Technical Review

Yakima River Basin Study

Proposed Integrated Water Resource Management Plan

Prepared for *the Yakima Basin Storage Alliance*

July 29, 2014

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Executive Summary

The purpose and goal of this Yakima Basin Integrated Plan Technical Review is to provide elected officials, policy makers, and the general public with an impartial, objective review of elements of the Yakima River Basin Study Proposed Integrated Water Resource Management Plan (or IP), prepared by the United States Bureau of Reclamation in 2011. This review was conducted at the request of the Yakima Basin Storage Alliance with the intent of encouraging new examination and discussion of the resulting outcomes from IP and is focused on the following three key questions:

1. *Do the projects resulting from the IP provide sufficient water for instream and out-of-stream water needs, including the current climate conditions and future conditions under the three climate change models identified in the IP?*
2. *Is the capacity of the surface water storage options presented in the IP sufficient to meet instream and out-of-stream needs over the long-term?*
3. *Will the timeline for constructing the water storage projects be achievable in a timely manner?*

Based on this review and analysis, we conclude that the IP does not provide sufficient information to adequately answer these fundamental questions. The level of doubt and uncertainty with the baseline data, resulting studies, and conclusions reached in the Plan is significant. The action identified in the IP does not provide the following:

- Basin Water Needs - The IP does not provide an accurate and complete accounting of the current water needs, most notably for instream flows. As a result, the IP does not include the information required to determine if it presents the best course of action for providing a reliable, long-term water supply to the Yakima Basin.
- Climate Change - The IP's detailed historical hydrologic assessment did not adequately quantify the current and future effects (e.g., reduced snowpack, earlier snowmelt and runoff events, increased temperatures, and single/multi-year droughts) of climate change on the Basin.
- Water and Tribal Rights - Under the current conditions highlighted in the IP, the junior water rights holders typically do not receive their full allocation - there is simply not enough water remaining to satisfy all water right holders. Additional water to support instream flows would have prior rights, and would need to be satisfied prior to any irrigation withdrawals, further aggravating the situation for junior right holders.
- Water Storage Elements - The IP's proposed water storage projects also will not provide enough water volume and predictable water supply and storage capacity for future

needs. In addition, the estimated cost is significant at $4.4 billion and will be implemented over a long time frame of 30-40 years.

- Groundwater Depletion - The IP studies cite a reduction of 50,000 acre-feet between low and high runoff years, which in turn decreases the inflow available for seasonal water storage and reduces instream flows available for fisheries and aquatic habitat.
- Economic Analysis - The IP Model is a single-year model and is therefore, not capable of providing an accurate assessment of the long-term results and effects of the IP, such as: estimating the direct economic effect to irrigators, cropping patterns, water conveyance efficiencies, and fixed crop water requirements in the Basin. The economic analysis also requires additional fidelity to support the values associated with water supply benefits to the ecosystem, fisheries (e.g., a new survey to assess fishery benefits), and agriculture.

In summary, water is critically important to the environmental, economic, social, and cultural well-being of the Yakima River Basin. In dry years, water supplies are inadequate to meet all needs, and water delivery shortages occur to irrigated agriculture. This results in a reduction in agricultural output and employment, and reduced activity in supporting economic sectors (e.g., processing, transportation, etc.). The proposed IP storage projects each present significant technical, political and funding challenges which are yet to be fully addressed. These challenges, in combination with the large cost for the proposed projects (up to $4.4 billion) ,will likely result in implementation delays, increased costs and the potential that one or more of the projects may never be built. Before additional significant public funds and time are expended, we urge further review and consideration of the points raised in this review.

Introduction

This Technical Review was prepared at the request of the Yakima Basin Storage Alliance, and provides a technical review of the elements and supporting documents for the Yakima River Basin Study Proposed Integrated Water Resource Management Plan (United States Bureau of Reclamation) (2011A).

The goals of this Technical Review are to provide an impartial, technical review of the following elements of the Integrated Plan (IP):

- Instream and out-of-stream water needs, including the current climate conditions and future conditions under the three climate change models identified in the IP;
- An assessment of whether the capacity of the surface water storage options presented in the IP are sufficient to meet instream and out-of-stream needs over the long-term; and
- An assessment of the timeline for constructing the water storage projects in a timely manner.

The target audience for this Technical Review is composed of elected officials, policy makers, and the general public.

Section 1.0 provides a summary of the methods used for the study, and an overview of the Yakima Basin, its location, geography, and critical issues. Section 2.0 provides a review of the water needs for the Yakima Basin, as provided in the Integrated Plan. Section 3.0 provides an overview of Treaty Rights and their implications on water rights in the Yakima Basin. Section 4.0 provides a comparison of basin diversion options. Section 5 provides an analysis of the economics of water supply in the Yakima Basin, with emphasis on reviewing the findings of the IP studies. The conclusions of this Technical Review are presented in Section 6.0.

1.0 Methods and Yakima Basin Background and Overview

1.1 Methods

This review of the IP is based on the documents included as part of the IP and other supporting studies. During our analysis, when quantitative information was required to support the review, the figures were drawn directly from the IP and its supporting documents, and the methods used to verify these figures reflect the methods used in the IP The reviewers used non-IP sources only where necessary to provide an understanding of the issues or a broader overview of related studies. A complete listing of the sources used for the Technical Review is provided in the Bibliography at the end of this study.

1.2 Background and Overview

The Yakima River (Figure 1) originates in Kittitas County, Washington State, on the eastern slope of the Cascade Mountains. The river flows 214 miles, heading southeast through the Kittitas and Yakima valleys, then discharges into the Columbia River near Richland, WA. Tributaries to the Yakima River include the Cle Elum, Teanaway, and Naches rivers, as well as numerous creeks. The confluence of the Yakima and Naches rivers at the City of Yakima divides the Yakima River into "upper" and "lower" portions. The Elevation in the Basin ranges from 2,496 meters (8,184 feet) above mean sea level in the Cascades to 104 meters (340 feet) at the river's confluence with the Columbia River near Richland, WA. Along with its tributaries, the river system drains about 6,155 square miles or 4 million acres[1]. Within the boundaries of the Basin, 62 percent is publicly-owned and 38 percent is privately owned[2]. The predominant land use in the Yakima subbasin includes irrigated agriculture (1,000 square miles), grazing (2,900 square miles, [USFW] [2011]), urbanization (50 square miles), and timber (2,200 square miles[3]).

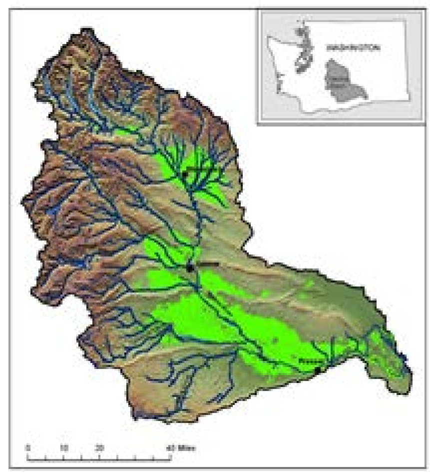


Figure 1. The Yakima Basin

Cropland accounts for 16 percent of the total subbasin of which 77 percent is irrigated[4]. A diverse variety of crops (mostly irrigated) are grown in Yakima Basin including fruit trees (i.e., apples, cherries, pears), hops, and grapes, plus a variety of vegetables, seeds, field crops, and cereal grains. The State's agriculture is highly diversified with some 300 commodities produced commercially, ranking first in the US for production for 11 commodities and with a value of production for crops and livestock reaching $6.7 billion in 2006 (USBR 2012). The State's food and agriculture industry contributes 11 percent to the state's economy (WSDA 2008).

Yakima County ranks fifth in the US in total agricultural production. Hay remains the largest cash crop in Kittitas County and was estimated to have an annual value of more than $30M (EDC of Kittitas Co.) (2011).

Since the origins of the Yakima Project in the early 1900's, the US Bureau of Reclamation (USBR) has operated the Yakima Project, which supplies irrigation water to most of the basin's agricultural community. The majority of crops in the basin are produced on approximately 500,000 acres of irrigated lands; these lands receive water from Yakima Project diversions.

There are five main reservoirs in the upper Yakima and Naches river basins: Bumping, Cle Elum, Kachess, Keechelus, and Tieton. These reservoirs have a total combined maximum storage capacity of about 1.07 million acre-feet (MAF)[5]. These reservoirs also provide water supply of approximately 30 percent of the river's mean annual flow and are operated by the USBR as a pooled system (USFWS 2011). Water released for irrigation from the upstream reservoirs is generally conveyed by the Yakima and Naches Rivers, and then diverted into canal systems operated by entities (e.g., irrigation districts and municipalities) for delivery to an array of water users. USBR considers annual snowmelt the sixth reservoir[6] and is an unpredictable source. USBR defines "good" snowpack as providing a source for water supply that provides an extended snowmelt period to fill the reservoirs by mid-June, and natural/unregulated runoff for irrigations diversions and instream flow through the spring months. The reservoirs store approximately 30 percent of the average annual runoff in the basin[7] (The average annual runoff is 3.4 MAF, Anchor QEA 2011), and attempt to operate to meet some of the irrigation demands, flood control needs, and instream flow requirements.

The Yakima River Reservoir system supplies irrigation water to over 464,000 acres[8]; and the divisions in the system include Kittitas, Roza, Wapato, Sunnyside Valley, Yakima-Tieton, and Kennewick (Figure 2). These six districts have "entitlements"[9] totaling 2.04 MAF[10]. Most of these entitlements (1.94 MAF[11]) are diverted above the USBR stream gage at the Parker gage, which is the main control point for the Yakima River where flows are closely monitored. This gage also serves as the basis for determining flows for irrigation distributions. The irrigation deliveries across the basin average 1.7 MAF. The IP identifies 28,000 acres of recorded idle land in the Wapato irrigation area and approximately 16,400 acres that could potentially be put into production[12].

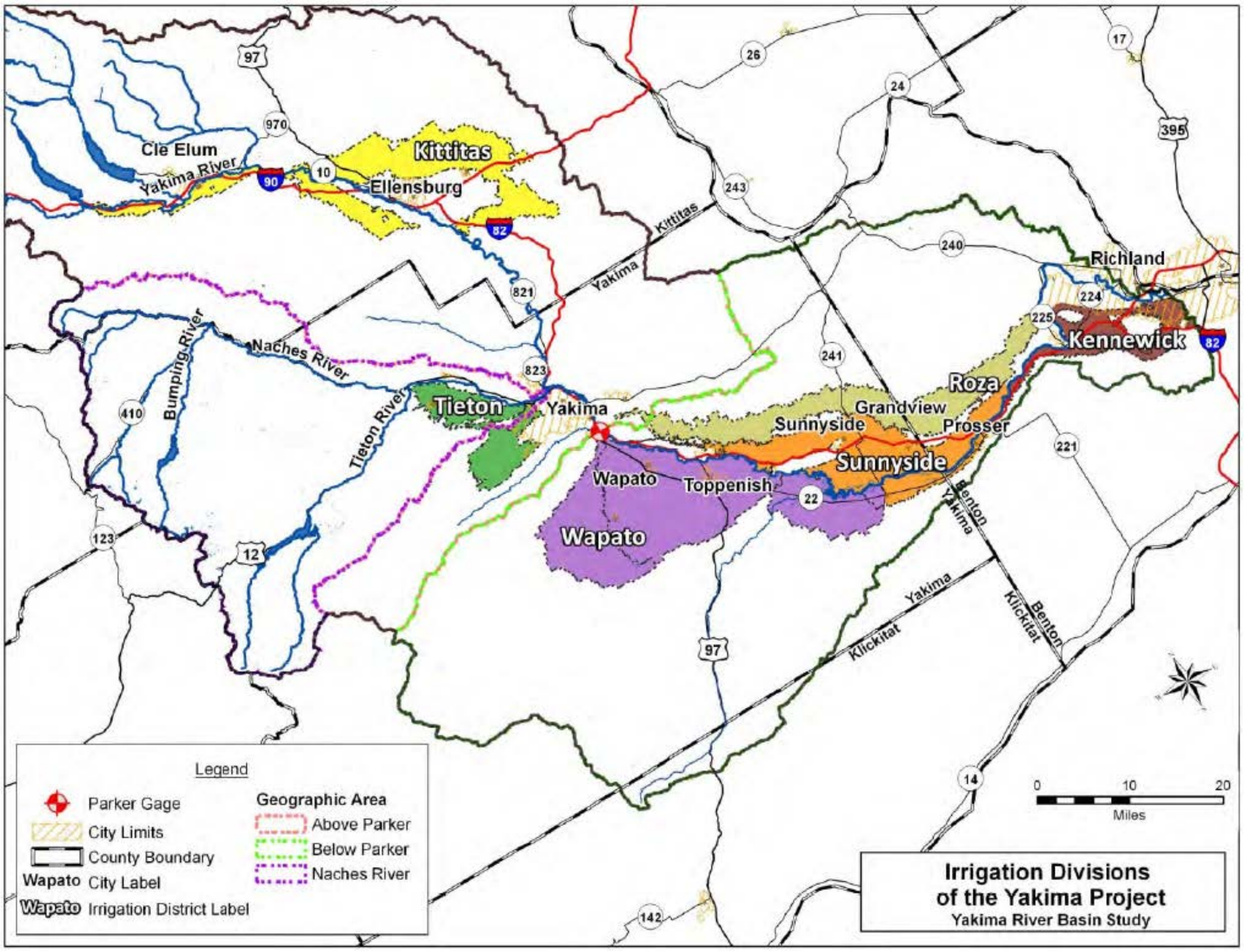


Figure 2. Yakima Basin Project Irrigation Districts (from *Water needs for Out-of-Stream Uses Technical Memorandum*, HDR and Anchor QEA 2011)

The volume of water from the Yakima Project to meet the instream and out-of-stream needs above the Parker gage is estimated annually beginning on April 1st and continuing for each month through October. Any deficiency in irrigation supply is first assessed against the junior (proratable) irrigation water rights, and then if necessary against the senior (nonproratable) irrigation water rights. The Acquavella Adjudication Court determined that the Yakama Nation's Right mandated that the instream flows for the anadromous fishery are time immemorial, and senior to all other water rights within the Basin[13].

As with many regions in the West, the river is the lifeblood of agricultural and economic activity in addition to being a prominent recreation resource. The river supports diverse fisheries resources including Chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), steelhead and rainbow trout (*O. mykiss*), sockeye (*O. nerka*), and bull trout (*Salvelinus confluentus*). Inadequate fish passage and protective facilities at many diversion sites have been a major factor in anadromous fish declines in the Yakima River Basin[14,15]. There are many other factors in the Basin that have contributed to population declines, including total blockage and dewatering of spawning and rearing habitat; overharvesting; construction of diversion dams without fish passage provisions; construction of diversion dams without adequate fish protection measures; and elimination of braids and natural floodways[16].

With these facts as a backdrop for this setting and discussion, the implementation of the Yakima Basin Integrated Plan was recently begun after 30 years or more of collaboration, negotiation, and compromise. Management and use of the water supplies provided by the Yakima Basin has been the subject of debate and contention for far longer than this recent period. Leaving aside much of the early debate, legal challenges involving water rights (including native treaty rights) led Congress in 1977 to authorize the Yakima River Basin Water Enhancement Project (YRBWEP). In the 1980's, junior water rights holders saw their water deliveries reduced by as much as two-thirds of historic allotments[17]. Drought conditions in 1987-1988, 1992-1994, 2001, and 2005 highlight the increasing agricultural demands in the Yakima Basin; these droughts have intensified the need to find long-term solutions to the Basin's water shortage problem[18].

In another development, the YRBWEP was given a boost due to the passage of the Secure Waters Act in 2008. This law authorized Federal water and science agencies to work together with state and local water managers to plan for climate change and the other threats to water supplies, and take action to secure water resources for the communities, economies, and ecosystems they support.

In 2009, the Bureau of Reclamation and Department of Ecology (Ecology) formed the Yakima River Basin Water Enhancement Project Workgroup. This Workgroup is composed of representatives from the Yakama Nation, irrigation districts, environmental organizations, and Federal, State, county and city governments (The complete list of members is provided in the Integrated Plan), who are to work together to develop a consensus-based solution to the basin's water problem. This Work Group ultimately developed the Yakima River Basin Integrated Water Resource Management Plan (IP).

The Yakima River Basin Integrated Water Resource Management Plan (Figure 3), was envisioned to be a forward-thinking plan serving to address current and future water needs in the basin. The plan was intended to provide a balanced approach to address anticipated water shortages through increased water storage features, enhanced water conservation, water marketing, better use of existing infrastructure, and making targeted land acquisitions where possible. The plan had the further objective of improving the overall ecological integrity of the Yakima Basin by protecting, enhancing, and mitigating fish and wildlife habitat with a focus on riparian and headwaters habitat; providing fish passage at reservoirs, provide increased operational flexibility to manage instream flows to meet ecological objectives; and improve the reliability of the water supply for irrigation, municipal supply and domestic/commercial uses. The IP also provided a detailed assessment of seven key elements: fish passage, structural and operational changes, surface water and groundwater storage, habitat/watershed protection and enhancement, enhanced water conservation, and market-based reallocation. The seven key elements are summarized below.

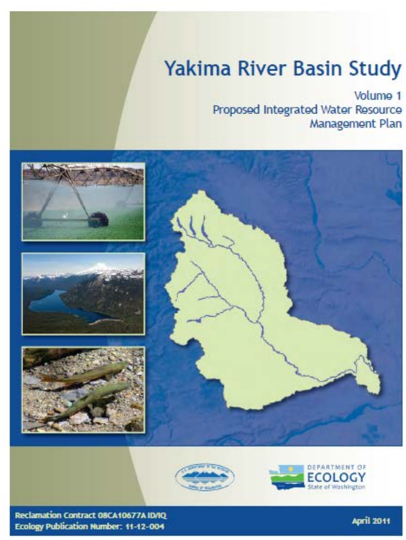


Figure 3. Yakima River Basin Study

- Fish Passage Element: Proposed providing up and downstream fish passage at five facilities: Cle Elum, Bumping, Kachess, Keechelus, and Rimrock. These projects were to provide access to high quality habitat, increase anadromous species abundance, allow reintroduction of sockeye, and provide genetic interchange for bull trout.
- Structural and Operational Element: Included Keechelus-to Kachess Tunnel/pipeline, Kittitas Reclamation District canal modifications and new pump station, reduce power diversions at Roza and Chandler Dams, Wapato Canal Improvements and raise Cle Elum Lake by 3 feet.
- Surface Water Storage Element: Proposed providing additional storage at Wymer (162,500 acre-feet [AF]), Kachess (200,000 AF all dead storage) and Bumping (156,300 AF).
- Surface Water and Groundwater Storage Element: Proposed enabling the use of surface water and aquifer recharge during periods of high runoff.
- Habitat/Watershed Protection and Enhancement Element: Included acquisition of three critical areas (46,000 acres in Teanaway Basin, 15,000 acres in Yakima County and 10,000 acres at Little Naches headwaters. In addition, there is consideration for protective designations on public lands and waters; plus fish habitat enhancement program in mainstem floodplain and tributaries.
- Enhanced Water Conservation Element: Provided for agricultural conservation up to 170,000 AF, and Municipal and Domestic Conservation Programs.
- Market Reallocation Element: Proposed on a near term, by building on existing water market programs and on a longer-term basis focusing on water transfers between districts and with districts outside the project boundaries, allow fallowing, and encourage changes in policies and regulations.

In March 2012, the USBR and Washington State Department of Ecology (Ecology) released the Final Programmatic Environmental Impact Statement (FPEIS) for the Yakima River Basin Integrated Water Resource Management Plan (Integrated Plan). Within the framework and structure of the plan and document, the Integrated Plan Alternative was selected as the Preferred Alternative for this extensive effort.

From these studies, the Agencies, Stakeholders, and the General Public hoped to have developed a series of plans and alternatives that would shape the future management and expansion of water supply in the Yakima Basin.

2.0 Review of Water Needs in the Yakima Basin and Assessment of Potential Supply

The following review of the Yakima Basin Integrated Plan provides the Team's findings regarding the current water needs and the sufficiency of the water supply provided in the IP for instream flows (fish and water quality), and out of stream uses (agricultural and municipal uses). The review includes a discussion of the effects of drought conditions as identified in the IP, and an analysis of the potential effects of climate change on water supply.

2.1 Current Water Needs in the Yakima Basin

For purposes of this review, a brief discussion of existing and proposed water storage features is necessary to establish a firm basis of understanding. Table 1 below provides a summary of existing water storage facilities in the Yakima Basin and their associated capacity, together with projected facility expansion potentially resulting from the IP.

Table 1: Yakima Basin Water Storage Features – Existing and Proposed.

Existing Storage Facility	Active Reservoir Storage Volume (Acre-feet)	Reservoir Crest Elevation (Feet NGVD*)	Percent of Total of Current Storage (%)
Keechelus Dam	157,800	2,517	15
Kachess Dam	239,000	2,262	22
Cle Elum Dam	436,900	2,240	41
Bumping Lake Dam	33,700	3,426	3
Tieton Dam/ Rimrock Lake	198,000	2,926	19
Total Existing Storage	*1,065,400*		*100*
Proposed Storage Features (Increased Capacity)			
Wymer Dam	162,500	1750**	
Kachess Inactive Storage	200,000	2,262 (Unchanged)	
Cle Elum Dam Raise	14,600	2,243 (3 foot pool raise)	
Enlarged Bumping Reservoir	156,300 (190,000 proposed – 33,700 current)	3,490	N/A
Total Proposed Storage Increase	533,400		

Note: Values in this table were obtained from various USBR sources and publications (percentages in table have been corrected by for this document), http://www.usbr.gov/pn//programs/yrbwep/2011integratedplan/index.html.
*. Crest elevation data from the Addendum to the Integrated Plan, page 10 (USBR 2011A).
**. Wymer Dam and Reservoir Summary Technical Memorandum (USBR 2011A).

As reflected in Table 1, seasonal snowmelt and runoff in this Basin is stored in five existing reservoirs (Keechelus, Kachess, Cle Elum, Rimrock and Bumping Lakes) and releases are controlled to supply irrigation diversions and instream flows throughout the basin (typically from April through October each year). In addition, the IP provides a framework for the proposed facility development, construction and expansion captured in the four primary storage projects: Wymer Dam, Kachess Inactive Storage, Cle Elum Dam Raise, and Enlarged Bumping Reservoir. The resulting combination of existing reservoir storage and potential storage from the proposed IP facilities will total approximately 1.6 million ac-ft. The IP considers "snowpack" a 6th reservoir, but does not specifically address changes to snowpack (Anchor QEA 2011).

Legislation authorizing the Yakima River Basin Water Storage Feasibility Study (Storage Study) directed the USBR to conduct a feasibility study of options for additional water storage in the Yakima River Basin, Washington, with emphasis on the feasibility of storing Columbia River water in the potential Black Rock reservoir. In 2004, USBR completed their appraisal assessment of likely configurations, sizes, and costs of proposed Black Rock Project facilities needed to pump, store, and deliver water to willing exchange participants in the Yakima Basin. The USBR FPEIS (USBR 2008A, completed December 2008) concluded that none of the action alternatives evaluated met Federal criteria for an economically and environmentally sound water project[19], which led USBR in 2006 to prepare an appraisal assessment of three alternatives apart from Black Rock, namely the Bumping Lake enlargement, Wymer Dam and reservoir, and Keechelus-to-Kachess pipeline.

The projects identified above result from years of examination of many different storage options considered by a variety of groups and interests. They represent "in-basin" solutions that are thought to be best suited for implementation at reasonable cost and time frames. They are positioned in geographic locations that allow for relatively efficient water distribution and each would potentially create aquatic resource benefits.

Water managers in the western US, including the Yakima Basin, have a difficult challenge each year of balancing forecasted runoff, flood control, reservoir holdover and projected inflow or return flows, and providing timely releases to downstream users and for instream flows. Within the boundaries of the Yakima Project, USBR operations and water district staff make use of "Total Water Supply Available" tool (TWSA) that is a regression-based forecasting methodology contingent on historic data records and climatic conditions. This model is dependent upon the fundamental assumption that regression parameters on which water supply forecasts are based will continue into the future, or more simply, that future Basin hydrology will be similar to the past.

This approach is a valid starting point for an annual assessment, but presently it does not reflect the necessary updates and adjustments. Additional complications and variables from: climate change and its associated impacts (e.g., reduced snowpack, earlier and reduced runoff, etc.); increased demand for water associated with population growth and crop transitions; pending adjustments in historic flow releases for fisheries recovery, passage and aquatic habitat enhancement programs; all need to be taken into account in current and future water management actions. Further, groundwater depletion is not addressed by this methodology. It is critical for all end users and society to develop a means of accounting, for groundwater depletion so it is included as a mandatory requirement in future water use regulations and management plans. The USBR should be encouraged to update the TWSA or apply a different methodology to better account for current and historic hydrologic and demand conditions as well as groundwater depletion. Time varying processes need to be better reflected in the water management scheme for this Basin (e.g., holding back additional water during low snowpack years).

2.1.1 Instream Flow Needs

The IP defines the term "instream flow" as the stream flows needed to protect and preserve instream resources and values, such as fish, wildlife, water quality, and recreation. In our efforts to evaluate and assess the ability of the IP to satisfy instream flow requirements we reviewed extensive documentation yielding the following:

A number of significant limitations were identified in the IP and the supporting documents with regard to water supply for instream uses in the Yakima Basin:

- First, the instream needs study section of the IP presents limited data on water quantity needs. The IP states "Specific instream flow numbers are not always provided in the reach analysis developed for the Yakima Basin Study, because scientific understanding of the relationship of flow to fish survival is limited in many instances" (USBR 2012).
- Next, the data presented in the Instream Flow Needs Technical Memorandum is presented as relative change in threshold flow volumes (e.g., reduce flows to 150 cubic feet per second), rather than as an absolute volume (acre-feet or similar).

An Instream Flow Needs Technical Memorandum (Anchor QEA and HDR Engineering 2011) was prepared in support of the Integrated Plan of the YRBWEP for the YRBWEP Workgroup and the Instream Flow Needs Subcommittee (IFN Subcommittee). The Memorandum describes a process for developing instream flow recommendations beginning with a list of previous recommendations for "background and their use in preparing recommendations for flow objectives" (Section 3.0, page 6). A summary of these flow recommendations is presented in Table A-1 of the Memorandum. There is, however, no indication that any context was provided to the IFN Subcommittee along with the summary.

For example, the oldest set of recommendations (Simmons 1981) was extensively reviewed by Parametrix and Hardin-Davis (1984) and TRPA (1995); both reviews identified substantial problems with reach representation, fish suitability criteria, and several aspects of the technical approach. The second set of flows (IFTAG 1984) is derived from Simmons (1981) and recommendations made by Parametrix and Hardin-Davis (1984) and came with the specific qualification that "These flow recommendations…are for planning purposes only. The reader should not construe the recommendations as minimum, optimum, or target flows for regulatory purposes." A later report to the Secretary of Interior by System Operations Advisory Committee ([SOAC], composed of fishery biologists representing the USFWS, Yakama Nation, WDFW, and YRJB) (1999) concluded that a "new habitat modeling effort is considered necessary", effectively rejecting this early work.[20] Inclusion of these abandoned recommendations could have easily introduced bias into the IP flow evaluation and analysis process.

The third set of flows from the Interim Comprehensive Operating Plan (USBR 2002) are not flow recommendations as stated in the Memorandum, but historical Reclamation fish-related operational streamflow targets that "are negotiated on annual basis with SOAC at river operations meetings." Similarly, the fourth set of flows (cited as Reclamation and Ecology 2009 in the text and as Reclamation 2008 in the table) is not comprised of flow recommendations as stated; but are monthly "flow objectives" for an average water year. Objectives are not the same as recommendations and there is no consideration for wet or dry water years. In addition, the report should have been cited in the Final PEIS instead of the Draft or, preferably, the flow objectives should have been attributed to the source document (USBR 2008B). Hubble (2010) relies on the same monthly median flow targets as USBR (2008B), and promotes a Yakima River hydrograph that resembles "the unregulated (normative) flow regime" as a means to "best address flow deficiencies".

The IP also does not cite several additional sources of instream flow recommendations that could have been reviewed and considered by the IFN Subcommittee. These include Mongillo and Faulconer (1980), USFWS (1982) – that was issued subsequent to the affidavit by Simmons (1981), the review report by Parametrix and Hardin-Davis (1984), a report to congress (IFFPOW 1987), a further affidavit by Simmons (1990), and another set of recommendations by SOAC (1992). It bears noting that many of the instream flow recommendations, objectives, or targets presented over the years lack consistency, which is indicative of the uncertainty in making or evaluating impacts to fish populations.

The lack of context or mischaracterization of cited reports and the omission of many previous flow recommendations apparently leave the IP with only the input of the IFN Subcommittee. This input may only have been verbal since there are no reports, memorandums, emails, or other communications evident in the record between the IFN Subcommittee, the YRBWEP Workgroup, or the authors of the IP. Despite the absence of sourcing, Section 5.0 High Priority Reach Conditions of the Instream Flow Technical Memorandum presents detailed instream flow objectives and uses them to predict salmonid species benefits under the modeled outcomes of the IP.

Based on these limitations, the Instream Flow Needs Technical Memorandum (and the sections if the IP that summarize it) does not provide sufficient information to assess the overall instream flow requirements for fish, nor whether the predicted flow changes will actually result in tangible effects on fish populations. The entire document relies on an analysis of alternatives based on the premise stated in Hubble (2010) that the Yakima River and tributaries would be best managed as if they were unregulated. While currently popular among river ecologists (Stanford et al. 1996), this normative river concept only indirectly incorporates biological and physical processes and according to the authors "should be viewed as a hypothesis derived from the principles of river ecology." Despite nearly 35 years of biological and physical process studies in the Yakima Basin, the IP still predominantly evaluates flow management alternatives against the standard of unimpaired hydrology. Where specific effects on fish are predicted, the given rationales are frequently only generic in nature.

The IP further notes that there is a limited understanding of the relationship between fish use and flows in some reaches in the project area. This comment is also reflected in the 2011 Instream Flow Needs Technical Memorandum, which notes that future studies are being prepared to assess the biological basis for flow management. It should also be noted that 2013, the number of fish recorded in the fish ladders in the Columbia River dams were at record levels (USACE 2013), in contrast to the trend in fish returns. This additional information should be incorporated into the IP to provide a more complete understanding of the fishery and the needs of fish for instream flows.

Summary

The Instream Flow Needs Technical Memorandum (Anchor QEA and HDR Engineering 2011) does not provide sufficient information to assess the overall instream flow requirements for fish, nor whether the predicted flow changes will actually result in tangible effects on fish populations. Although four sets of flow recommendations are provided, the first two sets date back to the early 1980's. Peer reviews of the initial set of flow (Simmons 1981) have identified substantial problems in reach representation, fish suitability criteria, and several aspects of the technical approach. The second set of flows (IFTAG 1984) was discarded by the System Operations Advisory Committee (1999) which found that a "new habitat modeling effort is considered necessary". The final two sets of flow recommendations (USBR 2002 and USBR and Ecology 2009), are actually monthly flow objectives, and do not represent actual flow recommendations. None of these flow recommendations address the deficiencies in the earliest flow recommendations or provide additional modeling recommended by SOAC. Furthermore, other studies that present instream flow recommendations were not cited in the Instream Flow Needs Technical Memorandum. As noted in the Instream Flow Needs Technical Memorandum, additional detailed studies are necessary to provide scientifically valid flow recommendations for the Yakima Basin.

2.1.2 Out-of-Stream Needs

Agricultural Uses

Overall, the methods and assumptions made to develop the estimates presented in the Water Needs for Out-of-Stream Uses Technical Memorandum appear to be based on a reasonable scientific and statistical approach. There are a number of inaccuracies, however, and the scale and scope of the assumptions indicate that the estimates presented should be considered a rough estimate of minimal water needs reflecting only the six major districts. Five of these districts divert water above the Parker gage. While it is

Figure 4. Combine at Fines Ranch (Private Collection, used by permission)

reasonable to place more emphasis on the districts which draw water from above the Parker gage where demand is greatest, these districts do not include the entire agricultural acreage in the Yakima Basin, nor the entire acreage which withdraws water above the Parker gage.

These limitations are noted in the technical memorandum itself, which states that "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". The memorandum further states that it "does not identify a specific 'target' quantity of water for the Integrated Plan …" (HDR and Anchor QEA 2011). Although these targets may be present in the RiverWare model used for the Yakima Project, this information is not included in the IP, and cannot be reviewed to evaluate its accuracy. In short, the water quantities provided in the Water Needs for Out-of-Stream Uses Technical Memorandum do not appear to present a complete and accurate assessment of the overall water needs for irrigation in the Yakima Basin.

A number of limitations and inconsistencies were identified in the review of water needs for agricultural uses in the IP and the supporting documents. These are listed below:

- Approximately 16.4 percent (~395,000 acre-feet of allocation) of the total basin entitlement withdrawn above the Parker gage is not represented.
- An additional 28,000 acres in the Wapato Irrigation District are currently idle. The acreage does not appear in the tables calculating potential need, and the methods for determining this need are not consistent with the need calculations for the other irrigated lands in the Wapato District. Potential idle lands in other irrigation districts are not identified in the IP.
- Kennewick is the only district that withdraws water below the Parker gage where entitlement and water need is addressed.
- The two primary data sources[21] used in the Water Needs for Out-of-Stream Uses Technical Memorandum present conflicting information on irrigated acreage, crop type by acreage, irrigation technique, and conveyance losses for the districts that are described in detail.
- Table 13 of the Water Needs for Out-of-Stream Uses Technical Memorandum., which identifies the estimated on-farm water needs, differs from the calculations identified in the text for nearly every cell. The source of these errors is not identified in the text or table, and the errors, while reflecting a small percentage of the total demand, do not appear to be the result of rounding errors.
- The assessment of whether the IP meets the water needs in the basin is based on a 70 percent allocation of water. This 70 percent allows for an additional crop of timothy hay, but does not necessarily provide sufficient water for continued agricultural growth, and does not address potential losses resulting to permanent crops (e.g., hops, grapes, mint, and orchards) that have higher water needs. Additional information on the potential impact of this is provided in the Economic Analysis (Section 5).

- Current groundwater needs are not addressed in the Water Needs for Out-of-Stream Uses Technical Memorandum, nor are changes to groundwater that may result from increased withdrawals during droughts or climate change scenarios.

With these inconsistencies and errors in mind, an analysis of the agricultural water needs in the basin was performed using the data and methods of calculation presented in the IP. This analysis is intended to serve as a comparison of the internal consistency of the IP documents, and is subject to the same errors and limitations identified above.

To review the data, the total on-farm need and conveyance loss were calculated using the methods described in the tables included in the Water Needs for Out-of-Stream Uses Technical Memorandum. These figures basically show the need for water at the farm based on the acreage and current crop types in the five primary irrigation districts that withdraw water above the Parker Gage.

These numbers (total water for the farms, plus the water lost in transit) provide an estimate for current crop needs at the point of diversion (the rivers, streams, and reservoirs of the Yakima Project). In theory, this should result in a number close to the average diversion. This is relatively accurate (2.1 to -8.9 percent) for the Kittitas, Wapato, and Sunnyside divisions. For Roza and Yakima-Tieton, the numbers developed by the IP team differed so greatly from average diversion, that the IP team reversed the equations, determining the total on-farm needs by subtracting conveyance loss from the average diversion[22]. The difference in methods (e.g. presuming all of the data are correct vs. presuming that the diversion and water lost in conveyance are correct) indicates an inconsistency in the acreage, crop data, or other data used by the IP team to calculate on-farm needs or conveyance loss. This errata was described in the Water Needs for Out-of-Stream Uses Technical Memorandum[23], but the source of the error was not determined.

Using the corrected data for all five districts, the differences between the 2001 and 2005 diversions were subtracted from the total need at the point of diversion to determine the shortfall in crop need for these dry periods. The same calculations (and corrections) were made for crop need and shortfall for 2001 and 2005 level diversions based on the information for the climate change scenario described in the Water Needs for Out-of-Stream Uses Technical Memorandum.

In summary, the reviewers followed the methods and data provided in the IP to calculate the overall irrigation need, and included the revised need for Roza and Yakima-Tieton as described above. The analysis is based on 100 percent of the total farm need for current crops in the five primary irrigation districts. This is not intended to imply that 100 percent is necessarily needed (or desired) by the districts, but rather is an attempt to provide a full accounting of the irrigation demand in the basin, and thereby determine whether the IP has accurately assessed the overall needs. The reader should also note that the total entitlements exceed the average water year diversions, so where the average diversion is not met, the total entitlement will likewise not be met. Two tables have been prepared to summarize the results of the analysis. Table 2 identifies the current demand for irrigation water and shortfall in crop needs under current conditions. Table 3 identifies the needs and shortfalls under the climate change scenario.

Table 2: Estimated Irrigation Need and Shortfall in Irrigation Districts with Diversions Above Parker Gage, Under Current Climate Conditions.

	Kittitas	Roza	Wapato	Sunnyside	Yakima-Tieton	Total
Current irrigated land, acres	55,516	72,491	109,115	99,243	27,900	364,265
Total entitlement in acre-feet (AF)	336,000	393,000	655,613	447,422	106,290	1,938,325
Total need* – on-farm (includes irrigation loss) (AF)	209,089	208,105	414,917	367,184	75,077	1,274,372
Total conveyance loss** (based on % loss from diversion) in (AF)	94,374	111,565	156,823	49,349	3,951	416,062
Total need* (Total on-farm + conveyance loss) at diversion (AF)	303,463	319,670	571,740	416,533	79,028	1,690,434
Avg. Diversion (AF)	285,983	319,670	560,081	429,122	79,029	1,673,885
Shortfall in AF, Average	(17,480)	0	(11,659)	12,589	1	(16,549)
Unused entitlement, Average (AF)	50,017	73,330	95,532	18,300	27,261	264,440
Shortfall in AF, 2001 drought	(180,466)	(149,345)	(166,380)	(69,417)	(3,554)	(569,162)
Shortfall in AF, 2005 drought (AF)	(158,545)	(122,899)	(142,903)	(83,873)	(3,724)	(511,944)

Numbers presented in this table are drawn from the Out-of-Stream Uses Technical Memorandum (HDR and Anchor QEA 2011).

*. Total need was calculated based on the data presented in Tables 3, 9 and 12 (HDR and Anchor QEA 2011) for the Kittitas, Wapato, and Sunnyside. Totals for Roza and Yakima-Tieton are based on the re-calculated data presented in Table 17 (HDR and Anchor QEA 2011).

**. Conveyance loss is a percentage of the total diversion, and would vary with that number. For the purposes of this review, conveyance was estimated using the same value for all the scenarios.

Table 2 shows that the diversions for two of the five districts fall short of need calculated using the numbers from the IP, however, the diversion for Sunnyside exceeds the calculated need, and the projects proposed in the IP would, in total, provide sufficient additional water to address the current agricultural need under average conditions. In order to satisfy irrigation need between the basins, the inter-district water trading described in the IP must also be implemented. The shortfall between 100 percent crop need and diversions during the 2001 drought (Table 2), in aggregate, exceeds the potential increase proposed in the IP, and the 2005 level diversions are within 21,500 AF[24] of the additional storage proposed in the IP. Satisfying the irrigation need under these two drought conditions also requires that inter-district water trading be implemented. Note that the increase in irrigation supply applies only for current acreage and crops only, and does not account for any new acreage, changes in crop pattern, increased municipal use, or additional instream flow needs.

Table 3 presents the same information for the climate change scenario. Total on-farm needs were recalculated using the revised Crop Irrigation Requirements (CIR) from Table 27 in Water Needs for Out-of-Stream Uses Technical Memorandum (HDR and Anchor QEA 2011). This revised CIR presents a single climate change scenario, and HDR notes that this revised CIR is based on rough estimates. As noted for Table 2, the total on-farm needs for Roza and Yakima Tieton were corrected based on the information in Table 17 and 27.

Table 3: Estimated Irrigation Need and Shortfall in Irrigation Districts with Diversions Above Parker Gage Under Climate Change Scenario.

	Kittitas	Roza	Wapato	Sunnyside	Yakima-Tieton	Total
Climate Change model (updates Crop Irrigation Requirements (CIR) only) *,**						
Total need (Total on-farm + conveyance loss***) at diversion, (AF)	316,994	340,064	598,738	441,359	85,710	1,782,865
Shortfall in AF (average year diversion assumed)	(31,011)	(20,394)	(38,657)	(12,237)	(6,681)	(108,980)
Shortfall in AF, (assuming 2001 entitlement levels)	(193,997)	(169,739)	(193,378)	(94,243)	(10,236)	(661,593)
Shortfall in AF, (assuming 2005 entitlement levels)	(172,076)	(143,293)	(169,901)	(108,699)	(10,406)	(604,375)

*. CIR for this scenario updated based on Table 27 (HDR and Anchor QEA 2011).

**. Total need was calculated based for Kittitas, Wapato, and Sunnyside Districts using the Table 3, 9, 12 and 27 (HDR and Anchor QEA 2011). Totals for Roza and Yakima-Tieton are based on the re-calculated data presented in Table 17 and the percentage increase in water identified in Table 27 (HDR and Anchor QEA 2011).

***. Conveyance loss is a percentage of the total diversion, and would vary with that number. For the purposes of this review, conveyance was estimated using the same value for all the scenarios.

Table 3 shows an increase in the average diversion shortfall from the existing conditions of 92,431 AF[25]. This is within the margin of error for the total 95,000 AF shown in Table 28 (HDR and Anchor QEA 2011), where the district totals have been rounded to the nearest 1,000 AF. The proposed storage improvements in the IP (Table 1) substantially exceed this increase for average years. The shortfall in the 2001 and 2005 drought level diversions exceeds the total new water supply provided under the IP (Table 1 and Table 3) for the five districts, although total need for Kittitas, Wapato, and Sunnyside can be met for the less severe 2001 drought. The increase in irrigation need does not include any potential changes in crop patterns in the basin. The additional storage would also be called upon for municipal use, domestic use and instream flows.

Detailed numbers for the other two climate scenarios identified in the IP are not provided in the Water Needs for Out-of-Stream Uses Technical Memorandum (HDR and Anchor QEA 2011). However, the IP notes that under the 25 year average conditions, the least adverse scenario (presuming increased rainfall) would result in only 88 percent irrigation prorationing levels. The moderately adverse scenario reflects 72 percent prorationing levels for these average years, and the most severe of the scenarios result in prorationing levels of only 50 percent under average year conditions, as shown in Table 4-6 of the IP (USBR 2011A). In summary, the storage improvements proposed in the IP under the historic averages only meet or exceed their goal of 70 percent prorationing (which falls short of the total demand) during the less adverse or moderately adverse climate change conditions for average conditions.

In the more severe 2001 level drought example, the proration level meets 70 percent prorationing for the least adverse scenario and falls to 61 percent prorationing in the moderate change scenario. In the most adverse climate change scenario, a mere 10 percent prorationing is provided. For the 2005 level droughts, the proration level of 70 percent is only met for the least adverse scenario, and supply falls to 61 percent for the moderate change scenario. Under most adverse change scenario, the prorationing falls to 21 percent. Under the 1994 year drought levels (which represents a 2 year drought period), the IP fares far worse in the moderate climate change scenario, providing only 25 percent proration levels, and 14 percent of prorationing levels in the most adverse climate change scenario (USBR 2011A, Table 4-6). In summary, for the modeled drought conditions under the three climate change scenarios, the storage improvements proposed in the IP only meet or exceed their goal of 70 percent proration (which falls short of the total demand) during the less adverse climate change scenarios.

Municipal Uses

The overall usage for municipal water supply reflects a relatively small percentage of the overall water supply, and much of this water is non-consumptive (i.e., the water is treated and returned to the water supply), and so is available for downstream use. The Out-of-Stream Water Uses Technical Memorandum indicates that the studies are based on information on growth and population trends from local planning documents, supplemented by information from local planning agencies, and assumes a growth rate of between 1 and 1.5 percent over the 2010-2060 period. The overall increase in water use over this period was calculated as 48,900 AF per year (only 19,560 AF being consumed). This small increase, however, is based on an assumption that 14,900 AF of the increase will be offset by conversion of agricultural lands to less consumptive urban land, and an additional 8,200 AF of demand will be offset by water conservation measures in urban areas. Without the potential savings from conservation and conversion of agricultural uses to urban land, the overall increase is approximately 72,000 AF (Table 4).

Table 4: 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**

Source: HDR Engineering and Anchor QEA (2011), Table 38.

From this detailed analysis it can be concluded that while the projected municipal demand increase represents a small portion of the total water demand in the Yakima Basin, any population increase occurring over the next 50 years will certainly result in additional demand for water in a basin where demand already exceeds the available supply.

Summary

Our review identified a number of limitations and inconsistencies in the review of water needs presented in the IP and the supporting documents. The most significant inconsistencies and omissions include an incomplete accounting of the total water need. The IP analysis was performed primarily for the areas above Parker gage, and does not full address the water needs of water users below the Parker gage. An additional 28,000 idle acres in the Wapato Irrigation District are not included in the assessment of irrigation needs, and the needs of smaller water right holders in the basin (approximately 395,000 AF) are not accounted for in the IP. Furthermore, the analysis of irrigation water need is based on a 70 percent allocation of water, which does not necessarily provide sufficient water for continued agricultural growth, and does not address potential losses resulting to permanent crops (e.g., hops, grapes, mint, and orchards) that have higher water needs. This may provide a reasonable evaluation for a single-year scenario, but does not address the effects of a 70 percent allocation over time, such as multi-year droughts.

Current groundwater needs are not addressed in the IP, nor are changes to groundwater that may result from increased withdrawals during droughts or climate change scenarios.

Based on the information presented in the IP, under average conditions the storage improvements proposed in the IP only meet or exceed their goal of 70 percent proration (which falls short of total demand) during the less adverse or moderately adverse climate change conditions (USBR 2011A, Table 4-6). Under conditions similar to the 2001 and 2005 droughts, the storage improvements proposed in the IP only meet or exceed their goal of 70 percent proration (which again, falls short of total demand) during the less adverse climate change scenarios, dropping to as little as 10 percent of demand for the most adverse scenario.

Municipal use represents a relatively small portion of the overall out-of-stream demand. The total increase in municipal water use resulting from projected growth in the Yakima Basin through 2060 is 72,000 AF. Taking into account savings from conversion of agricultural lands (14,900 AF) and improved conservation measures (8,200 AF), the overall increase in water use over this period was calculated as 48,900 AF per year. Of this, 19,560 AF will be fully consumed. Although this increase is small, any population increase occurring over the next 50 years will certainly result in additional demand for water in a basin where demand already exceeds the available supply.

The IP's proposed water storage projects will certainly provide some improvements to the Yakima Basin water supply; however the proposed projects will not provide enough water volume and predictable water supply for both a sustainable ecosystem and agricultural industry in the Yakima Basin under the climate change scenarios in the Integrated Plan.

2.2 Climate Change Analysis

2.2.1 Discussion of Climate Change and Drought Impacts on Water Storage in the Yakima Basin

Snowmelt and winter precipitation on the east slopes of the Cascade Mountains are the primary source for the water stored in the Yakima Basin reservoirs. For reference, average annual precipitation in the Yakima Basin ranges from 91 inches annually at Snoqualmie Pass (at the headwaters of the Yakima River in the Cascade Mountain Range) to just under 8 inches annually at the city of Yakima. This reality both emphasizes and dictates that the Basin is largely reliant on seasonal storage to satisfy municipal, fisheries and agricultural demands year round. The five existing reservoirs listed in Table 1 have a combined storage volume equating to roughly 30 percent of the Yakima River's mean annual flow.

This is particularly significant given the extent of business activity and economic impact reliant on water. Other river systems throughout the West have met their water storage needs with varying degrees of success and effectiveness. The Yakima Basin by this measure is on the low end of a relative comparison of providing sufficient water storage capacity for all of its users.

The State of Washington's system of allocating water, and more specifically water rights, is based on prioritization segregated into senior and junior water rights. Senior rights refer to the Yakama Nation's time immemorial rights to water reserved for fish, along with any irrigation water rights obtained prior to 1905. Under western water law, anyone obtaining a right after that date is considered junior and subject to having the right reduced or possibly shut off entirely during low water periods or a drought event. Allocation of limited resources such as water dates back to the earliest days of settlement in the West, and we will not attempt to summarize all this entails. For the purpose of this study, we can say that as climate change trends and impacts lead to reduced water supply, junior water rights holders and their livelihoods will be put at risk more and more frequently. Despite the positive outcomes of water use efficiency programs and advances made with highly controlled drip and spray irrigation delivery systems, agricultural water users find themselves facing a much more uncertain future than at any time in recent memory.

2.2.2 How Climate Change is Expected to Affect Precipitation

As indicated, the net effect of climate change in this region is predicted to result in a continuing decline in average snowpack, earlier snowmelt, and runoff events resulting in reduced water supplies for all end users. These trends place greater pressures on existing water allocations.

A full treatment of global warming and associated climate change is beyond the scope of this review, but a basic summary of collected data and trends strongly indicates and supports the contention that earlier snowmelt runoff and average snowpack below historic averages are more frequently being experienced. The combined result of this current finding yield reduced river flows in the Yakima Basin.

Previous climate change studies encompassing the Washington Cascade Mountains indicate a loss of between 10 to 20 percent of the typical April 1st snowpack with each 1° Celsius of warming, and as much as a 27 percent loss given a 2° Celsius temperature rise. (Ref. Casola et al. 2009, Elsner et al. 2009, and Vano et al. 2009). The outcome is a significant reduction in reservoir inflow and in turn, reduced flows to the Yakima River. One of many conclusions that can be drawn from Casola et al., Elsner et al., and Vano et al. and they stated that snowpack levels are highly sensitive to modest warming. This result is itself not surprising, but the associated effect on the timing and quantity of water supply is particularly troubling as outlined in the studies that were reviewed.

2.2.3 How Changed Precipitation Will Affect Water Storage

The water distribution infrastructure in the Yakima Basin, like other areas east of the Cascades, relies heavily on snowpack to transfer water from the wet winters to the dry summers, making the region especially vulnerable to a warming climate with less snow. In a climate change assessment performed by Elsner et al., two future scenarios were evaluated - "B1" and "A1B". A1B results in warmer climates by the end of the century and is considered a "medium" scenario in terms of warming, while B1 has less warming and is labeled the "low" warming scenario. For the purpose of this study, we looked at the A1B scenario. Precipitation change during the 21st century is expected to manifest as reduced precipitation during the winter months and earlier snowmelt runoff, resulting in lower flows during spring and summer as illustrated in the figure below (Figure 5, adapted from Elsner et al. 2010).

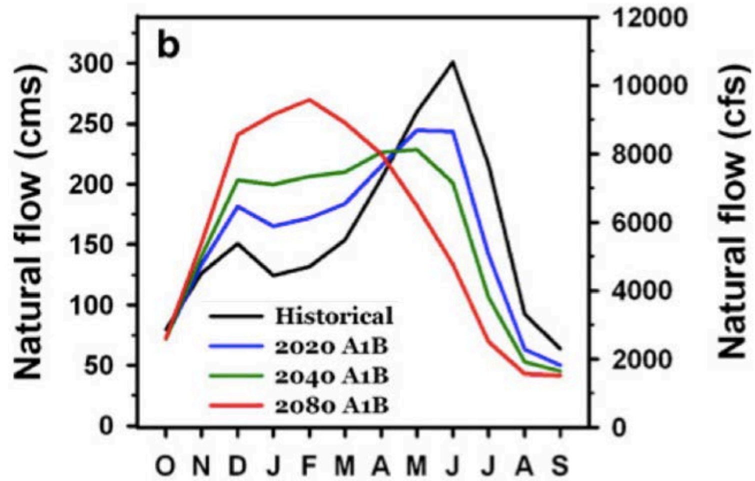


Figure 5. Natural Seasonal Inflows across Climate Change Scenarios.

The five reservoirs in the Yakima Basin have a combined total capacity of 1.07 MAF, while water distributed for irrigation is to the order of 2.2 MAF. Because the reservoirs historically capture only about 30 percent of the annual unregulated flow of the Yakima River, this discontinuity is typically compensated by unregulated flow, much of which is derived from snowpack (Vano et al. 2009). As the figure (Figure 6) below shows, reservoir storage peaks in May-June, which is separated by a few months from peak precipitation (snowfall) in higher elevations. During the intervening period between peak precipitation and peak storage, water is stored in the snowpack – the 'sixth reservoir'.

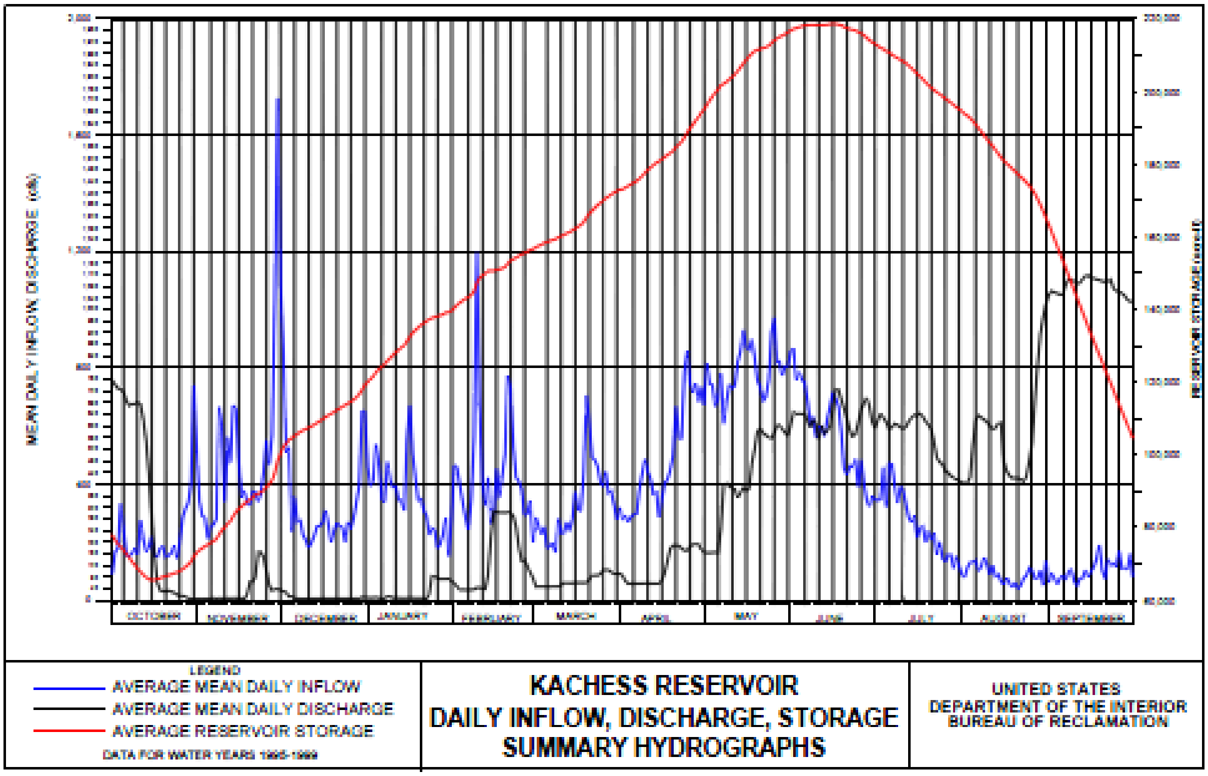


Figure 6. Kachess Reservoir Inflow

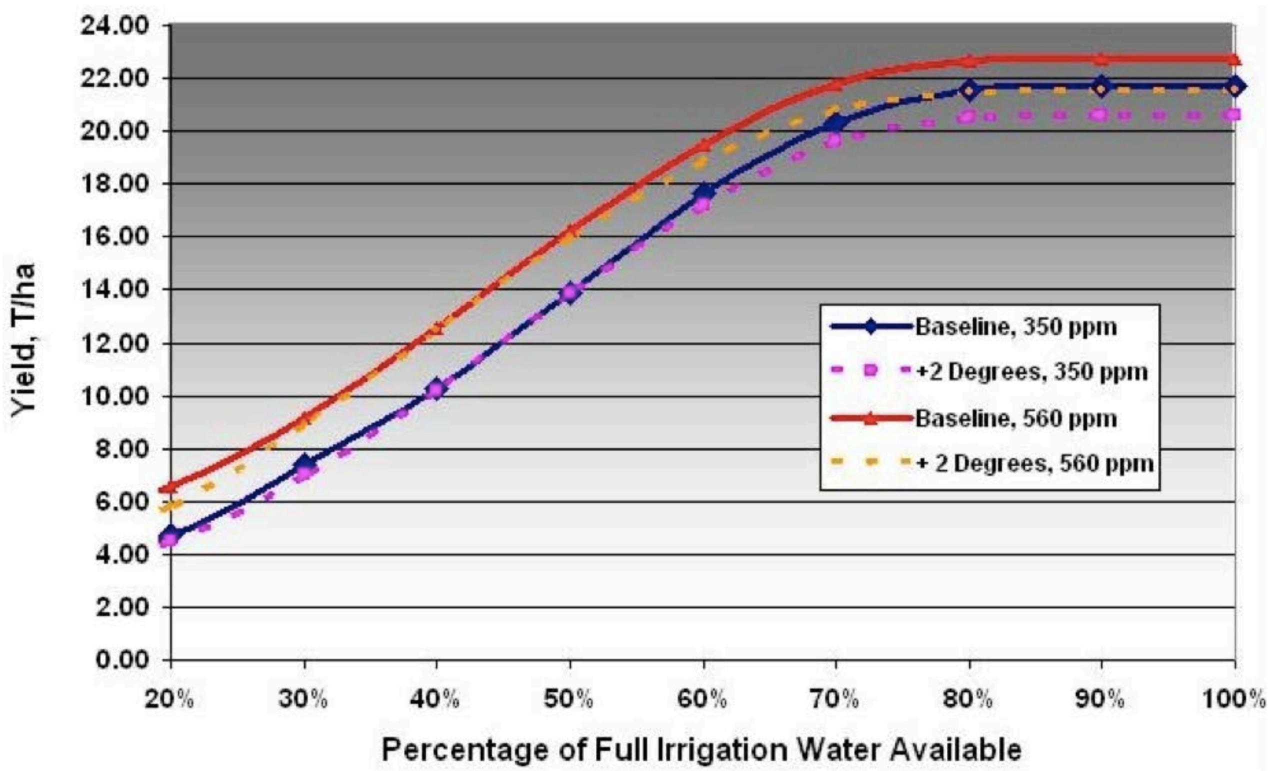
Studies have shown that the Washington Cascade Mountains, from which the Yakima River drains, are likely to lose about 20 percent of their April 1st snowpack with 1° Celsius increase in temperature, which may be expected as early at 2020 (Vano et al. 2009; Mote et al. 2003). Consequently, such a significant reduction in capacity of the 'sixth reservoir' will have a comparable effect on reservoir storage. Reservoir carry-over will undoubtedly be affected as reduced inflows occur associated with declining snowpack. This outlook reinforces the need for additional storage capability beyond that represented in the IP.

2.2.4 Altered Climate Regime and Impacts on Irrigated Agriculture

Because the water storage system in the Yakima Basin is heavily dependent on the water stored in the snowpack ('sixth reservoir'), an altered climate regime resulting in a significantly smaller snowpack (estimated 20 percent loss of April 1st snowpack by 2020; Mote, 2003) will have a direct and significant impact on irrigated agriculture.

As stated previously, the system's total reservoir capacity is 1.07 MAF is well short of the annual diversions of approximately 2.2 MAF. The remainder of the need is met by unregulated flows from the snowpack. The basin is expected to transition to earlier and reduced spring snowmelt as the century progresses. It is estimated that while historically the Yakima Basin has experienced water shortages[26] in 14 percent of past years, this might go up to a range of 27 percent-32 percent by 2020 (Vano et al. 2003).

Currently, in water-short years, the sum of all users' entitlements exceeds total water supply available, leading to a deficit in available supply. The deficit is resolved by proportionately reducing water allocations to the more junior irrigators, whose entitlements are considered to be "proratable." While prorationing results in up to 20% reduction in water supply, it has not been associated with lower agricultural productivity. However, there is a significant drop in productivity for prorationing that leads to a reduction in water supply by more than 20%. Figure 7 below) shows that when the percentage of irrigation water available drops from full supply to 50%, the corresponding crop yields drop by approximately 35% (Scott et al. 2004A). Thus, prorationing beyond a certain margin has a significant business impact on irrigated agriculture.



Note: ppm refers to level of dissolved solids in irrigation supply

Figure 7. Irrigation Water Availability.

Thus, with a significant increase in number of water-short years expected (27 percent-32 percent of years up from 14 percent in past years), a significant impact on irrigated agricultural can be expected. Reduced crop yields and production leading to significant economic losses and other negative consequences can be anticipated based on now well supported research and observed trends.

2.2.5 Altered Storage Regime and Impacts on Municipal Use

The altered climatic and storage regime is not expected to have impacts on municipal use. Currently, only the cities of Cle Elum and Yakima obtain their municipal and domestic water from the surface waters of the Yakima River basin. Groundwater supplies the remainder of the municipal and domestic needs (83 percent) and is the preferred source for meeting future needs.

3.0 Water Rights/Tribal Treaty Rights

The following section provides a review and summary of the water rights and Tribal Treaty rights relevant to the Yakima Basin. Although this is not a legal review (and should not be considered legal advice), Tribal Treaty rights and water allocation rights have a substantial impact on both instream and out-of-stream water uses in the Yakima Basin. In addition, an understanding of the major underpinnings and legal decisions on the subject is important to understanding water rights in the basin.

3.1 Water Rights

The difference between Federal and State laws is significant in understanding water rights in the Basin. Federal laws regarding treaty obligations are tied to the constitutional supremacy of the Federal government and have priority over State law[27]. With this understanding, we can proceed with a discussion of the applicable Federal and State policies and legal cases regarding water rights.

Water in Washington State is considered a public resource, and held in trust for the residents [28] of the state. The Washington State Department of Ecology manages this resource under a prior appropriation doctrine, which awards water rights to the parties who first take water and put it to beneficial use. One crucial component of this doctrine is the priority date, or the date to which water was put to beneficial use. This date determines the "senior" water right holders – or those water right holders who will have all of their water needs satisfied first. The "junior" water right holders share any remaining water after the senior water rights are satisfied. This model of water appropriation common in the western US, is often summarized as "first in time, first in right"[29].

Starting in the 1850's, irrigation projects were planned and constructed throughout the West. By 1900, irrigation demands consumed the majority of the Yakima River's natural flow. In 1905, the Washington State Legislature granted to the United States the right to exercise eminent domain in acquiring lands, water, and property for reservoirs and other irrigation works. The Bureau of Reclamation subsequently authorized the Yakima Project, which claimed all unappropriated water, to augment supplies through construction of five main water storage reservoirs. These reservoirs were then built between 1909 and 1933.

In 1908, the United States created a "Code Agreement" dividing water rights on the Yakima River, which provided twenty-five percent of the water to the Yakama Nation and seventy-five percent to non-tribal water users in the Yakima Basin on the north side of the Ahtanum Creek. During the same year, a significant legal decision was made in Winters v. United States (1908). The Supreme Court of the United States held that the creation of a reservation was presumed to establish a water right to meet all present and future water needs on the reservation. The decision extends to both irrigation and water to support fisheries on the reservation. This decision came to be known as the "Winters Doctrine", and is a pivotal case with regard to water rights on reservations.

During the first half of the 20th Century low water years resulted in disputes over water use. These disputes were resolved in the 1945 Consent Decree (Kittitas Reclamation District v. Sunnyside Valley Irrigation District, Civil Action No. 21). According to USBR (2002) the Consent Decree establishes the following:

- Rules under which the USBR should operate the Yakima Project to meet the water needs of both the irrigation districts and the rights of divisions formed in the Yakima Project;
- Water delivery entitlements are for all major irrigation systems in the Basin, except for the lower reaches of the Yakima River;
- Quantities of water to which all project water users are entitled (maximum monthly and annual diversion limits) and defines a method of prioritization to be placed into effect during water-deficient years.

Pursuant to the Consent Decree, USBR has annually determined the total water supply available for use in the Yakima Basin to serve as a basis for the annual allocation. Currently, the Kittitas and Rosa irrigation districts receive 100 percent from their water allocation from later proratable rights. The remaining four districts in the Yakima Project receive between 24 and 82 percent of their water from proratable rights (USBR 2012A).

3.2 Historic Water Deliveries to Senior and Junior Water Rights Holders

The Yakama Nation receives its time-immemorial water rights prior to all other users. The Yakama irrigation water rights (Treaty rights) receive water next, followed by the senior and junior water right holders. In general, theses earlier rights (Yakama Nation and other senior water rights) receive all of the water to which they hold rights prior to the junior users. The junior water right holders then divide the remaining water (prorating). In some years this means that junior water right holders do not receive enough water to irrigate crops. With current water demands, it is estimated that junior water rights would have been prorated 30 percent of the time and senior water rights would be affected only 1 percent of the time. However, with climate change, junior water right holders are found to be prorated more frequently.

Figure 8 (below) shows proration rate on the X-axis (a proration rate of 0.8 indicates junior water rights holders received 80 percent or less of their water supply) against Cumulative Distribution Function (CDF) which ranks the likelihood of water availability for junior water users in A1B – the “medium” warming scenario. Two modeling scenarios, A1B and B1, are shown. It is evident that the frequency with which water scarcity is faced by junior water users is significantly more in future years compared to current scenario (Vano et al. 2009).

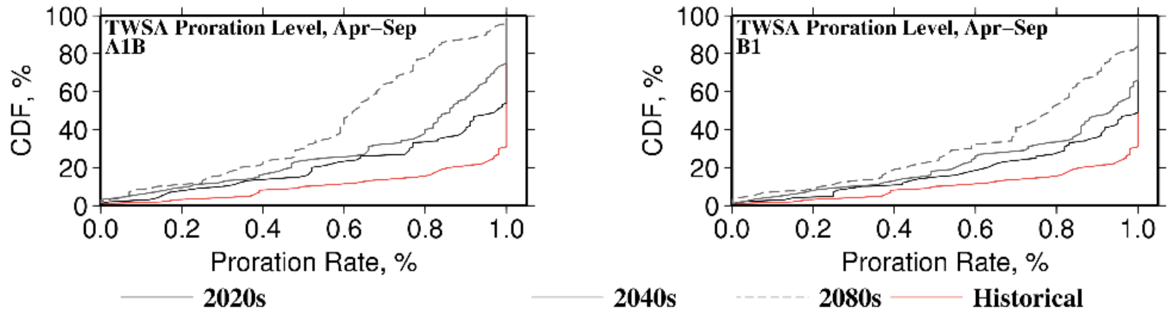


Figure 8. Prorationing Rate.

3.3 Tribal Fishing Rights

Figure 9. Eastern Washington fisherman and his catch (from a private collection, used with permission)

Tribal Treaty rights and water rights in the Yakima Basin have been linked since the Treaty between the United States and the Confederated Tribes and Yakama Nation (Nation) in 1855. This Treaty (and many of the other Treaties signed with Tribes in Washington State) included language that preserved the rights of tribal members to continue fishing for anadromous fish both on and off-reservation (Belsky, in Journal of Land Use and Environmental Law, Fall 1996, Vol. 12-1). In the 1960's and 70's, a number of significant legal cases were filed with regard to these off-reservation fishing rights. The decisions on these cases were to have a significant impact on fishing rights throughout the Pacific Northwest.

The first of these decisions was in the case of Sohappy vs. Smith (1969), commonly referred to as the Belloni decision (after Judge Robert C. Belloni, of the United States District Court for the District of Oregon). Ultimately, this case was combined with United States vs. Oregon. Judge Belloni ruled that the State of Oregon restrictions on native treaty fishing rights were invalid and that the treaties entitled tribal members to a "fair share" of the fish resources at all "usual and accustomed places" (Belsky 1996).

Another of the principal decisions regarding this tribal fishing right is known as the "Boldt decision" of 1974 (United States v. Washington 1974). The decision in this case was ultimately delivered in two phases. In Phase I, Judge Boldt held "*the right of taking fish, at all usual and accustomed grounds and stations, is further secured to said Indians in common with all citizens of the Territory*". Supreme Court of the United States ultimately affirmed that the tribes were entitled to a fair share, and further defined this as an equal share - up to fifty per cent of the available fish. Phase I of the Boldt Decision sets the groundwork for many of the later decisions with regard to tribal fishing rights.

Phase II of the Boldt Decision reserves the question of "whether the right of taking fish [guaranteed by treaty to the tribes] incorporates the right to have treaty fish protected from environmental degradation[30]". Judge Boldt deferred resolution of this portion of the decision, which was decided by Judge William H. Orrick, Jr. Judge Orrick determined that the Tribes had a right to actual fish, not simply the right to attempt to fish, and the State of Washington had the burden to show that any environmental degradation of the fishery would not harm the tribes' ability to meet their moderate living needs. The implications of Judge Orrick's decision in Boldt II are substantial, since they may be broadly applied to other parties affecting anadromous fish habitat[31].

In 1977, a drought was forecast for the Yakima Basin, and USBR estimated that only 15 percent of pro-ratable water rights would be available. Two legal actions followed. The first was an adjudication of water rights and priority for all waters in the Yakima Basin. This action was filed With the Superior Court of Yakima County by Ecology. The second action was filed by the Yakama Nation in US District Court, which requested a determination of the priority and water rights of the Yakama Nation under the Treaty of 1855. The Federal case was remanded to the prior Washington State case, and did not proceed. As a result, no determination was made for the priority and water rights of the Yakama Nation at that time.

In 1985, Ninth Circuit Court (Kittitas Reclamation District v. Sunnyside Valley Irrigation District) Judge Justin Quackenbush of the Federal District Court ruled that the water from the Yakima River for agrarian purposes was subordinate to providing water sufficient to protect the fisheries supply of the Yakama Indian Nation. In question was preservation of minimum flows to protect salmon redds. The results are commonly referred to as the "Quackenbush Decision". The flip-flop seasonal operations of the upper Yakima River reservoirs were also developed as a result of this decision[32].

In July, 1990, a partial summary judgment was delivered by Judge Walter Stauffacher of the Superior Court on the Treaty reserved rights of the Yakama Nation to instream flows in the Yakima Basin (Acquavella II). The Treaty rights were divided into separate rights; one for fish and the other for agriculture. In the appeals process, the Washington State Supreme Court determined that these Treaty irrigation rights of the Yakama Nation had been limited by the acts of Congress, agencies and tribunals. The Yakama Nation's irrigation rights were divided into non-proratable irrigation rights (1855 priority) and proratable irrigation rights (dated 1905).

The flow rights were held by Judge Stauffacher to be "the specific minimum instream flow necessary to support anadromous fish life in the river", and have a priority date of "time immemorial". The court also held that the minimum instream flows are to be determined by USBR, in consultation with the Yakima River Basin SOAC, irrigation districts, company managers and others. These flow rights were later extended to include all tributaries that support fish within the Yakama Nation's usual and accustomed fishing locations. Since water rights in the West are allocated on the "first in time is first in right" principle, the time immemorial date for the Yakama Nation's fishing rights would take precedence over any other, more recent water rights. This includes other senior irrigation rights with later dates of priority and any later proratable (junior) rights. These proratable rights include the majority of the water rights for the five irrigation districts that divert water above the Parker gage.

Other recent cases have supported the Tribes' claims to water rights for fisheries via Treaty obligations. In 2013, Federal district court Judge Ricardo Martinez issued a permanent injunction requiring the Washington State Department of Transportation and other state agencies to remove barriers to fish passage in hundreds of state-highway culverts. The March 29 decision ("Culvert case") expands on Phase II of the Boldt Decision (US v. Washington under Judge Orrick), and clearly extends tribal treaty fishing rights beyond water supply to the protection of potential habitat for anadromous fish.

Another relevant decision was rendered in Hubbard v. Department of Ecology (1997) which in summary states that ground water well discharge may be regulated if it affects stream flows. In this case, the issue of hydrologic connectivity between ground water and surface water is more clearly identified, and the State mandated instream flow is the priority water right[33]. Decisions in other parts of the West (Cappaert, in re Big Horn, and in re the Water Rights of Gila River System & Source) support the idea of a Federal interest in ground water allocation and use[34]. These decisions regarding the potential effects of ground water discharges (in some areas) on instream flows create another nexus where Tribal fishing rights implications may affect water availability.

3.4 Summary

In summary, the implications of reservation rights and Tribal Treaty rights are unquestionably far reaching. Senior water right holders are provided 100 percent of their allocation, while the junior right holder receive a prorated portion of their allocation based on the remaining available water. Under current conditions, these junior water rights holder (which included many of the irrigation divisions in the Yakima Basin) typically do not receive their full allocation. There is simply not enough water remaining to satisfy the full allocation for all water right holders.

The Yakama Nation has both irrigation rights and Treaty water rights. The irrigation rights include non-proratable irrigation rights with 1855 priority and proratable irrigation rights dated 1905. The Treaty water rights to include "minimum instream flow necessary to support anadromous fish life in the river" that support fish within the Yakama Nation's usual and accustomed fishing locations.

The trend over the last 100 years has been for the Tribes in the Pacific Northwest to pursue their tribal fishing rights and reservation rights to the fullest extent. Recent decisions from other lawsuits brought by the Tribes (e.g., Boldt II) have been based in the earlier precedents set in Winters v. US and US v. Washington, and have generally been successful in expanding the extent of these rights over other interests.

The Washington Office of the Attorney General notes with regard to on-reservation water uses,

> *"…the United States and the tribes, unlike most other appropriators, are not limited to the quantity of water historically put to beneficial use, nor may the state impose a "due diligence" requirement on the federal government."*

In his paper on Tribal Treaty rights (Morisset 2001), Mason Morisset of Morisset, Schlosser, Homer, Jozwiak, & McGaw, states:

> *"Because of the Supremacy Clause and the preeminence of Treaty Rights in the American scheme of law, it is not hard to envision Indian Treaty rights as "trumping" other property rights not based on the Treaties. Certainly most state law based rights, be they property rights or otherwise, will be overridden by the requirement that Indian Treaties be honored. The Federal Government, bound by the meaning of the Treaties and the concepts of trust responsibility will also be hard pressed to justify actions which destroy or harm habitat necessary for fish. On the other hand, tribal governments will undoubtedly be bound by legal concepts based on the United States Constitution."*

Since the quantities of water necessary to support instream flows are determined annually by USBR, the preeminence of Tribal water rights for both on-reservation use and off-reservation instream flows introduce additional uncertainty regarding the water supply for the Yakima Basin. Declining fisheries in the Pacific Northwest and the listing of anadromous fish under the Endangered Species Act provide additional impetus for the Tribes to seek legal recourse for habitat based instream flow needs.

The current trend in legal cases indicates that the Tribes would likely be successful in cases pursuing additional water under both the Winters Doctrine and the Boldt (I and II) Decisions and subsequent legal cases. Since the Yakama Nation right for water to support instream flow has a "time immemorial" priority date, this water would be "withdrawn" first, and would not available for any other needs. Furthermore, since the quantity of water needed for instream flows has not been accurately determined, this introduces additional uncertainty into the water supply.

4.0 Basin Diversion Comparison

4.1 Agricultural Irrigation Demand

4.1.1 Existing Demand

Approximately 450,000 acres are currently irrigated from the Yakima Project (USBR 2012A). Diversions for the Yakima Project above the Parker gage averaged approximately 1.77 MAF from 1990 to 2009, not counting drought years (USBR 2012A). An additional 100,000 AF was diverted annually below the Parker gage by the Kennewick Division (Yakima Basin River Study, pp. 22). In low snowpack years, such as 1992-1994, 2001, and 2005, water supply has been insufficient to meet demands, and in these years, water was allocated to junior users based on prorating according to the seniority of their water rights and the Total Water Supply Available (TWSA). Water availability for irrigators with junior water rights is a measure of how well the system meets its nominal water demands.

4.1.2 Future Demand

Demand forecasts specific to the Yakima Basin are not readily available but agricultural irrigation demand in the Columbia Basin in general is expected to increase by varying degrees depending on the climatic condition being considered, as shown in Figure 10 below (Ecology 2010).

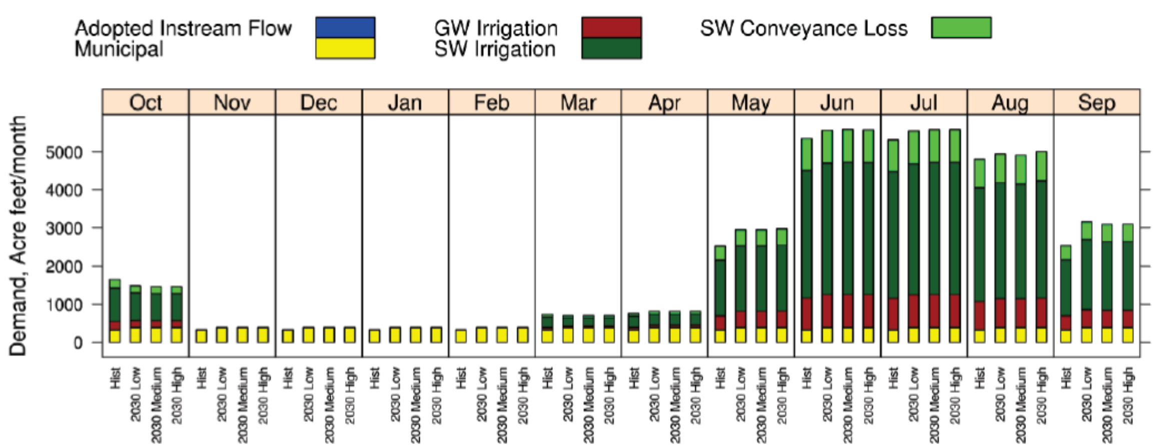


Figure 10. Irrigation Demand in the Columbia Basin.

4.1.3 Anticipated Future Impacts

Estimates based on climate change models show that under the current climate severe agricultural prorationing of about 50 percent or more occurs roughly 14 percent of the time; with a 2° Celsius warming, it will increase to about 54 percent of the time; and with a 4 ° Celsius warming, almost 92 percent of the time (Scott et al. 2004A). The latter is equivalent to an almost continuous drought under today's conditions. This situation is projected to persist even without considering increases in irrigation demands. In summary, it is estimated that, factoring demand increases, severe agricultural rationing can be expected to increase at least to 54 percent of the time (the current average being 14 percent).

4.2 Municipal Demand

4.2.1 Existing Demand

Municipal water demands were estimated to be 91,000 AF in 2010. This includes 42,000 AF for large public water systems serving the six largest cities of the Yakima Basin; 15,000 AF for smaller public water systems; and 34,000 AF for owners of domestic wells. Municipal uses include both surface and groundwater (including urban irrigation and potable uses), while the domestic wells are entirely groundwater. Groundwater accounts for about 83 percent of total supply and is the preferred source for future increases.

4.2.2 Future Demand

Water needs for municipal and domestic uses are expected to increase due to ongoing population growth in the Yakima River Basin. Based on a population growth forecast of 1.5 percent annually through 2024, and one percent annually from 2025 to 2060, and without adjusting for other factors (e.g., new conservation measures or conversion of lands to other uses), municipal water demand is projected to increase by 72,000 AF in the 50 years if water can be made available to serve this use. 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 AF. When return flows are included the net change in consumptive use is projected to be an increase of 20,000 AF from 2010 to year 2060 (USBR 2011A, pp. 26).

4.2.3 Anticipated Future Impacts

Because the reliance of municipal supplies on surface water is significantly less than agricultural irrigation, the impact of climate change and population increase on municipal water supply is expected to be marginal. Eighty-three percent of municipal supplies in the Yakima Basin are sourced from groundwater, which remains a preferred source for future expansions. However, this generally optimistic estimate of impact is not necessarily benign for certain communities which rely on surface water more than the average. While some of this demand may be met via groundwater wells, the effect of proposed IP projects on groundwater is unclear[35]. Furthermore, groundwater wells may be affected by changes in local reservoir levels and, conversely, the use of wells has the potential to affect nearby reservoirs where there is significant groundwater to surface water connectivity. Since withdrawal from groundwater wells is subject to approval by Ecology, this connectivity raises questions with regard to whether this demand can be fully met.

4.3 Other Uses

The Yakima River Basin has a number of other consumptive and non-consumptive water uses, including water supply diverted or withdrawn to support fish and wildlife propagation; commercial and industrial uses separate from municipal systems; livestock use; and non-community public water systems. These water uses are estimated to be about 26,000 AF annually (Yakima Basin River Study, USBR 2011A, pp. 26). Since this quantity is relatively small, projected increases in this category have not been analyzed for this study.

5.0 Economic Impacts

5.1 Background and Purpose

The Yakima Basin Integrated Plan (IP) identifies and analyzes a broad set of projects and actions intended to improve water supply reliability for out-of-stream uses as well as instream habitat for the benefit of anadromous fish species. Elements of the IP include:

- Changes to reservoir operations
- Expansion of existing reservoir storage space
- Development of new off-channel storage
- Aquifer recharge and recovery
- Enhanced water conservation
- Increased water market reallocation
- Construction of fish passage facilities
- Habitat protection and enhancement

The economic benefits associated with execution of the IP are addressed and described in a number of reports which were reviewed for this analysis. The primary reports include:

- *"Yakima River Basin Integrated Water Resource Management Plan, Framework for Implementation Report."* (USBR 2012B).

- *"Yakima River Basin Integrated Water Resource Management Plan, Four Accounts Analysis of the Integrated Plan."* (USBR 2012C).

- *"Yakima River Basin Study, Economic Effects of Yakima Basin Integrated Water Resources Management Plan."* (USBR 2011B).

A number of other economic reports were reviewed in support of this analysis. They include:

- *"The Economic Impacts of Improved Water Supply Reliability in the Yakima River Basin."* (Northwest Economic Associates 2004).

- *"Climate Change Impacts on Water Management and Irrigated Agriculture in the Yakima River Basin, Washington, USA."* (Vano et al. 2009).

- *"Water Exchanges: Tools to Beat El Nino Climate Variability in Irrigated Agriculture."* (Scott et al. 2004B).

- *"The Value of Heterogeneous Property Rights: The Costs of Water Volatility."* (Brent 2013).

5.2 Summary of Benefits

The estimated economic benefits associated with the IP are provided in Table 5. As shown, the present value of the estimated economic benefits ranges from $6.2 to $8.6 billion. This compares to the estimated present value of capital, operational, and maintenance costs of $2.7 billion to $4.4 billion. The vast majority (80 to 90 percent) of the estimated benefits are associated with the expected increase in anadromous fish (primarily sockeye salmon) that would result from fish passage and habitat improvements identified in the IP.

Total irrigation benefits were estimated to be $0.8 billion over the 100-year analysis period and are associated with improved water supplies during drought years to proratable water users in the basin. Projects implemented under the IP are also expected to improve future water supply reliability to municipal and domestic water users resulting in an estimated economic benefit of $0.4 billion.

Table 5: Estimated Economic Benefits.

Benefit Category	Estimated Value (2012$)	Expected IP Outcome
Fishery	$5.0 billion to $7.4 billion	Increase annual salmon/steelhead recruitment by 181,650 to 472,450 fish
Irrigation	$0.8 billion	Improve water deliveries during drought years from 30% to 70% to proratable entitlements
Municipal and Domestic	$0.4 billion	Increase municipal and domestic water supply by 50,000 AF (20,000 AF consumptive use)
Total	$6.2 billion to $8.6 billion	

Source: USBR, October 2012. "Yakima River Basin Integrated Water Resource Management Plan, Four Accounts Analysis of the Integrated Plan."

5.3 Irrigation Benefits

Water is critically important to the environmental, economic, social, and cultural well-being of the Yakima River Basin. In dry years, water supplies are inadequate to meet all needs, and water delivery shortages occur to irrigated agriculture. This results in a reduction in agricultural output and employment and reduced activity in supporting economic sectors (e.g., processing, transportation, etc.). The basin has experienced water shortages in a number of years including 1987, 1988, 1992, 1993, 1994, 2001, and 2005. The impacts of these droughts were especially severe for the irrigation districts in the basin which have junior (proratable) water rights. In 1994 and 2001, for example, proratable water users received only 37 percent of the surface water supplies associated with their contracts. The frequency and depth of water supply shortages in the basin is expected to increase due to the effects of climate change as highlighted in the IP.

The Yakima Project provides water supply primarily for six divisions: Roza, Wapato, Kittitas, Sunnyside, Tieton, and Kennewick. These six divisions total approximately 383,000 acres. The total allocated water supply for the Yakima Project is more than 2.41 MAF[36]. More than half (53 percent) of this supply is proratable during dry years. Roza, Kittitas, and Kennewick divisions are completely dependent upon proratable supplies.[37] Several of the elements of the IP are focused on improving water supply reliability to proratable water users. The IP targets deliveries of no less than 70 percent of proratable contract supplies during drought years.

Proratable water rights in the Yakima Project total 1,310,075 AF (excluding Kennewick Division). As described above, the worst droughts in recent decades have resulted in only 37 percent deliveries to proratable users. Increasing the minimum proratable deliveries from 37 percent to 70 percent requires increased deliveries of more than 430,000 AF during dry years[38]. The recent drought events and other periodic water supply reductions result in substantial impacts to proratable users.

In addition to this issue, there are significant differences in reported irrigation benefits among the IP economic reports completed in 2011 and 2012. These may be due to changes in the model inputs, assumptions, and/or structure over time. As described above, the IP reports that under full water supply conditions, the total annual net revenues for the five modeled districts (Kittitas, Roza, Sunnyside, Tieton, and Wapato) is approximately $480 million. However, other IP-related reports and analysis report significantly different values. For example, a March 2011 analysis[39] of the irrigation benefits associated with water market reallocation estimated full water supply net revenues of $280 million for the same five districts. Similarly, the June 2011 report estimates the total net present value of irrigation benefits to be $0.4 billion.[40] This compares with the estimated irrigation benefits reported in the IP of $0.8 billion.[41] Both of the analyses assume that proratable supplies are increased from 30 percent to 70 percent during drought years. Review of the available information suggests that the differences in the estimates relate primarily to changes (updates) in the estimates of net farm earnings by crop. For example, the 2011 estimates relied upon estimated alfalfa and timothy hay net revenues of $1/acre and $140/acre, respectively. These were updated for the 2012 analyses to estimated net revenues of $688/acre for alfalfa and $702/acre for timothy hay. Similar updates were applied to other crops contained in the model to make them more consistent with recent crop markets and production costs.

The IP analysis is reportedly consistent with the Principles and Guidelines[42] and focuses on estimating the change in net farm earnings from a change in irrigation water supplies. Irrigation benefits are estimated using an annual spreadsheet model that simulates cropping pattern and net revenues by district for a given water supply. Different levels of inter-district and intra-district water trading are assumed for the two scenarios considered.

Other analysis methods consistent with the Principle and Guidelines could be applied for comparative purposes. For example, agricultural land sales data in the basin could be used to develop an econometric model that estimates the difference in value between land with non-proratable and proratable water supplies.

The spreadsheet model applied in the IP is reportedly “adapted” from a model developed in 2004 by researchers at the Pacific Northwest National Laboratory (PNNL).[43] However, the IP reports do not explicitly describe how the PNNL model was changed when applied to the IP analysis. The PNNL model focuses heavily on crop-water yield relationships and impacts of climate change. No description of crop-water yield functions is provided in the IP reports. In fact, the documentation indicates that the IP analysis relies upon fixed crop yields and fixed crop water requirements, which are not consistent with the structure of the PNNL model. As a result, it does not appear that they were applied and the IP analysis relied only upon a selected set of inputs from the PNNL model. However, it would be necessary to obtain and run the actual model applied in the IP analysis to evaluate the IP's results.

Some of the key components of the IP irrigation benefits analysis are provided below:

- Analysis Period: 100 years
- Discount Rate: Federal Water Resources Planning Rate – 4 percent.
- Cropping Pattern: The model includes 17 different crops/crop categories and assumes that the acres of each crop within each district do not change over time or with changes in water supply reliability.
- Crop Prices: 3-year average crop prices are applied in the model.
- Crop Yields: Reported average yields by crop/crop category. The model assumes that crop yields do not vary by district.
- Crop Water Requirements: The model applies fixed crop water requirements (AF/acre) by crop and district.
- Scenario Water Supplies: Assumes that future baseline conditions supply 30 percent of contract entitlements to proratables during drought years. With the IP fully implemented (2026), the analysis assumes water deliveries of 70 percent of proratable entitlements during drought years. This represents an increase in dry year water deliveries of more than 500,000 AF. Both baseline and IP scenarios assume a single-year drought occurs 1 in 5 years and a 3-year drought occurs every 20 years. This is equivalent to a 30 percent chance that a severe drought will occur in any given year.
- Water Reallocation During Droughts: Baseline scenario assumes 30,000 AF of inter-district trading among Kittitas, Roza, and Sunnyside districts and (apparently unlimited) intra-district trading in all divisions during dry years. While difficult to interpret from the available reports, it appears that the IP scenario assumes an inter-district water trading cap of 10 percent of available district water supplies during dry years.[44] Based upon experience in other regions, this trading cap may be low. Increasing the inter-district water trading cap would likely lower the estimated economic benefits from improved water supply.

5.4 Agricultural Model Replication

A spreadsheet model using the inputs and assumptions described in the October 2012 report (USBR 2012B) was developed in an attempt to reproduce the IP analysis results. Reproduction of the model was difficult due to the limited details provided on model structure and assumptions. The IP model results could not be reproduced with the available information. Review of the actual model applied in the IP analysis would be the only way to effectively evaluate the estimated irrigation benefits.

Consistent with the IP analysis, the model developed for this review seeks to maximize total net revenues for a given water supply conditions (prorationing level). Water is allowed to move from lower valued to higher valued crops within each irrigation district as supplies become limited. In addition, inter-district transfers of up to 30,000 AF between Sunnyside, Roza, and Kittitas districts is allowed. This model does not attempt to make any adjustments to ensure a TWSA neutral water transfer. As in the IP analysis, the water transfer price is set at $150/AF/yr such that water is transferred only from crop acres earning net revenues less than $150/AF/yr. The same cropping pattern, net revenues, and crop water requirements used in the IP analysis are applied in the model.

Table 6 provides a summary of the results of this analysis. As shown, the estimated total annual net revenue under full water supply conditions (100 percent supplies to proratables) is approximately $479 million. This compares well with the $480 million estimated in the IP. Total water use is 1.674 million AF, which is equivalent to the full water requirements based upon the provided cropping pattern and water demands for the five modeled irrigation districts. It should be noted that total water available during full water years exceeds the total crop water requirements assumed in the IP. Consequently, irrigated acres and associated net revenues do not begin to decline until the water supply to proratables reaches approximately 80 percent. This indicates that the IP assumes that there is more water available than is needed for irrigation of existing crops in the Yakima Project when water supply to proratables exceeds 80 percent. Additional research should be conducted to confirm this result and to assess how, or if, water conveyance losses (e.g., seepage) were incorporated into the model. In addition, some IP actions, if implemented, would reduce water conveyance losses. It is not clear from the IP report how the efficiency gains relative to the baseline were incorporated into the analysis. A more thorough economic analysis of the agricultural benefits of improved water supply reliability would link the output from the water supply model to the economic model.

Consistent with the IP model, inter-district water trading is limited to 30,000 AF under the baseline scenario. In addition, water is allowed to freely move from lower to higher valued crops within each district as water supplies become limited. This is consistent with the reported conditions for the baseline scenario in the IP analysis. The assumption that available water supplies can freely move from low to high valued crops within each district effectively treats each district as if it were a single farm. This likely overstates the institutional and physical mobility of water within a district and understates the economic benefits associated with improved water supply reliability. As shown in Table 6, intra-district water trading does not reach the maximum level of 30,000 AF until the water supply to proratables is reduced to 60 percent. Internal district trading is significant and increases with reduced proratable water supplies. For example, during severe drought years, the model estimates that 30,000 AF (the maximum allowed) would be sold by irrigators in the Kittitas Division for use in the Roza Division.

The estimated irrigated area is 326,169 and 229,497 acres for a 70 percent and 30 percent water supply to proratables, respectively. This is a reduction of 96,673 irrigated acres. The IP model assumes that acres can be fallowed without cost other than foregone net revenues. This assumption would appear to be optimistic, as irrigators are unable to perfectly forecast water supply conditions and avoid all land costs. In reality, fallowing costs can be significant and depend, in part, upon the level of land preparation undertaken prior to the decision to fallow, and the carrying costs of the land and type of crops (e.g., hay vs. orchards) among other factors. For example, irrigators are required to pay district water assessments whether or not they are able to irrigate in a given year. Assuming $0/acre in net revenue for fallowed land results in an underestimate of the costs associated with reduced water supplies. These costs would be exacerbated by multiple years of drought which could affect the long-term financial viability of some farms (e.g., orchards and vineyard).

Figure 11 shows the estimated reductions in irrigated acres by crop associated with moving from a 70 percent to 30 percent proratable water supply. As shown, the majority of the fallowed acres involve hay, pasture, and wheat. However, a significant number of orchard crops also receive no water during a severe drought according to the model results (indicated by the green bars on the chart). The model operates to fallow the least profitable crops (as measured by gross revenues less variable costs) in favor of water supply to more profitable crops until water reallocation opportunities are exhausted. According to the model result completed for this analysis, orchard crops are predominately fallowed in the Roza Division where there is an inadequate amount of lower valued crops to temporarily idle and a limited supply of water that can be purchased from other districts (Kittitas and Sunnyside). It is important to note that the IP documentation does not provide any information on the crops that are fallowed by water year type and therefore cannot be compared with the results provided in Figure 11. However, this analysis reveals that under the baseline scenario, there is not adequate water supply to support some permanent plantings despite the assumptions applied in the IP regarding intra and inter-district water mobility. In reality, permanent crops would be deficit irrigated during dry years rather than fallowed.[45] Depending upon the severity of water deficit, permanent crops which are not adequately irrigated during dry years will likely suffer reduced yields (potentially suffering temporary, long-term or permanent damage) and reduced quality during the year and can suffer losses in production in the years following a drought. Multi-year drought events have the potential to result in total crop failures if for example, fruit and vineyard stock all die and must be replaced in total. These effects cannot be captured by the modeling approach applied in the IP analysis. They also highlight the problems associated with assuming that the cropping pattern remains fixed with changes in long-term basin-wide water supply reliability.

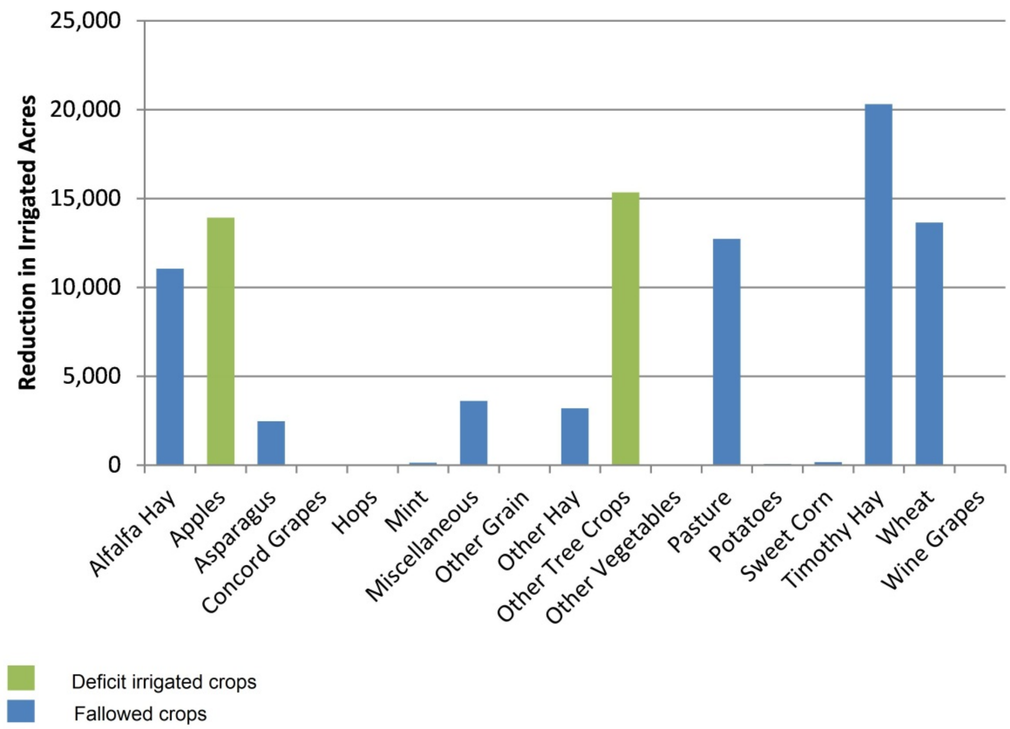


Figure 11. Estimated Fallowing by Crop during Drought Years.

The IP analysis estimated the irrigation benefits according to the difference in net revenues during years in which the water supply to proratables is increased from 30 percent to 70 percent. The baseline scenario assumes that the basin experiences a 30 percent allocation to proratable water users in 30 percent of the 100 years of analysis and that drought occurs with equal probability in each year.

Under the IP scenario, water supply to proratables is increased from 30 percent to 70 percent in all drought years and assumes the same frequency of drought as the baseline scenario. This analysis does not attempt to compare these assumptions with the results of water supply modeling conducted for the IP. However, it is not clear why the economic model did not incorporate output from the water supply model. Linking the two models, as is commonly done in other irrigation water supply feasibility studies, would have resulted in a more realistic and supportable estimate of long-term economic benefits.

The results provided in Table 6 indicate a difference of $77.2 million in net revenues between a 30 percent and 70 percent water supply year. The estimated benefits in the IP analysis are $140.7 million in 2026 when new reservoir storage becomes available.[46] This difference is large and cannot be easily explained given the documentation provided in the IP-related reports. This issue is further addressed below.

Table 6: Estimated Economic Benefits.

Proratable Water Supply (% of Entitlement)	Estimated Net Revenue ($)	Total Water Use (AF)	Irrigated Acres	Inter-District Water Trading (AF)	Total Water Trading (AF)
100%	$478,606,003	1,674,225	357,949	0	0
90%	$478,606,003	1,674,225	357,949	0	0
80%	$478,529,364	1,639,001	348,275	3,980	33,429
70%	$473,759,909	1,539,797	326,169	29,252	108,245
60%	$462,201,921	1,416,119	299,065	30,000	167,943
50%	$448,432,459	1,292,442	273,834	30,000	206,537
40%	$423,244,792	1,168,764	251,485	30,000	213,810
30%	$396,598,798	1,045,086	229,497	30,000	217,010
20%	$369,947,488	921,409	207,753	30,000	240,663
10%	$341,642,320	797,731	181,851	30,000	240,612
0%	$303,247,449	671,124	153,095	30,000	251,747

The difference between the estimated irrigation benefits reported here and those reported in the IP could not be fully reconciled with the available information. One possible explanation is that the IP analysis constrains the level of intra-district water reallocation during drought years. However, this is not consistent with the model assumptions as described in the available documentation. To test this, a simple model was constructed to allocate the available water supply in each district holding the proportion of the district's total available water supply to each crop constant. This removes the ability for water supply to be reallocated from low to high valued crops during drought years. In addition, intra-district water trading opportunities were eliminated. These assumptions understate the mobility of water both within and across districts thereby leading to an overestimate of the costs associated with reduced water supplies (and conversely, the benefits associated with water supply improvements). The results of this analysis are provided only for comparison purposes.

Table 7 provides a summary of the results of the analysis. As shown, the estimated net revenue under full water supply conditions is identical to that presented in Table 6 ($478.6 million). The estimated difference in total net revenues between a 30 percent and 70 percent water supply to proratables is approximately $119 million. This estimated annual value is again below the $140.7 million reported in the IP. More information would be needed to reproduce and confirm the results of the IP economic analysis. However, given the documented inputs and assumptions, it is unclear how the irrigation benefits following full implementation of the IP are as high as reported.

Table 7: Agricultural Model Results Holding Cropping Pattern Constant w/ No Water Trading[47].

Proratable Water Supply (% of Entitlement)	Estimated Net Revenue ($)	Water Use (AF)	Irrigated Acres	Intra-District Water Trading (AF)	Total Water Trading (AF)
100%	$478,606,003	1,674,225	357,949	0	0
90%	$448,881,197	1,566,360	335,206	0	0
80%	$419,156,392	1,458,495	312,462	0	0
70%	$389,431,586	1,350,631	289,719	0	0
60%	$359,706,780	1,242,766	266,976	0	0
50%	$329,981,974	1,134,901	244,233	0	0
40%	$300,257,169	1,027,037	221,489	0	0
30%	$270,532,363	919,172	198,746	0	0
20%	$240,807,557	811,307	176,003	0	0
10%	$211,082,752	703,442	153,259	0	0
0%	$181,357,946	595,578	130,516	0	0
100%	$478,606,003	1,674,225	357,949	0	0

5.5 Key IP Economic Model Issues

The following provides a summary of some of the key areas of concern associated with the IP economic model. The economic consequences of an inadequate water supply are so significant we consider it important to raise these points. Additional information and detail concerning the model applied in the IP analysis would most certainly allow for a more complete review and assessment. In addition, it may reveal why the estimated irrigation benefits reported in the IP are significantly higher than those estimated in this analysis, which attempts to use the same inputs and assumptions as provided in the IP.

Total Crop Water Requirements: The total crop water demand for the modeled districts indicated by the information provided in the reports is 1,674,225 AF/yr. In comparison, the total entitlements for the modeled districts is 1,938,325 AF/yr. As a result, total entitlements during a full water supply year exceed water demand by 264,100 AF/yr. It is not clear how the model addresses this discrepancy, if at all. If the assumed prorationing level is applied to the entitlement volume (as is indicated in the report), then the costs of drought (benefits of increased water supply) are likely underestimated. Based upon the attempted reproduction of the IP model completed for this analysis, the water supply to proratable entitlements would need to reach approximately 80 percent before the region experienced any decline in crop production and irrigation net revenues.

Future Water Supply Assumptions: The baseline economic model scenario assumes that all future droughts result in proratables receiving 30 percent of their entitlement volume, which increases to 70 percent under the IP scenario. These assumptions are not consistent with historical water supply conditions in the Yakima Basin and are not likely consistent with the water supply modeling completed for the IP. In effect, the IP economic analysis compares the assumed best case with the assumed worst case water supply conditions and applies them to every year of the analysis. This approach does not provide a sound basis from which to assess the feasibility of the IP. The economic model should be more directly linked with the output from the water supply modeling and should include information about any water conveyance and application efficiency projects incorporated into the IP.

Fixed Cropping Pattern Assumption: The IP model assumes that the crop patterns in the Yakima Basin do not change with improved water supply reliability. In reality, farms manage the planting of crops according to both the long-term and annual expected water supply conditions. The potential for deep droughts results in more plantings of lower valued annual and hay crops which can be temporarily idled at a lower cost to support water deliveries to higher valued crops. Eliminating the risk of prorationing below 70 percent, as the IP reports to accomplish would, subject to market limits for crops, result in a higher proportion of plantings to permanent and high valued crops. This would increase irrigation net revenues and increase employment, processing, and other related activities in the regional economy. Maintaining a fixed cropping pattern underestimates the economic benefits associated with improved water supply reliability to irrigators in the basin.

Fixed Crop Water Requirements: The IP model appears to assume that there is a fixed crop water requirement for each crop/district combination. During drought years when water supplies are inadequate to satisfy the crop water requirements, the model assumes that acres of crops with lower net returns are fallowed to satisfy the crop water needs for those acres that remain in production. This analysis indicates that if the IP model did in fact apply this assumption that some permanent crop plantings would be fallowed. A more reasonable modeling approach would be to apply crop-water yield curves as well as the maximum allowable deficit to support plant survival. Similar approaches have been applied in prior economic analyses of agricultural production in the Yakima Basin.

Crop Yields Assumption: The IP model assumes that crop yields do not vary by location within the Yakima Basin. This is not consistent with the published data. For example, alfalfa yields in Kittitas County are significantly lower than alfalfa yields in Benton County. The result is that net revenues per AF of applied water, a key parameter in the model, are not as well estimated as they should be. In addition, the IP model reportedly applies estimated net revenues according to assumed yields achievable under full water supply conditions. However, this is not clear as the documentation also reports that the yields applied in the IP model represent averages. If they are average crop yields, it is likely they inherently include observed yields during dry years and therefore underestimate full water yields and the economic benefits associated with improved water supply reliability.

Variable Crop Production Costs: The crop budgets used to define the variable costs of production are not adequately described in the IP-related documents to determine the cost categories that were included (or excluded) from the calculation. Further, by only considering variable production costs, the analysis does not account for the large, upfront financial investments required to establish some crops in the basin and therefore underestimates the risk and cost of single- or multi-year drought events.

Water Conservation: The IP includes a program to fund agricultural water conservation measures estimated to reduce diversion requirements by 171,700 AF. As described above, the IP model holds crop water diversion requirements fixed across the baseline and IP scenarios. By holding crop water requirements fixed, the IP model does not account for the potential economic benefits associated with reduced per acre water requirements that would result from the conservation improvements.

Short-Run Model: The IP model is a "short-run" analysis in that it fixes cropping patterns and irrigation/water conveyance efficiencies. A long-run model that allows for changes in both of these parameters would be more consistent with the projected long-run water supply reliability changes and a more appropriate platform from which to estimate economic benefits associated with the IP. Such a model would allow for a greater understanding of the limitations imposed by the current water supply conditions on investments in permanent crop plantings and the extent to which additional investment in these crops may be supported through improved water supply conditions. In general, acres planted to permanent and high valued crops support higher employment and economic activity in the region than that provided by acres planted to hay and grain crops.

Annual Model: The IP model is a single-year model and is therefore not capable of estimating the direct economic effects to irrigators associated with multiple-year droughts. Multiple-year droughts clearly threaten the financial viability of farms in the region lacking access to adequate water supplies. The IP model assumes "business as usual" following drought conditions and does not capture any of the subsequent year(s) impacts on crop productivity and production costs. These costs, under some conditions, may include crop re-establishment.

Fallowed Land Costs: The IP model appears to assume that there are no costs associated with fallowed land resulting from limited water supplies. This is unlikely to be the case as irrigators may incur costs associated with weed control and land management. In addition, irrigators must pay water assessments on fallowed acres. Irrigators may also have incurred land preparation and planting costs prior to deciding to fallow land due to imperfect water supply forecasts in the early spring. The IP model also does not account for crop yield losses or re-establishment costs in the year(s) after fallowing. As a result, based upon the available information, it appears that the IP model underestimates the costs associated with fallowing and underestimates the economic benefits associated with improved water supply reliability.

5.6 Municipal Benefits

The municipal benefits estimated in the IP are divided into two primary categories:

- Projected growth in municipal/domestic water demand.
- Municipal/domestic water demand at risk of future regulation to satisfy senior water rights.

The USBR guidelines offer a number of approaches that can be applied to estimate the economic benefits associated with municipal water supply and are consistent with the Principles and Guidelines.[48] The potential approaches are generally described as follows:

- A stated preference approach where the willingness of water users to pay[49] for an improved water supply is estimated using household surveys.
- A revealed preference approach where domestic water supply and demand relationships are estimated using observed market behavior and these relationships are then used to estimate changes in welfare from water supply changes.
- Use of price elasticity of demand estimates applicable to the study area along with current quantities and prices for water in the study area to derive a demand curve from which changes in benefits can be estimated.
- A benefits transfer approach where the results from previously completed studies are used to estimate benefits at the study site under consideration.
- A cost of the most likely alternative approach where the resource cost of the water supply alternative that would be implemented in the absence of the project under consideration is used as a proxy for water supply benefits.

The authors of the IP apply the last approach (cost of the most likely alternative) to estimate the economic benefits associated with municipal water supply in the Yakima Basin. In particular, the wholesale municipal water price is used to estimate the benefits associated with water supply for projected growth. In addition, the estimated market price associated with water right transfers is used to estimate the benefits associated with "firming" municipal supplies associated with junior water rights.

The two categories of municipal benefits are addressed in the following sections.

5.6.1 Projected Growth

Demand modeling completed for the IP indicate that municipal/domestic water demand will increase by 48,900 AF above 2010 levels to 140,000 AF by 2060. Each AF of "new" supply to municipal/domestic users is valued at $258/AF/yr, which is reported to be the wholesale municipal water price in the basin. The estimated present value associated with the 48,900 AF ranges from $115 to $117 million ($2,300 to $2,400/AF). As described in the IP report, these values reflect the cost of additional water supply incurred by municipal users and do not represent a willingness-to-pay measure. Willingness-to-pay represents the maximum price that a person would pay for a good (e.g., one AF of water) rather than go without. As a result, the estimated benefit likely underestimates the municipal willingness-to-pay (and economic benefits) for additional water supplies. While the applied method is acceptable under the Principles and Guidelines[50], a more consistent and accurate approach would be to estimate a municipal/domestic demand curve for water using relevant long-run price elasticity estimates and water rates. The net economic benefits would then be estimated according to the area under the demand curve that lies above the water rate for the new increment of supply.

5.6.2 Junior Municipal Water Rights

In addition, current municipal/domestic uses are at risk of future curtailment as they rely upon water rights that are junior to Yakima Project irrigation water rights. Implementation of the IP is anticipated to facilitate voluntary transfers of senior irrigation rights to address the estimated 10,500 AF of consumptive use associated with junior municipal/domestic water uses that are withdrawn above the Parker gage. The value of the water supply to junior municipal/domestic users provided by the IP is estimated according to the estimated market price for senior water rights - $2,500/AF of consumptive use. This value is then offset according to the estimated foregone net revenues from crop production on the land that the water rights are acquired from - $1,000/AF. The net value of $1,500/AF ($2,500 - $1,500) is then applied to the estimated water demand schedule over the 100-year period of analysis. Based upon this information, the IP estimates present value benefits of $280 million for the protection of existing junior municipal water rights.

The estimated benefits for this category appear to be greatly inflated. The value applied in the analysis reflects the permanent value associated with a senior water right acquisition. However, the IP analysis appears to treat them as though they are annual values that apply to each AF of water supply over the period of analysis. In effect, once permanently acquired, a senior water right provides water supply benefits in perpetuity. Table 8 corrects for this error in the analysis. As shown, the estimated benefits for the category of municipal water use should be $11.5 million, not $280 million as reported in the IP.

Table 8: Agricultural Model Results Holding Cropping Pattern Constant w/ No Water Trading[51].

Year	Cumulative Volume (AF)	Annual Volume Added (AF)	Nominal Annual Value ($)	Discounted Annual Value ($)
2013	583	583	$874,500	$874,500
2014	1166	583	$874,500	$840,865
2015	1749	583	$874,500	$808,524
2016	2332	583	$874,500	$777,427
2017	2915	583	$874,500	$747,526
2018	3498	583	$874,500	$718,775
2019	4081	583	$874,500	$691,130
2020	4664	583	$874,500	$664,548
2021	5247	583	$874,500	$638,989
2022	5830	583	$874,500	$614,412
2023	6413	583	$874,500	$590,781
2024	6996	583	$874,500	$568,059
2025	7579	583	$874,500	$546,210
2026	8162	583	$874,500	$525,202
2027	8745	583	$874,500	$505,002
2028	9328	583	$874,500	$485,579
2029	9911	583	$874,500	$466,903
2030	10494	583	$874,500	$448,945
2031	10500	6	$9,000	$4,443
			Total	**$11,517,820**

5.7 Fishery Benefits

The IP estimates the economic benefits associated with improvements in salmonid returns to the Columbia River resulting from the implementation of the IP. According to the information presented in the economic analysis, biological modeling conducted for the study estimated that, at full implementation, the IP will improve salmon and steelhead recruitment by 181,650 to 472,450 fish. The estimated economic benefits associated with this improvement range from $4.9 - $7.1 billion, not including the values derived from harvest which are addressed elsewhere in the IP report.

The benefit estimates rely upon an economic analysis completed in 1999.[52] The study completed by Layton, Brown, and Plummer (LBP) follows the accepted "contingent valuation" method. Due to the location, fish species, and methodology, the study results are highly relevant to the IP. For the LBP study, randomly selected Washington households in the survey would be willing to pay a specified amount in the form of additional monthly utility payments for a specified improvement in fish populations over a 20-year period. The LBP study addressed fish populations in five regions of the State, including the Columbia Basin. Statistical analysis of the survey responses was applied to generate functions describing the annual household willingness-to-pay for increases in Columbia Basin salmon/steelhead populations.

Two benefits functions were generated from the LBP study. The first was based upon the expressed willingness-to-pay by respondents that were shown that estimated Columbia Basin fish populations would remain stable over the 20-year period without additional action. The second was based upon the responses to surveys which indicated that the Columbia Basin fish population would decline over the 20-year period without additional action. The estimated household willingness-to-pay is higher for a declining baseline fish population indicating that households are willing to pay more to avoid a decline and potential species loss than they are for a population that is stable. The IP study relied upon the willingness-to-pay function based upon the lower, stable population assumption. The willingness-to-pay function increases at a decreasing rate which means that households are willing to pay less for an incremental fish population increase from 20 percent to 30 percent than they are for the first 10 percent increase. As a result, the estimated benefits are highly dependent upon the assumed baseline fish population. The IP analysis applies a current (baseline) fish population of 2 million which is consistent with the baseline applied in the LBP study.

Identifying the appropriate geographic region of analysis is central to the valuation approach applied in the IP. In most economic studies, the appropriate region includes the population that would most likely be affected or place some value on the resource. For example, a recreation site likely only has value to individuals with the potential to travel to it. People located further away would generally have access to alternative recreation sites and would be unwilling to pay for its establishment and maintenance. When valuing fish species, the appropriate geographic region is particularly difficult to identify. However, it is clear that the geographic area should coincide with the region containing the households that were the subject of the surveys supporting the original study. Extending beyond that region would likely yield an upward bias on value. For this reason, the IP authors chose to estimate the values for Washington State only in one scenario but also included Oregon residents in another scenario. Despite the fact that the LBP study surveyed only Washington households, it is reasonable to conclude that Oregon households value improvements to Columbia River salmon populations at a similar level. The IP authors correctly point out that only including Washington and Oregon households may underestimate the national value associated with the estimated fish population improvements.

Annual household willingness-to-pay estimates range from $73/household/yr to $113/household/yr for the modeled changes in Columbia Basin fish populations. This compares well with other willingness-to-pay based estimates applied to salmon and steelhead populations. For example, a meta-analysis completed by Richardson and Loomis (2009) found estimates ranging from $24.29 to $141.27 per household for protection of Pacific salmon and steelhead species, with a mean estimate of $89.99/household/yr.[53] A recent study completed in the Klamath Basin, Oregon found that households were willing to pay between $37.75 and $49.10 each year to reduce the extinction risk for Coho salmon from a high to moderate level.[54]

The wide range in estimated fish recruitment underscores the inherent uncertainty surrounding the biological estimates. The authors account for this by including a range of expected fish recruitment. However, the benefits functions used to estimate household willingness-to-pay for the improvements are treated as absolute. Due to the large magnitude of the estimated benefits and large public expenditure required to achieve the estimated biological outcomes, the IP analysis could be improved by incorporating a range of household benefits according to the statistical significance of the parameters estimated in the LBP study. The large estimated benefits and relative importance to the feasibility of the IP further suggest that the fishery benefits should be estimated through completion of a new economic analysis specific to the Yakima Basin rather than through a benefits-transfer approach applied to a study completed in 1999.

6.0 Conclusion

The purpose and goal of this Yakima Basin Integrated Plan Technical Review is to provide elected officials, policy makers, and the general public with an impartial, objective review of elements of the Yakima River Basin Study Proposed Integrated Water Resource Management Plan (or IP), prepared by the United States Bureau of Reclamation in 2011. This review was conducted at the request of the Yakima Basin Storage Alliance with the intent of encouraging new examination and discussion of the resulting outcomes from the Integrated Plan and is focused on the following three key questions:

Figure 12. Spring Creek, unable to return to the Yakima River (Yakima Subbasin Plan).

1. *Do the projects resulting from the IP provide sufficient water for instream and out-of-stream water needs, including the current climate conditions and future conditions under the three climate change models identified in the IP?*
2. *Is the capacity of the surface water storage options presented in the IP sufficient to meet instream and out-of-stream needs over the lifetime of the IP?*
3. *Will the timeline for constructing the water storage projects be achievable in a timely manner?*

Based on this review and analysis, we conclude that the IP does not provide sufficient information to adequately answer these fundamental questions. The level of doubt and uncertainty with the baseline data, resulting studies, and conclusions reached in the Plan is significant. The action steps identified in the IP do not include the information required to determine that the IP presents the best course of action for providing a reliable, long-term water supplies to the Yakima Basin. Before significant public funds and time are further expended, we urge further review and consideration of the points raised in this review.

Overview of Integrated Plan

The USBR's IP resulted from extensive dialogue and efforts over many years in an attempt to reach consensus to address the Yakima Basin's diverse water needs. The IP was intended to account for current and future water needs for both instream and out-of-stream uses, but the methodology for determining those needs requires reexamination and refinement. The primary intent of the IP is to provide sufficient instream flows for resident and anadromous fisheries, improve normal and drought year supplies to agricultural users and irrigation districts, reliable supply for municipal users, and to improve security of water rights in the Basin.

The following is a summary of our findings and a series of recommendations to remedy the existing situation.

Meeting the Basin's Water Needs

Management of the competing demands for water in the Yakima Basin requires judgment, compromise, and balance. The present means used to allocate water in the Basin; namely Total Water Supply Availability (TWSA) methodology looks back at historic use and diversions together with anticipated snowpack and runoff observations to quantify diversions for the coming year. It is time this approach was reconsidered using currently accepted methodologies and where needed, new studies should be undertaken. The present approach neglects the impacts of climate change and receding groundwater levels and does not account for the effects of multi-year droughts on instream flows, reservoir carry-over and irrigation supplies. We noted that the IP provided a detailed historical hydrologic assessment of Basin hydrology in a broad sense, but the treatment of climate change impacts to future water supplies in the IP did not adequately quantify current and future effects on required storage.

According to the IP and its supporting Technical Memoranda, climate change impacts in the region will reduce snowpack, generate earlier snowmelt and runoff events, and increase temperatures. Full treatment of global warming and associated climate change was beyond the scope of this review, but a basic summary of collected data and trends currently indicate that average snow levels are below historic levels with earlier snowmelt runoff occurring more frequently in the western states and in the Yakima Basin. This has resulted in reduced river flows and water supply to the region, thus further depleting historic diversions, reducing water available in streams, aquifers, and existing reservoirs. The IP does not fully address the potential impacts of multi-year droughts and what additional measures are needed to meet single-year droughts.

Water Rights and Tribal Treaty Rights

The implications of "Water Rights and Tribal Treaty Rights" are unquestionably far reaching. Senior water right holders are typically provided 100 percent of their allocation, while the junior right holder receive a portion of their allocation, based on what water remains after the senior water rights are met. Under the current conditions, the junior water right holders (which included many of the irrigation divisions in the Yakima Basin) typically do not receive their full allocation - there is simply not enough water remaining to satisfy the full demand.

The Yakama Nation has both irrigation rights and Treaty water rights in the Yakima Basin. The irrigation rights include non-proratable irrigation rights with 1855 priority and proratable irrigation rights dated 1905. The Treaty water rights include sufficient water for the "minimum instream flow necessary to support anadromous fish life in the river" in order to support fish within the Yakama Nation's usual and accustomed fishing locations.

The trend over the last 100 years has been for the Tribes in the Pacific Northwest to pursue their tribal fishing rights and reservation rights to the fullest extent. Recent decisions from other lawsuits brought by the Tribes (e.g., Boldt II) have been based in the earlier precedents set in

Winters v. US and US v. Washington, and have generally been successful in expanding the extent of these rights over other interests. Morisset (2001) states: *"Because of the Supremacy Clause and the preeminence of Treaty Rights in the American scheme of law, it is not hard to envision Indian Treaty rights as "trumping" other property rights not based on the Treaties. Certainly most state law based rights, be they property rights or otherwise, will be overridden by the requirement that Indian Treaties be honored".*

Since the quantities of water necessary to support instream flows are determined annually by USBR, the preeminence of Tribal water rights for both on-reservation use and off-reservation instream flows introduce additional uncertainty regarding the water supply for the Yakima Basin. Declining fisheries in the Pacific Northwest and the listing of anadromous fish under the Endangered Species act provide additional impetus for the Tribes to seek legal recourse for habitat based instream flow needs.

The current trend in legal cases indicates that the Tribes would likely be successful in cases pursuing additional water under both the Winters Doctrine and the Boldt (I and II) Decisions and subsequent legal cases. Since the Yakama Nation right for water to support instream flow has a "time immemorial" priority date, this water would be "withdrawn" first, and would not be available for any other needs. Furthermore, since the quantity of water needed for instream flows has not been accurately determined, this introduces additional uncertainty into the water supply.

Storage Elements of the IP

The IP's proposed water storage projects will certainly provide some improvements to the Yakima Basin water supply and have the potential to benefit fisheries and aquatic habitat conditions. However, the proposed water storage projects will not provide enough water volume and predictable water supply for both a sustainable ecosystem and agricultural industry in the Yakima Basin under the climate change scenarios in the Integrated Plan.

The IP and supporting documents do not provide a complete and accurate view of the current water needs and the sufficiency of the complete water storage picture in the Basin. The IP's proposed storage projects fall far short of providing the necessary water storage capacity for future water demands. As evidence, the Yakima Basin's total reservoir capacity of 1.07 MAF is well short of the present day annual diversions of approximately 2.2 MAF. The remainder of the Basin's needs are met by unregulated flows from snowpack and other unaccounted sources.

The adequacy and reliability of the proposed water storage projects (e.g., Bumping Lake Reservoir Enlargement, Wymer Dam and Reservoir, Kachess Inactive Storage, Cle Elm Dam Raise) will not meet the IP stated objectives to sustain the region's population growth, municipal demands, agriculture economy, and the anadromous fishery (e.g., fisheries recovery passage and aquatic habitat enhancement) either under single or multi-year drought conditions for all users (including irrigators). Furthermore, during the period prior to project completion, junior water rights holders are exposed to considerable additional risk of not having enough water to meet their needs.

Groundwater Depletion

The linkage between surface and groundwater systems in the Yakima Basin and the recent significant declines in groundwater aquifer levels is also a major concern. USGS groundwater studies in recent years provide an estimate of deep aquifer depletion on the order of 30,000 AF annually, and the IP itself documents a reduction of 50,000 AF between low runoff and high runoff years (IP 2011). These studies have shown that declining groundwater levels reduce the amount of inflow available for seasonal water storage, and declining groundwater levels translate into reduced instream flows available for fisheries and aquatic habitat. Further study is needed to understand and assess the impact of these groundwater changes on instream flows, municipal water supplies and other uses. Due to the linkage between surface and groundwater system and aquifer depletion, restrictions have been implemented on groundwater withdrawals in the upper Kittitas County portion of the Yakima Basin.

Economic Impacts Associated With Implementation of the IP

Water is critically important to the environmental, economic, social, and cultural well-being of the Yakima River Basin. In dry years, water supplies are inadequate to meet all needs, and water delivery shortages occur to irrigated agriculture. This results in a reduction in agricultural output and employment and reduced activity in supporting economic sectors (e.g., processing, transportation, etc.).

The estimated economic benefits associated with the IP range from $6.2 to $8.6 billion, at a cost ranging from $2.7 billion to $4.4 billion. The vast majority (80 to 90 percent) of the estimated benefits are associated with an increase in anadromous fish populations (primarily sockeye salmon) that would result from fish passage and habitat improvements. Total irrigation benefits were estimated to be $0.8 billion over the 100-year analysis period.

The following provides a summary of some of the key areas of concern associated with the IP economic model.

- Total water entitlements during a full water supply year exceed water demand by 264,100 AF/yr. It is not clear how the model addresses this discrepancy, if at all.
- The baseline economic model scenario presented in the IP assumes that all future droughts result in proratables receiving 30 percent of their entitlement volume, under current operations and increases to 70 percent under the IP scenario. These assumptions are not consistent with historical water supply conditions in the Yakima Basin and are not likely consistent with the water supply modeling completed for the IP. In effect, the IP economic analysis compares the assumed best case with the assumed worst case water supply conditions and applies them to every year of the analysis.
- The IP model assumes that the crop patterns in the Yakima Basin do not change with improved water supply reliability. In reality, farms manage the planting of crops according to both the long-term and annual expected water supply conditions. Maintaining a fixed cropping pattern underestimates the economic benefits associated

with improved water supply reliability to irrigators in the basin and, therefore, the benefit of additional storage.

- The IP model appears to assume that there is a fixed crop water requirement for each crop/district combination. During drought years when water supplies are inadequate to satisfy the crop water requirements, the model assumes that acres of crops with lower net returns are fallowed to satisfy the crop water needs for those acres that remain in production.
- The IP model assumes that crop yields do not vary by location within the Yakima Basin. This is not consistent with the published data.
- The crop budgets used to define the variable costs of production are not adequately described in the IP-related documents to determine the cost categories that were included (or excluded) from the calculation. As a result, the analysis does not account for the large, upfront financial investments required to establish some crops in the basin and, therefore, underestimates the risk and cost of single- or multi-year drought events.
- By holding crop water requirements fixed, the IP model does not account for the potential economic benefits associated with reduced per acre water requirements that would result from the conservation improvements.
- The IP model is a “short-run” analysis in that it fixes cropping patterns and irrigation/water conveyance efficiencies. A long-run model would be more consistent with the projected long-run water supply reliability changes and a more appropriate platform from which to estimate economic benefits associated with the IP. This would allow for a greater understanding of the limitations of the current water supply conditions on investments in permanent crop, which support higher employment and economic activity in the region.
- The IP model is a single-year model and is therefore, not capable of estimating the direct economic effects to irrigators associated with multiple-year droughts. Multiple-year droughts clearly threaten the financial viability of farms in the region due to the lack of access to adequate water supplies. The IP model assumes “business as usual” following drought conditions and does not capture any of the subsequent year(s) impacts on crop productivity and production costs. These costs, under some conditions, may include crop re-establishment, which is a significant issue for orchards and vineyards.
- The IP model appears to assume that there are no costs associated with fallowing land due to limited water supplies. This does not account for costs associated with weed control and land management, water assessments on fallowed acres, or land preparation and planting costs incurred prior to deciding to fallow land. The IP model also does not account for crop yield losses or re-establishment costs in the year(s) after fallowing. As a result, based upon the available information, it appears that the IP model underestimates the costs associated with fallowing and underestimates the economic benefits associated with improved water supply reliability.

Fisheries benefits identified in the IP rely upon an economic analysis of household willingness to pay for fish which was completed in 1999. This study incorporated information via a survey from households in multiple states. The benefits presented in the IP include a wide range of estimates in fish recruitment. Due to the large estimated benefits ($5.0 to 7.4 billion) and large public expenditure required for the IP ($2.7 to $4.4 billion), the IP analysis could be improved by incorporating a range of benefits. A new economic analysis specific to the Yakima Basin should be prepared to more accurately estimate the fishery benefits in the IP.

The economic analysis in the IP also requires additional fidelity to support the values of associated with water supply benefits to the ecosystem and agriculture. The IP model is a single-year model and is therefore not capable of providing an accurate assessment of the long-term results/effects such: as estimating the direct economic effect to irrigators, cropping patterns, water conveyance efficiencies, and fixed crop water requirements in the Basin.

Implementation of the IP

Timely construction of additional capacity to the proposed surface water storage projects (if completed) will reduce the risk of adverse economic impacts caused by inadequate water supplies. However, until ALL of the projects are completed, all water users apart from tribal fisheries will continue to be exposed to risks and economic loss resulting from water shortages. The proposed IP storage projects each present significant technical, environmental, political, legal, and funding challenges which are yet to be fully addressed. These challenges are likely to result in implementation and legal delays, added costs (e.g., inflation rates), and funding limitations. The cost of executing the proposed IP is an estimated $2.7 to $4.4 billion and will be implemented over 30-40 years. A growing number of groups and organizations within the Basin have already expressed concerns and/or opposition to some of the projects. Increased project costs due to delays or to address concerns of interested parties, may render the project(s) as no longer viable. The longer these projects are delayed, the greater the risk of exposure for significant agriculture and economic losses to the region.

It is hoped that the execution of the IP will provide improved stream flow conditions, improved operational flexibility to manage flows, improved connectivity/viability of native fish populations (i.e., bull trout), increased populations of anadromous fish, and improved habitat in floodplain, riparian zones, and forested watersheds. However, the efficacy of the improved instream flow conditions on anadromous fish populations (due to the proposed IP storage projects) is uncertain, since the necessary field study and research has never been done and are not provided in the IP.

Conclusions

The IP accounts for current and future water needs for both instream and out-of-stream uses, but the methodology for determining those needs requires updating and refinement.

The IP's proposed water storage projects will provide improvements to the Yakima Basin water supply and will benefit fisheries and aquatic habitat conditions. However the proposed water storage projects, under the future use and climate change scenarios in the IP, collectively will not provide enough water volume and predictable water supply for both a sustainable ecosystem and agricultural industry in the Yakima Basin. Linkage between surface and groundwater systems in the Yakima Basin and the recent significant declines evident in groundwater aquifer levels is also a major concern. USGS groundwater studies in recent years provide an estimate of deep aquifer depletion on the order of 30,000 AF annually, and the IP itself documents a reduction of 50,000 AF between low runoff and high runoff years. These studies have shown that declining groundwater levels reduce the amount of inflow available for seasonal water storage, and declining groundwater levels translate into reduced instream flows available for fisheries and aquatic habitat.

Since the quantities of water necessary to support instream flows are determined annually by the USBR, the preeminence of Tribal water rights for both on-reservation use and off-reservation instream flows introduces additional uncertainty into the water supply for the Yakima Basin. Declining fisheries in the Pacific Northwest and the listing of anadromous fish under the Endangered Species Act provide additional impetus for the Tribes to seek legal recourse for habitat-based instream flow needs. Current trends and decisions rendered in related legal cases indicate that Tribes would likely be successful in cases pursuing additional water for fisheries-related purposes in the Basin. The IP disregards these issues to a large extent.

Timely implementation of the major surface water storage projects put forth in the IP (if completed) will reduce the risk of adverse economic impacts to the region during periods of drought. However, until the projects are completed, all water users will continue to be exposed to risk and economic loss from water shortages.

The proposed IP storage projects each present significant technical, political and funding challenges which are yet to be fully addressed. The technical, political, and funding challenges in the proposed $2.7 to $4.4 billion in projects will undoubtedly result in implementation delays, added costs, land acquisition issues and the possible likelihood that one or more of the projects may never be built. Before additional significant public funds and time are expended, we urge further review and consideration of the points raised in this review.

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Bibliography

Anchor QEA. 2011. Yakima River Basin Study Yakima River Basin Water Resources Technical Memorandum. Prepared as part of Volume 2 of the Integrated Plan.

Anchor QEA and HDR Engineering. 2011. Yakima River Basin Study, Instream Flow Needs Technical Memorandum, US Bureau of Reclamation, Contract No. 08CA10677A ID/IQ, Task 3. Report prepared for Bureau of Reclamation and Washington Department of Ecology. April 2011. 24pp + apps. Prepared as part of Volume 2 of the Integrated Plan.

Berg, Laura (Editor). 2001. Feen, J. Hubble, J., McCorquodale, S., Nicolai, S., Puckett, K., and Watson, B . Draft Yakima Subbasin Summary. Prepared for the Northwest Power Planning Council.

Brent, D. 2013. "The Value of Heterogeneous Property Rights: The Costs of Water Volatility." University of Washington Economics.

Casola, Joseph H., Cuo, L., Livneh, B., Lettenmaier, D. P., Stoelinga, M. T., Mote, P. W. and John M. Wallace. 2009. Assessing the Impacts of Global Warming on Snowpack in the Washington Cascades. Journal of Climate, 22, 2758–2772.

Dick, Timothy A. 1993. Yakima Project. A history prepared by the Bureau of Reclamation.

Elsner, Marketa, Cue, L., Voisin, N., Deems, J. S., Hamlet, A. F., Vano, J., Mickelson, K. E. B., Lee, S., and D. Lettenmaier 2010. Implications of 21st century climate change for the hydrology of Washington State. Climatic Change 102: 225-260.

HDR Inc., Anchor QEA. 2011. Yakima River Basin Study Water Needs for Out-of-Stream Uses Technical Memorandum US Bureau of Reclamation Contract No. 08CA10677A ID/IQ, Task 2.1

Hubble, Joel. 2010. Discussion of Biologically Based Flows for the Purpose of Determination of Average Water Year Instream Flow Demand for the Yakima River Basin Study (Hubble, undated but provided to subcommittee in 2010).

Instream Flow and Fish Production Objectives Workgroup (IFFPOW). 1987. Final Report to Yakima River Basin Water Enhancement Policy Group. Completion Report for the Yakima River Basin Water Enhancement Project. US Bureau of Reclamation, December 1987.

Instream Flow Technical Advisory Group (IFTAG). 1984. Initial Flow Recommendations, Yakima River Basin, Washington. Final Memorandum, Yakima, Washington, dated December 21, 1984. 6pp + app.

Layton, D., G. Brown, and M. Plummer. 1999. "Valuing Multiple Programs to Improve Fish Populations." Washington State Department of Ecology.

Metcalf, S. 1997. Water Rights Law for Municipal Lawyers: The Basics, Ruthlessly Simplified. Prepared by Sharon Metcalf, Assistant City Attorney, Seattle, Legal Notes: Proceedings of the Washington State Association of Municipal Attorneys' Annual Fall Conference, October 8-10, 1997. MRSC Information Bulletin No. 499, October 1997.

Mongillo, P., and L. Faulconer. 1980. Yakima fisheries enhancement study final report. Washington Department of Game, Applied Wildlife Ecology. Water and Power Resources Services contract 7-07-S0038. 171pp.

Morisset, Mason D. 2001. Tribal Rights and Their Effect on our Concept of Property Rights in the Northwest. Prepared by Mason D. Morisset, November 15 & 16, 2001 Morisset, Schlosser, Homer, Jozwiak, & McGaw, Seattle Washington.

Mote, P.W., E.A. Parson, A.F. Hamlet, K.N. Ideker, W.S. Keeton, D.P. Lettenmaier, N.J. Mantua, E.L. Miles, D.W. Peterson, D.L. Peterson, R. Slaughter, and A.K. Snover.2003. Preparing for Climatic Change: The Water, Salmon, and Forests of the Pacific Northwest. Climatic Change 61:45-88.

Northwest Economic Associates. 2004. "The Economic Impacts of Improved Water Supply Reliability in the Yakima River Basin." Prepared for Benton County.

Parametrix, Inc., and Hardin-Davis. 1984. Initial flow recommendations Yakima River Basin. Document No. 84-1031-0019F. Report to US Department of Interior, Bureau of Reclamation, Boise, Idaho.

Richardson, L. and J. Loomis. 2009. The Total Economic Value of Threatened, Endangered, and Rare Species: An Updated Meta-Analysis. Ecological Economics, pp. 1535-1548.

RTI International. 2012. Final Report, Klamath River Restoration Nonuse Value Survey. Report to NOAA Fisheries.

Scott M.J., Vail, L.W., Stockle, C.O., and A. Kemanian. 2004A. "Climate Change and Adaptation in Irrigated Agriculture - A Case Study of the Yakima River." Presented at UCOWR conference on 20 July 2004.

Scott M.J., Vail, L.W., Jaksch, J.A., Stockle, C.O., and A. Kemanian. 2004B. "Water Exchanges: Tools to Beat El Nino Climate Variability in Irrigated Agriculture." Journal of American Water Resources Association. 40(1):15-31.

Simmons, Dell. 1981. Affidavit No 77-2-01484-5, Yakima County Superior Court.

Simmons, C.D. 1990. Washington Superior Court affidavit filed in the Aquavella water rights case, No. 77-2-01484, dated July 24, 1990. 13pp.

Stanford, J.A., J.V. Ward, W.J. Liss, C.A. Frissell, R.N. Williams, J.A. Lichatowich, and C.C. Coutant. 1996. A general protocol for restoration of regulated rivers. Regulated Rivers: Research and Management, Vol. 12:391-413 (1996).

System Operations Advisory Committee (SOAC). 1992. Instream flow recommendations made to the Bureau of Reclamation, dated April 10, 1992. (Response letter of May 8, 1992, not the original)

System Operations Advisory Committee (SOAC). 1999. Report on Biologically Based Flows for the Yakima River Basin. Report to the Secretary of the Interior, Yakima, Washington, May 4, 1999. 43pp + intro & apps.

Thomas R. Payne & Associates. 1995. Yakima River IFIM Analysis. Report Prepared for Yakima Basin Defense Coalition. Yakima, Washington. 93pp + apps.

US Army Corps of Engineers (USACE). 2013. Historic numbers of Chinook salmon passing Bonneville Dam News release, September 2013. ttp://www.nwp.usace.army.mil/Media/NewsReleases/tabid/1888/Article/18195/historic-numbers-of-chinook-salmon-passing-bonneville-dam.aspx

United States Bureau of Reclamation (USBR). 2012A. Yakima River Basin Integrated Water Resource Management Plan, Final Programmatic Environmental Impact Statement BENTON, KITTITAS, KLICKITAT AND YAKIMA COUNTIES US Department of the Interior State of Washington Bureau of Reclamation Department of Ecology Pacific Northwest Region Central Regional Office Columbia-Cascades Area Office Yakima, Washington Yakima, Washington Ecology Publication Number: 12-12-002

US Bureau of Reclamation (USBR), October 2012B. "Yakima River Basin Integrated Water Resource Management Plan, Framework for Implementation Report."

US Bureau of Reclamation, October 2012C. "Yakima River Basin Integrated Water Resource Management Plan, Four Accounts Analysis of the Integrated Plan."

US Bureau of Reclamation. 2011A. Yakima River Basin Study Volume 1 Proposed Integrated Water Resource Management Plan. Prepared by HDR Engineering, Anchor QEA, ECONorthwest, ESA Adolfson, Golder Associates.

U.S. Bureau of Reclamation, June 2011B. "Yakima River Basin Study, Economic Effects of Yakima Basin Integrated Water Resources Management Plan."

US Bureau of Reclamation. 2008A. Final Planning Report/Environmental Impact Statement, Volume 1, Yakima River Basin Water Storage Feasibility Study, Yakima Project, Washington. U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Region, Upper Columbia Area Office, Yakima, Washington. December 2008

US Bureau of Reclamation. 2008B. Aquatic Ecosystem Evaluation for the Yakima River Basin, A Component of Yakima River Basin Water Storage Feasibility Study, Washington. Technical Series No. TS–YSS–22. US Department of the Interior, Bureau of Reclamation, Pacific Northwest Region, Upper Columbia Area Office, Yakima, Washington. January 2008. 202pp

US Bureau of Reclamation, June 2002. "Interim Comprehensive Basin Operating Plan for the Yakima Project Washington." November, 2002.

Reclamation (United States Bureau of Reclamation) and Ecology (Washington State Department of Ecology) 2009. Preliminary Integrated Water Resource Management Plan for the Yakima River Basin Yakima Project Washington.

US Fish and Wildlife Service. 2011. Yakima River Basin Integrated Water Resource Management Plan Draft Fish and Wildlife Coordination Act Report. Prepared for the Pacific Northwest Region Bureau of Reclamation.

US Fish and Wildlife Service (USFWS). 1982. Yakima River Water Basin Enhancement Project, Planning Aid Report on Wildlife and Resident Fish Resources in the Yakima Basin. February 1982. 61pp + app.

US Department of Interior. 1983. "Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies."

Vano, J. A., Scott, M., Voisin, N., Stöckle, C. O., Hamlet, A. F., Mickelson, K. E. B. , Elsner, M. M., and D. P. Lettenmaier. 2009. "Climate Change Impacts on Water Management and Irrigated Agriculture in the Yakima River Basin, Washington, USA."

Washington State Department of Ecology (Ecology). 2010. Columbia River Basin Long-Term Water Supply and Demand Forecast.

Washington State Office of Attorney General. 2000. "An Introduction to Washington Water Law".

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[1] Anchor 2011, page 1.
[2] Berg 2001, page 7.
[3] Berg 2001, page 7.
[4] Berg 2001, page 7.
[5] Anchor QEA and HDR 2011, page 1.
[6] Anchor QEA 2011, page 8.
[7] Anchor QEA 2011, page 8.
[8] Dick 1993, page 2.
[9] HDR and Anchor QEA 2011, page 9.
[10] HDR and Anchor QEA 2011, page 9.
[11] HDR and Anchor QEA 2011, page 9.
[12] HDR and Anchor QEA 2011, page 6.
[13] Anchor QEA 2011, page 7.
[14] Anadromous and resident fish populations are seriously depleted from historic levels and some species have been eliminated from the basin or listed as threatened under the Endangered Species Act (ESA) due to the following major factors: Dams, dewatering, and other obstructions block fish passage to upstream tributaries and spawning grounds; (USBR 2012A).
[15] Anchor QEA 2011, page 7. Early in YRBWEP implementation, fish passage problems were identified as needing immediate attention.
[16] Summary of factors in fish decline presented in (USBR 2012A), page 1-10.
[17] Anchor QEA 2011, page 16.
[18] USBR 2012, page i. Demand for irrigation water by existing users significantly exceeds supply in dry and drought years, leading to severe prorationing for proratable, or junior, water rights holders.
[19] USBR 2012A, page 1-35.
[20] Three signatories of the SOAC (1999) report participated as members of the Instream Flow Needs Subcommittee.

[21] Data provided by the irrigation districts and data provided by Washington State Department of Agriculture. See HDR and Anchor QEA 2011, pp 12-19 for details on inconsistencies.
[22] Water Needs for Out-of-Stream Uses Technical Memorandum, page 19.
[23] "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. Water Needs for Out-of-Stream Uses Technical Memorandum, page 19.
[24] 2005 shortfall total (Table 2) minus total new supply (Table 1) 511,944 AF– 533,400 AF = 21,456 AF.
[25] Total need under the climate chance scenario (Table 3) minus total need under current conditions (Table 2) 1,782,865 - 1,690,434 = 92,431.
[26] Years in which substantial prorating of deliveries to junior water users was required.
[27] Washington State Office of Attorney General 2000, page VIII: l.
[28] A comprehensive summary of water law is Washington state is provided in "An Introduction to Washington Water Law", prepared by the Washington State Office of Attorney General in 2000.
[29] Washington State Office of Attorney General 2000, pages 2-5.
[30] Belsky 1996, page 57.
[31] Belsky 1996, page 57-60.
[32] USBR 2012A, pages 1-21 and 1-22.
[33] Washington State Office of Attorney General 2000, page IV:27-28, and V:30.
[34] Washington State Office of Attorney General 2000, page VIII:16.
[35] The addition of surface-water storage and conveyance facilities could affect the groundwater resource by providing the opportunity for water to seep into the ground. This additional seepage could have either beneficial or detrimental effects, depending on the quantity and location. Anchor QEA 2011, page 24.
[36] USBR 2012, pages 3-19.
[37] This overstates the actual proratable supplies to KID. KID is served from below Parker and has an agreement that allows diversions from the Yakima River without respect to proration level provided instream flow requirements are met.
[38] (70%-37%) X 1,310,075 AF = 432,325 AF.
[39] Expected annual values are reported to be $42.2 million. Assuming a drought probability of 30%, the drought year benefits are $140.2 million ($42.2 million/30%).
[40] US Bureau of Reclamation. June 2011. "Economic Effects of Yakima Basin Integrated Water Resource Management Plan." Technical Memorandum.
[41] US Bureau of Reclamation. October 2012. "Yakima River Basin Integrated Water Resource Management Plan, Four Accounts Analysis of the Integrated Plan.
[42] US Department of Interior. 1983. "Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies."

[43] Scott, M.J. et al. 2004. "Water Exchanges: Tools to Beat El Nino Climate Variability in Irrigated Agriculture." Journal of American Water Resources Association. 40(1):15-31.
[44] However, water trading is unlikely to reach these levels during drought years following implementation of the IP as the supply to proratables will always be 70% or more of the entitlement volume.
[45] Deficit irrigation is the application of less water than is needed to fully satisfy crop water demands.
[46] The IP reports expected annual benefits of $42.2 million. Assuming a 30% chance of severe drought in any given year, the single-year drought benefits are $140.7 million ($42.2 million/30%).
[47] This analysis does not address the difference between total entitlements during a full water year and the full crop water requirements considered in the IP analysis.
[48] Bureau of Reclamation, February 2009. "Evaluating Economic and Financial Feasibility of Municipal and Industrial Water Projects.
[49] Willingness to pay is the dollar amount that an individual is willing to give up or pay to acquire a good or service.
[50] US Department of Interior. 1983. "Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies."
[51] This analysis does not address the difference between total entitlements during a full water year and the full crop water requirements considered in the IP analysis.
[52] Layton, D., G. Brown, and M. Plummer. 1999. "Valuing Multiple Programs to Improve Fish Populations." Washington State Department of Ecology.
[53] Richardson, L. and J. Loomis. 2009. The Total Economic Value of Threatened, Endangered, and Rare Species: An Updated Meta-Analysis. Ecological Economics, pp. 1535-1548.
[54] RTI International. 2012. Final Report, Klamath River Restoration Nonuse Value Survey. Report to NOAA Fisheries.