated Monthly Non-Project Diversion and Acreage by Diversion Source (Excludes All Acreage Inside of the Federal Project)

Geographic Area	Acres Irrigated			Estimated Diversion											
	Surface Water (Acres)	Ground Water - Primary (Acres)	Total (Acres)	January (Acre-Feet)	February (Acre-Feet)	March (Acre-Feet)	April (Acre-Feet)	May (Acre-Feet)	June (Acre-Feet)	July (Acre-Feet)	August (Acre-Feet)	September (Acre-Feet)	October (Acre-Feet)	November (Acre-Feet)	December (Acre-Feet)	Total (Acre-Feet)
Above Parker	36,942	21,221	58,163	0	0	2,780	8,145	43,191	67,603	89,513	73,080	38,668	11,910	0	0	334,890
Below Parker	10,649	16,703	27,351	0	0	454	2,925	15,715	24,903	34,581	28,404	16,077	4,772	0	0	127,830
Naches River	4,903	3,086	7,989	0	0	83	740	5,678	9,134	12,842	10,340	6,363	1,788	0	0	46,967
Total	52,494	41,010	93,503	0	0	3,316	11,810	64,584	101,640	136,936	111,823	61,108	18,470	0	0	509,687

Notes: 1. Excludes All Acreage Inside of the Federal Project.
2. Excludes fields with Irrigation types of "None" and "N/A".

Figure B-3. Irrigation Demand for “Outside District” and “Outside Project-Inside District”



Appendix C

Estimates of Climate Change Effects on Crop Irrigation Requirements

Appendix C
Estimates of Climate Change Effects on Crop Irrigation Requirements

Introduction

The University of Washington (UW) Climate Impacts Group published estimates of future crop water demands for two important crops in the Yakima River Basin: cherries and apples (UW 2009). The UW study predicted that the net irrigation requirements for apples under climate change conditions would decrease by 20 percent by the 2040s because of a shorter fruit-growing season, even though temperatures would increase and precipitation would slightly decrease.

The reduction in net irrigation requirement for cherries in the 2040s was even greater than apples. The Out-of-Stream Water Needs Subcommittee of the YRBWEP Workgroup, which includes irrigation district managers and fruit tree growers did not believe this to be accurate because of water needs for cooling and groundcover in orchards. The subcommittee also noted that limiting the analysis to apples and cherries does not account for the full range of crops grown in the Yakima River Basin. Therefore the subcommittee asked the consultant team to develop another estimate.

This estimate of future water needs under climate change conditions is preliminary and is based on available data and reports. Since estimates of water needs for agriculture contained in the Out-of-Stream Water Needs Technical Memorandum are based on the Washington Irrigation Guide (WIG) (U.S. Department of Agriculture 1985), the WIG is also used in this estimate to ensure consistency in the calculations.

The estimates of future water use will be used in the RiverWare model to test the effectiveness of the Integrated Water Resource Management Plan in meeting the challenges of changing runoff patterns and water demands. We understand that a much more comprehensive analysis of future water needs will be performed by Washington State University as part of their contract with Washington State Department of Ecology for the Columbia River Water Supply Investment Plan: A Strategy to Develop Water Supply to Meet Water Demand Through 2030.

Methodology

The consultant team did not have access to the detailed modeling that predicted future crop water needs for the UW study and therefore could not review its methodology. Since the Water Needs study is supposed to use existing, published information and budget was not available for the type of modeling used in the UW study, a simpler approach was used. This approach compares the UW estimates of current and future potential evapotranspiration (PET) for a reference crop of short grass and applies the ratio of those PETs to the irrigation requirements listed in the WIG for short grass and other crops that are grown in the Yakima River Basin.

The specific steps followed are summarized below.

* We obtained estimates of current and future PET rates for the standard reference crop of short grass from the UW study for locations in the Yakima River Basin.

* We obtained estimates of future precipitation rates from UW study for locations in the Yakima River Basin to compare to existing rates.

- We estimated future effective precipitation rates using current estimates of effective precipitation in the WIG. Effective precipitation is defined as the amount of precipitation that enters the soil and becomes available to the plant for growth. It is less than total precipitation because of surface evaporation of small amounts of rainfall and runoff or deep percolation of larger amounts of rainfall.

- We estimated future irrigation requirements for individual crops by multiplying estimates of evapotranspiration (ET) for those crops (as derived from WIG) by the ratio of future-to-current PET of the reference crop and subtracting the future effective precipitation. We used the same growing season listed in the WIG. We multiplied the future irrigation requirements for each crop by their acreage in each Yakima Project district to obtain a weighted estimate of future water needs. That estimate was then compared to estimates of current water needs to estimate the percentage increase in future water needs. Changes in crop mix due to climate change and market forces are not considered in this estimate.

The result of these calculations is an estimate of the percentage increase in out-of-stream water needs, by district, in the Yakima Project. We used this estimate to adjust the demands in the RiverWare model to represent potential future demands under the climate change scenario selected for this study. The estimate is based on averaged climatic conditions, including precipitation predicted for the 2040s. Since crop water needs will vary from year to year based on climate conditions, this estimate should be viewed only as indicative of potential water demands.

The results provided below show detailed calculations performed for the Sunnyside weather station. The same procedure was followed for other weather stations that represent crop water demands in the Yakima River Basin, as described in Section 3.4 of the Water Needs for Out-of Stream Uses Technical Memorandum.

Current and Future PET for Sunnyside

Current and future PET rates for the short grass reference crop at Sunnyside were estimated using UW's monthly grid climate change model data. Using the full period of record (water years 1926-2006), average monthly PET rates were computed by UW for current and future conditions for the reference crop. The current PET rates are based on the historical model, and the future PET rates are based on the 2040s (2030-2059) "moderate effect" climate change model (Model 6 – HAD-CM B1) selected for the Yakima Basin Study RiverWare model run. Table 1 presents the estimated PET rates for the reference crop at the Sunnyside station.

Table 1. Estimated Monthly Potential Evapotranspiration Rates for Reference Crop (Short Grass) – Sunnyside Station													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Current PET	1.19	1.86	3.24	4.47	6.03	6.84	7.72	6.46	4.25	2.65	1.70	1.19	47.61
Future PET	1.21	1.80	3.20	4.46	6.26	7.20	8.38	7.10	4.65	2.73	1.68	1.16	49.83
Ratio	102%	97%	99%	100%	104%	105%	108%	110%	109%	103%	99%	97%	105%
Notes: PET (potential evapotranspiration) values in inches. Data from UW (2009) Study; "Future PET" represents 2040s rate using "moderate effect" climate change model.													

Current and Future Precipitation for Sunnyside

Current and future precipitation rates for Sunnyside were estimated using UW's monthly grid climate change model data. Using the full period of record (Water Years 1926-2006), average monthly precipitation rates were computed by UW for current and future conditions. The current precipitation rates are based on the historical model, and the future precipitation rates are based on the 2040s (2030-2059) "moderate effect" climate change model (Model 6 – HAD-CM B1). Table 2 presents the estimated precipitation rates for the Sunnyside station.

Table 2. Estimated Monthly Precipitation Rates – Sunnyside Station													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Current	0.92	0.62	0.64	0.53	0.50	0.45	0.15	0.29	0.51	0.60	0.89	1.13	7.24
Future	0.88	0.64	0.73	0.46	0.42	0.33	0.15	0.17	0.24	0.68	1.07	1.10	6.87
Difference	-0.04	0.02	0.09	-0.07	-0.08	-0.12	0.00	-0.12	-0.27	0.08	0.18	-0.03	-0.37
Notes: All values in inches. Data from UW (2009) Study; "Future" represents 2040s rate using "moderate effect" climate change model.													

Change in Effective Precipitation Rates

Future effective precipitation rates were estimated by using the ratio of effective-to-total precipitation that is contained in the WIG and applying that ratio to future precipitation estimates. Because the estimates of future precipitation rates are slightly less than current rates, this methodology should give slightly conservative results (lower effective precipitation values leading to slightly higher crop irrigation requirements). That is because a greater percentage of the precipitation can be effective at lower precipitation rates. Table 3 gives the monthly total precipitation and effective precipitation rates from the WIG.

Table 3. Monthly Precipitation Rates – Sunnyside Station													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Total	1.03	0.58	0.42	0.51	0.53	0.45	0.20	0.30	0.37	0.49	0.83	0.99	6.70
Effective	0.00	0.23	0.27	0.38	0.45	0.42	0.20	0.28	0.29	0.32	0.16	0.00	3.00
Ratio	0%	40%	64%	75%	85%	93%	100%	93%	78%	65%	19%	0%	45%
Notes: All values in inches. Source of data: WIG (US Department of Agriculture 1985).													

Table 4 gives the estimated change in effective precipitation based on the change in precipitation rates shown in Table 2 and the percentage of effective precipitation from Table 3.

Table 4. Estimated Change in Effective Precipitation Rates – Sunnyside Station												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Change in Precipitation	-0.04	0.02	0.09	-0.07	-0.08	-0.12	0.00	-0.12	-0.27	0.08	0.18	-0.03
Ratio of Effective to Total	0%	40%	64%	75%	85%	93%	100%	93%	78%	65%	19%	0%
Change in Effective Precipitation	0.00	0.01	0.06	-0.05	-0.07	-0.11	0.00	-0.11	-0.21	0.05	0.03	0.00
Note: Precipitation values in inches.												

Estimated Future Irrigation Requirements

The procedure for estimating crop irrigation requirements (CIRs) is to estimate the individual crop ET and subtract the effective precipitation. The individual crop ET is estimated by multiplying the PET for a reference crop by coefficients that represent the difference in water demand by month between the reference crop and the individual crop. WIG estimates of crop irrigation requirements factor in those coefficients. Previous calculations of CIRs for the Yakima River Basin Study that are contained in the Out-of-Stream Water Needs Technical Memorandum were performed using data from the WIG. To be consistent with those calculations, WIG data was used in this memo and adjusted by our estimate of change in ET due to climate change.

For this estimate of future water demands, we assumed existing crop coefficients will remain the same in the future and the season of use listed in the WIG for each crop does not change. The future ET for each crop was then estimated by multiplying the current crop ET provided by WIG by the ratio of future-to-current PET of the reference crop provided by UW. That ratio is shown on a monthly basis in Table 1. The results of that calculation are shown in Table 5.

Table 5. Estimated Current and Future PET for Reference Crop (Short Grass) – Within Irrigation Season – Sunnyside Station (Using WIG data)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Current (WIG)	0.00	0.00	0.00	0.91	6.70	8.08	9.85	8.12	5.32	2.11	0.00	0.00	41.09
Multiplier	1.02	0.97	0.99	1.00	1.04	1.05	1.08	1.10	1.09	1.03	0.99	0.97	Not Applicable
Future	0.00	0.00	0.00	0.91	6.97	8.48	10.64	8.93	5.80	2.17	0.00	0.00	43.90
Notes: All values in inches. Irrigation season assumed to be same as WIG (April 23 to October 27 for this crop).													

The future CIRs were estimated by adjusting crop ETs in the WIG for each crop in the Yakima River Basin and subtracting effective precipitation. A prorated effective precipitation rate was used for partial months (at the beginning and end of the irrigation season). For example, if the irrigation season for a crop ends October 14, then 45 percent (14 divided by 31) of the effective precipitation for October was used to calculate the future CIR for October. Table 6 presents the estimated future CIRs for the Sunnyside station.

The results in Table 6 show a range of 5 percent to 12 percent higher annual irrigation requirements for future conditions at the Sunnyside station. Similar results occur for the other four stations used in Section 3.4 of the Water Needs Technical Memorandum (Ellensburg, Wapato, Yakima and Richland). Those results can be found in Tables 9 to 32 at the end of this appendix.

Table 6. Estimated Future Crop Irrigation Requirements (inches) – Sunnyside Station												
Crop Type	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Total**	**Current**	**Difference**	**% Difference**
Caneberry		1.49	6.92	9.88	12.62	10.09	4.87	0.69	46.56	42.91	3.65	8.5%
Currant		1.49	6.92	9.88	12.62	10.09	4.87	0.69	46.56	42.91	3.65	8.5%
Barley	0.78	3.87	7.61	9.24	4.32				25.82	24.56	1.26	5.1%
Corn, Field			1.50	4.74	11.27	10.09	4.73		32.33	29.31	3.02	10.3%
Oat	0.78	3.87	7.61	9.24	4.32				25.82	24.56	1.26	5.1%
Rye	0.78	3.87	7.61	9.24	4.32				25.82	24.56	1.26	5.1%
Triticale	0.78	3.87	7.61	9.24	4.32				25.82	24.56	1.26	5.1%
Wheat	1.37	4.81	7.61	7.60	1.61	1.15	0.71	0.95	25.81	24.35	1.46	6.0%
Green Manure	0.78	3.87	7.61	9.24	4.32				25.82	24.56	1.26	5.1%
Alfalfa, Hay		0.77	6.21	7.76	9.95	8.31	5.46	1.74	40.22	37.02	3.20	8.6%
Alfalfa/Grass, Hay		0.77	6.21	7.76	9.95	8.31	5.46	1.74	40.22	37.02	3.20	8.6%
Clover, Hay		0.86	6.92	8.61	11.01	9.20	6.04	1.97	44.62	41.13	3.49	8.5%
Grass, Hay		0.86	6.92	8.61	11.01	9.20	6.04	1.97	44.62	41.13	3.49	8.5%
Hay/Silage, Unknown		0.86	6.92	8.61	11.01	9.20	6.04	1.97	44.62	41.13	3.49	8.5%
Sorghum				3.11	9.19	9.65	5.55	0.30	27.81	25.13	2.68	10.7%
Sudangrass		0.86	6.92	8.61	11.01	9.20	6.04	1.97	44.62	41.13	3.49	8.5%
Timothy		0.86	6.92	8.61	11.01	9.20	6.04	1.97	44.62	41.13	3.49	8.5%
Hops		0.36	3.09	6.91	9.95	13.22			33.54	30.76	2.78	9.0%
Watermelon									16.49	15.17	1.32	8.7%
Mint		0.36	3.09	4.79	11.55	10.55	6.92	2.09	39.34	35.94	3.40	9.5%
Pasture									32.03	29.47	2.56	8.7%
Wildlife Feed			1.50	4.74	11.27	10.09	4.73		32.33	29.31	3.02	10.3%
Apple		0.48	5.52	9.46	13.15	10.98	6.92	1.74	48.25	44.37	3.88	8.7%
Apricot	0.14	1.72	5.18	8.61	12.09	10.09	6.34	1.50	45.67	42.05	3.62	8.6%
Cherry		1.06	5.52	9.46	13.15	10.98	6.92	1.74	48.83	44.93	3.90	8.7%
Nectarine/Peach		1.54	5.18	8.61	12.09	10.09	6.34	1.50	45.34	41.71	3.63	8.7%
Orchard, Unknown		0.48	5.52	9.46	13.15	10.98	6.92	1.74	48.25	44.37	3.88	8.7%
Pear		0.90	5.18	8.61	12.09	10.09	6.34	1.50	44.71	41.09	3.62	8.8%
Plum		0.90	5.18	8.61	12.09	10.09	6.34	1.50	44.71	41.09	3.62	8.8%
Driving Range		0.82	6.57	8.19	10.48	8.75	5.75	1.85	42.41	39.07	3.34	8.6%
Golf Course		0.82	6.57	8.19	10.48	8.75	5.75	1.85	42.41	39.07	3.34	8.6%
Sod Farm		0.82	6.57	8.19	10.48	8.75	5.75	1.85	42.41	39.07	3.34	8.6%
Asparagus									32.55	29.96	2.60	8.7%
Bean, Dry				3.78	11.95	8.89	0.49		25.10	22.66	2.44	10.8%
Bean, Green				3.11	8.94	8.38			20.43	18.56	1.87	10.1%
Corn, Sweet			1.50	6.15	12.08	3.20			22.92	21.02	1.90	9.1%
Cucumber				2.92	7.30	8.31	5.34	0.44	24.32	21.93	2.39	10.9%
Market Crops			1.50	4.11	10.26	9.65	4.80	0.06	30.37	27.52	2.85	10.3%
Onion		2.56	6.70	8.61	10.86	6.99			35.73	33.20	2.53	7.6%
Potato			1.50	5.23	11.94	9.86	3.22		31.75	28.80	2.95	10.2%
Pumpkin				2.92	7.30	8.17	1.61		20.00	17.93	2.07	11.6%
Squash				2.92	7.30	8.17	1.61		20.00	17.93	2.07	11.6%
Tomato			1.50	4.11	10.26	9.65	4.80	0.06	30.37	27.52	2.85	10.3%
Vegetable, Unknown			1.50	4.11	10.26	9.65	4.80	0.06	30.37	27.52	2.85	10.3%
Grape, Concord			1.63	5.64	8.88	7.86	4.87	1.15	30.04	27.34	2.70	9.9%
Grape, Wine			1.63	5.64	8.88	7.86	4.87	1.15	30.04	27.34	2.70	9.9%

Estimated Increase in Future Irrigation Requirements

The crop acreage in each of the six Yakima Project districts was multiplied by the future CIRs for each crop and used to calculate a district-wide weighted average CIR under future climate change conditions. The future weighted-average CIR was then compared to the current CIR to estimate the increase in CIRs for Yakima Project districts under climate change conditions.

Table 7 summarizes the results for each district. Detailed spreadsheet calculations are provided in Tables 33 to 38 at the end of the appendix for both current and future CIRs. The increases range from 7.8% for Kennewick Irrigation District to 9.8% for Kittitas Reclamation District. These CIRs represent only the consumptive use of crops district-wide, and do not include seepage and evaporation losses that occur on-farm and district-wide.

Table 7. Summary of Weighted Current and Future Crop Irrigation Requirements (CIR)

District	Current CIR (ft)	Future CIR (ft)	Percent Increase
KRD	2.51	2.75	9.8%
Roza	2.97	3.24	9.0%
WIP	2.78	3.03	8.7%
SVID	2.72	2.97	9.2%
YTID	2.61	2.84	8.9%
KID	2.96	3.19	7.8%

Note: District names, as listed, top to bottom: Kittitas Reclamation District, Roza Irrigation District, Wapato Irrigation Project, Sunnyside Valley Irrigation District, Yakima-Tieton Irrigation District, Kennewick Irrigation District.

The percentage increase listed in Table 7 was used to adjust consumptive use estimates for each irrigation district in the RiverWare model. A similar adjustment was made to the consumptive portion of municipal demands in the RiverWare model, since consumptive use in the municipal demand sector is largely due to outdoor irrigation.

Using the estimates in Table 7 and district acreage data, the estimated increase in consumptive use for Yakima Project irrigation districts is approximately 95,000 acre-feet per year, as shown in Table 8. That estimate assumes current cropping patterns will continue in the future and therefore does not account for potential responses to climate change and additional water shortfalls by Yakima River Basin water users. The estimate also assumes a full water supply is available for all currently irrigated crops; in drought years less water would be available and the increase in consumptive use would be less.

Table 8. Estimated Increase in Consumptive Use Under Climate Change Conditions					
District	**Current CIR (ft)**	**Future CIR (ft)**	**Increase in CIR (ft)**	**Irrigated Land (ac)**	**Increase (ac-ft)**
KRD	2.51	2.75	0.24	55,516	13,000
Roza	2.97	3.24	0.27	72,491	20,000
WIP	2.78	3.03	0.25	109,115	27,000
SVID	2.72	2.97	0.25	99,243	25,000
YTID	2.61	2.84	0.23	27,900	6,000
KID	2.96	3.19	0.23	18,441	4,000
				Total	**95,000**

University of Washington Climate Impacts Group Review of Appendix

A draft of this appendix was forwarded to the UW Climate Impacts Group for review since there was disagreement on UW's findings of irrigation demand decreasing for apples and cherries with climate change.

UW's responded (Stockle, pers. comm.) that there was an error in reporting their findings of impacts to irrigation demands with climate change. The reduction in irrigation demand shown in their report actually represents the shortfall in irrigation supply and does not represent the impact on net irrigation requirements. They also stated that it is correct to assume that PET, as an engineering calculation, will increase with climate change. However there are other factors such as response to CO2 concentrations and a shorter growing season that will increase water demand less than we projected using standard PET calculations, perhaps on the order of 3 to 5 percent. An additional demand of 5 percent results in an increase in consumptive use of 53,000 acre-feet, using the same methodology shown in Table 8.

For the purposes of hydrologic modeling the increases in consumptive use shown in Table 8 were used. That results in conservative estimates of the effect of climate change on irrigation demands in the Yakima River Basin.

Additional Tables

Table 9. Estimated Monthly Potential Evapotranspiration Rates for Reference Crop (Short Grass) – Ellensburg Station (UW Study)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Current PET	0.81	1.51	3.38	4.43	5.59	6.29	7.21	6.06	3.92	2.67	1.93	1.08	44.86
Future PET	0.88	1.58	3.36	4.32	5.69	6.64	7.86	6.72	4.29	2.61	1.93	1.21	47.09
Ratio	109%	105%	99%	98%	102%	106%	109%	111%	109%	98%	100%	113%	105%

Notes: PET (potential evapotranspiration) values in inches. Data from UW (2009) Study; "Future PET" represents 2040s rate using "moderate effect" climate change model.

Table 10. Estimated Monthly Precipitation Rates – Ellensburg Station (UW Study)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Current	1.29	0.92	0.81	0.58	0.55	0.62	0.28	0.31	0.49	0.65	1.07	1.54	9.11
Future	1.18	0.92	0.90	0.51	0.46	0.46	0.23	0.19	0.24	0.78	1.24	1.51	8.62
Difference	-0.11	0.00	0.09	-0.07	-0.09	-0.16	-0.05	-0.12	-0.25	0.13	0.17	-0.03	-0.49

Notes: All values in inches. Data from UW (2009) Study; "Future" represents 2040s rate using "moderate effect" climate change model.

Table 11. Monthly Precipitation Rates – Ellensburg Station (WIG)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Total	1.20	1.14	0.67	0.51	0.54	0.59	0.34	0.61	0.64	0.54	1.21	1.59	9.58
Effective	0.00	0.09	0.42	0.36	0.44	0.52	0.33	0.55	0.48	0.33	0.00	0.00	3.51
Ratio	0%	8%	63%	71%	81%	88%	97%	90%	75%	61%	0%	0%	37%

Notes: All values in inches. Source of data: WIG (US Department of Agriculture 1985).

Table 12. Estimated Change in Effective Precipitation Rates – Ellensburg Station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Change in Precipitation	-0.11	0.00	0.09	-0.07	-0.09	-0.16	-0.05	-0.12	-0.25	0.13	0.17	-0.03
Ratio of Effective to Total	0%	8%	63%	71%	81%	88%	97%	90%	75%	61%	0%	0%
Change in Effective Precipitation	0.00	0.00	0.06	-0.05	-0.07	-0.15	-0.05	-0.11	-0.18	0.08	0.00	0.00

Note: Precipitation values in inches.

Table 13. Estimated Current and Future ET for Reference Crop (Short Grass) – Within Irrigation Season – Ellensburg Station (Using WIG data)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Current (WIG)	0.00	0.00	0.00	0.00	3.34	7.32	9.65	7.98	4.71	0.75	0.00	0.00	33.75
Multiplier	1.09	1.05	0.99	0.98	1.02	1.06	1.09	1.11	1.09	0.98	1.00	1.13	Not Applicable
Future	0.00	0.00	0.00	0.00	3.41	7.76	10.52	8.86	5.13	0.74	0.00	0.00	36.42

Notes: All values in inches. Irrigation season assumed to be same as WIG (May 13 to October 14 for this crop).

Table 14. Estimated Future Crop Irrigation Requirements – Ellensburg Station												
Crop Type	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Total**	**Current**	**Difference**	**% Difference**
Caneberry		0.26	6.20	8.89	12.35	9.74	4.08	0.14	41.66	38.11	3.55	9.3%
Currant		0.26	6.20	8.89	12.35	9.74	4.08	0.14	41.66	38.11	3.55	9.3%
Barley	0.02	2.20	6.14	8.50	10.77	1.89			29.52	27.44	2.08	7.6%
Corn, Field			0.08	3.02	8.31	9.72	5.34	0.33	26.80	23.98	2.82	11.8%
Oat	0.02	2.20	6.14	8.50	10.77	1.89			29.52	27.44	2.08	7.6%
Rye	0.02	2.20	6.14	8.50	10.77	1.89			29.52	27.44	2.08	7.6%
Triticale	0.02	2.20	6.14	8.50	10.77	1.89			29.52	27.44	2.08	7.6%
Wheat	0.04	3.48	6.81	8.50	7.95	0.53	0.30	0.57	28.18	26.31	1.87	7.1%
Green Manure	0.02	2.20	6.14	8.50	10.77	1.89			29.52	27.44	2.08	7.6%
Alfalfa, Hay			3.01	6.96	9.71	7.97	4.59	0.51	32.76	29.76	3.00	10.1%
Alfalfa/Grass, Hay			3.01	6.96	9.71	7.97	4.59	0.51	32.76	29.76	3.00	10.1%
Clover, Hay			3.35	7.73	10.77	8.86	5.11	0.59	36.40	33.14	3.26	9.8%
Grass, Hay			3.35	7.73	10.77	8.86	5.11	0.59	36.40	33.14	3.26	9.8%
Hay/Silage, Unknown			3.35	7.73	10.77	8.86	5.11	0.59	36.40	33.14	3.26	9.8%
Sorghum				1.25	6.06	9.01	5.28	0.33	21.94	19.56	2.38	12.2%
Sudangrass			3.35	7.73	10.77	8.86	5.11	0.59	36.40	33.14	3.26	9.8%
Timothy			3.35	7.73	10.77	8.86	5.11	0.59	36.40	33.14	3.26	9.8%
Hops			1.46	6.19	9.71	12.84			30.21	27.35	2.86	10.5%
Watermelon									13.43	12.20	1.23	10.1%
Mint			1.46	4.26	11.30	10.19	5.89	0.63	33.72	30.43	3.29	10.8%
Pasture									26.09	23.70	2.39	10.1%
Wildlife Feed			0.08	3.02	8.31	9.72	5.34	0.33	26.80	23.98	2.82	11.8%
Apple			3.44	8.50	12.88	10.63	5.89	0.51	41.85	38.11	3.74	9.8%
Apricot		0.91	4.63	7.73	11.82	9.74	5.37	0.42	40.63	37.10	3.53	9.5%
Cherry		0.09	4.95	8.50	12.88	10.63	5.89	0.51	43.44	39.66	3.78	9.5%
Nectarine/Peach		0.57	4.63	7.73	11.82	9.74	5.37	0.42	40.28	36.76	3.52	9.6%
Orchard, Unknown			3.44	8.50	12.88	10.63	5.89	0.51	41.85	38.11	3.74	9.8%
Pear		0.00	4.39	7.73	11.82	9.74	5.37	0.42	39.47	35.96	3.51	9.8%
Plum		0.00	4.39	7.73	11.82	9.74	5.37	0.42	39.47	35.96	3.51	9.8%
Driving Range			3.17	7.35	10.24	8.41	4.86	0.55	34.58	31.45	3.13	10.0%
Golf Course			3.17	7.35	10.24	8.41	4.86	0.55	34.58	31.45	3.13	10.0%
Sod Farm			3.17	7.35	10.24	8.41	4.86	0.55	34.58	31.45	3.13	10.0%
Asparagus									26.51	24.09	2.43	10.1%
Bean, Dry				1.25	8.69	10.18	2.15		22.27	19.78	2.49	12.6%
Bean, Green				1.25	6.06	8.35	2.26		17.92	15.82	2.10	13.3%
Corn, Sweet			0.08	3.32	10.35	8.61			22.36	20.08	2.28	11.3%
Cucumber				1.25	5.01	7.47	4.59	0.45	18.78	16.70	2.08	12.5%
Market Crops			0.08	2.94	7.14	9.14	5.20	0.23	24.73	22.08	2.65	12.0%
Onion		0.33	3.87	7.72	10.77	8.50	2.72		33.92	30.80	3.12	10.1%
Potato			0.08	3.06	9.47	9.74	5.02	0.17	27.54	24.64	2.90	11.8%
Pumpkin				1.25	5.01	7.47	3.32		17.06	15.04	2.02	13.4%
Squash				1.25	5.01	7.47	3.32		17.06	15.04	2.02	13.4%
Tomato			0.08	2.94	7.14	9.14	5.20	0.23	24.73	22.08	2.65	12.0%
Vegetable, Unknown			0.08	2.94	7.14	9.14	5.20	0.23	24.73	22.08	2.65	12.0%
Grape, Concord			0.08	5.03	8.67	7.52	4.08	0.30	25.68	23.05	2.63	11.4%
Grape, Wine			0.08	5.03	8.67	7.52	4.08	0.30	25.68	23.05	2.63	11.4%
Note: All values in inches.												

Table 15. Estimated Monthly Potential Evapotranspiration Rates for Reference Crop (Short Grass) – Yakima Station (UW Study)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Current PET	1.00	1.71	3.00	4.28	5.77	6.58	7.48	6.27	4.07	2.48	1.67	1.12	45.43
Future PET	1.10	1.62	2.99	4.25	5.96	6.93	8.11	6.91	4.46	2.56	1.58	1.16	47.63
Ratio	110%	95%	100%	99%	103%	105%	109%	110%	109%	103%	95%	104%	105%

Notes: PET (potential evapotranspiration) values in inches. Data from UW (2009) Study; "Future PET" represents 2040s rate using "moderate effect" climate change model.

Table 16. Estimated Monthly Precipitation Rates – Yakima Station (UW Study)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Current	1.37	0.82	0.74	0.57	0.48	0.56	0.27	0.33	0.47	0.59	1.01	1.58	8.79
Future	1.26	0.81	0.82	0.50	0.40	0.42	0.24	0.20	0.23	0.69	1.17	1.53	8.28
Difference	-0.11	-0.01	0.08	-0.07	-0.08	-0.14	-0.03	-0.13	-0.24	0.10	0.16	-0.05	-0.51

Notes: All values in inches. Data from UW (2009) Study; "Future" represents 2040s rate using "moderate effect" climate change model.

Table 17. Monthly Precipitation Rates – Yakima Station (WIG)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Total	1.44	0.74	0.65	0.50	0.48	0.60	0.14	0.36	0.33	0.47	0.97	1.30	7.98
Effective	0.00	0.18	0.42	0.36	0.40	0.53	0.14	0.33	0.26	0.30	0.12	0.00	3.04
Ratio	0%	24%	65%	72%	83%	88%	100%	92%	79%	64%	12%	0%	38%

Notes: All values in inches. Source of data: WIG (US Department of Agriculture 1985).

Table 18. Estimated Change in Effective Precipitation Rates – Yakima Station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Change in Precipitation	-0.11	-0.01	0.08	-0.07	-0.08	-0.14	-0.03	-0.13	-0.24	0.10	0.16	-0.05
Ratio of Effective to Total	0%	24%	65%	72%	83%	88%	100%	92%	79%	64%	12%	0%
Change in Effective Precipitation	0.00	-0.00	0.05	-0.05	-0.07	-0.13	-0.03	-0.12	-0.19	0.06	0.02	0.00

Note: Precipitation values in inches.

Table 19. Estimated Current and Future ET for Reference Crop (Short Grass) – Within Irrigation Season – Yakima Station (Using WIG data)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Current (WIG)	0.00	0.00	0.00	0.84	6.33	7.71	9.56	7.86	5.06	1.93	0.00	0.00	39.29
Multiplier	1.10	0.95	1.00	0.99	1.03	1.05	1.09	1.10	1.09	1.03	0.95	1.04	Not Applicable
Future	0.00	0.00	0.00	0.83	6.52	8.10	10.42	8.65	5.52	1.99	0.00	0.00	42.03

Notes: All values in inches. Irrigation season assumed to be same as WIG (April 23 to October 27 for this crop).

Table 20. Estimated Future Crop Irrigation Requirements – Yakima Station												
Crop Type	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Total**	**Current**	**Difference**	**% Difference**
Caneberry		1.37	6.53	9.35	12.34	9.74	4.63	0.60	44.56	41.02	3.54	8.6%
Currant		1.37	6.53	9.35	12.34	9.74	4.63	0.60	44.56	41.02	3.54	8.6%
Barley	0.51	3.60	7.18	8.73	4.27				24.29	23.06	1.23	5.3%
Corn, Field			1.46	4.46	11.05	9.74	4.50		31.21	28.22	2.99	10.6%
Oat	0.51	3.60	7.18	8.73	4.27				24.29	23.06	1.23	5.3%
Rye	0.51	3.60	7.18	8.73	4.27				24.29	23.06	1.23	5.3%
Triticale	0.51	3.60	7.18	8.73	4.27				24.29	23.06	1.23	5.3%
Wheat	1.06	4.45	7.18	7.16	1.62	1.05	0.68	0.88	24.07	22.67	1.40	6.2%
Green Manure	0.51	3.60	7.18	8.73	4.27				24.29	23.06	1.23	5.3%
Alfalfa, Hay		0.71	5.88	7.32	9.74	8.02	5.19	1.56	38.41	35.31	3.10	8.8%
Alfalfa/Grass, Hay		0.71	5.88	7.32	9.74	8.02	5.19	1.56	38.41	35.31	3.10	8.8%
Clover, Hay		0.80	6.53	8.13	10.78	8.87	5.74	1.78	42.62	39.25	3.37	8.6%
Grass, Hay		0.80	6.53	8.13	10.78	8.87	5.74	1.78	42.62	39.25	3.37	8.6%
Hay/Silage, Unknown		0.80	6.53	8.13	10.78	8.87	5.74	1.78	42.62	39.25	3.37	8.6%
Sorghum				2.87	9.03	9.31	5.27	0.26	26.74	24.10	2.64	11.0%
Sudangrass		0.80	6.53	8.13	10.78	8.87	5.74	1.78	42.62	39.25	3.37	8.6%
Timothy		0.80	6.53	8.13	10.78	8.87	5.74	1.78	42.62	39.25	3.37	8.6%
Hops		0.33	2.93	6.51	9.74	12.77			32.28	29.51	2.77	9.4%
Watermelon									15.75	14.47	1.27	8.8%
Mint		0.33	2.93	4.47	11.31	10.17	6.57	1.88	37.66	34.34	3.32	9.7%
Pasture									30.59	28.12	2.47	8.8%
Wildlife Feed			1.46	4.46	11.05	9.74	4.50		31.21	28.22	2.99	10.6%
Apple		0.43	5.22	8.94	12.86	10.61	6.57	1.56	46.19	42.42	3.77	8.9%
Apricot	0.06	1.58	4.90	8.13	11.82	9.74	6.02	1.35	43.60	40.09	3.51	8.8%
Cherry		0.96	5.22	8.94	12.86	10.61	6.57	1.56	46.71	42.93	3.78	8.8%
Nectarine/Peach		1.39	4.90	8.13	11.82	9.74	6.02	1.35	43.35	39.82	3.53	8.9%
Orchard, Unknown		0.43	5.22	8.94	12.86	10.61	6.57	1.56	46.19	42.42	3.77	8.9%
Pear		0.81	4.90	8.13	11.82	9.74	6.02	1.35	42.77	39.26	3.51	9.0%
Plum		0.81	4.90	8.13	11.82	9.74	6.02	1.35	42.77	39.26	3.51	9.0%
Driving Range		0.75	6.20	7.72	10.26	8.44	5.46	1.67	40.51	37.27	3.24	8.7%
Golf Course		0.75	6.20	7.72	10.26	8.44	5.46	1.67	40.51	37.27	3.24	8.7%
Sod Farm		0.75	6.20	7.72	10.26	8.44	5.46	1.67	40.51	37.27	3.24	8.7%
Asparagus									31.09	28.58	2.51	8.8%
Bean, Dry				3.51	11.69	8.57	0.45		24.21	21.77	2.44	11.2%
Bean, Green				2.87	8.78	8.07			19.72	17.82	1.90	10.7%
Corn, Sweet			1.46	5.80	11.82	3.09			22.17	20.24	1.93	9.5%
Cucumber				2.69	7.20	8.02	5.08	0.37	23.37	21.01	2.36	11.2%
Market Crops			1.46	3.87	10.06	9.31	4.57	0.03	29.30	26.50	2.80	10.6%
Onion		2.44	6.33	8.13	10.63	6.74			34.27	31.78	2.49	7.8%
Potato			1.46	4.94	11.67	9.51	3.06		30.64	27.72	2.92	10.5%
Pumpkin				2.69	7.20	7.88	1.51		19.29	17.22	2.07	12.0%
Squash				2.69	7.20	7.88	1.51		19.29	17.22	2.07	12.0%
Tomato			1.46	3.87	10.06	9.31	4.57	0.03	29.30	26.50	2.80	10.6%
Vegetable, Unknown			1.46	3.87	10.06	9.31	4.57	0.03	29.30	26.50	2.80	10.6%
Grape, Concord			1.55	5.28	8.71	7.57	4.63	1.02	28.78	26.13	2.65	10.1%
Grape, Wine			1.55	5.28	8.71	7.57	4.63	1.02	28.78	26.13	2.65	10.1%
Note: All values in inches.												

Table 21. Estimated Monthly Potential Evapotranspiration Rates for Reference Crop (Short Grass) – Wapato Station (UW Study)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Current PET	1.09	1.80	3.11	4.35	5.90	6.73	7.64	6.38	4.18	2.60	1.76	1.20	46.74
Future PET	1.21	1.72	3.10	4.32	6.09	7.08	8.28	7.01	4.56	2.66	1.67	1.24	48.97
Ratio	111%	96%	100%	99%	103%	105%	108%	110%	109%	102%	95%	104%	105%

Notes: PET (potential evapotranspiration) values in inches. Data from UW (2009) Study; "Future PET" represents 2040s rate using "moderate effect" climate change model.

Table 22. Estimated Monthly Precipitation Rates – Wapato Station (UW Study)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Current	1.33	0.79	0.71	0.50	0.46	0.54	0.22	0.31	0.42	0.58	0.96	1.43	8.26
Future	1.21	0.79	0.79	0.44	0.38	0.40	0.20	0.19	0.21	0.68	1.11	1.38	7.78
Difference	-0.12	0.00	0.08	-0.06	-0.08	-0.14	-0.02	-0.12	-0.21	0.10	0.15	-0.05	-0.48

Notes: All values in inches. Data from UW (2009) Study; "Future" represents 2040s rate using "moderate effect" climate change model.

Table 23. Monthly Precipitation Rates – Wapato Station (WIG)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Total	1.20	0.64	0.56	0.51	0.45	0.53	0.19	0.36	0.34	0.43	0.93	1.10	7.24
Effective	0.00	0.23	0.37	0.37	0.39	0.49	0.19	0.34	0.27	0.28	0.15	0.00	3.11
Ratio	0%	36%	66%	73%	87%	92%	100%	94%	79%	65%	16%	0%	43%

Notes: All values in inches. Source of data: WIG (US Department of Agriculture 1985).

Table 24. Estimated Change in Effective Precipitation Rates – Wapato Station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Change in Precipitation	-0.12	0.00	0.08	-0.06	-0.08	-0.14	-0.02	-0.12	-0.21	0.10	0.15	-0.05
Ratio of Effective to Total	0%	36%	66%	73%	87%	92%	100%	94%	79%	65%	16%	0%
Change in Effective Precipitation	0.00	0.00	0.05	-0.04	-0.07	-0.13	-0.02	-0.12	-0.17	0.06	0.02	0.00

Note: Precipitation values in inches.

Table 25. Estimated Current and Future ET for Reference Crop (Short Grass) – Within Irrigation Season – Wapato Station (Using WIG data)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Current (WIG)	0.00	0.00	0.00	0.93	6.94	8.30	10.29	8.46	5.48	2.16	0.00	0.00	42.56
Multiplier	1.11	0.96	1.00	0.99	1.03	1.05	1.08	1.10	1.09	1.02	0.95	1.04	Not Applicable
Future	0.00	0.00	0.00	0.92	7.15	8.72	11.11	9.31	5.97	2.20	0.00	0.00	45.38

Notes: All values in inches. Irrigation season assumed to be same as WIG (April 23 to October 27 for this crop).

Table 26. Estimated Future Crop Irrigation Requirements – Wapato Station												
Crop Type	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Total**	**Current**	**Difference**	**% Difference**
Caneberry		1.51	7.19	10.12	13.22	10.47	4.99	0.74	48.23	44.55	3.68	8.3%
Currant		1.51	7.19	10.12	13.22	10.47	4.99	0.74	48.23	44.55	3.68	8.3%
Barley	0.69	3.95	7.91	9.45	4.56				26.56	25.27	1.29	5.1%
Corn, Field			1.58	4.78	11.81	10.47	4.84		33.48	30.39	3.09	10.2%
Oat	0.69	3.95	7.91	9.45	4.56				26.56	25.27	1.29	5.1%
Rye	0.69	3.95	7.91	9.45	4.56				26.56	25.27	1.29	5.1%
Triticale	0.69	3.95	7.91	9.45	4.56				26.56	25.27	1.29	5.1%
Wheat	1.29	4.91	7.91	7.77	1.71	1.15	0.72	1.02	26.47	25.04	1.43	5.7%
Green Manure	0.69	3.95	7.91	9.45	4.56				26.56	25.27	1.29	5.1%
Alfalfa, Hay		0.80	6.48	7.93	10.43	8.61	5.59	1.80	41.64	38.42	3.22	8.4%
Alfalfa/Grass, Hay		0.80	6.48	7.93	10.43	8.61	5.59	1.80	41.64	38.42	3.22	8.4%
Clover, Hay		0.89	7.19	8.80	11.55	9.54	6.19	2.04	46.20	42.69	3.51	8.2%
Grass, Hay		0.89	7.19	8.80	11.55	9.54	6.19	2.04	46.20	42.69	3.51	8.2%
Hay/Silage, Unknown		0.89	7.19	8.80	11.55	9.54	6.19	2.04	46.20	42.69	3.51	8.2%
Sorghum				3.12	9.63	10.00	5.67	0.32	28.75	26.02	2.73	10.5%
Sudangrass		0.89	7.19	8.80	11.55	9.54	6.19	2.04	46.20	42.69	3.51	8.2%
Timothy		0.89	7.19	8.80	11.55	9.54	6.19	2.04	46.20	42.69	3.51	8.2%
Hops		0.38	3.26	7.06	10.43	13.72			34.84	31.95	2.89	9.1%
Watermelon									17.07	15.75	1.32	8.4%
Mint		0.38	3.26	4.88	12.10	10.94	7.08	2.15	40.79	37.35	3.44	9.2%
Pasture									33.16	30.59	2.57	8.4%
Wildlife Feed			1.58	4.78	11.81	10.47	4.84		33.48	30.39	3.09	10.2%
Apple		0.49	5.76	9.67	13.77	11.40	7.08	1.80	49.98	46.06	3.92	8.5%
Apricot	0.11	1.75	5.41	8.80	12.66	10.47	6.48	1.57	47.25	43.61	3.64	8.4%
Cherry		1.08	5.76	9.67	13.77	11.40	7.08	1.80	50.57	46.64	3.93	8.4%
Nectarine/Peach		1.57	5.41	8.80	12.66	10.47	6.48	1.57	46.96	43.30	3.66	8.5%
Orchard, Unknown		0.49	5.76	9.67	13.77	11.40	7.08	1.80	49.98	46.06	3.92	8.5%
Pear		0.92	5.41	8.80	12.66	10.47	6.48	1.57	46.31	42.66	3.65	8.6%
Plum		0.92	5.41	8.80	12.66	10.47	6.48	1.57	46.31	42.66	3.65	8.6%
Driving Range		0.84	6.84	8.37	10.98	9.07	5.88	1.92	43.90	40.54	3.36	8.3%
Golf Course		0.84	6.84	8.37	10.98	9.07	5.88	1.92	43.90	40.54	3.36	8.3%
Sod Farm		0.84	6.84	8.37	10.98	9.07	5.88	1.92	43.90	40.54	3.36	8.3%
Asparagus									33.70	31.09	2.61	8.4%
Bean, Dry				3.82	12.51	9.20	0.46		25.99	23.47	2.52	10.7%
Bean, Green				3.12	9.37	8.69			21.18	19.20	1.98	10.3%
Corn, Sweet			1.58	6.25	12.65	3.32			23.81	21.80	2.01	9.2%
Cucumber				2.92	7.65	8.61	5.47	0.44	25.09	22.66	2.43	10.7%
Market Crops			1.58	4.14	10.73	10.00	4.91	0.05	31.43	28.53	2.90	10.2%
Onion		2.61	6.97	8.80	11.39	7.25			37.01	34.41	2.60	7.6%
Potato			1.58	5.30	12.50	10.22	3.28		32.89	29.87	3.02	10.1%
Pumpkin			0.00	2.92	7.65	8.47	1.61		20.65	18.52	2.13	11.5%
Squash			0.00	2.92	7.65	8.47	1.61		20.65	18.52	2.13	11.5%
Tomato			1.58	4.14	10.73	10.00	4.91	0.05	31.43	28.53	2.90	10.2%
Vegetable, Unknown			1.58	4.14	10.73	10.00	4.91	0.05	31.43	28.53	2.90	10.2%
Grape, Concord			1.75	5.75	9.31	8.15	4.99	1.21	31.16	28.42	2.74	9.6%
Grape, Wine			1.75	5.75	9.31	8.15	4.99	1.21	31.16	28.42	2.74	9.6%
Note: All values in inches.												

Table 27. Estimated Monthly Potential Evapotranspiration Rates for Reference Crop (Short Grass) – Richland Station (UW Study)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Current PET	1.22	1.68	2.93	4.19	5.86	6.62	7.41	6.11	4.13	2.44	1.44	1.14	45.17
Future PET	1.23	1.65	2.90	4.21	6.07	6.95	7.97	6.66	4.48	2.57	1.38	1.09	47.14
Ratio	101%	98%	99%	100%	103%	105%	108%	109%	109%	105%	95%	96%	104%
Notes: PET (potential evapotranspiration) values in inches. Data from UW (2009) Study; "Future PET" represents 2040s rate using "moderate effect" climate change model.													

Table 28. Estimated Monthly Precipitation Rates – Richland Station (UW Study)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Current	1.02	0.73	0.70	0.51	0.55	0.41	0.19	0.26	0.33	0.56	0.97	1.10	7.32
Future	0.99	0.76	0.80	0.45	0.49	0.32	0.20	0.18	0.19	0.62	1.18	1.10	7.27
Difference	-0.03	0.03	0.10	-0.06	-0.06	-0.09	0.01	-0.08	-0.14	0.06	0.21	0.00	-0.05
Notes: All values in inches. Data from UW (2009) Study; "Future" represents 2040s rate using "moderate effect" climate change model.													

Table 29. Monthly Precipitation Rates – Richland Station (WIG)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Total	1.03	0.69	0.50	0.42	0.53	0.44	0.14	0.32	0.28	0.46	0.91	1.06	6.78
Effective	0.00	0.27	0.33	0.32	0.46	0.42	0.14	0.31	0.23	0.31	0.20	0.00	2.98
Ratio	0%	39%	66%	76%	87%	95%	100%	97%	82%	67%	22%	0%	44%
Notes: All values in inches. Source of data: WIG (US Department of Agriculture 1985).													

Table 30. Estimated Change in Effective Precipitation Rates – Richland Station												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Change in Precipitation	-0.03	0.03	0.10	-0.06	-0.06	-0.09	0.01	-0.09	-0.14	0.06	0.21	0.00
Ratio of Effective to Total	0%	39%	66%	76%	87%	95%	100%	97%	82%	67%	22%	0%
Change in Effective Precipitation	0.00	0.01	0.07	-0.05	-0.05	-0.08	0.01	-0.09	-0.12	0.04	0.05	0.00
Note: Precipitation values in inches.												

Table 31. Estimated Current and Future ET for Reference Crop (Short Grass) – Within Irrigation Season – Richland Station (Using WIG data)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Current (WIG)	0.00	0.00	0.00	0.97	7.05	8.47	10.45	8.67	5.72	2.34	0.00	0.00	43.67
Multiplier	1.01	0.98	0.99	1.00	1.03	1.05	1.08	1.09	1.09	1.05	0.95	0.96	Not Applicable
Future	0.00	0.00	0.00	0.97	7.26	8.89	11.29	9.45	6.23	2.46	0.00	0.00	46.55
Notes: All values in inches. Irrigation season assumed to be same as WIG (April 23 to October 27 for this crop).													

Table 32. Estimated Future Crop Irrigation Requirements – Richland Station												
Crop Type	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Total**	**Current**	**Difference**	**% Difference**
Caneberry		1.66	7.25	10.33	13.34	10.64	5.16	0.85	49.24	45.81	3.43	7.5%
Currant		1.66	7.25	10.33	13.34	10.64	5.16	0.85	49.24	45.81	3.43	7.5%
Barley	0.76	4.20	7.98	9.66	4.59				27.20	25.99	1.21	4.6%
Corn, Field			1.55	4.89	11.92	10.64	5.03		34.03	31.26	2.77	8.9%
Oat	0.76	4.20	7.98	9.66	4.59				27.20	25.99	1.21	4.6%
Rye	0.76	4.20	7.98	9.66	4.59				27.20	25.99	1.21	4.6%
Triticale	0.76	4.20	7.98	9.66	4.59				27.20	25.99	1.21	4.6%
Wheat	1.40	5.22	7.98	7.93	1.71	1.18	0.77	1.12	27.32	25.97	1.35	5.2%
Green Manure	0.76	4.20	7.98	9.66	4.59				27.20	25.99	1.21	4.6%
Alfalfa, Hay		0.86	6.53	8.10	10.53	8.76	5.78	2.02	42.58	39.56	3.02	7.6%
Alfalfa/Grass, Hay		0.86	6.53	8.10	10.53	8.76	5.78	2.02	42.58	39.56	3.02	7.6%
Clover, Hay		0.95	7.25	8.99	11.65	9.71	6.41	2.29	47.25	43.94	3.31	7.5%
Grass, Hay		0.95	7.25	8.99	11.65	9.71	6.41	2.29	47.25	43.94	3.31	7.5%
Hay/Silage, Unknown		0.95	7.25	8.99	11.65	9.71	6.41	2.29	47.25	43.94	3.31	7.5%
Sorghum				3.20	9.72	10.17	5.88	0.39	29.36	26.89	2.47	9.2%
Sudangrass		0.95	7.25	8.99	11.65	9.71	6.41	2.29	47.25	43.94	3.31	7.5%
Timothy		0.95	7.25	8.99	11.65	9.71	6.41	2.29	47.25	43.94	3.31	7.5%
Hops		0.41	3.24	7.22	10.53	13.96			35.36	32.73	2.63	8.0%
Watermelon									17.45	16.22	1.24	7.6%
Mint		0.41	3.24	5.00	12.21	11.12	7.33	2.41	41.73	38.51	3.22	8.4%
Pasture									33.91	31.50	2.40	7.6%
Wildlife Feed			1.55	4.89	11.92	10.64	5.03		34.03	31.26	2.77	8.9%
Apple		0.55	5.79	9.89	13.90	11.59	7.33	2.02	51.08	47.40	3.68	7.8%
Apricot	0.14	1.92	5.43	8.99	12.78	10.64	6.71	1.77	48.39	44.97	3.42	7.6%
Cherry		1.21	5.79	9.89	13.90	11.59	7.33	2.02	51.74	48.04	3.70	7.7%
Nectarine/Peach		1.76	5.43	8.99	12.78	10.64	6.71	1.77	48.09	44.65	3.44	7.7%
Orchard, Unknown		0.55	5.79	9.89	13.90	11.59	7.33	2.02	51.08	47.40	3.68	7.8%
Pear		1.03	5.43	8.99	12.78	10.64	6.71	1.77	47.37	43.95	3.42	7.8%
Plum		1.03	5.43	8.99	12.78	10.64	6.71	1.77	47.37	43.95	3.42	7.8%
Driving Range		0.90	6.89	8.55	11.09	9.23	6.10	2.16	44.91	41.75	3.16	7.6%
Golf Course		0.90	6.89	8.55	11.09	9.23	6.10	2.16	44.91	41.75	3.16	7.6%
Sod Farm		0.90	6.89	8.55	11.09	9.23	6.10	2.16	44.91	41.75	3.16	7.6%
Asparagus									34.46	32.02	2.44	7.6%
Bean, Dry				3.90	12.62	9.37	0.42		26.31	24.10	2.21	9.2%
Bean, Green				3.21	9.46	8.84			21.51	19.76	1.75	8.9%
Corn, Sweet			1.55	6.38	12.77	3.35			24.05	22.27	1.78	8.0%
Cucumber				3.00	7.71	8.76	5.66	0.53	25.66	23.47	2.19	9.3%
Market Crops			1.55	4.24	10.83	10.17	5.09	0.08	31.97	29.35	2.62	8.9%
Onion		2.77	7.02	8.99	11.49	7.37			37.65	35.24	2.41	6.8%
Potato			1.55	5.42	12.62	10.40	3.39		33.38	30.68	2.70	8.8%
Pumpkin				3.00	7.71	8.60	1.63		20.95	19.09	1.86	9.7%
Squash				3.00	7.71	8.60	1.63		20.95	19.09	1.86	9.7%
Tomato			1.55	4.24	10.83	10.17	5.09	0.08	31.97	29.35	2.62	8.9%
Vegetable, Unknown			1.55	4.24	10.83	10.17	5.09	0.08	31.97	29.35	2.62	8.9%
Grape, Concord		0.05	1.72	5.89	9.40	8.29	5.16	1.38	31.89	29.33	2.56	8.7%
Grape, Wine		0.05	1.72	5.89	9.40	8.29	5.16	1.38	31.89	29.33	2.56	8.7%
Note: All values in inches.												

Table 33. Estimated Future Irrigation Requirements – KRD					
Crop Type	**% Acreage**	**Current CIR**	**Weighted CIR**	**Increase in CIR**	**Weighted Increase**
Timothy	53.3%	33.14	17.67	3.26	1.74
Pasture	23.7%	23.70	5.61	2.39	0.56
Grass, Hay	6.5%	33.14	2.15	3.26	0.21
Alfalfa, Hay	3.2%	29.76	0.95	3.00	0.10
Wheat	3.1%	26.31	0.81	1.87	0.06
Oat	3.1%	27.44	0.84	2.08	0.06
Corn, Sweet	2.5%	20.08	0.49	2.28	0.06
Sudangrass	1.9%	33.14	0.61	3.26	0.06
Apple	1.0%	38.11	0.38	3.74	0.04
Alfalfa/Grass, Hay	0.6%	29.76	0.18	3.00	0.02
Barley	0.5%	27.44	0.13	2.08	0.01
Pear	0.3%	35.96	0.11	3.51	0.01
Potato	0.2%	24.64	0.04	2.90	0.00
Cherry	0.2%	39.66	0.06	3.78	0.01
Golf Course	0.1%	31.45	0.04	3.13	0.00
Grape, Wine	0.0%	23.05	0.00	2.63	0.00
Market Crops	0.0%	22.08	0.00	2.65	0.00
Onion	0.0%	30.80	0.00	3.12	0.00
Total			30.09		2.94
% Increase					9.8%
Note: All values in inches. Acreage does not include crop types that were assumed to have a CIR equal to the weighted average of all crops.					

Table 34. Estimated Future Irrigation Requirements – Roza					
Crop Type	**% Acreage**	**Current CIR**	**Weighted CIR**	**Increase in CIR**	**Weighted Increase**
Apple	33.6%	44.37	14.90	3.88	1.30
Grape, Wine	16.8%	27.34	4.60	2.70	0.45
Grape, Concord	16.7%	27.34	4.56	2.70	0.45
Cherry	7.4%	44.93	3.31	3.90	0.29
Hops	5.0%	30.76	1.53	2.78	0.14
Alfalfa, Hay	4.0%	37.02	1.49	3.20	0.13
Pear	3.5%	41.09	1.44	3.62	0.13
Corn, Field	3.2%	29.31	0.92	3.02	0.10
Wheat	1.9%	24.35	0.45	1.46	0.03
Sorghum	2.0%	25.13	0.51	2.68	0.05
Nectarine/Peach	1.0%	41.71	0.42	3.63	0.04
Triticale	1.0%	24.56	0.25	1.26	0.01
Asparagus	0.9%	29.96	0.27	2.60	0.02
Apricot	0.4%	42.05	0.15	3.62	0.01
Alfalfa/Grass, Hay	0.4%	37.02	0.16	3.20	0.01
Green Manure	0.4%	24.56	0.10	1.26	0.01
Caneberry	0.3%	42.91	0.14	3.65	0.01
Corn, Sweet	0.2%	21.02	0.05	1.90	0.00
Rye	0.2%	24.56	0.06	1.26	0.00
Mint	0.2%	35.94	0.07	3.40	0.01
Squash	0.2%	17.93	0.03	2.07	0.00
Grass, Hay	0.2%	41.13	0.06	3.49	0.01
Pumpkin	0.1%	17.93	0.02	2.07	0.00
Potato	0.1%	28.80	0.03	2.95	0.00
Pasture	0.1%	29.47	0.03	2.56	0.00
Tomato	0.1%	27.52	0.02	2.85	0.00
Plum	0.1%	41.09	0.03	3.62	0.00
Barley	0.1%	24.56	0.01	1.26	0.00
Hay/Silage, Unknown	0.0%	41.13	0.01	3.49	0.00
Market Crops	0.0%	27.52	0.00	2.85	0.00
Total			35.64		3.22
% Increase					9.0%

Note: All values in inches. Acreage does not include crop types that were assumed to have a CIR equal to the weighted average of all crops.

Table 35. Estimated Future Irrigation Requirements – WIP					
Crop Type	**% Acreage**	**Current CIR**	**Weighted CIR**	**Increase in CIR**	**Weighted Increase**
Corn, Field	21.1%	30.39	6.41	3.09	0.65
Wheat	14.6%	25.04	3.65	1.43	0.21
Hops	14.3%	31.95	4.57	2.89	0.41
Alfalfa, Hay	12.1%	38.42	4.64	3.22	0.39
Apple	9.7%	46.06	4.49	3.92	0.38
Mint	8.8%	37.35	3.28	3.44	0.30
Grape, Concord	4.6%	28.42	1.31	2.74	0.13
Alfalfa/Grass, Hay	1.7%	38.42	0.65	3.22	0.05
Pasture	1.8%	30.59	0.56	2.57	0.05
Asparagus	1.7%	31.09	0.53	2.61	0.04
Grass, Hay	1.3%	42.69	0.55	3.51	0.05
Nectarine/Peach	1.1%	43.30	0.48	3.66	0.04
Potato	1.1%	29.87	0.32	3.02	0.03
Pear	1.0%	42.66	0.44	3.65	0.04
Corn, Sweet	0.8%	21.80	0.19	2.01	0.02
Onion	0.8%	34.41	0.26	2.60	0.02
Market Crops	0.7%	28.53	0.20	2.90	0.02
Cherry	0.7%	46.64	0.32	3.93	0.03
Bean, Dry	0.6%	23.47	0.14	2.52	0.02
Sorghum	0.5%	26.02	0.12	2.73	0.01
Squash	0.2%	18.52	0.04	2.13	0.00
Oat	0.1%	25.27	0.04	1.29	0.00
Timothy	0.1%	42.69	0.05	3.51	0.00
Golf Course	0.1%	40.54	0.04	3.36	0.00
Plum	0.1%	42.66	0.03	3.65	0.00
Apricot	0.1%	43.61	0.03	3.64	0.00
Cucumber	0.1%	22.66	0.02	2.43	0.00
Tomato	0.1%	28.53	0.02	2.90	0.00
Pumpkin	0.0%	18.52	0.01	2.13	0.00
Vegetable, Unknown	0.0%	28.53	0.01	2.90	0.00
Bean, Green	0.0%	19.20	0.01	1.98	0.00
Watermelon	0.0%	15.75	0.00	1.32	0.00
Grape, Wine	0.0%	28.42	0.00	2.74	0.00
Driving Range	0.0%	40.54	0.00	3.36	0.00
Total			33.41		2.91
% Increase					8.7%
Note: All values in inches. Acreage does not include crop types that were assumed to have a CIR equal to the weighted average of all crops.					

Table 36. Estimated Future Irrigation Requirements – SVID					
Crop Type	**% Acreage**	**Current CIR**	**Weighted CIR**	**Increase in CIR**	**Weighted Increase**
Grape, Concord	21.3%	27.34	5.82	2.70	0.57
Corn, Field	19.1%	29.31	5.64	3.02	0.58
Alfalfa, Hay	12.5%	37.02	4.61	3.20	0.40
Hops	11.2%	30.76	3.44	2.78	0.31
Cherry	8.0%	44.93	3.58	3.90	0.31
Apple	6.9%	44.37	3.04	3.88	0.27
Wheat	3.0%	24.35	0.72	1.46	0.04
Asparagus	2.7%	29.96	0.81	2.60	0.07
Alfalfa/Grass, Hay	2.4%	37.02	0.90	3.20	0.08
Grape, Wine	2.0%	27.34	0.56	2.70	0.06
Mint	1.8%	35.94	0.65	3.40	0.06
Sorghum	1.4%	25.13	0.35	2.68	0.04
Triticale	1.3%	24.56	0.34	1.26	0.02
Grass, Hay	1.4%	41.13	0.56	3.49	0.05
Pear	1.3%	41.09	0.52	3.62	0.05
Pasture	1.2%	29.47	0.34	2.56	0.03
Squash	0.4%	17.93	0.07	2.07	0.01
Oat	0.3%	24.56	0.08	1.26	0.00
Plum	0.3%	41.09	0.12	3.62	0.01
Golf Course	0.3%	39.07	0.10	3.34	0.01
Barley	0.2%	24.56	0.05	1.26	0.00
Rye	0.2%	24.56	0.04	1.26	0.00
Nectarine/Peach	0.2%	41.71	0.07	3.63	0.01
Watermelon	0.2%	15.17	0.02	1.32	0.00
Market Crops	0.1%	27.52	0.04	2.85	0.00
Caneberry	0.1%	42.91	0.06	3.65	0.00
Green Manure	0.1%	24.56	0.01	1.26	0.00
Apricot	0.0%	42.05	0.02	3.62	0.00
Pumpkin	0.0%	17.93	0.01	2.07	0.00
Corn, Sweet	0.0%	21.02	0.01	1.90	0.00
Currant	0.0%	42.91	0.01	3.65	0.00
Driving Range	0.0%	39.07	0.00	3.34	0.00
Orchard, Unknown	0.0%	44.37	0.00	3.88	0.00
Total			32.62		2.99
% Increase					9.2%

Note: All values in inches. Acreage does not include crop types that were assumed to have a CIR equal to the weighted average of all crops.

Table 37. Estimated Future Irrigation Requirements – YTID					
Crop Type	**% Acreage**	**Current CIR**	**Weighted CIR**	**Increase in CIR**	**Weighted Increase**
Apple	80.1%	31.82	25.49	2.83	2.27
Pear	7.9%	29.45	2.32	2.64	0.21
Cherry	4.7%	32.20	1.50	2.84	0.13
Alfalfa/Grass, Hay	3.8%	26.48	1.02	2.33	0.09
Grass, Hay	1.1%	29.44	0.31	2.53	0.03
Golf Course	0.9%	27.95	0.26	2.43	0.02
Alfalfa, Hay	0.6%	26.48	0.15	2.33	0.01
Sod Farm	0.4%	27.95	0.12	2.43	0.01
Caneberry	0.3%	30.77	0.08	2.65	0.01
Barley	0.1%	17.30	0.02	0.92	0.00
Nectarine/Peach	0.1%	29.87	0.02	2.65	0.00
Orchard, Unknown	0.0%	31.82	0.02	2.83	0.00
Grape, Wine	0.0%	19.60	0.01	1.99	0.00
Total			31.31		2.78
% Increase					8.9%
Note: All values in inches. Acreage does not include crop types that were assumed to have a CIR equal to the weighted average of all crops.					

Table 38. Estimated Future Irrigation Requirements – KID					
Crop Type	**% Acreage**	**Current CIR**	**Weighted CIR**	**Increase in CIR**	**Weighted Increase**
Grape, Wine	25.8%	29.33	7.57	2.56	0.66
Apple	15.5%	47.40	7.35	3.68	0.57
Alfalfa, Hay	15.5%	39.56	6.13	3.02	0.47
Wheat	11.8%	25.97	3.05	1.35	0.16
Cherry	8.0%	48.04	3.82	3.70	0.29
Asparagus	3.7%	32.02	1.18	2.44	0.09
Alfalfa/Grass, Hay	3.6%	39.56	1.41	3.02	0.11
Corn, Field	3.5%	31.26	1.10	2.77	0.10
Potato	2.8%	30.68	0.87	2.70	0.08
Corn, Sweet	2.6%	22.27	0.58	1.78	0.05
Pasture	2.0%	31.50	0.62	2.40	0.05
Pumpkin	1.9%	19.09	0.36	1.86	0.03
Golf Course	1.8%	41.75	0.73	3.16	0.06
Pear	0.8%	43.95	0.37	3.42	0.03
Grass, Hay	0.6%	43.94	0.27	3.31	0.02
Plum	0.1%	43.95	0.05	3.42	0.00
Nectarine/Peach	0.1%	44.65	0.04	3.44	0.00
Total			35.51		2.76
% Increase					7.8%
Note: All values in inches. Acreage does not include crop types that were assumed to have a CIR equal to the weighted average of all crops.					

Appendix D

Land Use Conversion Calculations

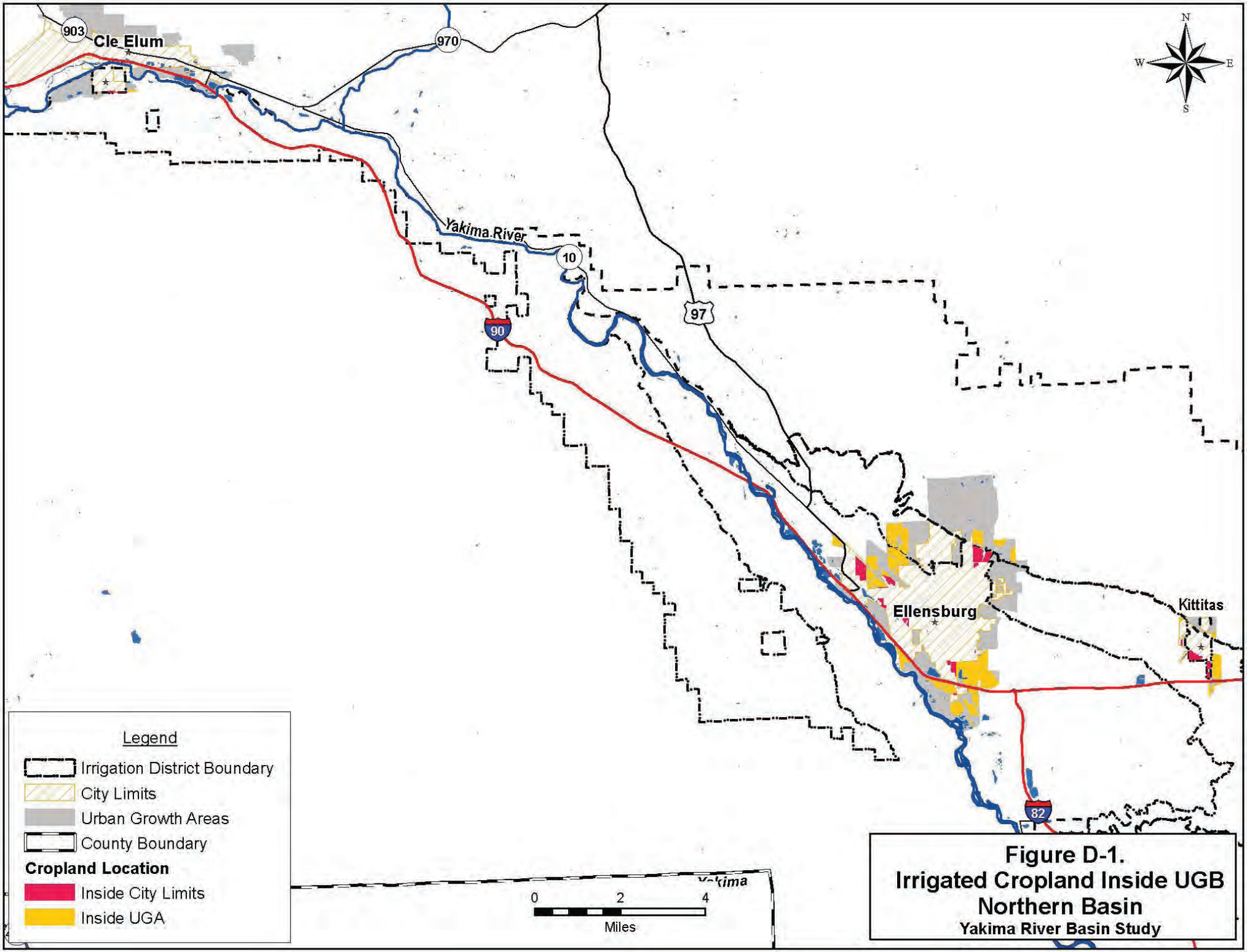
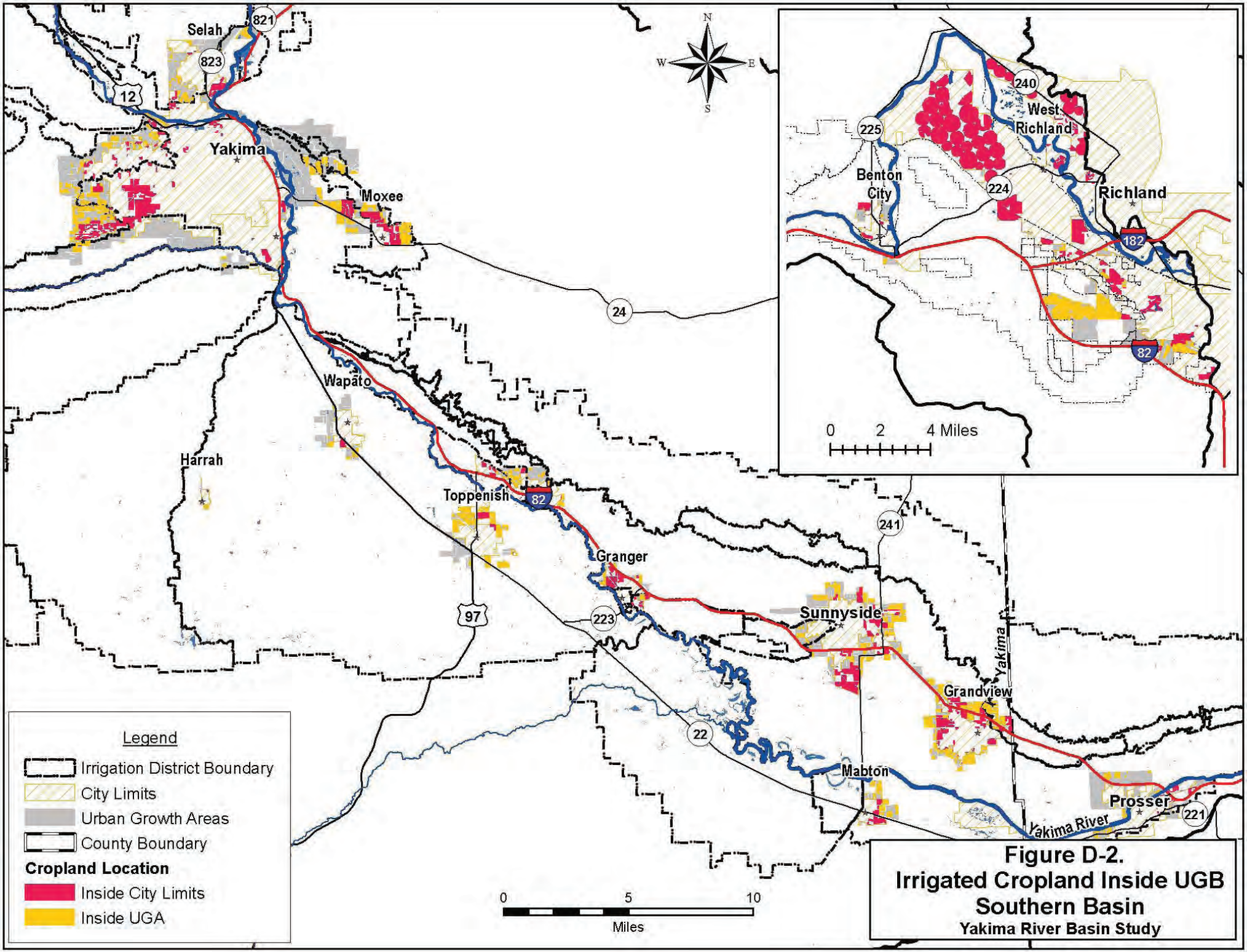


Figure D-1.
Irrigated Cropland Inside UGB
Northern Basin
Yakima River Basin Study


Selah
821
823
12
Yakima
Moxee
24
Wapato
Harrah
Toppenish
82
Granger
97
223
Sunnyside
241
Yakima
Grandview
22
Mabton
Prosser
221
Yakima River
N
W
E
S
240
West Richland
225
Benton City
224
Richland
182
82
0 2 4 Miles
Legend
Irrigation District Boundary
City Limits
Urban Growth Areas
County Boundary
Cropland Location
Inside City Limits
Inside UGA
0 5 10
Miles
Figure D-2.
Irrigated Cropland Inside UGB
Southern Basin
Yakima River Basin Study

Acreage within Urban Growth Boundaries (UGBs)

Tables D-1 and D-2 summarize the irrigated acreage located within the urban growth boundaries (UGBs) of the cities and counties in the Yakima basin. This analysis includes irrigated lands located within city limits and within city- or county-designated urban growth areas (UGAs). The tables compare acreage in UGAs, city limits, and rural areas outside any UGAs.

Table D-1 presents the acreage with irrigation type "none" (e.g., not irrigated in 2008); irrigated acreage, and the total acreage. The yellow highlight in the center columns of Table D-1 indicates the irrigated acreage. Acreage inside UGA and inside City limits was considered in the assessment of potential conversion to urban uses.

Table D-2 presents a summary of the irrigated acreage (yellow highlighted columns from Table D-1) by number and percentage.

Table D-1. Estimated Acreage by UGA and City Limit Location

Geographic Area	Acres with Irrigation Type = "None" or "#N/A"			Acres with Specified Irrigation Type			Total Acres		
	Surface Water	Ground Water - Primary	Total	Surface Water	Ground Water - Primary	Total	Surface Water	Ground Water - Primary	Total
	(Acres)	*(Acres)*	*(Acres)*	*(Acres)*	*(Acres)*	*(Acres)*	*(Acres)*	*(Acres)*	*(Acres)*
Inside UGA	318	109	427	7,938	1,083	9,021	8,256	1,192	9,448
Inside City Limits	619	177	796	8,769	3,230	12,000	9,388	3,407	12,795
Rural	49,465	26,427	75,893	301,194	36,696	337,891	350,659	63,124	413,783
Total	50,402	26,713	77,115	317,901	41,010	358,911	368,303	67,723	436,026

Table D-2. Acreage by UGA/City Limit Location (Excluding NONE)

Geographic Area	Total	
	(Acres)	*(%)*
Inside UGA	9,021	3%
Inside City Limits	12,000	3%
Rural	337,891	94%
Total	358,911	100%

Note: Excludes Acreage with Irrigation method of "NONE".

Current Agricultural Application within UGBs

Table D-3 presents the current estimated irrigation application (excluding conveyance losses) for irrigated areas by location (federal district, non-federal district, and outside all districts) for four UGB areas (1.) Ellensburg, 2.) Yakima, 3.) Richland/West Richland, 4.) and all other jurisdictions).

Table D-3. Estimated Acreage and Application by Destination Irrigation District & Federal Project for UGA and City Limits

Geographic Area	Acres Irrigated			Annual Irrigation Requirement			Annual Irrigation Efficiency Loss			Estimated Annual Application		
	Surface Water (Acres)	Groundwater - Primary (Acres)	Total (Acres)	Surface Water (Acre-Feet)	Groundwater - Primary (Acre-Feet)	Total (Acre-Feet)	Surface Water (Acre-Feet)	Groundwater - Primary (Acre-Feet)	Total (Acre-Feet)	Surface Water (Acre-Feet)	Groundwater - Primary (Acre-Feet)	Total (Acre-Feet)
Non-Federal District												
Ellensburg (UGA and City Limits)	138	0	138	205	0	205	205	0	205	410	0	410
Yakima (UGA and City Limits)	398	0	398	1,215	0	1,215	414	0	414	1,630	0	1,630
Richland (UGA and City Limits)[3]	1,152	0	1,152	3,519	0	3,519	1,002	0	1,002	4,520	0	4,520
All Other (UGA and City Limits)	964	0	964	2,620	0	2,620	952	0	952	3,573	0	3,573
Subtotal	2,653	0	2,653	7,559	0	7,559	2,573	0	2,573	10,133	0	10,133
Federal District												
Ellensburg (UGA and City Limits)	97	0	97	262	0	262	228	0	228	490	0	490
Yakima (UGA and City Limits)	1,324	0	1,324	4,921	0	4,921	1,726	0	1,726	6,647	0	6,647
Richland (UGA and City Limits)[3]	626	0	626	1,810	0	1,810	539	0	539	2,349	0	2,349
All Other (UGA and City Limits)	6,888	0	6,888	18,019	0	18,019	9,907	0	9,907	27,926	0	27,926
Subtotal	8,936	0	8,936	25,013	0	25,013	12,400	0	12,400	37,413	0	37,413
Outside District												
Ellensburg (UGA and City Limits)	856	91	947	1,974	209	2,184	1,562	166	1,728	3,536	375	3,912
Yakima (UGA and City Limits)	0	1,440	1,440	0	4,303	4,303	0	1,400	1,400	0	5,703	5,703
Richland (UGA and City Limits)[3]	4,214	1,642	5,856	12,562	4,894	17,456	3,224	1,256	4,480	15,787	6,150	21,936
All Other (UGA and City Limits)	47	1,141	1,188	128	3,310	3,438	121	1,172	1,294	249	4,482	4,732
Subtotal	5,118	4,313	9,431	14,665	12,716	27,381	4,908	3,994	8,902	19,572	16,710	36,283
Total												
Ellensburg (UGA and City Limits)	1,092	91	1,182	2,442	209	2,651	1,995	166	2,161	4,437	375	4,812
Yakima (UGA and City Limits)	1,723	1,440	3,163	6,137	4,303	10,439	2,140	1,400	3,540	8,277	5,703	13,980
Richland (UGA and City Limits)[3]	5,993	1,642	7,634	17,891	4,894	22,785	4,765	1,256	6,021	22,656	6,150	28,806
All Other (UGA and City Limits)	7,900	1,141	9,041	20,768	3,310	24,078	10,981	1,172	12,153	31,748	4,482	36,231
Grand Total	16,707	4,313	21,020	47,237	12,716	59,953	19,881	3,994	23,875	67,117	16,710	83,828

Notes: 1. Excludes Annual Conveyance Efficiency Losses.

2. Excludes fields with Irrigation types of "None" and "#NA."

3. Includes both Richland and West Richland.

Urban Conversion of Agricultural Land – Method 1

Tables D-4 and D-5 present two methods used to estimate potential change in water use due to future conversion of agricultural land to urban uses. It was assumed that 1/3 of the irrigated acreage within UGBs would be converted by 2030, and 2/3 would be converted by 2060.

The first method used an average residential density of 4 dwelling units per acre to estimate future urban water use.

Table D-4. Estimated Domestic Use with Conversion of Existing Crop Land in Cities and Urban Growth Areas – Method 1

	Current			Future Use Assumptions				2030 Forecast					2060 Forecast				
Geographic Area	Acres Irrigated (Acres)	Agricultural Application (Acre-Feet)	Agricultural Use Per Acre (Acre-Feet/Acre)	Housing Density (Dwelling Units (DU)/Acre)	Domestic Use Per Unit (gallons/ DU/day)	Domestic Use Per Acre (Acre-Feet / Acre)	Change in Use Per Acre with Urban Conversion (Acre-Feet / Acre)	Acres Irrigated (Acres)	Agricultural Application (Acre-Feet)	Converted Acreage (1/3 of Irrigated Acres) (Acres)	Annual Domestic Water Use (Acre-Feet)	Change in Water Use from Current (Acre-Feet)	Acres Irrigated (Acres)	Agricultural Application (Acre-Feet)	Converted Acreage (2/3 of Irrigated Acres) (Acres)	Annual Domestic Water Use (Acre-Feet)	Change in Water Use from Current (Acre-Feet)
Non-Federal District																	
Ellensburg (UGA and City Limits)	138	410	2.97	4.0	700	3.14	0.17	92	274	46	144	8	46	137	92	289	15
Yakima (UGA and City Limits)	398	1,630	4.09	4.0	700	3.14	-0.95	266	1,086	133	416	-127	133	543	266	833	-254
Richland (UGA and City Limits)[3]	1,152	4,520	3.92	4.0	700	3.14	-0.79	768	3,013	384	1,204	-302	384	1,507	768	2,409	-605
All Other (UGA and City Limits)	964	3,573	3.70	4.0	700	3.14	-0.57	643	2,382	321	1,008	-183	321	1,191	643	2,017	-365
Subtotal	2,653	10,133	3.82	n/a	n/a	3.14	-0.68	1,769	6,755	884	2,773	-604	884	3,378	1,769	5,547	-1,208
Federal District																	
Ellensburg (UGA and City Limits)	97	490	5.05	4.0	700	3.14	-1.91	65	327	32	101	-62	32	163	65	203	-124
Yakima (UGA and City Limits)	1,324	6,647	5.02	4.0	700	3.14	-1.88	883	4,431	441	1,384	-831	441	2,216	883	2,769	-1,662
Richland (UGA and City Limits)[3]	626	2,349	3.75	4.0	700	3.14	-0.61	418	1,566	209	655	-128	209	783	418	1,310	-256
All Other (UGA and City Limits)	6,888	27,926	4.05	4.0	700	3.14	-0.92	4,592	18,618	2,296	7,202	-2,107	2,296	9,309	4,592	14,403	-4,214
Subtotal	8,936	37,413	4.19	n/a	n/a	3.14	-1.05	5,957	24,942	2,979	9,342	-3,128	2,979	12,471	5,957	18,685	-6,257
Outside District																	
Ellensburg (UGA and City Limits)	947	3,912	4.13	4.0	700	3.14	-0.99	632	2,608	316	990	-313	316	1,304	632	1,981	-627
Yakima (UGA and City Limits)	1,440	5,703	3.96	4.0	700	3.14	-0.82	960	3,802	480	1,505	-396	480	1,901	960	3,011	-791
Richland (UGA and City Limits)[3]	5,856	21,936	3.75	4.0	700	3.14	-0.61	3,904	14,624	1,952	6,122	-1,190	1,952	7,312	3,904	12,244	-2,380
All Other (UGA and City Limits)	1,188	4,732	3.98	4.0	700	3.14	-0.85	792	3,154	396	1,242	-335	396	1,577	792	2,484	-670
Subtotal	9,431	36,283	3.85	n/a	n/a	3.14	-0.71	6,288	24,189	3,144	9,860	-2,234	3,144	12,094	6,288	19,720	-4,468
Total																	
Ellensburg (UGA and City Limits)	1,182	4,812	4.07	n/a	n/a	3.14	-0.93	788	3,208	394	1,236	-368	394	1,604	788	2,472	-735
Yakima (UGA and City Limits)	3,163	13,980	4.42	n/a	n/a	3.14	-1.28	2,108	9,320	1,054	3,306	-1,354	1,054	4,660	2,108	6,613	-2,707
Richland (UGA and City Limits)[3]	7,634	28,806	3.77	n/a	n/a	3.14	-0.64	5,090	19,204	2,545	7,981	-1,620	2,545	9,602	5,090	15,963	-3,241
All Other (UGA and City Limits)	9,041	36,231	4.01	n/a	n/a	3.14	-0.87	6,027	24,154	3,014	9,452	-2,625	3,014	12,077	6,027	18,904	-5,250
Grand Total	21,020	83,828	3.99	n/a	n/a	3.14	-0.85	14,014	55,885	7,007	21,976	-5,967	7,007	27,943	14,014	43,952	-11,933

Notes: 1. Excludes Annual Conveyance Efficiency Losses.

2. Excludes fields with Irrigation types of "None" and "NA."

3. Includes both Richland and West Richland.

Urban Conversion of Agricultural Land – Method 2

Method 2 used the current average water use per acre in Yakima and Ellensburg, estimated at 1.65 acre feet per acre, to estimate future water use.

Table D-5. Estimated Domestic Use with Conversion of Existing Crop Land in Cities and Urban Growth Areas – Method 2

Geographic	Current			Future Use Assumptions		2030 Forecast					2060 Forecast				
Area	Acres Irrigated (Acres)	Agricultural Application (Acre-Feet)	Agricultural Use Per Acre (Acre-Feet/Acre)	Domestic Use Per Acre (Acre-Feet / Acre)	Change in Domestic Use Per Acre (Acre-Feet / Acre)	Acres Irrigated (Acres)	Agricultural Application (Acre-Feet)	Converted Acreage (1/3 of Irrigated Acres) (Acres)	Annual Domestic Water Use (Acre-Feet)	Change in Water Use from Current (Acre-Feet)	Acres Irrigated (Acres)	Agricultural Application (Acre-Feet)	Converted Acreage (2/3 of Irrigated Acres) (Acres)	Annual Domestic Water Use (Acre-Feet)	Change in Water Use from Current (Acre-Feet)
Non-Federal District															
Ellensburg (UGA and City Limits)	138	410	2.97	1.65	-1.32	92	274	46	76	-61	46	137	92	152	-122
Yakima (UGA and City Limits)	398	1,630	4.09	1.65	-2.44	266	1,086	133	219	-324	133	543	266	438	-648
Richland (UGA and City Limits)[3]	1,152	4,520	3.92	1.65	-2.27	768	3,013	384	634	-873	384	1,507	768	1,267	-1,746
All Other (UGA and City Limits)	964	3,573	3.70	1.65	-2.05	643	2,382	321	530	-660	321	1,191	643	1,061	-1,321
Subtotal	2,653	10,133	3.82	1.65	-2.17	1,769	6,755	884	1,459	-1,918	884	3,378	1,769	2,918	-3,837
Federal District															
Ellensburg (UGA and City Limits)	97	490	5.05	1.65	-3.40	65	327	32	53	-110	32	163	65	107	-220
Yakima (UGA and City Limits)	1,324	6,647	5.02	1.65	-3.37	883	4,431	441	728	-1,487	441	2,216	883	1,457	-2,975
Richland (UGA and City Limits)[3]	626	2,349	3.75	1.65	-2.10	418	1,566	209	345	-438	209	783	418	689	-877
All Other (UGA and City Limits)	6,888	27,926	4.05	1.65	-2.40	4,592	18,618	2,296	3,789	-5,520	2,296	9,309	4,592	7,577	-11,040
Subtotal	8,936	37,413	4.19	1.65	-2.54	5,957	24,942	2,979	4,915	-7,556	2,979	12,471	5,957	9,830	-15,112
Outside District															
Ellensburg (UGA and City Limits)	947	3,912	4.13	1.65	-2.48	632	2,608	316	521	-783	316	1,304	632	1,042	-1,566
Yakima (UGA and City Limits)	1,440	5,703	3.96	1.65	-2.31	960	3,802	480	792	-1,109	480	1,901	960	1,584	-2,218
Richland (UGA and City Limits)[3]	5,856	21,936	3.75	1.65	-2.10	3,904	14,624	1,952	3,221	-4,091	1,952	7,312	3,904	6,442	-8,183
All Other (UGA and City Limits)	1,188	4,732	3.98	1.65	-2.33	792	3,154	396	653	-924	396	1,577	792	1,307	-1,847
Subtotal	9,431	36,283	3.85	1.65	-2.20	6,288	24,189	3,144	5,187	-6,907	4,192	12,094	6,288	10,374	-13,814
Total															
Ellensburg (UGA and City Limits)	1,182	4,812	4.07	1.65	-2.42	788	3,208	394	650	-954	394	1,604	788	1,301	-1,907
Yakima (UGA and City Limits)	3,163	13,980	4.42	1.65	-2.77	2,108	9,320	1,054	1,739	-2,921	1,054	4,660	2,108	3,479	-5,841
Richland (UGA and City Limits)[3]	7,634	28,806	3.77	1.65	-2.12	5,090	19,204	2,545	4,199	-5,403	2,545	9,602	5,090	8,398	-10,806
All Other (UGA and City Limits)	9,041	36,231	4.01	1.65	-2.36	6,027	24,154	3,014	4,973	-7,104	3,014	12,077	6,027	9,945	-14,209
Grand Total	21,020	83,828	3.99	1.65	-2.34	14,014	55,885	7,007	11,561	-16,382	7,007	27,943	14,014	23,122	-32,763

Notes: 1. Excludes Annual Conveyance Efficiency Losses.
2. Excludes fields with irrigation types of "None" and "N/A".
3. Includes both Richland and West Richland.