RECLAMATION

Managing Water in the West

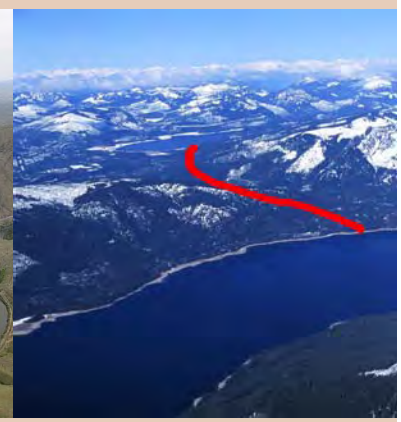
Yakima River Basin Storage Alternatives Appraisal Assessment

A component of
Yakima River Basin Water Storage Feasibility Study, Washington

Technical Series No. TS-YSS-8

Bumping Lake

Wymer Damsite



Keechelus-to-Kachess Pipeline

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region

May 2006

The mission of the U.S. Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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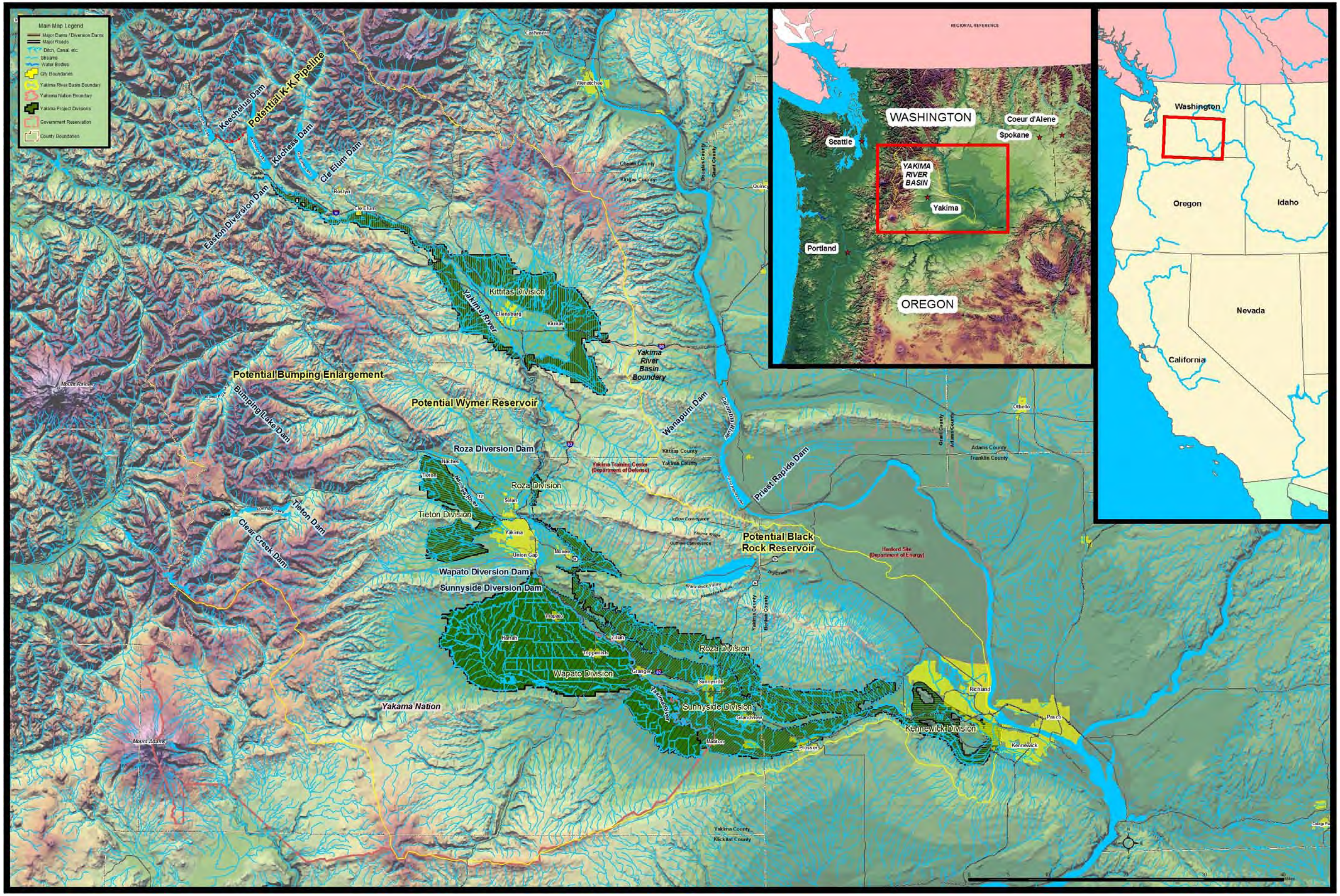

Frontispiece

CONTENTS

Tables

Figures

Executive Summary

Yakima River Basin Storage Alternatives

Appraisal Assessment

Background

Congress, in the Act of February 20, 2003, directed the Secretary of the Interior, acting through the Bureau of Reclamation, to conduct a feasibility study of options for additional water storage for the Yakima River basin. Reclamation initiated the Yakima River Basin Water Storage Feasibility Study (Storage Study) in May 2003. Funding has been provided to Reclamation for Storage Study activities under a Memorandum of Agreement for Cost Sharing entered into with the Washington State Department of Ecology (Ecology) on November 14, 2003, and by congressional appropriations.

Due to the congressional authorization, Reclamation initially placed priority on study activities related to the Black Rock Alternative. Reclamation released the *Appraisal Assessment of the Black Rock Alternative* (*Black Rock Appraisal Assessment*) in February 2005. In that *Black Rock Appraisal Assessment*, Reclamation concluded that, based on current information, a potential Black Rock Alternative appears to be technically viable and could meet the goals of the Storage Study. Therefore, Reclamation decided to carry the Black Rock Alternative forward into the Plan Formulation Phase.

This *Yakima River Basin Storage Alternatives Appraisal Assessment* (*Yakima Alternatives Appraisal Assessment*) analyzes the technical viability and capability of three in-basin storage alternatives—Bumping Lake enlargement, Wymer dam and reservoir, and Keechelus-to-Kachess pipeline—to meet the storage study goals. Reclamation used the analysis in this document to decide which, if any, of the three Yakima River basin storage alternative(s) to bring forward into the Plan Formulation Phase of the Storage Study along with the Black Rock Alternative. The objective of plan formulation is to define the most viable storage alternative for the feasibility report/environmental impact statement (FR/EIS). Reclamation and the Secretary of the Interior will use the FR/EIS to decide whether to seek congressional authorization for construction of a viable Storage Study alternative. Reclamation expects to complete the FR/EIS by the end of 2008.

Purpose and Need

The purpose of the Yakima River Basin Water Storage Feasibility Study is to evaluate alternatives that would create additional water storage for the Yakima River basin and assess their potential to supply the water needed for ecosystem aquatic habitat, basinwide agriculture, and municipal demands.

The need for the study is based on the existing finite water supply and limited storage capability of the Yakima River basin in low water years. This finite supply and limited storage capacity does not meet the water supply demands in all years and results in significant adverse impact to the Yakima River basin's economy, which is agriculture-based, and to the basin's aquatic habitat, specifically, anadromous fisheries. Reclamation seeks to identify means of increasing water supplies available for purposes of improving anadromous fish habitat and meeting irrigation and municipal needs.

Goals

This *Yakima Alternatives Appraisal Assessment* is a component of the Storage Study. Reclamation prepared this report to address the technical viability of the three Yakima River basin storage alternatives and the extent the additional stored water supply provided by these alternatives would assist in meeting the Storage Study goals.

The Storage Study goals are to:

- Improve anadromous fish habitat.
- Improve the water supply for proratable irrigation water rights.
- Meet future municipal water supply.

Yakima Basin Storage Alternatives

Reclamation is considering three Yakima River basin storage alternatives: a new Bumping Lake Dam and enlarged reservoir, Wymer dam and reservoir, and Keechelus-to-Kachess pipeline.

To assess technical viability of these alternatives, Reclamation used prior Yakima River basin water resource reports and supporting technical documents (relating primarily to engineering, geologic, and seismotectonic information) to set the physical parameters of the alternatives.

Features

A new Bumping Lake Dam and enlarged reservoir would be constructed on the Bumping River, approximately 4,500 feet downstream of the present dam. The enlarged reservoir would include up to 458,000 acre-feet of storage capacity (about 424,300 acre-feet additional storage and 33,700 acre-feet replacement storage for the existing Bumping Lake).

A new Wymer dam, dike, and reservoir would be constructed on Lmuma Creek, about 1½ mile upstream of its confluence with the Yakima River. The 174,000-acre-foot-capacity Wymer reservoir would be filled by a new 400 cfs-pumping plant operating when Yakima River flows are available and not required for downstream needs (primarily in the winter and spring).

Table ES-1 shows the physical features of the potential Bumping Lake enlargement and Wymer dam, dike, and reservoir, and pumping plant.

Table ES-1. Bumping Lake Enlargement and Wymer Dam, Dike, Pumping Plant, and Reservoir Characteristics

Item	Data		
	Bumping Lake Enlargement	Wymer	
		Dam	Dike
Dam			
Type	Zoned rockfill	Concrete-faced rockfill	
Height	230 feet	415 feet	130 feet
Crest elevation	3580 feet	1745 feet	1745 feet
Crest length	3300 feet	2,855 feet	2,310 feet
Crest width	30 feet	30 feet	30 feet
Reservoir			
Active capacity	458,000 acre-feet*	174,000 acre-feet	
Pumping Plant			
Capacity		400 cfs	
Total head range		345 to 475 feet	

*consists of 424,300 acre-feet new storage and 33,700 acre-feet replacement storage for existing Bumping Lake.

The concept of a Keechelus-to-Kachess pipeline alternative is to transport Keechelus Lake watershed runoff which, at times, exceeds the capacity of Keechelus Lake, for storage in Kachess Lake. The conceptual plan is to modify the outlet works of Keechelus Dam to permit releases to a potential gravity-flow pipeline extending approximately 5 miles to Kachess Lake, as well as maintain current releases to the Yakima River. This potential pipeline, 5 feet in diameter, would start at the outlet works and cross under Interstate Highway 90 to Kachess

Lake. The maximum carrying capacity of the pipeline would be 210 cfs when Keechelus Lake is at full pool.

Project Costs

Reclamation developed appraisal-level field construction costs for each of the three storage alternatives by indexing the mid-1980s Yakima River Basin Water Enhancement Project storage investigations costs to July 2004 prices.[1] The mid-1980s appraisal-level field construction costs were based on available, but limited, field data and preliminary designs and drawings, and professional assumptions.

Estimated appraisal-level field construction and total project costs, indexed to July 2004 prices, are shown in Table ES-2. The total estimated field costs are:

- Bumping Lake enlargement - $210 million.
- Wymer dam and reservoir - $280 million.
- Keechelus-to-Kachess pipeline - $18.5 million.

The total estimated field costs for all three Yakima River basin storage alternatives combined is approximately $508.5 million.

The costs for preparing final engineering designs and specifications, land acquisition, regulatory compliance and permitting activities, environmental mitigation and monitoring, and construction contract administration and management are estimated to be from 20 to 35 percent of the field construction costs. Based on the indexed appraisal-level field construction cost estimates and industrywide, accepted cost estimating methodology, standards, and practices, the total project cost estimates for all three alternatives combined range from $612 million to $685 million, at July 2004 price levels.

The ranges of total project costs for individual alternatives are as follows (at July 2004 price levels):

- Bumping Lake enlargement - $250 million to $280 million.
- Wymer dam and reservoir - $340 million to $380 million.
- Keechelus-to-Kachess pipeline - $22 million to $25 million.

[1] The Black Rock Alternative field construction cost estimates are based on June 2004 price levels. However, Bureau of Reclamation Cost Trends are reported on a quarterly basis (January, April, July, and October), so July 2004 was used, as a close approximation of June 2004 prices.

These costs are for comparison purposes only. It is highly probable that these cost estimates will increase with more detailed analysis and the application of 2006 or later unit prices for materials, labor, and equipment.

Table ES-2. Appraisal-Level Project Costs for the Yakima Basin Storage Alternatives (July 2004)*

	Bumping Lake Enlargement	Wymer Dam, Reservoir, and Pumping Plant	Keechelus-to-Kachess Pipeline
Construction Pay Items (indexed to June 2004)	$139,881,060	$187,524,675	$12,146,845
Total mobilization costs (5%)	$7,000,000	$9,400,000	$610,000
Total unlisted Items (15%)	$23,188,940	$33,075,325	$1,913,527
Construction Contract Cost	$170,000,000	$230,000,000	$14,500,000
Total Contingencies (25%)	$40,000,000	$50,000,000	$4,000,000
Total Field Construction Cost	$210,000,000	$280,000,000	$18,500,000
Non-Contract Cost (35%)	$70,000,000	$100,000,000	$6,500,000
Total Project Cost (rounded)	$280,000,000	$380,000,000	$25,000,000

*The Black Rock Alternative field construction cost estimates are based on June 2004 price levels. However, Bureau of Reclamation Cost Trends are reported on a quarterly basis (January, April, July, and October), so July 2004 was used, as a close approximation of June 2004 prices.

Operations

Reclamation operates the Yakima Project to meet the purposes of irrigation water supply, instream flows for fish, flood control, hydroelectric generation, and recreation. Reclamation combined the three alternatives in one integrated operation scenario for this *Yakima Alternatives Appraisal Assessment*.

The Yakima RiverWare (Yak-RW) model, a daily time-step hydrologic model simulating reservoir and river operations, was used in conducting operation studies for this *Yakima Alternatives Appraisal Assessment*. The 23-year period-of-record (1981-2003) used in the model includes 17 nonproration water years (wet and average water supply conditions) and 6 proration years (dry water supply conditions).

The *Yakima Alternatives Appraisal Assessment* contains three operation scenarios:

- Current Operation Scenario – Simulates present Yakima Project operations over the 23-year period of hydrologic record.

- Integrated Operation Scenario – Combines all three Yakima River basin storage alternatives together, plus the existing Yakima Project facilities. The enlarged Bumping Lake was operated to improve the dry-year irrigation water supply available for proratable entitlements. In the RiverWare model, Wymer reservoir was operated to meet Public Law 103-434, *Title XII, Yakima River Basin Water Enhancement Project* (Title XII) target flows at the Parker gauge whenever stored water releases are necessary in dry years, in lieu of releasing water from upstream reservoirs. This operation permits retention of stored water in the Yakima Project reservoirs to improve the dry-year water supply available for all Yakima River basin proratable water rights. The Keechelus-to-Kachess pipeline was used to move water in an attempt to increase reservoir storage in Kachess.

  The integrated operation scenario includes three operation studies in which different thresholds (100 percent, 70 percent, and 50 percent) are used in prorated water years for allocating the additional water supply made available by the three storage alternatives. In each operation study, the proratable water supply which would have been provided by the Yakima Project without the three storage alternatives is determined. Then, the additional water supply resulting from the three storage alternatives is allocated pursuant to the thresholds. For example, if a prorationed water supply of 80 percent is determined, the results for the three thresholds are to provide up to 100 percent, and 80 percent and 80 percent, respectively. If a prorationed water supply of 40 percent is determined, the results are to provide up to 100 percent, 70 percent, and 50 percent respectively.

  Table ES-3 illustrates these results.

Table ES-3. Example of Proratable Water Supply Provided with the Three Storage Alternatives

Computed Proration Level Without Three Storage Alternatives	Integrated 100%	Integrated 70%	Integrated 50%
80%	up to 100% (if available)	80%	80%
40%	up to 100% (if available)	70% (if available)	50% (if available)

Application of the 70- and 50-percent criteria results in carrying over some of the available stored water rather than fully allocating the water supply in 1 year, as is done using the integrated 100-percent operation. The analyses and conclusions in the *Yakima Alternatives Appraisal Assessment* are based on the integrated 70-percent operation scenario.

- Natural (unregulated) Scenario – Represents an unregulated Yakima Project streamflow regime, which shows flows as if there were no reservoir impoundments, diversions, or associated irrigation return flows.

Reclamation developed hydrographs for the current and integrated scenarios, and the flow regimes were compared to show the extent to which they would resemble the shape of the natural (unregulated) hydrograph.

Findings

Technical Viability

Based on information available at this time, the three Yakima River basin storage alternatives (Bumping Lake enlargement, Wymer dam and reservoir, and Keechelus-to-Kachess pipeline) appear to be technically viable.

These findings do not consider economic, financial, environmental, cultural, and social aspects of the three storage alternatives.

Storage Study Goals

The dry-year irrigation water supply goal can be met by these three alternatives. The municipal water supply goal is assumed to be met. There is potential to meet the fish habitat goal on the Yakima River by constructing Wymer dam and reservoir. However, the fish habitat goal for the Naches River cannot be met by constructing Bumping Lake enlargement.

Fish Habitat

Reclamation's RiverWare modeling of the three alternatives shows that enlarging Bumping Lake is detrimental to the shape of the Bumping and Naches River hydrographs by decreasing the quantity and shifting the timing of the spring flows. This is because the current hydrograph resembles the natural (unregulated) hydrograph. Bumping Lake enlargement also adds to the total water supply available (TWSA), which, in some years, may result in increasing the Title XII target flows at Parker. In addition, an enlarged Bumping Lake could result in further adverse environmental impacts by inundating adjacent creeks and streams.

The Wymer dam and reservoir alternative would require pumping water when there are excess flows in the Yakima River. This means that diversion to Wymer reservoir could diminish the spring freshet during the average and wet years. However, during dry years, it may be possible to operate the reservoir in a manner that benefits fish. These benefits could include pulse or flushing flows during the spring. During meetings with stakeholder groups on the three alternatives, they recommended that Reclamation explore such potential benefits further. The Wymer alternative also adds to the TWSA, which, in some years, may result in increasing the Title XII target flows at Parker.

The Keechelus-to-Kachess pipeline improves Kachess Lake storage contents in only 1 year of the 23-year period of record. This additional stored supply amounts to only about 400 acre-feet (1985). The capability to bypass up to a maximum of 210 cfs of summer releases from Keechelus Lake could provide a benefit to the fishery in the Yakima River reach from Keechelus Dam to Easton Dam.

RiverWare modeling also indicated all the integrated operation scenarios do not appear to move the river flow regime toward a natural (unregulated) hydrograph because of the need to transport a high volume of water from the upper Yakima River reservoirs (primarily Cle Elum Lake) to irrigation users in the middle Yakima River basin area. Moving this high volume of water during the summer and fall seasons results in high flows, which is contrary to the natural (unregulated) hydrograph. Therefore, the integrated 70-percent operation scenario does not eliminate or significantly diminish the current flip-flop reservoir operation.

Dry-Year Irrigation Water Supply

All three alternatives were modeled together to provide enough water storage to meet the 70-percent irrigation water supply goal. The 23-year average TWSA is 3,220,000 acre-feet with the integrated 70-percent operation, as compared to the current operation TWSA of 2,850,000 acre-feet. With additional basin storage alternatives and an operating plan that uses the additional storage capacity primarily as carryover, the 23-year average TWSA could be increased by 370,000 acre-feet.

One-year droughts which follow 2 or more wet years could have a 30-percent improvement. This is demonstrated by drought year 2001, for which the modeled current operation provided a 41 percent proratable water supply, but the integrated 70-percent operation provided a 70-percent proratable supply.

The operations modeling shows the irrigation water supply conditions are improved in the prolonged 3-year dry period of 1992-1994. The three in-basin storage alternatives increased the proratable water supply in 1992 and 1993 to not less than 70 percent. The 1994 proratable water supply was increased to 66 percent; 4 percentage points below the 70-percent threshold. It is estimated the 4-percent difference equals about 50,000 acre-feet.

Municipal Water Supply

In the *Black Rock Appraisal Assessment,* Reclamation had assumed the future surface water need of 10,000 acre-feet for the cities of Cle Elum and Yakima (the only current municipal surface water users) could be met with any new storage facilities. After reviewing the water supply estimates in the January 2003 *Watershed Management Plan* (Yakima River Basin Watershed Planning Unit and Tri-County Water Resources Agency, 2003), Reclamation concluded if the results of ongoing groundwater investigations show there is a connectivity of surface and groundwater, any increase in groundwater use by municipalities and domestic users may require mitigation by surface water supplies. If this were to occur, the future municipal and domestic water needs could be as much as 82,000 acre-feet by year 2050.

As information regarding the surface and groundwater connectivity becomes available, Reclamation will work with local and state entities to develop a strategy, including hydrologic modeling, to accommodate the volume and priority of municipal and domestic water supply demands.

Conclusions

Reclamation will not perform further analysis on the Bumping Lake enlargement and Keechelus-to-Kachess pipeline in the Plan Formulation Phase. However, Reclamation will retain the Wymer dam and reservoir alternative for further investigation in the Plan Formulation Phase.

Reclamation, through its hydrologic analysis, has determined that storing more water in an enlarged Bumping Lake would cause the spring flows in the Bumping River to decrease in volume and shift in timing. This shift in flow quantity and timing carries through the Bumping River into the lower Naches River. Since the Bumping River hydrograph currently resembles the natural (unregulated) hydrograph, this change in the hydrograph is unacceptable. The extra storage in Bumping Lake enlargement does help meet the irrigation water supply goal in all years except the last year of a 3-year drought. Reclamation is assuming that the municipal water supply goal will be met with this alternative. Even though the irrigation water supply goal could be partially met with this alternative, the negative impact to the hydrograph and the potential environmental impacts identified in previous studies indicate that this alternative should not be carried forward.

Reclamation, through its hydrologic analysis, has determined that the Keechelus-to-Kachess pipeline provides neither irrigation nor fish habitat benefits, as it only provides extra storage in 1 year out of the 23-year period of record and does not move the flow regime toward the natural (unregulated) hydrograph. Reclamation is assuming that this alternative will not help meet the municipal water supply goal. Therefore, Reclamation will not forward the Keechelus-to-Kachess pipeline alternative into the Plan Formulation Phase.

Reclamation's current analysis does not show if the Wymer dam alternative impacts the hydrograph, either in a positive or negative manner. Reclamation is assuming the municipal water supply goal may be met with this alternative. Although Wymer does not appear to meet the Storage Study goals by itself, it does meet the purpose and need, and it is technically viable. Because of stakeholder interest and its potential for providing fish habitat benefits, Wymer will be analyzed further in the Plan Formulation Phase.

Further investigations of Wymer dam and reservoir could include various operation scenarios and the potential for a Columbia River water supply. Field data at the Wymer damsite appears sufficient for plan formulation.

Chapter 1.0 Introduction

This chapter identifies the authorization for the Storage Study, its purpose and need, its goals, and the study process.

1.1 STORAGE STUDY

The Yakima River Basin Water Storage Feasibility Study (Storage Study) is an ongoing evaluation of how to provide additional stored water for the benefit of endangered and threatened fish, irrigation, and municipal water supply within the Yakima River basin. Potential alternatives (as shown on frontispiece) include constructing new facilities to impound Yakima River basin water and importing water from the Columbia River for exchange with irrigation entities willing to forego all or part of their current Yakima River diversions.

1.2 AUTHORIZATION

In February 2003, Congress authorized the Secretary of the Interior, acting through the Bureau of Reclamation, to conduct a feasibility study of options for additional water storage for the Yakima River basin. Section 214 of the Act of February 20, 2003, (Public Law 108-7) contains this authorization which includes the provision ". . . with emphasis on the feasibility of storage of Columbia River water in the potential Black Rock reservoir and the benefit of additional storage to endangered and threatened fish, irrigated agriculture, and municipal water supply."

Reclamation initiated the Storage Study in May 2003. As guided by the authorization, the Storage Study will identify and examine the viability and acceptability of various potential storage alternatives.

1.3 PURPOSE AND NEED

The purpose of the Yakima River Basin Water Storage Feasibility Study is to evaluate alternatives that would create additional water storage for the Yakima River basin and assess their potential to supply the water needed for ecosystem aquatic habitat, basinwide agriculture, and municipal demands.

The need for the study is based on the existing finite water supply and limited storage capability of the Yakima River basin in low water years. This finite supply and limited storage capacity do not meet the water supply demands in all years and result in significant adverse impact to the Yakima River basin's economy, which is agriculture-based, and to the basin's aquatic habitat, specifically, anadromous fisheries. The study seeks to identify means of increasing water supplies available for purposes of improving anadromous fish habitat and meeting irrigation and municipal water supply needs.

1.4 Storage Study Goals

Reclamation has developed the following storage study goals, based on the congressional authorization and the purpose and need for the Storage Study.

- Improve anadromous fish habitat by restoring the flow regimes of the Yakima and Naches Rivers to more closely resemble the natural (unregulated) hydrograph.

- Improve the water supply for proratable irrigation water rights in dry years by providing not less than a 70-percent irrigation water supply during dry years at diversions subject to proration.

- Meet future municipal water supply needs by maintaining a full municipal water supply for existing users and providing additional surface water supply for population growth to the year 2050.

1.5 State of Washington Participation

The 2003 Washington Legislature provided cost-sharing for the Storage Study through the Washington Department of Ecology (Ecology) with the provision that the funds " . . . are provided solely for expenditure under a contract between the Department of Ecology and the United States Bureau of Reclamation for the development of plans, engineering, and financing reports and other preconstruction activities associated with the development of water storage projects in the Yakima River basin, consistent with the Yakima River Basin Water Enhancement Project, Public Law 103-434. The initial water storage feasibility study shall be for the Black Rock reservoir project."

Reclamation and Ecology entered into a Memorandum of Agreement for Cost Sharing on November 14, 2003. This agreement complies with Reclamation's framework for general principles and administration of cost sharing for the Storage Study.

1.6 PROCESS

Reclamation's Upper Columbia Area Office in Yakima, Washington, is managing and directing the Storage Study. The Storage Study is a four-phase,[2] multiyear process, culminating with the Storage Study Feasibility Report/Environmental Impact Statement. The Feasibility Report/Environmental Impact Statement will be the document used by Reclamation and the Secretary of the Interior to decide whether to seek congressional authorization for construction of a viable Storage Study alternative.

Reclamation (2003) prepared and published a *Plan of Study* (Phase 1), which is available on the Storage Study website at http://www.usbr.gov/pn/programs/storage_study/index.html. The *Plan of Study* outlines the activities and schedule to complete the Storage Study.

1.7 BLACK ROCK ALTERNATIVE

Reclamation placed priority on study activities related to the Black Rock Alternative due to the congressional authorization. The *Appraisal Assessment of the Black Rock Alternative* (*Black Rock Appraisal Assessment*) (Reclamation, 2004) provided further information on a water exchange, assisted in understanding the major features of the alternative and its potential effects, and helped guide future Storage Study activities.

The primary objectives of the *Black Rock Appraisal Assessment* were to determine whether a Columbia River-Yakima River water exchange using the Black Rock Alternative is technically viable, whether it would meet the goals of the Storage Study, and whether it should continue to be included as an element of the Storage Study. However, it is important to note that the *Black Rock Appraisal Assessment* did not analyze the alternative for economic, environmental, social, and cultural impacts. It also identified two issues needing further clarification – groundwater movement and seismic movement potential at the damsite.

Reclamation concluded that, based on current information, a potential Black Rock Alternative appears to be technically viable. Reclamation also concluded that a potential water exchange could meet the goals of the Storage Study. The Black Rock Alternative is being carried forward into the Plan Formulation Phase.

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[2] The September 2003 *Plan of Study* structured the Storage Study into four phases: Organize and Develop Plan of Study (Phase 1), Pre-Plan Formulation (Phase 2), Plan Formulation (Phase 3), and Feasibility Analysis and Environmental Impact Statement Analysis (Phase 4).

Chapter 2.0 Yakima River Basin Storage Alternatives Appraisal Assessment

This chapter describes the purpose and scope of the *Yakima River Basin Storage Alternatives Appraisal Assessment* (*Yakima Alternatives Appraisal Assessment*).

2.1 PURPOSE

The purpose of this *Yakima Alternatives Appraisal Assessment* is to determine the extent a Bumping Lake enlargement, a Wymer dam and reservoir, and a Keechelus-to-Kachess pipeline would satisfy the goals of the Storage Study. The alternatives, collectively or individually, which are deemed technically viable, meet the purpose and need of the Storage Study, and have the potential to meet the Storage Study goals, will be considered in the Plan Formulation Phase of the Storage Study.

2.2 SCOPE

The scope of this *Yakima Alternatives Appraisal Assessment* is to review, summarize, and document the pertinent findings of reported prior investigations of the Yakima River basin alternatives–Bumping Lake enlargement, Wymer dam and reservoir, and Keechelus-to-Kachess pipeline. This *Yakima Alternatives Appraisal Assessment* uses the most up-to-date information regarding fish and wildlife resource issues and Yakima Project system operations. Future municipal water supply needs are based on prior investigations. Deficiencies in data for these alternatives are identified for further consideration. Prior project cost estimates are indexed to July 2004 prices (similar to Black Rock prices).

Reclamation used the following criteria to evaluate, compare, and screen the alternatives. This is the same criteria used in the *Black Rock Appraisal Assessment*; except the municipal water supply goal, which was taken to year 2020 in the *Black Rock Appraisal Assessment*. More detailed analysis will be applied later in the Storage Study.

- Improve anadromous fish habitat - Move the existing flow regime toward the natural (unregulated) hydrograph.

- Improve the water supply for proratable irrigation water rights in dry years – Supply not less than 70 percent of the irrigation water supply to proratable irrigators.

- Meet future municipal water supply needs – Supply the future municipal and domestic water supply needs to the year 2050.

Reclamation and the State of Washington reported the most recent studies of these three alternatives (1986). Subsequent work was conducted by a private consultant (Montgomery Water Group, Inc., 2002) with respect to Bumping Lake enlargement and a Wymer dam and reservoir. This work was in conjunction with preparation of a state-authorized and funded *Watershed Management Plan, Yakima River Basin* (2003).

This *Yakima Alternatives Appraisal Assessment* does not quantify annual monetary benefits that may be realized from any of these alternatives. A benefit-cost analysis has not been prepared, and this report does not address whether any of these alternatives is economically justified. Likewise, a cost allocation to reimbursable and nonreimbursable project purposes has not been made, and an analysis of the ability to repay the reimbursable costs has yet to be prepared. Further, environmental, social, and cultural impacts have not been evaluated. This is consistent with the information presented in the *Black Rock Appraisal Assessment.*

Chapter 3.0 Prior Yakima River Basin Storage Studies

Chapter 3 summarizes the more recent efforts and investigations to develop additional storage in the Yakima River basin, beginning with the 1976 *Bumping Lake Enlargement Joint Feasibility Report* by Reclamation and the U.S. Fish and Wildlife Service (Service). This chapter also includes the Yakima River Basin Water Enhancement Project (YRBWEP) storage studies of the early- to mid-1980s, the Yakima River Basin Watershed Council's work of the mid-1990s, and the activities of the Yakima River Basin Watershed Planning Unit and Tri-County Water Resources Agency of the early 2000s.

The current water resources infrastructure of the Yakima River basin has not been capable of consistently meeting instream flow demands for fish and wildlife habitat, dry-year irrigation needs, and municipal water supply needs. Since Reclamation's Yakima Project facilities were completed in 1933, there have been numerous efforts and investigations addressing the need for additional storage to meet water supply deficiencies.

It should be noted that, in these prior investigations, the instream flow goal was to maintain target flows for a specific duration at specific river reaches in the Yakima River basin. The Storage Study's fish habitat goal discussed in Chapter 4 is to move the current Yakima and Naches Rivers' hydrographs toward a more natural (unregulated) hydrograph.

3.1 Bumping Lake Enlargement Joint Feasibility Report

3.1.1 Purpose

The *Bumping Lake Enlargement Joint Feasibility Report* was prepared in 1976 by Reclamation and the U.S. Fish and Wildlife Service. The purpose of this feasibility study, authorized by the Act of September 7, 1966 (Public Law 89-56) and the Fish and Wildlife Coordination Act,[3] was to address the water-related problems and needs of the Yakima River basin. A preliminary feasibility report

[3] The Fish and Wildlife Coordination Act, approved by Congress March 10, 1943, was substantially rearranged and expanded by the Act of August 14, 1946, Public Law 79-732. Further amendments subsequent to this date have also occurred.

was completed in March 1968 and, following a public hearing, the proposed report was forwarded to the Secretary of the Interior for consideration. During this process, recreation development proposed in the recommended plan became a concern as to its compatibility with the proposed Cougar Mountain (William O. Douglas) Wilderness Area then under consideration. It was determined that the recommended plan should be reevaluated and modified.

Appropriations for reevaluation and modification of the *Joint Feasibility Report* became available in 1974. The revised *Joint Feasibility Report* was resubmitted to the Commissioner of Reclamation and the Director, U.S. Fish and Wildlife Service, in 1976. That report included an addendum addressing requirements of the Water Resources Council for Application of the Principles and Standards for Water Planning and Land Resources, published in the *Federal Register* July 24, 1974, and amended February 12, 1975. The *Joint Feasibility Report* was approved by the Secretary of the Interior in 1979. Reclamation filed a *Final Environmental Impact Statement, Proposed Bumping Lake Enlargement,* with the Council of Environmental Quality August 23, 1979.

3.1.2 Scope of Study

The scope of the feasibility study focused on the water-related problems and needs of the Yakima River basin. The problems identified included instream flows on the Yakima and Naches Rivers, irrigation water needs, flood control, recreation, wildlife, municipal, and water quality problems.

3.1.3 Water Supply Goals

The primary water supply goals of the feasibility study were to: (1) increase instream flows within the Yakima River system during low-flow periods for fishery enhancement purposes and (2) provide water on an "insurance storage basis" for presently irrigated lands of the Roza Division in low water supply years.

3.1.4 Water Operation Studies

The potential Bumping Lake enlargement under consideration includes a new dam on the Bumping River approximately 4,500 feet downstream of the existing dam. The potential dam was a rolled earth-fill structure with a height of 223 feet above streambed and a crest length of 3,300 feet. The enlarged reservoir would have a storage capacity of 458,000 acre-feet. Approximately 324,300 acre-feet would be available to maintain minimum flows for enhancement of habitat for anadromous fisheries. The irrigation supply includes 133,700 acre-feet, of which 33,700 acre-feet was for replacement of the existing Bumping Lake storage and

100,000 acre-feet was to improve the water supply of the Roza Division in dry years.

Preliminary estimates of minimum suggested flows were developed in cooperation with fish and wildlife agencies for use in the feasibility water operation studies. Funds were included as a part of the project costs to finance a streamflow study to be conducted at a later date to provide more precise minimum flow recommendations for anadromous and resident fisheries. This work was to be conducted as a part of the activities following project authorization. Table 3-1 shows the preliminary minimum suggested flow estimates used in the operation studies.

Table 3-1. Preliminary Estimates of Minimum Suggested Instream Flows

Location	Minimum Flow (cfs)	
	Nov-June	July-Oct
Yakima River below Keechelus Lake	25	25
Kachess River below Kachess Lake	0	0
Yakima River below Easton Dam	100	100
Cle Elum River below Cle Elum Lake	25	25
Yakima River below Cle Elum River	140	140
Teanaway River below Forks	Natural	Natural
Yakima River below Teanaway River	155	155
Yakima River below Umtanum	200	200
Little Naches River near Nile	Natural	Natural
Bumping River near Nile	50	104
Naches River near Oak Flat	50	104
Tieton River below Tieton Dam	50	50
Tieton River below Tieton Diversion	50	50
Naches River below Tieton River	70	124
Yakima River below Parker	180	234
Yakima River below Prosser Diversion	250	304
Yakima River below Kiona	300	300

Operation studies showed that with a 1973 level of irrigated agricultural development, and the addition to the Yakima Project storage system of an enlarged Bumping Lake, the preliminary minimum suggested instream flows could be met every year in a repetition of the 1926-1973 water conditions. The water supply available to the Roza Division during the 10 dry years of that time period would increase.[4] As an example, in the year of the largest irrigation

[4] The 10 dry years of this 48-year period are 1926, 1929, 1930, 1931, 1940, 1941, 1942, 1944, 1945, and 1973.

shortage, 1941, the Roza Division would receive 58 percent of its water rights, as compared to a supply of 49 percent without Bumping Lake enlargement.

The Washington Department of Fish and Game developed the addendum to the *Joint Feasibility Report*, which included preliminary estimates of suggested optimum instream flows the for migration, spawning, and rearing of anadromous fish. It was noted that while such flows would further enhance fishery habitat, they were considerably greater than could be provided with Bumping Lake enlargement if dry-year irrigation needs were also to be met.[5] Table 3-2 shows these suggested optimum flow estimates.

Table 3-2. Preliminary Estimates of Suggested Optimum Instream Flows

Location	Optimum Flows (cfs)	
	Apr-June	July-Mar
Yakima River below Keechelus Lake	100	100
Kachess River below Kachess Lake	50	50
Yakima River below Easton Dam	150	150
Cle Elum River below Cle Elum Lake	393	393
Yakima River below Cle Elum River	300	300
Teanaway River below Forks	200	100
Yakima River below Teanaway River	500	400
Yakima River below Umtanum	500	400
Little Naches River near Nile	100	100
Bumping River near Nile	199	199
Naches River near Oak Flat	250	250
Tieton River below Tieton Dam	113	113
Tieton River below Tieton Diversion	50	50
Naches River below Tieton River	205	205
Yakima River below Parker	600	600
Yakima River below Prosser Diversion	600	600
Yakima River below Kiona	900	900

[5] The preliminary estimates of optimum instream flows were developed using the most recent flow data available and the judgment of biologists familiar with the Yakima River system.

3.1.5 Storage Alternatives Considered

Numerous storage alternatives in addition to Bumping Lake enlargement were identified. These included new storage on the mainstem Yakima and Naches Rivers; new storage on tributary streams; storage development upstream of existing Kachess, Cle Elum, and Tieton Dams; and modification of existing storage. Alternatives also included transbasin diversions from the Snoqualmie River drainage into Keechelus Lake, from the Cowlitz River into Tieton River, and from the Klickitat River to a new reservoir on Simcoe Creek on the Yakama Indian Reservation. Diversion of Columbia River water from Priest Rapids Reservoir was also discussed as a supply for new irrigation development in the Moxee and Black Rock Valleys and on South Rattlesnake slope.

3.1.6 Other Considerations

During the environmental impact statement public process (1977), water conservation and water rights acquisition were proposed as possible alternatives to storage development. The report stated, however, that even with Bumping Lake enlargement, there would be a deficiency of supply to meet water needs in the basin. For instance, the instream flows for fish provided from the Bumping Lake enlargement, while contributing greatly to the improvement of habitat, would fall far short of the estimated “optimum” instream flows.

3.1.7 Primary Conclusions/Recommendations

The report recommended that authorization should be pursued with Congress for construction of a new dam on the Bumping River approximately 4,500 feet downstream of existing Bumping Lake Dam. The recommended capacity of the enlarged reservoir was 458,000 acre-feet, of which 324,300 acre-feet would be used to maintain minimum flows for anadromous and resident fish and 133,700 acre-feet for irrigation (33,700 acre-feet for replacement of existing Bumping Lake storage and 100,000 acre-feet for the Roza Division in low water supply years).

The report also recommended that fish ladders and fish screens be installed at seven diversion dams and canal intakes (Wanawish [formerly Horn Rapids], Prosser, Sunnyside, Wapato, Roza, Town Ditch, and Easton).[6] Fish screens would also be installed at Thorp Mill Ditch and the Old Reservation Canal. Construction of anadromous fish incubation and rearing facilities was also recommended.

[6] The fish ladders and fish screens at Wanawish, Prosser, Sunnyside, Wapato, Roza, Town Ditch, and Easton have been built and installed.

3.1.8 Actions Taken

The Secretary of the Interior approved the *Bumping Lake Enlargement Joint Feasibility Report* in January 1979. Bills were introduced in Congress in 1979, 1981, and 1985 to authorize construction of Bumping Lake enlargement, but Congress did not take any action.

3.2 Yakima River Basin Water Enhancement Project Feasibility Study

3.2.1 Background

The 1977 drought in the Yakima River basin prompted legislative action for studies for additional water supply. In 1979, the State Legislature[7] provided $500,000 for "... preparation of feasibility studies related to a comprehensive water supply project designed to alleviate water shortages in the Yakima River basin." Also in 1979, Congress authorized, provided funds for, and directed the Department of the Interior to "... conduct a feasibility study of the Yakima River Basin Water Enhancement Project" in cooperation with the State.[8]

The study, initiated in April 1981, had the following objectives:

- Provide supplemental water to presently authorized and irrigated lands for use during water-short years.
- Provide water to new irrigation lands on the Yakama Indian Reservation.
- Provide water for increased instream flows for anadromous and resident fish.
- Significantly reduce the need for costly and time-consuming litigation, both pending and future.

The Yakima River Basin Water Enhancement Project (YRBWEP) had two planning phases. Phase 1 was a preliminary identification of water needs, available resources, and potential plan elements. This Phase involved an extensive storage-site inventory and public review process, during which

[7] Chapter 263, Substitute Senate Bill 2504, Laws of 1979.
[8] Act of December 28, 1979, Public Law 96-162.

35 storage sites were identified and evaluated.[9] Plan elements were combined to see if study objectives could be met by an economically justifiable plan.

The Bureau of Reclamation and the Department of Ecology issued a Phase 1 report in 1982, with the conclusion that a plan which would meet off-reservation[10] dry-year irrigation and streamflow water enhancement needs appeared economically justified and financially feasible. The report recommended that detailed feasibility studies be pursued in Phase 2, and that early construction of fish passage and protection facilities be pursued. Congress provided authority in 1984 for the Secretary of the Interior to proceed with the fish passage and protection facilities. This is commonly referred to as Phase I of YRBWEP.

Phase 2 of the feasibility study, initiated in September 1982, was divided between on-reservation and off-reservation work activities. The off-reservation work was directed to prepare detailed studies of basin water needs (primarily irrigation and instream flows), refining system operation models, identifying and evaluating potential nonstorage opportunities, and examining the storage sites which appeared to be technically and socially viable.

Reclamation and Ecology (1985) published the Phase 2 status report. To illustrate the level of needs that could be met and what it takes to meet these needs in terms of costs, environmental impacts, possible institutional and legal changes, and public acceptability, four off-reservation studies were selected as reference points. These studies ranged from maximum storage to maximum nonstorage with two intermediate mixes of storage and nonstorage. In addition, the YRBWEP study team identified three areas for new on-reservation irrigation development (Satus Creek, Toppenish-Simcoe Creeks, and Ahtanum Creek), and presented preliminary development plans for these areas.

Following receipt of public input, the Directors of Reclamation and Ecology instructed the YRBWEP study team to proceed with off-reservation plans under the following two scenarios:

<u>Scenario I</u>: A block of new storage established specifically for instream flows separate from the existing water supply. Nonstorage measures would be used to improve the dry-year irrigation supply of proratable water rights.

<u>Scenario II</u>: New storage and nonstorage measures for both instream flows and dry-year irrigation supply for proratable water rights.

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[9] Ultimately, in 1985, the 35 storage sites were screened down to 3 sites for further consideration (Bumping Lake enlargement, Wymer dam and reservoir, and Cle Elum Lake enlargement).
[10] Off the Yakama Nation reservation.

The study team evaluated 15 alternatives within the two scenarios and shared its initial plans in a November 1985 newsletter and briefing materials. Reclamation held public meetings and group discussions in the Yakima Valley in December 1985 to critique the broad array of alternatives. In January 1986, the YRBWEP study team presented a *Plan Formulation Summary Report* (Reclamation and Ecology, 1986). This report contained four off-reservation alternative plans, each of which included "core measures" common to each plan, storage measures, and nonstorage measures. The YRBWEP study team recommended that Reclamation and Ecology conduct further analysis and evaluation in advance of a subsequent environmental impact statement.

3.2.2 Yakima River Basin Water Enhancement Project Plan Formulation Summary Report

The following sections provide information on the water supply goals, four alternative plans, and preliminary conclusions contained in the Yakima River Basin Water Enhancement Project's *Plan Formulation Summary Report.*

3.2.2.1 *Water Supply Goals*

3.2.2.1.1 Irrigation Surface Water Supply Goal. The irrigation water supply criteria selected for plan formulation purposes were based on the average water diversions of the major Yakima River basin irrigators over the 10-year period of 1973-1982, exclusive of 3 dry years (1973, 1977, and 1979). Since this average was less than the irrigation water rights, the YRBWEP study team defined the irrigation water supply goal as one that would meet the following criteria for plan formulation purposes:

- The proratable supply would not fall below 70 percent of the irrigation entity's computed average diversion in a recurrence of the single worst water year of record which, in this instance, was 1941.

- Recurrence of the worst 10 consecutive years of record would not reduce any entity's water supply for the period by more than 100 percent of the entity's computed average diversion. It was noted that use of this water supply goal did not alter the water entitlements under the 1945 Consent Decree.

3.2.2.1.2 Instream Flow Water Supply Goal. At the time of this YRBWEP study, the Instream Flow Incremental Methodology (IFIM) was considered the best available technique for estimating desirable flows for fish. IFIM relates streamflow to the weighted useable area (habitat) for a specific species or lifestage.

The YRBWEP study team, in consultation with fishery biologists working in the Yakima River basin area, conducted an extensive IFIM field data collection program to identify instream flows for anadromous and resident fisheries, and to supplement prior IFIM work by others for use as target flow goals in formulating alternative plans. Subsequently, Reclamation contracted with Parametrix, Inc., to review the technical adequacy of all IFIM data for the Yakima River basin and to prepare independent flow recommendations. Reclamation also established a group of Federal, State, Tribal, and irrigation district fishery biologists known as the Instream Flow Technical Advisory Group (IFTAG) to review Parametrix's work and to present their own recommendations.

Table 3-3 shows the monthly flow recommendations for the 13 reaches in the Yakima and Naches Rivers used in formulating the four alternative plans of the *Plan Formulation Summary Report*.

3.2.2.2 *Alternative Plans*

The YRBWEP study team recommended four alternative plans be carried forward to detailed analysis and evaluation (Table 3-4):

- Alternative 1 – Core measures + Bumping Lake Enlargement (400k)
- Alternative 2 – Core measures + Wymer + Trust Fund nonstorage measures.[11]
- Alternative 3 – Core measures + Bumping Lake Enlargement (250k) + Trust Fund nonstorage measures.
- Alternative 4 – Core measures + Bumping Lake Enlargement (458k) + Trust Fund nonstorage measures.

3.2.2.3 *Water Operation Studies*

The capability of each alternative to meet the irrigation and fisheries water supply goals was examined by using computer model studies simulating reservoir operations, diversions, and river flows. The computer model used a 52-year historical water supply period of 1926-1977, simulated monthly operations of the existing Yakima Project, and an expanded Yakima Project for each alternative plan.

In the simulations, each alternative plan improved the irrigation water supply. Based on the 10-year average diversion, the nonproratable water rights were met each year. Using the same 10-year average diversion, proratable water rights

[11] "Trust Fund nonstorage measures" indicates a block of entity and on-farm water conservation measures that could be implemented as part of a proposed alternative(s).

were met in all years, except 1941, when only 70 percent of the proratable water supply was available. Table 3-5 shows the water supply which would have been available to the Roza Division and the Kittitas Reclamation District from the Yakima Project with and without the alternative plan in a repetition of a 1941 dry water year.

Table 3-3. Summary of Flow Recommendations for the Yakima River Basin (IFTAG)

Reach	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Yakima River												
1. Keechelus Dam-Easton Dam	125	125	100	100	100	125	125	125	125	100	100	100
2. Easton Dam-Cle Elum River	400	400	350	350	275	275	275	275	275	225	225	225
3. Cle Elum River	200	200	200	200	200	275	275	275	275	300	300	300
4. Cle Elum River-Teanaway River	650	650	600	600	525	525	500	500	500	600	600	600
5. Wilson Creek-Roza Dam	750	1,000	1,000	750	750	900	900	750	750	750	750	750
6. Roza Dam-Naches River	750	800	800	750	750	900	900	750	750	750	750	750
7. Sunnyside Dam-Marion Drain	800	700	700	700	700	600	700	800	800	800	800	800
8. Prosser Dam-Chandler Power Plant	800	1,000	1,000	800	800	800	800	700	700	800	800	800
9. Horn Rapids Dam-Columbia River	900	1,300	1,300	900	900	900	900	800	800	800	800	800
Naches River												
10. Bumping River	150	150	150	150	150	150	200	200	200	100	100	150
11. Bumping River-Nile	500	500	500	450	450	450	450	450	450	300	300	500
12. Lower Tieton River	150	200	200	200	200	125	125	125	125	200	200	150
13. Wapatox Dam	275	275	225	225	225	225	225	250	250	250	250	250

Table 3-4. Alternative Plans

<table>
<tr><th>Alternative 1</th><th>Alternative 2</th><th>Alternative 3</th><th>Alternative 4</th></tr>
<tr><td>Core Measures</td><td>Core Measures</td><td>Core Measures</td><td>Core Measures</td></tr>
<tr><td colspan="4">Core measures include fish passage and screen improvements; subordination of Wapatox, Roza, and Chandler power operations to instream flows; 3-foot raise in Cle Elum Lake; Roza and Sunnyside Irrigation canal automation; and anadromous fish planting during construction.</td></tr>
<tr><td>+</td><td>+</td><td>+</td><td>+</td></tr>
<tr><td rowspan="5">Storage[1]
400,000-acre-foot
Bumping Lake
enlargement</td><td>Storage[1]
142,000-acre-foot
Wymer Reservoir</td><td>Storage[1]
250,000-acre-foot
Bumping Lake
enlargement</td><td>Storage[2]
458,000-acre-foot
Bumping Lake
enlargement</td></tr>
<tr><td>+</td><td>+</td><td>+</td></tr>
<tr><td>Trust Fund
Nonstorage
Measures[3]</td><td>Trust Fund
Nonstorage
Measures[3]</td><td>Trust Fund
Nonstorage
Measures[3]</td></tr>
<tr><td colspan="3">Measures used in this analysis for illustration that could be implemented under a trust fund concept include Roza Irrigation District reregulating reservoir; Roza Irrigation District groundwater; Kittitas Reclamation District, and Union Gap areas. Some additional measures could be included in the trust fund.</td></tr>
<tr></tr>
<tr><td colspan="4">[1] Storage would be dedicated to instream flows for fish. Irrigation would be returned to pre-1980 water supply conditions.</td></tr>
<tr><td colspan="4">[2] 350,000 acre-feet of storage would be dedicated to instream flows for fish. Irrigation would be returned to pre-1980 water supply conditions. 108,000 acre-feet of storage would be dedicated to irrigation to improve water supply above pre-1980 conditions.</td></tr>
<tr><td colspan="4">[3] Water yield from nonstorage measures would be used first to improve proratable water supplies to 70 percent of the 10-year average diversion. Remaining water would go to instream flows.</td></tr>
</table>

Table 3-5. Water Supply Available in Repetition of 1941 Dry Year

Entity	Water Right (acre-feet)	Average Diversion (acre-feet)		70% of Average (acre-feet)	
Roza Irrigation District	375,000	353,800		247,700	
Kittitas Reclamation District	336,000	298,000		208,600	
	Without	With Alternative Plan			
		Alt. 1	Alt. 2	Alt. 3	Alt. 4
	(Percent of Average Diversion)				
Roza Irrigation District	37	72	87	87	97
Kittitas Reclamation District	37	70	73	73	83

Improved fishery habitat resulting from the instream target flows was expressed in terms of estimated anadromous fish "spawning escapement" and harvest of progeny from these salmon and steelhead. All four alternatives resulted in a significant increase in spawning escapement and were within approximately 10 percent of each other. Resident fish populations would also increase.

Streamflows would improve throughout the Yakima River system. For instance, with each alternative plan, the average June, July, and August Yakima River flows at Parker (Sunnyside Diversion Dam) were in the range of 600 to 700 cfs, compared to approximately 300 cfs in the No Action Alternative. Table 3-6 displays instream flow results at selected points in the river system.

Table 3-6. Flow Achievements for Selected Reaches and Months

River Reach (months)[1]	Recommended Flow	No Action Alt.	Alt. 1	Alt. 2	Alt. 3	Alt. 4
Yakima River						
6. Roza Diversion Dam to Naches River (Sep)	750	389	573	589	592	608
7. Sunnyside Diversion Dam to Marion Drain (Jun-Jul-Aug)	800	309	615	726	616	673
8. Prosser Diversion Dam to Chandler Power Plant (Oct)	1,000	470	713	930	691	756
Naches River						
10. Bumping River (Mar)	200	86	135	164	129	145
11. Bumping River near the Nile (Oct)	500	234	301	319	281	328
12. Lower Tieton River (Nov)	200	101	136	176	169	162
13. Wapatox Dam (Oct)	275	111	197	227	191	200

[1] Months selected for each reach are traditionally low-flow months for that specific reach (reach numbering taken from Table 3-3. Summary of Flow Recommendations for the Yakima River Basin (IFTAG)
). Important fish activities during the timeframe are generally rearing and adult migration.

3.2.2.4 *Primary Conclusions*

The YRBWEP study team concluded that nonstorage and additional storage measures were emerging as key elements of any acceptable plan, and decisions would have to be made on tradeoffs between storage sites. To facilitate this decisionmaking process, they recommended that more detailed evaluations be done to give the public and involved interests further opportunity to consider tradeoffs, impacts, and consequences of the alternative plans to decide on a preferred plan. On this basis, the YRBWEP study team recommended that the four alternative plans be the focus of the detailed analysis and evaluation of the environmental impact statement.

Because interest shifted to water conservation, further work involving storage plan elements did not occur. Activities of the 1980s and early 1990s resulted in a cooperative Federal, State, Tribal, and local undertaking to formulate and implement Phase I (fish ladders and fish screens) and Phase II [Public Law 103-434, *Title XII, Yakima River Basin Water Enhancement Project* (Title XII), with primary focus on a basin conservation program] of the YRBWEP. Appendix A includes a description of activities leading up to the enactment of Title XII.

3.3 A 20/20 Vision for a Viable Future of the Water Resource of the Yakima River Basin

3.3.1 Introduction

The Yakima River Watershed Council (Watershed Council) was formed in March 1994 as a nonprofit organization. Its membership included more than 800 individuals representing water-based interests in the Yakima River basin. The obligations of the Watershed Council were to:

- Educate its members on the state of the Yakima River basin water resources, their management, and other concerns and issues.
- Put forth conclusions and recommendations addressing concerns and issues.
- Inform the public.
- Develop strategies and a plan(s) that could be implemented to provide consistent and adequate water to meet the economic, cultural, and natural environmental needs in the Yakima River basin.

The first activity of the Watershed Council toward developing a plan was to issue a report in July 1996, called the *State of the Water Resources of the Yakima River Basin.* This was an assessment of problems and needs from the perspective of water supply, water quality, and water management.

Following development of planning goals, the Watershed Council (1997) prepared the draft plan, *A 20/20 Vision for a Viable Future of the Water Resource of the Yakima River Basin*. A review and comment period followed, and the Council issued and circulated a revised draft plan dated June 9, 1998, for review and comment.

During the same timeframe, the Tri-County Water Resources Agency was formed (1995), the State Legislature enacted the State Watershed Management Act (1997), and the Tri-County Water Resources Agency subsequently received a Washington State planning grant for Yakima River basin watershed planning. Due to these circumstances, the Watershed Council terminated its activities in July 1998, and did not finalize the draft *A 20/20 Vision for a Viable Future of the Water Resource of the Yakima River Basin*.

3.3.2 Scope

The draft plan, *A 20/20 Vision for a Viable Future of the Water Resource of the Yakima River Basin*, studies the entire water resources of the Yakima River basin, including tributaries to the Yakima River. The draft plan focuses on five primary areas/activities for which management strategies are considered. Those are:

- Water conservation, transfer, and marketing.
- Storage.
- Water quality.
- Habitat restoration.
- Water management.

The Watershed Council considered each of these activities to be a part of the management solution, and all activities should be analyzed together.

3.3.3 Water Supply Goals

The draft report set forth numerous goals. The goals, as they pertained to irrigation, instream flows, and municipal supply, are stated below.

3.3.3.1 *Irrigation Surface Water Supply Goal*

The irrigation surface water supply goal was to develop an adequate water supply from the Yakima River and its tributaries to provide, in water-deficient years such as 1994, a full water supply to nonproratable entitlements (water rights) and a 70-percent proratable water supply, and maintain a healthy river system to aid in recovery of wild salmonid species.

In quantifying this goal, the Watershed Council used the year 1994 as an indicator of the maximum irrigation shortage and assumed that for the proratable users, the deficit was as follows:

- Demand for proratables at 70 percent 800,000 acre-feet
- 1994 water supply available - 425,000 acre-feet
- Additional water supply needed 375,000 acre-feet

3.3.3.2 *Instream Flow Water Supply Goal*

The instream flow water supply goal was to develop an adequate water supply from the Yakima River and its tributaries to provide a target flow of 700 cfs over Sunnyside and Prosser Diversion Dams, water for anadromous fish flushing flows (50,000 acre-feet), and water for winter flows (30,000 acre-feet). The enhanced target flow of 700 cfs would require 400 cfs in addition to the Yakima Project's current "base" operational flow of 300 cfs. The additional flow of 400 cfs for the period of April through October would require a water supply of about 170,000 acre-feet. Thus, the instream flow water supply goal totaled 250,000 acre-feet.

The Watershed Council adopted the specific 700 cfs number as derived from the IFIM analysis, which considers the benefits of increased flows to salmon. The IFIM analysis indicated that flow increases above 700 cfs provided only a minimal additional benefit to the fishery.

3.3.3.3 *Municipal Water Supply Goal*

The municipal water supply goal was to develop an adequate surface water supply from the Yakima River and its tributaries. Since municipal purveyors used significant quantities of groundwater, the Watershed Council supported further studies of groundwater aquifers to provide for future demands.

In quantifying this demand, the Watershed Council estimated that the increment of additional supply required for the entire basin in year 2014 was 65,000 acre-feet. Using the existing percentage of groundwater versus surface water use, the Watershed Council estimated an additional 30,000 acre-feet would be required from surface water and 35,000 acre-feet from groundwater. In quantifying future demand, the Watershed Council relied primarily on the city of Yakima's 1994 *Water Comprehensive Plan* to estimate the total 1994 Yakima River basin municipal water use from surface and groundwater as 86,000 acre-feet. Using population forecasts from Federal and State statistics, and the city of Yakima's 1994 *Water Comprehensive Plan*, a total demand of 151,000 acre-feet was projected for the year 2014 (a 65,000 acre-foot increase). The Watershed Council estimated that of the total 65,000 acre-foot demand increase, 30,000 acre-feet would be required from surface water and 35,000 acre-feet from groundwater.

The sum of the additional needs for irrigation (375,000 acre-feet), instream flows (250,000 acre-feet), and municipal supply (30,000 acre-feet) was 655,000 acre-feet.

3.3.4 Storage Alternatives Considered

The Watershed Council recognized that stored water can take many forms, including surface water storage in reservoirs; re-regulating facilities; natural storage in the riparian, wetland, and floodplain areas; and direct recharge of groundwater.

With respect to surface storage in reservoirs, the Watershed Council analyzed a number of storage solutions and sites. This analysis relied upon past studies conducted by Reclamation and others in the early to mid-1980s. Table 3-7 summarizes the project/sites.

From this review, the Council recommended three projects for further consideration:

1. Enlargement of Bumping Lake to a capacity of approximately 400,000 acre-feet to store runoff of the Bumping River in excess of the existing reservoir's capacity (33,700 acre-feet).
2. Construction of Wymer dam and reservoir, an off-channel, 142,000-acre-foot-capacity reservoir upstream of Roza Diversion Dam, in the Lmuma Creek Canyon, to be filled by pumping from the Yakima River when flows are in excess of downstream needs.
3. Construction of Horsetail Reservoir on the Little Naches River with a storage capacity of about 182,700 acre-feet.

Table 3-7. Project/Storage Alternatives Reviewed

Project	Location
Bumping Lake enlargement	Bumping River, 4,500 feet downstream of existing dam
Cle Elum Lake enlargement	Cle Elum River, increase capacity in existing reservoir
Rimrock Lake enlargement	Tieton River, increase capacity in existing reservoir
Kachess Lake augmentation	Diversions from Cabin Creek and Silver Creek
Forks	Teanaway River below Three Forks
Wymer	Lmuma Creek Canyon, east side of Yakima River
Horsetail	Little Naches River, 1½ miles above Naches River
Devils Table	Rattlesnake Creek, 6½ miles upstream of Nile
Roza Reregulating	Roza Irrigation District
Tampico	Ahtanum Creek, 7 miles west of Tampico
Simcoe	Simcoe Creek, 4 miles west of White Swan (Yakama Nation)
Satus	Satus Creek, 8 miles west of Satus (Yakama Nation)
Black Rock	East end of Black Rock Valley, Columbia River supply

The Watershed Council acknowledged a number of "technical realities" associated with these projects. For instance, operation studies had not been conducted to determine the effectiveness of existing and new storage to meet the primary water supply goal over a sequence of below-normal water supply years. Further, the environmental impacts of storage development at these sites had not been recently evaluated, construction and operating costs had not been updated, and potential sources of construction funding had not been identified.

3.3.5 Primary Conclusions

As to potential storage projects, the Watershed Council adopted the following recommendation:

> *The Watershed Council recommends pursuing the least cost, least ecologically damaging surface water storage reservoirs as a potential way of making water available during water short years for the recovery of the basin's at risk fish species and the legitimate needs of the current agricultural and municipal base.*

In conjunction with this recommendation, the Watershed Council provided a storage action plan that identified future study activities related to storage project costs, project operations, and modeling activities. The action plan included a proposed timeline and assignment of study activities.

3.4 *WATERSHED MANAGEMENT PLAN, YAKIMA RIVER BASIN*

3.4.1 Purpose

The Yakima River Basin Watershed Planning Unit and Tri-County Water Resources Agency prepared the *Watershed Management Plan*, *Yakima River Basin*, in January 2003, pursuant to provisions of the State Watershed Management Act (Chapter 90.82 RCW), enacted in 1997. The legislation authorized a process and provided funding for local citizens to develop and adopt goals and objectives for water resource management and development within their watershed. Under the guidance of the Tri-County Water Resources Agency, a Yakima River Basin Watershed Planning Unit was established in 1998 and, with the assistance of consultants, the Watershed Planning Unit prepared a *Watershed Assessment* (2001) and developed the *Watershed Management Plan*. The *Watershed Management Plan* became a “road map” for maintaining and improving the Yakima River basin’s economic base, planning responsibility for expected growth in population, managing water resources for the long term, and protecting the basin’s natural resources and fish runs.

Yakima and Benton Counties adopted the *Watershed Management Plan*, which is recognized as satisfying the watershed planning authority of the Washington Department of Ecology. Kittitas County has not adopted the *Watershed Management Plan*, as of May 2006. Ecology will use the *Watershed Management Plan* as the framework for making future water resources decisions for the Yakima River basin.

3.4.2 Scope of Plan

Geographically, the *Watershed Management Plan* covers the entire Yakima River basin, except for the Yakama Nation Reservation. The Planning Unit excluded the Reservation at the request of the Yakama Nation.

As to subject matter, the Watershed Management Act required that issues of water supply and use be addressed and that strategies for future use be developed. Optional planning components were water quality, instream flows, and habitat. The Planning Unit elected to address all components except instream flows.

3.4.3 Water Supply Goals

The Planning Unit addressed seven goals for a balanced management of water resources in the Yakima River basin. Four of these goals are directly related to management of surface water and are as follows:

1. Improve the reliability of surface water supply for irrigation use.
2. Provide for growth in municipal, rural domestic, and industrial demand.
3. Improve instream flows for all uses with emphasis on improving fish habitat.
4. Maintain economic prosperity by providing an adequate water supply for all uses.

The Planning Unit developed the following estimates of additional water supply needed to meet these goals.

3.4.3.1 *Irrigated Agriculture*

An additional 375,000 acre-feet of water would be needed to supply at least 70 percent of all proratable irrigation water rights in a dry year, as represented by year 1994.

3.4.3.2 *Instream Flow*

Three alternative needs were examined for providing additional water supply for purposes of:

1. Meeting target flows at the Parker gauging station under the following two conditions:
    a. Providing a minimum of 450 cfs to meet modified Title XII target flows.[12]
    b. Providing 800 cfs as a minimum target flow for all months as previously defined by IFTAG.[13]
2. Providing a minimum of 200 cfs below Keechelus Dam during all months.

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[12] The modified target flow of 450 cfs represents an increase of 150 cfs from the base 300 cfs Title XII target flow. This increase was applied, based on several assumptions regarding implementation of irrigation district water conservation plans and the associated Title XII requirement for increasing target flows, based on reduced annual diversions.

[13] This would require the following additional volume of water: 1994 (dry year), 110,000 acre-feet; 1998 (average year), 48,000 acre-feet; and 1997 (wet year), 1,200 acre-feet.

3. Eliminating the "flip-flop" operation. The flip-flop reservoir operation is coordinated with the beginning of spring Chinook salmon spawning about mid-September in the upper Yakima River system. Irrigation releases from Cle Elum Lake are decreased, and releases from Rimrock Lake are increased to meet irrigation demands downstream from the Naches River confluence. The decrease in Cle Elum Lake releases encourages spawning in the main river channels rather than along the stream banks. This operation allows more reservoir inflow to be stored in Cle Elum Lake later in the year rather than being released to cover redds that otherwise would have been deposited along the stream banks.

3.4.3.3 *Municipal and Domestic Supply*

The Yakima River Basin Watershed Planning Unit and the Tri-County Water Resources Agency prepared municipal and domestic water estimates as part of the watershed planning process to represent current use and projected needs. They developed estimates for both public water systems comprised of 1,000 connections or more, and smaller community and noncommunity systems and households with individual wells for year 2000, and for projected year 2010 and year 2020 needs. Information for public water systems serving 1,000 connections or more were obtained from the most current water plans prepared by the respective water purveyors and from personal communications with staff. This information is generally available for a 20-year timespan.

Projected needs beyond the year 2020 were developed by applying the U.S. Bureau of Economic Analysis annual median demographic growth projection for the State of Washington (0.8 percent). These projected needs for years 2030 to 2050 were not specifically identified by public water supply systems of 1,000 connections or more, smaller community and non-community systems, and households with individual wells.

The information in Table 3-8 shows estimated municipal and domestic water use for year 2000 and projected needs for years 2010, 2020 and 2050. The cities of Richland and West Richland, together with the cities of Kennewick and Pasco, which are outside the Yakima River basin, have integrated their individual water system plans and developed a regional water supply plan using the Columbia River as their water source. Therefore, the needs of the cities of Richland and West Richland are subtracted from the Yakima River basin total to determine the projected municipal and domestic needs to be supplied from Yakima River basin groundwater and surface water resources.

Table 3-8. Municipal and Domestic Water Needs (Years 2000, 2010, 2020, and 2050

	No. of Services (in 1999)	Needs (acre-feet)			
		2000[1]	2010[1]	2020[1]	2050
Yakima Basin Total	**109,180**	**115,772**	**138,199**	**163,316**	**215,000[2]**
Upper Yakima Subarea					
Ellensburg	3,230	4,820	6,053	7,062	
Cle Elum	1,000	897	1,009	1,121	
Other Community and Class B PWS	3,111	3,139	3,845	4,551	
Noncommunity	881	988	1,210	1,432	
Yakima Training Center	4	90	90	90	
Households with own well	5,602	5,652	6,924	8,195	
Total Upper Yakima	13,828	15,585	19,130	22,451	29,000
Middle Yakima Subarea					
City of Yakima (potable supply)	16,756	17,151	18,384	19,393	
City of Yakima (irrigation supply)		n/a	2,242	2,242	
Nob Hill Water Association	7,595	3,811	4,708	5,717	
Selah	1,682	2,915	3,363	3,699	
Union Gap	1,200	1,211	1,398	1,586	
Terrace Heights	1,104	673	1009	1,223	
Other Community and Class B PWS	3,489	3,520	4,066	4,611	
Noncommunity	154	173	199	226	
Yakima Training Center	109	90	90	90	
Households with own well	18,720	18,887	21,814	24,741	
Total Middle Yakima	50,809	48,430	57,274	63,539	70,000
Naches Subarea					
Other Community and Class B PWS	1,474	1,487	1,755	2,022	
Noncommunity	607	680	803	925	
Households with own well	2,575	2,598	3,066	3,533	
Total Naches	4,656	4,565	5,623	6,481	18,000
Lower Yakima Subarea					
Sunnyside	2,956	3,252	3,399	4,260	
Grandview	2,300	3,139	4,148	5,381	
Toppenish	2,000	2,018	2,331	2,643	
Wapato	1,104	1,345	2,803	3,139	
Benton City	729	224	785	1,345	
Prosser	1,600	3,139	3,587	3,924	
Richland	5,451	9,192	9,753	15,358	
West Richland	2,200	2,915	3,924	6,278	
Other Community and Class B PWS	6,777	6,837	7,897	8,957	
Noncommunity	272	305	353	399	
Households with own well	14,498	14,627	16,894	19,161	
Total Lower Yakima	39,887	46,992	56,172	70,844	98,000[4]
LESS: Richland and West Richland[3]	-7,561	-12,107	-13,677	-21,636	-29,000[5]
Adjusted Lower Basin	32,326	34,885	42,495	49,208	69,000
Yakima Basin Groundwater and Surface Water Supply	**101,619**	**103,465**	**124,522**	**141,679**	**186,000**
Increase from Year 2000			**20,000**	**38,000**	**82,000**

Footnotes from **Table 3-8, Municipal and Domestic Water Needs (Years 2000, 2010, 2020, and 2050)**

[1] From Table 6 of the *Municipal, Domestic, and Industrial Water Needs and Supply Strategies,* January 2002, Technical Memorandum prepared by Economics and Engineering Services. This is consistent with Table 2-1 of the January 6, 2003, *Watershed Management Plan.*

[2] From Exhibit 2-2 of the January 6, 2003, *Water Management Plan*.

[3] Water system plans provide for joint development of Columbia River surface supply.

[4] Page 3-6 of the January 6, 2003, *Water Management Plan* provides information on the extent of increased needs in the upper Yakima, middle Yakima, and Naches subareas from year 2000 to year 2050. These increased needs were added to the respective subareas' year 2000 use to provide a year 2050 total of 117,000 acre-feet for the three subareas. The 117,000 acre-feet was subtracted from the Yakima River basin total need of 215,000 acre-feet, providing a figure of 98,000 acre-feet for the lower Yakima subarea.

[5] The year 2020 need of the cities of Richland and West Richland is 30 percent of the lower Yakima subarea year 2020 estimated need. The 30 percent figure was applied to the lower Yakima subarea year 2050 need of 98,000 acre-feet, resulting in a year 2050 estimated need of 29,000 acre-feet for these two cities.

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.

In the *Watershed Management Plan*, the Yakima River Basin Watershed Planning Unit and the Tri-County Water Resources Agency noted the importance of the relationship between surface and groundwater in managing water resources in the Yakima River basin. They indicated pumping groundwater from some aquifers at some locations may reduce flows in surface waters, affecting fish and other aquatic resources, or may impair senior water rights. (This relationship is referred to as "connectivity.") In other cases, pumping groundwater may have little effect on surface waters, or may have effects that are delayed in time or occur at distances far from the well.

Because groundwater is the preferred source for municipal and domestic water supply, and the extent of connectivity of surface and groundwater is unknown at this time, the *Watershed Management Plan* took a conservative approach by assuming that surface water withdrawals would meet the future municipal and domestic water supply needs. U.S. Geological Survey expects to complete their investigation of the groundwater aquifers in the Yakima River basin and clarify the surface and groundwater relationship in 2007.

3.4.4 Storage Alternatives Considered

Five storage projects were considered for meeting the planning objectives. The first four listed below are within the Yakima River basin,[14] followed by the Black Rock Alternative.

- **Bumping Lake Enlargement** - Construct a new dam and reservoir on the Bumping River approximately 4,500 feet downstream of the existing dam to provide 400,000 acre-feet of storage.

- **Wymer Dam and Reservoir** - Construct a new off-channel dam and reservoir in the Lmuma Creek Canyon between Ellensburg and Selah on the east side of the Yakima River. The active capacity, assumed to be 142,000 acre-feet, would be filled by pumping from the Yakima River.

- **Cle Elum Lake Enlargement –** Increase the storage capacity of the existing reservoir by modifying the radial gates at Cle Elum Dam for additional reservoir storage of 14,500 acre-feet.

- **Kachess Lake Augmentation –** Divert and store excess flows of Silver and Cabin Creeks in Kachess Lake.

- **Black Rock Dam and Reservoir –** Construct a new dam and reservoir in Black Rock Valley east of the city of Yakima. A Black Rock reservoir would be filled by pumping water from the Columbia River. Two reservoir sizes were examined: a "large" reservoir with an annual yield of 500,000 acre-feet and a "small" reservoir with an annual yield of 250,000 acre-feet.

3.4.5 Water Operation Studies

Reclamation conducted hydrologic modeling to compare the effectiveness of the alternate concepts in meeting instream flow and irrigation water supply goals. Reclamation used the Yakima Project model, which is a daily time-step reservoir and river operation model of the Yakima Project created with the RiverWare software. Input to the model included runoff from the 1991-1996 time period, irrigation demands that represent average annual diversions, municipal and industrial needs for current and future conditions, and flow targets used by Reclamation for instream needs. The RiverWare model produced results for each operation scenario evaluated.

[14] A new dam and reservoir on the Little Naches River with a potential storage capacity of about 182,700 acre-feet was also reviewed, but was not included in the operation studies conducted for the *Water Management Plan*.

The five storage projects described above were combined into two alternate concepts (major and medium storage enhancement) for modeling and comparison purposes. The Major Enhancement Concept contained subsets (1A, 1B, and 1C). In addition, each alternative included three potential irrigation district water use efficiency projects, as shown in Table 3-9.

Table 3-9. Storage Enhancement Concepts for Water Operation Studies

Major			Medium
1A	1B	1C	
Bumping Lake	Black Rock reservoir		Wymer reservoir
Wymer reservoir	250,000 acre-feet annual supply	500,000 acre-feet annual supply	
Cle Elum enlargement			
Kachess augmentation			
Water use efficiency projects of Kittitas Reclamation District, Roza Irrigation District, and Roza-Sunnyside Joint Board of Control)			

Reclamation made three modeling runs for each of the Major Enhancement Concepts. Each modeling run assumed an instream flow priority, with any excess water applied to improving irrigation. The instream priorities were to:

- Provide a minimum flow of 200 cfs below Keechelus Dam.
- Meet IFTAG flows at Parker (800 cfs).
- Eliminate flip-flop and mini flip-flop operations.

For the Medium Enhancement Concept (Wymer dam and reservoir), two modeling runs were made with assumed priorities to:

- Meet the increased flow target (200 cfs) below Keechelus Dam.
- Meet modified Title XII flows (450 cfs) at Parker.

In addition to the storage enhancement concepts described above, modeling was conducted for a water efficiency-only concept. In this case, all of the irrigation districts' water-use efficiency projects being considered under the *Basin Conservation Plan* (Yakima River Basin Conservation Advisory Group, 1998) of Title XII were assumed to be implemented. Two model runs were made similar to the Medium Enhancement Concept.

3.4.6 Model Results

Reclamation selected the modeling analysis period of 1991-1996 to represent a range of hydrologic conditions including a 3-year drought in 1992, 1993, and

1994. That period represented the worst condition of consecutive drought years on record for the Yakima River basin.

Table 3-10 shows the extent each scenario met the 70-percent dry-year proratable irrigation reliability goal and a specific instream target flow goal for five hydrologic operation model runs. The first line of the respective model run indicates the years in which the 70-percent dry-year irrigation water supply goal are met; the second line of the model run indicates if the scenario met ("Yes") or did not meet ("No") the specific instream target goal. An "N/A" means the objective was not applicable for the scenario in the model run.

Table 3-10 scenarios are:

- 1A=Yakima River basin projects plus conservation for three irrigation entities.
- 1B=Small Black Rock, plus conservation for three irrigation entities.
- 1C=Large Black Rock, plus conservation for three irrigation entities.
- 2=Wymer plus conservation for three irrigation entities.
- 3=Conservation for all irrigation entities being considered under the *Basin Conservation Plan.*

Table 3-10. Summary of Ability to Meet 70% Proratable Dry-Year Irrigation Water Supply Goal and Specific Instream Target Flow Goals, 1992, 1993, 1994

Model Run	Objective of Model Run	1A	1B	1C	2	3
1	Dry-year irrigation water supply goal met in year(s)	1992, 1993, 1994	1992, 1993	1992, 1993, 1994	1992, 1993	1992, 1993
	Target flow below Keechelus (200 cfs fall/winter)	Yes	No	Yes	No	No
2	Dry-year irrigation water supply goal met in year(s)	1992, 1993	1993	1992, 1993, 1994	N/A	N/A
	IFTAG flows at Parker (800 cfs)	No	No	Yes	N/A	N/A
3	Dry-year irrigation water supply goal met in year(s)	N/A	N/A	N/A	1992, 1993	1993
	Modified Title XII flows at Parker (450 cfs)	N/A	N/A3	N/A	No	No
4	Dry-year irrigation water supply goal met in year(s)	1992, 1993, 1994	1992, 1993	1992, 1993, 1994	N/A	N/A
	Reduce peak flip-flop flows	Yes	No	Yes	N/A	N/A

3.4.7 Primary Conclusions

The Watershed Planning Unit recommended the Major Enhancement Concept as the preferred alternative. It concluded that "only a major enhancement of the basin's water storage capacity can offer the needed improvements in water reliability, while simultaneously permitting significant improvements in streamflow management."

With regard to water use efficiency, transfers, and other surface water management actions, the Watershed Planning Unit concluded that the preferred alternative was intended to be consistent with and supportive of the YRBWEP program. The preferred alternative includes extensive modifications to irrigation systems to improve water use efficiency and reduce diversions. The Watershed Planning Unit concluded that the analyses in the *Watershed Management Plan* showed that the water use efficiency measures and other provisions of YRBWEP could not by themselves meet the challenge of improving water supply reliability and instream flows simultaneously. Additional storage capacity would be needed to meet the water supply goals.

3.5 Resource Issues Raised

The concerns and issues raised at the time of the 1970s and 1980s studies are presented below. Reclamation has not addressed these issues in this *Yakima Alternatives Appraisal Assessment.*

As indicated previously, planning studies in the 1970s and 1980s considered Bumping Lake enlargement to be the primary potential addition to the Yakima Project storage system. The potential dam would be on a regulated stream; the capital investment and annual operating costs were reasonable; and it was expected to be fully integrated into Yakima Project operations to improve instream flows and the reliability of irrigation water supply in dry years. Some, however, viewed Bumping Lake enlargement differently, raising concerns and issues as to its public and environmental acceptability.

Wymer dam and reservoir, an off-channel facility filled by pumping Yakima River flows "excess" to other needs, did not emerge as a potential storage alternative until the planning activities of the 1980s. While the public voiced some concerns and issues, they were not as extensive as those related to Bumping Lake enlargement.

3.5.1 Bumping Lake Enlargement

The Bumping Lake enlargement proposal consisted of a new dam approximately 4,500 feet downstream of the existing dam and an enlarged reservoir capacity of about 400,000 to 458,000 acre-feet. The zoned rockfill dam would be approximately 233 feet high, with a crest length of about 3,300 feet. The existing Bumping Lake Dam would be breached.

Concerns and issues raised by some of the publics associated with the possible construction and operation of the project were:

- Aesthetic impacts of reservoir drawdown on the William O. Douglas Wilderness Area.
- Inundation of old growth timber.
- Loss of stream habitat and wildlife habitat.
- Reservoir filling and refilling.
- Relocation of summer homes.
- Construction and long-term impacts to the community of Goose Prairie.

3.5.1.1 *Proximity to William O. Douglas Wilderness Area*

The William O. Douglas Wilderness Area, approximately 170,000 acres, is adjacent to the existing Bumping Lake. None of the reservoir enlargement options that were considered infringed on the Wilderness Area. The opinion of some people was that the enlarged reservoir would be visible from various vantage points and detract from the scenic vistas and aesthetic values of the Wilderness Area through reservoir drawdown and exposure of the reservoir bottom area.

3.5.1.2 *Inundation of Old Growth Timber*

Enlargement of Bumping Lake to a capacity in the range of 400,000 to 458,000 acre-feet would inundate an additional 2,800 acres. Approximately 1,900 acres of the additional acres was old growth timber. The issue was the potential adverse impact on spotted owl habitat, a listed endangered species which uses the old growth forest as habitat.

3.5.1.3 *Loss of Stream and Wildlife Habitat*

With Bumping Lake enlargement, some perennial and intermittent stream habitat downstream of the existing dam and upstream of the existing reservoir area would be inundated. Further, about 2,600 acres of wildlife habitat would be inundated by the enlarged reservoir.

3.5.1.4 *Reservoir Filling and Refilling*

The larger capacity reservoir would not fill on a regular basis and would not be a reliable source of water.

3.5.1.5 *Relocation of Summer Homes and Recreational Facilities*

The studies identified approximately 14 summer homes as being within the impact area of the enlarged reservoir. It was proposed these summer homes would need to be relocated downstream of the new dam. Some of the owners opposed downstream relocation.

The enlarged reservoir would inundate existing recreational facilities and eliminate road access to campgrounds above the existing reservoir.

3.5.1.6 *Impacts to the Community of Goose Prairie*

Increased traffic associated with construction activities at the new dam, including logging of the enlarged reservoir area, would have an adverse impact on the community of Goose Prairie. Further, increased recreation use at an enlarged reservoir could also adversely affect the community.

3.5.2 Wymer Dam and Reservoir

The potential Wymer dam would be a concrete rockfill structure across Lmuma Creek approximately 415 feet high, creating a 142,000-acre-foot-capacity reservoir extending from about ¾-mile east of the Yakima River to Interstate 82. The proposal also included construction of a 130-foot-high concrete rockfill dam in a saddle on the north side of the reservoir. The reservoir would be filled by pumping from the Yakima River, with reservoir releases being supplied back to the Yakima River by gravity. The possibility for hydroelectric generation when releasing from the reservoir back into the Yakima River would be a consideration in future work.

The following major resource concerns and issues were raised in regard to constructing a Wymer dam and reservoir:

- Loss of about 1,200 acres of wildlife habitat in the reservoir basin.
- Possible cultural resources inundated by the reservoir.
- Potential for false attraction at the pumping plant of migrating salmonids.

- Pumping energy demands and associated impacts on the region's power resources.

Chapter 4.0 Storage Study Goals

The purpose of this chapter is to describe the goals of the Storage Study and the background of their development. Reclamation developed the following goals and their evaluation criteria in accordance with the congressional authorization and in consultation with other entities.

- Improve anadromous fish habitat by moving the flow regimes of the Yakima and Naches Rivers toward a more natural (unregulated) hydrograph.

- Improve the water supply for proratable irrigation water rights in dry years by providing not less than a 70-percent irrigation water supply during dry years.

- Meet future municipal water supply needs by maintaining a full municipal water supply for existing users and providing additional water supply for population growth to the year 2050.

These three goals are further discussed below.

4.1 FISH HABITAT

To measure potential fish habitat improvement, Reclamation compared the modeled hydrographs of the three alternatives to the current hydrograph. It should be noted the goal is not to quantitatively match the natural (unregulated) hydrograph, but to resemble elements of the natural (unregulated) hydrograph to the highest degree possible, while meeting the dry-year irrigation and municipal water supply goals.

4.1.1 Existing Conditions

Under current Yakima Project operations, streamflows in the mainstem Yakima and lower Naches Rivers often do not reflect the annual flow patterns or the natural (unregulated) hydrograph described below. However, the upper Naches River above the confluence of the Tieton River does currently resemble the natural (unregulated) flow. The upper Naches watershed is mostly unregulated, with Bumping Lake having a small storage capacity relative to the total annual streamflows of the Bumping watershed.

During the summer irrigation season, streamflows in the upper Yakima River generally exceed the estimated unregulated summer low flow, and streamflows in the Yakima River below Sunnyside Diversion Dam are less than the estimated unregulated low flow. The September flip-flop river operations, unique to the Yakima River basin and designed to address upper Yakima spring Chinook spawning and incubation flows, result in decreased in streamflows in the upper Yakima and Cle Elum Rivers, and increased streamflows in the Tieton and Naches Rivers.

A variety of legal requirements exist related to providing and/or maintaining instream flows in the Yakima River basin. Generally, these are based on court orders and Federal legislation related to the Yakima Project. The State of Washington has not established minimum instream flows for the Yakima River basin. Rather, Reclamation determines the volume of water available for the fisheries annually, based on existing prevailing conditions. The State and Federal courts have mandated that Reclamation operate the Yakima Project to reduce impacts to the fisheries resource, treaty-reserved rights for fish, and instream flows to support treaty fishing rights at “usual and accustomed places.” The System Operations Advisory Committee (SOAC) advises Reclamation on an annual basis how to operate the project to meet these mandates.

Instream flows included in Title XII of the Act of October 31, 1994, (Public Law 103-464), are quantified “target flows” at two points in the Yakima River basin (Sunnyside and Prosser Diversion Dams). The legislation provides that the Yakima Project Superintendent shall estimate the water supply, which is anticipated to be available to meet water rights, and provide instream flows in accordance with the Title XII criteria shown in Table 4-1. This operational regime was initiated by the Yakima Project Superintendent in 1995.

Table 4-1. Water Supply Estimates/Instream Flow Targets

Water Supply Estimate for Period (million acre-feet)					Target Flow from Date of Estimate through October Downstream of:	
Scenario	April through September	May through September	June through September	July through September	Sunnyside Diversion Dam (cfs)	Prosser Diversion Dam (cfs)
1	3.20	2.90	2.40	1.90	600	600
2	2.90	2.65	2.20	1.70	500	500
3	2.65	2.40	2.00	1.50	400	400
Less than Scenario 3 water supply					300	300

Title XII target flows do not necessarily provide for a natural (unregulated) ecosystem function and cannot be expected to fully achieve the objectives of enhancing and recovering anadromous fish populations. Title XII target flows at the two control points do not address fish habitat and food web needs at the basin level and thus, by themselves, cannot be expected to lead to recovery of anadromous fish runs.[15]

4.1.2 Desired Conditions

Reclamation made the assumption in this analysis that moving toward a natural (unregulated) hydrograph, as defined in the normative ecosystem concept, can improve fish habitat, and, therefore, provide benefits to fish.

One of the first to introduce the normative ecosystem concept was the Independent Scientific Group (ISG) in *Return to the River* (Williams, *et al.*, 1996). This concept is based on the ecological principles, theory, and empirical observations that, by improving river ecosystem processes and functions, the health of salmonid populations would improve. Improvement means increasing population abundance, productivity, and life history diversity.

The normative ecosystem concept encompasses several key physical elements such as habitat complexity, hydrograph, sediment transport, riparian zone, in-channel large woody debris, and nutrient cycles. The degree to which each of these key elements can be restored toward a more historic condition, the more normative, or natural-like, the river ecosystem will be. Once a more normative ecosystem is established, there would follow positive biological responses, beginning with primary production (*i.e.*, algae and diatoms), followed by aquatic insects, and then the fish community.

In this report, Reclamation is focusing only on the hydrograph element of the normative concept to evaluate the fish habitat goal. Consequently, Reclamation is evaluating how the different alternatives affect the current flow regime in the Yakima River basin in terms of making the existing hydrograph more natural-like. Achieving a more natural-like, or unregulated, hydrograph is only one, albeit important, element to moving toward a more normative river ecosystem (Williams, *et al.*, 1996). Of equal importance is the preservation of existing high value habitat and restoring existing habitat. Furthermore, the Storage Study analysis presented in this report is qualitative in nature and is not designed to define natural (unregulated) flows in the basin in quantitative terms.

[15] *Report on Biologically Based Flows for the Yakima River Basin*, System Operations Advisory Committee, May 1999 (pages 1-4).

Many in the scientific community recognize that a more natural (unregulated) flow regime is a key element to achieving a more normative river ecosystem. Excerpts from several of these sources follow:

- SOAC (1999) states in its report entitled, *Report on the Biologically Based Flows for the Yakima River Basin*:

  "The key to recovering anadromous fish populations in the Yakima Basin is to re-establish lost or altered ecosystem functions within the framework of the 'normative ecosystem concept' (Williams et al., 1996). A normative ecosystem may be described as an ecosystem that biologically sustains all life stages of diverse salmonid populations. Further, the normative ecosystem is not a static target or a single unique state of the river. It is a continuum of conditions from slightly better than the current state of the river at one end of the continuum, to nearly pristine at the other end. (Williams, et al., 1996)."

- Stanford, *et al.*, (2002) in their report entitled, *The Reaches Project: Ecological and Geomorphic Studies Supporting Normative Flows in the Yakima River Basin, Washington*, makes the following summary statements:

  "Through this research effort, we conclude that recovery of salmonid runs in the Yakima is dependent on (1) the provision of normative flows, which we outline, and (2) the protection and enhancement of flood plain habitat."

  "Normative flows would reconnect the Yakima flood plain ecosystem in all three physical dimensions (laterally, vertically and longitudinally)."

- In the *Final Plan, Yakima Subbasin Plan* (2004), the Yakima Subbasin Fish and Wildlife Planning Board (YSPB) states as their second guiding principle:

  "That the quality of water and a near natural timing and quantity of water flow (normative hydrograph) are principle indicators of a healthy river ecosystem."

- Adoption of the normative ecosystem concept is most directly stated under the water quantity goal of the *Interim Comprehensive Basin Operating Plan for the Yakima Project* (Reclamation, 2002):

> *"To develop streamflows in the Yakima River that mimic the unregulated hydrograph in frequency, duration, timing, magnitude; and rate of change to the extent necessary to restore riverine ecosystem processes that support healthy, sustainable native aquatic plant and animal communities; and which also provide for the efficient implementation of other legitimate project purposes."*

For example, a normative, or natural (unregulated), flow pattern or hydrograph for the Yakima River basin shows peak streamflows occurring in the spring with the onset of snowmelt. During the seasonal transition from spring to summer, streamflows would decrease steadily until they reached their base flow in September or October. The onset of fall usually brings precipitation in the form of rain, which causes brief, small increases in streamflows. Below-freezing temperatures dominate during the winter months, resulting in decreased streamflows, which may occasionally spike during the winter due to rain-on-snow events. Generally, throughout the Yakima River basin, spring peak flows are reduced as streamflows are captured in reservoir storage or used for irrigation demand.

4.2 DRY-YEAR IRRIGATION

The reliability of the surface water supply for irrigation use is of concern because of droughts that periodically occur in the Yakima River basin. Current Yakima Project legal, contractual, and operational parameters provide that when there is a deficiency in the available water supply to meet recognized water rights, senior (nonproratable) water rights are served first, and shortages are assessed against junior (proratable) water rights. In recent years, the Yakima River basin has experienced water shortages in 1987, 1992, 1993, 1994, 2001, and 2005. The most severe years were 1994, 2001, and 2005, when proratable water rights received a 37-percent supply (1994 and 2001) and a 42-percent supply (2005).

As a part of the work conducted for the *Watershed Management Plan* during the early 2000s, the Yakima River Basin Watershed Planning Unit and the Tri-County Water Resources Agency examined criteria to evaluate water supply strategies and to estimate the volume of water needed to meet irrigation demands. This included work by Northwest Economic Associates conducted for the Tri-County Water Resources Agency in 1997 and by the Yakima River Watershed Council in 1998. Information from both was circulated to irrigation entities and conservation districts in the Yakima River basin to solicit comments about establishing irrigation water supply reliability criteria. It was the opinion of those responding that if a supply of not less than 70 percent of the proratable water rights could be provided in dry years, major economic losses could be averted.

Reclamation has adopted this criteria for the irrigation water supply goal for the Storage Study. Reclamation will measure all alternatives by their ability to provide a dry-year supply of not less than 70 percent of the proratable water rights. Table 4-2 shows the proratable water rights upstream of the Parker gauge (RM 104.0) for the period April through October (irrigation season).

Table 4-2. Proratable Water Rights

Irrigation Entity	Proratable Acre-Feet Per Year
Major	
Kittitas Division (Kittitas Reclamation District)	336,000
Roza Division (Roza Irrigation District)	375,000
Tieton Division (Yakima-Tieton Irrigation District)	34,835
Wapato Irrigation Project	350,000
Sunnyside Division (Sunnyside Valley Irrigation District and others)	142,684*
Subtotal	**1,238,519**
Others	**Proratable Acre-Feet Per Year**
Westside Irrigation Company	8,200
City of Ellensburg	6,000
Selah-Moxee Irrigation District	4,281*
Union Gap Irrigation District	4,642
City of Yakima	6,000
Naches-Selah Irrigation District	4,486
Yakima Valley Canal Company	4,305
Other entities (9)	3,441
Subtotal	**41,355**
Total	**1,279,874***

*Numbers reflect Reclamation's irrigation proratable allocations from a tabulation dated April 29, 1994.

Using the above total proratable water rights, a 70-percent irrigation water supply would be 896,000 acre-feet. In a dry year (such as 1994 and 2001) when the proratable supply was 37 percent (474,000 acre-feet), an additional 422,000 acre-feet would be needed to meet the 70-percent irrigation water supply criterion.

4.3 MUNICIPAL

Communities in the Yakima River basin presently rely primarily on groundwater (83 percent) and some surface water to meet current municipal and domestic water needs. These systems include large and small public water systems, individual household wells, and wells provided by self-supplied industrial users. As discussed in section 3.4.3.3, the year 2000 estimated municipal and domestic water use in the Yakima River basin from groundwater and surface water resources is about 104,000 acre-feet. The projected municipal and domestic water needs in year 2050 from Yakima River basin surface and groundwater sources is about 186,000 acre-feet; an increase of 82,000 acre-feet from year 2000.

Presently, only the cities of Cle Elum and Yakima divert and treat Yakima River basin surface water for municipal and domestic purposes; groundwater is considered the preferred water source to meet future needs. In preparing the *Watershed Management Plan*, the Yakima River Basin Watershed Planning Unit and Tri-County Water Resources Agency assumed the increased need would be met by surface water withdrawals. This approach was adopted because there is a potential connectivity of surface and groundwater. This approach takes into account the volume of surface water, which could mitigate groundwater withdrawals by the release of water from storage facilities, if it is determined necessary and/or required by State law.

Assuming a 1-to-1 groundwater-to-surface water mitigation, 82,000 acre-feet could be required for mitigation. On the other hand, assuming mitigation is not necessary, and only those presently using surface water as their municipal and domestic water supply (cities of Cle Elum and Yakima) would do so in the future, the additional surface water needs are estimated at about 10,000 acre-feet. As more information regarding surface and groundwater connectivity becomes available, Reclamation will work with local and State entities to develop a strategy regarding the volume and priority of future municipal and domestic water demand. This issue will be addressed further in the Plan Formulation Phase.

Chapter 5.0 Water Rights

This chapter delineates the history of water rights as they relate to the Yakima Reclamation Project.

5.1 YAKIMA RECLAMATION PROJECT WATER RIGHTS

The Bureau of Reclamation is directed to acquire water rights under prevailing state water law under Section 8 of the 1902 Federal Reclamation Act. For projects proposed under the 1902 Act, the United States has a unique status under Washington State law.

In 1905, the Washington legislature enacted Chapter 90.40 Revised Codes of Washington State (RCW) to facilitate construction of the Yakima Project and other Reclamation projects in Washington. The statute allows the withdrawal of public waters from appropriation upon request of the Secretary of the Interior. Upon notice to the State that the United States intends to make examinations or surveys for the use of certain specified waters, those waters are not subject to appropriation by others for a period of 1 year from the date of the notice. If the United States certifies in writing within the 1-year period that the project contemplated in the notice appears to be viable and investigations will be made in detail, the waters continue to be withdrawn from appropriation for 3 years and such further time as the State may grant by extension. During a withdrawal, state law prevents adverse claims to that water except where formally released in writing by the United States.

At such time as a construction contract is let for storage of irrigation water, the United States may appropriate that volume of the withdrawn or reserved water as is necessary for the storage project ". . . in the same manner and to the same extent as though such appropriation had been made by a private person, corporation or association" (RCW 90.40.040). The priority date of such appropriation relates back to the date of the withdrawal or reservation.

5.2 MAY 10, 1905, WITHDRAWAL

Using the provisions of Chapter 90.40 RCW, the Secretary of the Interior withdrew all the unappropriated waters of the Yakima River and tributaries for benefit of the proposed Yakima Reclamation Project. The withdrawal was effective from its May 10, 1905, initiation to its December 31, 1951, expiration.

In that span of 45 years, water rights were established under Washington law for the developed project facilities. The Acquavella adjudication, commenced in 1977 in Yakima County Superior Court, will determine and quantify the rights of the Bureau of Reclamation.[16]

Of the six major storage dams and reservoirs which comprise the Storage Division of the Yakima Project, the Bumping Lake storage facility is an anomaly with respect to water right status. Applications for storage rights on all reservoirs were filed with the State in 1930. Certificates of water right were subsequently issued under a May 10, 1905, priority for all reservoirs except Bumping Lake. This storage reservoir was held in permit status (Permit R-100) for the developed capacity of about 38,768 acre-feet. This status was prompted by the United States' intent to enlarge the Bumping project.

On December 29, 1951 (prior to expiration of the 1905 withdrawal), the United States filed application 10948 with the State to increase the reservoir capacity to 188,000 acre-feet for irrigation, power and domestic use. The application contained the remark: "*The priority date of May 10, 1905, is applicable to this planned development*." The application was amended in 1958 to increase the proposed storage to a total of 400,000 acre-feet and to add the preservation and propagation of fish as a purpose of use. The application is currently in active status.

The Acquavella Court has stated its intent to confirm a storage water right for the Bumping Lake facility as it currently exists.[17] If Reclamation enlarges Bumping Lake under the pending application, Washington Department of Ecology may elect to combine the existing and enlarged storage capacity into one state water right certificate. Alternatively, Ecology may keep the two rights separate–one certificate of adjudicated water right for the first 38,768 acre-feet, and a certificate of water right for the balance, once developed. In either case, Bumping Lake storage would have a May 10, 1905, priority and could be seamlessly integrated into current Project operations.

Bumping Lake enlargement would proceed under the existing permit and would have a May 10, 1905, water right. Reclamation anticipates the conditional final order of the Acquavella adjudication will maintain the right to fill, release from, and refill this reservoir to store and control available water without limitation to the static capacity of the reservoir.

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[16] The Report of the Court concerning the water rights for the United States, Bureau of Reclamation (State v. Acquavella, *et al.*) was issued April 14, 2005. Reclamation expects the Bumping Lake right of 38,768 acre-feet to be included in the court's conditional final order to be issued this year.

[17] April 14, 2005, Report of the Court.

5.3 February 17, 1981, Withdrawal

In a February 13, 1981, letter to the Washington Department of Ecology, referenced "Withdrawal of Waters for Yakima River Basin Enhancement Study," Reclamation filed notice that it ". . . intends to make examinations and surveys for the utilization of the unappropriated waters of the Yakima River and its tributaries for multipurpose use under the Federal Reclamation laws." By this notice, Reclamation withdrew surface water of the Yakima River basin from appropriation. Reclamation's 1981 withdrawal did include a "blanket" exception for all domestic diversions of 25 gallons per minute or less.[18] The State considered this withdrawal to be linked to the Yakima River Basin Water Enhancement Project, which has the goal of improving the Yakima River basin water supply for irrigation, fish, and wildlife.

Reclamation certified on January 16, 1982, that the project was feasible and that investigations would be made in detail. Pursuant to RCW 90.40.030, this certification of feasibility continued the withdrawal until January 18, 1985.

State law allows Ecology to extend a withdrawal upon application by the United States and publication of legal notice in newspapers in the project location (in this case, Kittitas, Yakima, and Benton Counties). The United States consistently requested extensions in 5-year increments in the intervening years.

Not all extensions were without controversy. In January 1984, the United States requested a 5-year extension and published notice in Kittitas and Yakima County newspapers. Two Kittitas County residents filed objections to the extension request on numerous grounds. The Department of Ecology denied the objections and granted the extensions on July 29, 1986. The Ellensburg Water Company appealed Ecology's grant of the extension to the State Pollution Control Hearings Board (PCHB). The PCHB affirmed the extension, but found the administrative process deficient for failure to publish notice in Benton County. The Order was remanded for proper publication of notice and a redetermination by the Department of Ecology.

The most recent extension request was filed by the United States on April 9, 2002. By Order dated March 7, 2002, the Department of Ecology determined that ". . . the time within which the United States is required to complete plans for the utilization of the withdrawn waters of the Yakima River and its tributaries and file applications for permits for the appropriation thereof be and is hereby extended to the 18th day of January, 2008."

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[18] By State statute, a notice of withdrawal is effective as of the date of receipt, which was February 17, 1981, in this instance.

5.4 RELATIONSHIP TO YAKIMA BASIN STORAGE PROJECTS

The current withdrawal of Yakima River basin unappropriated surface water is for benefit of the YRBWEP program. While the current YRBWEP Act does not authorize new storage reservoirs, it does authorize investigations into storage as a way to augment project supply.[19] To build additional storage, Reclamation will require Federal authorization, either through a "Phase III" YRBWEP Act, or through another congressional authorization. In either case, new storage to meet all the needs of irrigation and anadromous fish restoration would qualify for state water rights under this withdrawal.

[19] Title XII of the Act of October 31, 1994 (Public Law 103-434), authorized the *Basin Conservation Plan* and other measures. This Act is commonly referred to as Phase II of YRBWEP.

Chapter 6.0 Yakima River Basin Storage Alternatives Characteristics

The description of project facilities of individual storage alternatives contained in this chapter is a compilation and summary of information found in prior study reports. Many of these reports are cited and discussed in Chapter 3.0, "Prior Yakima River Basin Storage Studies." A "References" section listing the reports used as source material for this document is included at the end of this report.

6.1 BUMPING LAKE ENLARGEMENT

6.1.1 Site Characteristics

6.1.1.1 *Location*

The potential damsite is about 40 miles northwest of the city of Yakima on the Bumping River. It is within the Snoqualmie National Forest in Yakima County and is located about approximately 4,500 feet (0.85 mile) downstream from the existing Bumping Lake Dam and Reservoir.[20] The general and site-specific locations are shown in Figure 6-1 and Figure 6-2.

6.1.1.2 *Topography*

The damsite is in a deep, steep-walled erosional canyon at an elevation of about 3,350 feet. The width of the valley floor at the damsite is about 2,500 feet.

6.1.1.3 *Geology*

The Bumping River valley is a typical erosional valley which has been modified by the action of alpine glaciers. The glacial deposits consist mostly of an unsorted mixture of boulders, cobbles, gravel, and sand, with some silt. Exposures of hard, sound volcanic flows occur at various places along the valley walls.

[20] The existing dam was constructed in 1909-1910 at the outlet of a natural lake located 16.6 miles upstream from the confluence of the Little Naches River.

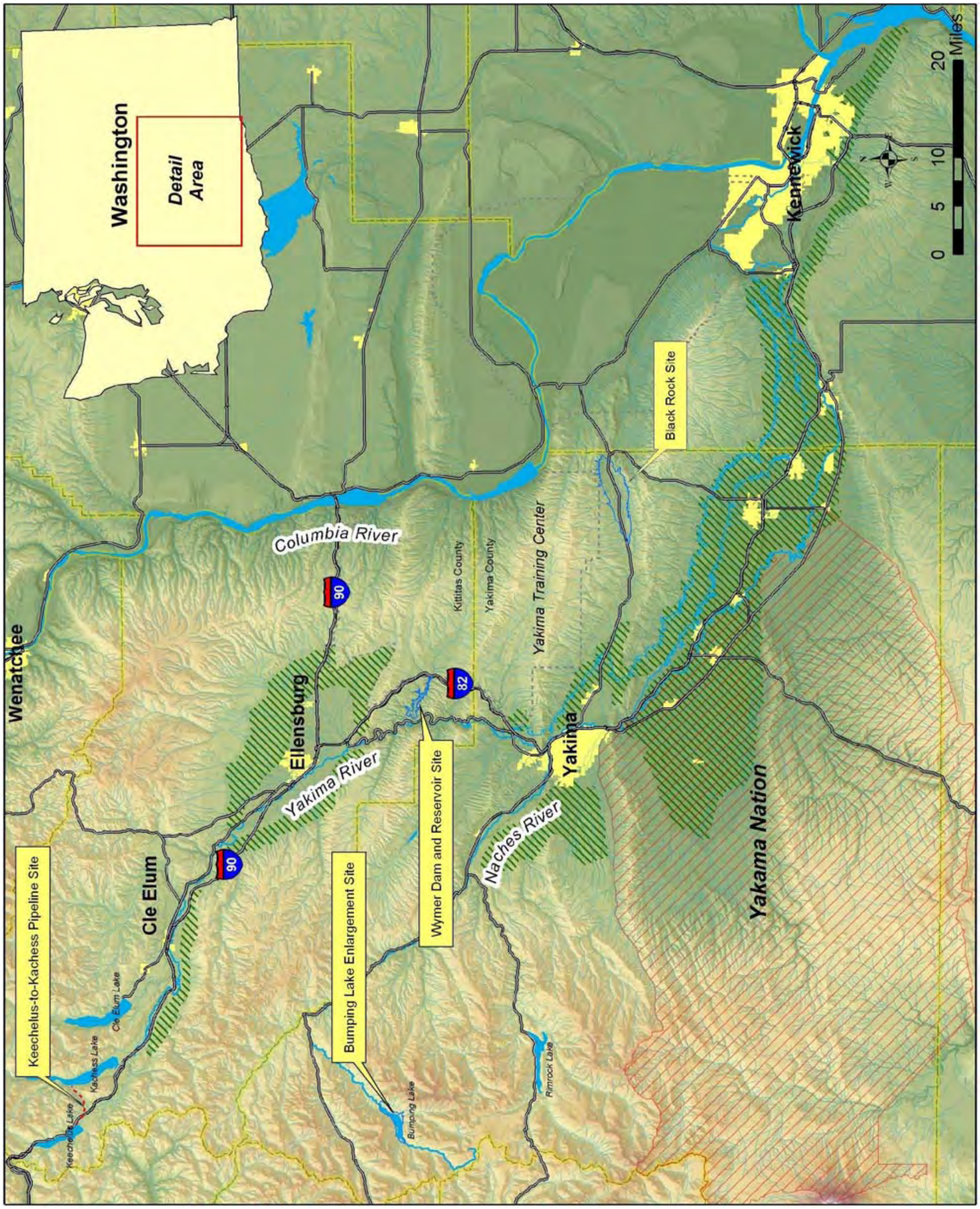

Figure 6-1. Overview of Yakima River Basin

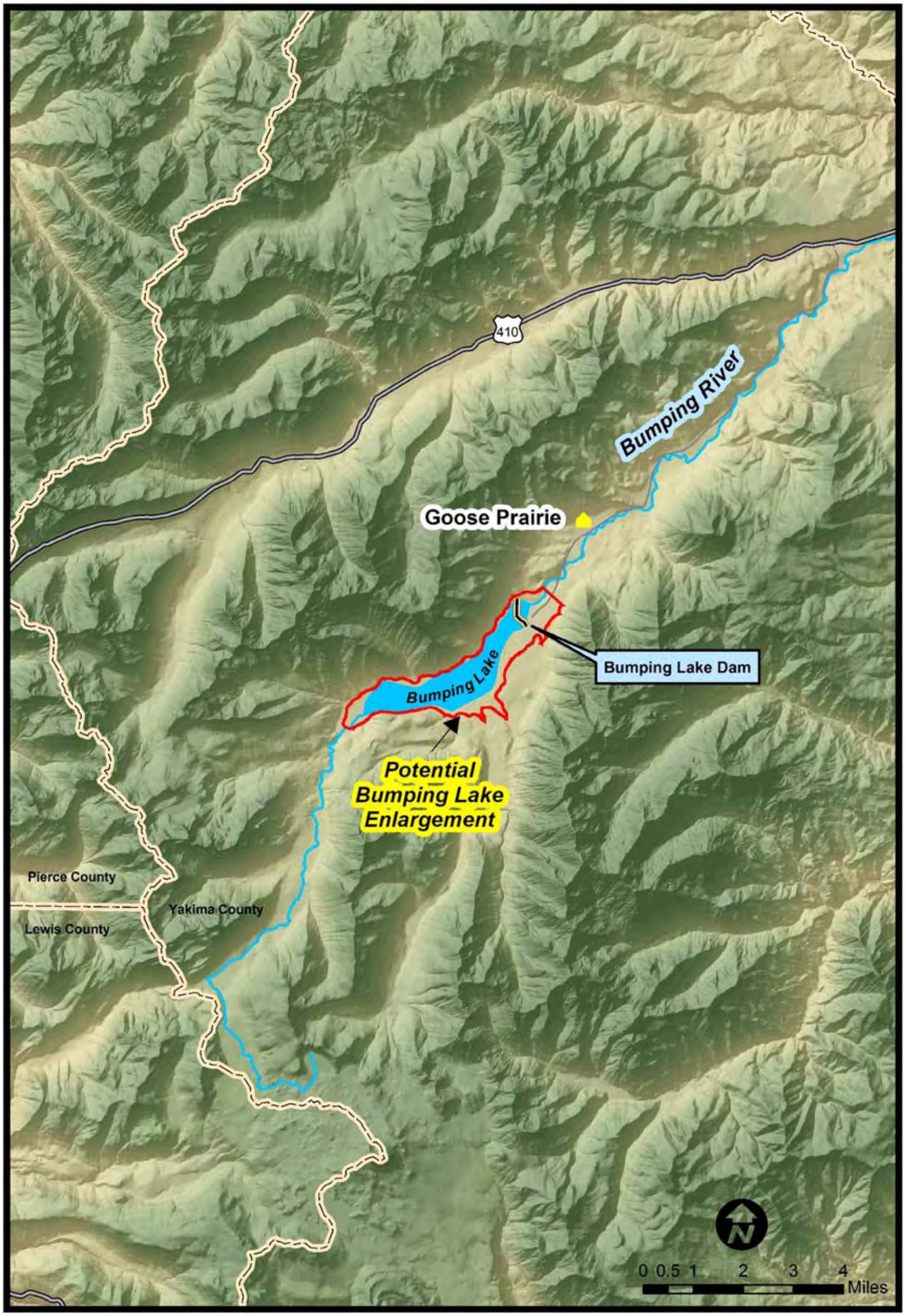

Figure 6-2. Bumping Lake Enlargement Location Map

Site investigations date to 1940, when the Corps of Engineers drilled two foundation exploration holes in the valley section of the damsite to depths of about 100 feet. Reclamation drilled one hole to a depth of 200 feet in the fall of 1951, and eight holes in the summer and fall of 1952. One test pit was dug at the site in 1951, and six pits were dug in prospective borrow areas during 1952. Subsequent to 1953, there were various reviews and updating of the geologic data, including the following: In 1963, an area within the reservoir basin was explored for pervious and impervious materials; in 1973, the seepage loss estimates in the glacial materials beneath the damsite were reviewed; and, in 1976, a reconnaissance examination for riprap sources was conducted. In addition, several geologic reports have been published by the U.S. Geological Survey (USGS) that include the Bumping Lake area.

In 1983, the Yakima River Basin Water Enhancement Project (YRBWEP) Damsite and Structure Review Team recommended explorations to determine depth and characteristics of the deep valley fill and explorations at the site of the spillway stilling basin. However, due to funding constraints, only a seismic refraction survey was conducted in an attempt to determine the depth of the alluvial material in the valley section of the damsite.

6.1.1.3.1 Damsite Geology. Past investigations indicate the major bedrock formation underlying the damsite is the Ohanapecosh formation of Eocene age, consisting mostly of a complex layered sequence of volcanic tuff, breccias, and andesitic lava flows. The Ohanapecosh formation has been intruded and cross-cut by younger volcanic dikes, plugs, stocks, and sills. This bedrock sequence is present on the right abutment of the damsite where it is mantled by talus cones and glacial deposits ranging from 12 to 136 feet thick.

The valley floor section of the damsite consists of glacial till and outwash interbedded with alluvial sediment deposited by the Bumping River. Test drilling in seven holes across the valley section in 1952 indicate that these deposits are at least 200 feet thick, as none of the holes intercepted bedrock. A seismic refraction survey performed at the damsite in 1984 identified a significant velocity change at about 250 feet in depth, which was interpreted to be the top of bedrock. The drill hole information generally shows that the glacial deposits and alluvium consist of differing layers of silt, sand, gravel, cobbles, and boulders, with the finer-grained materials occurring at depth. These layers do not correlate well between drill holes. It does appear, however, there may be layers of fine, clean sand up to several tens of feet thick present within the foundation of the damsite that could be susceptible to liquefaction during ground shaking caused by large earthquakes. Additional testing, using newer technology not available in the 1950s, is needed to evaluate the liquefaction potential of the site, if the Bumping Lake enlargement option is carried forward to the feasibility study.

Dam safety investigations conducted for Bumping Lake Dam in the 1990s identified the presence of a widespread mudflow deposit within the foundation of the existing dam. This mudflow deposit consists of low-density volcanic ash mixed with fine-grained sediment and organic debris, including charred logs and trees. This material is unsuitable as a foundation material for the dam. The logs of the 1950s drill holes suggest that the mudflow material may also be present at the enlargement damsite. Additional investigation would be required to determine the presence and extent of any potential mudflow debris at the site.

The left abutment of the damsite consists of a hard, competent andesite exposed in a high, steep slope extending about 250 feet above the river. This outcrop of andesite is part of a large (1 mile square) erosional remnant of an intercanyon lava flow that, at one time, extended for many miles in the Bumping River valley. The thickness of the flow is not exactly known, but extends in depth to at least 50 feet in the test holes completed on the abutment. Thin veneers of glacial till and talus are present across the abutment. The geology of the deeper abutment is not known at present, but glacial deposits and alluvium likely underlie the andesite as well as the Ohanapecosh formation.

The permeability of the glacial till formation, based on the 1952 drill hole permeability tests, suggest that an isotropic permeability value of 35,000 feet per year, applied to the entire cross-section of the aquifer, is appropriate and reasonable. This permeability value gives a seepage loss estimate from a full reservoir pool of 80 to 100 cfs under the dam design concept used for this site. This seepage loss is high, and additional testing at the site, using newer technology not available in the 1950s, would be needed to verify that the 1952 data is valid and realistic for this type of foundation.

6.1.1.3.2 Spillway and Outlet Works Geology. The spillway and outlet works, under the dam design concept used for this site, would be founded on the competent andesite flow of the left abutment, except for the stilling basin, which may be founded on glacial till. Even though the geologic section of the spillway shows a steep drop-off of bedrock into the stilling basin area, the spillway alignment should not be changed until some exploration can clarify the geology of this area.

6.1.1.3.3 Reservoir Geology. The reservoir site is rather narrow and is flanked on both sides by steep canyon walls that rise more than 3,000 feet above the valley floor. The valley floor ranges between 2,500 to 4,500 feet in width.

Few exposures of bedrock exist in the valley floor, but outcrops of andesite, basalt, dacite, tuff, and granite have been noted on the valley walls. Lava flows appear to be horizontal, and some are more than 100 feet thick. Exposures appear to be only lightly weathered, intensely jointed, and hard.

Nearly all the valley floor contains alluvial and glacial deposits of varying thicknesses. Thickness at the damsite is estimated to be 250 feet. Material exposed in cuts range from boulders several feet wide to cobbles, gravel, sand, silt, rock flour, and clay. Layers and lenses of stratified materials indicate that glacial-melt waters sorted portions of the deposits dropped by the ice, leading to some degree of stratification.

It is not anticipated an enlarged reservoir would affect the rim stability or water-holding capability of the reservoir.

6.1.1.3.4 Construction Materials. In 1962, explorations were made for a construction materials borrow area within the enlarged reservoir basin. The borrow area is located on Deep Creek, on the right side of the valley, about 2½ miles upstream from the enlargement site. The explorations indicate about 70 million cubic yards of sand and gravel for pervious fill and silty sand and gravel for impervious fill occur within 50 feet of the surface.

A reconnaissance geologic field review of potential sources of riprap was made in August 1976. The best source identified is from a large exposure of rock and talus about ½-mile upstream of the left abutment at, or just above, the potential reservoir pool level. The talus contains an estimated 200,000 cubic yards of suitable rock, and the andesite bedrock could be quarried for additional riprap.

6.1.1.3.5 Further Geologic Investigations. Additional geologic-related studies identified in the October 1984 *Addendum Geologic Report* (Reclamation, 1984) are noted below:

- The main geologic concern at the damsite is the glacial/alluvial sequence that forms the foundation for the major portion of the dam. Explorations (5 or 6 drill holes) would be needed to determine the engineering characteristics of the glacial materials. This may include standard penetration tests, undisturbed samples, and percolation tests. One hole would be needed on the left abutment to determine the depth of the andesite flow and to obtain information on the contact between the flow and the underlying formation.

- Spillway and outlet works explorations are recommended and would depend on the size and exact location of the structure. The foundation conditions at the stilling basin site need to be resolved in any potential exploration program.

- Further explorations, by backhoe and/or drilling, on an established grid system are needed in the potential borrow site for determining exact classification and volume of the pervious and impervious earthen materials. Riprap sources should be further defined, surveyed, and sampled.

- Additional studies completed after the 1984 report indicate that an unsuitable mudflow deposit may be present as a surface mantle across the damsite. Further investigation would be needed to determine if the mudflow is present and, if so, the extent of the deposit across the foundation of the dam.

6.1.1.4 *Groundwater*

A detailed investigation of the groundwater occurrence at the reservoir site has not been conducted. Information collected from the 1952 drill holes indicated a groundwater table depth of about 22 feet adjacent to the Bumping River, and about 53 feet near the right abutment on the damsite axis. Drilling was not conducted on the left abutment of the damsite.

6.1.1.5 *Seismotectonics*

Due to the close proximity of the enlargement site to the existing Bumping Lake Dam, current seismic hazards analyses for the existing dam are applicable to the potential damsite. The most recent evaluation of seismic hazards for the area was summarized in the *Comprehensive Facility Review* (CFR) *for Bumping Lake Dam* (Reclamation, 2001). Geomatrix Consultants completed a seismotectonic study of the Yakima area, including Bumping Lake Dam, for Reclamation in 1988. A seismic hazard analysis was performed by URS Greiner Woodward Clyde for the CFR (Wong, *et al.*, 2000). These reports form the basis for the following discussion of seismicity for the Bumping Lake enlargement. Dam safety modifications to address seismic issues at the existing Bumping Lake Dam were completed in 1995 by Reclamation.

Seismic sources incorporated into the preliminary seismic hazard analysis include 19 fault sources within about 100 km of the dam—megathrust and intraslab sources associated with the Cascadia subduction zone; three seismic sources in the Cascade range; and four background or random regional source zones. Because Bumping Lake is far from any active faults, both the peak horizontal acceleration and the 1.0-sec spectral acceleration hazards are dominated by the closest regional source zone, the Yakima fold and thrust belt, and/or the Cascadia sources. For Bumping Lake Dam, the estimated high-frequency hazard is 0.36 g for a return period of 10,000 years, and 0.55 g for a 50,000-year return period (Reclamation, 2001). A review of the seismic hazard for the Yakima fold and thrust belt source would be required if the Bumping Lake enlargement alternative is carried forward into the feasibility study.

6.1.1.6 *Probable Maximum Flood*

Reclamation (1985) reported Probable Maximum Floods (PMFs) under three scenarios (see Table 6-1). Reclamation assumed the reservoir is full to the top of the active conservation capacity at the beginning of the flood event, and that both the spillway and outlet works are available to pass the flood flows.

Table 6-1. Probable Maximum Flood Characteristics

Event	Peak Discharge (cfs)	Volume (acre-feet)
Early cold season general rain-on-snow with frozen ground	43,620	110,540 (7-day)
Spring-early summer general rain with spring snowmelt	34,650	101,820 (7-day)
Summer thunderstorm with 100-year antecedent storm	73,430	34,160 (2½-day)

Reclamation determined the inflow design flood for Bumping Lake enlargement is equivalent to the PMF, which produces the highest reservoir water surface elevation. Based on the dam design concept used for this site, the inflow design flood is the early cold season rain-on-snow with frozen ground event, which has a peak of 43,620 cfs and a 7-day volume of 110,540 acre-feet.

A 100-year frequency flood was developed for use as an antecedent flood for the summer thunderstorm PMF. It has a peak of 17,545 cfs and a 24-hour volume of approximately 5,400 cfs.

Should Bumping Lake enlargement be carried forward in the Storage Study, it is recommended a new design flow analysis be conducted.

6.1.2 Project Facilities

The *Planning Design Summary* presented the results of the appraisal-level designs and cost estimates of a 230-foot-high dam (crest elevation 3580.0 feet), storing 458,000 acre-feet at elevation 3560.0 feet (top of normal full pool), with a reservoir surface area of 4,120 acres.[21] Two alternatives for the dam embankment

[21] This is the active capacity and includes 424,300 acre-feet of new storage and 33,700 acre-feet of replacement storage for existing Bumping Lake. Reservoir capacities from 250,000 acre-feet to 458,000 acre-feet were considered in the planning investigations of the mid-1980s discussed in section 3.2 of this report.

design were evaluated. The basic difference between the two was the foundation treatment used to control seepage. Alternative I was a zoned rockfill dam with a concrete cutoff wall into bedrock in the foundation. Alternative II was an earth-fill dam with an upstream blanket. Both alternatives included an uncontrolled overflow crest spillway with chute and stilling basin on the left abutment and an outlet works tunnel and gate chamber in the left abutment.

Reclamation found Alternative I (zoned rockfill dam) to be the preferred design. For this reason and, given the preliminary status of the design, the description below of project facilities is limited to Alternative I. The primary physical characteristics of this alternative are shown in Table 6-2 and in Figure 6-3.

Table 6-2. Bumping Lake Enlargement Physical Characteristics

Item	Data
Dam (Zoned Rockfill)	
Height	230 feet
Crest elevation	3580 feet
Crest length	3300 feet
Crest width	30 feet
Reservoir	
Total capacity	458,000 acre-feet
Maximum water surface elevation	3574.2 feet
Surface elevation normal full pool	3560.0 feet
Surface area	4,120 acres
Lands to be secured	2,800 acres

6.1.2.1 *Dam Alignment*

The damsite is located at a constriction in the valley floor. Hard, competent andesite forms the left abutment and extends about 250 feet above the river, and a competent porphyritic dacite forms the right abutment. This alignment utilizes one of two low saddles on the left abutment for the spillway. The outlet works tunnel and gate chamber will be located in this same andesite flow on the left abutment, except at the stilling basin. A total of 11 drill holes were completed at the site in 1940 and 1952 for evaluation of depth to bedrock, foundation permeability, depth to groundwater table, etc. One seismic refraction line was run in 1984 to confirm the previous estimates of depth to bedrock closer to the river. Additional exploration at the damsite will be required before final design to better determine the engineering characteristics of the bedrock and the glacial materials.

6.1.2.2 *Dam Foundation*

The 2,500-foot-wide valley floor consists of glacial deposits, layers of silt, sand, gravel, cobbles, and boulders up to 250 feet in total thickness. A study of the permeability of these materials indicates total dam under-seepage would be 80 to 100 cfs. For seepage control, a concrete cutoff wall located beneath the control core of the dam and extending 2 to 3 feet into bedrock is recommended. Additionally, downstream relief wells are to be provided, spaced about 100 feet apart. The wells would penetrate to bedrock or to a maximum depth of 200 feet.

Liquefaction, or excessive deformation of the foundation material caused by earthquake loading, is a concern. It appears that layers of clean, fine sand up to 30 feet thick may exist in the foundation. The susceptibility of these layers to liquefaction must be determined for final design. Other damsite foundation concerns which need to be resolved with field explorations are additional permeability testing of the glacial deposits at the damsite, evaluation of the groundwater table, and determination of the depth to bedrock between the left abutment and the left end of the seismic refraction line surveyed in 1984. Further evaluation is also needed to define the presence and extent of a mudflow observed at the existing dam upstream of the enlargement site. This information will be required to proceed with final design.

6.1.2.3 *Dam Structure*

A zoned rockfill dam with concrete cutoff walls is proposed, based on serious concern of seepage through the dam foundation. Various other factors such as the width, depth, and variability of the glacial deposits in the foundation, the 210 feet of reservoir head to be controlled, and the 458,000 acre-feet of reservoir storage, favor the zoned rockfill dam design.

The embankment design consists of two primary zones—the central zone 1 impervious core and the upstream and downstream zone 2 rockfill sections. A transition zone on the core upstream face and a filter zone on the downstream face are provided.

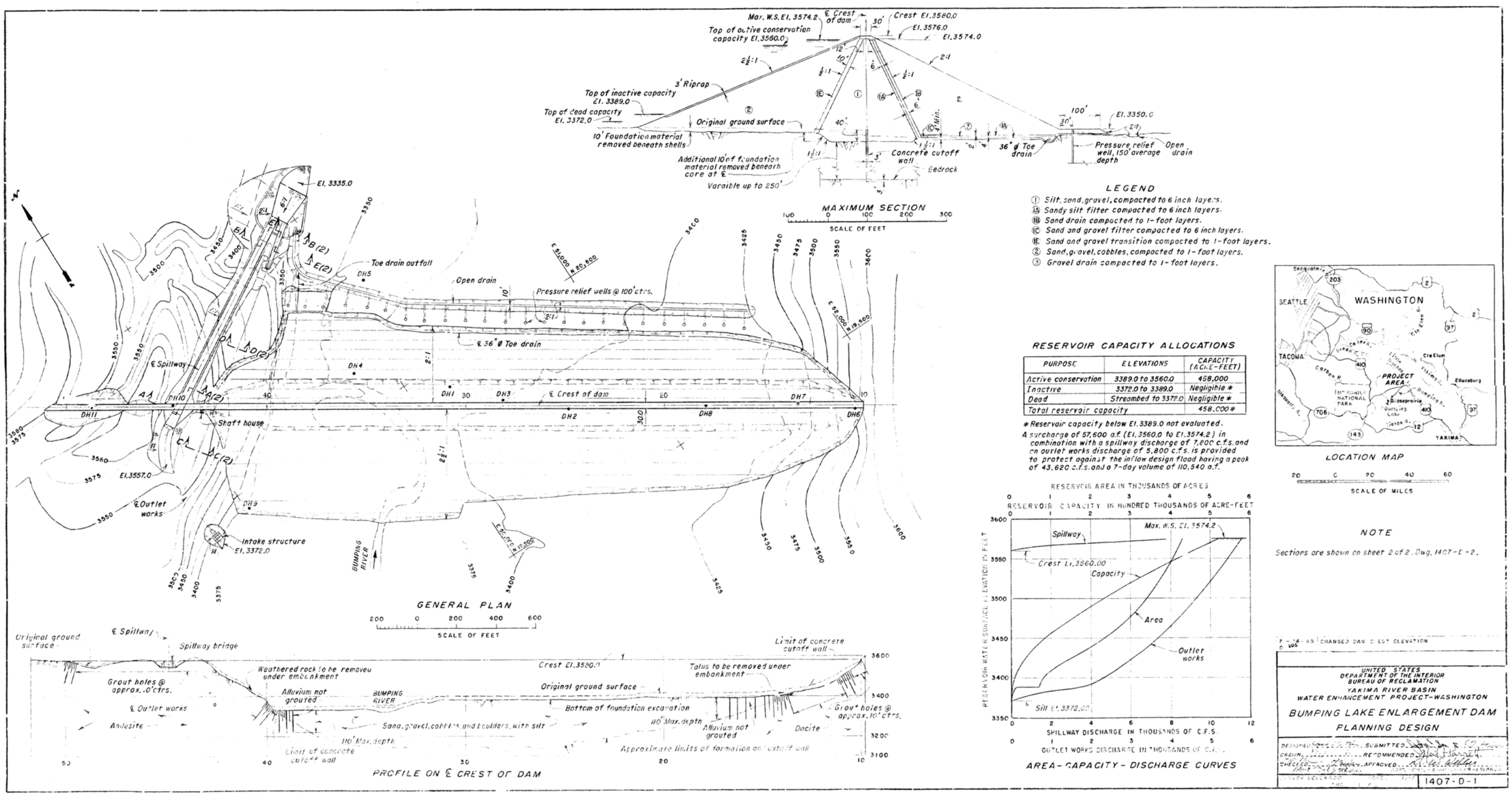

Figure 6-3. Bumping Lake Enlargement Planning Design (1985).

The 1985 *Planning Design Summary* called for excavation of 10 feet of surface foundation material beneath the rockfill zones, and 20 feet of material beneath the zone 1 core due to unknown density of the glacial foundation materials and earthquake loading concerns.

Riprap is required for almost the entire upstream slope. The reservoir would have a gently curving fetch of about 5 miles, with the dam at the northeast end. A freeboard of 8.8 feet is provided above the maximum water surface elevation. Due to the coarseness of the zone 2 material, no bedding is considered necessary beneath the riprap, but filter requirements would need to be verified.

6.1.2.4 *Reservoir*

Bumping Lake would be enlarged to a total capacity of 458,000 acre-feet at elevation 3560.0, as compared to the present reservoir capacity of only 33,700 acre-feet at elevation 3426.0. The existing dam would be breached following construction to allow full use of the existing pool. The enlarged reservoir would inundate up to 4,120 acres of land, of which 1,300 acres are in the existing reservoir. The reservoir would extend 5½ miles upstream and create an additional 17 miles of shoreline. All required rights-of-way would be within the Snoqualmie National Forest.

6.1.2.5 *Spillway*

The spillway consists of a 40-foot-wide concrete overflow crest, open chute, and hydraulic jump stilling basin located on the left abutment of the dam. This location is subject to further investigation since geologic reports suggest the stilling basin may be founded on glacial till rather than bedrock.

The spillway design capacity is 7,800 cfs which, in combination with an outlet works capacity of 5,800 cfs and a flood surcharge of 57,600 acre-feet, would be capable of accommodating the inflow design flood with a maximum water surface elevation of 3574.2 feet. A combined outlet channel for both the spillway and the outlet works would be required to carry discharges to the Bumping River.

6.1.2.6 *Outlet Works*

The potential outlet works consist of a trash-racked, single-level intake structure; an 11-foot-diameter circular tunnel with a gate chamber; a chute; and a hydraulic-jump stilling basin. These works would be located at the dam's left abutment.

Design criteria for the outlet works required downstream irrigation and fish enhancement reservoir releases for the entire year. Reservoir releases in June and July for irrigation purposes represented 58,000 acre-feet in 30 days with 125,000 acre-feet of storage, or 74,000 acre-feet in 30 days with 242,000 acre-feet of storage. Diversion during construction required an estimated discharge of 800 cfs, based on the capacity of the outlet works for the existing dam upstream. All of these requirements are met by the outlet works design having a capacity of 5,600 cfs at the top of active conservation capacity at elevation 3560.0 feet.

6.1.2.7 *Existing Bumping Lake Dam*

The existing Bumping Lake Dam is located approximately 4,500 feet upstream from the potential enlargement dam and was completed in 1910. The dam is a puddle core earthfill structure having a structural height of 61 feet and a crest length of 2,925 feet at elevation 3435.4 feet. The outlet works consists of a concrete conduit through the base of the dam, and includes two 5-foot-square regulating gates and two 5-foot-square guard gates located in a concrete intake tower. A concrete chute spillway with a downstream timber flume is located at the left end of the dam. Dam safety modifications to Bumping Lake Dam were completed in 1995 for seismic concerns and included the construction of upstream and downstream stability berms and modifications to the outlet tunnel conduit. These structures would be inundated by the enlarged reservoir.

The existing dam would be breached after construction of the downstream enlargement dam. Complete removal of the existing structure is not believed necessary because of expected infrequent exposure.

6.2 Wymer Dam and Reservoir

6.2.1 Site Characteristics

6.2.1.1 *Location*

Wymer dam and reservoir would be situated in Lmuma Creek Canyon, approximately 15 miles north of Yakima. The general and site-specific locations are shown in Figure 6-1 and Figure 6-4. Two potential damsites were initially considered--an upper site located about 1½ miles upstream of the confluence with the Yakima River, and a lower site about ¾-mile from the confluence. The upper site envisioned a 515-foot-high embankment dam with a crest elevation of 1873 feet, a crest length of about 4,600 feet, and a reservoir capacity of 320,000 acre-feet. However, this would require relocating the west- and east-lane bridges of Interstate Highway 82 crossing Lmuma Creek. Consequently, interest shifted to the lower damsite.

Wymer dam and reservoir would be an off-channel reservoir extending upstream about 6 miles on Lmuma Creek and about 2 miles on Scorpion Coulee Creek. The volume of water available from Lmuma Creek is minimal, and the reservoir

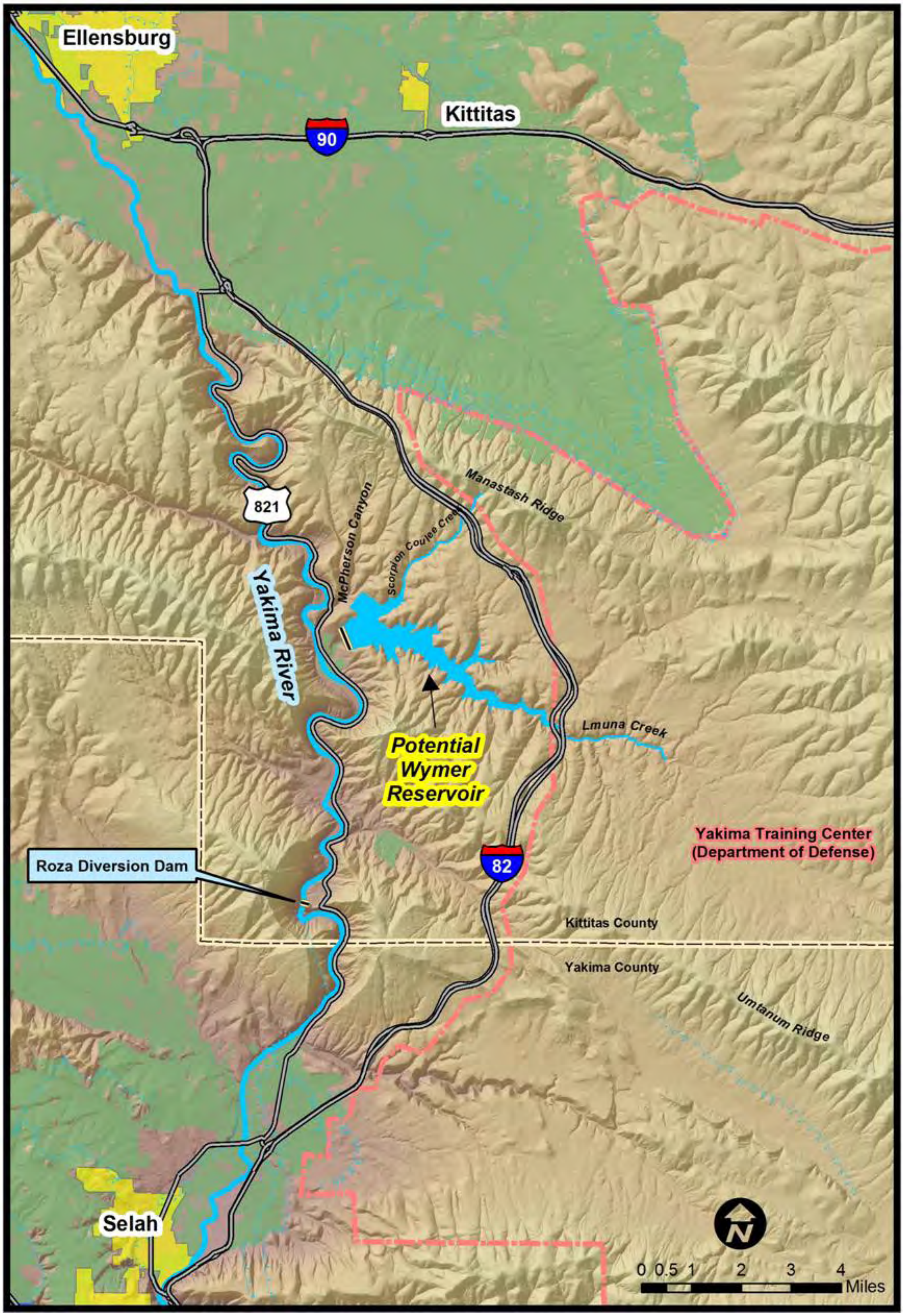

Figure 6-4. Wymer Dam and Reservoir Location Map

would have to be filled primarily by pumping from the Yakima River when flows exceed downstream target flows and irrigation demands.

6.2.1.2 *Topography*

In the Lmuma Creek Canyon area, the sagebrush-covered hills form a broad, plateau-like feature between the Yakima River Canyon to the west, the Manastash Ridge to the northeast, and the Umtanum Ridge to the south. These and other northwest-trending smaller ridges influence the drainage patterns.

6.2.1.3 *Geology*

Geologic investigations of the Lmuma Creek Canyon area were undertaken in 1984 and in 1985 (Reclamation, 1984). The earlier work was done at the upper damsite and consisted of geologic mapping of the area, drilling one core hole on each abutment of the upper damsite to determine the characteristics of the bedrock, visual reconnaissance of possible borrow sites, and a literature search of all pertinent geologic data of the area.

Geologic explorations at the lower site were made in 1985 and are described below.

The Miocene Yakima basalt subgroup is the bedrock for the engineering structures being considered. The subgroup in this area consists of (from older to younger) the Rocky Coulee member, the Museum member, the Vantage sandstone interflow, and the Frenchman Springs member. Most of the lower basalt lava flows (locally called pre-Vantage) are competent rocks, even though some sections are weathered and contain much soft palagonite. The Vantage sandstone interflow zone is of main concern, and occurs on the upper parts of the canyon walls. This zone is about 70 feet thick and consists of friable, poorly cemented sandstone, claystone, and siltstone with variable quantities of organic materials. Along the canyon walls, some small landslides are common in the Vantage sandstone.

Talus and slopewash cover much of the valley sides from a few feet up to an estimated 10 feet deep. Along the Lmuma Creek valley bottom, the alluvival materials are approximately 20 feet deep.

6.2.1.3.1 Damsite Geology. In the damsite and dike areas, the lava flows dip gently southwestward. Much of the canyon sides and bottom are covered by overburden materials. Exposed in large, bold outcrops in some places along the lower canyon wall are the basalt lava flows of the Rocky Coulee member. Where exposed, this consists of several flows of dark, hard, moderately fractured basalt, in cliffs up to 50 feet high. Overlying the Rocky Coulee, and occurring as a strong marker bed in some places, is the Museum member. Where exposed, it is a dark, hard, slightly vesicular, lightly-to-moderately fractured rock with apparent low permeability, evidenced by some seeps along the upper contact.

Overlying the above-described basalts is the Vantage sandstone interbed consisting of about 70 feet of low-strength sandstones, siltstones, and claystones. The Vantage sandstone is poorly exposed, but is recognized on the aerial photographs and in many places in the field by light-colored, sandy slopes that, in some places, support vegetation growth. Seeps and springs are also common at the lower contact of this sandstone.

The left abutment extends from the creek bottom, elevation 1328 feet, to the top of the ridge, at about elevation 1820 feet. Except for a small outcrop of basalt rock near the top of the ridge, the abutment is covered with slopewash. A test pit on the left abutment at elevation 1490 feet encountered platy basalt bedrock underlying about 5 feet of slopewash. From surface geology mapping, it appears the Vantage sandstone interflow occurs from about elevation 1540 to 1620 feet. There is some evidence for a small landslide in the Vantage interflow on the left abutment just upstream from the dam axis.

The pre-Vantage basalt flows are expected to be in the lower abutment beneath the slopewash. On the upper part of the abutment, outcropping in a small area near the top of the potential dam are the flows of the post-Vantage Frenchman Springs member.

The relatively flat-lying valley floor is approximately 300 feet wide. Three drill holes were bored: one on the dam axis near the right valley side and two approximately 780 feet upstream (one near the center of the valley and one on the left valley side).

These explorations show the alluvial fill is approximately 20 feet thick; the underlying Museum or Rocky Coulee basalt bedrock, explored to a depth of about 50 feet, is mostly hard competent rock. Two of the drill holes encountered artesian water that flowed at the surface at a rate of about 20 gallons per minute; the artesian water was found under pressure in the basalt at a depth of about 35 feet.

The right abutment extends upward from the creek bottom, elevation 1328 feet, to the top of the ridge, at about elevation 1880 feet. There is a rather strong outcrop of pre-Vantage basalt on the lower abutment; otherwise, it is covered by slopewash. The three test pits dug on the right abutment show the slopewash materials are quite shallow, about 1 to 3 feet deep. The Vantage sandstone interflow is positioned on the abutment between approximate elevations 1600 and 1660 feet. However, the shallow, hand-dug pits may not be conclusive of the true depth of the overburden materials or the identity of the underlying rock formation.

Above the interflow zone, the bedrock is expected to be the Frenchman Springs basalt member.

6.2.1.3.2 Dike Geology. The site for the dike is the broad, low saddle on the right canyon side, approximately 2,000 feet upstream from the right abutment of the damsite. There are no outcrops in the vicinity of the dike site. Surface geology mapping indicates that the left (downstream) abutment will be similar to the right abutment, with the Vantage sandstone interflow occurring between approximate elevations 1650 and 1710 feet. On the right (downstream) abutment, it appears the Vantage sandstone interflow zone is above the top of the potential dam; thus, the bedrock for the right abutment of the dike will be the pre-Vantage basalt flows. One drill hole was bored near the dike axis in the lowest part of the saddle. This showed 0.3 to 13.8 feet as the slopewash; 13.8 to 20.0 feet as highly altered and fractured basaltic products; and 20.0 to 42.9 feet as alternating soft and hard, altered scoriaceous-to-vesicular basaltic rock. This occurrence of poor quality rock in the pre-Vantage Museum member is probably only a local deviation of the mostly hard, competent rock seen in nearby outcrops.

The dike area has also been considered as an offsite spillway, with the water discharging into McPherson Canyon and flowing approximately 1 mile southwest, partly along the alignment of the State Highway to the Yakima River. Much of McPherson Canyon is naturally rock-lined from the hard, competent flows of the pre-Vantage basalt flows, so any spillway water would probably not cause excessive erosion.

6.2.1.3.3 Reservoir Basin Geology. The geology of the reservoir basin is mostly flat-lying lava flows exposed in a steep, narrow canyon that extends upstream for about 6 miles on Lmuma Creek and about 2 miles upstream in the broader canyon of Scorpion Creek. The Vantage sandstone interflow zone is present on both canyon sides and will be within the reservoir pool in most of the reservoir basin. Under a reservoir environment, the interflow zone will be subject to some small landslides as the pool fluctuates. The slopewash deposits along the canyon sides will also be subject to sloughing and minor sliding along the reservoir shoreline.

The potential reservoir seepage losses are judged to be inconsequential for the major, upstream part of the reservoir. However, near the damsite (and the dike site) the potential for reservoir seepage becomes more of a concern, given the steep gradient from a full reservoir across relatively narrow reservoir rims to adjacent deep, dry drainages.

6.2.1.3.4 Pumping Plant Site Geology. The site for the pumping plant is in alluvial materials on the left bank of the Yakima River just upstream from the mouth of Lmuma Creek. No explorations have been made at this location. It is estimated depth to bedrock at the site will be approximately 50 feet deep. No explorations or detailed surface geologic mapping have been made for the pump-to-reservoir delivery system.

6.2.1.3.5 Further Geologic Investigations. Preconstruction geologic data would be needed at the Wymer (lower) site as listed below:

Damsite—At least two drill holes, one on each abutment, would be needed to determine the sequence and characteristics of the geologic formations, especially in the Vantage sandstone interflow zone. Test pits would be helpful to develop the top of rock profile on the abutments. Explorations would be needed on an alignment for a spillway on the left abutment area.

Dike site—As at the damsite, two holes, one on each abutment, would be needed. Additional drilling and/or test pitting or trenching is needed to delineate the soft materials in the lower part of the saddle. Test pits would also help delineate the top of rock on the abutments. Any siting of a spillway in this area would require some explorations; detailed geologic mapping would also be needed in the spillway channel leading to the Yakima River.

Reservoir basin—The potential reservoir seepage losses through the relatively narrow reservoir rims near the damsite and dike site are of concern. The investigations for seepage losses would involve several deep drill holes.

Pumping plant site—At least one hole should be drilled at the intended pumping plant site. Additional drilling may be required, depending on the results of the initial hole. The discharge line or canal system to the reservoir site should be mapped in detail.

Borrow materials—The sources of the onsite, natural, and manufactured construction materials need to be identified, explored, and sampled.

6.2.1.4 *Groundwater*

Groundwater investigations in the reservoir basin and along the dam and dike axis have not been conducted. These investigations would be required if the alternative is carried into the Feasibility Phase.

6.2.1.5 *Seismicity*

Preliminary seismic hazards were addressed in the 1985 *Planning Design Summary* (Reclamation, 1985) for the Wymer damsite. Preliminary seismotectonic conclusions for the area show a maximum credible earthquake of 6.1 at an epicentral distance of 0-15 kilometers, and a focal depth of

5-15 kilometers. This seismic hazards analysis is very dated and does not address seismic sources for either the Yakima fold and thrust belt or the megathrust and intraslab sources associated with the Cascadia subduction zone. These sources generally control the seismic hazard for the region. An updated preliminary seismic hazard analysis should be completed for the Wymer damsite if this alternative is carried forward into the feasibility study.

6.2.1.6 *Probable Maximum Flood*

Three probable maximum floods were analyzed for the Wymer storage project. The inflow design flood used for the appraisal-level designs is the “local event” PMF involving a peak discharge of about 110,000 cfs and a 2½-day volume of 43,000 acre-feet. The flood routing criteria used for the design required the reservoir be at the top of the active conservation capacity (elevation 1730.0 feet) at the onset of any flood, and use of only the spillway to make flood releases. An additional restriction is keeping the reservoir’s maximum water surface at or below elevation 1740 feet, resulting in a maximum allowable surcharge of 10 feet and a volume of 14,400 acre-feet. This restriction is intended to prevent inundating the roadbed of the east lane bridge of Interstate Highway 82 crossing Lmuma Creek approximately 5 miles upstream of the damsite.[22]

6.2.2 Project Facilities

The *Planning Design Summary* is the basis for the appraisal-level designs and cost estimates. Principal structures include two concrete-faced rockfill embankments (Wymer dam and a dike in a saddle on the reservoir rim northeast of the right abutment), a pumping plant on the Yakima River, a conduit to convey water from the pumping plant to the reservoir, and a reservoir with an active capacity of about 174,000 acre-feet.[23]

The primary characteristics of the Wymer storage facilities are shown in Table 6-3 and Figure 6-5.

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[22] As-built drawings of the Lmuma Creek bridge were obtained from the Washington Department of Transportation for this *Yakima Alternatives Appraisal Assessment*. These drawings indicate the bottom elevation of the bridge is 1743.8 feet.

[23] Section 3.2 refers to a Wymer reservoir with an active capacity of 142,000 acre-feet. The appraisal-level designs and cost estimates represent a reservoir with an active capacity of about 174,000 acre-feet.

Table 6-3. Wymer Dam, Dike, Pumping Plant, and Reservoir Characteristics

Item	Data	
	Dam	Dike
Dam and Dike (concrete-faced rockfill)		
Height	415 feet	130 feet
Crest elevation	1745 feet	1745 feet
Crest length	2,855 feet	2,310 feet
Crest width	30 feet	30 feet
Pumping Plant	400 cfs	
Reservoir	Elevation (feet)	Volume (acre-feet)
Surcharge	1730-1740	14,400
Active conservation	1450-1730	173,780
Inactive conservation	1351-1450	7,090
Dead storage	1330-1351	210

6.2.2.1 *Embankment Dam and Dike*

The alignments for the two structures were selected to minimize material requirements by using the shortest length of crest required at the design crest elevation. Embankment slopes of 2:1 and 1.5:1 were used for the respective upstream and downstream slopes of these two structures.

A concrete face on the upstream embankment slope would serve as the impervious water barrier to impound the reservoir. A "toe plinth" was provided as a footing for the concrete face and to tie the face to the foundation grout curtain. Below the plinth, a double-row grout curtain was provided to a maximum depth of 130 feet as a seepage cutoff in the foundation.

Foundation treatment requires removal of slopewash and channel alluvium down to bedrock. Slopewash was assumed to be 10 feet thick on the abutment. Alluvium in the valley was assumed to be 50 feet deep. However, as previously indicated, the drilling in 1985 indicated basalt bedrock underlying about 3 to 5 feet of slopewash on the abutments, and about 20 feet of alluvial fill in the valley floor.

6.2.2.2 *Pumping Plant*

The pumping plant was sited on the east bank of the Yakima River, approximately 0.6-mile northwest of Wymer dam. The designs provided an indoor-type pumping plant structure consisting of five electric motor-driven spiral case pumping units: three units rated at 100 cfs, and two units rated at 50 cfs.

Pumping capacity would be 400 cfs, with a total head range of 345 to 475 feet. The intake for the pumping plant would provide a smooth transition for the flow of water from the Yakima River to the plant with a minimum of hydraulic loss.

A 96-inch-diameter discharge line would extend from the pumping plant to the reservoir. The discharge line would "daylight" at elevation 1630 feet within the reservoir. The normal range of pumping operations at Wymer pumping plant would be elevation 1450 feet, minimum, to elevation 1730 feet, maximum.

6.2.2.3 *Spillway*

The spillway was located on the left abutment of the dam. It would include a control structure with a 100-foot-long crest at elevation 1700.0 feet, with three 32-foot-high radial gates, an open chute, and a slotted bucket-type energy dissipater. This would provide a maximum discharge of 50,000 cfs at maximum reservoir elevation 1740.0 feet.

6.2.2.4 *Outlet Works*

The outlet works chosen for the appraisal-level design was sited on the left abutment and would consist of the following: a box-type trashrack/inlet structure with bulkhead gate; an 8-foot-diameter concrete-lined upstream tunnel; a gate chamber with an emergency gate; a 12-foot-diameter concrete-lined downstream tunnel with a 72-inch steel pipe; and a control structure with a bifurcation to two 72-inch-diameter pipes. The average outflow through this system is 365 cfs. The physical layout of the outlet works was influenced by the option for adding a powerplant in the future. For this reason, the system was designed to be pressure flow for its entire length with a "stub-out" at the downstream end for a possible powerplant.

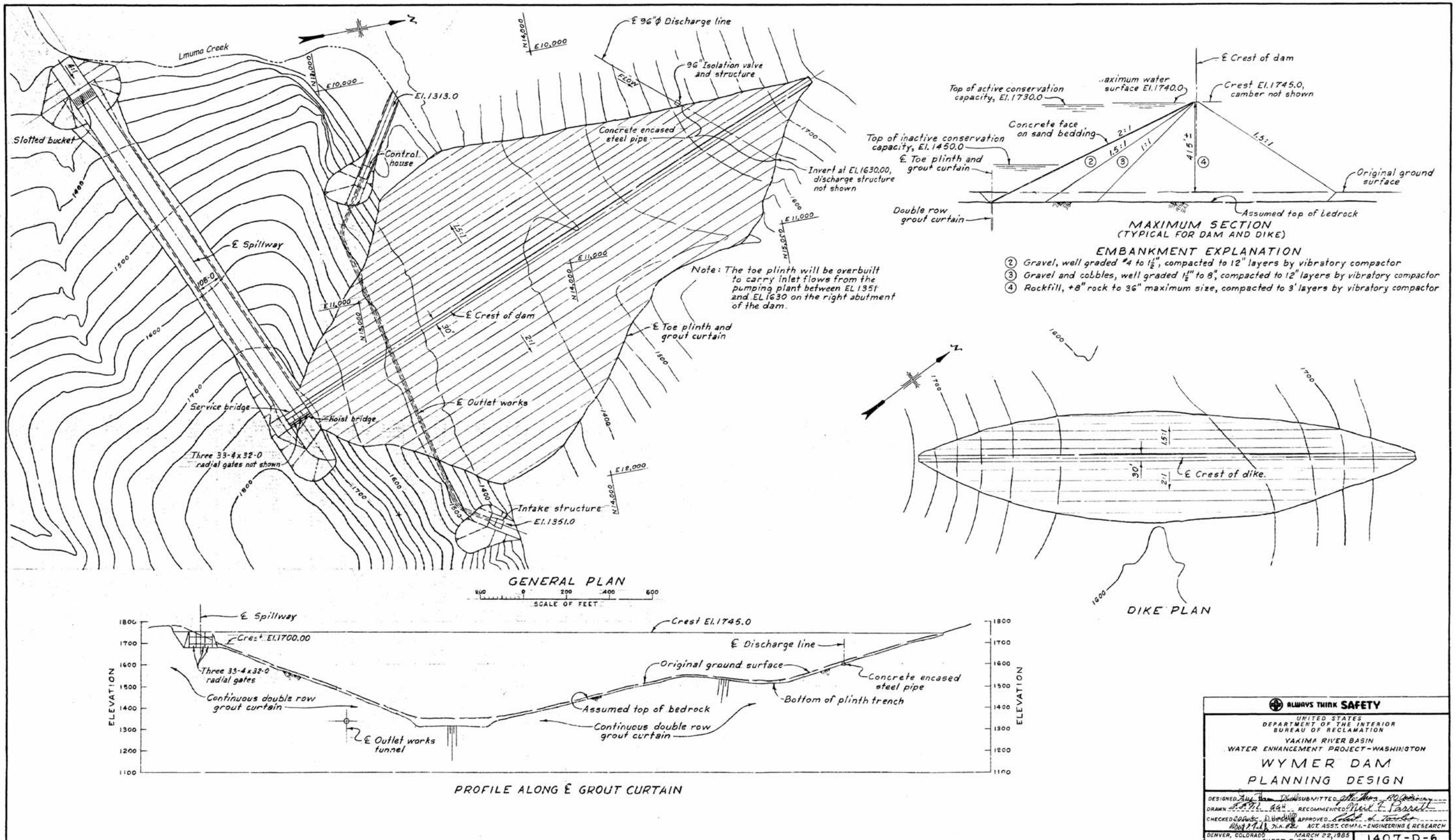

Figure 6-5. Wymer Dam Planning Design (1985)

6.3 KEECHELUS-TO-KACHESS PIPELINE

A pipeline extending from Keechelus to Kachess Dams has been considered for the primary purpose of improving water storage in Kachess Lake. A secondary purpose is streamflow management in the upper Yakima River from Keechelus Dam to Easton Diversion Dam.

The average annual runoff in the Keechelus watershed is about 246,000 acre-feet, and the lake has an active storage capacity of 157,800 acre-feet. In contrast, the Kachess watershed has an average annual runoff of about 214,000 acre-feet, but Kachess Lake has an active storage capacity of about 239,000 acre-feet. The concept is to transfer water from Keechelus Lake to Kachess Lake to increase the volume of total stored water. The pipeline could also be used to bypass some of the releases from Keechelus Dam during the irrigation season in the 11-mile Yakima River reach upstream of the Kachess confluence for anadromous fishery management, primarily during September spawning.

6.3.1 Site Characteristics

6.3.1.1 *Location*

Keechelus Dam and Lake and Kachess Dam and Lake are situated in the upper Yakima River watershed upstream of Easton Diversion Dam (RM 202.5), the diversion point for the Kittitas Main Canal of the Kittitas Reclamation District (see Figure 6-1 and Figure 6-6).

Keechelus Dam was constructed at the downstream end of a natural lake (RM 214.5) near the head of the Yakima River, approximately 12 miles upstream of Easton Diversion Dam.

Kachess Dam, also constructed at the downstream end of a natural lake, is located on the Kachess River, approximately 1 mile upstream of its confluence with the Yakima River; the confluence is 1 mile above Easton Diversion Dam.

6.3.1.2 *Geology*

It appears that most of the excavation for the pipeline would consist of silty sand and alluvial deposits. Hard, competent basalt would probably be found in the deep excavation through the saddle between the Keechelus and Kachess watersheds.

Excavation in the alluvium and glacial materials can be made by common methods. However, blasting would be necessary in the bedrock. Select bedding material for the pipeline would have to be hauled from a commercial source.

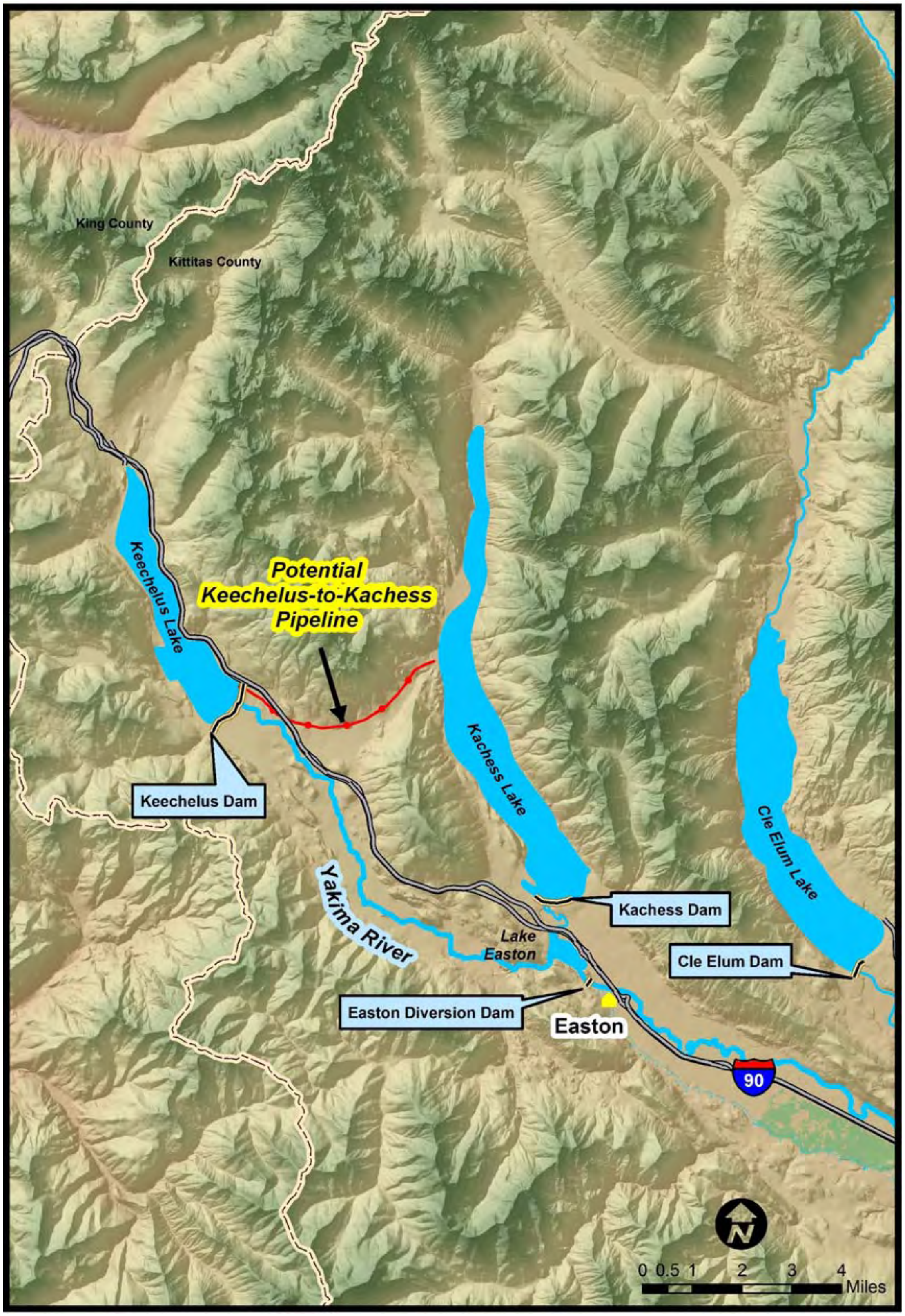

Figure 6-6. Keechelus-to-Kachess Pipeline Location Map

6.3.2 Project Facilities

The conceptual plan is to modify the outlet works of Keechelus Dam to permit releases to a potential gravity-flow pipeline extending approximately 5 miles to Kachess Lake, as well as maintain current releases to the Yakima River. The conveyance capacity of the pipeline would be directly related to Keechelus Lake contents and the depth of the cut through the saddle between the two watersheds, which is about 3 miles from the pipeline inlet. Table 6-4 shows the relationship of Keechelus Lake elevation to pipeline flow, assuming a 50-foot cut through the intervening saddle and a 5-foot-diameter pipe.

Table 6-4. Keechelus Lake Elevation/Pipeline Flow Relationship

Lake Elevation (feet)	Pipeline Flow (cfs)
2430	0
2450	100
2460	120
2480	160
2500	185
2517	210

The pipeline would have a minimum of 4 feet of cover. Most of the alignment is covered with dense underbrush and trees. The pipe alignment would begin on the southwest side of Interstate Highway 90, cross under Interstate Highway 90 to the northeast side, and continue on to Kachess Lake. A 50-foot-wide strip right-of-way is proposed along the pipe alignment, amounting to about 30 acres of land acquisition.

Modifications of Keechelus Dam's outlet works may be needed. The unpressurized outlet conduit is a modified horseshoe section with discharge controlled by slide gates located below the intake tower upstream of the dam. Modifications to pressurize the outlet works might include installing a 9-foot-diameter steel pipe in the conduit and connecting it to the existing gate chamber, filling the voids between the outside of the pipe and the inside of the conduit with concrete. Then, a wye would be installed at the downstream end of the pipe, with one leg of the wye leading to a new hollow jet valve, which would be the outlet control for the dam. The other leg of the wye would be reduced to a 5-foot-diameter pipe connected to a 5-foot-diameter butterfly valve to control the discharge to the pipe inlet. The outlet of the pipeline at Kachess Lake would include an energy-dissipating structure.

Chapter 7.0 Project Cost Estimates

This chapter presents appraisal-level field construction cost estimates for three Yakima Basin Storage Study alternatives:

- Bumping Lake enlargement.
- Wymer dam, reservoir and pumping plant.
- Keechelus-to-Kachess pipeline.

These field construction cost estimates were prepared in the mid-1980s as part of the YRBWEP investigations using industrywide, accepted cost estimating methodology, standards, and practices. They have been indexed to July 2004 prices to be comparable to the price levels used for the Black Rock Alternative reported in the *Black Rock Appraisal Assessment*, December 2004.[24]

Field construction costs are limited to the costs of construction contracts (construction pay items), plus allowances for mobilization, unlisted items, and contingencies. They do not include costs for lands and rights-of-way and noncontract costs such as preparation of final engineering designs and specifications, regulatory compliance and permitting activities, environmental mitigation and monitoring, and construction contract administration and management. A range of noncontract and total project costs is included at the end of this chapter.

Final total project cost estimates can only be accurately determined through a comprehensive process of feasibility studies and detailed design engineering, which will be completed in the Feasibility Phase of the Storage Study. More detailed estimates may vary substantially from those used for the purposes of alternative comparisons in this report. The use of these estimated construction costs outside the context of this report would be misleading and inappropriate.

[24] The Black Rock alternative field construction cost estimates are based on June 2004 price levels. However, the Bureau of Reclamation Cost Trends are reported on a quarterly basis (January, April, July, and October), so July 2004 was used, as a close approximation of June 2004 prices.

7.1 FIELD DATA

Appraisal-level designs of the three storage alternatives are based on the field data investigations discussed in Chapter 6. The designs address questions at the Bumping Lake enlargement damsite regarding depth to bedrock and seepage from the reservoir basin. However, the question of whether the presence of low-density volcanic ash deposits mixed with fine-grained sediment and organic debris, identified in the 1990s during Safety of Dams investigations at the existing Bumping Lake Dam, extends to the enlargement site has not been addressed.

Geologic explorations at the Wymer damsite showed the alluvial fill is approximately 20 feet thick, underlain by hard, competent bedrock. While hydrogeologic investigations were not conducted, potential seepage from the reservoir basin was judged inconsequential. However, near the damsite, seepage could be a concern to adjacent, dry drainages due to the steep gradient from a full reservoir across relatively narrow reservoir rims. Geologic explorations were not conducted at the Wymer pumping plant site or along the discharge line alignment.

While Reclamation has recently performed extensive geologic investigations at Keechelus and Kachess Dams as a part of its Safety of Dams Program, no work has been done along the pipeline alignment.

Designs and cost estimates were prepared within this framework and are limited by available field data. These field construction cost estimates will inevitably change if more data is collected, designs are refined, and feasibility-level analyses are prepared.

7.2 COST ESTIMATES

7.2.1 Construction Pay Items

Anticipated in-field activities are the primary basis for preparing cost estimates of construction pay items. These in-field activities include those costs that would be incurred by contractors for labor and materials such as the following:

- Excavation of materials for structure foundations such as pumping plants, dams, spillway channels, and outlet works; alignment of pipelines, channels, canals, access roads; and relocation of existing facilities.

- Drilling and cement grouting in the foundation and abutments of the embankment storage dam.

- Furnishing, forming, and placing reinforced concrete for structures.
- Furnishing, placing, and compacting earth and rock materials for the embankment storage dam and backfilling and covering of structures and pipelines.
- Furnishing and installing mechanical and electrical equipment in structures.

Based on preliminary general designs and drawings, approximate quantities (such as cubic yards of excavation, cubic yards of earth and rock material required for embankments, cubic yards of concrete, pounds of steel, and capacity requirements for specific items of equipment such as pumps and motors) were developed for the primary activities, or pay items. Unit prices (July 1985) were then determined and multiplied by these quantities.

7.2.2 Indexing

The July 1985 (Bumping Lake enlargement and Wymer dam, reservoir and pumping plant) and July 1986 (Keechelus-to-Kachess pipeline) cost estimates from the 1985 and 1986 reports were indexed to July 2004 costs using the Bureau of Reclamation Construction Cost Trend indices (found at www.usbr.gov/pmts/estimate/cost_trend.html). Applying construction cost indices is a method of updating previous cost estimates to present-day prices by means of a multiplier that corrects for cost escalation. For instance, in updating previous cost estimates for an earthfill dam structure, spillway, and outlet works, Bureau of Reclamation Construction Cost Trends were used to index the prices which had been applied to the estimated quantities and materials of the construction pay items. A multiplier of 1.59 for the dam structure was calculated by dividing the July 2004 Construction Index (204) by the July 1985 Construction Index (128). This was then applied to the July 1985 price of the specific construction activity, and an adjusted cost for the construction pay item computed.

The detailed cost estimating spreadsheets and supporting information are included in Appendix B.

In the event that these alternatives were carried forward into the Feasibility Phase of the Storage Study, further field data would be required, and the designs and cost estimates would need to be reevaluated and re-priced.

7.2.3 Field Construction Costs

Field costs include construction pay items, mobilization, and an allowance for unlisted items and contingencies.

Mobilization and preparation costs include mobilizing contractor personnel and equipment to the worksite during initial startup. The assumed 5 percent of the pay items subtotal cost used in this *Yakima Alternatives Appraisal Assessment* is based on past experience with similar projects and was also used in the Black Rock Alternative cost estimate in the *Black Rock Appraisal Assessment*.

Unlisted items are a means to recognize the confidence level in the estimate, the level of detail, and the knowledge of site characteristics that was used to develop the estimated cost. This line item covers minor design changes and also provides an allowance for minor pay items that have not been itemized, but that would have some influence on the total construction cost. Reclamation's *Cost Estimating Handbook* (1989) guidelines state the allowance for unlisted items in appraisal-level estimates should be at least 10 percent of the listed items. Typically, a value of 15 percent is used. This *Yakima Alternatives Appraisal Assessment's* cost estimates unlisted items were set at 15 percent of the sum of the pay item cost and mobilization costs for all facilities. (Due to the greater level of detail, the *Black Rock Appraisal Assessment* used 10 percent for unlisted items.) The unlisted line item is a rounded value per Reclamation rounding criteria that may cause the dollar value to deviate from the actual percentage shown.

Contingencies are then added as a percentage to the construction contract cost (the sum of the pay items, mobilization costs, and unlisted items) to determine the field cost. Contingencies are funds to be used after construction starts to pay contractors for items such as quantity overruns, changed site conditions, and change orders. Reclamation's *Cost Estimating Handbook* guidelines state that appraisal-level estimates should have at least 25 percent added for contingencies. To be consistent with the Black Rock Alternative, a 25-percent contingency was applied.

The estimated field costs for the three Yakima River basin storage alternatives indexed from the original appraisal-level cost estimate developed for the YRBWEP investigations are shown in Table 7-1.

As indicated, these indexed appraisal-level field construction cost estimates are based on available, but limited, data, preliminary designs and drawings, and professional assumptions. Cost indexing does not necessarily reflect current unit prices for construction materials, which could cause variations in field construction costs.

7.3 SUMMARY OF FIELD CONSTRUCTION COST ESTIMATES

Using mid-1980s appraisal-level designs and indexing the July 1985 and July 1986 cost estimates to July 2004 price levels, the appraisal-level field construction cost estimate of the three Yakima River basin storage alternatives are:

- Bumping Lake enlargement, - $210 million.
- Wymer dam, reservoir and pumping plant - $280 million.
- Keechelus-to-Kachess pipeline - $18.5 million.

The total field construction cost of the combined alternatives is estimated at about $508.5 million.

7.4 TOTAL PROJECT COSTS

Total project costs include the field construction costs and other additional costs required to complete a project. The additional costs are incurred after congressional construction authorization and appropriations are completed and before and during construction. Some of the additional costs include acquisition of lands and rights of way for construction and the subsequent operation of project facilities. Other additional costs are noncontract costs for such items as final design data collection, preparation of final designs, preparation of technical specifications, issuing and awarding construction contracts, coordination and project construction management by Reclamation and the contractor, and estimated costs associated with regulatory requirements, such as environmental activities, would be necessary. Noncontract costs of 20 to 35 percent of the field construction cost were used; the same percentages as for the Black Rock Alternative. This provides approximate total project costs from $612 million to $685 million. The range of appraisal-level project costs for individual alternatives is as follows–Bumping Lake enlargement ranges from $250 million to $280 million; Wymer, $340 million to $380 million; and Keechelus-to-Kachess pipeline, $22 million to $25 million, at July 2004 price levels (see Table 7-1).

Additional data would need to be collected prior to refining potential concepts and project configurations. Value engineering methods and analysis would be applied to identify needs, major cost components, and to reduce overall costs. Value engineering is a problem-solving methodology that examines potential component features of a potential project to determine pertinent functions, governing criteria, and associated costs. Other proposals are then developed that either meet the necessary requirements at lower costs or that increase the long-term value.

Table 7-1. Appraisal-Level Project Costs for the Yakima Basin Storage Alternatives (July 2004)

Feature	Bumping Lake enlargement 458,000 acre-feet	Wymer dam and reservoir 172,000 acre-feet	Keechelus-to-Kachess pipeline with 50-foot-cut through saddle
Dam structure	$118,881,520	$121,867,935	n/a
Spillway	$6,808,100	$27,841,700	n/a
Outlet structure	$13,747,425	$9,448,500	n/a
Breach existing dam	$444,015	n/a	n/a
Pumping plant and switchyard	n/a	$28,366,540	n/a
Waterways	n/a	n/a	$9,035,785
Waterway structures	n/a	n/a	$2,908,500
Interstate 90 crossing	n/a	n/a	$176,015
Baffled pipe outlet	n/a	n/a	$26,545
Subtotal of pay items	$139,881,060	$187,524,675	$12,146,845
Total mobilization costs (5%)	$7,000,000	$9,400,000	$610,000
Total unlisted items (15%)	$23,118,940	$33,075,325	$1,913,527
Construction contract cost	$170,000,000	$230,000,000	$14,500,000
Total Contingencies (25%)	$40,000,000	$50,000,000	$4,000,000
Total field cost	$210,000,000	$280,000,000	$18,500,000
Non-contract costs (35%)	$70,000,000	$100,000,000	$6,500,000
Total project cost (rounded)	$280,000,000	$380,000,000	$25,000,000
NOTE: Right-of-way costs ($800,000) were included in the original cost estimate, but not included in the indexed costs for Keechelus-to-Kachess pipeline.			

Chapter 8.0 Yakima Basin Fisheries

This chapter summarizes the life history and status of Yakima River basin anadromous fish, and the bull trout. This is followed by a general description of the Yakima River basin's natural (unregulated) hydrograph and the biological importance of the natural (unregulated) hydrograph to the life cycle of salmon and steelhead. The information presented in this chapter is designed to provide the reader with an understanding from a fisheries perspective of the importance of the Yakima River basin hydrograph to these species.

8.1 ANADROMOUS FISH

8.1.1 Steelhead Salmon

Yakima River steelhead occur within the middle Columbia River steelhead evolutionary significant unit (ESU), and were listed as threatened under the Endangered Species Act, effective March 25, 1999. Middle Columbia River steelhead status was reaffirmed as threatened on January 5, 2006. Primary steelhead populations are located in order of abundance in the following subbasins—Satus, Toppenish, Naches, upper Yakima, Ahtanum and Cowiche. The average annual number of returning adults was estimated at 2,115 for the 10-year period of 1995-2004 (Bill Bosch, pers. comm., 2006). Steelhead upstream migration occurs from August to May, with two peaks generally in fall and late winter. Spawning occurs first in the lower river subbasins in March and April, and in the upper river subbasins in May and June. Fry emergence occurs from May into July, and is earlier for the lower river subbasins. Steelhead juveniles spend 1-3 years in the freshwater before migrating to the ocean as a smolt. Peak smolt outmigration occurs in April and May (see Table 8-1).

8.1.2 Bull Trout

Yakima River basin bull trout populations were listed as threatened under the Endangered Species Act, effective July 10, 1998. Washington State Department of Fish and Wildlife recognizes nine distinct bull trout stocks in the Yakima River basin (Yakima Subbasin Plan, 2004). The Ahtanum Creek stock has a strict resident (fish spawn and rear in their natal stream) life history type; while the Naches River and Teanaway River stocks are an admixture of both resident and fluvial (adult fish that reside in a lake and spawn in a tributary) life history types. The Yakima River stock that resides in the Yakima River between Keechelus Dam and Lake Easton is considered to have a strict fluvial life history type. The

Bumping Lake, Cle Elum River (upper), Kachess Lake, Keechelus Lake, and Rimrock Lake stocks all have the adfluvial life history type. The bull trout life history cycle is shown in Table 8-1.

There was an annual average of 497 bull trout redds counted in the Yakima basin, based on index areas surveyed for the period 2001-05 (Scott Willey, pers. comm., 2006).

8.2 OTHER SPECIES

8.2.1 Spring Chinook Salmon

The 10-year (1995-2004) average annual adult count for spring Chinook salmon in the Yakima River basin was estimated to be 9,141 fish (Bill Bosch, pers. comm., 2006). There are three populations—upper Yakima, Naches, and American. Since 1999, the upper Yakima population has been supplemented with hatchery smolt releases produced at the Cle Elum Research and Supplementation Hatchery, near Cle Elum, Washington, which has increased the abundance of adult spawners.

Peak spring Chinook upstream migration past Prosser Dam occurs April through June. Spawning occurs first in August in the American River, followed by the Naches and upper Yakima populations in September to mid-October. Fry emergence begins in April and extends into mid-June. A portion of the juveniles from each population display a downstream movement that extends from the time of emergence in the spring through the winter. There is a pronounced increase in pre-smolt outmigrants from natal areas beginning in late September. Juveniles spend one year in freshwater and outmigrate the following spring in April and May (see Table 8-2).

8.2.2 Fall Chinook Salmon

The average annual adult count for fall Chinook salmon in the Yakima River basin for the period 1995-2004 was estimated at 9,182 fish, based on the premise that 70 percent of the fish spawn below Prosser Dam (Bill Bosch, pers. comm., 2006). There are two genetically distinct stocks recognized in the Yakima River basin. The mainstem stock is found throughout the lower Yakima River (roughly the lower 100 miles from about Sunnyside Diversion Dam), and a stock endemic to the Marion Drain (a manmade drainage ditch for the Wapato Irrigation Project).

Fall Chinook enter the Yakima River between September to mid-November. Spawning takes place October through November in the Yakima River downstream of the Naches River confluence and in the upper end of Marion Drain. Areas of concentrated spawning are near Granger (RM 80-83), below Prosser Dam (RM 47.1), and below Wanawish Dam (RM 18.0). Fry emergence begins in late March and extends into June. Juveniles spend only a few months rearing in the Yakima River basin before outmigrating as a smolt. Peak smolt outmigration is from May through June (Table 8-2).

8.2.3 Coho Salmon

For the past 10 years (1995-2004), the average annual adult count for coho salmon in the Yakima River basin was estimated at 2,882 fish (Bill Bosch, pers. comm., 2006). Native coho salmon were extirpated in the Yakima River basin in the early 1980s. Subsequently, in the mid-1980s, the Yakama Nation began reintroducing hatchery smolts into the basin, primarily for harvest augmentation. In the late 1990s, a program was started to test the feasibility of establishing a naturally produced coho salmon population with initial hatchery supplementation.

Currently, the greatest coho salmon spawning density occurs in the Wapato reach, the lower Naches, and the upper Yakima near Ellensburg and Ahtanum Creek. Limited spawning has been documented in several other tributaries throughout the basin. Adult spawners enter the Yakima River from September to mid-December and spawn in the areas previously mentioned in October through December. Peak fry emergence occurs in April and May. Juveniles rear for 1 year in the basin, and outmigrate as smolts the following spring during April and May (Table 8-2).

8.2.4 Sockeye Salmon

The historical adult count of Yakima River sockeye has been estimated at either 100,000 or 200,000. Since sockeye salmon have been extirpated from the Yakima River basin for nearly a century, their specific life history cycle is not known. However, historically, it most likely resembled that of the existing Wenatchee River sockeye population. Reclamation, along with the Yakama Nation, Washington State Department of Fish and Wildlife, and the Service, is presently evaluating the feasibility of providing adult and juvenile fish passage at the Cle Elum and Bumping Reservoirs. This entails evaluating the sockeye rearing potential in these two reservoirs and their tributaries.

Table 8-1. Steelhead Salmon and Bull Trout Life History Cycle by Life Stage in the Yakima Basin

Year	Year 1												Year 2											
Month	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**
Steelhead																								
Upmigration											■	■	■	■	■	■	■	■	■					
Spawn																	■	■	■	■				
Incubation																	■	■	■	■	■			
Emergence																		■	■	■	■			
Summer rear																		■	■	■	■	■	■	
Winter rear	■	■	■	■																				■
Smolt outmigration					■	■																		
Bull Trout																								
Upmigration								■	■	■	■	■												
Spawn (general)											■	■												
Spawn (Mineral Creek)										■														
Spawn (Deep Creek)												■	■											
Incubation										■	■	■	■	■	■	■	■	■	■					
Emergence																		■	■					
Rearing																			■	■	■	■	■	

Table 8-2. Spring Chinook Salmon, Fall Chinook Salmon, and Coho Salmon Life History Cycly by Life Stage in the Yakima Basin

Year	Year 1												Year 2											
Month	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**
Spring Chinook Salmon																								
Upmigration																								
Spawn																								
Incubation																								
Emergence																								
Summer rear																								
Winter rear																								
Smolt outmigration																								
Fall Chinook Salmon																								
Upmigration																								
Spawn																								
Incubation																								
Emergence																								
Smolt outmigration																								
Coho Salmon																								
Upmigration																								
Spawn																								
Incubation																								
Emergence																								
Summer rear																								
Winter rear																								
Smolt outmigration																								

8.2.5 Pacific Lamprey

The Pacific Lamprey is a Washington State fish species of concern and is under consideration for Endangered Species Act listing by the U.S. Fish and Wildlife Service. Juvenile Pacific Lamprey are currently found in the mainstem Yakima and Naches Rivers. Recent adult counts at Prosser Dam were: 1 in 1996, 22 in 2002, 85 in 2003, and 65 in 2004. The life history cycle for the Pacific Lamprey is shown in Table 8-3.

8.3 Resident Fish

There are several species of resident fish in the Yakima River basin, as listed in the *Yakima Subbasin Plan*. In this report, however, Reclamation will discuss only the bull trout, which is listed as threatened under the Endangered Species Act.

8.4 The Natural (Unregulated) Hydrograph

8.4.1 Historical Yakima Basin Hydrograph

The character of the Yakima River basin's annual hydrological pattern is driven by the accumulation of snow from November to March in the Cascade Mountains along the western and northern boundaries of the basin. The spring snowmelt results in peak freshet events (Figure 8-1), which cause streamflows to rise and fall with alternating warming and cooling weather patterns. During the peak runoff period, out-of-bank events (*i.e.*, floods) distribute surface water across the flood plain reaches (*i.e.*, Easton, Cle Elum, Ellensburg, lower Naches, Union Gap and Wapato), which recharge the aquifer. Furthermore, these out-of-bank events cleanse the stream bottom by flushing fine sediments downstream and depositing them in the depositional zones (*i.e.*, low-gradient reaches) and increasing channel complexity, which allows for increased egg and juvenile over-winter survival, and increased habitat complexity for multiple salmonid species and life stages. However, above bank-full flood events are rare today, because of regulation by the reservoir system (flood control storage).

Table 8-3. Pacific Lamprey Life History Cycle by Life Stage in the Yakima Basin

Year	Year 1												Year 2												Year 3											
Month	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Upmigration			■	■	■	■	■	■	■	■																										
Spawning																■	■	■	■	■																
Incubation																	■	■	■	■																
Ammocoete freshwater residence	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Metamorphosis																			■	■	■	■	■													
Outmigration																											■	■	■	■	■					
Ocean rearing	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Source: *Final Plan*, *Yakima Subbasin Plan*, November 26, 2004, (Yakima Subbasin Fish and Wildlife Planning Board)

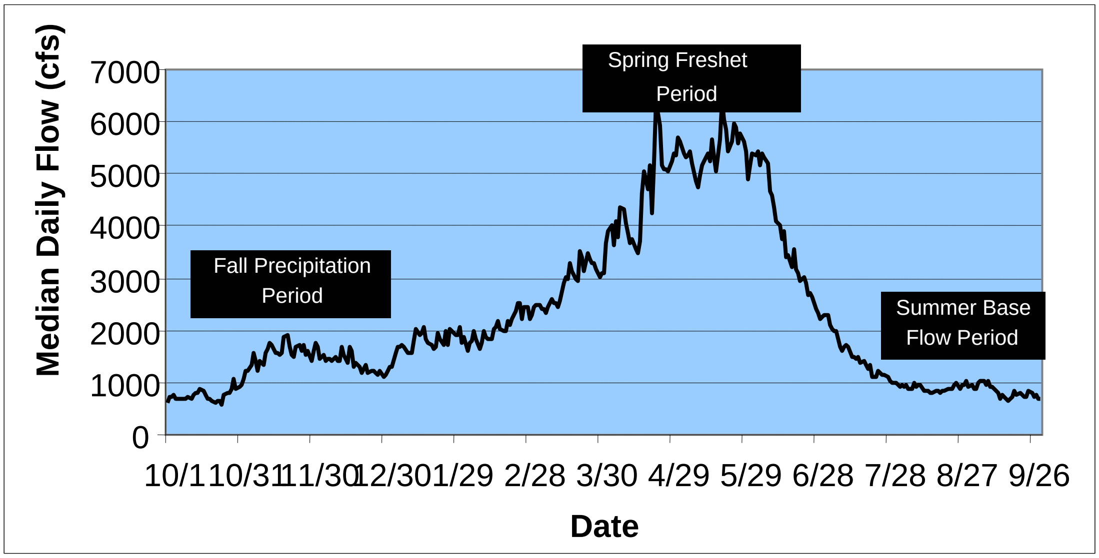

Figure 8-1. Typical Yakima Basin Annual Hydrograph Under Unregulated Conditions

Streamflows begin to decline after the majority of the snowpack has melted by early summer. By late summer, streamflows have reached base flow conditions (summer low flow). Groundwater stored during the spring runoff is typically the primary source of the base flows and provide the cooler water for sustaining fish habitat. Typically, fall precipitation in the form of rain causes streamflows to increase from summer low flows. From fall into winter, flows increase slowly, with small peak flow events that coincide with storm events.

Anadromous salmonids residing in the Yakima River basin have adapted their life cycle to the previously described annual hydrograph to maximize their survival (*i.e.*, abundance, productivity, and diversity). A description of key adaptations to the annual hydrograph by species or collectively, depending on the life stage, follows.

8.4.1.1 *Spring Freshet Period*

The peak flow events that occur in the spring as a result of snowmelt are very important to the smolt life stage for all anadromous salmonids. Smolts can be 3 months, 1 year, 2 year, or 3 years of age, depending on the species. Smolts outmigrate to the ocean and physiologically transition from life in freshwater to life in saltwater. There is a biological window in the spring in which smolts must reach the ocean; failure to do so can result in mortality or failure to smolt.[25]

Smolts outmigrate passively, meaning they allow the current to move them downstream, as opposed to actively swimming, and, in fact, they move downstream tail first. Thus, the accelerated water velocity during spring freshets helps to flush them to the ocean within a limited biological window of opportunity and reduces their exposure to in-river predators. The spring freshets also increase water turbidity, which decreases the predators' capture efficiency.

In late spring, when streamflows are still high, spring and fall Chinook and coho salmon begin to emerge from spawning beds. They are typically 1.2 to 1.4 inches in length and weigh less than a gram. Because emergent fry are very vulnerable to predation and physical impingement, it is critical they initially rear in shallow, slow-velocity habitat (*i.e.*, side channels, bank margins, backwater pools, etc.). These habitat features are most abundant in the flood plains. High spring flows inundate these flood plains, creating essential nursery areas.

8.4.1.2 *Summer Base Flow Period*

By summer, juvenile spring Chinook and coho salmon are 2 to 3.5 inches in length and prefer deeper, faster water located out from the stream margin in the mainstem and large side channels. By this time, fall Chinook have smolted and outmigrated to the ocean. Juvenile spring Chinook and coho take up residence in the slow-velocity water, preferably downstream of large, woody debris, to minimize energy expended to remain stationary. A shear zone (Figure 8-2) runs longitudinally in the river and defines the boundary between fast- (near the middle) and slow-velocity (along the stream edge) water. The shear zone provides a feeding lane, whereby a fish will dart out into the faster water to consume a floating insect, then move back to its slow-water resident area. As streamflows decline from spring to summer, the quantity of shear zone habitat increases and shows a clear distinction between pool, riffle, and glide habitats.

Steelhead emerge from the gravel in June-July as streamflows are decreasing to the summer low-flow period. At emergence, steelhead fry are slightly smaller than salmon fry, averaging 1 to 1.2 inches in length. Steelhead fry, like salmon fry, seek out the shallow, slow-velocity habitat that exists along the stream margin in the mainstem, side channels, and off-channel rearing areas.

[25] Failure to smolt is commonly referred to as smolt residualism. Residualism refers to a smolt that fails to reach the ocean and physiologically reverts back to conditions necessary for living in freshwater. This is most common for steelhead. In the case of steelhead, the fish may smolt the following spring or remain in the river as a resident trout.

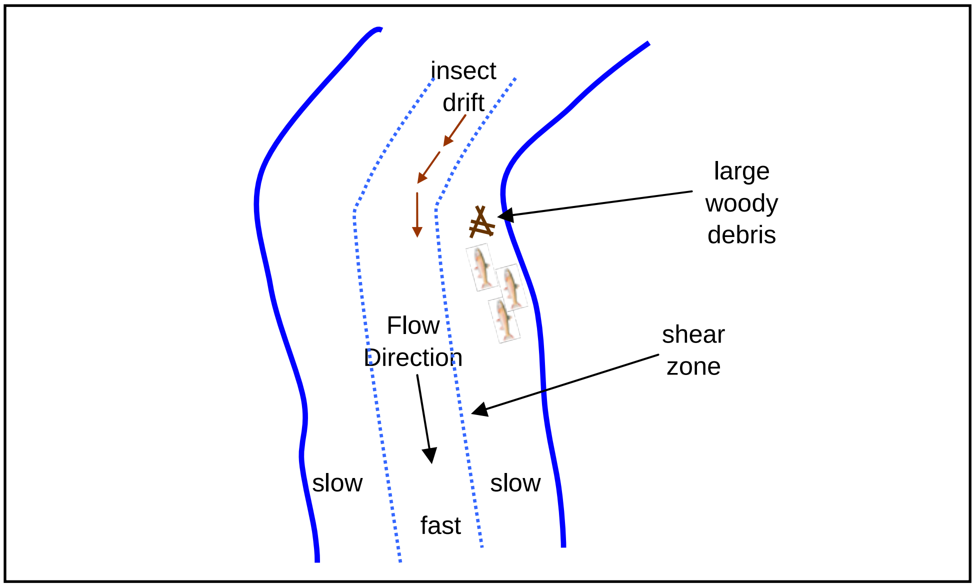

Figure 8-2. Location of Juvenile Salmonid Rearing Habitat in Relation to the Shear Zone and Feeding Lanes

8.4.1.3 *Fall Precipitation Period*

Beginning in late October, Pacific winter storms produce a series of small peak-flow events and a trend toward higher winter base flows. Increases in fall-winter flows inundate previously dry to minimally wetted side and off-channel habitat. Juvenile salmonids begin to seek over-wintering habitat with the onset of decreasing water temperatures and shorter days. Over-wintering habitat is mainstem, side channels, and off-channel habitats that provide shelter from winter high-flow events. These are areas that ideally have warmer groundwater inflow. Deep, slow-water velocity, with sufficient instream and overhead cover, describe the desired habitat features. Depending on the species, the large crevices in the stream substrate provide important over-wintering habitat (*e.g.*, steelhead).

A majority of juvenile spring Chinook in the Yakima River basin moves downstream from their natal area and over-winter in the Yakima River between the Naches River confluence and Prosser Diversion Dam. Juvenile coho, even more than spring Chinook, prefer to over-winter in off-channel habitat with ample instream cover and pools. Juvenile coho produced in the three primary mainstem spawning areas of the upper Yakima River near Ellensburg, the lower Naches River, and the Wapato reach of the Yakima River are thought to over-winter in their natal areas. Steelhead juveniles both outmigrate downstream into the lower Yakima and Naches Rivers and remain in their natal areas to seek out suitable over-wintering habitat.

Chapter 9.0 Yakima Basin Alternative Effects

Chapter 9 describes the present-day Yakima Project operation and the potential operation scenario, integrating the three storage alternatives (Bumping Lake enlargement, Wymer dam and reservoir, and Keechelus-to-Kachess pipeline) with the Yakima Project. In addition, this chapter evaluates the operational capability of the existing Yakima Project's storage facilities with the addition of the three basin storage alternatives, to meet the Storage Study goals described in Chapter 4.

This chapter also includes an overview of Yakima River inflow to the Columbia River (current and potential)[26] and Yakima River basin fish and wildlife issues and data needs.

9.1 SYSTEM OPERATION STUDIES

Operation studies were conducted to analyze Yakima Project system operations for this *Yakima Alternatives Appraisal Assessment*. The following two operation scenarios were developed:

1. Current Yakima Project operation scenario – the way the system is currently operated.

2. Integrated operation scenario – the three Yakima River basin storage alternatives are integrated with the existing Yakima Project facilities.

In addition, a natural (unregulated) flow regime for the Yakima, Naches, Bumping, Tieton, and Cle Elum Rivers was developed by modeling the river system without the existing Yakima Project storage facilities and diversions and associated return flows.

The integrated operation scenario involves three operation studies in which different "thresholds" (100 percent, 70 percent, and 50 percent) are used in prorated water years for determining how the water supply available is allocated to proratable water entitlements. These operation studies are referred to as integrated 100-percent operation, integrated 70-percent operation, and integrated 50-percent operation.

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[26] The Columbia River inflow overview is similar to that provided in section 8.2 of the *Summary Report, Appraisal Assessment of the Black Rock Alternative*, December 2004.

Initially, the only integrated operation study prepared was the integrated 100-percent operation study. In this study, proratable water entitlements were supplied up to 100 percent of their entitlements in prorated years, if the proratable supply was available. However, the 100-percent operation study showed the irrigation water supply goal could not be met in the third year of a dry-year cycle such as 1992-1994.

Subsequently, the integrated 70-percent and 50-percent operation studies were prepared. These studies limited the supply provided to proratable entitlements in prorated years to what would have been provided by the Yakima Project without the three storage alternatives. Table 9-1 uses two examples of proration levels (80 percent and 40 percent) to illustrate what the proratable supply would be with application of the 100-percent, 70-percent, 50-percent, criteria. For example, if the computed proration level without the three storage alternatives would have been 80 percent (or any volume over the threshold level), irrigators would receive up to 100 percent of their proratable rights under the integrated 100-percent scenario (if the supply is available), 80 percent under the integrated 70-percent scenario, and 80 percent under the integrated 50-percent scenario. Under this scenario, proratable irrigators would receive at least what they would have received historically, under any of the integrated operations.

On the other hand, if, without the three storage alternatives, the proratable supply is 40 percent (or any supply less than the integrated operation threshold), they would receive up to that threshold level, *i.e.*, 50 percent under the integrated 50-percent scenario, and 70 percent under the integrated 70-percent scenario, and 100 percent under the integrated 100-percent scenario, if the supply is available.

Table 9-1. Example of Proratable Water Supply Provided With The Three Storage Alternatives

Computed Proration Level Without the Three Storage Alternatives	Integrated 100%	Integrated 70%	Integrated 50%
80%	up to100% (if available)	80%	80%
40%	up to 100% (if available)	70% (if available)	50% (if available)

The application of the 70- and 50-percent criteria results in carrying over some of the available storage water rather than fully allocating the water supply in 1 year, as is done using the integrated 100-percent criteria. Otherwise, the three studies are similar.

The information presented in Chapter 9 is the integrated 70-percent operation study. However, the results of all three integrated operation studies are presented for comparison in Appendix D.

9.1.1 Hydrologic Model

The system operational analysis conducted by Reclamation for this *Yakima Alternatives Appraisal Assessment* involves use of the Yakima Project RiverWare (Yak-RW) model. This model is a daily time-step reservoir and river operation simulation computer model of the Yakima Project, created with the RiverWare software. The software was developed at the Center for Advanced Decision Support for Water and Environmental Support at the University of Colorado, in cooperation with Reclamation and the Tennessee Valley Authority.

The RiverWare modeling software uses an object-oriented modeling approach in which objects represent features of the project such as storage reservoirs, stream reaches, diversions, and canals. Each object contains its own physical processes, algorithms and data. For instance, reservoir objects include elevation-volume data, flood-control rule curve information, and outflow data. Objects are interconnected into a "network" which represents the flow of water from one object to another.

The network file of the Yak-RW model consists of the five major project reservoirs (Keechelus, Kachess, Cle Elum, Bumping, and Rimrock) and 56 major and minor river diversions and canal systems. All river diversions, canal losses, on-farm losses, and return flows are represented in the model. The network also includes simulation of Kittitas Reclamation District's 1146 Wasteway used to assist in the mini flip-flop fall operation, and the Roza and Chandler Powerplants.[27]

The hydrologic base for the Yak-RW model is represented by the 23 water years of 1981 through 2003 (November 1, 1980, through October 31, 2003). This 23-year period includes 17 nonproration water years (wet and average water supply conditions) and 6 proration years (dry water supply conditions). A description of the input to the Yak-RW model and how it works is included in Appendix C.

[27] The Wapatox Powerplant was acquired by Reclamation in 2003 and is no longer in operation. The "power water" diversion now remains in the Naches River.

9.1.2 Current Operation Scenario

The objective of the current operation is to fill the reservoir system to its full active capacity of about 1 million acre-feet, while providing "minimum" flows downstream of the dams, meeting Title XII flows at Sunnyside and Prosser Diversion Dams, and providing reservoir space for possible flood control operations. Runoff from the watershed upstream of the five major Yakima Project reservoirs is stored, subject to flood control space requirements, following the end of the irrigation season in October and continuing through the fall, winter, and early spring months to accomplish this objective. Once the reservoirs are full, the inflows are passed through.

The irrigation season starts about the first of April, though the "priming" of the main conveyance canals generally begins by mid-March. During the initial part of the irrigation season, unregulated runoff from tributaries below the five reservoirs is generally adequate to meet irrigation diversion demands and the Title XII target instream flows at Sunnyside Diversion Dam (Parker gauge, RM 103.7). Irrigation return flows also contribute to meeting irrigation diversion demands. Figure 9-1, "Yakima River Basin Schematic," shows the Yakima River Basin irrigation diversions and irrigation return flows. On average, unregulated flows and irrigation return flows are adequate in meeting diversion demands until about June 24. The earliest unregulated flows have been unable to meet demands is April 1, and the latest is August 17.

Once the unregulated flows fail to meet diversion demands and Title XII target flows, reservoir releases must be made, resulting in depletions in the stored water supply. The time when this occurs is commonly referred to as the beginning of the storage control period.

Table 9-2 shows the current Yakima Project operations during the storage control period. This operation was initiated in 1981 as the result of a Federal District Court ruling directing Reclamation to manage the Yakima Project reservoirs to provide appropriate flows during anadromous fish spawning and incubation periods, while providing water for irrigation purposes.

From the beginning of the storage control period until the first of September, releases from Cle Elum Dam are maximized to the extent possible to meet mainstem Yakima River diversion demands extending from the Cle Elum River confluence (RM 179.6) to Sunnyside Diversion Dam (RM 103.8). A major portion of these demands is in the middle Yakima River basin, from Roza Diversion Dam (RM 127.9) downstream, including the Roza Division, Wapato Irrigation Project (RM 106.7), and the Sunnyside Division. These demands total an annual irrigation water right of about 1.46 million acre-feet, out of a basin total of about 2.34 million acre-feet upstream of the Parker gauge. This results in a

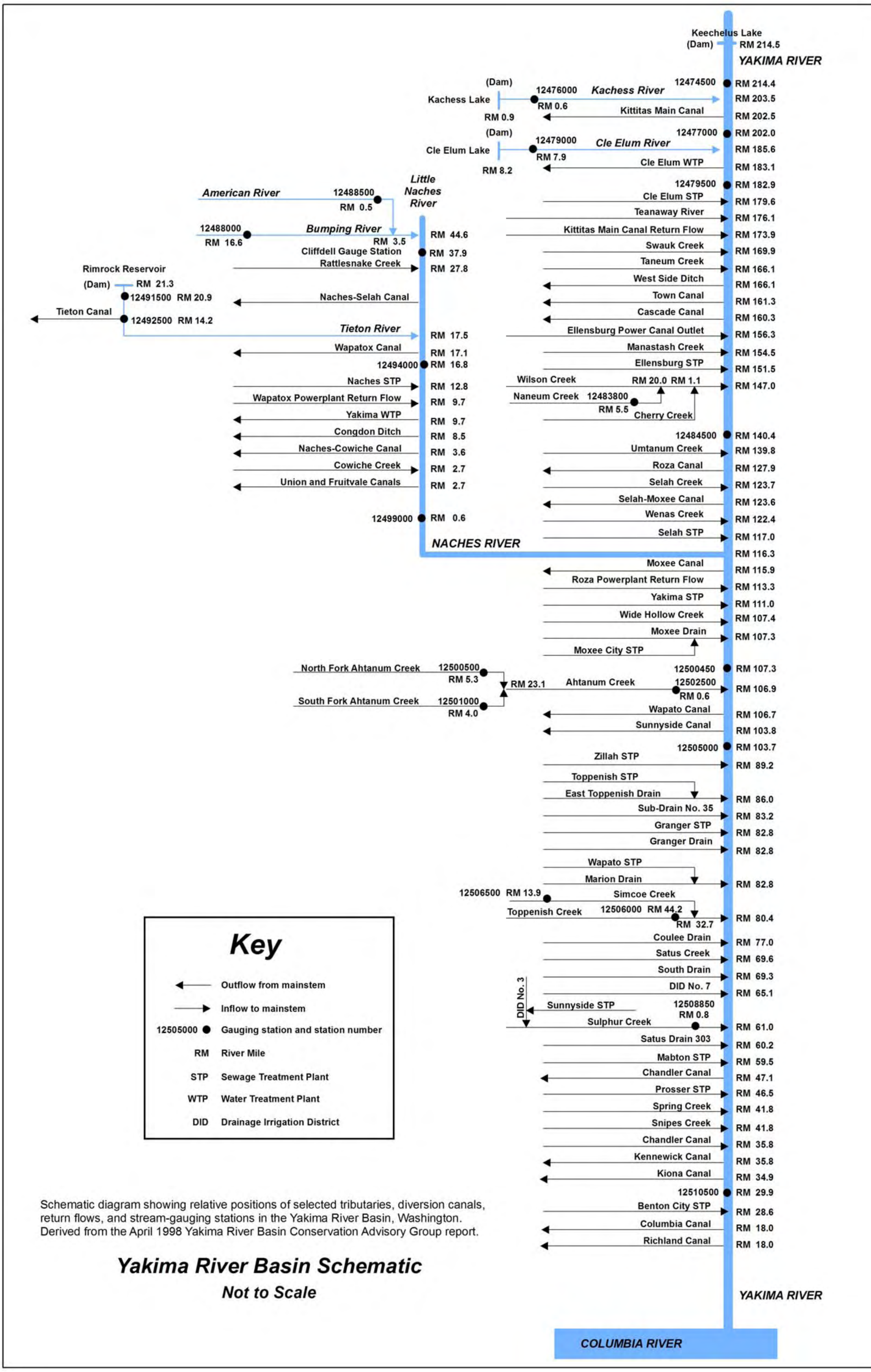

Figure 9-1. Yakima River Basin Schematic for Irrigation Diversions and Irrigation Return Flows.

high volume of water being transported from the upper to middle basin by the Yakima River. At peak, about 3,600 cfs for irrigation diversion is being moved through this area.

Table 9-2. Yakima River Flows and Major Diversions[1] (Easton Diversion Dam to Sunnyside Diversion Dam)

Gauging Station	Mid-July	Mid-August	Mid-September
	(cubic feet per second)		
Yakima River at Easton Diversion Dam (RM 202.5)	220	360	220
Below Cle Elum Dam	2,830	2,950	220
Yakima River at Cle Elum (RM 183.1)	3,210	3,530	540
Yakima River at Umtanum (RM 140.4)	3,640	3,930	1,510
RID Diversion[2] (RM 127.9)	-1,060	-1,080	-730
Yakima River below Roza Dam (RM 127.9)	2,580	2,850	780
Naches River at Naches (RM 16.8)	1,270	990	2,090
Yakima River below Roza Dam + Naches River at Naches	3,850	3,840	2,870
WIP Diversion (RM 106.7)	-1,890	-1,850	-1,200
Sunnyside Diversion (RM 103.8)	-1,220	-1,220	-1,060
Other Diversions	-240	-250	-90
Yakima River at Parker (RM 103.7)	500	520	520

[1] Diversions are denoted by a minus (-) sign.
[2] For irrigation, diversions for hydropower generation at Roza Powerplant return to the Yakima River downstream of the Naches River confluence.

However, about September 1, the Yakima Project moves into what is called the flip-flop operation. At this time, Cle Elum Lake releases are substantially reduced over a 10-day period (from about 3,000 cfs to 220 cfs). During this interval, releases from Rimrock Lake are substantially increased to meet the September-through-October irrigation demands downstream of the confluence of the Naches and Yakima Rivers (from about 1,000 cfs to 2,000 cfs); the major portion of which is the Wapato Irrigation Project and the Sunnyside Division. The purpose of the flip-flop operation is to encourage upper Yakima River spring Chinook to spawn in the main channels of the upper Yakima River (RM 156 to RM 202) and the Cle Elum River, rather than in areas which would be dewatered at the end of the irrigation season when storage accumulation begins. This allows protection of the redds, or incubating eggs, throughout the fall and winter months with a lesser storage release, thus improving the stored water supply for the next irrigation season.[28]

During this same period (the beginning of storage control to the first of September), a similar operation, referred to as mini flip-flop, is performed between Keechelus and Kachess Lakes in years of sufficient water supply. Greater releases are initially made from Keechelus Lake to meet the upper basin demands (primarily the Kittitas Reclamation Division), and releases from Kachess Lake are restrained. Then, in September and October, the opposite is done with greater releases being made from Kachess to meet upper basin demands, and releases from Keechelus reduced to provide suitable spawning flows in the Yakima River reach from Keechelus Dam (RM 214.5) to the backwaters of Lake Easton (about RM 203.5).

Concurrent with the September shift in major water releases from Keechelus Lake to Kachess Lake, Kittitas Reclamation District's main canal (which has excess carrying capacity due to diminishing irrigation demands) is used to convey water for downstream use (such as the Roza Irrigation District) around the Easton Reach. This water reenters the Yakima River through the 1146 Wasteway,[29] approximately 28 miles downstream of Easton Diversion Dam. This operation provides an average of approximately 220 cfs spring Chinook spawning flow through the Easton reach.

9.1.3 Integrated Operation Scenario

This section provides information on water availability at the Bumping Lake enlargement damsite and at the Yakima River Wymer pumping plant site. It also discusses how the available water supply is used in the integrated 70-percent operation.

The results of the integrated operation are then discussed as they relate to meeting the Storage Study's fish habitat and irrigation and municipal water supply goals.

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[28] A detailed history and description of the flip-flop river operation, instituted in the early 1980s, can be found in the *Interim Comprehensive Basin Plan* (Reclamation, 2002)

[29] The 1146 Wasteway conveys excess water from Kittitas Reclamation District's main canal to the Yakima River at RM 173.9.

9.1.3.1 *Water Availability*

As noted in section 5.3, the unappropriated surface waters of the Yakima River basin have been withdrawn from appropriation by Reclamation. This withdrawal, approved by Washington Department of Ecology, is in effect until January 18, 2008.

9.1.3.1.1 Bumping Lake Enlargement. The runoff available from the Bumping River watershed for storage in an enlarged Bumping Lake is represented by the inflow to the enlarged reservoir, less a minimum instream flow requirement of 130 cfs in the Bumping River downstream of the new dam. The average annual runoff available is illustrated in Figure 9-2. The monthly volume during the 1981-2003 period is shown in Table 9-3.

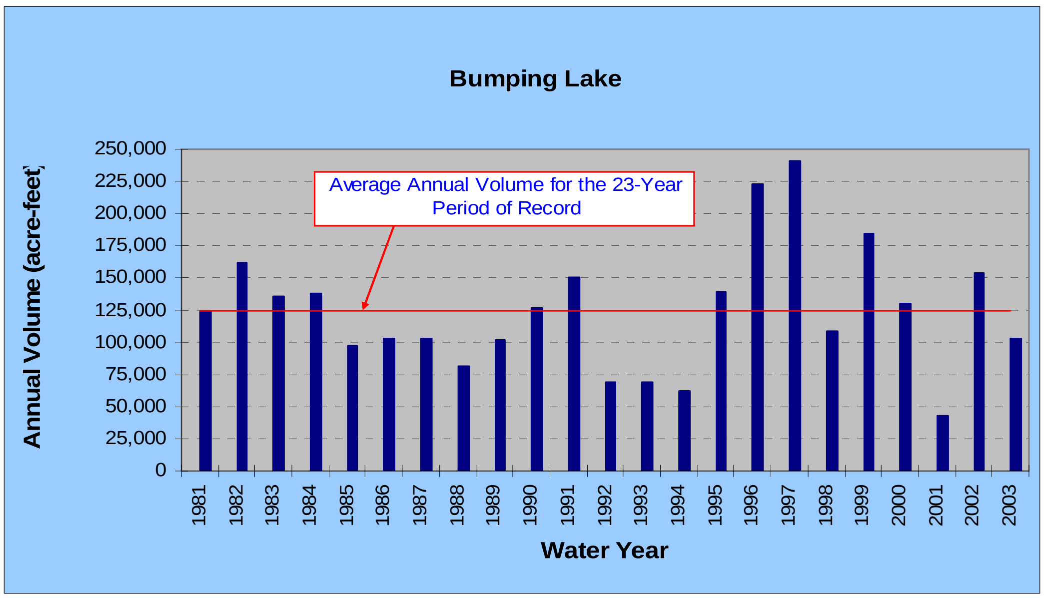

Figure 9-2. Annual Volume Available for Bumping Lake Based on Minimum Release of 130 cfs with Integrated 70% Operation (average 123,955 acre-feet)

Table 9-3. Bumping Lake Enlargement Inflows Available for Storage (Inflow Less Minimum Release)

Water Year	Monthly Volumes (acre-feet)												Annual Volume (acre-feet)
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	
1981	11,137	41,043	13,233	15,001	3,463	6,659	19,468	13,498	687	0	0	648	124,836
1982	1,337	3,963	911	27,038	9,416	4,509	37,651	60,260	14,786	345	75	1,347	161,639
1983	1,731	10,131	11,383	3,414	10,567	7,731	43,284	34,721	13,100	178	18	0	136,259
1984	9,780	4,950	17,362	4,167	6,501	5,817	27,017	46,809	15,835	124	0	185	138,546
1985	729	0	0	0	0	12,507	37,770	40,815	2,243	0	0	3,743	97,806
1986	5,997	0	3,595	10,475	19,057	13,648	28,563	20,786	144	0	0	322	102,587
1987	13,175	1,695	62	1,093	11,154	21,331	43,056	10,837	72	0	0	0	102,475
1988	0	1,635	231	37	3,388	21,048	31,570	21,232	2,399	0	0	250	81,791
1989	7,177	3,463	1.396	61	1,373	21,700	32,171	31,056	3,056	0	0	0	101,454
1990	3,140	9,986	14,587	1,867	1,283	29,515	24,826	30,417	7,481	116	0	3,669	126,888
1991	33,989	7,506	6,721	21,701	4,453	11,572	23,992	26,841	13,018	325	0	0	150,118
1992	3,201	3,102	5,454	5,437	9,918	18,429	20,701	2,882	0	0	154	0	69,279
1993	66	0	919	0	4,755	7,952	42,095	12,694	162	0	0	0	68,643
1994	0	0	350	0	3,953	17,504	27,721	10,322	322	0	0	2,286	62,459
1995	1,607	11,278	4,219	31,231	11,202	6,881	38,823	26,361	4,309	0	1	3,106	139,017
1996	51,175	24,737	19,462	45,155	9,241	22,147	22,227	23,518	4,409	66	0	429	222,567
1997	4,006	3,466	14,937	8,944	17,458	19,176	63,677	63,198	27,394	1,180	2,372	15,400	241,208
1998	11,062	4,784	2,848	185	4,102	9,964	46,301	27,007	2,785	0	0	0	109,039
1999	7,287	12,949	8,577	628	494	5,033	28,326	61,505	47,828	11,660	32	155	184,474
2000	24,267	12,369	1,139	364	0	20,035	32,147	33,877	6,092	0	80	162	130,532
2001	0	0	0	0	1,142	4,633	27,049	10,136	380	0	0	191	43,531
2002	7,991	2,665	15,222	3,200	2,485	16,950	32,195	58,987	13,604	0	0	0	153,297
2003	14	272	16,638	12,240	9,733	12,435	25,240	23,769	754	0	0	1,424	102,519
Avg	8,647	6,956	6,924	8,358	6,310	13,790	32,864	30,067	7,863	608	119	1,449	123,995
Daily Available for Storage (cfs) by Month													
Avg	145	113	113	149	103	232	534	505	128	10	2	24	
Max	5,297	4,989	3,450	4,556	1,324	1,390	2.096	2,445	1,158	470	225	2,101	
Min	0	0	0	0	0	0	111	0	0	0	0	0	

The monthly volume of water available for storage does not represent the volume actually stored, as the volume actually stored is a function of the manner in which the enlarged reservoir is operated in conjunction with the present Yakima Project facilities.

9.1.3.1.2 Wymer Dam and Reservoir. Yakima River flows available for diversion to Wymer reservoir are limited to nonproration water supply years with pumping occurring when flows are (1) greater than 1,475 cfs upstream of Roza Diversion Dam during the nonirrigation season,[30] and (2) greater than Title XII flows over Sunnyside Diversion Dam during the irrigation season.

Figure 9-3 shows the average annual Yakima River flows available for pumping to Wymer reservoir.

Table 9-4 shows the monthly volume of Yakima River water available for diversion to Wymer reservoir.

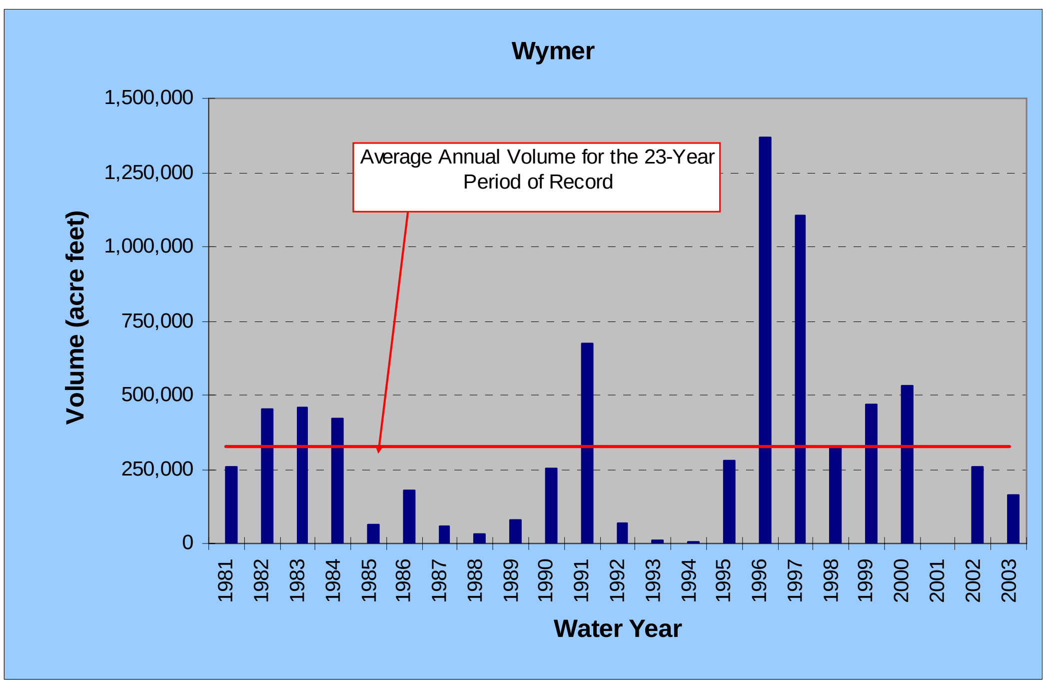

Figure 9-3. Yakima River Flows Available for Pumping into Wymer Reservoir with Integrated 70% Operation (average 325,801 acre-feet)

[30] Maximum generation at Roza Powerplant requires a flow of 1,075 cfs. In addition, 400 cfs is required at Roza Diversion Dam to divert the power water.

Table 9-4. Yakima River Flows Available for Pumping into Wymer Reservoir with Integrated 70% Operation

Water Year	Monthly flows (acre-feet)												Annual Flow (acre-feet)
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	
1981	0	113,049	35,737	86,446	22,330	0	0	0	0	0	0	0	257,562
1982	0	0	31,037	107,298	81,340	26,643	89,866	97,538	19,235	0	0	0	452,956
1983	0	633	84,681	27,030	133,892	76,455	59,242	60,795	14,164	0	0	0	456,892
1984	2,857	0	120,525	35,431	70,926	35,246	2,285	132,880	19,079	0	0	0	419,229
1985	0	0	0	0	0	56,302	7,563	0	0	0	0	221	64,085
1986	8,340	0	0	40,368	120,875	10,514	0	0	0	0	0	0	180,098
1987	14,331	0	0	0	32,907	6,763	3,102	0	0	0	0	0	57,103
1988	0	0	0	1,286	0	29,998	0	0	0	0	0	0	31,284
1989	1,107	3,864	3,253	4,032	5,602	60,252	1,589	0	0	0	0	0	79,698
1990	946	7,801	14,769	21,461	38,466	119,666	136	37,256	8,315	0	0	3,151	251,968
1991	178,470	73,606	100,179	85,700	55,420	94,341	31,848	40,975	14,176	0	0	0	674,715
1992	0	12,657	9,206	17,308	28,729	0	0	0	0	0	0	0	67,900
1993	0	0	0	0	3,919	1,606	3,208	0	0	0	0	0	8,733
1994	0	0	0	0	143	2,750	0	0	0	0	0	0	2,893
1995	444	10,840	12,173	138,166	69,851	11,777	17,405	14,520	1,307	0	0	0	276,482
1996	119,157	194,790	208,890	346,668	213,774	202,482	31,979	48,485	0	0	0	0	1,366,226
1997	0	0	42,731	84,579	267,528	262,382	315,312	102,213	25,207	0	0	3,224	1,103,177
1998	36,637	1,568	8,311	22,330	56,661	83,310	85,495	26,451	0	0	0	0	320,764
1999	106	21,380	56,294	7,620	39,135	54,360	145,056	86,691	57,879	2,208	0	0	470,728
2000	128,846	134,842	5,066	0	6,361	138,425	26,239	83,665	8,341	0	0	0	531,784
2001	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	916	573	10,900	7,818	2,556	49,348	41,216	138,493	5,112	0	0	0	256,931
2003	0	0	20,128	48,780	59,069	31,437	2,792	0	0	0	0	0	162,206
Avg	21,398	25,026	33,212	47,057	56,934	58,872	37,580	37,824	7,514	96	0	287	325,801
Daily Available for Storage (cfs) by Month													
Avg	360	407	540	847	926	989	611	636	122	2	0	5	
Max	11162	11341	6455	15264	11678	9719	11333	5685	2544	602	0	783	
Min	0	0	0	0	0	0	0	0	0	0	0	0	

9.1.3.1.3 Keechelus-to-Kachess Pipeline. Figure 9-4 shows the volume of water conveyed through the pipeline from June through September for the period of record. The Keechelus-to-Kachess Pipeline was used to convey water from June through September in the integrated operation scenario. This timeframe is used because all flows prior to June released to the Yakima River from Keechelus Reservoir make that reach resemble the natural (unregulated) hydrograph. After September, the reservoir inflows are used to fill each reservoir to reach the winter carryover capacity. The amount and timing of water conveyance through the pipeline involve the available water storage capacity in each reservoir and minimum flows required below each reservoir.

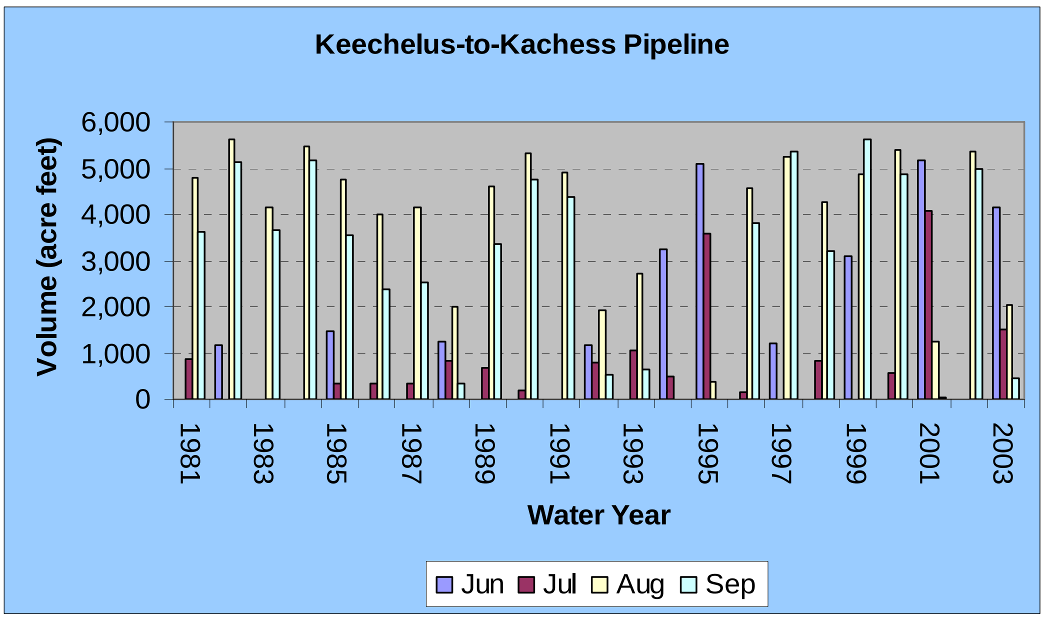

Figure 9-4. Monthly Flows Conveyed from Keechelus Reservoir to Kachess Reservoir

9.1.3.2 *Storage Contents*

For the integrated operation studies, the emphasis is on meeting instream flow targets downstream of the dams (see Table 9-5), Title XII flows (see Table 4-1), and the irrigation water supply goal. In the integrated operation scenario, no attempt was made to move the Yakima and Naches Rivers flow regime toward the natural (unregulated) hydrograph. To do so would result in not meeting the irrigation water supply goal. Rather, the RiverWare model uses the integrated operation total water supply available (TWSA),[31] to set the Title XII target flows. Additional flows resulting from increased TWSA of the integrated operations (as compared to the current operation) are then equated to a "block of stored water," which could be used for other fishery purposes if desired. This is discussed further in section 9.1.4.1.1.

Table 9-5. Minimum Target Flows Used by the Model

River Location	Daily Flows (cfs)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tieton Dam	45	45	45	45	45	45	45	45	45	45	45	45
Bumping Dam	130	130	130	130	130	130	130	130	130	130	130	130
Keechelus Dam	80	80	80	80	80	80	80	80	100	100	80	80
Kachess Dam	15	15	15	15	15	15	15	15	15	15	15	15
Cle Elum Dam	220	220	220	220	220	220	220	220	220	220	220	220
Easton Diversion Dam	220	220	220	220	220	220	220	220	220	220	220	220
Naches River at Naches	Minimum of natural flow right or 450 cfs											
Parker			Title XII flows*									
*see Table 4-1 for more information regarding Title XII flows												

9.1.3.2.1 Bumping Lake Enlargement. Figure 9-5 shows Bumping Lake enlargement storage contents for the 23-year hydrologic period. The increasing line represents inflow available for storage being retained in the reservoir during the storage period beginning about November 1 with maximum reservoir contents usually occurring mid-June to early July. The decreasing lines are the reservoir releases during the storage control period resulting in the lowest reservoir contents occurring at the end of the irrigation season in October.

The operating emphasis of an enlarged Bumping Lake is to make it a carryover reservoir to improve the dry-year water supply available for proratable water

[31] Reclamation prepares forecasts of the total water supply available upstream of the Yakima River at Parker for the period April through September, beginning in March, then monthly through July. TWSA is the forecasted amount of water available from natural flow, storage, and return flows, and is the basis for determining the adequacy to meet irrigation water entitlements, taking into account Title XII instream flows.

rights. This results in major reservoir drawdown and minimum reservoir contents in the consecutive dry years of 1992-1994 and in year 2001.

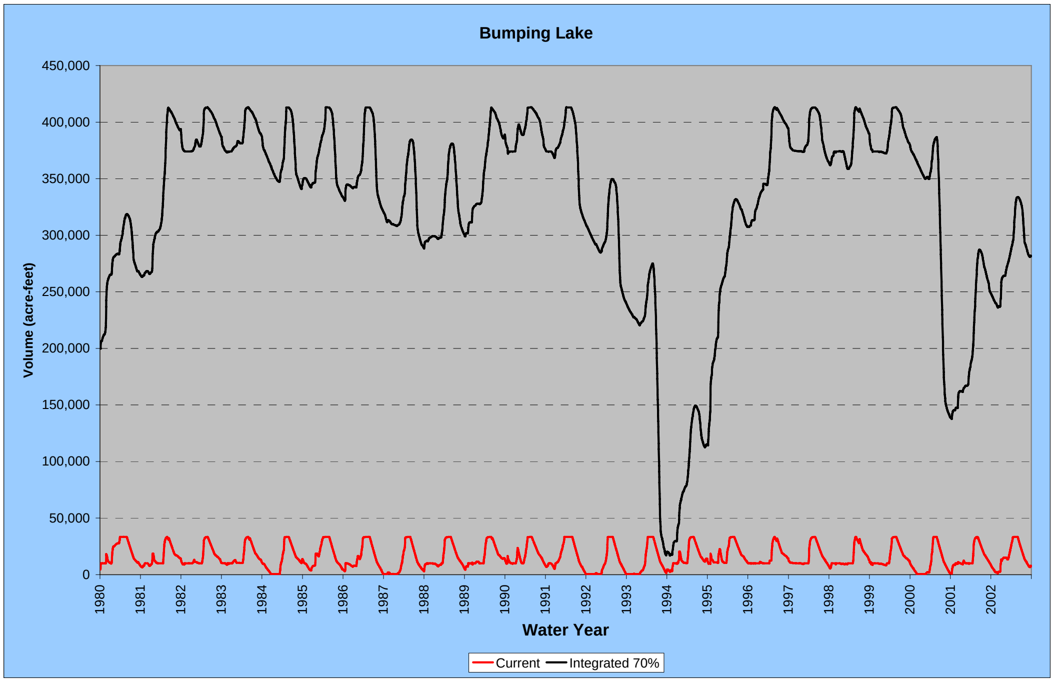

Figure 9-5. Bumping Lake Enlargement Contents for the Integrated 70% Operation Study

9.1.3.2.2 Wymer Dam and Reservoir. Table 9-6 shows the monthly pumping to Wymer reservoir and the releases back to the Yakima River. For this *Yakima Alternatives Appraisal Assessment*, the capacity of the Wymer pumping plant and the outlet works is 400 cfs.

Wymer reservoir would be filled mainly during the winter and spring months and releases would be made in the dry years when stored water is required in meeting Title XII target flows at Sunnyside Diversion Dam. This operation, shown in Figure 9-6, permits retention of stored water in the other Yakima Project reservoirs to improve the dry-year water supply available for all Yakima River basin proratable water rights. Only a minimum release would have been possible in 1994, because Wymer reservoir would have been empty in 1993, and there would have been little excess flow in 1994 to pump. In addition, diversion to Wymer reservoir would diminish the spring freshet by up to 400 cfs.

Table 9-6. Inflows and Releases from Wymer Reservoir with Integrated 70% Operation

	Monthly Inflow (acre-feet)													
Water Year	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Annual Inflow (a-f)**	**Annual Release (a-f)**
1981	0	14,853	10,709	11,901	13,796	Rel.*	Rel.	Rel.	Rel.	Rel.	Rel.	0	51,259	116,904
1982	0	0	8,727	17,745	24,595	17,157	24,595	16,579	7,649	0	0	0	117,048	0
1983	0	633	21,319	11,208	14,437	Full	Full	Full	Full	Full	Full	Full	47,597	0
1984	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1985	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1986	Full	Full	Full	Full	Full	Full	Full	Rel.	Rel.	Rel.	Rel.	Rel.	0	96,926
1987	6,557	0	0	0	13,959	6,245	2,901	Rel.	Rel.	Rel.	Rel.	Rel.	29,662	92,278
1988	0	0	0	1,286	0	13,744	0	Rel.	Rel.	0	0	0	15,030	19,563
1989	1,107	3,864	3,171	3,271	5,195	19,290	1589	0	0	0	0	0	37,486	0
1990	946	5,984	7,143	11,165	19,471	21,721	136	11,085	3,399	0	0	3,151	84,200	0
1991	19,463	22,925	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	42,388	0
1992	Full	Full	Full	Full	Full	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	0	131,988
1993	0	0	0	0	3,919	1,606	3,208	Rel.	Rel.	Rel.	0	0	8,733	41,256
1994	0	0	0	0	143	2,750	Rel.	0	0	0	0	0	2,893	3,174
1995	444	9,022	4,603	22,215	23,911	8,515	10,346	8,696	1,143	0	0	0	88,894	0
1996	18,638	24,595	24,595	8,070	Full	Full	Full	Full	Full	Full	Full	Full	75,898	0
1997	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1998	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1999	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
2000	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
2001	Full	Full	Full	Full	Full	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	0	141,795
2002	916	573	7,251	5,479	2,556	17,949	19,835	22,265	2,826	0	0	0	79,649	0
2003	0	0	4,823	17,668	18,670	15,969	2,792	Rel.	Rel.	Rel.	Rel.	0	59,923	80,926
Avg	2,090	3,585	4,015	4,783	6,115	5,433	2,844	2,546	653	0	0	137	32,203	31,513
	Average Daily Inflow (cfs) by Month												**Average Daily (cfs)**	
Avg	337	358	355	344	349	333	323	356	315	0	0	227	343	390
Max	400	400	400	400	400	400	400	400	400	0	0	311	400	400
Min	67	59	59	52	66	53	50	59	57	0	0	80	50	19

* "Rel." means releases were made from Wymer to the Yakima River.

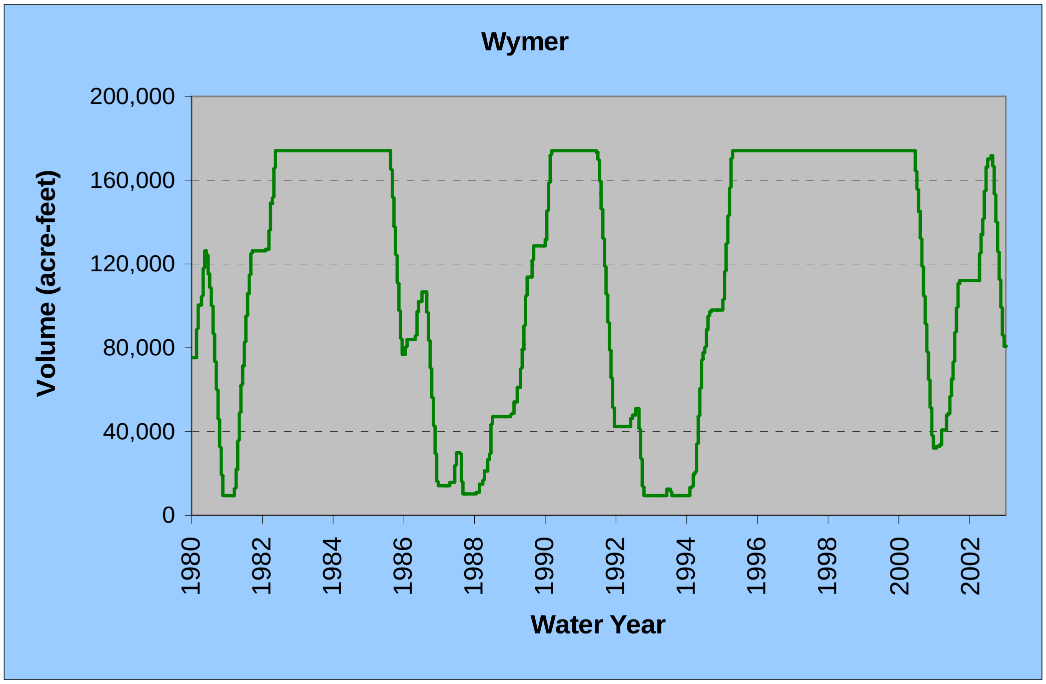

Figure 9-6. Wymer Reservoir Storage Contents for the 23-year Hydrologic Period

9.1.3.2.3 Keechelus-to-Kachess Pipeline. Figure 9-7 shows the volumes of water conveyed through the pipeline each year. While there was water conveyed in each year, the TWSA was increased in only one year, 1985, by 400 acre feet. The reservoir operation results in such small benefit for storage augmentation because, in wet years, Kachess Reservoir fills from its own watershed. During dry years, there would not be enough water in the Keechelus watershed to fill Keechelus Lake, so no water is conveyed to Kachess Reservoir.

9.1.3.2.4 Integrated Total System Storage. Storage contents of the existing five major Yakima Project reservoirs with and without the addition of the three storage alternatives are shown in Figure 9-8.

The five major Yakima Project reservoirs have an active storage capacity of 1,031,100 acre-feet. The three storage alternatives add 554,300 acre-feet of active storage.

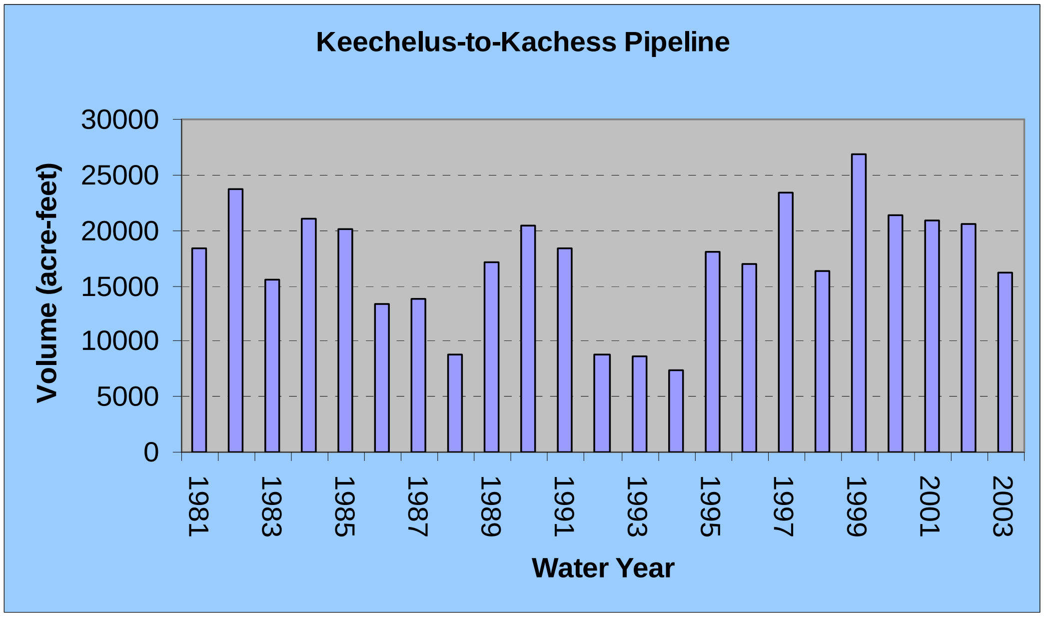

Figure 9-7. Total Volume of Water Conveyed from Keechelus Reservoir to Kachess Reservoir

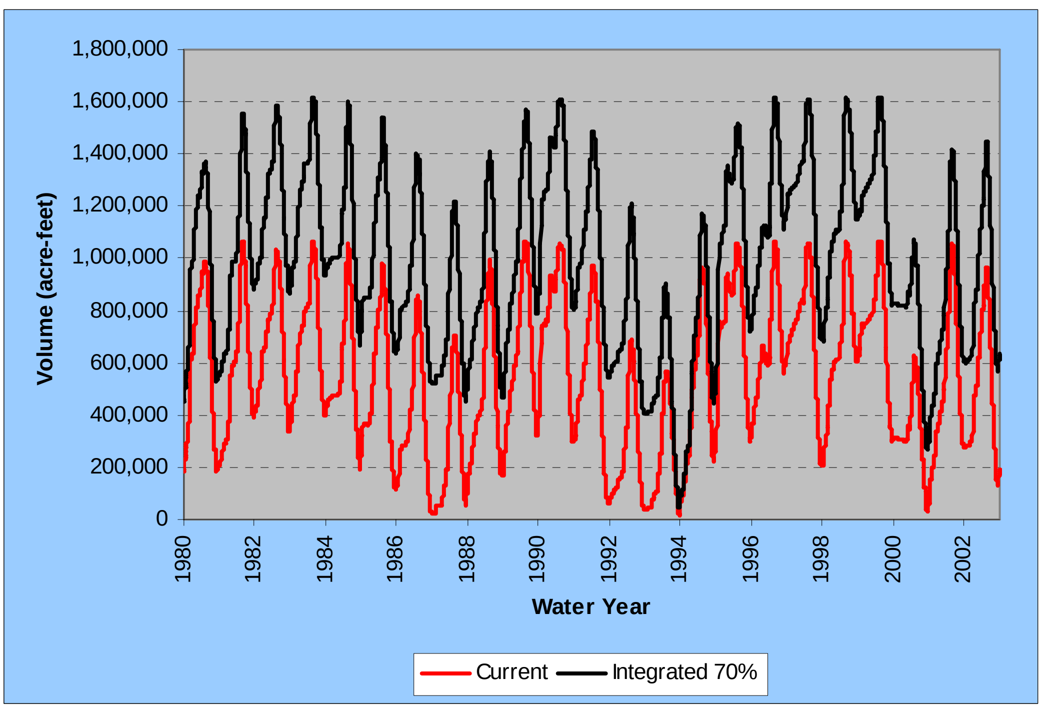

Figure 9-8. Total Reservoir System Storage - Integrated 70%

9.1.4 System Operation Results

9.1.4.1 *Fish Habitat*

9.1.4.1.1 Title XII Instream Target Flows. Title XII instream target flows at Parker range from 300 cfs to 600 cfs, depending on the estimated TWSA "threshold level" (see Table 4-1). The addition of the three storage alternatives would increase the "storage content" portion of the TWSA estimate, and could result in moving the target flows up from one threshold level to the next. If this occurred, and, if unregulated runoff failed to meet irrigation diversion demands and Title XII flows, reservoir releases would be required.

Table 9-7 summarizes the average increased flow rate (cfs) and the number of days at the increased flow rate, which would be provided from stored water resulting from the integrated scenarios. Also shown is the volume (acre-feet) of the increased flow estimated to be provided from stored water. This is for the period from the beginning of storage control through the end of the irrigation season. The integrated operations do not provide significant increases in Title XII instream flows. The additional water in storage is generally used to meet irrigation demands. In some years, it might be possible to use this increased volume for other fishery purposes rather than for increased Title XII instream target flows. For example, releasing stored water for a short duration could create "pulse flows" to enhance smolt outmigration.

9.1.4.1.2 River Reach Analysis. The fish habitat goal, as defined in Chapter 4, is to move the current flow regime of the Yakima and Naches Rivers to more closely resemble the natural (unregulated) flow regime. Reclamation chose seven reaches representing different flow patterns in the Yakima and Naches Rivers to compare the integrated 70-percent operation scenario to the current flow regime. This comparison is shown in the seven representative hydrographs (Figures 9-10 through 9-16). Table 9-8 shows the locations of these seven gauges and their corresponding stream reaches. The results of the analysis are shown later in this chapter. The flows at the gauging stations shown below were used to represent the flow regime for the corresponding stream reaches (see also Figure 9-9).

The hydrographs show median monthly flows for the water years 1981 through 2003 for the natural (unregulated) scenario, the current operation scenario, and the integrated 70-percent operation scenario for the seven stream reaches identified below. The median monthly flow is the flow which ranks 12th highest of the 23-year period of record. There are 11 months higher and 11 months lower. The hydrographs follow the typical October 1 to September 30 water year. The Yakima River basin irrigation season commences April 1 and ends October 15.

Table 9-7. Increased Title XII Flows at Sunnyside Diversion Dam

Year	Average Increased Flow Rate (cfs) (Number of Days at the Increased Flow Rate)			Volume of Increased Flow From Stored Water (acre-feet)		
	Integrated 70% Operation	Integrated 50% Operation	Integrated 100% Operation	Integrated 70% Operation	Integrated 50% Operation	Integrated 100% Operation
1981	200 (134 days)	200 (134 days)	200 (131 days)	53,000	53,000	52,000
1982	100 (91 days)	100 (86 days)	100 (91 days)	18,000	17,000	18,000
1983	100 (91 days)	100 (91 days)	100 (91 days)	18,000	18,000	18,000
1984	100 (111 days)	100 (111 days)	100 (111 days)	22,000	22,000	22,000
1985	300 (133 days)	300 (133 days)	300 (133 days)	79,000	79,000	79,000
1986	200 (164 days)	200 (164 days)	200 (156 days)	65,000	65,000	62,000
1987	100 (171 days)	100 (171 days)	200 (33 days)	32,000	34,000	13,000
1988	100 (151 days)	100 (151 days)	- -	30,000	30,000	- -
1989	200 (118 days)	200 (118 days)	- -	47,000	47,000	- -
1990	200 (126 days)	200 (129 days)	100 (121 days)	50,000	51,000	24,000
1991	200 (118 days)	200 (118 days)	200 (118 days)	47,000	47,000	47,000
1992	100 (126 days)	100 (126 days)	- -	25,000	25,000	- -
1993	100 (116 days)	100 (116 days)	- -	23,000	23,000	- -
1994	- -	- -	- -	- -	- -	- -
1995	- -	100 (101 days)	- -	- -	20,000	- -
1996	200 (129 days)	200 (129 days)	200 (129 days)	51,000	51,000	51,000
1997	- -	- -	- -	- -	- -	- -
1998	300 (119 days)	300 (119 days)	300 (119 days)	71,000	71,000	71,000
1999	- -	- -	- -	- -	- -	- -
2000	200 (108 days)	200 (108 days)	200 (108days)	43,000	43,000	43,000
2001	- -	- -	- -	- -	- -	- -
2002	200 (103 days)	200 (101 days)	100 (106 days)	41,000	40,000	21,000
2003	200 (129 days)	200 (144 days)	100 (136 days)	37,000	57,000	27,000

Table 9-8. Gauging Stations and Stream Reaches

Gauge Station/ Hydrograph	Reach Name	Stream Reach
Keechelus (RM 214.5)	Keechelus-Easton	Yakima River: Keechelus Dam (RM 214.5) to Lake Easton (RM 203.5)
Easton (RM 202.0)	Easton	Yakima River: Easton Dam (RM 202.5) to Cle Elum River confluence (RM 185.6)
Umtanum (RM 140.4)	Ellensburg	Yakima River: Cle Elum River confluence (RM 185.6) to Roza Diversion Dam (RM 127.9).
Bumping Dam outlet (RM 17.0)	Bumping	Bumping River: Bumping Dam (RM 17.0) to American River confluence (RM 0.0)
Cliffdell (RM 37.9)	Upper Naches	Naches River: Little Naches confluence (RM 44.6) to Tieton River confluence (RM 17.5)
Naches at Naches River (RM 16.8)	Lower Naches	Naches River: Tieton River confluence (RM 44.6) to the Naches River confluence (RM 0.0)
Parker (RM 108.7)	Wapato	Yakima River: Sunnyside Diversion Dam (RM 103.8) to Granger (RM 83.0)

The hydrographs illustrate the three scenarios, which are represented by the following:

- Unregulated (black line)—Simulates the natural (unregulated) flow regime from 1981-2003. These flows represent the flow regime that would have happened without any storage reservoirs.

- Current (red line)—Simulates current river operations as described in the *Interim Comprehensive Basin Operating Plan* (Reclamation, 2002).

- Integrated 70-percent (green line)—Simulates the combined effect of Bumping Lake enlargement, Wymer dam and reservoir, and Keechelus-to-Kachess pipeline alternatives with the existing irrigation system and operations.

The vertical lines on the hydrograph represent variations of flow from the 75th percentile (top of the line) to the 25th percentile (bottom of the line). For example, the median flow was 285 cfs for the natural (unregulated) scenario in October at Easton; the 75th-percentile flow was 450 cfs, and the 25th-percentile flow was 157 cfs. The 75th-percentile flow of 450 cfs means that for all the daily mean flows recorded in the month of October for the 23-year period of record, 75 percent of these daily mean flows were less than 450 cfs.

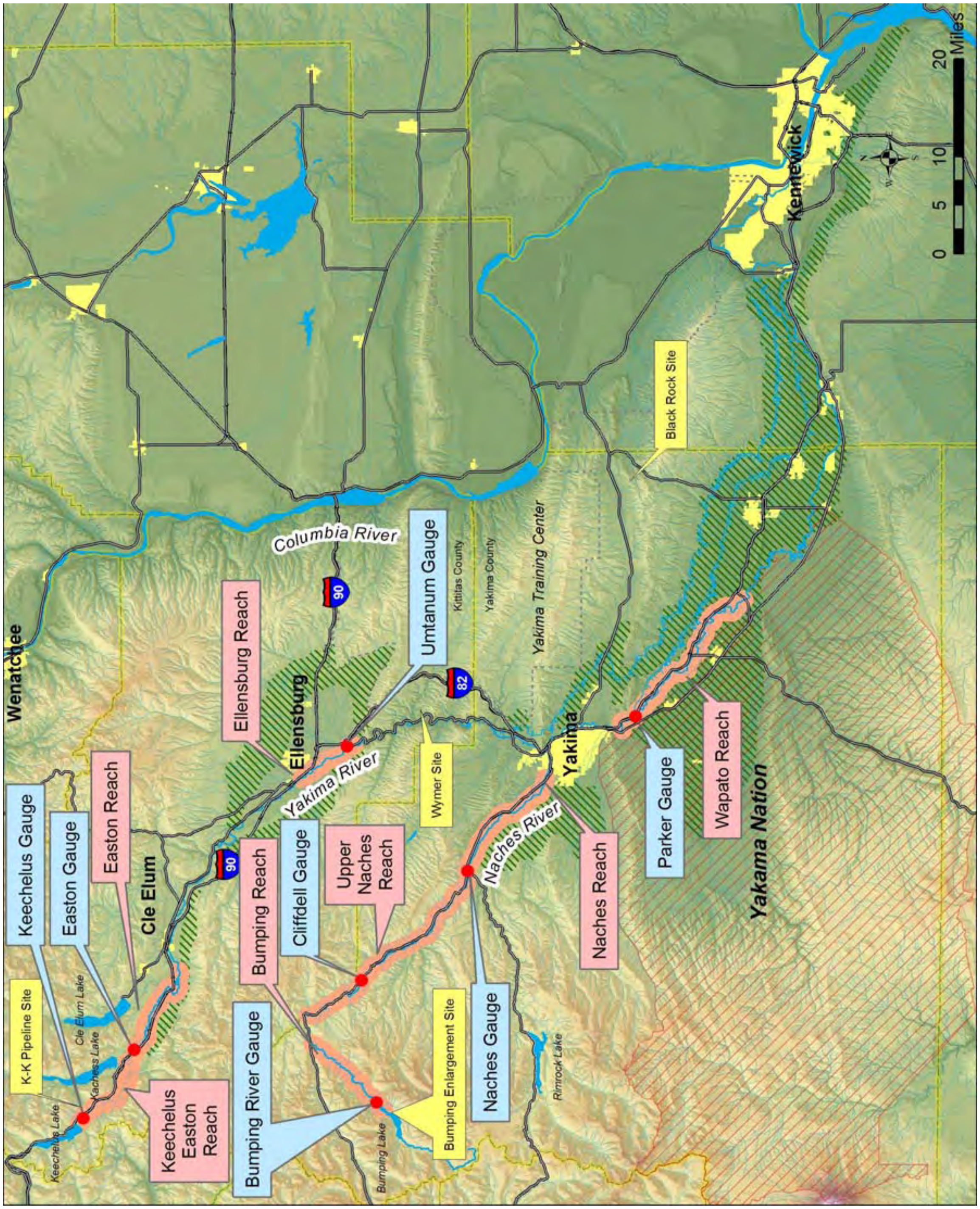

Figure 9-9. Stream Reaches and Gauges Location Map

A reach-by-reach discussion of the differences in flow regimes between the current and integrated 70-percent scenarios follows.

Keechelus Dam Outlet, Yakima River (RM 214.5)

The integrated 70-percent operation scenario resembles the current operation scenario with some improvements in spring and summer flows. The April median flow would increase by 303.8 percent for the integrated 70-percent operation scenario (80 cfs), compared to the current operation scenario (323 cfs); while May and June median flows were within 12 percent of each other for both scenarios. The other improvement was a decrease in median flows in July and August for the integrated 70-percent operation scenario, compared to current operation scenario. The median monthly flows would decrease in July by 12.7 percent and in August by 55.1 percent (see Figure 9-10).

Changes in the current flow regime to more closely resemble the natural (unregulated) hydrograph at the Keechelus-Easton Reach would be:

- To shift the peak flow period to be centered on May.
- To provide a decreasing trend in streamflows from May through September, with base flows occurring in August and September.

These desired improvements in flow conditions would not be appreciably met by the integrated 70-percent operation scenario.

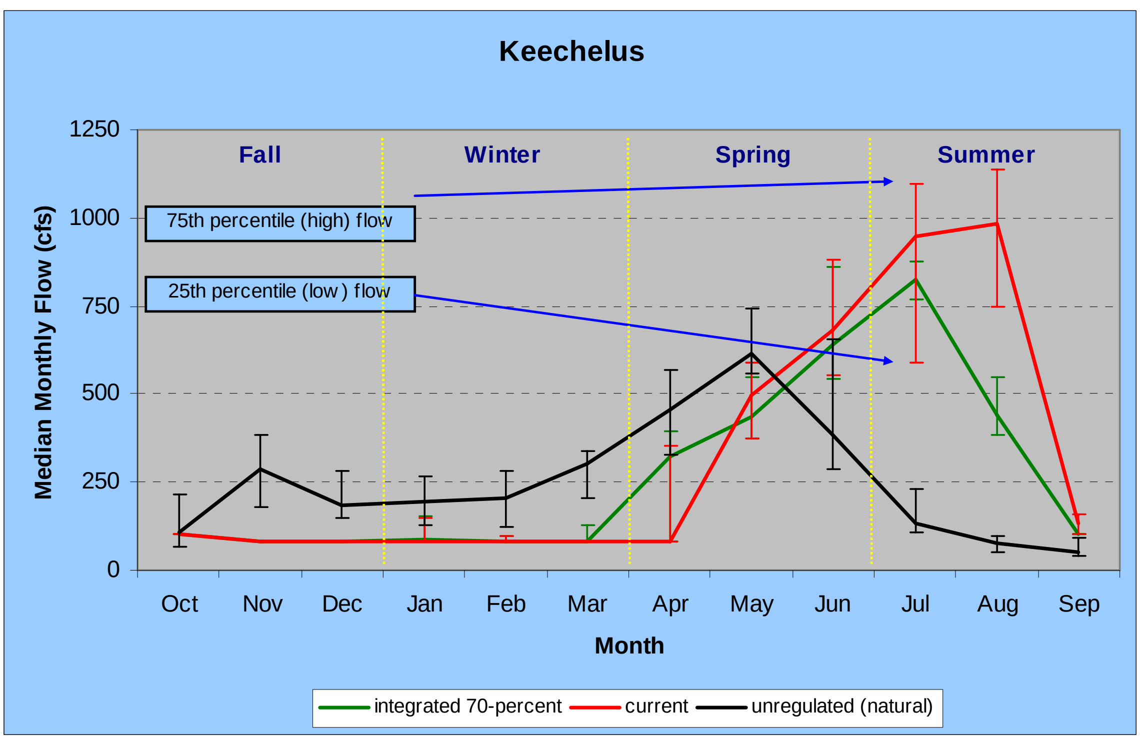

Figure 9-10. Representative Hydrograph at the Keechelus Dam Outlet, Yakima River Gauging Station (RM 214.5)

Easton, Yakima River (RM 202.0)

There was essentially no change in the flow regime between the integrated 70-percent and current scenarios for the Easton reach of the Yakima River (Figure 9-11). The monthly median flows between the two scenarios were nearly identical, with differences only occurring in November, December and August, and never deviating more than ±50 cfs in monthly median flow. Similarly, there was no change in the eight qualitative hydrologic flow parameters for the integrated 70-percent scenario compared to the current scenario.

Changes in the current flow regime to more closely resemble the natural (unregulated) hydrograph at the Easton Reach would be:

- Spring peak flows of greater magnitude and, more importantly, better timing with the natural (unregulated) hydrograph, where flows begin to increase in April, peak in May, and decline in June.
- An increase in late fall and winter streamflows that allow for a more natural variation to the daily/weekly flows (opposed to a constant minimum flow).
- A decrease in summer flows.

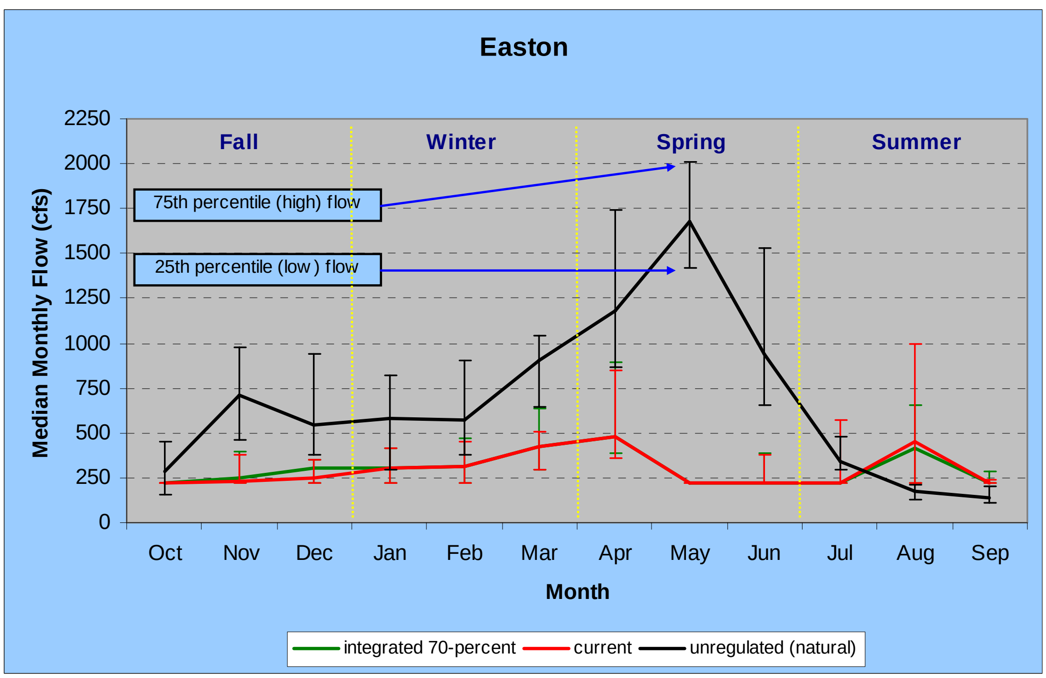

Figure 9-11. Representative Hydrograph at the Easton, Yakima River, Gauging Station (RM 202.0)

Umtanum, Yakima River (RM 140.4)

There was no significant change in the flow regime between the current and Integrated 70-percent operation scenarios (Figure 9-12). The greatest percent difference for any given month between the two scenarios was -10.8 percent (-179 cfs) (February). The percent difference in monthly median flows between the integrated 70-percent and current scenarios is as follows: April, -8.7 percent; May, +6.5 percent; and June, +2.8 percent. Late fall and winter flows for both scenarios are generally within the natural (unregulated) 25th and 75th percentile flow criteria.

However, both operations create flows that significantly deviate from the natural (unregulated) hydrograph during the months of April, May, July, and August. The April-May deviation is due to filling the reservoirs (mainly Cle Elum) to full capacity during the snowmelt period. The July-August deviation is due to transporting irrigation water from Cle Elum Lake via the Yakima River to entities in the middle Yakima River basin during the peak irrigation season. The integrated operation does not alleviate or significantly modify the operation that presently exists. The percent change in flow from August to September was -63.4 percent for the current operations scenario, and -60.7 percent for the integrated 70-percent operation scenario.

Changes in the current flow regime to more closely resemble the natural (unregulated) hydrograph at the Ellensburg Reach would be:

- Timing that is more comparable to the natural (unregulated) hydrograph, meaning flows begin to increase in April, peak in May, and decline in June, with a somewhat greater flow magnitude in April and May.

- Reduced summer flows, especially in July and August that resemble closer to natural (unregulated) summer flow regime, and the elimination or significant reduction in the flip-flop operation.

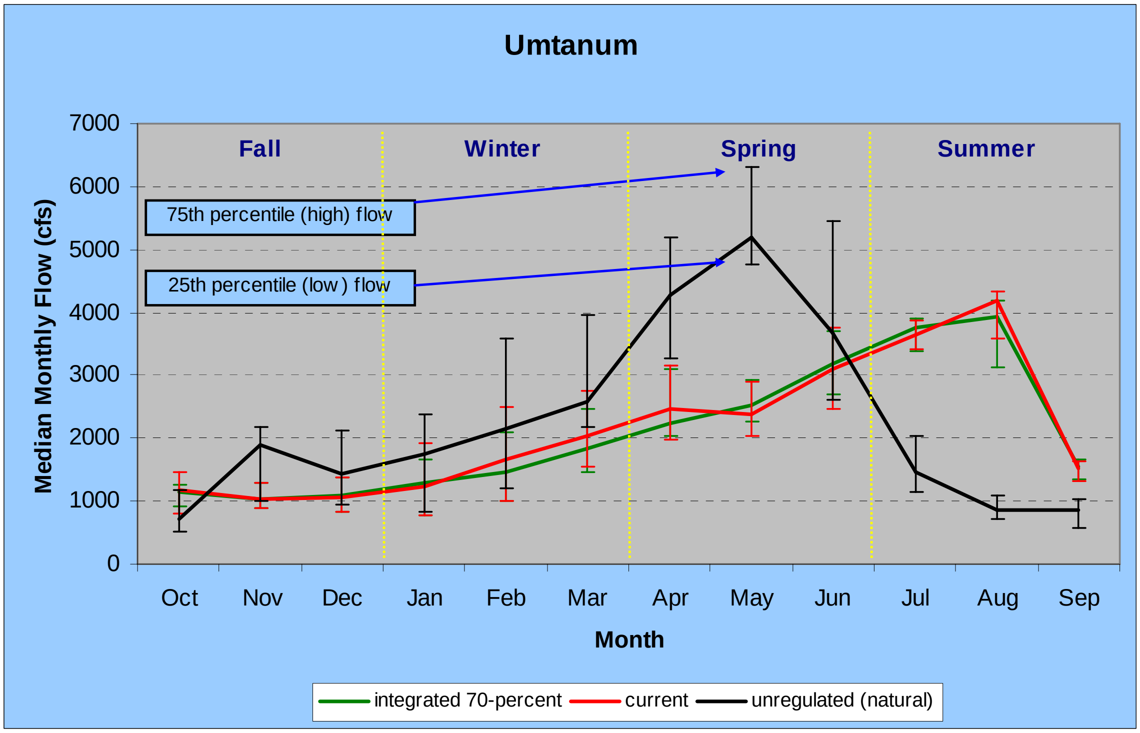

Figure 9-12. Representative Hydrograph at the Umtanum, Yakima River, Gauging Station (RM 140.4)

Bumping Dam Outlet, Bumping River (RM 17.0)

The current operation of the Bumping River resembles the natural (unregulated) hydrograph September through March, and then deviates April through August (Figure 9-13). The small capacity of the reservoir (33,700 acre-feet) allows the majority of flow in the Bumping River to pass in an unregulated manner, especially during the snowmelt period. Peak spring flows equal the natural (unregulated) magnitude, but occur one month later (June), with a shorter duration. Historically, peak flows occurred in April, May, and June; they now occur in May, June, and July. The second deviation from the natural (unregulated) hydrograph occurs in later summer from July to August as flows are increased in the Naches basin for the flip-flop operation.

The integrated 70-percent operation scenario did not improve the current operation scenario and, in fact, the existing flow regime became less natural. Spring flows were reduced in May by 45.0 percent (113 cfs) and in June by

65.9 percent (365 cfs), and winter flows in January by 12.8 percent (20 cfs) and in March by 23.3 percent (40 cfs), from the current operation. These reductions move the peak flow month from June to August, which further disturbed the natural (unregulated) spring peak flow period. These reductions in winter and spring flows, and the change in timing of the peak flows, are due to water being stored in the larger reservoir.

The integrated 70-percent scenario August median flows increased by 120.3 percent (264 cfs), and September median flows increased by 85.0 percent (111 cfs), compared to the current scenario. The reason for increased summer flows is because additional stored water is available to meet irrigation demand in the lower basin, especially in water-short years.

It should be noted that changes in the flows in the Bumping River will change flows at all locations below on the Naches and Yakima Rivers.

Changes in the current flow regime to more closely resemble the natural (unregulated) hydrograph at the Bumping Reach would be:

- Shifting the peak flow period to April, May, and June.
- Reduced summer flows, especially in July, August, and September.

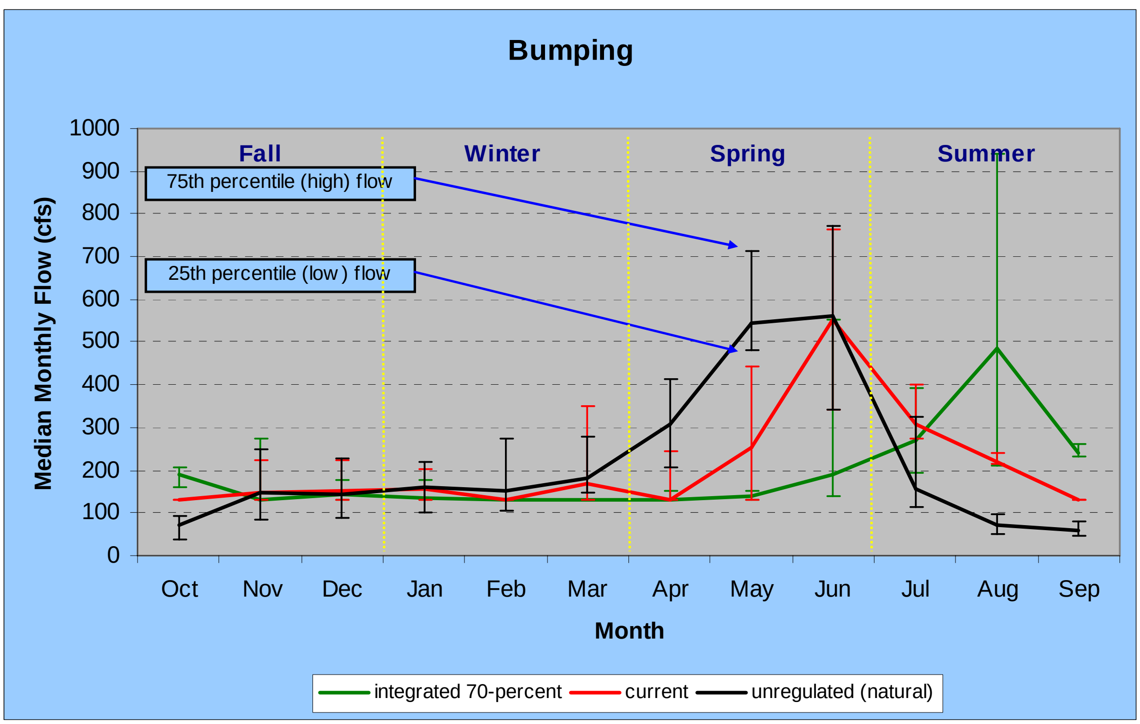

Figure 9-13. Representative Hydrograph at the Bumping Dam Outlet, Bumping River (RM 17.0)

Naches River at Cliffdell (RM 37.9)

The current operation of the upper Naches River closely resembles the natural (unregulated) hydrograph throughout the year (Figure 9-14). Monthly median flows are slightly lower in the spring and somewhat higher in the summer. The integrated 70-percent operation scenario would decrease median flows in May by 16.0 percent and in June by 23.1 percent compared to the current operation scenario. The decrease in spring peak flow would result from the filling of the enlarged Bumping Lake.

The integrated 70-percent operation scenario would create a flip-flop event in August and September. There is currently a decreasing trend in streamflow from July through September, which is comparable to the natural (unregulated) flow pattern. However, for the integrated 70-percent operation scenario, streamflows would increase from July to August and then decrease again in September. The August median flow for the integrated 70-percent operation scenario would increase 115.4 percent compared to the current operation scenario. The release of water stored in an enlarged Bumping Lake to meet downstream irrigation demands would create a flip-flop event in the upper Naches River. This event would be more pronounced in proration years than in average or wet water years.

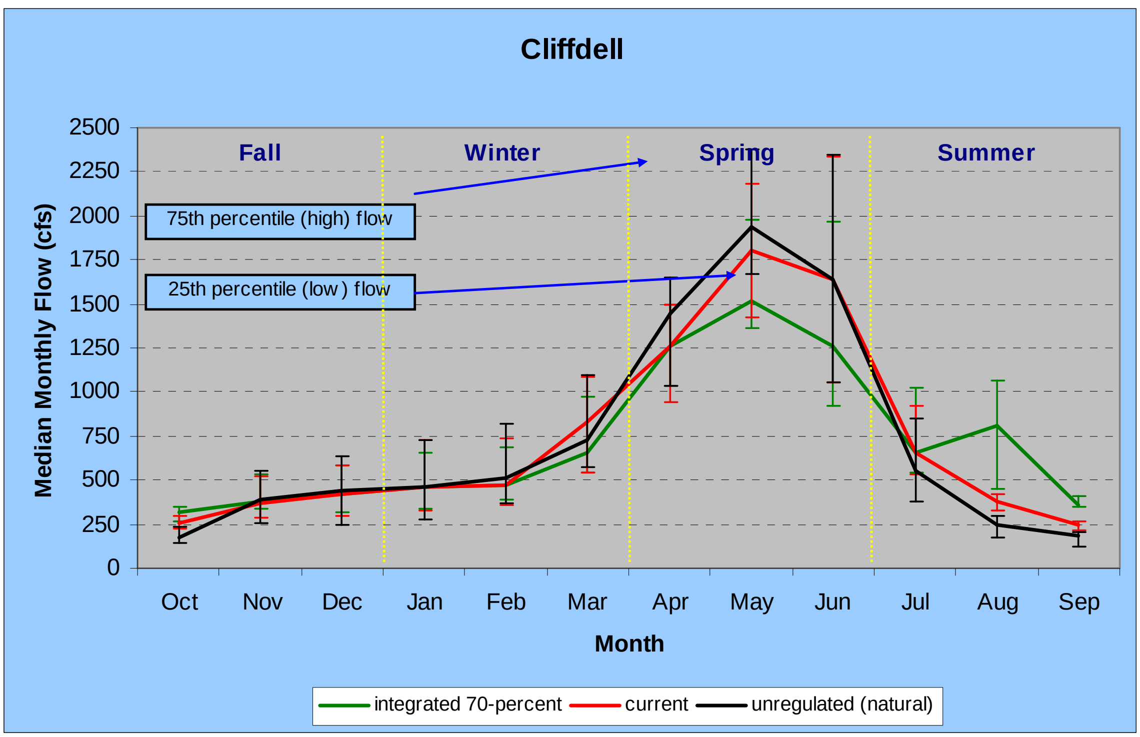

Figure 9-14. Representative Hydrograph at the Naches River at Cliffdell Gauging Station (RM 37.9)

Naches at Naches River (RM 16.8).

Like the Bumping River, the current operation scenario flow regime of the lower Naches River resembles the natural (unregulated) flow regime October through March, then begins to deviate April through September (Figure 9-15). Peak spring runoff occurs in June for the current operation scenario compared to May for the natural (unregulated) scenario. Similarly, the spring peak flow period is shifted ahead one month to May, June, and July for the current operation scenario, compared to April, May, and June for the natural (unregulated) scenario. The flip-flop operation results in unnatural high flows beginning in late August through September.

The integrated 70-percent scenario did not improve the existing lower Naches flow regime and, in fact, it resulted in a less natural flow regime than currently exists. The integrated 70-percent scenario decreased spring flows in April by 1.9 percent (-34 cfs), in May by 11.7 percent (-265 cfs), and in June by 11.4 percent (-287 cfs) relative to the current operation scenario, and peak spring flows remained shifted one month ahead (May, June, and July).

The integrated 70-percent scenario increased summer and fall flows in July by 12.9 percent (150 cfs), in August by 115.1 percent (557 cfs), in September by 8.7 percent (157 cfs), and in October, by 53.4 percent (315 cfs) relative to the current operation scenario. As previously mentioned for the Bumping River, the increase in summer flows is due to using the additional storage capacity in Bumping Lake to meet irrigation demand in the lower basin, especially in water-short years.

In August and September, the integrated 70-percent operation scenario changes the median monthly flows less than the current operation. This is based on the percent change in flows from August to September. The August to September flows increased 264 percent (from 484 cfs to 1760 cfs) for the current operation scenario, while the flows increased 84 percent (from 1041 cfs to 1914 cfs) for the integrated 70-percent scenario.

Changes in the current flow regime to more closely resemble the natural (unregulated) hydrograph at the Lower Naches Reach would be:

- To shift the peak flow period to April, May, and June.
- To reduce summer flows in September to eliminate or significantly reduce the flip-flop operation.

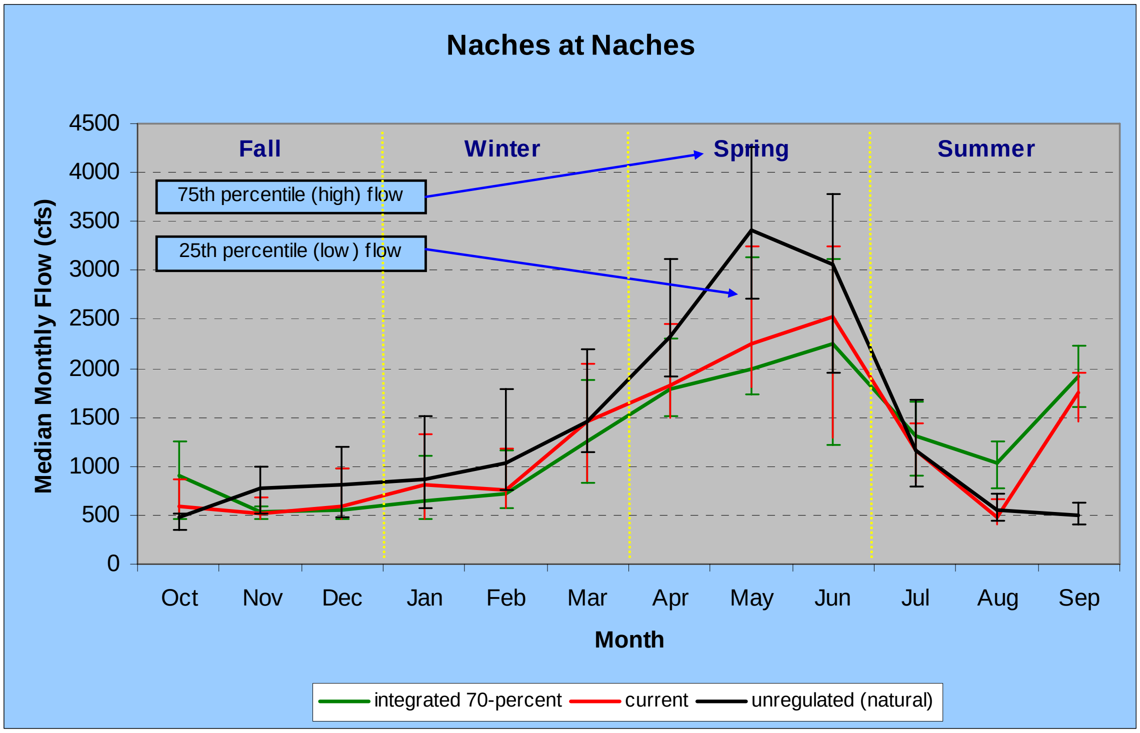

Figure 9-15. Representative Hydrograph at the Naches at Naches River Gauging Station (RM 16.8)

Parker, Yakima River (RM 108.7)

There was minimal difference in the flow regime between the integrated 70-percent and current operation scenarios for all seasons (Figure 9-16). Both resemble the natural (unregulated) fall and winter flow regime pattern.

The spring and summer flow magnitudes are less than the natural (unregulated) flows for both the integrated 70-percent and current scenarios. The monthly median flow was reduced by -2.8 percent (17 cfs) in May and by -35.7 percent (480 cfs) in June, compared to the current operation. For both scenarios, peak flows occur in March at a reduced magnitude and steadily decline April through June, instead of peaking in May, with much higher flows in April and June, as in the natural (unregulated) scenario.

Summer (July-September) median flows do increase from an average of 313 cfs to 616 cfs (+96 percent) for the integrated 70-percent scenario compared to the current scenario. This increase is attributable to an average increase in the TWSA for the period of record, which increases the Title XII flows at Parker.

Changes in the current flow regime to more closely resemble the natural (unregulated) hydrograph at the Wapato Reach would be:

- To improve timing in the spring seasonal flows, as well as increasing the flow magnitude.
- To increase the magnitude of the summer seasonal flows.

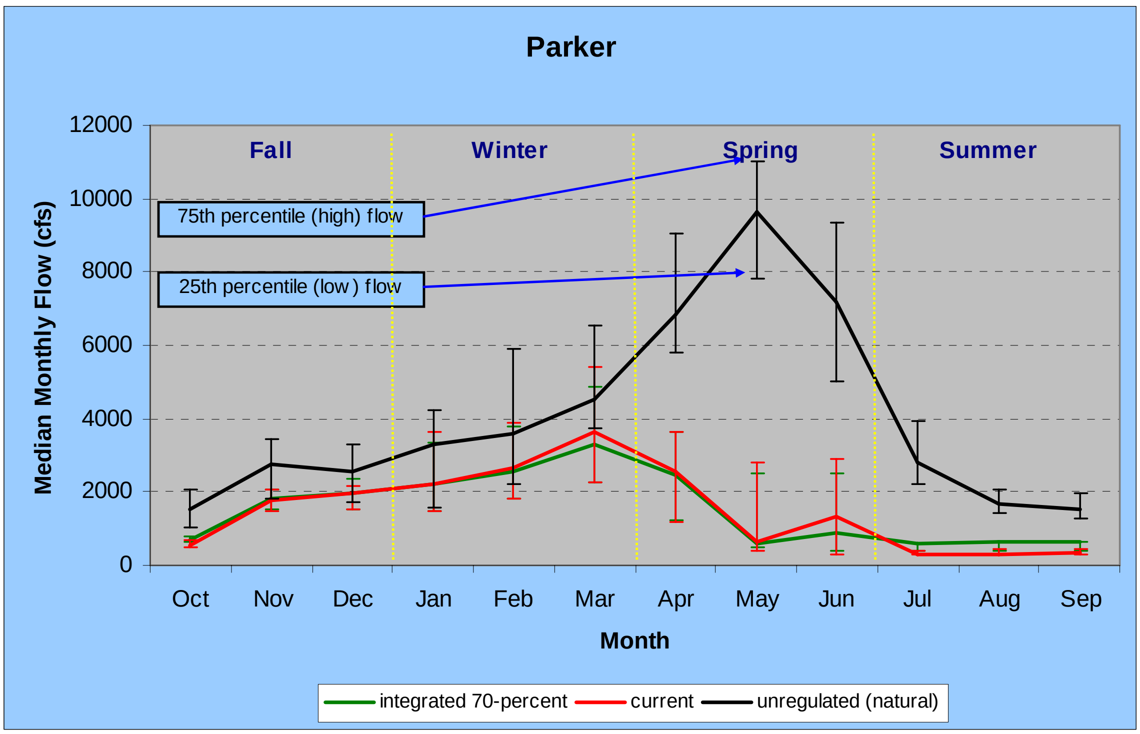

Figure 9-16. Representative Hydrograph at the Parker, Yakima River, Gauging Station (RM 108.7).

The information presented in Table 9-9 is derived from the Indicator of Hydrologic Alterations (IHA) model.[32] The IHA model has been used throughout the United States to evaluate river operations and impacts on the riverine ecosystem. The IHA model generates a set of descriptive flow statistics that describe the flow conditions of a particular scenario relative to the natural (unregulated) condition. The IHA model is a diagnostic tool that analyzes which flow parameters are within, or out of, criteria, compared to the natural (unregulated) condition.

Reclamation took the results of the IHA model, compiled it into eight hydrologic flow parameters (similar to IHA parameters), and separated them into three groups. These eight parameters were used in Table 9-9 to show the relative effects of the integrated 70-percent operation scenario compared to current operations. Background information for Table 9-9 is available upon request. The parameters and groups are shown below.

Group I - - Seasonal Magnitude.

The IHA model evaluates three flow ranges: low flows (<25th percentile of occurrence); middle flows (≥25th and ≤75th percentile of occurrence); and high flows (>75th percentile of occurrence), for a particular scenario relative to the natural (unregulated) condition. This comparison was conducted for each month. In Group I, there are 36 monthly flow parameters and 3 flow ranges for each month (12). These 36 parameters were then organized by season; defined as follows: spring (April, May, June); summer (July, August, September); fall (October, November, December); and winter (January, February, March).

Reclamation used the IHA model to compare each of the 36 integrated 70-percent operation scenario monthly flow parameters to the corresponding current operation scenario parameters. Reclamation then recorded whether each integrated 70-percent monthly flow parameter was better, worse, or showed no change relative to the corresponding current operation scenario monthly flow parameter. The results were summarized for each season and expressed as a percent of the number of monthly flow parameters that were better, worse, or no change, relative to the current operation scenario.

The "better," "worse," and "no change" categories for Group I and Group II shown in Table 9-9 refers to the comparison of integrated 70-percent operation scenario flow parameters to the current operation scenario. The question being addressed is, "Did flow parameter X get better, worse, or show no change for the

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[32] The Nature Conservancy developed the IHA software. The Nature Conservancy's website (www.freshwaters.org/tools) provides a download of the software and supporting documents.

integrated 70-percent operation scenario, compared to the current operation scenario?"

Group II - - Magnitude-Duration.

Group II consists of 30 flow parameters, 15 for the minimum flow parameter, and 15 for the maximum flow parameter. Each minimum and maximum flow parameter is organized into the three IHA flow ranges: low; middle; and high, based on the percentile of occurrence as described above for the Seasonal Magnitude flow parameter. Thus, Group II is made up of six groups (*i.e.*, minimum-IHA low flow range; minimum-IHA middle flow range; minimum-IHA high flow range; and maximum-IHA low flow range; maximum-IHA middle flow range; and maximum-IHA high flow range,) with five streamflow durations—1-day, 3-day, 7-day, 30-day, and 90-day. For example, within water year 1984, the model will calculate which 30-day period resulted in the highest or lowest average streamflow. There is no time element associated with these two parameters, meaning it is not known when this event occurred during the water year.

The analysis was conducted similar to that described for Group I, meaning each of the 30 integrated 70-percent operation scenario flow parameters was compared to the corresponding current operation scenario flow parameter. Results from the 30 comparisons were recorded as "better," "worse," or "no change." The results were summarized for the minimum and maximum flow parameters and expressed as a percentage in the better, worse, and no change categories.

Group III - - Peak and Base Flow Timing.

The peak flow and base flow parameters define Group III. The peak and base flow periods are defined by the natural (unregulated) peak and base flows. Peak and base flow timing was analyzed in two steps. Step one determined how many months peak or base flows occurred within the natural (unregulated) defined peak and base flow period. This was summarized in Table 9-9, under Group III, for both the current operation and the integrated 70-percent operation scenarios. For example, the first occurrence in Table 9-9 is for the Bumping gauge, for the peak flow parameter for the current operation scenario which reads, "2 of 3." This means for the current operation scenario, two out of a possible three months coincided with the natural (unregulated) peak flow period (April, May, and June). The second step compares the peak and base flow parameters between the current operation and integrated 70-percent operation scenarios for each gauge station. In the previous example, the current operation produced peak flows in 2 out of 3 months (*i.e.*, "2 of 3"). The integrated 70-percent operation scenario for the peak flow parameter for the Bumping gauge station did not produce any peak flows in that period, which reads “0 of 3.” This means that none of the integrated 70-percent operation scenario peak flow months coincided with the natural (unregulated) peak flow period. Therefore, compared to the current operation scenario, the integrated 70-percent operation scenario had two fewer months that coincided with the natural (unregulated) peak flow period. This results in a “worse” rating for this particular item.

Table 9-9. Summary of Hydrologic Flow Parameter Comparison Between the Current and Integrated 70% Scenarios for the Bumping, Naches at Naches, Easton, Umtanum, and Parker Gauge Stations

			Bumping	Naches at Naches	Easton	Umtanum	Parker
	Hydrologic Parameters	Change Category	Change in Scores	Change in Scores	Change in Scores	Change in Scores	Change in Scores
Group I	Seasonal Magnitude Parameters						
	Spring (Apr-Jun)	Better	0.0%	22.2%	44.4%	22.2%	0.0%
		No change	0.0%	55.5%	55.5%	55.5%	77.8%
		Worse	100.0%	22.2%	0.0%	22.2%	22.2%
	Summer (Jul-Sep)	Better	11.1%	22.2%	11.1%	0.0%	0.0%
		No change	77.7%	33.3%	78.8%	77.8%	100.0%
		Worse	11.1%	44.4%	11.1%	22.2%	0.0%
	Fall (Oct-Dec)	Better	0.0%	33.3%	11.1%	22.2%	22.2%
		No change	33.3%	44.4%	78.8%	66.7%	77.8%
		Worse	66.7%	22.2%	11.1%	11.1%	0.0%
	Winter (Jan-Mar)	Better	0.0%	0,0%	33.3%	22.2%	0.0%
		No change	0.0%	55.5%	67.7%	55.5%	77.8%
		Worse	100.0%	44.4%	0.0%	22.2%	22.2%
Group II	Magnitude/Duration Parameters						
	Minimum Flows	Better	0.0%	40.0%	0,0%	0.0%	0.0%
		No change	6.6%	26.7%	86.7%	47.0%	100.0%
		Worse	93.3%	33.3%	13.3%	53.0%	0.0%
	Maximum Flows	Better	46.6%	6.7%	26.7%	6.7%	13.3%
		No change	6.6%	0.0%	73.3%	73.3%	33.3%
		Worse	46.6%	93.3%	0.0%	20.0%	53.3%
Conclusion			Worse	Worse	No change	No change	No change
Group III	Peak & Base Flow Timing Parameters						
	Peak Flow (typically Apr-Jun)	Current: Number of months within unregulated peak flow period	2 of 3	3 of 3	1 of 3	1 of 3	1 of 3
		Integrated 70%: Number of months within unregulated base flow period	0 of 3	3 of 3	1 of 3	1 of 3	1 of 3
		Net Change in Peak Month Timing	-2	0	0	0	0
	Base Flow (typically Aug-Oct)	Current: Number of months within unregulated peak flow period	2 of 3	1 of 3	1 of 3	1 of 3	2 of 3
		Integrated 70%: Number of months within unregulated base flow period	0 of 3	0 of 3	1 of 3	1 of 3	2 of 3
		Net Change in Base Month Timing	-2	-1	0	0	0
Reach Summary Conclusion			Worse	Worse	No change	No change	No change

9.1.4.2 *Dry-Year Irrigation Water Supply*

The 23-year average TWSA is 3,210,000 acre-feet with the integrated 70-percent operation, as compared to the current operation TWSA of 2,850,000 acre-feet. With additional basin storage of 554,300 acre-feet,[33] and an operating plan that uses the additional storage capacity primarily as carryover, the 23-year average TWSA is increased by 360,000 acre-feet.

One-year droughts which follow 2 or more wet years could see a substantial improvement in water supply available over the current operation proration level. This is demonstrated by drought year 2001, where the modeled operation proration level was 41 percent, and the integrated 70-percent operation proration level is brought up to 70 percent.

Irrigation water supply conditions are improved in the prolonged dry period, such as 1992-1994. The additional storage alternatives increased the volume of proratable water supply in 1992 and 1993 to not less than 70 percent. The 1994 proratable supply was increased to 66 percent; 4 percentage points less than the 70-percent irrigation supply threshold. It is estimated the 4 percent difference in supply equals about 50,000 acre-feet.

Table 9-10 shows the proration levels for the current and integrated operation studies using the Yak-RW model and the historical water conditions of water years 1981 through 2003. The proration levels generated by the Yak-RW model for the "current operation" are different than actually experienced in the prorated years of the 1981-2003 period. This is because current-day operational criteria such as the Title XII instream target flows were implemented in 1995, and minimum streamflow maintenance releases from existing Yakima Project reservoirs are input into the model for the entire 23-year period. Further, actual day-to-day "hands-on" operation decisions cannot be reflected in the Yak-RW model.

[33] Bumping Lake enlargement active capacity of about 413,000 acre-feet (used in the operation study) less 33,700 acre-feet for the existing Bumping Lake, plus Wymer reservoir active capacity of about 175,000 acre-feet = 554,300 acre-feet (413,000 – 33,700 + 175,000 = 554,300).

Table 9-10. Water Supply Conditions in Yakima Basin Above Parker and Water Supply Available for Proratable Entitlements

		April 1 TWSA (million acre-feet)		Proratable Supply (%)			
Water Year	Unregulated Runoff Volume (million a-f)	Current Operation	Integrated 70% Operation	Current Operation	Integrated 70% Operation	Integrated 50% Operation	Integrated 100% Operation
1981	3.57	2.48	2.86	95	91	91	100
1982	4.26	3.39	3.85	100	100	100	100
1983	3.96	3.33	3.89	100	100	100	100
1984	4.06	3.23	3.79	100	100	100	100
1985	2.80	2.74	3.27	100	100	100	100
1986	3.06	2.50	3.00	92	89	88	100
1987	2.64	2.26	2.82	65	70	69	100
1988	2.75	2.33	2.84	73	89	87	90
1989	3.10	2.66	3.10	98	100	100	100
1990	3.72	3.10	3.50	100	100	100	100
1991	4.02	3.01	3.57	100	100	100	100
1992	2.45	2.14	2.65	69	70	65	100
1993	2.36	2.07	2.57	54	72	75	74
1994	2.06	1.74	2.14	26	66	50	27
1995	4.15	2.90	3.07	100	100	100	100
1996	5.71	3.22	3.65	100	100	100	100
1997	5.70	4.50	4.99	100	100	100	100
1998	3.38	3.15	3.68	100	100	100	100
1999	4.63	3.99	4.49	100	100	100	100
2000	3.66	3.26	3.78	100	100	100	100
2001	1.77	1.81	2.34	41	70	50	84
2002	3.79	3.23	3.57	100	100	100	100
2003	3.06	2.56	2.97	97	92	92	100
Average	3.51	2.85	3.21				

9.1.4.3 *Municipal Water Supply*

In the *Black Rock Appraisal Assessment,* Reclamation had assumed the future surface water need of 10,000 acre-feet for the cities of Cle Elum and Yakima (the only current municipal surface water users) could be met with any new storage facilities. After reviewing the water supply estimates in the 2003 *Watershed Management Plan*, Reclamation determined the future total municipal and domestic water needs could be as much as 82,000 acre-feet by the year 2050. If the results of ongoing groundwater investigation, scheduled for completion in

2007, show that there is connectivity of surface and groundwater, any increase in groundwater use by municipalities and domestic users may require mitigation by surface water supplies.

As information regarding the surface and groundwater connectivity becomes available, Reclamation will work with local and state entities to develop a strategy, including hydrologic modeling, to accommodate the volume and priority of municipal and domestic water demands. This issue will be addressed further in the Plan Formulation Phase of the Storage Study.

9.2 YAKIMA RIVER INFLOW TO COLUMBIA RIVER

Using the Yak-RW model to simulate current Yakima Project operations, the Yakima River basin annual water supply is grouped into three water supply conditions of wet, average, and dry years, as represented by the April 1 total water supply available. The total water supply available is an indicator of the water supply projected to be available to the Yakima Project upstream from the Parker gauge (RM 103.7) from natural runoff, irrigation return flows, and stored waters for irrigation and instream flow targets during April 1 through September 30 of each year. For purposes of this analysis, wet, average, and dry years are defined as follows:

- Wet year: April 1 TWSA is greater than 3,250,000 acre-feet.
- Average year: April 1 TWSA is between 2,250,000 and 3,250,000 acre-feet.
- Dry year: April 1 TWSA is less than 2,250,000 acre-feet.

Average monthly flows at Kiona gauge (RM 29.9) were then determined for the respective wet, average, and dry water supply conditions using the Yak-RW model monthly output for two alternatives: current Yakima Project operations and projected Yakima Project operations with the three basin storage alternatives. Current operations reflect the present Yakima Project management for flood control, irrigation, and streamflow operations. Streamflow operations include the flow targets at Sunnyside (RM 103.8) and Prosser (RM 47.1) Diversion Dams (as provided by Title XII of the Act of October 31, 1994), as well as flip-flop reservoir operations, and other present instream operations throughout the river system as generally described in the *Interim Comprehensive Basin Operating Plan*, in Chapter 5, “Current Project Operations/Total Water Supply Available.”

Yakima River flows at Kiona gauge are comprised of the following:

1. Natural (unregulated) flows.

2. Surface and subsurface return flows accruing primarily from irrigation.

3. Yakima Project reservoir operations specifically for streamflow enhancement, such as would occur from use of exchange water in resembling the natural (unregulated) flow regime.

Table 9-11 shows the resulting average monthly flows for wet, average, and dry Yakima River water supply conditions for the two alternatives. Annually, it is projected the additional flow in the Yakima River at its mouth could be slightly less with wet and average water supply conditions, and slightly more with dry water supply conditions.

Table 9-11. Average Monthly Flows (cfs) for Yakima River at Kiona, Based on Wet, Normal, and Dry Water Supply Conditions

Month	Current Operation	Wet Years Increased Yakima Storage	Difference	Current Operation	Normal Years Increased Yakima Storage	Difference	Current Operation	Dry Years Increased Yakima Storage	Difference
Nov	3,100	3,300	200	3,500	3,400	(100)	2,200	2,300	100
Dec	3,600	3,600	-	4,000	3,800	(200)	2,300	2,300	-
Jan	5,400	5,300	(100)	4,000	3,900	(100)	2,300	2,300	-
Feb	5,300	5,100	(200)	5,800	5,600	(200)	2,600	2,600	-
Mar	6,700	6,400	(300)	5,400	5,100	(300)	3,300	3,300	-
Apr	6,000	6,000	-	4,300	4,100	(200)	2,000	2,000	-
May	5,600	5,200	(400)	2,800	2,700	(100)	1,300	1,300	-
Jun	5,700	5,300	(400)	2,500	2,200	(300)	900	1,000	100
Jul	2,700	2,700	-	1,400	1,500	100	800	900	100
Aug	1,600	1,600	-	1,300	1,400	100	800	900	100
Sep	1,700	1,800	100	1,400	1,500	100	900	900	-
Oct	2,000	2,000	-	1,800	1,900	100	1,400	1,400	-
Annual (a-f)	2,976,400	2,910,900	(65,500)	2,286,100	2,221,100	(65,000)	1,257,900	1,279,300	21,400

Figure 9-17, Figure 9-18, and Figure 9-19 show hydrographs of average monthly flows at Kiona gauge (RM 29.9) for the three scenarios under wet, average, and dry water supply conditions, respectively.

Wet water supply years are defined as years when TWSA volumes are greater than 3,250,000 acre-feet from the current operation run for the period-of-record 1981 to 2003.

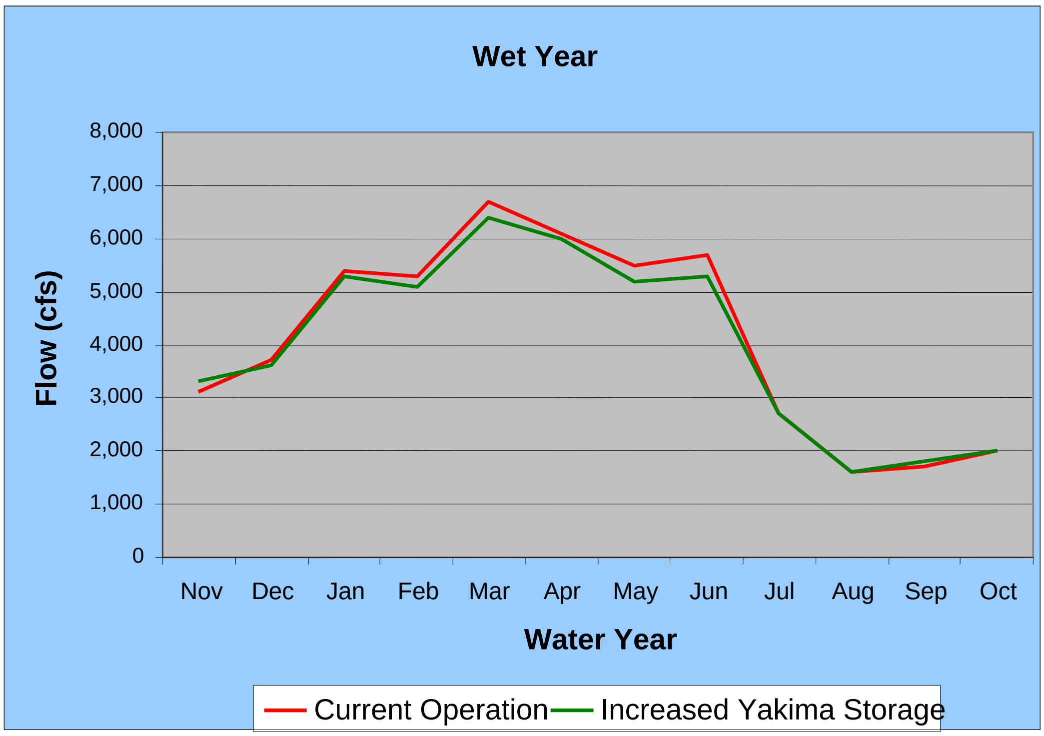

Figure 9-17. Wet Condition Average Monthly RiverWare Flow Results for Yakima River at Kiona

Average years are years when the current-operation-run TWSA volumes are between 3,250,000 acre-feet and 2,250,000 acre-feet from the period-of-record 1981 to 2003.

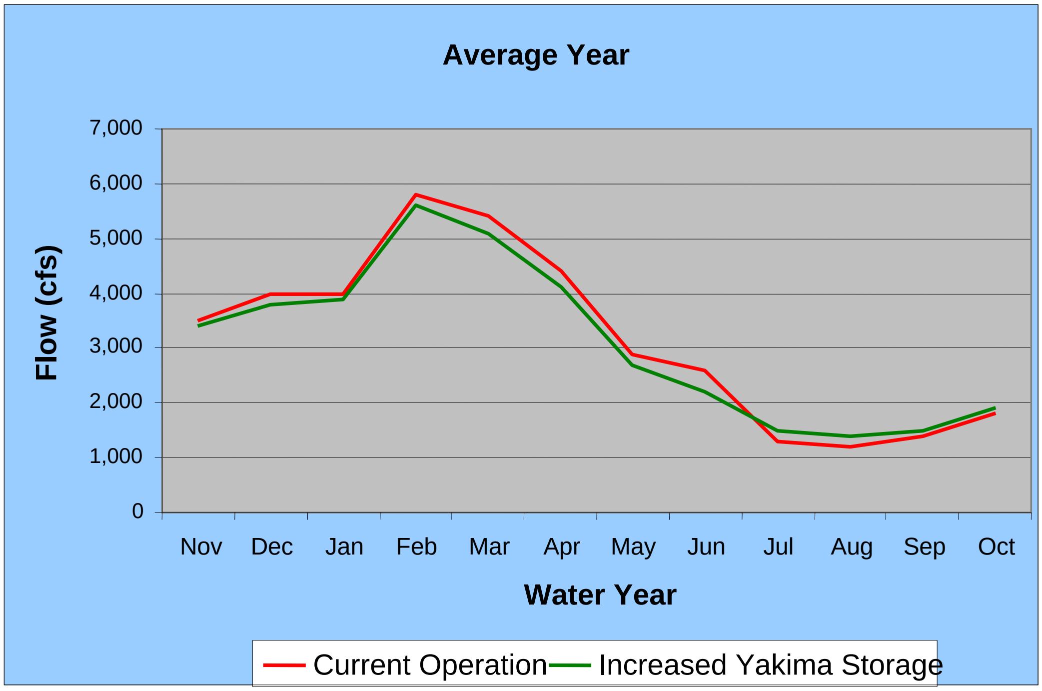

Figure 9-18. Normal Condition Average Monthly RiverWare Flow Results for Yakima River at Kiona

Dry water supply years are those when TWSA volumes are less than 2,250,000 acre-feet from the current operation run from the period-of-record 1981 to 2003.

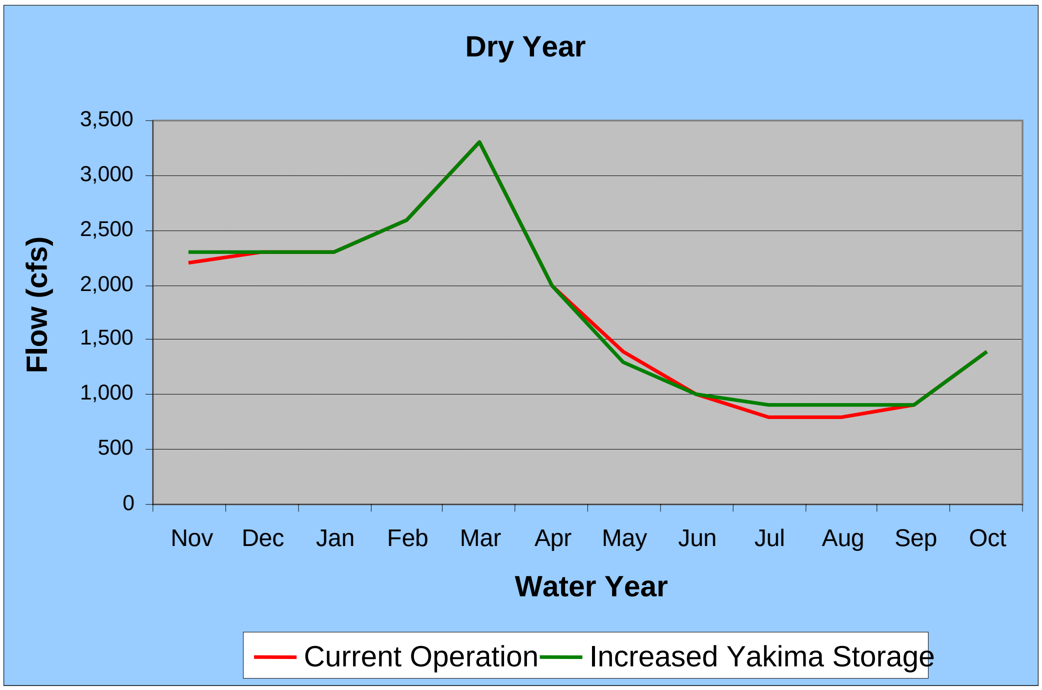

Figure 9-19. Dry Conditions Average Monthly RiverWare Flow Results for Yakima River at Kiona

9.3 WYMER PUMPING COSTS

Table 9-6 shows monthly pumping from the Yakima River to Wymer reservoir for the 23-year hydrologic period of record (1981-2003). The monthly volume pumped is determined by the Yakima River flows available in excess of target flows (see section 9.1.3.1.2.) and the availability of reservoir storage space. The Wymer reservoir operation for this *Yakima Alternatives Appraisal Assessment* involves release of water in dry years to meet Title XII target flows at Sunnyside Diversion Dam during the storage control period, instead of releasing water from upstream reservoirs. Consequently, this operation is characterized by extended periods when no releases are made, the reservoir remains full, and no pumping occurs.

The amount of energy required to pump water from the Yakima River into Wymer reservoir was computed using daily flow data from the Yak-RW model. The difference in pumping head was computed from the daily elevation of the water in the reservoir and the average elevation of the Yakima River at the pumping plant. Since the elevation of the water of the Yakima River at the pumping plant ranged from 1272.5 to 1284 feet, the average elevation used in the daily computations was 1278 feet. The daily energy used was totaled, and an average computed for each month. The average monthly power required is shown in Table 9-12. On average, the monthly pumping power requirement ranges from 0 MW in August and September to 3.6 MW in March. The average annual pumping power requirement is 1.6 MW.

The average monthly megawatt hours of pumping was then determined. From this, the average monthly pumping cost was computed by applying monthly pumping energy cost estimates forecast by the Bonneville Power Administration in its August 2003 rate case (Table 9-13). These reflect an average hourly rate for the respective month. The monthly average pumping costs are shown in Table 9-12. These range from about $0 in August and September to about $113,000 in March. Therefore, the total average annual pumping costs are estimated at about $600,000, but this could be higher or lower if a new rates analysis is performed due to changes in market conditions.

It should also be noted that the average monthly pumping costs in Table 9-12 include months when no pumping occurred. For instance, in the month of November, pumping occurred in 7 years of the 23-year hydrologic period. In these 7 years, the water pumped ranged from an average of about 500 acre-feet to about 20,000 acre-feet (Table 9-6). The average monthly power required (1.4 MW) is the average for all 23 months of November, including the 16 months of November when there was no pumping.

Table 9-12. Average Monthly Pumping Power Requirements and Costs

Month	Average Monthly Power Required (MW)	Average Monthly Pumping Costs ($)
October	0.1	4,100
November	1.4	58,600
December	2.1	88,000
January	2.4	84,400
February	2.9	98,700
March	3.6	112,900
April	3.1	83,900
May	1.7	40,400
June	1.6	26,100
July	0.4	9,600
August	0.0	0
September	0.0	0
Average Annual	19.3	606,700

Table 9-13. Average Monthly Energy Values

Month	Energy Values ($/MWH)
October	55.56
November	58.16
December	56.32
January	47.27
February	50.63
March	42.14
April	37.60
May	31.92
June	22.68
July	32.24
August	40.69
September	43.64
Average Monthly	43.24

9.4 FISH ISSUES AND DATA NEEDS

Reclamation initiated studies to address fish and wildlife resource issues associated with alternatives that may result from the Storage Study. Reclamation requested the Washington Department of Fish and Wildlife (WDFW) to identify fish and wildlife issues that the Storage Study should address. WDFW prepared a 45-item list which was refined down to 16 significant issues to serve as the foundation for fish and wildlife analyses and an environmental impact assessment. Reclamation defined a fish or wildlife issue as significant if the resource response: (1) is anticipated to be measurable (*i.e.*, either a positive or negative change from existing conditions); and (2) could be linked to more or less water in the Columbia or Yakima River systems resulting from implementation of an alternative of the Storage Study.

Reclamation asked area fish and wildlife experts to form a Biology Technical Work Group (Biology TWG). The Biology TWG consists of technical representatives from National Oceanic and Atmospheric Administration (NOAA) Fisheries, U.S. Fish and Wildlife Service, WDFW, Ecology, the Yakama Nation, Yakima Basin Joint Board, Yakima Subbasin Fish and Wildlife Planning Board, and Reclamation's Upper Columbia Area Office (UCAO) and Technical Service Center. The goals of the Biology TWG were to:

- Identify and define significant fish and wildlife resource issues that may be associated with developing Bumping Lake enlargement, Wymer reservoir, Keechelus-to-Kachess pipeline, Black Rock reservoir (these are all Storage Study alternatives), or some combination of the identified features that result in additional water storage.

- Identify for significant resource issues those questions for which there is adequate information for proper analysis and existing basic technical data references, and those questions requiring additional information before proceeding with proper analysis.

The Biology TWG transformed the 45-item list into 16 significant fish and wildlife issues, nine associated with the Yakima River basin, and seven with the Columbia River basin,[34] during two workshop sessions (in March and April 2004) in Yakima, Washington. Using the WDFW list, the Biology TWG used their expertise to identify and define issues that should be addressed in the Storage Study.

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[34] The seven issues associated with the Columbia River Basin are discussed in the *Summary Report, Appraisal Assessment of the Black Rock Alternative*, December 2004.

The nine issues related to the Yakima River basin are:

1. How would additional storage and resulting changes in water delivery operations affect water temperature and water chemistry parameters?

2. How would additional storage and resulting changes in water delivery operations affect channel forming and other floodplain processes?

3. How would additional storage and resulting changes in water delivery operations affect anadromous fish spawning and rearing habitat, fry and juvenile stranding, and passage and migration?

4. How would additional storage and resulting changes in water delivery operations affect resident fish spawning and rearing habitat?

5. How would additional storage and resulting changes in water delivery operations affect reservoir fisheries, including passage of salmon and bull trout at reservoirs in the Yakima River basin?

6. How would additional storage and resulting changes in water delivery operations affect cottonwood regeneration?

7. How would additional storage and resulting changes in water delivery operations affect aquatic biota?

8. How would additional storage and resulting changes in water delivery operations affect false attraction of salmonids in situations where Yakima River fish are attracted into or delayed at inappropriate locations, and/or situations where Columbia River fish are attracted into or delayed at Yakima River locations?

9. How would construction and presence of a Wymer reservoir, a pipeline between Keechelus and Kachess Lakes, and/or an enlarged Bumping Reservoir affect the loss of shrub-steppe and old-growth forest habitats, and the potential for isolation of local wildlife populations and disruption of movement corridors?

The *Defining Fish and Wildlife Resource Issues for the Yakima River Basin Water Storage Feasibility Study* report (Biology Technical Work Group, 2004), describes the above Storage Study activities in more detail.

Chapter 10.0 Cultural Resources

This chapter outlines what is currently known about cultural resources and how they will be addressed in the Storage Study. All analyses will include consultations with the appropriate Native American Tribes.

Historic properties are defined as buildings, sites, structures, or objects that may have historical, architectural, archeological, cultural, or scientific importance [36 CFR PART 800.16(1)(1)]. There is a legislative and regulatory basis that requires the identification, evaluation, protection, and management of historic resources in Federal undertakings. As a result, the following discussion is in response to the data needs required principally by the National Historic Preservation Act of 1966 (NHPA), as amended.

NHPA requires that Federal agencies complete inventories and site evaluation actions to identify cultural resources that may be eligible for listing in the National Register of Historic Places (National Register) and then ensure those resources “are not inadvertently transferred, sold, demolished, substantially altered, or allowed to deteriorate significantly.” Regulations entitled, “Protection of Historic Properties” (36 CFR 800) defines the process for implementing requirements of the NHPA, including consultation with the appropriate State Historic Preservation Office (SHPO) and Advisory Council on Historic Preservation.

The Archeological Resources Protection Act of 1979 (ARPA) prevents the study agency from disclosing specific site locations. ARPA and the Native American Graves Protection and Repatriation Act of 1990 (NAGPRA) define the notification and tribal consultation processes the study agency must implement if human remains of Native American ancestry are inadvertently discovered during the course of an action on Federal land. NAGPRA also encourages agencies to have a discovery plan in place when actions will occur in an area that has the potential for human remains. Finally, NAGPRA defines a process for agencies to determine if recovered human remains are affiliated with federally recognized tribes and a process for disposition of affiliated remains.

10.1 CONTEXT

All three of the Storage Study alternatives lie within the area home to speakers of the Echeesh-Keen language (formerly known as “Sahaptin”), including the expanse of the Columbia River above its juncture with the Snake River, and the hinterlands adjacent to the river on either side. Today, these people refer to themselves as Echeesh-Keen Sinwit, although to nonnative people they are known, generally and collectively, as “Yakama.”

The Yakama Nation, in its legally recognized construction, consists of fourteen tribes and bands who were combined socially and politically following the Walla Walla Treaty of June 9, 1855. The Yakama Nation governing Tribal Council, located at the Yakama Nation Reservation headquarters at Toppenish, Washington, speaks for the interests of the constituent fourteen bands and tribes.

Prior to Euro-American contact, the subsistence pattern of these groups was dependent on resources acquired by fishing-hunting-gathering activities, with an emphasis placed on salmon and other aquatic species. Food resources were harvested utilizing a seasonal round; native groups procured resources through their own and adjacent territories to pursue the seasonally changing opportunities for available foods. The seasonal round began with the abandonment of the winter villages in the spring, when small family groups moved to camps in upland areas close to desired resources (Gundy, 1998).

Strict political boundaries for these groups are almost impossible to accurately determine. Although tribes were known to inhabit separate home areas, lands were shared, and territorial boundaries commonly overlapped. The tribes customarily met at various places during their summer travels for trading and social interaction. Native people used and occupied much of the landscape in common, and that strict ownership of territory and its resources had greater meaning only in close proximity to a winter village. Winter villages were located along the Columbia River and some of its tributaries. Dispersal into post-winter quarters occurred as the various natural resources became available during the seasons (Gundy, 1998; Walker, 1998).

The first documented Euro-Americans near the project area were members of the Lewis and Clark Expedition. After the United States 1803 Louisiana Purchase, President Thomas Jefferson sent the expedition to survey newly acquired lands in 1805. The Corps of Discovery camped along the Columbia River near the mouth of the Yakima River on October 16, 1805, on their way to the Pacific Ocean. Fur trappers, missionaries, and homesteaders soon followed (Churchill and Griffin, 1998).

The Hudson Bay Company was active in the Columbia Basin from the early 1800s to approximately 1860. Early fur traders mostly populated the Columbia River; however, they did utilize established native overland routes through the project area. During the mid-1800s, an increased number of homesteaders emigrated from the eastern United States with the establishment of the Oregon Trail and, subsequently, railroads (Axton, *et. al,* 2000).

In 1853, the United States began to explore the possibility of constructing a route across the Northern Cascades, providing a northern route to the Puget Sound. Previously, most wagon trains would divert to the Willamette Valley to the south, where passage was easier. George McClellan was sent by Governor Isaac Stevens in 1853 and 1854 to find a route for a wagon road. While searching for the route that would later become known as Snoqualmie Pass, McClellan passed through the Lake Keechelus and Lake Cle Elum area (Churchill and Griffin, 1998).

The passage of the Homestead Act in 1862 and the construction of a wagon road over Snoqualmie Pass in 1865 brought about an increase in Euro-American activity through the project area. Early interest in the area focused on the available mineral wealth including coal, gold, and iron. In 1867, the Northern Pacific Railroad sent surveyors to the Snoqualmie area to establish access routes across the Cascade Range (Churchill and Griffin, 1998).

There was an increase in commercial interests in the project area, including coal mining and timber harvesting, in the late 1800s and throughout the 1900s. The construction of an extensive irrigation system and dams and reservoirs, including Keechelus, Kachess, Cle Elum, Rimrock, and Bumping Reservoirs, led to an increase in agricultural communities throughout the Yakima River basin. These structures are largely responsible for the current population of the project area. The Yakima project was authorized in 1905, and Federal funds were allocated for development of the first diversions—Sunnyside and Tieton. The six project storage reservoirs were constructed between 1909 and 1933, with Bumping Lake Dam completed in 1910 and Cle Elum Dam in 1933.

10.2 BUMPING LAKE ENLARGEMENT

The potential Bumping Lake enlargement is located on the Bumping River, approximately 4,500 feet below the existing dam. This alternative includes the inundation of the existing Bumping Lake Dam and expansion of the reservoir.

Surveys pertaining to the project area are generally limited to timber sales undertaken by the Forest Service. The following is a sampling of studies conducted in the area and should not be considered exhaustive:

- In 1986, as part of Phase II of the Yakima River Basin Water Enhancement Project, Reclamation contracted for a Class I survey focused on historic-era resources. The overview, entitled “Yakama River Basin Historical Resource Survey: Overview and Management Recommendations,” includes Bumping Lake and the Wymer reservoir site.

- A survey conducted by Morris Uebelacker for the Wenatchee National Forest in 1980 identified several potentially significant historic resources in the potential project area. Titled, *Land and Life in the Naches River Basin*, the report included the dam construction camp, a timber camp, a Civilian Conservation Corps camp, and a campground.

- In 1979, Uebelacker and John Flettre conducted a survey for the Wenatchee National Forest in connection with the Glassy Timber Sale. Although located outside of the area, it identified historic cultural resources related to sheep herding that could prove useful in evaluating such sites if they are found in the project area.

- A survey conducted by Greg Cleveland in the vicinity of Bumping Lake through the Washington Archeological Research Center, Pullman, Washington, for Reclamation, in 1975.

Sites associated with these reports identified the presence of a number of historic resources including: a 1941 Civilian Conservation Corps camp, timber clearing camps, Jack Nelson's 1940s Normandie Lodge, a U.S. Forest Service campground, and sites associated with the 1910 construction of Bumping Dam. These include the dam itself, the construction camp, the Watchman's House, and a fish hatchery.

10.3 WYMER DAM AND RESERVOIR

The potential Wymer reservoir site is located on Lmuma Creek, historically referred to as "Squaw Creek," 1½ miles upstream from the Yakima River. Affected lands are private, Bureau of Land Management, and the U.S. Army.

There have been numerous cultural resource surveys in or near the potential area for the Wymer project. The majority of these studies were conducted for the Yakima Firing Center, and all of the Yakima Firing Center studies focused on the upper reaches of Lmuma Creek. Most focused on archeological resources, although some noted the presence of historic silica mines and limited occupation associated with homesteading, sheep herding, or cattle grazing.

The only site within the project area identified in these reports indicates a "line shack" of unknown association, which would be inundated by the potential reservoir.

Additionally in 1986, as part of Phase II of the Yakima River Basin Water Enhancement Project, Reclamation contracted for a Class I survey focused on historic-era resources. The overview, entitled, *Yakama River Basin Historical*

Resource Survey: Overview and Management Recommendations (Babcock *et. al*, 1986), includes Bumping Lake and the Wymer reservoir site.

10.4 KEECHELUS-TO-KACHESS PIPELINE

The Keechelus-to-Kachess pipeline alternative involves constructing a pipeline extending from Keechelus Lake to Kachess Lake to augment the Yakima River basin's stored water supply. Construction of a pipeline could transport runoff in excess of Keechelus storage capacity to Kachess Lake. This additional stored water would then be used for irrigation and instream flow maintenance.

There have been numerous investigations germane to the Keechelus and Kachess area. The following is a sampling of studies conducted and should not be considered exhaustive:

- Boas, Inc., conducted a cultural resource survey along Cle Elum, Kachess, and Keechelus Lakes in 1993. This survey included lands within the project area. The study identified a number of prehistoric sites around the reservoirs and historic sites associated with the construction of the dams.

- Archaeological Frontiers conducted a cultural resource survey for the proposed Mountainstar Resort near the Cle Elum River. The study identified 7 prehistoric sites and 49 historic sites. The latter were associated with timber harvest activities, coal mining, waterline construction activities, and recreation (Churchill, 1998).

- A survey was conducted in 2003 for an environmental impact statement dealing with improvements to Interstate 90 over Snoqualmie Pass by the Federal Highway Administration and the Washington State Department of Transportation. This document identifies 58 cultural resources: 43 historic and 12 prehistoric; 3 have components of both. Six of these properties were recommended as eligible for listing in the National Register.

10.5 MANAGING CULTURAL AND HISTORIC RESOURCES

Previous studies indicate the potential for, and existence of, historic resources in the project area. Implementation of any one of these alternatives would require further investigation under the requirements of Section 106 of the NHPA. This study may include any or all of the following elements:

- Class I survey, which involves researching previous investigations in and surrounding the project area. This data will provide the foundation for an archeological, ethnographic, and historical context for this alternative.

- Class II survey, a selective field survey that focuses on specific areas deemed high in site probability or involving activities that may include significant ground disturbance.

- Class III survey, an intensive field survey that covers the majority of the area of potential effect.

- Evaluate previously and/or newly identified sites for eligibility to the National Register of Historic Places.

- Develop mitigation measures for unavoidable effects to eligible properties.

- Develop post-project site management, interpretation, and stewardship.

If historic properties are identified within the project area, further study will be required to determine their eligibility for inclusion in the National Register. Effects to significant historic properties will require the development of a mitigation plan with the Washington State Office of Archaeology and Historic Preservation and/or applicable tribes.

Chapter 11.0 Findings and Conclusions

This chapter explains the findings of the analysis that Reclamation has performed on the three alternatives—Bumping Lake enlargement, Wymer dam and reservoir, and Keechelus-to-Kachess pipeline. Because of results from previous studies indicating potential water supply available from these three alternatives, Reclamation combined all three alternatives in the hydrologic analyses to determine the extent the Storage Study goals could be achieved. The conclusions reached from these analyses are also presented.

Reclamation met with several stakeholder groups to discuss the preliminary technical analysis performed on these alternatives. Reclamation considered these discussions when making the following conclusions. The information sent to those groups is in the *Yakima River Basin Alternatives Technical Information and Hydrologic Analysis* (Appendix E).

11.1 FINDINGS

11.1.1 Technical Viability

Based on information available at this time, the three Yakima River basin storage alternatives (Bumping Lake enlargement, Wymer dam and reservoir, and Keechelus-to-Kachess pipeline) appear to be technically viable.

These findings do not consider economic, financial, environmental, cultural, and social aspects of the three storage alternatives.

11.1.2 Storage Study Goals

The dry-year irrigation water supply goal can be met by these three alternatives. The municipal water supply goal is assumed to be met. There is potential to meet the fish habitat goal on the Yakima River by constructing Wymer dam and reservoir. However, the fish habitat goal for the Naches River cannot be met by constructing Bumping Lake enlargement.

11.1.2.1 *Fish Habitat*

Reclamation's RiverWare modeling of the three alternatives shows that enlarging Bumping Lake is detrimental to the shape of the Bumping and Naches River hydrographs by decreasing the quantity and shifting the timing of the spring flows. This is detrimental because the current hydrograph resembles the natural (unregulated) hydrograph. Bumping Lake enlargement also adds to the total water supply available (TWSA), which, in some years, may result in increasing the Title XII target flows at Parker. In addition, an enlarged Bumping Lake could result in further adverse environmental impacts by inundating adjacent creeks and streams.

The Wymer dam and reservoir alternative would require pumping water when there are excess flows in the Yakima River. This means that diversion to Wymer reservoir could diminish the spring freshet during the average and wet years. However, during dry years, it may be possible to operate the reservoir in a manner that benefits fish. These benefits could include pulse or flushing flows during the spring. During meetings with stakeholder groups on the three alternatives, they recommended that Reclamation explore such potential benefits further. The Wymer alternative also adds to the TWSA, which, in some years, may result in increasing the Title XII target flows at Parker.

The Keechelus-to-Kachess pipeline improves Kachess Lake storage contents in only 1 year of the 23-year period of record. This additional stored supply amounts to only about 400 acre-feet (1985). The capability to bypass up to a maximum of 210 cfs of summer releases from Keechelus Lake could provide a benefit to the fishery in the Yakima River reach from Keechelus Dam to Easton Dam.

RiverWare modeling also indicated all the integrated operation scenarios do not appear to move the river flow regime toward a natural (unregulated) hydrograph because of the need to transport a high volume of water from the upper Yakima River reservoirs (primarily Cle Elum Lake) to irrigation users in the middle Yakima River basin area. Moving this high volume of water during the summer and fall seasons results in high flows, which is contrary to the natural (unregulated) hydrograph. Therefore, the integrated 70-percent operation scenario does not eliminate or significantly diminish the current flip-flop reservoir operation.

11.1.2.2 *Dry-Year Irrigation Water Supply*

All three alternatives were modeled together to provide enough water storage to meet the 70-percent irrigation water supply goal. The 23-year average TWSA is 3,220,000 acre-feet with the integrated 70-percent operation, as compared to the current operation TWSA of 2,850,000 acre-feet. With additional basin storage alternatives and an operating plan that uses the additional storage capacity primarily as carryover, the 23-year average TWSA could be increased by 370,000 acre-feet.

One-year droughts which follow 2 or more wet years could have a 30-percent improvement. This is demonstrated by drought year 2001, for which the modeled current operation provided a 41 percent proratable water supply, but the integrated 70-percent operation provided a 70-percent proratable supply.

The operations modeling shows the irrigation water supply conditions are improved in the prolonged 3-year dry period of 1992-1994. The three in-basin storage alternatives increased the proratable water supply in 1992 and 1993 to not less than 70 percent. The 1994 proratable water supply was increased to 66 percent; 4 percentage points below the 70-percent threshold. It is estimated the 4-percent difference equals about 50,000 acre-feet.

11.1.2.3 *Municipal Water Supply*

In the *Black Rock Appraisal Assessment*, Reclamation had assumed the future surface water need of 10,000 acre-feet for the cities of Cle Elum and Yakima (the only current municipal surface water users) could be met with any new storage facilities. After reviewing the water supply estimates in the January 2003 *Watershed Management Plan* (Yakima River Basin Watershed Planning Unit and Tri-County Water Resources Agency, 2003), Reclamation concluded if the results of ongoing groundwater investigations show there is a connectivity of surface and groundwater, any increase in groundwater use by municipalities and domestic users may require mitigation by surface water supplies. If this were to occur, the future municipal and domestic water needs could be as much as 82,000 acre-feet by year 2050.

As information regarding the surface and groundwater connectivity becomes available, Reclamation will work with local and state entities to develop a strategy, including hydrologic modeling, to accommodate the volume and priority of municipal and domestic water supply demands.

11.2 CONCLUSIONS

Reclamation will not perform further analysis on the Bumping Lake enlargement and Keechelus-to-Kachess pipeline in the Plan Formulation Phase. However, Reclamation will retain the Wymer dam and reservoir alternative for further investigation in the Plan Formulation Phase.

Reclamation, through its hydrologic analysis, has determined that storing more water in an enlarged Bumping Lake would cause the spring flows in the Bumping River to decrease in volume and shift in timing. This shift in flow quantity and timing carries through the Bumping River into the lower Naches River. Since the Bumping River hydrograph currently resembles the natural (unregulated) hydrograph, this change in the hydrograph is unacceptable. The extra storage in Bumping Lake enlargement does help meet the irrigation water supply goal in all years except the last year of a 3-year drought. Reclamation is assuming that the municipal water supply goal will be met with this alternative. Even though the irrigation water supply goal could be partially met with this alternative, the negative impact to the hydrograph and the potential environmental impacts identified in previous studies indicate that this alternative should not be carried forward.

Reclamation, through its hydrologic analysis, has determined that the Keechelus-to-Kachess pipeline provides neither irrigation nor fish habitat benefits, as it only provides extra storage in 1 year out of the 23-year period of record and does not move the flow regime toward the natural (unregulated) hydrograph. Reclamation is assuming that this alternative will not help meet the municipal water supply goal. Therefore, Reclamation will not forward the Keechelus-to-Kachess pipeline alternative into the Plan Formulation Phase.

Reclamation's current analysis does not show if the Wymer dam alternative impacts the hydrograph, either in a positive or negative manner. Reclamation is assuming the municipal water supply goal may be met with this alternative. Although Wymer does not appear to meet the Storage Study goals by itself, it does meet the purpose and need, and it is technically viable. Because of stakeholder interest and its potential for providing fish habitat benefits, Wymer will be analyzed further in the Plan Formulation Phase.

11.2.1 Further Technical Investigations

As discussed in Chapter 6, collection and evaluation of additional field data would be necessary at some future time to address various technical aspects of the Wymer alternative. For instance, more recent investigations identified potential seismic sources closer to the Wymer damsite than when the design and cost estimates were prepared in 1985. The current extent of activity of these sources is not known. If future investigations were to conclude these seismic sources are potentially active, then consideration would need to be given to possible design changes. Consequently, this could increase the construction cost estimates from the current indexed July 2004 amount indicated in Chapter 7.

In addition, more information on the probable maximum flood operation of Wymer reservoir is needed to assure adequate "freeboard" at the Lmuma Creek Interstate Highway 82 bridge crossing, including wave action that could result from high winds.

In retaining the Wymer dam and reservoir alternative for further consideration in the Plan Formulation Phase, it is understood that it meets the purpose and need of the Storage Study. The objective of further investigating Wymer would be to define to what extent it could meet the Storage Study goals. These investigations could include various operations scenarios and the potential for a Columbia River water supply.

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Glossary and Acronyms

Acquavella case	A Yakima River basin water adjudication court case in Yakima County Superior Court.
active capacity	The reservoir capacity or quantity of water which lies above the inactive reservoir capacity and is normally usable for storage and regulation of reservoir inflow to meet established reservoir operating requirements.
adfluvial	Fish that spawn in tributaries and, as adults, reside in lakes.
alluvial	Composed of clay, silt, sand, gravel, or similar material deposited by running water.
anadromous	Fish that migrate from salt water to freshwater to breed. Going up rivers to spawn.
antecedent flood	A flood or series of floods assumed to occur prior to the occurrence of an inflow flood used to design a specific dam.
appraisal-level design	Designs based on limited analyses, available design data, and professional assumptions, but of sufficient detail to provide satisfactory quantities and preliminary field cost estimates.
aquatic biota	Collective term describing the organisms living in or depending on the aquatic environment.
average water supply year	A water supply in the Yakima River basin between 2,250,000 and 3,250,000 acre-feet.
bank-full	The water level, or stage, at which a stream or river is at the top of its banks and any further rise would result in water moving into the flood plain.
Black Rock Appraisal Assessment	*Appraisal Assessment of the Black Rock Alternative,* December 2004.

cfs (or ft^3/s)	Flow rate in cubic feet per second.
dry year	A water supply in the Yakima River basin less than 2,250,000 acre-feet.
Ecology	Washington Department of Ecology.
emergence	Refers to the fry lifestage of the salmon when they swim up through the substrate from their incubation nest (redd) to live along the stream edge.
ethnographic	Relating to the branch of anthropology that deals historically with the origin and filiation of races and cultures.
flip-flop	A term relating to changes in operations in the Yakima River basin in late summer.
fluvial	Fish that spawn in tributaries and, as adults, reside in rivers.
freshet	A great rise or overflowing of a stream caused by heavy rains of snowmelt.
friable	Easily crumbled.
fry	The life stage of fish between the egg and fingerling stages.
kWh	Kilowatt-hour.
liquefaction	A loss of material strength during earthquake shaking that can result in large areas of slope failure or settlement of the ground surface.
nonprorated water rights	Pre-Yakima Project senior water rights related to natural flows that are served first and cannot be reduced until all the proratable rights are regulated to zero.
overburden	A thick deposit of sediments overlying bedrock.

PMF	Probable maximum flood.
prorated water rights	Newer junior water rights related to storage water that, in water short years, receive less than their full right on a prorated basis.
RCW	Revised Codes of Washington; State laws.
Reclamation	U.S. Department of the Interior, Bureau of Reclamation.
redd	the nest that a spawning female salmon digs in gravel to deposit her eggs.
RiverWare (also, Yak-RW)	Yakima Project RiverWare model; a daily time-step reservoir and river operation computer model of the Yakima Project created with the RiverWare software.
RM	River mile.
Roza Division	Division of Yakima Project comprised of Roza Irrigation District.
Roza Powerplant	The existing powerplant located at Roza Canal MP11.
slopewash	Soil and rock material that has moved downslope, assisted by running water that is not channelized.
smolt	A young salmon or sea trout about 2 years old that is at the stage of development when it assumes the silvery color of the adult and is ready to migrate to the sea.
Storage Study	Yakima River Basin Water Storage Feasibility Study; a multiyear evaluation of the viability and acceptability of several storage augmentation alternatives, including a potential water exchange, for the benefit of fish, irrigation, and municipal water supply within the Yakima River basin.
storage water	Water that has been stored and purposefully released.

System Operations Advisory Committee (SOAC)	Committee comprised of the Yakima Basin Joint Board, Yakama Nation, Washington State Department of Fish and Wildlife, U.S. Fish and Wildlife Service.
Summary Report	*Summary Report - Appraisal Assessment of the Black Rock Alternative,* December 2004.
Sunnyside Division	A division of Yakima Project comprised of Sunnyside Valley Irrigation District and eight other irrigation districts, companies, and cities.
tailrace	The body of water immediately downstream from a powerplant or pumping plant that regulates fluctuating discharges from the plant.
talus	A slope formed by an accumulation of rock debris.
Title XII target flows	Specific instream target flows established for Yakima project operations at Sunnyside and Prosser Diversion Dams.
toe plinth	A concrete pedestal or footing located beneath the base of a dam's concrete face.
total capacity	The total reservoir capacity or quantity of water which can be impounded in the reservoir below the maximum water surface elevation.
TWSA	Total water supply availability.
UCAO	Reclamation's Upper Columbia Area Office in Yakima, Washington.
unregulated flow	The flow regime of a stream as it would occur under completely natural conditions; that is, not subjected to modification by reservoirs, diversions, or other human works.
vesicular basaltic rock	Rock that contains many small holes or cavities formed as the rock solidifies.

WAC	Washington Administrative Code; State rules and regulations.
WDFW	Washington Department of Fish and Wildlife.
wet year	A water supply in the Yakima River basin greater than 3,250,000 acre-feet.
Work Group	Biology Technical Work Group; consists of technical representatives from NOAA Fisheries, U.S. Fish and Wildlife Service, Washington Department of Fish and Wildlife, Washington Department of Ecology, the Yakama Nation, Yakima Basin Joint Board, Yakima Subbasin Fish and Wildlife Planning, and Reclamation's Upper Columbia Area Office and Technical Service Center.
Yakima Alternatives Appraisal Assessment	The gathering and appraisal-level assessment of the data and information contained in this *Yakima River Basin Storage Alternatives Appraisal Assessment*.

Appendix A YAKIMA RIVER BASIN WATER ENHANCEMENT PROGRAM ACTIVITIES OCCURRING BETWEEN 1986 AND 1994

Early Implementation Program

This Appendix describes the activities occurring between 1986 and 1994 when Phase II of the Yakima River Basin Water Enhancement Program (YRBWEP) was authorized by Title XII of the Act of October 31, 1994.

In 1986, emphasis shifted to seeking congressional authorization of an early implementation program consisting primarily of nonstorage measures. This early implementation program would be an integral part of the overall YRBWEP. As a result, further work on the *Feasibility Planning Report/Environmental Impact Statement* was deferred.

In June 1986, an early implementation program, consisting primarily of nonstorage elements, was developed and a report entitled, *Preliminary Evaluation of Non-Storage Elements Being Considered for Early Implementation*, was prepared. In June 1986, Senate Bill 2519 and House Resolution 4997 were introduced in the 99th Congress, 2d Session. The Senate Subcommittee on Water and Power of the Committee on Energy and Natural Resources conducted a hearing in July 1986, in Yakima, Washington, to receive input on this proposed legislation. Action on the bills during the residual part of the 99th congressional session did not occur.

In June 1987, legislation to authorize a similar early implementation program was introduced in the 100th Congress, 1st Session (Senate Bill 1435 and House Resolution 2814). Senate subcommittee field hearings were held in October 1987, in Yakima, Washington.

Policy Group

In 1987, a "Policy Group" was structured to provide a forum for oversight of the YRBWEP with respect to (1) plan proposals, (2) guidance on matters of a policy nature, and (3) public involvement participation. The Policy Group included the following:

- Senator Daniel Evans
- Senator Brock Adams
- Congressman Sid Morrison
- Melvin Sampson, Chairman, Yakama Indian Nation
- Andrea Riniker, Director, Washington State Department of Ecology
- Alan Pettibone, Director, Washington State Department of Agriculture
- John Keys, Regional Director, Bureau of Reclamation

One of the Policy Group's first actions was to form ad hoc work groups to address issues, evaluate alternatives, and provide recommendations in the following four areas:

- Instream Flows and Fish Production Objectives
- Off-reservation Storage Site Selection
- Water Conservation
- Legal and Institutional

These work groups were functional during October 1987 through February 1988. They submitted their reports to the Policy Group at a February 1988 meeting. This was a key meeting regarding legislative action, as the decision was made to pursue the following legislative proposals:

- Early implementation legislation (Senate Bill 1435 and House Resolution. 2814) as it may subsequently be modified
- Comprehensive Federal legislation.

Comprehensive Federal Legislation

A preliminary draft of legislation providing for a comprehensive solution to the water supply needs of the Yakima River Basin was provided to the Policy Group by Senator Evans in March 1988. Senator Evans indicated he was prepared to introduce the draft legislation, or an amended draft, if there was agreement that it at least constitutes a workable framework. As the result of input, an amended draft was prepared and on April 25, 1988, Senate Bill 2322 and House Resolution 4953 were introduced in the 100th Congress, 2d Session. Hearings were held in Washington, D.C., on June 28, 1988, by the Senate Subcommittee on Water and Power of the Senate Committee on Energy and Natural Resources.

Following introduction, and as the result of numerous discussions with various basin interests, five modified drafts were prepared from June through the first of

September 1988, in an effort to move toward acceptable comprehensive Federal legislation. The last draft of comprehensive Federal legislation stipulated the volume of water to be available to the Yakama Indian Reservation, to off-reservation irrigation entities, and for instream flows. It also authorized early implementation elements, on-reservation programs, a Basin Conservation Program, and construction of additional off-reservation storage.

However, after extensive efforts to reach consensus on comprehensive Federal legislation, Senator Evans announced in the fall of 1988 that he was abandoning further work on the proposed legislation. This was attributed primarily to the view of some off-reservation irrigators that they should continue the adjudication process rather than pursue a stipulated settlement.

Enhancement Roundtable Group

Following termination of efforts to secure comprehensive Federal legislation, and with the announcement by Senator Evans he would not seek reelection, Congressman Morrison initiated discussions with the Directors of the State of Washington Departments of Ecology, Agriculture, and Fisheries, the Washington Governor's Office, and the Regional Director of the Bureau of Reclamation. The objective of these discussions was to structure a proposed forum for discussion among all of the parties from which a recommended course of action could be developed.

As the result of this effort, the Enhancement Roundtable Group was formed, consisting of the following representatives:

- Congressman Sid Morrison, representing the Washington Congressional Delegation
- Melvin Sampson, Chairman, Tribal Council, Yakama Indian Nation
- T.C. Richmond, Special Assistant to the Governor representing the respective state agencies
- Gene McIntire, President, Yakima River Basin Association of Irrigation Districts, representing the basin irrigators
- John Keys, Regional Director, Bureau of Reclamation.

A Technical Activities Group to provide guidance and oversight on YRBWEP work activities was also structured as a component of the Enhancement Policy Group. A representative of the irrigators, the Yakama Nation, the State, Bonneville Power Administration, and Reclamation comprised this group.

The first meeting of the Enhancement Roundtable Group occurred in April 1989. Two subsequent meetings were held in July and October 1989. The major thrust of these meetings was toward development of draft Federal legislation to authorize a "pilot" water conservation program (Phase II of YRBWEP).

There appeared to be considerable support for Phase II. However, at the October 1989, meeting, the irrigator's representative voiced concern with the legislation in view of the motion for partial summary judgment filed by several irrigation districts in the Adjudication Court with respect to the waters claimed on behalf of the Yakama Nation. Unsuccessful attempts were made to resolve the impasse on the proposed legislation. Consequently, a "hold" was placed on further Phase II legislative activities pending a decision by the Adjudication Court on the motion for a partial summary judgment.

Phase II Federal Legislation

A summary judgment addressing the waters claimed on behalf of the Yakama Nation was issued by the Adjudication Court May 29, 1990. Following this, there was renewed interest in proceeding with the Phase II legislative concept. The Enhancement Roundtable Group met in August 1990. The outgrowth of this meeting was a goal to have an acceptable draft of Phase II legislation available in late 1990, for possible early introduction in the next session of the Congress. House Resolution 3097 and Senate Bill 1609 were introduced in July 1991, by Congressman Morrison and Senator Gorton, respectively.

By resolution dated April 8, 1992, the Tribal Council indicated its support for the bill as modified by its suggested changes. This resolution was followed by meetings of tribal representatives with congressional staff in Washington, D.C.

Legislation authorizing Phase II of the YRBWEP was enacted as Title XII of the Act of October 31, 1994, Public Law 103-434. Title XII directs the Secretary of the Interior (acting through Reclamation), in consultation with the State of Washington, the Yakama Nation, Yakima River basin irrigators, and other interested parties, to establish and administer a Yakima River Basin Water Conservation Program (Basin Conservation Program) for the purpose of evaluating and implementing measures to improve the availability of water supplies for irrigation and the protection and enhancement of fish and wildlife resources, including wetlands, while improving the quality of water in the Yakima Basin.

Pursuant to Title XII, the Basin Conservation Program is to encourage and provide funding assistance in the following four phases of water conservation: development of water conservation plans, investigation of specific potential water conservation measures identified in the plans, implementation of water conservations measures determined to be feasible, and post-implementation monitoring and evaluation of implemented measures.[1]

Instream target flows were established for Yakima project operations at Sunnyside and Prosser Diversion Dams. Criteria are included for increasing target flows as a result of water savings realized through the Basin Conservation Program.

Title XII also directs Reclamation to facilitate water and water right transfers, water banking, dry-year options, the sale and leasing of water, and other innovative allocation tools to maximize existing Yakima River Basin water supplies.

Appropriated funds may be used by Reclamation to purchase or lease land, water, or water rights from any entity or individual willing to limit or forego water use on a temporary or permanent basis. These activities are not subject to the cost-sharing provisions of the Basin Conservation Program.

Funds are provided for improvements to the Wapato Irrigation Project and other on-reservation measures. In addition, there is authorization for flow enhancement of Yakima River Basin tributaries; modification of the radial gates at Cle Elum Dam to provide an additional 14,600 acre-feet of storage capacity in Cle Elum Lake; and for augmentation of Kachess Reservoir-stored water by diverting flows of Cabin and Silver Creeks' excess-to-system demands. Also, Reclamation was to prepare an Interim Comprehensive Operating Plan providing a general framework for operation of the Yakima project. This plan was completed in 2002.

Title XII also provides for completion of two reports, with recommendations which shall provide a basis for the third phase of the YRBWEP. These reports are (1) to address the adequacy of the water supply available to sustain the agricultural economy of the Yakima River Basin, and (2) to evaluate what is necessary to have biologically-based instream target flows. Title XII indicates these reports and recommendations therein shall provide the basis for the third phase of the YRBWEP. The irrigation water supply report has not been prepared. The biologically-based target flow report was published May 1999.

[1] House Document 108-644 supporting Title XII states, in part: "The authorized level of funding is not expected to be sufficient to meet all needs to demonstrate conservation potential and test various measures. Information from the Conservation Program is expected to be sufficient to determine the scope of a complete conservation program for authorization in a future and final phase of the enhancement project."

Appendix B COMPARISON OF COST ESTIMATES USED IN THE YAKIMA RIVER BASIN WATERSHED MANAGEMENT PLAN AND THE YAKIMA RIVER BASIN APPRAISAL ASSESSMENT

In the reports written for the Yakima River Basin Watershed Planning Unit and Tri-County Water Resources Agency in the preparation of the *Yakima River Basin Watershed Management Plan*, Montgomery Water Group, Inc., used construction cost estimates prepared by Reclamation for Bumping Lake enlargement and Wymer dam, reservoir, and pumping plant as a part of the mid-1980s Yakima River Basin Water Enhancement Project investigations. These cost estimates were based on April 1985 prices, which Montgomery Water Group, Inc., indexed to 2001 prices (month not indicated) for Bumping Lake enlargement, and July 2002 prices for Wymer dam, reservoir and pumping plant.

The April 1985 cost estimates were subsequently reevaluated by Reclamation, and high, most probable, and low estimates were prepared based on July 1985 prices. This range of cost estimates reflected different assumptions regarding the extent of excavation, haul distance for the embankment dams, and other items. For the *Yakima River Basin Storage Alternatives Appraisal Assessment* (*Yakima Appraisal Assessment*), the most probable construction cost estimates are used.

The following is a comparison of the April 1985 and July 1985 estimates of construction pay items for Bumping Lake enlargement and Wymer dam, reservoir and pumping plant.

Bumping Lake Enlargement

The report entitled, *Storage Strategies, Yakima River Watershed Basin* (Montgomery Water Group, Inc., 2002) shows the April 1985 cost estimates developed by Reclamation in Table 4-3 of that report. The cost estimates shown in Table 4-3 include construction pay items, plus cost additives for contractor mobilization and unlisted items. Further, the total $134,510,000 in the table includes contingencies and $4 million more for the dam structure. The $4 million addition is not explained.

The July 1985 Reclamation "most probable" cost estimate is used in this *Yakima Appraisal Assessment* and indexed to July 2004 to be comparable to the Black Rock Alternative cost estimate shown in the *Summary Report, Appraisal Assessment of the Black Rock Alternative,* December 2004 (Table B-1).[2]

Table B-1. Bumping Lake Enlargement Cost Estimates

Item	April 1985 (dollars)	July 1985 (dollars)
Dam Structure	72,013,000	74,594,000
Spillway	4,020,000	4,136,000
Outlet Works	8,470,000	8,146,000
Breach Existing Dam	273,000	273,000
Subtotal of Pay Items	84,776,000	87,149,000
Added Costs for Table 4-3		
Mobilization costs	4,233,000	
Unlisted Items	13,221,000	
Contingencies	28,280,000	
Dam Structure	4,000,000	
Total shown on Table 4-3 of *Storage Strategies*	134,510,000	

Wymer Dam, Reservoir and Pumping Plant

The *Yakima River Basin Watershed Management Plan Technical Memorandum, Wymer Dam and Reservoir Project Review* (Montgomery Water Group, Inc., 2002), shows in Table 5-1 the April 1985 cost estimates prepared by Reclamation. The cost estimates shown in Table 5-1 of that memorandum include construction pay items, plus cost additives for contractor mobilization. Mobilization estimates have been removed for comparison purposes.

The July 1985 Reclamation "most probable" cost estimate is used in the *Yakima Appraisal Assessment* (Table B-2) and is indexed to July 2004 to be comparable

[2] The Black Rock Alternative field construction cost estimates are based on June 2004 price levels. However, the Bureau of Reclamation Cost Trends are reported on a quarterly basis (January, April, July, and October), so July 2004 was used, as a close approximation of June 2004 prices.

to the Black Rock Alternative cost estimate shown in the *Black Rock Summary Report*, December 2004.

Table B-2. Wymer Dam, Reservoir, and Pumping Plant Cost Estimates

Item	April 1985 (dollars)	July 1985 (dollars)
Dam Structure	100,506,000	74,646,000
Spillway	18,813,000	16,874,000
Outlet Works	5,767,000	5,624,000
Pumping Plant and Switchyard	16,694,000	17,058,000
Subtotal of Pay Items	141,780,000	114,202,000
Total mobilization costs	7,058,000	
Subtotal of pay items plus mobilization shown on Table 5-1 of *Wymer Dam and Reservoir Project Review*	148,838,000	

Montgomery Water Group, Inc., further includes a “budget estimate” of $10 million for possible Interstate Highway and Lmuma Creek bridge crossing reconstruction or relocation costs. As noted in section 6.2.1.6, a restriction placed on Wymer reservoir operation is that the maximum water surface cannot exceed elevation 1740 feet, to prevent inundation of the east lane of Interstate Highway 82 crossing Lmuma Creek about 5 miles upstream of the damsite.

As-built drawings of the Lmuma Creek Bridge were obtained from the Washington Department of Transportation. These indicated that the bottom elevation of the bridge is at elevation 1743.8 feet.

Montgomery Water Group, Inc., also noted that control of the water temperature released from Wymer reservoir to the Yakima River might be needed to meet State water quality standards for dissolved oxygen and temperature. If a multilevel outlet works tower were necessary, they estimated the additional cost at $14 million. Montgomery Water Group, Inc., indicated, however, this cost is much less than the allowance for unlisted items or the contingency used and is probably covered by these if a multilevel outlet structure is needed.

Appendix C YAKIMA RIVER BASIN STORAGE ASSESSMENT YAKIMA PROJECT RIVERWARE MODEL – JANUARY 2006

Yakima Project RiverWare Model

The system operation studies conducted by Reclamation for this assessment involve the use of the Yakima Project RiverWare (Yak-RW) model. This model is a daily time-step reservoir and river operation simulation computer model of the Yakima Project created with the RiverWare software. The software was developed at the Center for Advanced Decision Support for Water and Environmental Support at the University of Colorado, in cooperation with Reclamation and the Tennessee Valley Authority.

The RiverWare modeling software uses an object-oriented modeling approach in which objects represent features of the project such as storage reservoirs, stream reaches, diversions, and canals. Each object contains its own physical processes, algorithms and data. For instance, reservoir objects include elevation-volume data, flood-control rule curve information, and outflow data. Objects are interconnected into a "network" which represents the flow of water from one object to another.

The network file of the Yak-RW model consists of the five major project reservoirs (Keechelus, Kachess, Cle Elum, Bumping, and Rimrock) and fifty-six major and minor river diversions and canal systems. River diversions represented in the model include associated canal losses, on-farm losses, and return flows with each diversion. The network also includes simulation of Kittitas Reclamation District's 1146 Wasteway to assist in the "mini flip-flop" fall operation, and the Roza and Chandler power plants.[3] The RiverWare network diagram is available upon request.

The hydrologic base for the Yak-RW model is represented by the 23 water years of 1981 through 2003 (November 1, 1980, through October 31, 2003). This 23-year period includes 17 nonproration water years (wet and average water supply conditions) and 6 proration years (dry water supply conditions). This

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[3] The Wapatox Powerplant was acquired by Reclamation in 2003 and is no longer in operation. The "power water" diversion now remains in the Naches River.

represents the longest dry cycle (1992-1994) and the largest single dry year (2001) in combination with wet and average water supply conditions. The period of record used is appropriate as it has a range of wet, dry, and average years. It is standard practice by hydrologists to have 20 years of record (minimum) for a modeling study to capture a range of flows with a standard variability to be statistically valid.

Table C-1 shows the April 1 Total Water Supply Available (TWSA) estimate, when water proration was necessary, and the proratable water supply available in these years.[4]

Table C-1. Yakima River Basin Water Supply Conditions (1981-2003)

Water Year	Historic April 1 TWSA (million acre-feet)	Proratable Water Supply Available (%)
1981	2.52	100
1982	3.43	100
1983	3.39	100
1984	3.31	100
1985	2.77	100
1986	2.49	90*
1987	2.37	68
1988	2.47	90
1989	2.84	100
1990	3.15	100
1991	3.06	100
1992	2.15	58
1993	2.16	67
1994	1.83	37
1995	2.97	100
1996	3.21	100
1997	4.59	100
1998	3.13	100
1999	3.94	100
2000	3.17	100
2001	1.79	37
2002	3.31	100
2003	2.64	92*

* Proration was not declared in these years, as there was an informal agreement to keep diversions near the average.

[4] The proratable water supply available is expressed as a percent of the total proratable water entitlements.

The daily diversion of each of the 56 diverters used in the Yak-RW model is determined as follows:

Five Yakima Project Divisions and Two Major Canals - - The average daily irrigation diversion for each of the 5 Yakima Project divisions above Parker (Kittitas, Roza, Tieton, Wapato, and Sunnyside) and for 2 major canals (Westside Irrigation Company and Naches-Selah Irrigation District) were determined by using the daily measured diversions for 7 non-proration water years of 1991, and 1995-2000.[5] An irrigation season average daily demand curve of flow (cfs) vs. day was then developed.

Forty-Nine Other Diverters - - For the 49 other diverters, the average daily irrigation diversion of each diverter was computed by: (1) extracting the daily flow from the irrigation demand curve of the Westside Irrigation Company for Yakima River diverters above Roza Diversion Dam, and the Naches-Selah Irrigation District for Yakima River and Naches River diverters below Roza Diversion; and (2) multiplying this daily flow figure by the ratio the specific diverter's water entitlement is to the water entitlement of either the Westside Canal Company or the Naches-Selah Irrigation District. This procedure is illustrated below:

$$\textbf{cfs from demand curve of representative entity} \times \frac{\textbf{water right of diverter}}{\textbf{water right of representative entity}}$$

Figure C-1 is the nonproration water year irrigation demand curve for the five Yakima Project divisions and the two major canals. March flood waters are included in this figure.

[5] These 7 nonproration years are representative of a full water supply and diversions.

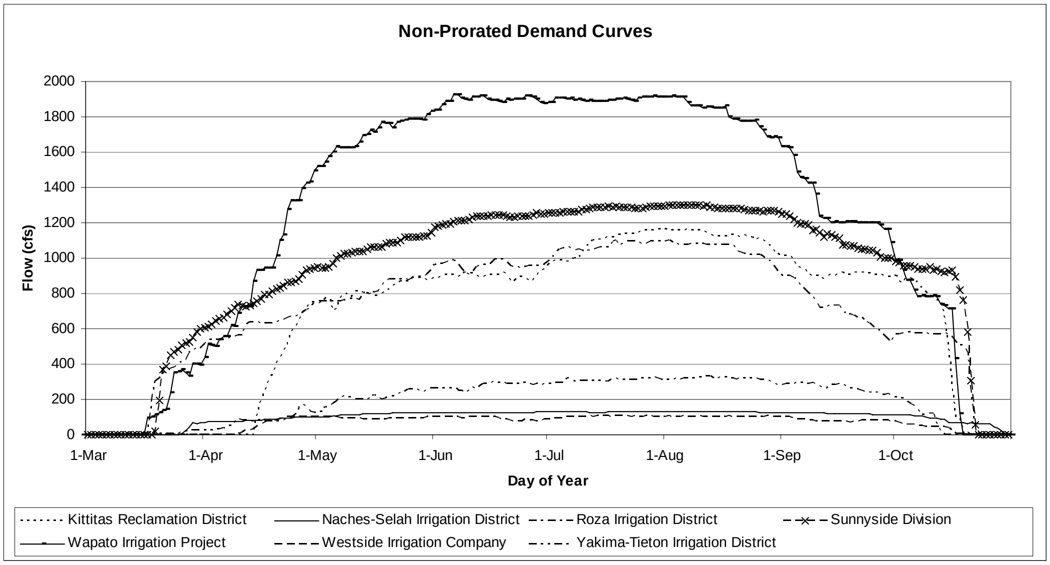

Figure C-1. Nonproration Water Year Irrigation Average Daily Demand Curves

In proration water years, the diversions are limited to water rights adjusted by the Natural Runoff Proportion (NRP) or water rights adjusted by the proration level.[6] However, at no time between April and September are diversions set greater than the average nonproration year computed average diversion shown in figure 24. Further, in years of proration, October diversions at no time are set greater than the October irrigation demand curve shown in Figure C-2.

[6] Natural Runoff Proportion (NRP) attempts to maximize the use of natural runoff (the unregulated runoff below storage reservoirs) and return flows and, at the same time, minimize storage releases to meet demands. The major water users above Parker voluntarily agree to share natural runoff and return flow supply proportionally based on their water rights. If reservoir releases are called for prior to storage control and formal prorationing, they will be deducted from the requesting entity's water bucket when prorationing formally begins.

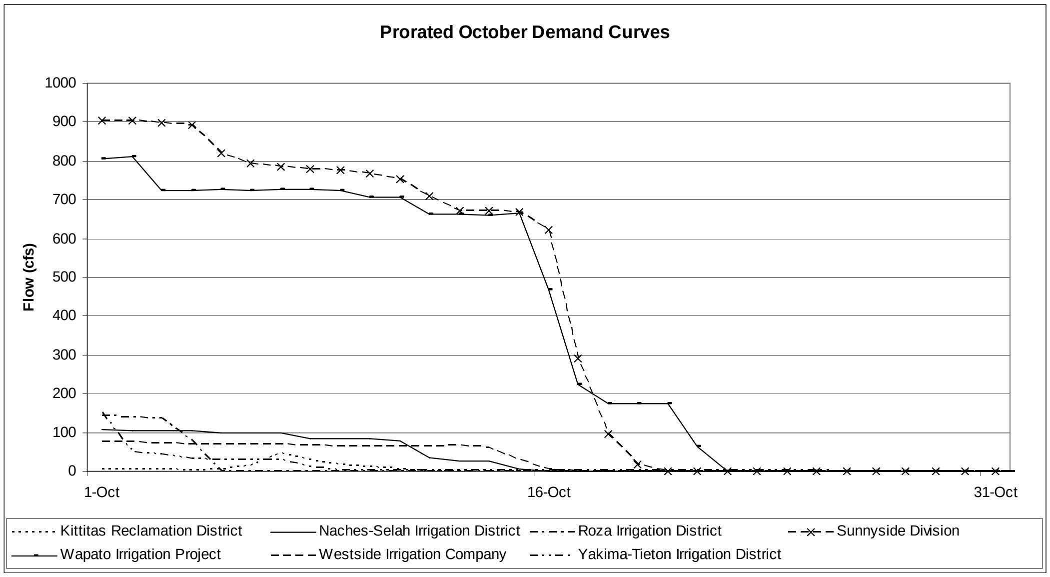

Figure C-2. Prorated Water Year October Irrigation Average Daily Demand Curves

Table C-2 shows the computed 7-year average April-October diversions and the water rights for the five Yakima Project divisions above Parker, and for the Westside Irrigation Company and the Naches-Selah Irrigation District. The water entitlements represent the total irrigation season entitlements as summarized in Chapter 5 of the *Interim Comprehensive Basin Operating Plan* (Bureau of Reclamation, 2002). Water entitlements for all entities included in the Yak-RW model can be found in Table C-5 at the end of this Appendix.

Table C-2. Average April-October Nonproration Diversion and Water Entitlements for Seven Entities

Entity	Average April-October Diversion (acre-feet)	Water Entitlement for Determining Proration Level and Nonproratable Supply (acre-feet)		
		Nonproratable	Proratable	Total
Kittitas Reclamation District	334,100	- - - -	336,000	336,000
Roza Irrigation District	339,700	- - - -	375,000	375,000
Yakima-Tieton Irrigation District	92,200	75,865	20,746	96,611[7]
Wapato Irrigation Project	604,800	305,613	350,000	655,613
Sunnyside Division	435,422[8]	315,836	142,684	458,520
Westside Irrigation Company	33,100	31,128	8,200	39,328
Naches-Selah Irrigation District	47,500	49,658	4,486	54,144

How the Model Works (Operating Rules)

The Yak-RW model is based on current Yakima Project operations (ruleset) described in the *Interim Comprehensive Basin Operating Plan, Chapter 5: Current Project Operations*. The model operation of items such as the current minimum target flows downstream of existing dams, the flip-flop operation, and the Title XII instream target flow operations, begun at different times during the period of record, have been included in the model for the entire 23 years. Because of this, as well as adjustments made during the "hands-on operation,"

[7] Through a Water Right Settlement among the Yakima-Tieton Irrigation District, the Washington State Department of Ecology, the United States, and the Yakama Nation, up to 96,611 acre-feet was confirmed to the United States on behalf of the Yakima-Tieton Irrigation District from the Tieton River for the period of April-October. The quantities set forth in the 1945 Consent Decree are to be used in determining proration, as limited by the foregoing volume.

[8] The average April-October diversion for the 7 years is 444,300 acre-feet. However, through a Water Right Settlement Agreement filed with the Superior Court for Yakima County, the Sunnyside Division agreed to a diversion of 435,422 acre-feet, with a further reduction by December 31, 2016. Thus, the water right is used for the diversion volume. The quantities set forth in the 1945 Consent Decree are used in determining proration, but the total to be diverted is limited to 435,422 acre-feet.

there will be differences in the modeled results, such as proration levels, when compared to historic operations.

The primary ruleset components and how they are applied in the model follow:

First, the total water supply available (TWSA) estimated to be available above Parker for the April 1 to September 30 irrigation season is computed from calibrated inflows, modeled reservoir contents, and estimated irrigation return flows. TWSA is used to set instream target flows at Parker in accordance with Title XII and determine the water supply available to meet irrigation water rights; the latter is used to determine if irrigation proration will be necessary.

The water supply available for irrigation is determined by reducing TWSA by flows estimated to pass Parker and the volume of stored water required (76,000 acre-feet) to meet irrigation demands from October 1 to the end of the irrigation season, which is generally October 15 to 20. The irrigation proration level is calculated as the water supply available for irrigation, less the April-through-September nonproratable water rights, divided by the April-through-September proratable water rights.

Prior to using the proration level to limit irrigation diversions, an estimate of natural runoff to meet irrigation demands is made. If the natural runoff can be used to meet up to 75 percent of the irrigation demands, then this is done. However, once 75 percent of the demands cannot be met from the natural runoff, proration is declared and the proration level is used to limit the demands.

> *At this point, the current day's irrigation demands and the Parker instream target flows are known.*

Second, operating guidelines for each reservoir are determined based on the flood control system rule curve and a targeted September 1 reservoir volume. The winter and spring operating guidelines (November 1 through June 30) are based on the "Flood Control Rule Curve," dated February 25, 1974, which is premised on attempting to maintain flows at Parker to no more than 12,000 cfs during the nonirrigation season, and 17,200 cfs during the irrigation season, including diversions of 5,200 cfs above Parker. These rule curves attempt to fill each reservoir on or near June 30.

After determining the required system storage space from the flood control rule curve, the space requirement within each reservoir is determined as follows: Keechelus, 13 percent; Kachess, 12 percent; Cle Elum, 42 percent; Bumping, 13 percent; and Rimrock, 20 percent.

Once the system is on storage control (generally about June 24), operating guidelines are used to draft from the reservoirs.[9] The goal of these guidelines is to maximize storage carryover by first using water from the reservoirs with the highest refill ratios, and to allow for flip-flop operations, which are achieved by targeting September 1 elevations at each reservoir. The basic concept is to call on Cle Elum and Keechelus Reservoirs to meet Yakima River irrigation demands prior to September 1. After September 1, Kachess Reservoir is used to meet Yakima River irrigation demands above the Naches River confluence, and Rimrock Reservoir is used to meet Yakima River irrigation demands below the Naches River confluence.

At this point, the day's desired reservoir elevations are known.

Third, once the Parker instream target flows, irrigation diversion allocations, and desired reservoir elevations are determined, releases from each reservoir can be calculated. The volume to be released from a particular reservoir each day is subject to minimum flow requirements below project dam(s), desired reservoir elevations, maximum channel capacities, downstream irrigation demands and the point(s) of diversion, and instream target flows at Parker. Minimum flow requirements and instream target flows are shown in Table C-3; Parker target flows are shown in Table C-4.

At this point, water releases from each reservoir are known.

Lastly, once releases have been made at each reservoir, river reach flows can be determined. The model is able to control the operation of the Kittitas Reclamation District's 1146 Wasteway to bypass fall reservoir releases around the Easton Reach and for operation of the Roza and Chandler Power Plants.

[9] The system is on storage control when the Yakima River flow at Parker can be controlled to the Title XII target flows only by using supplemental storage releases. Once unregulated streamflow fails to meet diversion demand and target flows downstream, reservoirs release water to meet these demands, causing a depletion of reservoir storage.

Table C-3. Minimum Target Flows Used by the Model

River Location	Daily Flows (cfs)											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Tieton Dam	45	45	45	45	45	45	45	45	45	45	45	45
Bumping Dam	130	130	130	130	130	130	130	130	130	130	130	130
Keechelus Dam	80	80	80	80	80	80	80	80	100	100	80	80
Kachess Dam	15	15	15	15	15	15	15	15	15	15	15	15
Cle Elum Dam	220	220	220	220	220	220	220	220	220	220	220	220
Easton Diversion Dam	220	220	220	220	220	220	220	220	220	220	220	220
Naches River at Naches	Minimum of natural flow right or 450 cfs											
Parker				Title XII flows								

Table C-4. Parker Instream Target Flows

Total Water Supply Estimate (million acre-feet)				Parker Flow (cfs)
April thru Sept.	**May thru Sept.**	**June thru Sept.**	**July thru Sept.**	
3.2	2.9	2.4	1.9	600
2.9	2.65	2.2	1.7	500
2.65	2.4	2.0	1.5	400
Less than above				300

Table C-5. Entitlements Used in the Yakima RiverWare Model (acre-feet)

	Total	Annual		April		May		June		July		August		September		October	
		Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro
Anderson Ditch	1,570	1,570	0	140	0	330	0	270	0	260	0	310	0	130	0	130	0
Blue Slough Ditch	4,245	4,245	0	595	0	615	0	595	0	615	0	615	0	595	0	615	0
Boise Cascade	9,259	9,159	100	1,354	15	1,399	15	1,354	15	1,399	15	1,399	15	1,354	15	900	10
Bull Ditch	6,471	6,471	0	1,012	0	1,045	0	1,012	0	1,045	0	1,045	0	1,012	0	300	0
Carmack Parker Ditch	639	639	0	95	0	98	0	95	0	98	0	98	0	95	0	60	0
Cascade Ditch	49,525	49,525	0	8,925	0	9,223	0	8,925	0	8,452	0	5,600	0	5,600	0	2,800	0
Chapman Nelson Ditch	7,641	7,641	0	1,071	0	1,107	0	1,071	0	1,107	0	1,107	0	1,071	0	1,107	0
City of Cle Elum M and I	1,260	1,260	0	180	0	180	0	180	0	180	0	180	0	180	0	180	0
City of Ellensburg M and I	6,000	0	6,000	0	120	0	1,020	0	1,260	0	1,260	0	1,200	0	780	0	360
City of Yakima Irrigation	10,305	8,805	1,500	1,232	225	1,273	262	1,232	342	1,273	218	1,273	218	1,232	165	1,290	70
City of Yakima M and I	9,359	4,859	4,500	681	675	704	788	681	1,028	704	652	704	652	681	495	704	210
Clark Ditch	4,562	4,562	0	714	0	739	0	714	0	739	0	739	0	536	0	381	0
Cobb Upper Ditch	727	727	0	119	0	123	0	119	0	123	0	123	0	60	0	60	0
Congdon Ditch	28,025	23,720	4,305	3,808	690	3,935	713	3,808	690	3,935	713	3,935	713	2,469	446	1,830	340
Ellensburg Mill and Feed Ditch	4,804	4,804	0	702	0	726	0	702	0	726	0	726	0	702	0	520	0
Ellensburg Power Ditch	6,031	6,031	0	928	0	959	0	928	0	959	0	959	0	928	0	370	0
Ellensburg Town Ditch	47,758	47,758	0	7,438	0	7,686	0	7,438	0	7,686	0	7,686	0	5,950	0	3,874	0
Emerick Ditch	687	687	0	119	0	123	0	119	0	123	0	123	0	60	0	20	0
Fogarty Dyer Ditch	3,690	3,690	0	108	0	638	0	717	0	794	0	733	0	480	0	220	0
Foster Naches Ditch	1,510	1,510	0	100	0	280	0	300	0	320	0	270	0	200	0	40	0
Fredricks Hunting Ditch	950	950	0	120	0	130	0	170	0	170	0	180	0	140	0	40	0
Fruitvale Ditch	17,708	17,708	0	2,791	0	2,884	0	2,791	0	2,884	0	2,884	0	2,011	0	1,463	0
Gleed Ditch	22,819	22,819	0	3,618	0	3,738	0	3,618	0	3,738	0	3,738	0	2,475	0	1,894	0
Hubbard Ditch	11,165	11,165	0	1,785	0	1,845	0	1,785	0	1,845	0	1,845	0	1,250	0	810	0
Kelly Lowry Ditch	8,490	8,490	0	1,190	0	1,230	0	1,190	0	1,230	0	1,230	0	1,190	0	1,230	0
Knoke Ditch	1,600	1,600	0	110	0	300	0	350	0	370	0	330	0	120	0	20	0
Kittitas Reclamation District	336,000	0	336,000	0	6,720	0	57,120	0	70,560	0	70,560	0	67,200	0	43,680	0	20,160
Mills and Son Ditch	7,530	7,530	0	1,190	0	1,230	0	1,190	0	1,230	0	1,230	0	1,190	0	270	0
Morrissey Ditch	1,206	1,206	0	178	0	184	0	178	0	184	0	184	0	178	0	120	0
Moxee Irrigation District	5,205	4,245	960	595	86	615	144	595	182	615	182	615	182	595	125	615	59
Naches Cowiche Ditch	15,096	15,096	0	2,380	0	2,460	0	2,380	0	2,460	0	2,460	0	1,726	0	1,230	0
Naches Selah Irrigation District	54,144	49,658	4,486	7,080	674	7,263	811	7,080	901	7,321	1,050	7,321	1,050	6,884	0	6,709	0
Nile Valley Ditch	4,350	4,350	0	230	0	470	0	730	0	980	0	970	0	670	0	300	0
Oconner Ditch	3,100	3,100	0	0	0	330	0	660	0	830	0	740	0	450	0	90	0
Old Union Ditch	17,675	17,675	0	2,813	0	2,907	0	2,813	0	2,907	0	2,907	0	1,875	0	1,453	0
Wapato Irrigation Project	655,613	305,613	350,000	42,843	31,500	44,271	73,500	42,843	70,000	44,271	80,500	44,271	73,500	42,843	21,000	44,271	0
Richartz Ditch	6,364	6,364	0	892	0	922	0	892	0	922	0	922	0	892	0	922	0
Roza Irrigation District	375,000	0	375,000	0	37,500	0	56,250	0	71,250	0	71,250	0	71,250	0	45,000	0	22,500
Selah Moxee Irrigation District	31,774	27,493	4,281	4,284	427	4,427	685	4,284	814	4,427	898	4,427	857	3,320	600	2,324	0

Table C-5. Entitlements Used in the Yakima RiverWare Model (acre-feet) (con't)

	Total	Annual		April		May		June		July		August		September		October	
		Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro
Sinclair Ditch	786	786	0	119	0	123	0	119	0	123	0	123	0	119	0	60	0
South Naches Ditch	22,946	22,946	0	3,689	0	3,812	0	3,689	0	3,812	0	3,812	0	3,272	0	860	0
Stanfield Ditch	1,600	1,600	0	30	0	280	0	370	0	430	0	330	0	100	0	60	0
Stevens Ditch	1,950	1,950	0	60	0	410	0	350	0	410	0	320	0	290	0	110	0
Sunnyside Division	458,520	315,836	142,684	47,070	7,840	48,636	27,874	47,066	31,234	48,637	31,443	48,637	31,443	47,070	12,850	28,720	0
Taylor Ditch	8,000	8,000	0	1,190	0	1,230	0	1,190	0	1,230	0	1,230	0	1,190	0	740	0
Tenant Ditch	1,570	1,570	0	110	0	210	0	220	0	410	0	320	0	230	0	70	0
Yakima-Tieton Irrigation District	114,049	75,865	38,181	0	6,000	15,372	6,641	14,876	7,141	15,372	6,641	15,372	6,641	14,876	5,117	0	0
Tjossem Ditch	4,771	4,771	0	756	0	781	0	756	0	781	0	781	0	756	0	160	0
Vertrees 1 Ditch	2,164	2,164	0	181	0	407	0	400	0	551	0	428	0	177	0	20	0
Vertrees 2 Ditch	704	704	0	107	0	111	0	107	0	111	0	111	0	107	0	50	0
Wapatox Ditch	20,230	20,230	0	3,064	0	3,167	0	3,064	0	3,167	0	3,167	0	3,064	0	1,537	0
Westside Irrigation Company	39,328	31,128	8,200	4,760	550	4,919	1,550	4,760	1,500	4,919	1,550	4,919	1,550	4,760	1,500	2,091	0
Woldale Ditch	12,973	12,973	0	2,023	0	2,091	0	2,023	0	2,091	0	2,091	0	1,547	0	1,107	0
Younger Ditch	3,010	3,010	0	40	0	440	0	780	0	790	0	740	0	180	0	40	0
Union Gap Irrigation District	25,303	20,697	4,606	3,273	571	3,382	734	3,273	785	3,382	812	3,382	872	2,279	582	1,726	250
Total	2,497,761	1,216,958	1,280,803														

Appendix D YAKIMA RIVER BASIN STORAGE ASSESSMENT INTEGRATED OPERATION SCENARIO AND COMPARISON OF RESULTS -- JANUARY 2006

Purpose of Appendix D

Appendix D provides more detailed information on the integrated operation scenario, the results of the three operation studies conducted for the integrated operation scenario, and a comparison of the results with the current operation scenario.

Scenario Definition

Different operation scenarios can be analyzed with the Yak-RW model by modifying network object data and by adding new objects and data, such as additional storage reservoirs. Following is a discussion of the two operation scenarios and the operation studies conducted for the *Yakima Appraisal Assessment*.

The two operation scenarios are:

- Current Operation Scenario – The current operation scenario represents management of the existing Yakima Project as reflected in Appendix C.
- Integrated Operation Scenario – Integrated operation whereby the three Yakima basin storage alternatives are integrated with the existing Yakima Project facilities.

In addition to the two operation scenarios, a natural (unregulated) flow regime was developed for the mainstem Yakima and Naches Rivers and for the Bumping River. This represents an estimated unregulated Yakima Project streamflow regime unimpeded by reservoir impoundments or altered by diversions and the associated irrigation return flows.

Integrated Operations

Criteria

The primary criteria used for the three storage alternatives included in the integrated operation scenario are shown below:

Bumping Lake Enlargement

Location: On the Bumping River, approximately 4,500 feet downstream from the existing Bumping Dam.

Reservoir Active Capacity: About 415,000 acre-feet (includes replacement capacity of 33,700 acre-feet of the existing reservoir).

Operating Strategy: Maximize storage carryover for use in dry water supply years.

Wymer Dam, Reservoir, and Pumping Plant

Location: Near Yakima River at confluence of Lmuma Creek.

Reservoir Active Capacity: 175,000 acre-feet.

Pumping Plant and Reservoir Discharge Capacity: 400 cfs.

Operating Strategy:

Inflow: Limited to nonprorated water supply years. Pumping to Wymer reservoir occurs when Yakima River flows are:

- Greater than 1,475 cfs upstream of Roza Diversion Dam during the nonirrigation season; and
- Greater than Title XII flows over Sunnyside Diversion Dam during the irrigation season.[10]

Outflow: Limited to prorated water supply years and when reservoir releases are required for meeting Title XII target flows at Sunnyside Diversion Dam. Using Wymer reservoir to meet these instream flows permits stored water in the other reservoirs to be used to assist in improving the irrigation proratable water supply throughout the basin.

[10] Maximum generation at Roza Powerplant requires a flow of 1,075 cfs. In addition, 400 cfs is required at Roza Diversion Dam to divert the power water.

Keechelus-to-Kachess Pipeline

Pipeline Capacity: Ranges from 100 cfs at Keechelus Reservoir elevation 2450 feet, to 210 cfs at elevation 2517 feet (see table 6-4 of *Yakima Appraisal Assessment*).

Operating Strategy: Operate through June 1 and September 30 to siphon Keechelus Dam releases to Kachess Reservoir.

For the integrated operation scenario, the focus is on meeting current instream flow requirements downstream of the dams, Title XII instream target flows, and the irrigation water supply goal. Specific criteria are not included in the integrated operation scenario in an attempt to move the Yakima and Naches Rivers' flow regimes toward the natural (unregulated) hydrograph. Rather, the Yak-RW model uses the post-TWSA to set Title XII target flows over Sunnyside and Prosser diversion dams. This results in higher Title XII flows in some years, depending on the extent of the increase in TWSA and the Title XII criteria threshold levels. These additional flows are then equated to a block of stored water which could be used for other fishery purposes if desired. In this manner, the water supply available for specific fishery operations is identified.

Total Water Supply Available and Proration

For the integrated operation scenario, three operation studies were conducted in which the following "thresholds" of proration were used:

- Integrated 100-percent operation which represents the present proration process where there is no constraint in any year on the proratable entitlements, except as limited by the volume of TWSA.
- Integrated 70-percent operation, where the allotment in any prorated year is limited to the water that would have been available without the storage alternatives, and capped at 70 percent of the proratable entitlements with the storage alternatives, except as limited by the volume of TWSA.
- Integrated 50-percent operation, where the allotment in any prorated year is limited to the water that would have been available without the storage alternatives, and capped at 50 percent of the proratable entitlements with the storage alternatives, except as limited by the volume of TWSA.

To determine the 70-percent and 50-percent thresholds, a "post-" and "pre-" TWSA was computed. The post-TWSA computation includes the stored water available in the existing storage system, plus the stored water available in the storage alternatives. The pre-TWSA computation considers only the stored water available in the existing storage system. The other components of TWSA remained the same. These TWSA computations are shown below:

Post-TWSA = Prior day contents of Keechelus, Kachess, Cle Elum, Rimrock, Bumping Lake enlargement and Wymer + total runoff above Parker + usable return flow above Parker.

Pre-TWSA = Prior day contents of Keechelus, Kachess, Cle Elum, Rimrock, and Existing Bumping Lake + total runoff above Parker + usable return flow above Parker.

The proration thresholds and the allotment of the proratable irrigation TWSA used in the integrated operation scenario are illustrated Table D-1.

The integrated operation scenario included operation studies with three "thresholds" of water supply—100-percent, 70-percent, and 50-percent. Table ES-3 uses two examples of proration levels (80-percent and 40-percent) to illustrate what the proratable supply would be with application of the 100-percent, 70-percent, and 50-percent, criteria. For example, if the computed proration level without the three storage alternatives would have been 80 percent (or any supply over the threshold level), irrigators would receive up to 100 percent of their proratable rights under the integrated 100-percent scenario (if the supply is available), 80 percent under the integrated 70-percent scenario, and 80 percent under the integrated 50-percent scenario. In other words, proratable irrigators would receive what they would have received without any program in place, under any of the integrated operations.

On the other hand, if, without the three storage alternatives, the proratable supply is 40 percent (or any supply less than the integrated operation threshold), they would receive up to that threshold level, *i.e.*, 50 percent under the integrated 50-percent scenario, and 70 percent under the integrated 70-percent scenario, and 100 percent under the integrated 100-percent scenario, if the supply is available.

Table D-1. Example of Proratable Supply Provided With The Three Storage Alternatives

Computed Proration Level Without Three Storage Alternatives	Integrated 100%	Integrated 70%	Integrated 50%
80%	up to 100% (if available)	80%	80%
40%	up to 100% (if available)	70% (if available)	50% (if available)

The computed pre-TWSA may not be the same as in the current operation scenario TWSA. This is because the integrated system operation of the Yakima Project results in differences in the contents of the existing storage system.

Comparison of Results of Integrated Operation Studies

Irrigation Water Supply

Integrated 100-Percent Operation Study

One-year droughts which follow 2 or more wet years could see a 40-percent improvement in the proratable water supply over the current operation scenario. This is demonstrated by drought year 2001, where the current operation scenario proratable supply available is 41 percent, and the integrated 100-percent operation study is 84 percent.

Proratable water supply conditions are improved in some years of a prolonged dry period such as 1992-1994. The additional storage alternatives provided a full (100-percent) proratable supply in 1992 and increased the 1993 supply from 54 percent (current operation) to 74 percent. However, this results in the enlarged Bumping Lake reservoir and Wymer reservoir being significantly drawn down. The April 1 TWSA for the 1994 irrigation season is about the same as the current operation scenario. This shows there was not enough runoff to build up the stored water supply following the 1992 and 1993 dry years, and the proratable water supply provided in 1994 is only 27 percent (a 1-percent increase from the current operation scenario).

Integrated 70-Percent Operation Study

One-year droughts which follow 2 or more wet years could see about a 30-percent improvement. This is demonstrated by drought year 2001, where the modeled current operation proration level is 41 percent, and the integrated 70-percent operation proration level is brought up to 70 percent.

Irrigation water supply conditions are improved in the prolonged 3-year dry period of 1992-1994. The additional storage alternatives increased the proratable water supply in 1992 and 1993 to not less than 70 percent. The 1994 proratable water supply was increased to 66 percent; 4 percentage points below the 70-percent threshold. It is estimated the 4-percent difference equals about 50,000 acre-feet.

Integrated 50-Percent Operation Study

The integrated 50-percent operation study results in a proratable water supply within the same range as the integrated 70-percent operation study in years 1992 and 1993. For the third year of the 3-year dry period, the proratable water supply provided is at the 50-percent threshold.

Summary of Results

Table D-2 provides information on the annual water supply conditions above Parker. The information in the table is described below:

Column 1, *Water Year*: The Water Year of the 23-year historical period used in the Yak-RW model.

Column 2, *Current*: This is the current operation scenario April 1-September 30 TWSA estimate produced by the Yak-RW model.

Column 3, *100 percent*: This is the April 1-September 30 TWSA estimate produced by the Yak-RW model for the integrated 100-percent operation scenario.

Column 4, *70 percent*: This is the April 1-September 30 TWSA estimate produced by the Yak-RW model for the integrated 70-percent operation scenario.

Column 5, *+TWSA*: The increase in the April 1-September 30 TWSA estimate between the integrated 70-percent operation scenario and the current operation scenario is shown in this column.

Column 6, *50 percent*: This is the April 1-September 30 TWSA estimate produced by the Yak-RW model for the integrated 50-percent operation study.

Columns 7-10, *Proratable Water Supply Provided*: These columns show the volume of the water supply provided to proratable entitlements for the current and integrated operation scenarios.

Table D-2. Yakima Project Current and Integrated Operation Scenarios--TWSA and Proratable Supply

Water Year	April 1 – September 30 TWSA (million acre-feet)					Proratable Water Supply Provided (%)			
	Current Operation Scenario	Integrated Operation Scenario				Current Operation Scenario	Integrated Operation Scenario		
		100%	70%	+TWSA	50%		100%	70%	50%
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1981	2.48	2.85	2.86	.38	2.86	95	100	91	91
1982	3.39	3.79	3.83	.46	3.85	100	100	100	100
1983	3.30	3.88	3.89	.56	3.89	100	100	100	100
1984	3.23	3.79	3.79	.56	3.79	100	100	100	100
1985	2.74	3.27	3.27	.53	3.27	100	100	100	100
1986	2.50	3.00	3.00	.50	3.00	92	100	89	88
1987	2.26	2.64	2.82	.56	2.82	65	100	70	69
1988	2.33	2.47	2.84	.51	2.84	73	90	89	87
1989	2.66	2.73	3.10	.44	3.11	98	100	100	100
1990	3.10	3.16	3.50	.40	3.52	100	100	100	100
1991	3.01	3.41	3.57	.55	3.57	100	100	100	100
1992	2.14	2.56	2.65	.52	2.64	69	100	70	65
1993	2.07	2.23	2.57	.50	2.62	54	74	72	75
1994	1.74	1.75	2.14	.41	2.16	26	27	66	50
1995	2.90	3.01	3.07	.17	3.19	100	100	100	100
1996	3.22	3.64	3.65	.45	3.77	100	100	100	100
1997	4.50	4.99	4.99	.49	5.01	100	100	100	100
1998	3.15	3.68	3.68	.53	3.68	100	100	100	100
1999	3.99	4.48	4.49	.50	4.48	100	100	100	100
2000	3.26	3.78	3.78	.52	3.78	100	100	100	100
2001	1.81	2.35	2.34	.53	2.33	41	84	70	50
2002	3.23	3.39	3.57	.33	3.77	100	100	100	100
2003	2.56	2.84	2.97	.41	3.06	97	100	92	92

Instream Flows

Table D-3 summarizes the annual increase in the Title XII volume estimated to be provided from stored water for the integrated operation scenario.

Title XII instream target flows at Parker ranges from 300 cfs to 600 cfs, depending on the estimated TWSA “threshold level” (see Table 4-1). With addition of the three storage alternatives, the “storage content” portion of the TWSA estimate increases and may result in moving the target flow from one threshold level to the next. When this occurs in the integrated operation scenarios, the instream flow at Parker is increased. At such time as unregulated flow fails to meet diversion demands and Title XII target flows, reservoir releases are required.

Table D-3 summarizes the average increased flow rate (cfs) and the number of days at the increased flow rate resulting from the three integrated operation scenarios. Also shown is the volume (acre-feet) of the increase flow estimated to be provided from stored water. In some years, it may be possible to use this increased volume for other fishery purposes rather than for increased Title XII instream target flows.

Figures of Current and Integrated Operation Scenarios

The following tables and figures comparing current and integrated operation scenarios are included for information:

Table	**Contents**
Table D-4	Yakima River Flows Available for Wymer – Integrated 50% Operation Study
Table D-5	Yakima River Flows Available for Wymer – Integrated 100% Operation Study
Table D-6	Inflow and Releases from Wymer – Integrated 50% Operation Study
Table D-7	Inflow and Releases from Wymer – Integrated 100% Operation Study
Figure	**Contents** *Current and Integrated (100%, 70%, 50%) Scenarios*
Figure D-1	Storage Contents for Water Years 1981-2003 – Total System
Figure D-2	Storage Contents for Water Years 1981-2003 – Bumping Lake
Figure D-3	Storage Contents for Water Years 1981-2003 – Wymer
Figure D-4	Storage Contents for Water Years 1989-1996 – Total System
Figure D-5	Storage Contents for Water Years 1989-1996 – Bumping Lake
Figure D-6	Bumping Lake Outflow for Water Years 1989-1996

Table D-3. Increased Title XII Flows at Parker

Water Year	Average Increased Flow Rate (cfs) and Number of Days at the Increased Flow Rate			Volume of Increased Flow from Stored Water (acre-feet)		
	Integrated 70% Operation	Integrated 50% Operation	Integrated 100% Operation	Integrated 70% Operation	Integrated 50% Operation	Integrated 100% Operation
1981	200 (134 days)	200 (134 days)	200 (131 days)	53,000	53,000	52,000
1982	100 (91 days)	100 (86 days)	100 (91 days)	18,000	17,000	18,000
1983	100 (91 days)	100 (91 days)	100 (91 days)	18,000	18,000	18,000
1984	100 (111 days)	100 (111 days)	100 (111 days)	22,000	22,000	22,000
1985	300 (133 days)	300 (133 days)	300 (133 days)	79,000	79,000	79,000
1986	200 (164 days)	200 (164 days)	200 (156 days)	65,000	65,000	62,000
1987	100 (171 days)	100 (171 days)	200 (33 days)	32,000	34,000	13,000
1988	100 (151 days)	100 (151 days)	- -	30,000	30,000	- -
1989	200 (118 days)	200 (118 days)	- -	47,000	47,000	- -
1990	200 (126 days)	200 (129 days)	100 (121 days)	50,000	51,000	24,000
1991	200 (118 days)	200 (118 days)	200 (118 days)	47,000	47,000	47,000
1992	100 (126 days)	100 (126 days)	- -	25,000	25,000	- -
1993	100 (116 days)	100 (116 days)	- -	23,000	23,000	- -
1994	- -	- -	- -	- -	- -	- -
1995	- -	100 (101 days)	- -	- -	20,000	- -
1996	200 (129 days)	200 (129 days)	200 (129 days)	51,000	51,000	51,000
1997	- -	- -	- -	- -	- -	- -
1998	300 (119 days)	300 (119 days)	300 (119 days)	71,000	71,000	71,000
1999	- -	- -	- -	- -	- -	- -
2000	200 (108 days)	200 (108 days)	200 (108days)	43,000	43,000	43,000
2001	- -	- -	- -	- -	- -	- -
2002	200 (103 days)	200 (101 days)	100 (106 days)	41,000	40,000	21,000
2003	200 (129 days)	200 (144 days)	100 (136 days)	37,000	57,000	27,000

Table D-4. Yakima River Flows Available for Pumping into Wymer Reservoir with Integrated 50% Operation

Water Year	Monthly flows (acre-feet)												Annual Flow (a-f)
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	
1981	0	113,049	35,737	86,446	22,330	0	0	0	0	0	0	0	257,562
1982	0	0	31,037	107,298	76,043	26,784	89,866	97,538	18,705	0	0	0	447,270
1983	0	633	84,681	27,030	133,892	76,455	58,950	60,795	14,164	0	0	0	456,600
1984	2,857	0	120,525	35,431	70,926	35,246	2,285	132,880	19,079	0	0	0	419,229
1985	0	0	0	0	0	56,302	7,563	0	0	0	0	221	64,085
1986	8,340	0	0	40,368	120,875	10,513	0	0	0	0	0	0	180,097
1987	14,310	0	0	0	32,906	6,759	3,093	0	0	0	0	0	57,068
1988	0	0	0	1,285	0	29,981	0	0	0	0	0	0	31,266
1989	1,075	3,840	3,248	4,029	5,601	60,251	1,589	0	0	0	0	0	79,633
1990	946	7,801	14,769	21,461	26,347	119,666	136	44,131	6,816	0	0	3,151	245,226
1991	180,520	73,606	99,936	85,700	55,420	94,341	31,848	40,975	14,176	0	0	0	676,521
1992	0	12,657	9,206	17,308	28,729	0	0	0	0	0	0	0	67,900
1993	0	0	0	0	3,918	1,606	3,215	0	0	0	0	0	8,739
1994	0	0	0	0	143	2,753	0	0	0	0	0	0	2,896
1995	409	10,571	12,105	138,108	69,833	11,775	17,404	14,209	0	0	0	0	274,414
1996	113,548	181,069	214,229	345,150	212,284	202,475	31,971	50,728	0	0	0	0	1,351,453
1997	0	0	42,731	85,024	270,063	262,460	320,808	102,221	25,207	0	0	3,224	1,111,739
1998	36,637	1,568	8,311	22,330	56,661	83,310	85,495	26,451	0	0	0	0	320,764
1999	106	21,380	56,294	7,620	40,333	50,012	145,038	86,691	57,879	2,208	0	0	467,560
2000	128,846	134,842	5,066	0	6,361	138,425	26,239	83,665	8,341	0	0	0	531,784
2001	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	733	500	10,781	7,805	11,450	123,680	29,468	139,422	2,692	0	0	0	326,532
2003	0	0	20,128	48,780	60,990	33,191	2,795	0	0	0	0	0	165,883
Avg	21,232	24,414	33,425	47,008	56,744	61,999	37,294	38,248	7,263	96	0	287	328,010
Daily Available for Storage (cfs)													
Avg	357	397	544	846	923	1,042	607	643	118	2	0	5	
Max	10730	11255	6944	15264	11717	9759	11333	5685	2544	602	0	783	
Min	0	0	0	0	0	0	0	0	0	0	0	0	

Table D-5. Yakima River Flows Available for Pumping into Wymer Reservoir with Integrated 100% Operation

Water Year	Monthly flows (acre-feet)												Annual Flow (a-f)
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	
1981	0	113,049	35,737	86,446	22,330	0	1,857	0	0	0	0	0	259,419
1982	0	0	31,344	107,618	58,129	7,726	65,475	85,742	17,010	0	0	0	373,045
1983	0	633	83,456	27,030	133,892	68,524	58,988	60,795	14,164	0	0	0	447,482
1984	2,857	0	120,525	35,431	70,926	35,246	2,285	132,880	19,079	0	0	0	419,229
1985	0	0	0	0	0	56,302	7,563	0	0	0	0	221	64,085
1986	8,340	0	0	40,368	120,875	10,833	0	0	0	0	0	0	180,417
1987	15,825	0	0	0	33,001	6,793	2,849	0	0	0	0	0	58,468
1988	0	0	0	1,308	0	29,994	0	0	0	0	0	0	31,302
1989	1,087	3,829	3,244	4,027	5,600	60,251	1,588	0	0	0	0	0	79,627
1990	946	7,801	14,769	21,461	25,020	106,921	136	30,025	6,845	0	0	3,151	217,076
1991	176,082	72,743	99,910	85,700	55,420	94,341	31,145	30,760	11,394	0	0	0	657,496
1992	0	12,657	9,206	17,308	28,729	435	0	0	0	0	0	0	68,335
1993	0	0	0	0	3,941	1,615	3,211	0	0	0	0	0	8,768
1994	0	0	0	0	143	2,754	0	0	0	0	0	0	2,897
1995	362	10,203	12,013	138,029	69,809	11,771	17,404	15,091	1,279	0	0	0	275,962
1996	117,226	194,696	203,684	346,599	212,255	202,476	31,972	48,485	0	0	0	0	1,357,394
1997	0	0	42,731	84,670	267,231	262,383	315,319	102,208	25,207	0	0	3,224	1,102,973
1998	36,637	1,568	8,311	22,330	56,661	83,310	85,495	26,451	0	0	0	0	320,764
1999	106	21,380	56,294	7,620	40,333	50,012	145,038	86,691	57,879	2,208	0	0	467,560
2000	128,846	134,842	5,066	0	6,361	138,425	26,239	83,665	8,341	0	0	0	531,784
2001	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	1,150	718	10,960	7,824	2,560	48,140	22,969	91,378	7,791	0	0	0	193,490
2003	0	0	20,128	48,780	58,743	30,018	1,887	0	0	0	0	0	159,556
Avg	21,281	24,962	32,929	47,067	55,303	56,881	35,714	34,529	7,347	96	0	287	316,397
Daily Available for Storage (cfs)													
Avg	358	406	536	847	899	956	581	580	119	2	-	5	
Max	11154	11333	6455	15036	11678	9719	11333	4773	2544	602	0	783	
Min	0	0	0	0	0	0	0	0	0	0	0	0	

Table D-6. Inflows and Releases from Wymer Reservoir with Integrated 50% Operation

Water Year	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Annual	
													Inflow	Release
1981	0	14,853	10,709	11,901	13,796	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	0	51,259	116,904
1982	0	0	8,727	17,745	24,595	17,157	24,595	16,579	7,013	0	0	0	116,412	0
1983	0	633	21,319	11,208	15,073	Full	Full	Full	Full	Full	Full	Full	48,233	0
1984	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1985	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1986	Full	Full	Full	Full	Full	Full	Full	Rel.	Rel.	Rel.	Rel.	Rel.	0	97,728
1987	6,550	0	0	0	13,959	6,242	2,895	Rel.	Rel.	Rel.	Rel.	0	29,647	96,000
1988	0	0	0	1,285	0	13,740	0	Rel.	0	0	0	0	15,025	15,597
1989	1,075	3,840	3,166	3,270	5,194	19,290	1,589	0	0	0	0	0	37,424	0
1990	946	5,984	7,143	11,165	18,998	21,721	136	12,985	3,549	0	0	3,151	85,778	0
1991	19,463	21,987	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	41,450	0
1992	Full	Full	Full	Full	Full	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	0	131,294
1993	0	0	0	0	3,918	1,606	3,215	Rel.	Rel.	Rel.	0	0	8,739	42,050
1994	0	0	0	0	143	2,753	Rel.	0	0	0	0	0	2,896	2,380
1995	409	8,913	4,547	22,215	23,910	8,514	10,346	8,320	0	0	0	0	87,174	0
1996	18,638	24,595	24,595	9,087	Full	Full	Full	Full	Full	Full	Full	Full	76,915	0
1997	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1998	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1999	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
2000	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
2001	Full	Full	Full	Full	Full	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	0	134,275
2002	733	500	7,193	5,475	10,732	23,236	16,910	22,265	1,587	0	0	0	88,631	0
2003	0	0	4,823	17,668	18,670	Full	Full	Rel.	Rel.	Rel.	Rel.	0	41,162	80,875
Avg	2,079	3,535	4,010	4,827	6,478	5,163	2,595	2,615	528	0	0	137	31,966	31,178
	Daily Inflow (cfs)												**Average Daily (cfs)**	
Avg	335	356	355	346	348	348	331	370	340	0	0	227	348	389
Max	400	400	400	400	400	400	400	400	400	0	0	311	400	400
Min	66	52	57	52	66	53	51	77	97	0	0	80	51	1

Table D-7. Inflows and Releases from Wymer Reservoir with Integrated 100% Operation

Water Year	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Annual Inflow	Annual Release
1981	0	14,853	10,709	11,901	13,796	0	1,601	0	0	0	0	0	52,860	0
1982	0	0	8,727	17,800	19,612	Full	Full	Full	Full	Full	Full	Full	46,140	0
1983	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1984	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1985	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1986	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1987	Full	Full	Full	Full	Full	Full	Full	Rel.	Rel.	Rel.	Rel.	Rel.	0	96,882
1988	0	0	0	1,308	0	13,745	0	Rel.	Rel.	Rel.	Rel.	0	15,054	82,512
1989	1,087	3,829	3,163	3,269	5,194	19,290	1,588	0	0	0	0	0	37,421	0
1990	946	5,984	7,143	11,165	18,998	21,721	136	9,144	3,555	0	0	3,151	81,943	0
1991	19,119	24,573	1,286	Full	Full	Full	Full	Full	Full	Full	Full	Full	44,977	0
1992	Full	Full	Full	Full	Full	Full	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	0	113,337
1993	0	0	0	0	3,941	1,615	3,211	Rel.	Rel.	Rel.	0	0	8,768	59,829
1994	0	0	0	0	143	2,754	Rel.	0	0	0	0	0	2,897	2,881
1995	362	8,764	4,470	22,215	23,908	8,513	10,346	8,696	1,129	0	0	0	88,403	0
1996	18,638	24,595	24,595	8,152	Full	Full	Full	Full	Full	Full	Full	Full	75,980	0
1997	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1998	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1999	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
2000	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
2001	Full	Full	Full	Full	Full	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	0	142,443
2002	1,150	718	7,279	5,480	2,560	17,417	16,581	17,303	3,898	0	0	0	72,386	0
2003	0	0	4,823	17,668	18,670	14,789	1,887	0	0	0	0	0	57,838	0
Avg	1,796	3,622	3,139	4,303	4,645	4,341	1,537	1,528	373	0	0	137	25,420	21,647
Daily Flows (cfs)														
Avg	331	362	337	346	339	333	274	334	333	0	0	0	335	382
Max	400	400	400	400	400	400	400	400	400	0	0	311	400	400
Min	66	54	59	56	69	53	51	72	169	0	0	80	51	3

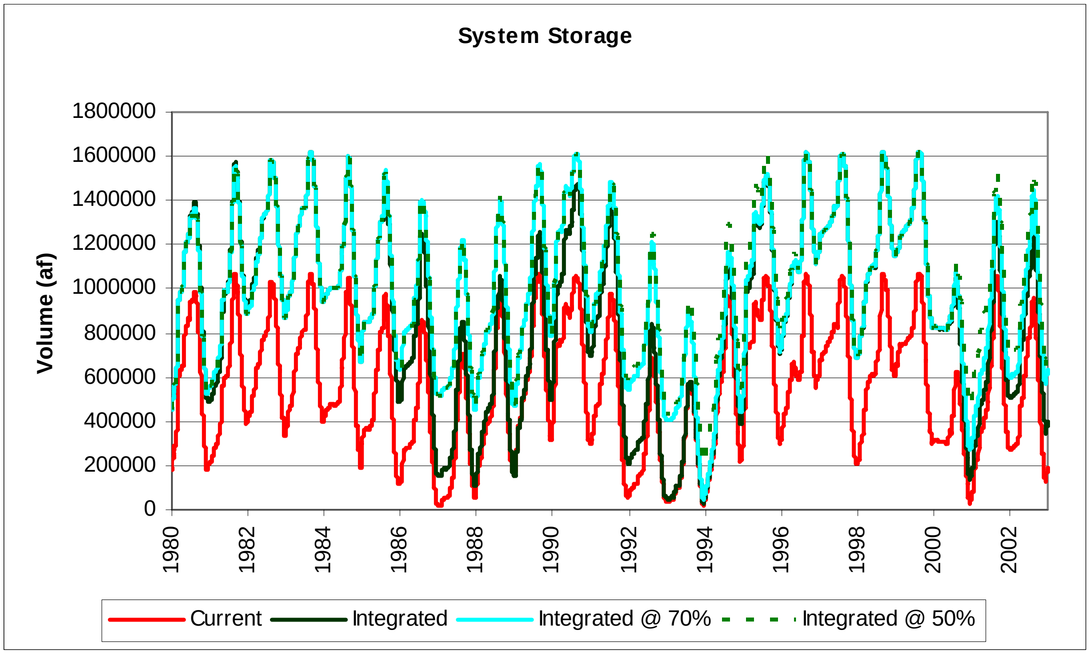

Figure D-1. System Storage Contents for Water Years 1981-2003--Current and Integrated Scenarios

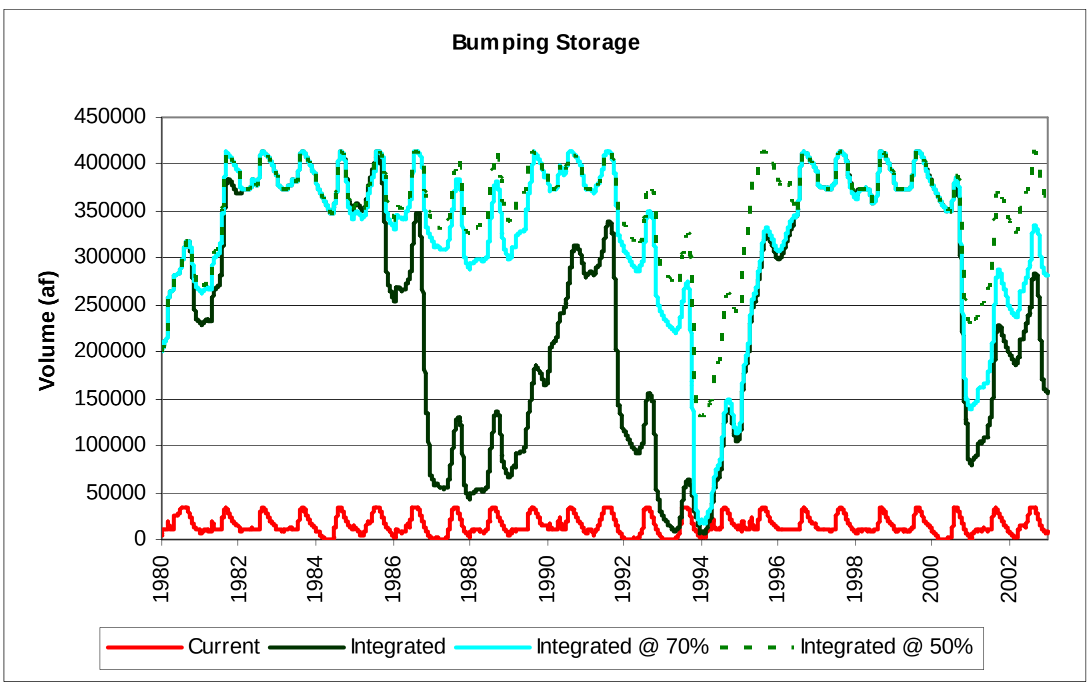

Figure D-2. Bumping Lake Enlargement Storage Contents for Water Years 1981-2003--Current and Integrated Scenarios

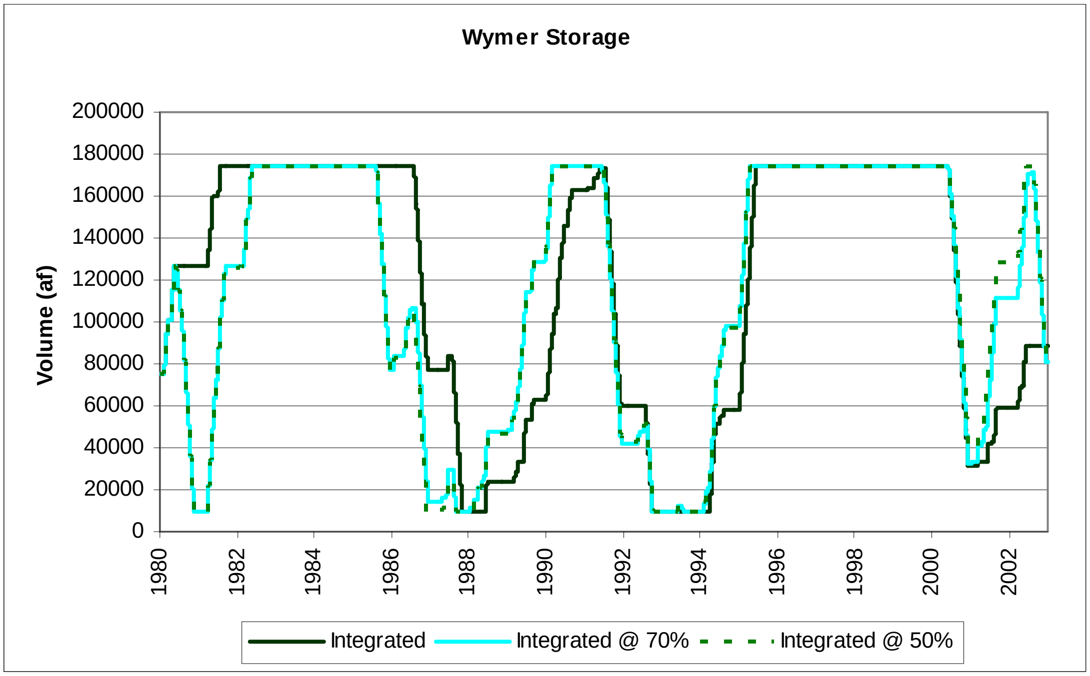

Figure D-3. Wymer Storage Contents for Water Years 1981-2003--Integrated Scenario

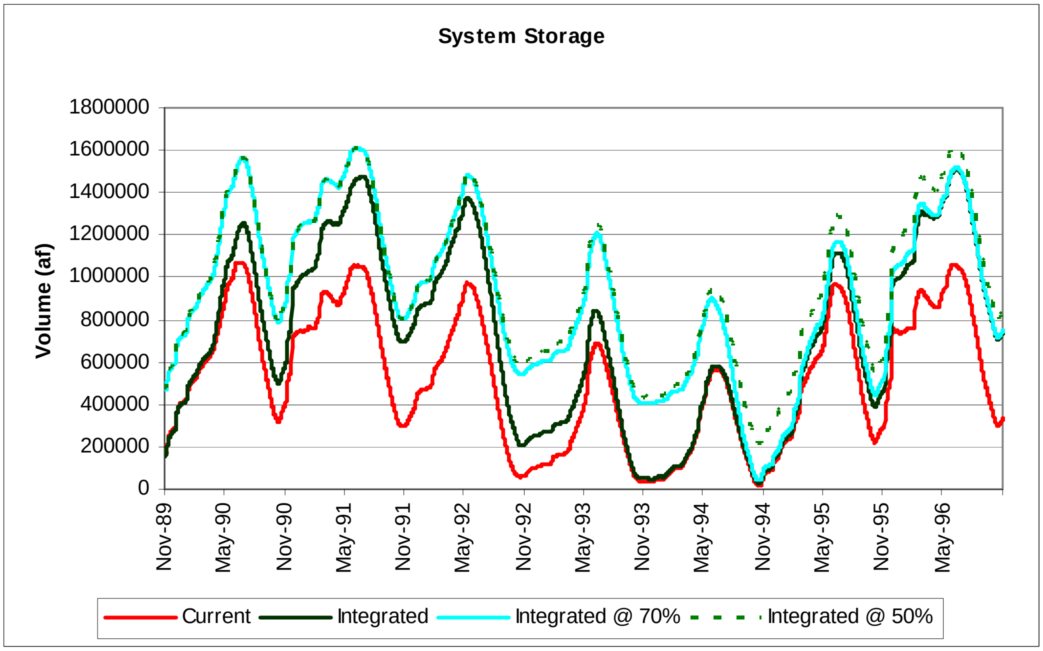

Figure D-4. System Storage Contents for Water Years 1990-1996--Current and Integrated Scenarios

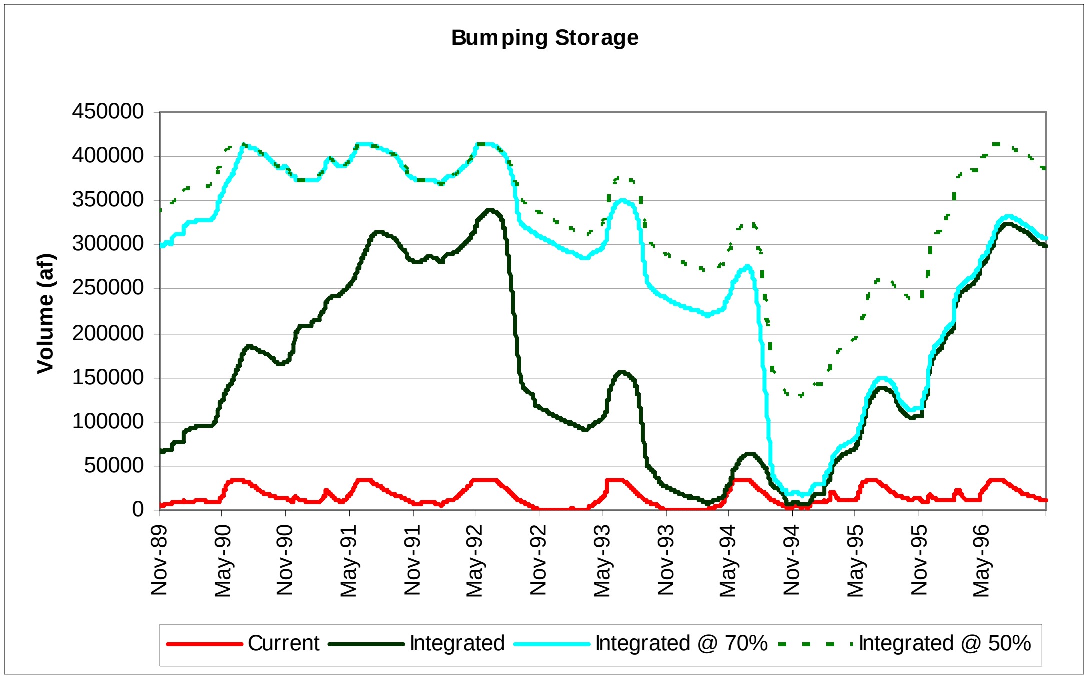

Figure D-5. Bumping Lake Enlargement Storage Contents for Water Years 1990-1996--Current and Integrated Scenarios

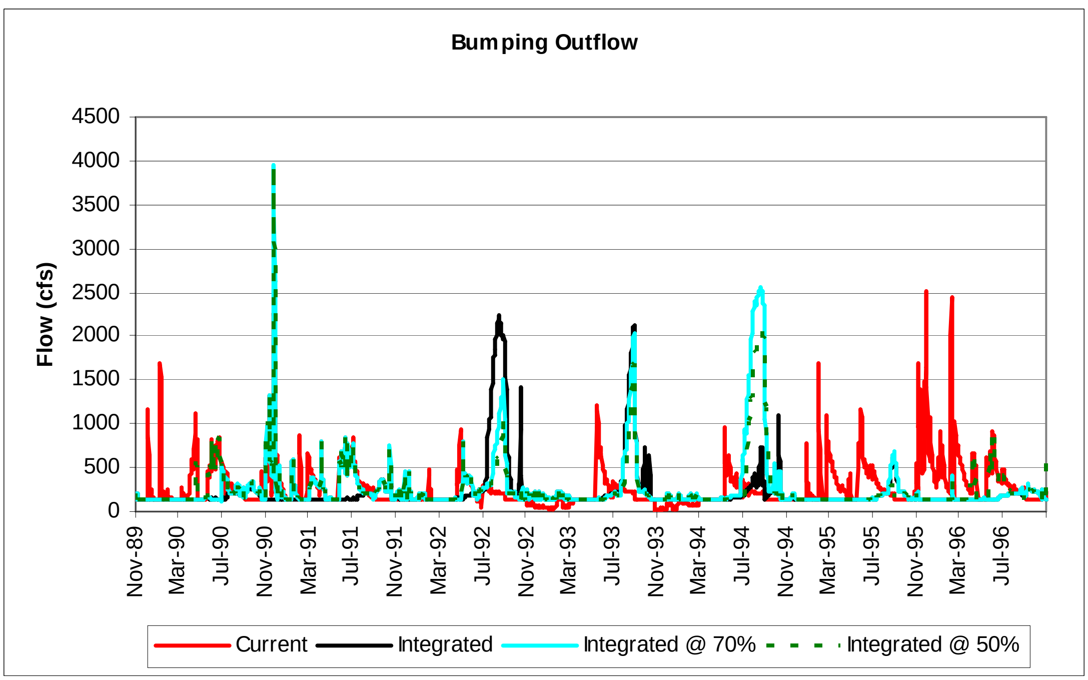

Figure D-6. Bumping Lake Enlargement Outflow for Water Years 1990-1996--Current and Integrated Scenarios

Appendix E YAKIMA RIVER BASIN ALTERNATIVES TECHNICAL INFORMATION AND HYDROLOGIC ANALYSIS AND CORRESPONDENCE

Reclamation distributed the *Yakima River Basin Alternatives Technical Information and Hydrologic Analysis* (technical information) to stakeholders who are responsible for fish production and protection, water distribution, power production, and other water uses in the Yakima River basin, on January 19, 2006 (a list of stakeholders is included in following information).

Between February 3-17, 2006, Reclamation met with the following stakeholders:

- Washington State Department of Ecology
- Washington State Department of Fish & Wildlife
- Yakima Basin Storage Alliance
- Yakima Basin Joint Board Washington State Department of Ecology
- National Marine Fisheries Service

The input received from these stakeholders was used in preparing this *Yakima Appraisal Assessment*. A copy of Reclamation's letters to stakeholders and attached technical information.

United States Department of the Interior

BUREAU OF RECLAMATION
Upper Columbia Area Office
1917 Marsh Road
Yakima, Washington 98901-2058

IN REPLY REFER TO:
UCA-1120
PRJ-1.10

JAN 19 2006

Mr. Louis Cloud
Chairman
Yakama Nation Tribal Council
P.O. Box 151
Toppenish, WA 98948

Subject: Review and Comment of Technical Information and Hydrologic Analysis for Yakima River Basin Alternatives for the Yakima River Basin Water Storage Feasibility Study (Storage Study).

Dear Mr. Cloud:

The Bureau of Reclamation has completed the appraisal level hydrologic analysis of the three Yakima River basin alternatives (Bumping Lake enlargement, Wymer dam, and the Keechelus-Kachess pipeline). We are soliciting input from the stakeholders who are responsible for fish production and protection, water distribution, power production, and other water uses in the Yakima River basin.

We are including the technical information of the hydrologic analysis for your review. We would like to meet and discuss our hydrologic analysis with you by February 10, 2006, if that can be arranged. Your input to our analysis will assist us in developing our recommendations and completing our report on which alternatives to include in the plan formulation phase of the Storage Study.

This meeting will be with you and your staff or other people that you designate. Mr. Kim McCartney, Storage Study Manager, will contact you to set up a time and date for this meeting. He can be reached at 509-575-5848, extension 370.

At this time, we invite you to review the attached technical documentation and prepare your comments on the three alternatives. You can present your comments to us in written form or discuss them with us at the meeting.

Sincerely,

Robert S. Ries

Acting for Gerald W. Kelso
Area Manager

Enclosures

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YAKIMA RIVER BASIN ALTERNATIVES TECHNICAL INFORMATION AND HYDROLOGIC ANALYSIS

What is the Purpose of this Information?

This information summarizes the current available technical data used to analyze the Bumping Lake enlargement, Wymer dam and reservoir, and the Keechelus-to-Kachess pipeline alternatives of the Yakima River Basin Storage Feasibility Study (Storage Study). The technical information and hydrologic analysis will be used to determine which alternatives, if any, should be studied further in the Plan Formulation Phase of the Storage Study. These alternatives were formulated to determine if they would provide more storage of Yakima River water for the benefit of irrigation, threatened and endangered fish species, and municipal water supply in the basin. Reclamation will use comments on this information by basin entities that are responsible for fish production and protection, water distribution, power production, and other water uses, to decide which alternatives will be carried forward to the Plan Formulation Phase of the Storage Study.

Why a *Yakima River Basin Storage Alternatives Appraisal Assessment* (*Yakima Appraisal Assessment*)?

The Storage Study was authorized to analyze all storage alternatives which would provide benefits to irrigation, threatened and endangered fish, and municipal water supplies. The *Yakima Appraisal Assessment* will evaluate various aspects of alternatives in the Yakima River Basin and will determine if the alternatives are technically viable and could be operated in conjunction with existing Yakima Project storage facilities to meet the Storage Study's water supply goals.

In February 2005, Reclamation released the *Appraisal Assessment of the Black Rock Alternative* (*Black Rock Assessment*) (Bureau of Reclamation, 2004), one alternative of the Storage Study, which provided water with a Columbia River – Yakima River water exchange. The *Black Rock Assessment* outlined the major features of the Black Rock storage alternative, the potential for the alternative to meet the Storage Study goals, and outlined activities needed if the alternative was to move forward in the Storage Study. In the *Black Rock Assessment*, Reclamation concluded that, based on current information, a potential Black Rock storage alternative appeared to be technically viable and could meet the water supply goals of the Storage Study. The Black Rock storage alternative is being carried forward into the Plan Formulation Phase.

What is the Scope of the Yakima Appraisal Assessment?

The scope of the *Yakima Appraisal Assessment* is to review, summarize, and document the pertinent findings of reported prior investigations of Bumping Lake enlargement, Wymer dam and reservoir, and a Keechelus-to-Kachess pipeline. The most up-to-date information regarding fish and wildlife resource issues and Yakima Project system operations will be utilized in this analysis. Deficiencies in data for these alternatives will be identified for further consideration. Prior project cost estimates will be indexed to July 2004 prices (similar to Black Rock prices).

The *Yakima Appraisal Assessment* does not quantify annual monetary benefits for any of these alternatives, and does not address whether these alternatives are economically justified. The *Yakima Appraisal Assessment* does not include a cost allocation to reimbursable and nonreimbursable project purposes or an analysis of the ability to repay the reimbursable costs. The environmental, social, and cultural impacts have not been evaluated. This is consistent with the information presented in the *Black Rock Assessment.*

What Did We Do?

Reviewed Prior Reports

Investigations of Bumping Lake enlargement, Wymer dam and reservoir, and Keechelus-to-Kachess pipeline have been conducted by Reclamation and others in the past. The following were reviewed as information sources for the *Yakima Appraisal Assessment*:

- The *Bumping Lake Enlargement Joint Feasibility Report*, initially prepared in 1970 by Reclamation and the U.S. Fish and Wildlife Service, and revised in 1976 to address concerns of compatibility with the proposed Cougar Mountain (William O. Douglas) Wilderness Area then under consideration.

  A revised joint feasibility report was approved by the Secretary of the Interior in 1979. A *Final Environmental Impact Statement* was filed with the Council of Environmental Quality August 27, 1979.

  This report proposed construction of a new Bumping Lake dam downstream of the existing dam, creating a 458,000-acre-foot reservoir. About 324,000 acre-feet of storage capacity would be available to provide minimum flows throughout the Yakima basin for fishery purposes. For example, at Parker, November-June flows of 180 cfs, and July-October flows of 234 cfs, would be provided. The irrigation stored water supply consisted of 133,700 acre-feet, of which 33,700 acre-feet was for replacement of the existing Bumping Lake storage and 100,000 acre-feet to improve the water supply of the Roza Irrigation District in dry years.

- The Yakima River Basin Water Enhancement Project (YRBWEP) investigations were authorized by the Act of December 28, 1979. Various reports were prepared as a part of this study. An initial part of the investigation involved an extensive storage-site inventory and public review process, during which some 35 storage sites were identified and evaluated. The primary report used for the *Yakima Appraisal Assessment* is the YRBWEP's *Plan Formulation Summary* (Bureau of Reclamation and Washington State Department of Ecology, 1986) which considered Bumping Lake enlargement with reservoir capacities ranging from 250,000 to 458,000 acre-feet and Wymer dam and reservoir with a capacity of 142,000 acre-feet as the prime storage alternatives.

Monthly target flow recommendations for 13 reaches in the Yakima and Naches Rivers were used in formulating alternative plans. For example, recommended target flows at Parker ranged from 600-800 cfs. The proratable irrigation dry-year water supply was to be not less than 70 percent in a recurrence of the single worst year of record (in this case, 1940).

- The Yakima River Watershed Council's (Watershed Council) draft report, *A 20/20 Vision for a Viable Future of the Water Resources of the Yakima River Basin,* (Yakima River Watershed Council, 1997. The Watershed Council, formed in March 1994, consisted of more than 800 individuals representing water-based interests in the Yakima basin.

  The Watershed Council analyzed a number of storage sites and recommended the following three projects for further consideration: enlargement of Bumping Lake reservoir to a capacity of 400,000 acre-feet; Wymer dam and reservoir, with storage of 142,000 acre-feet; Horsetail reservoir on the Little Naches River, with storage capacity of about 182,700 acre-feet.

- *The Watershed Management Plan, Yakima River Basin* (Yakima River Basin Watershed Planning Unit and Tri-County Water Resources Agency, 2003) was completed in January 2003, under the provisions of the State Watershed Management Act (Chapter 90.82 RCW), enacted in 1997. Under the guidance of the Tri-County Water Resources Agency, a Yakima River Basin Watershed Planning Unit was established in 1998 and, with the assistance of consultants, prepared a *Watershed Assessment* in 2001 (Yakima River Basin Watershed Planning Unit and Tri-County Water Resources Agency, 2001) and the *Watershed Management Plan*. This *Watershed Management Plan* has been characterized as a "road map" for maintaining and improving the Yakima basin's economic base, planning responsibility for expected growth in population, managing water resources for the long term, and protecting the basin's natural resources and fish runs.

  Four in-basin storage alternatives were considered: Bumping Lake enlargement (400,000 acre-feet of storage); Wymer dam and reservoir (142,000 acre-feet of storage); Cle Elum Lake enlargement (an additional 14,500 acre-feet of capacity); and Kachess Lake storage augmentation by flow supplementation from Cabin and Silver Creeks. A fifth storage alternative consisting of a new dam and reservoir in the Black Rock Valley with an annual yield of 250,000-500,000 acre-feet filled by pumping from the Columbia River was also considered.

Conducted Operation Studies

The following two Yakima Project operating scenarios were developed and operation studies prepared:

1. Current Operating Scenario - Represents current operating criteria and management of the existing Yakima Project system.

2. Integrated Operating Scenario with Three Storage Alternatives - Represents three operation studies using different "thresholds" for allocating the water supply available to meet proratable water entitlements in years when proration is used. They are as follows:

- 100 percent, which represents the present Yakima Project proration process whereby there is no constraint in any year of proration on the amount of the proratable water supply allotted.

- 70 percent, whereby the amount of the proratable water supply allotted in a year of proration is limited to not more than would have been available without the storage alternatives, but not less than 70 percent with the storage alternatives.

- 50 percent, whereby the amount of the proratable water supply allotted in a year of proration is limited to not more than would have been available without the storage alternatives, but not less than 50 percent with the storage alternatives.

In addition, a natural (unregulated) flow regime for the mainstem rivers was developed to represent an estimated natural streamflow regime that predates the Yakima Project, unimpeded by reservoir impoundments or altered by diversions and the associated irrigation return flows.

What Are the Water Supply Goals?

As directed by congressional authorization, the Storage Study is to examine the feasibility and acceptability of storage augmentation for benefit of endangered and threatened fish, irrigated agriculture, and municipal water supply within the Yakima River basin. This general guidance resulted in adoption of the following water supply goals for study purposes:

1. Improve anadromous fish habitat by restoring the flow regime of the Yakima and Naches Rivers to more closely resemble the natural (unregulated) hydrograph.

2. Provide not less than a 70-percent irrigation water supply during dry years at diversions subject to proration.

3. Maintain a full municipal water supply for existing users and provide additional surface water supply for population growth to the year 2020.

Instream Flows

Legal Requirements

A variety of legal requirements exist related to providing and/or maintaining instream flows in the Yakima River basin. Generally, these are based on court orders and Federal legislation related to the Yakima Project. The State of Washington has not established minimum instream flows for the Yakima River basin.

Instream flows in the Yakima River basin mandated by the courts are not quantified. Rather, the amount of water available for the fisheries is determined annually, depending on existing prevailing water supply conditions. Specific mandates from the State and Federal courts include orders directed at Reclamation's operation of the Yakima Project to reduce impacts on the fisheries resource, orders with respect to treaty reserved rights for fish, and orders with respect to instream flows to support treaty fishing rights at "usual and accustomed places."

Instream flows included in Title XII of the Act of October 31, 1994 (Public Law 103-464), are quantified "target flows" at two points in the Yakima River basin (Sunnyside and Roza Diversion Dams). The legislation provides that the Yakima Project Superintendent shall estimate the water supply, which is anticipated to be available to meet water rights, and provide instream flows in accordance with the Title XII criteria shown in table 1. This new operational regime was initiated by the Yakima Project Superintendent in 1995.

Table 1. Water Supply Estimates/Instream Flow Targets

Water Supply Estimate for Period (million acre-feet)					Target Flow From Date of Estimate through October Downstream of:	
Scenario	April through September	May through September	June through September	July through September	Sunnyside Diversion Dam (cfs)	Prosser Diversio Dam (cfs)
1	3.2	2.9	2.4	1.9	600	600
2	2.9	2.65	2.2	1.7	500	500
3	2.65	2.4	2.0	1.5	400	400
Less than Scenario 3 water supply					300	300

Title XII target flows do not provide for a natural (unregulated) ecosystem function and cannot be expected to fully achieve the objectives of enhancing and recovering anadromous fish populations. Regulated flows can cause unnatural, severe flow fluctuations below both control points, which may negatively affect fish and invertebrate habitat. Additionally, Title XII target flows at the two control points do not address fish habitat and food web needs at the basin level and, thus, by themselves, cannot be expected to lead to recovery of anadromous fish runs.[1]

Restoring the Natural (Unregulated) Hydrograph

A natural (unregulated) flow pattern, or hydrograph, for the Yakima River basin shows peak streamflows occurring in the spring with the onset of snowmelt. During the seasonal transition from spring to summer, streamflows would decrease steadily until they reached their base flow in September or October. The onset of fall usually brings precipitation in the form of rain, which

[1] *Report on Biologically Based Flows for the Yakima River Basin*, System Operations Advisory Committee, May 1999 (pages 1-4).

causes brief, small increases in streamflows. Below-freezing temperatures dominate during the winter months, resulting in decreased streamflows, which occasionally may spike during the winter due to rain-on-snow events.

Under current Yakima Project operations, streamflows in the mainstem Yakima and Naches Rivers often do not reflect the annual flow patterns or hydrograph described above. Generally, spring peak flows are reduced as streamflow is captured in reservoir storage or is used for irrigation demand. During the summer irrigation season, streamflows in the upper Yakima River generally exceed the estimated unregulated summer low flow, and streamflows in the Yakima River are less than the estimated unregulated low flow below Sunnyside Diversion Dam. The September "flip-flop" river operations, unique to the Yakima River basin and designed to address upper Yakima spring Chinook and incubation flows, result in a decrease in streamflows in the upper Yakima and Cle Elum Rivers and increased streamflows in the Tieton and Naches Rivers. The flip-flop operation is discussed in more detail later in this report.

The Storage Study will evaluate how storage could improve these nonnatural streamflow characteristics throughout the entire Yakima basin mainstem rivers. It should be noted the goal is not to quantitatively match the natural (unregulated) hydrograph, but to mimic the shape of the annual hydrograph to the highest degree possible, while balancing the water supply goal.

Irrigation

The reliability of the surface water supply for irrigation use is of concern because of droughts that periodically occur in the Yakima River basin. Current Yakima Project legal, contractual, and operational parameters provide that when there is a deficiency in the available water supply to meet recognized water rights, senior (nonproratable) water rights are served first, and shortages are assessed against junior (proratable) water rights. In recent years, the Yakima River basin has experienced water shortages in 1987, 1988, 1992, 1993, 1994, 2001, and 2005. The most severe years were 1994, 2001, and 2005, when proratable water rights received a 37-percent supply (1994 and 2001) and a 42-percent supply (2005).

As a part of the work conducted for the *Watershed Management Plan* during the early 2000s, the Yakima River Basin Watershed Planning Unit and the Tri-County Water Resource Agency examined criteria to evaluate water supply strategies and to estimate the amount of water needed to meet irrigation demands. This included work by Northwest Economic Associates conducted for the Tri-County Water Resource Agency in 1997 and by the Yakima River Watershed Council in 1998. Information on both was circulated to irrigation entities and conservation districts in the Yakima basin to solicit comments on an approach to establishing irrigation water supply reliability criteria. It was the opinion of those responding that if a supply of not less than 70 percent of the proratable water rights could be provided in dry years, major economic losses could be averted.

The irrigation water supply goal for the Storage Study is to provide a dry-year supply of not less than 70 percent of the proratable water rights. Table 2 shows the extent of the proratable water rights involved upstream from the Parker gauge (RM 104) for the period April through October (irrigation season).

Using the above total proratable water rights, a 70-percent water supply would amount to 896,000 acre-feet. In a dry year (such as 1994 and 2001), when the proratable supply was 37 percent (474,000 acre-feet), an additional 422,000 acre-feet would be needed to provide a 70-percent water supply.

Table 2. Proratable Water Rights

Irrigation Entity	Proratable Acre-Feet Per Year
Major	
Kittitas Division (Kittitas Reclamation District)	336,000
Roza Division (Roza Irrigation District)	375,000
Tieton Division (Yakima-Tieton Irrigation District)	34,835
Wapato Irrigation Project	350,000
Sunnyside Division (Sunnyside Valley Irrigation District and others)	142,684*
Subtotal	**1,238,519**
Others	
Westside Irrigation Company	8,200
City of Ellensburg	6,000
Selah-Moxee Irrigation District	4,281*
Union Gap Irrigation District	4,642
City of Yakima	6,000
Naches-Selah Irrigation District	4,486
Yakima Valley Canal Company	4,305
Other entities (9)	3,441
Subtotal	**41,355**
Total	**1,279,874*** **
*Numbers reflect Reclamation's irrigation proratable allocations from a tabulation dated April 29, 1994.	

Municipal

Communities in the Yakima River basin rely on a variety of delivery systems to meet the needs for municipal and domestic water supply, landscape irrigation, commercial supply, and industrial supply. Such systems include large municipal systems, small public water systems, individual household wells, and wells provided by self-supplied industrial users. The year 2000 annual use for all systems (except for self-supplied industrial users) was estimated at 116,295 acre-feet in the *Watershed Assessment*.

In determining potential future municipal water supply demands for purposes of the Storage Study, only public water systems serving 1,000 connections or more were considered. On this basis, the year 2000 annual use from both surface and groundwater would be 54,340 acre-feet.

Most of the surface water use in the Yakima River basin for municipal and domestic purposes is diverted by two cities—Cle Elum and Yakima. Their combined year 2000 water use was 19,506 acre-feet, based on information contained in the *Watershed Assessment*. This represents about 36 percent of the total basin use for municipal supply and identifies the importance of groundwater for this category of water use.

To meet ever-increasing population growth and to foster a healthy economic climate for the three counties, an increase to about 30,000 acre-feet of surface water by the year 2020 will be needed to meet future municipal supply needs of the cities of Cle Elum and Yakima. This supply requirement is summarized in table 3.

Table 3. Current and Projected Annual Municipal Water Demands

Public Water Systems Serving 1,000 or More Connections	Year (Annual Acre-Feet)		
	2000	**2010**	**2020**
Basin Total (surface and groundwater)	54,340	66,690	83,620
Basin Total (Surface Water)			
City of Cle Elum	897	1,054	1,169
City of Yakima	18,609	22,932	28,119
Total	19,506	23,986	29,288
Percent Surface Supply is of Basin Total	36	34	34

Yakima Basin Storage Alternatives

Figure 1 shows the general location of the three Yakima basin storage alternatives—Bumping Lake enlargement, Wymer dam and reservoir, and Keechelus-to-Kachess pipeline, in addition to the Black Rock Alternative. A brief description of these alternatives follows:

Bumping Lake Enlargement

The proposed Bumping Lake damsite is about 40 miles northwest of the city of Yakima on the Bumping River (figure 2). It is within the Snoqualmie National Forest in Yakima County, and is located approximately 4,500 feet downstream of the existing Bumping Lake Dam.

The damsite is in a deep steep-walled erosional canyon at an elevation of about 3350 feet. The width of the valley floor at the damsite is about 2,500 feet.

The appraisal-level designs prepared in 1985 provided for a 230-foot-high dam storing 458,000 acre feet at elevation 3560 feet, with a reservoir surface area of 4,120 acres. The design consisted of a zoned rockfill dam with a concrete cutoff wall into bedrock in the foundation. An uncontrolled overflow crest spillway with chute and stilling basin is on the left abutment. An outlet works tunnel and gate chamber are also in the left abutment.

The primary physical characteristics of the Bumping Lake enlargement project are shown in table 4 and figure 3.

Table 4. Bumping Lake Enlargement Physical Characteristics

Item	Data
Dam (Zoned Rockfill)	
Height (feet)	230
Crest elevation (feet)	3580
Crest length (feet)	3,300
Crest width (feet)	30
Reservoir	
Total capacity (acre-feet)	458,000
Maximum water surface elevation (feet)	3574.2
Surface elevation normal full pool (feet)	3560
Surface area (acres)	4,120
Lands to be secured (acres)	2,800

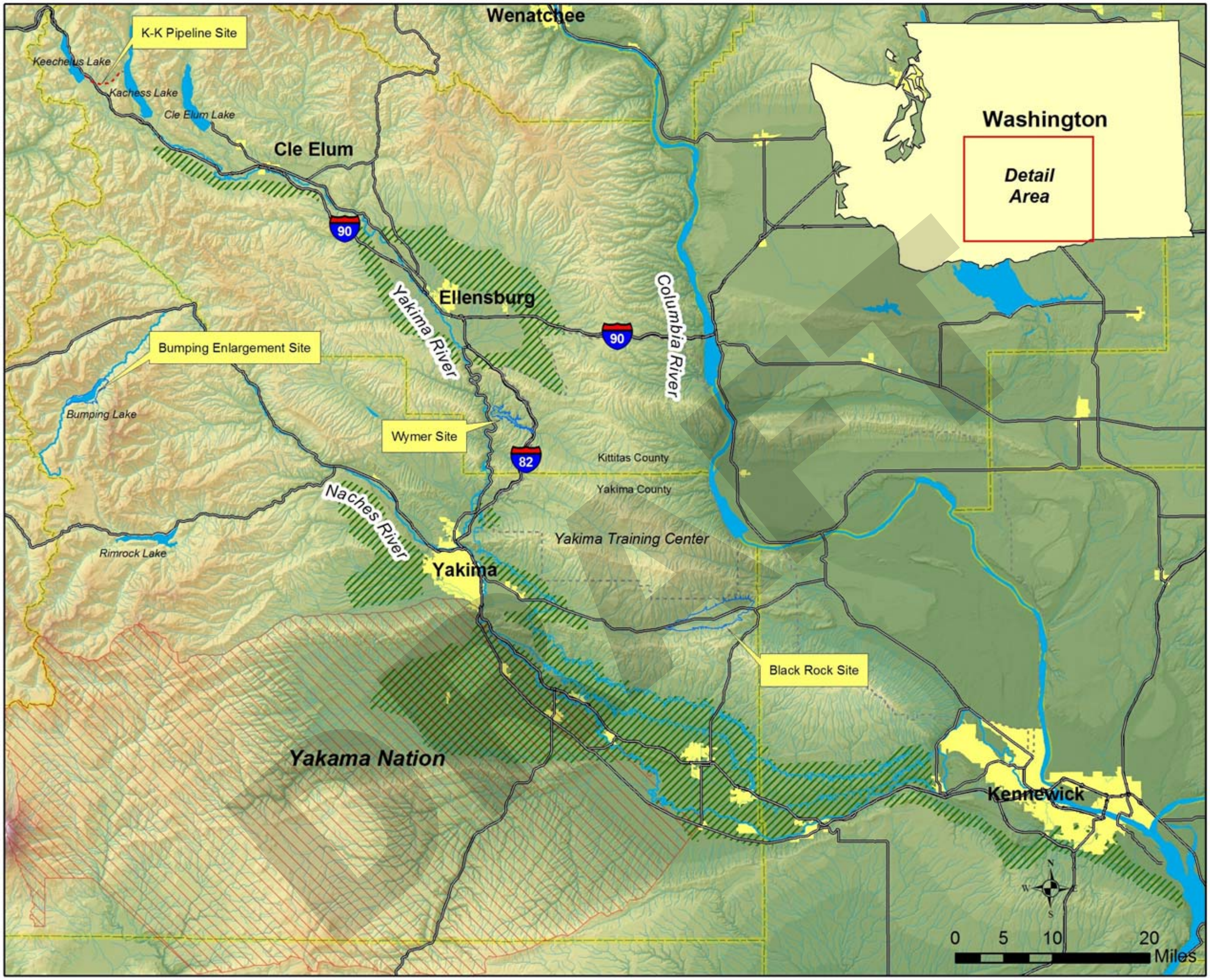

Figure 1. Overview map of the Yakima River Basin Storage Alternatives

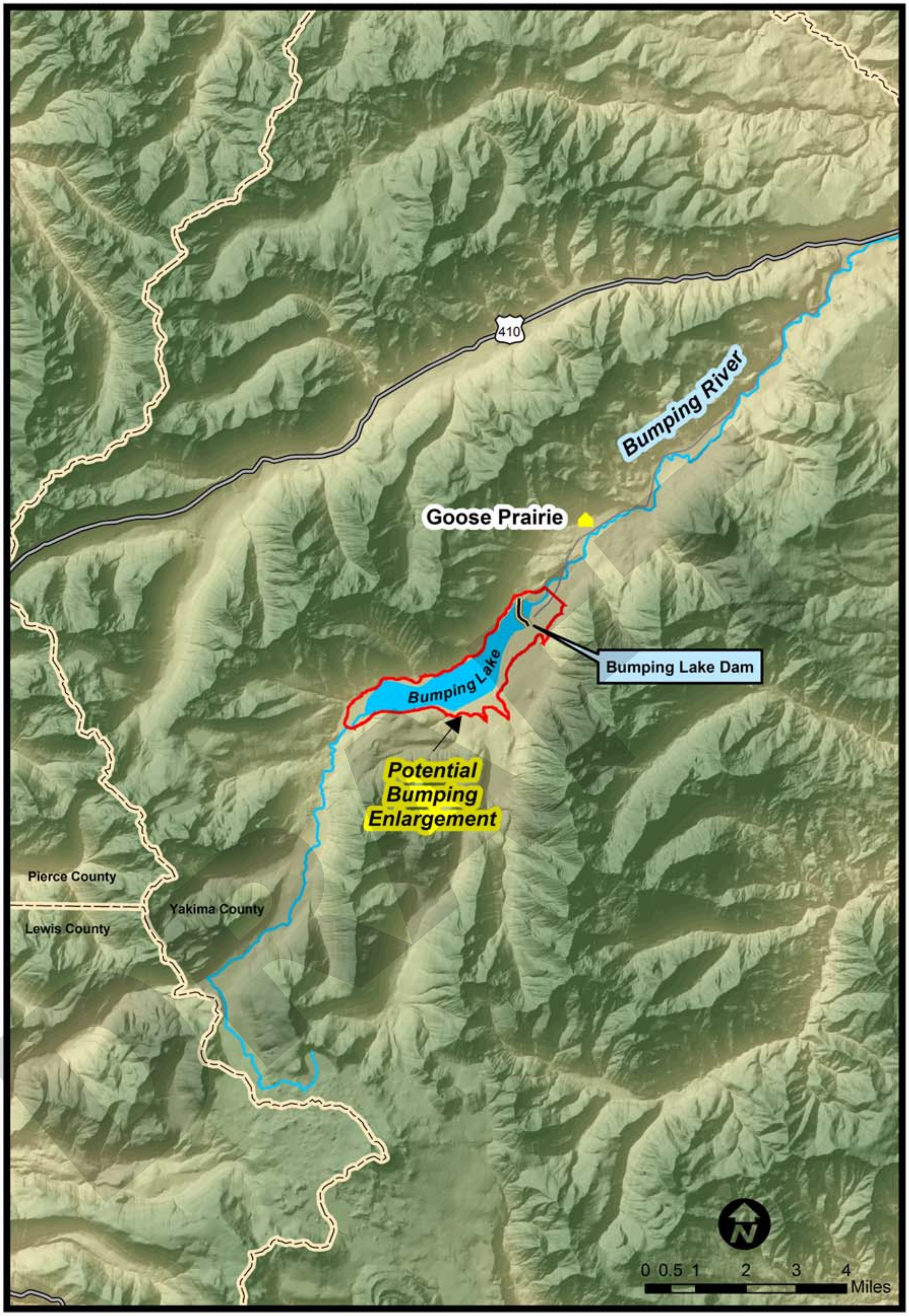

Figure 2. Bumping Lake Enlargement Alternative location map

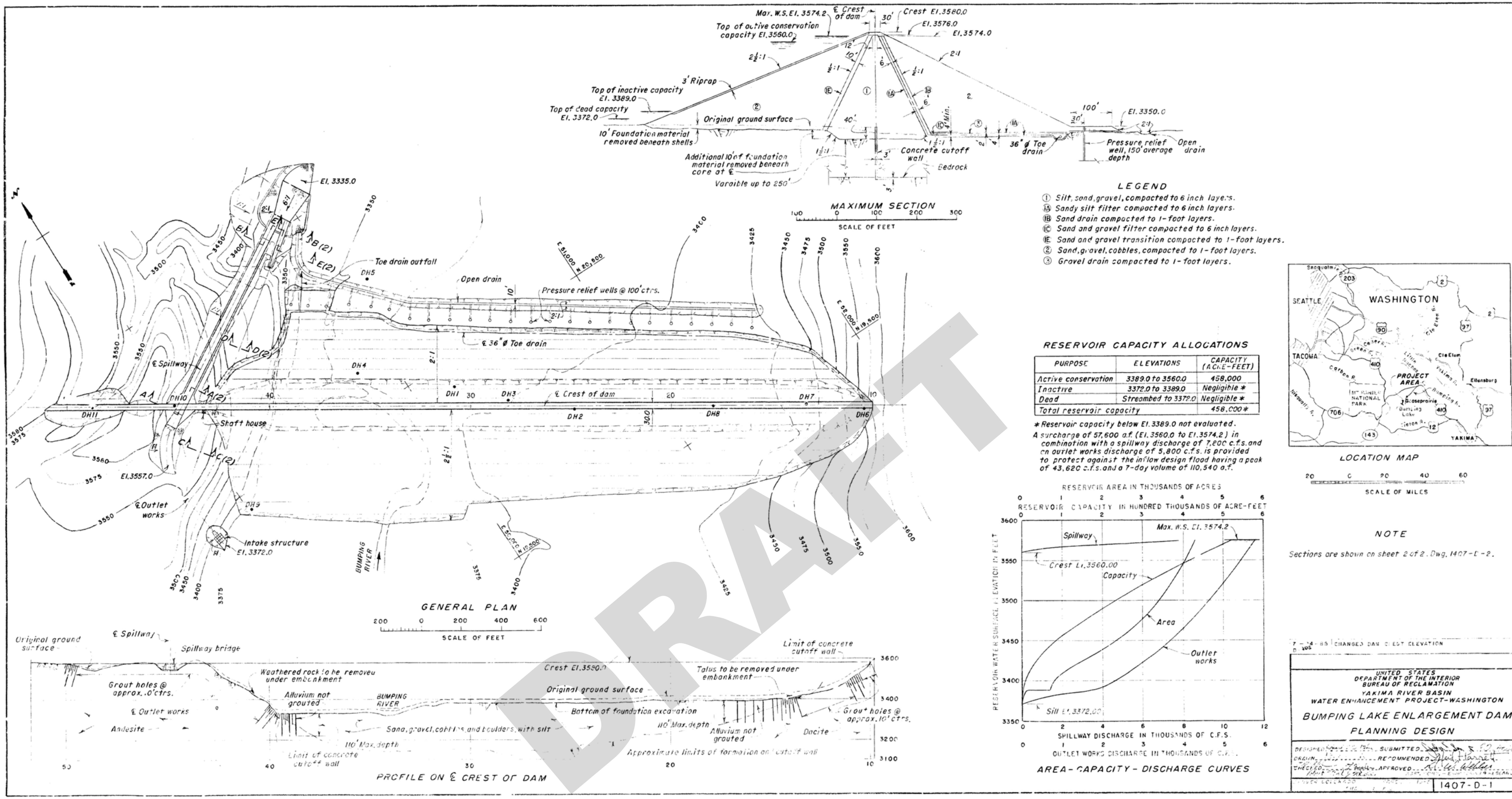

Figure 3. Bumping Dam Enlargement Planning Design (1985)

Wymer Dam, Reservoir and Pumping Plant

Wymer dam and reservoir would be situated in Lmuma Creek Canyon, approximately 15 miles north of Yakima and about ¾ mile upstream of the Lmuma Creek-Yakima River confluence (figure 4). Wymer reservoir would extend upstream about 6 miles on Lmuma Creek and about 2 miles on Scorpion Coulee Creek. This is an off-channel reservoir being filled by pumping from the Yakima River when flows exceed downstream instream target flows and demands, which generally occurs in the spring months. The amount of water available from Lmuma Creek is minimal, so the reservoir would be filled mostly by pumping.

Principal structures of the 1985 appraisal-level designs include two concrete-faced rockfill embankments (Wymer dam and a dike in a saddle on the reservoir rim northeast of the right abutment), a pumping plant on the Yakima River, an inlet conduit to convey discharges from the pumping plant, an outlet conduit from the reservoir to the Yakima River, and a reservoir with an active capacity of about 174,000 acre-feet.

The pumping plant was sited on the east bank of the Yakima River approximately 0.6 mile northwest of Wymer dam. The designs are for an indoor-type structure consisting of five electric motor-driven spiral case pumping units: three units rated at 100 cfs and two units rated at 50 cfs. Pumping capacity will be 400 cfs, with a total head range of 345 to 475 feet. The outlet to the Yakima River will also have a capacity of 400 cfs.

The primary characteristics of the Wymer storage facilities are shown in table 5 and figure 5.

Table 5. Wymer Dam, Dike, Pumping Plant, and Reservoir Characteristics

Item	Data	
	Dam	**Dike**
Dam and Dike (concrete-faced rockfill)		
Height (feet)	415	130
Crest elevation (feet)	1745	1745
Crest length (feet)	2,855	2,310
Crest width (feet)	30	30
Pumping Plant (cfs)	400	
Reservoir	**Elevation (feet)**	**Volume (acre-feet)**
Surcharge	1730-1740	14,400
Active conservation	1450-1730	173,780
Inactive conservation	1351-1450	7,090
Dead storage	1330-1351	210

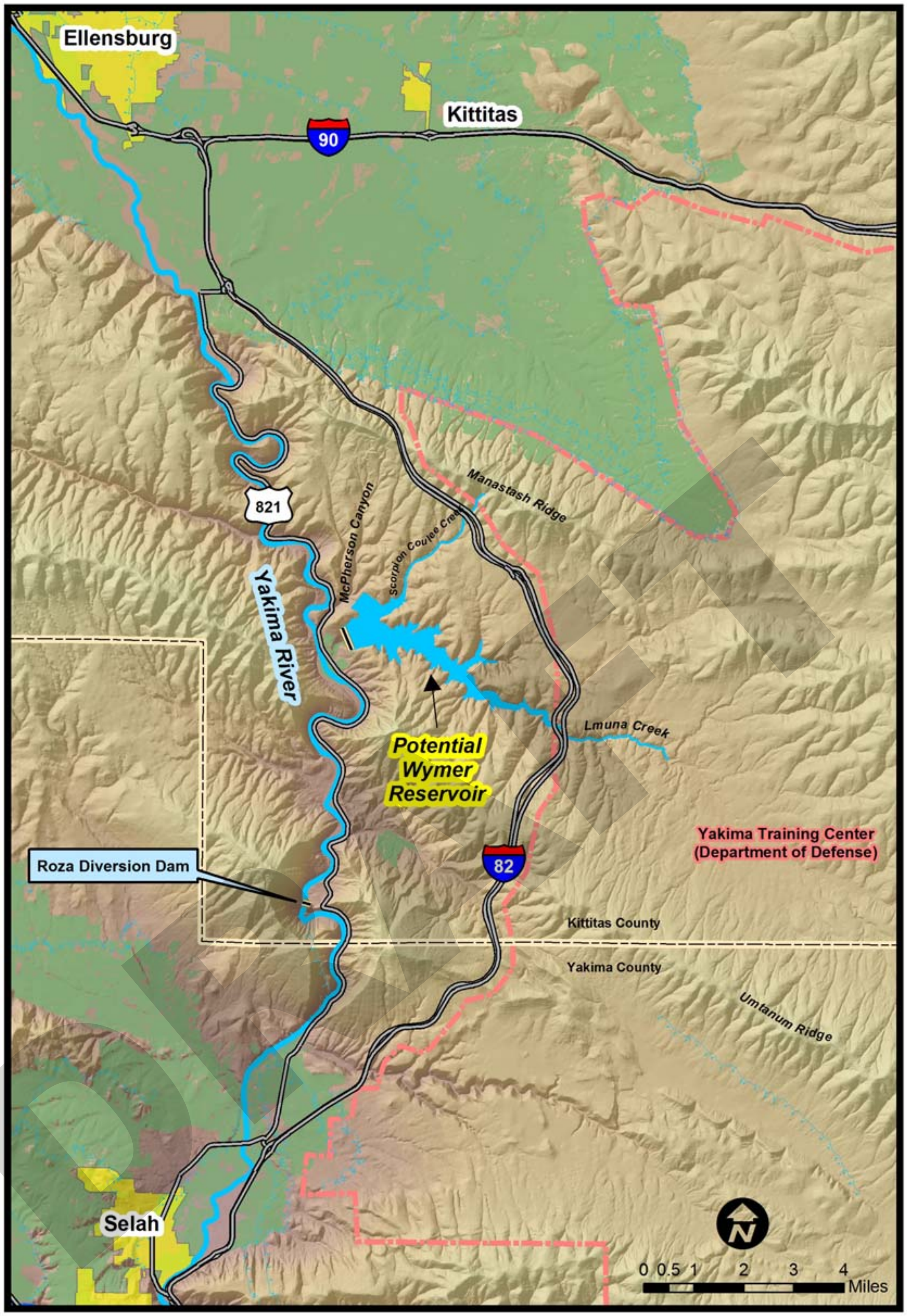

Figure 4. Wymer Reservoir Alternative location map

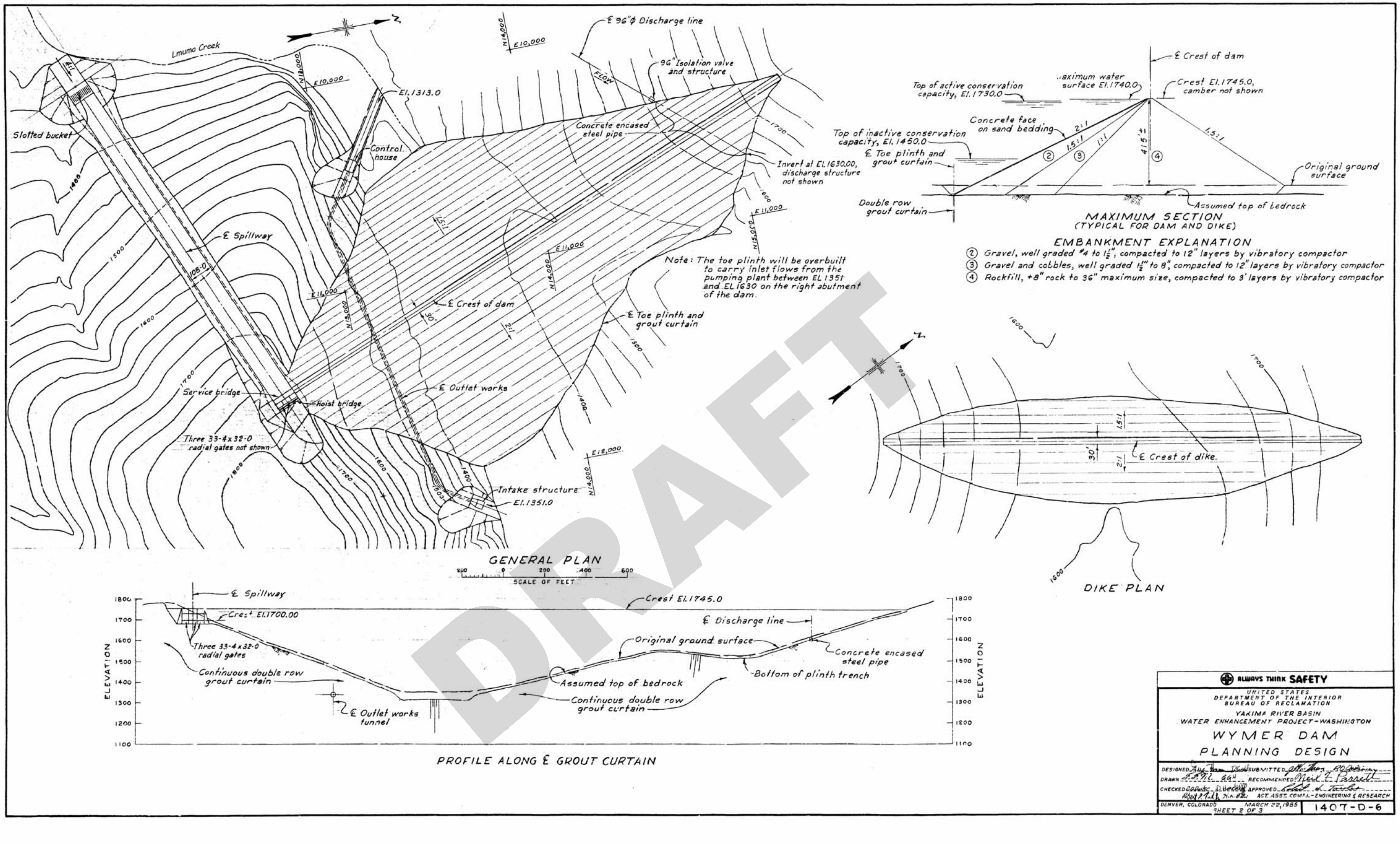

Figure 5. Wymer Dam Planning Design (1985)

Keechelus-to-Kachess Pipeline

Keechelus Dam and Lake and Kachess Dam and Lake are situated in the upper Yakima River watershed upstream of Easton Dam (RM 202.5), the diversion point for the Kittitas Main Canal of the Kittitas Reclamation District. Keechelus Dam was constructed at the downstream end of a natural lake (RM 214.5) near the head of the Yakima River, about 12 miles upstream of Easton Diversion Dam, and Kachess Dam is located on the Kachess River about 1 mile upstream of its confluence with the Yakima River (figure 6).

The average annual runoff in the Keechelus watershed is about 246,000 acre-feet, and the lake has an active storage capacity of 157,800 acre-feet. In contrast, the Kachess watershed has an average annual runoff of about 214,000 acre-feet, but Kachess Lake has an active storage capacity of about 239,000 acre-feet. The concept is to transfer water from Keechelus Lake to Kachess Lake to increase the amount of total stored water. The pipeline could also be used to bypass some of the releases from Keechelus Dam during the irrigation season in the 11-mile Yakima River reach upstream of the Kachess confluence for anadromous fishery management, primarily during September spawning.

The conceptual plan is to modify the outlet works of Keechelus Dam to permit downstream releases as well as releases to a potential gravity flow pipeline (60-inch-diameter), extending about 5 miles to Kachess Lake. The conveyance capacity of the pipeline is approximately 210 cfs at Keechelus Lake full-pool elevation of 2517 feet. Note: A lower reservoir pool elevation will result in a lower flow in the pipeline. Operation of the pipeline would generally be from June 1 through September 30.

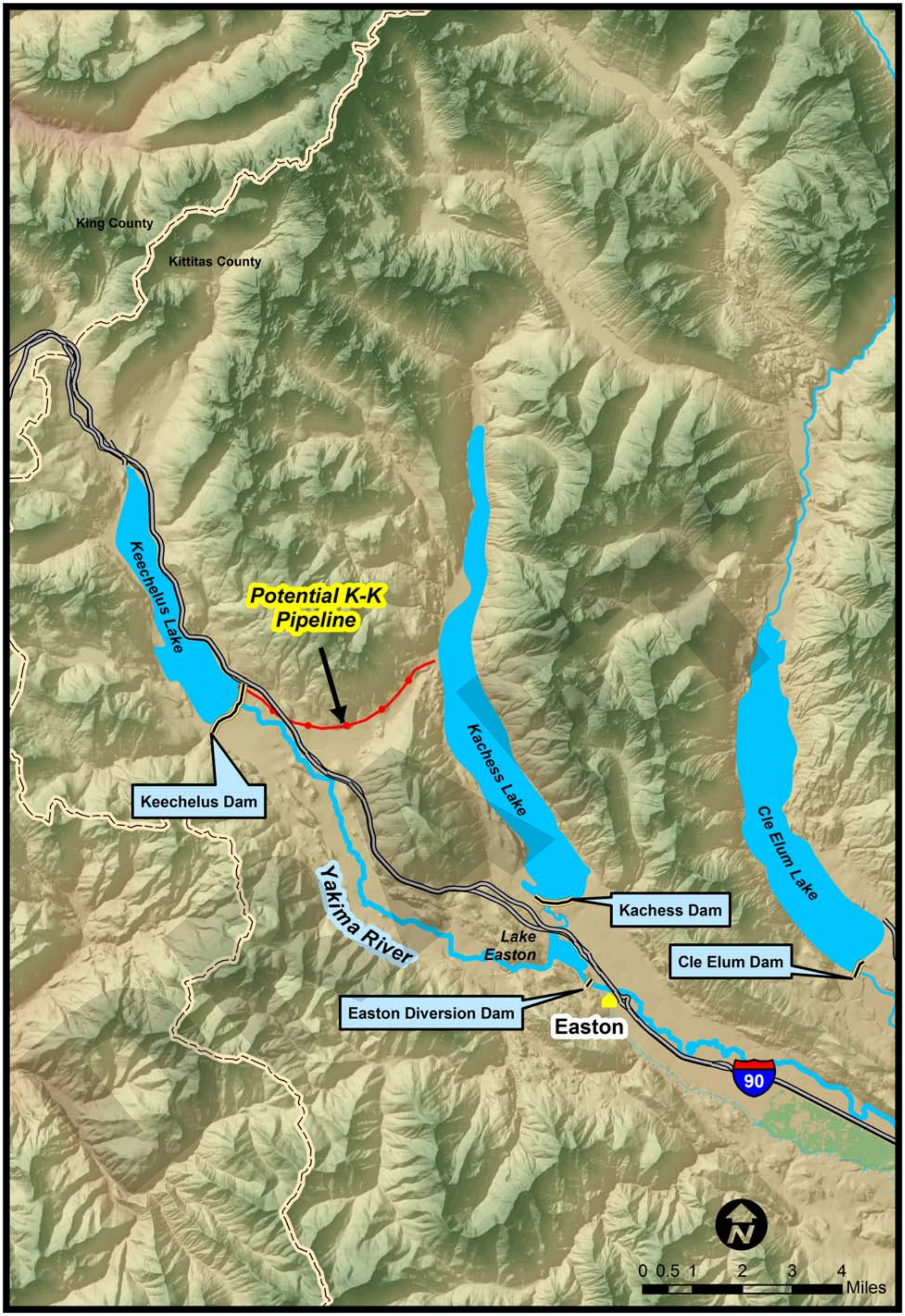

Figure 6. Keechelus-to-Kachess Alternative location map

Historical Hydrograph

Historical Yakima Basin Hydrograph

The character of the Yakima basin's annual hydrological pattern is driven by the accumulation of snow from November to March in the Cascade Mountains along the western and northern boundaries of the basin. The spring snowmelt results in peak freshet events (figure 7) which cause streamflows to rise and fall with alternating warming and cooling weather patterns. During the peak runoff period, above bank-full events (i.e., floods) distribute surface water across the flood plain reaches (i.e., Easton, Cle Elum, Ellensburg, lower Naches, Union Gap and Wapato), which recharge the aquifer. Further, these bank-full events cleanse the stream bottom by flushing fine sediments downstream and depositing them in the depositional zones (i.e., low-gradient reaches) and increasing channel complexity, which allows for increased egg and juvenile over-winter survival, and increased habitat complexity for multiple salmonid species and life stages.

Streamflows begin to decline after the majority of the snowpack has melted by early summer. By late summer, streamflows have reached base flows (summer low flow). Groundwater stored during the spring runoff is typically the primary source of the base flows and provide the cooler water for fishery habitat. Typically, fall precipitation in the form of rain causes streamflows to increase from summer low flows. From fall into winter, flows increase slowly, with small peak flow events that coincide with storm events.

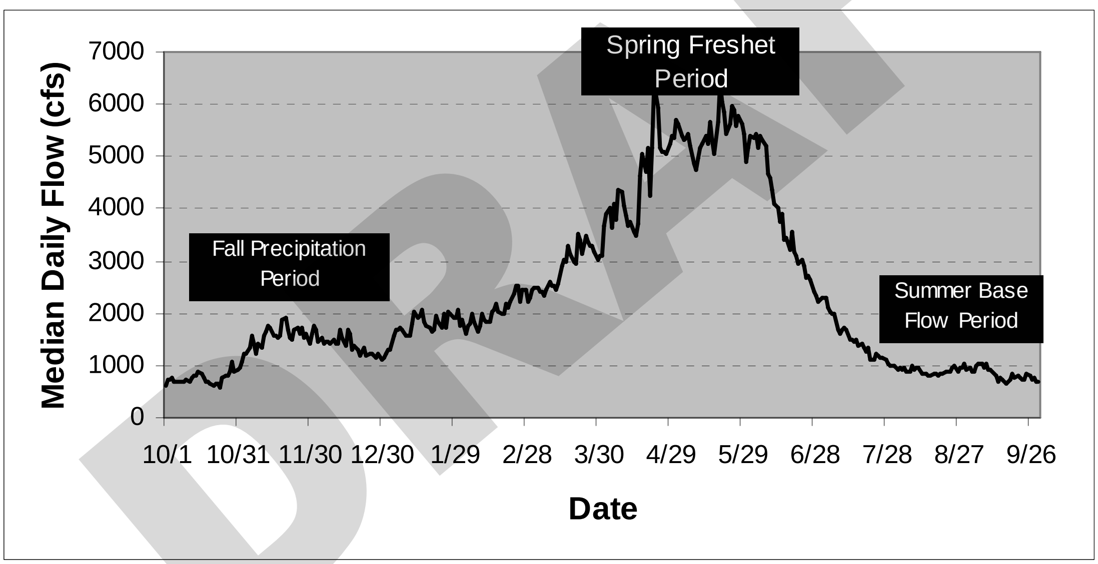

Figure 7. Typical Yakima Basin Annual Hydrograph Under Unregulated Conditions

Anadromous salmonids residing in the Yakima basin have adapted their life cycle to the previously described annual hydrograph to maximize their survival (i.e., abundance, productivity, and diversity). A description of key adaptations to the annual hydrograph by species or collectively, depending on the life stage, follows.

Spring Freshet Period

The peak flow events that occur in the spring as a result of snowmelt are very important to the smolt life stage for all anadromous salmonids. Smolts can be 3 months, 1 year, 2 year, or 3 years of age, depending on the species. Smolts outmigrate to the ocean and physiologically transition from life in freshwater to life in saltwater. There is a biological window in the spring in which smolts must reach the ocean; failure to do so can result in mortality or failure to smolt.[2]

Smolts outmigrate passively, meaning they allow the current to move them downstream as opposed to actively swimming, and, in fact, they move downstream tail first. Because of this behavior, having spring freshets with accelerated water velocity is important to flush them to the ocean in a timely manner within their biological window of opportunity. Increased water velocities from spring freshets reduce smolt travel time to the ocean, thereby minimizing exposure to these predators while in the river. Increased water turbidity associated with spring freshets decreases the capture efficiency of these predators.

In late spring, when streamflows are still high, spring and fall Chinook and coho begin to emerge from spawning beds. They typically are 30-35 mm in length and weigh less than a gram. Because emergent fry are very vulnerable to predation and physical impingement, it is critical that they initially rear in shallow, slow-velocity habitat (i.e., side channels, bank margins, backwater pools, etc.). These habitat features are most abundant in the flood plains. High spring flows inundate these flood plains, creating essential nursery areas.

Summer Base Flow Period

By summer, juvenile spring Chinook and coho are 50-90 mm in length and prefer deeper, faster water located out from the stream margin, in the mainstem and large side channels. By this time, fall Chinook have smolted and outmigrated to the ocean. Both spring Chinook and coho prefer shear zone (slow-moving) areas in the river, preferably with large, woody debris associated with them. A shear zone (figure 8) runs longitudinally in the river and defines the boundary between fast- (near the middle) and slow-velocity (along the stream edge) water. Juvenile spring Chinook and coho take up residence in the slow-velocity water, preferably downstream of large, woody debris to minimize energy expended to remain stationary. The shear zone provides a feeding lane, whereby a fish will dart out into the faster water to consume a floating insect, then move back to its slow water resident area. As streamflows decline from spring to summer, the amount of shear zone habitat increases and shows a clear distinction between pool, riffle, and glide habitats.

Steelhead emerge from the gravel in June-July as streamflows are decreasing to the summer low-flow period. At emergence, steelhead fry are slightly smaller than salmon fry, averaging 25-30 mm in length. Steelhead fry, like salmon fry, seek out the shallow, slow-velocity habitat that exists along the stream margin in the mainstem, side channels, and off-channel rearing areas.

[2] Failure to smolt is commonly referred to as smolt residualism. Residualism refers to a smolt that fails to reach the ocean and physiologically reverts back to conditions necessary for living in freshwater. This is most common for steelhead. In the case of steelhead, the fish may smolt the following spring or remain in the river as a resident trout.

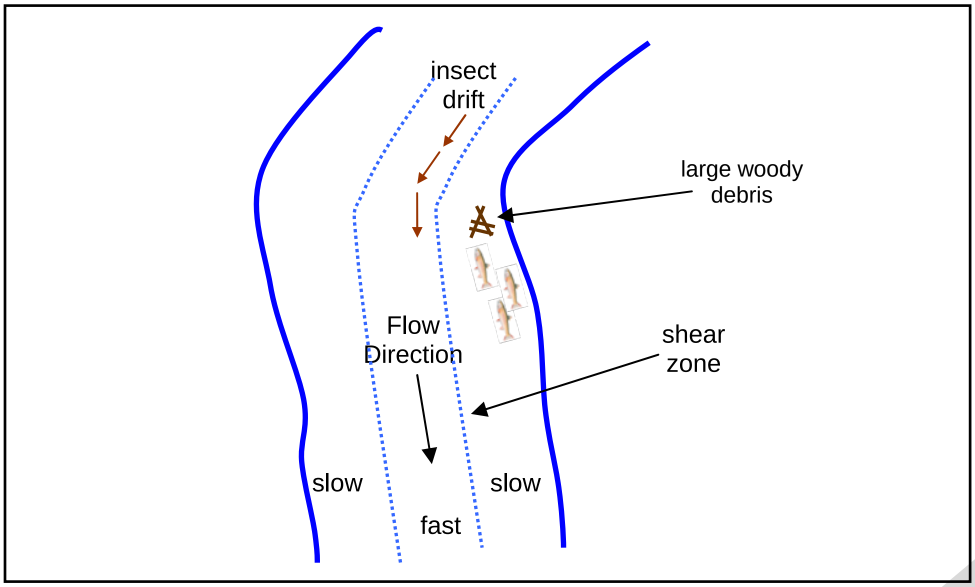

Figure 8. Location of Juvenile Salmonid Rearing Habitat in Relation to the Shear Zone and Feeding Lanes

Fall Precipitation Period

Beginning in late October, Pacific winter storms result in a series of small peak flow events and a trend to higher winter base flows. Increases in fall-winter flows inundate previously dry to minimally wetted side and off-channel habitat. Juvenile salmonids begin to seek over-wintering habitat with the onset of decreasing water temperatures and shorter days. Over-wintering habitat is mainstem, side, and off-channel habitats that provide shelter from winter high-flow events. These are areas that ideally have warmer groundwater inflow. Deep, slow-water velocity with sufficient instream and overhead cover describe the desired habitat features. Depending on the species, the large crevices in the stream substrate provide important over-wintering habitat (e.g., steelhead).

A majority of juvenile spring Chinook in the Yakima basin moves downstream from their natal area and over-winter in the Yakima River between the Naches River confluence and Prosser Diversion Dam. Juvenile coho, even more than spring Chinook, prefer to over-winter in off-channel habitat with ample instream cover. Juvenile coho produced in the three primary mainstem spawning areas of the upper Yakima River near Ellensburg, the lower Naches River, and the Wapato reach of the Yakima River, are thought to over-winter in their natal areas. Steelhead juveniles both outmigrate downstream into the lower Yakima and Naches Rivers and remain in their natal areas to seek out suitable over-wintering habitat.

The Normative Ecosystem Concept

The normative ecosystem concept is predicated on the assumption that by increasing river ecosystem processes and functions, the health of salmonid populations would improve. Improvement means increasing population abundance, productivity, and life history diversity. The normative ecosystem concept encompasses several key physical elements such as habitat complexity, the hydrograph, sediment transport, riparian zone, in-channel large woody debris, and nutrient cycles. The degree to which each of these key elements can be restored toward a more historic state, the more normative, or natural-like, the river ecosystem will be. Once a more normative ecosystem is established, there would follow a positive biological response, beginning with primary production (i.e., algae and diatoms), followed by aquatic insects, and then benefits to the fish community. One of the first to introduce the normative ecosystem concept was the Independent Scientific Group (ISG) in *Return to the River* (Williams, et. al., 1996).

The Storage Study is focused solely on evaluating the feasibility of increased water storage in the Yakima basin. Consequently, Reclamation has limited this evaluation to how different Storage Study alternatives affect the current flow regime in the Yakima basin in terms of making the existing hydrograph more natural-like. Achieving a more natural-like, or unregulated, hydrograph is only one, albeit important, element in moving toward a more normative river ecosystem. Clearly of equal importance is the preservation of existing high value habitat and restoring existing habitat. Furthermore, the Storage Study analysis presented in this report is qualitative in nature and is not designed to define natural (unregulated) flows in the basin in quantitative terms. We anticipate the need to quantify natural (unregulated) flows in the basin to complete the Storage Study feasibility report/environmental impact statement.

Many in the scientific community recognize that a more natural (unregulated) flow regime is a key element to achieving a more normative river ecosystem. Excerpts from previous reports follow:

- The ISG (Williams, et. al., 1996) placed the importance of a natural flow regime in the broader context of the normative river concept. As one example of the importance of a natural flow regime, they state:

  > *"At least three generalized actions could begin to rebuild habitat quantity and quality of the mainstem and tributaries:*
  > *(a) reregulate flows to restore the spring high-water peak to revitalize the mosaic of habitats in alluvial riverine reaches; . . ."*

- Influenced by the ISG *Return to the River* (Williams, et. al., 1996) document, the System Operations Advisory Committee (SOAC) state in their 1999 report entitled, *Report on the Biologically Based Flows for the Yakima River Basin* (System Operations Advisory Committee, 1999) as Recommendation 4 to:

  > *"Implement a Normative Flow Regime – Within the various restraints associated with river development, immediately initiate some level of modified flows to incrementally move toward predevelopment hydrologic parameters."*

  Further in this report, SOAC states that:

  > *"The key to recovering anadromous fish populations in the Yakima Basin is to re-establish lost or altered ecosystem functions within the framework of the*

> *'normative ecosystem concept' (Williams et. al., 1996). A normative ecosystem may be described as an ecosystem that biologically sustains all life stages of diverse salmonid populations. Further, the normative ecosystem is not a static target or a single unique state of the river. It is a continuum of conditions from slightly better than the current state of the river at one end of the continuum, to nearly pristine at the other end. (Williams et al., 1996)."*

- Stanford, et. al., (2002) in their report entitled, *The Reaches Project: Ecological and Geomorphic Studies Supporting Normative Flows in the Yakima River Basin, Washington*, makes the following summary statements:

> "*Through this research effort, we conclude that recovery of salmonid runs in the Yakima is dependent on (1) the provision of normative flows, which we outline, and (2) the protection and enhancement of flood plain habitat."*

> *"Normative flows would reconnect the Yakima flood plain ecosystem in all three physical dimensions (laterally, vertically and longitudinally)."*

- In the *Final Plan, Yakima Subbasin Plan* (2004), the Yakima Subbasin Fish and Wildlife Planning Board (YSPB) states as their second guiding principle:

> "*That the quality of water and a near natural timing and quantity of water flow (normative hydrograph) are principle indicators of a healthy river ecosystem."*

- Similarly, in the *Draft Yakima Subbasin Salmon Recovery Plan* (Freudenthal, et. al., 2005), the YSPB states as one of their guiding principles:

> "*The quality of water and a near natural timing and quantity of water flow (normative hydrograph) are principal indicators of a healthy river ecosystem. These indicators must be improved and monitored."*

System Operation Studies

Hydrologic Model

The system operational analysis conducted by Reclamation for this *Yakima Basin Assessment* involves use of the Yakima Project RiverWare (Yak-RW) model. This model is a daily time-step reservoir and river operation simulation computer model of the Yakima Project, created with the RiverWare software. The software was developed at the Center for Advanced Decision Support for Water and Environmental Support at the University of Colorado in cooperation with Reclamation and the Tennessee Valley Authority.

The RiverWare modeling software uses an object-oriented modeling approach in which objects represent features of the project such as storage reservoirs, stream reaches, diversions, and canals. Each object contains its own physical processes, algorithms and data. For instance, reservoir objects include elevation-volume data, flood-control rule curve information, and outflow data. Objects are interconnected by a “network” of lines representing the flow of water from one object to another.

The network file of the Yak-RW model consists of the five major project reservoirs (Keechelus, Kachess, Cle Elum, Bumping, and Rimrock) and 56 major and minor river diversions and canal systems. All river diversions, canal losses, on-farm losses, and return flows are represented in the model. The network also includes simulation of Kittitas Reclamation District’s 1146 Wasteway to assist in the “mini flip-flop” fall operation, and the Roza and Chandler powerplants.[3]

The hydrologic base for the Yak-RW model is represented by the 23 water years of 1981 through 2003 (November 1, 1980, through October 31, 2003). This 23-year period includes 17 non-proration water years (wet and average water supply conditions) and 6 proration years (dry water supply conditions).

Current Operation Scenario

The objective of the current operation is to fill the reservoir system to its full active capacity of about 1 million acre-feet, while providing “minimum” flows downstream of the dams, meeting Title XII flows at Sunnyside and Prosser Diversion Dams, and providing reservoir space for possible flood control operations. Runoff from the watershed upstream of the five major Yakima Project reservoirs is stored following the end of the irrigation season in October and continuing through the fall, winter, and early spring months to accomplish this objective.

The irrigation season starts about the first of April, though the “priming” of the main conveyance canals generally begins by mid-March. During the initial part of the irrigation season, unregulated runoff from tributaries below the five reservoirs is generally adequate to meet irrigation diversion demands and the Title XII target instream flows at Sunnyside Diversion Dam (Parker gauge, RM 103.7). Irrigation return flows also contribute to meeting irrigation diversion demands. On average, unregulated flows and irrigation return flows are adequate in meeting diversion demands until about June 24. The earliest unregulated flows have been unable to meet demands is April 1, and the latest is August 17.

Once the unregulated flows fail to meet diversion demands and Title XII target flows, reservoir releases must be made, resulting in depletions in the stored water supply. The time when this occurs is commonly referred to as the beginning of the storage control period.

From the beginning of the storage control period until the first of September, releases from Cle Elum Dam are maximized to the extent possible to meet mainstem Yakima River diversion demands extending from the Cle Elum River confluence (RM 179.6) to Sunnyside Diversion Dam (RM 103.8). A major portion of these demands is in the middle Yakima basin, from Roza

[3]The Wapatox Powerplant was acquired by Reclamation in 2003 and is no longer in operation. The “power water” diversion now remains in the Naches River.

Diversion Dam (RM 127.9) downstream, including the Roza Division, Wapato Irrigation Project (RM 106.7), and the Sunnyside Division. These demands total an annual irrigation water right of about 1.46 million acre-feet, out of a basin total of about 2.34 million acre-feet upstream of the Parker gauge. This results in a high volume of water being transported from the upper to middle basin by the Yakima River. At peak, about 3,600 cfs for irrigation diversion is being moved through this area.

However, about September 1, the Yakima Project moves into what is called the "flip-flop" operation. At this time, Cle Elum Lake releases are significantly reduced over a 10-day period. During this interval, releases from Rimrock Lake are significantly increased to meet the September-through-October irrigation demands downstream of the confluence of the Naches and Yakima Rivers; the major portion of which is the Wapato Irrigation Project and the Sunnyside Division. The purpose of the flip-flop operation is to encourage upper Yakima River spring Chinook to spawn in the main channels of the upper Yakima River (RM 156 to RM 202) and the Cle Elum River, rather than in areas which would be dewatered at the end of the irrigation season when storage accumulation begins. This allows protection of the redds, or incubating eggs, throughout the fall and winter months with a lesser storage release, thus improving the stored water supply for the next irrigation season.[4]

The flip-flop operation during the storage control period is illustrated in table 6.

During this same period (the beginning of storage control to the first of September), a similar operation, referred to as "mini flip-flop," is performed between Keechelus and Kachess Lakes in years of sufficient water supply. Greater releases are initially made from Keechelus Lake to meet the upper basin demands (primarily the Kittitas Reclamation Division), and releases from Kachess Lake are restrained. Then, in September and October, the opposite is done, with greater releases being made from Kachess to meet upper basin demands, and releases from Keechelus reduced to provide suitable spawning flows in the Yakima River reach from Keechelus Dam (RM 214.5) to the backwaters of Lake Easton (about RM 203.5).

Concurrent with the September shift in major water releases from Keechelus Lake to Kachess Lake, Kittitas Reclamation District's main canal (which has excess carrying capacity due to diminishing irrigation demands) is used to convey water for downstream use (such as the Roza Irrigation District) around the Easton Reach. This water reenters the Yakima River through the 1146 Wasteway,[5] approximately 28 miles downstream of Easton Diversion Dam. This operation provides a maximum of 200 cfs spring Chinook spawning flow through the Easton reach.

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[4] A detailed history and description of the "flip-flop" river operation, instituted in the early 1980s, can be found in the *Interim Comprehensive Basin Plan* (Reclamation, 2002).
[5] The 1146 Wasteway conveys excess water from Kittitas Reclamation District's main canal at Station 1146+30 to the Yakima River at RM 173.9.

Table 6. Yakima River Flows and Major Diversions (Easton Diversion Dam to Sunnyside Diversion Dam)

Gauging Station	Mid-July	Mid-August	Mid-September
	(cubic feet per second)		
Yakima River @ Easton Diversion Dam (RM 202.5)	220	360	220
Below Cle Elum Dam	2,830	2,950	220
Yakima River @ Cle Elum (RM 183.1)	+3,210	+3,530	+540
Yakima River @ Umtanum (RM 140.4)	3,640	3,930	1,510
RID Diversion[1] (RM 127.9)	-1,060	-1,080	-730
Yakima River below Roza Dam (RM 127.9)	2,580	2,850	780
Naches River @ Naches (RM 16.8)	+1,270	+990	+2,090
Yakima River below Roza Dam + Naches River @ Naches	3,850	3,840	2,870
WIP Diversion (RM 106.7)	-1,890	-1,850	-1,200
Sunnyside Diversion (RM 103.8)	-1,220	-1,220	-1,060
Other Diversions	-240	-250	-90
Yakima River at Parker (RM 103.7)	500	520	520

[1]For irrigation, diversions for hydrogeneration at Roza Powerplant return to the Yakima River downstream of the Naches River confluence.

Integrated Operation Scenario

This section provides information on water availability at Bumping Lake enlargement damsite and at the Yakima River Wymer pumping plant site. It also discusses how the available water supply is used in the integrated 70-percent operation.

The results of the integrated operation are then discussed as they relate to meeting the Storage Study's irrigation, instream, and municipal water supply goals.

Water Availability

The unappropriated surface waters of the Yakima River basin have been withdrawn from appropriation by Reclamation. This withdrawal, approved by Washington Department of Ecology, is in effect until January 18, 2008.

Bumping Lake Enlargement. The runoff available from the Bumping River watershed for storage in an enlarged Bumping Lake reservoir is represented by the inflow to the enlarged reservoir, less a minimum instream flow requirement of 130 cfs in the Bumping River downstream of the new dam. The monthly volume during the 1981-2003 period is shown in table 7. The average annual runoff available is illustrated in figure 9.

The monthly volume of water available for storage does not represent the volume actually stored, as the amount actually stored is a function of the manner in which the enlarged reservoir is operated in conjunction with the present Yakima Project facilities.

Table 7. Bumping Lake Enlargement Inflows Available for Storage (Inflow Less Minimum Release)

Water Year	Monthly Volumes (acre-feet)												Annual Volume (a-f)
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	
1981	11,137	41,043	13,233	15,001	3,463	6,659	19,468	13,498	687	0	0	648	124,836
1982	1,337	3,963	911	27,038	9,416	4,509	37,651	60,260	14,786	345	75	1,347	161,639
1983	1,731	10,131	11,383	3,414	10,567	7,731	43,284	34,721	13,100	178	18	0	136,259
1984	9,780	4,950	17,362	4,167	6,501	5,817	27,017	46,809	15,835	124	0	185	138,546
1985	729	0	0	0	0	12,507	37,770	40,815	2,243	0	0	3,743	97,806
1986	5,997	0	3,595	10,475	19,057	13,648	28,563	20,786	144	0	0	322	102,587
1987	13,175	1,695	62	1,093	11,154	21,331	43,056	10,837	72	0	0	0	102,475
1988	0	1,635	231	37	3,388	21,048	31,570	21,232	2,399	0	0	250	81,791
1989	7,177	3,463	1,396	61	1,373	21,700	32,171	31,056	3,056	0	0	0	101,454
1990	3,140	9,986	14,587	1,867	1,283	29,515	24,826	30,417	7,481	116	0	3,669	126,888
1991	33,989	7,506	6,721	21,701	4,453	11,572	23,992	26,841	13,018	325	0	0	150,118
1992	3,201	3,102	5,454	5,437	9,918	18,429	20,701	2,882	0	0	154	0	69,279
1993	66	0	919	0	4,755	7,952	42,095	12,694	162	0	0	0	68,643
1994	0	0	350	0	3,953	17,504	27,721	10,322	322	0	0	2,286	62,459
1995	1,607	11,278	4,219	31,231	11,202	6,881	38,823	26,361	4,309	0	1	3,106	139,017
1996	51,175	24,737	19,462	45,155	9,241	22,147	22,227	23,518	4,409	66	0	429	222,567
1997	4,006	3,466	14,937	8,944	17,458	19,176	63,677	63,198	27,394	1,180	2,372	15,400	241,208
1998	11,062	4,784	2,848	185	4,102	9,964	46,301	27,007	2,785	0	0	0	109,039
1999	7,287	12,949	8,577	628	494	5,033	28,326	61,505	47,828	11,660	32	155	184,474
2000	24,267	12,369	1,139	364	0	20,035	32,147	33,877	6,092	0	80	162	130,532
2001	0	0	0	0	1,142	4,633	27,049	10,136	380	0	0	191	43,531
2002	7,991	2,665	15,222	3,200	2,485	16,950	32,195	58,987	13,604	0	0	0	153,297
2003	14	272	16,638	12,240	9,733	12,435	25,240	23,769	754	0	0	1,424	102,519
Average	8,647	6,956	6,924	8,358	6,310	13,790	32,864	30,067	7,863	608	119	1,449	123,955
Daily Available for Storage (cfs) by Month													
Average	145	113	113	149	103	232	534	505	128	10	2	24	
Maximum	5,297	4,989	3,450	4,556	1,324	1,390	2,096	2,445	1,158	470	225	2,101	
Minimum	0	0	0	0	0	0	111	0	0	0	0	0	

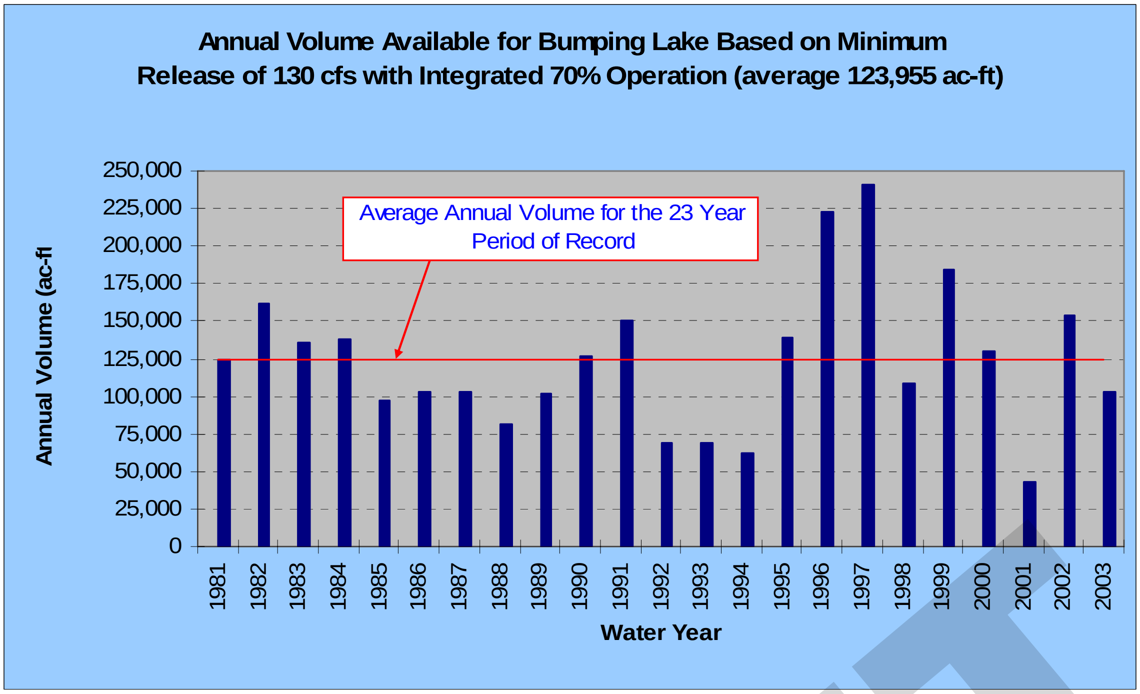

Figure 9. Bumping Lake Inflows Available for Storage (Inflow Less Minimum Releases)

Wymer Dam and Reservoir. Yakima River flows available for diversion to Wymer reservoir are limited to nonproration water supply years, with pumping occurring when flows are (1) greater than 1,475 cfs upstream of Roza Diversion Dam during the nonirrigation season,[6] and (2) greater than Title XII flows over Sunnyside Diversion Dam during the irrigation season.

Table 8 shows the monthly volume of Yakima River water available for diversion to Wymer reservoir.

Figure10 shows the average annual Yakima River flows available for pumping to Wymer reservoir.

[6] Maximum generation at Roza Powerplant requires a flow of 1,075 cfs. In addition, 400 cfs is required at Roza Diversion Dam to divert the power water.

Table 8. Yakima River Flows Available for Pumping into Wymer Reservoir with Integrated 70% Operation

Water Year	Monthly flows (acre-feet)												Annual Flow (acre-feet)
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	
1981	0	113,049	35,737	86,446	22,330	0	0	0	0	0	0	0	257,562
1982	0	0	31,037	107,298	81,340	26,643	89,866	97,538	19,235	0	0	0	452,956
1983	0	633	84,681	27,030	133,892	76,455	59,242	60,795	14,164	0	0	0	456,892
1984	2,857	0	120,525	35,431	70,926	35,246	2,285	132,880	19,079	0	0	0	419,229
1985	0	0	0	0	0	56,302	7,563	0	0	0	0	221	64,085
1986	8,340	0	0	40,368	120,875	10,514	0	0	0	0	0	0	180,098
1987	14,331	0	0	0	32,907	6,763	3,102	0	0	0	0	0	57,103
1988	0	0	0	1,286	0	29,998	0	0	0	0	0	0	31,284
1989	1,107	3,864	3,253	4,032	5,602	60,252	1,589	0	0	0	0	0	79,698
1990	946	7,801	14,769	21,461	38,466	119,666	136	37,256	8,315	0	0	3,151	251,968
1991	178,470	73,606	100,179	85,700	55,420	94,341	31,848	40,975	14,176	0	0	0	674,715
1992	0	12,657	9,206	17,308	28,729	0	0	0	0	0	0	0	67,900
1993	0	0	0	0	3,919	1,606	3,208	0	0	0	0	0	8,733
1994	0	0	0	0	143	2,750	0	0	0	0	0	0	2,893
1995	444	10,840	12,173	138,166	69,851	11,777	17,405	14,520	1,307	0	0	0	276,482
1996	119,157	194,790	208,890	346,668	213,774	202,482	31,979	48,485	0	0	0	0	1,366,226
1997	0	0	42,731	84,579	267,528	262,382	315,312	102,213	25,207	0	0	3,224	1,103,177
1998	36,637	1,568	8,311	22,330	56,661	83,310	85,495	26,451	0	0	0	0	320,764
1999	106	21,380	56,294	7,620	39,135	54,360	145,056	86,691	57,879	2,208	0	0	470,728
2000	128,846	134,842	5,066	0	6,361	138,425	26,239	83,665	8,341	0	0	0	531,784
2001	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	916	573	10,900	7,818	2,556	49,348	41,216	138,493	5,112	0	0	0	256,931
2003	0	0	20,128	48,780	59,069	31,437	2,792	0	0	0	0	0	162,206
Ave	21,398	25,026	33,212	47,057	56,934	58,872	37,580	37,824	7,514	96	0	287	325,801
Average Daily Available for Storage (cfs) by Month													
Ave	360	407	540	847	926	989	611	636	122	2	0	5	
Max	11162	11341	6455	15264	11678	9719	11333	5685	2544	602	0	783	
Min	0	0	0	0	0	0	0	0	0	0	0	0	

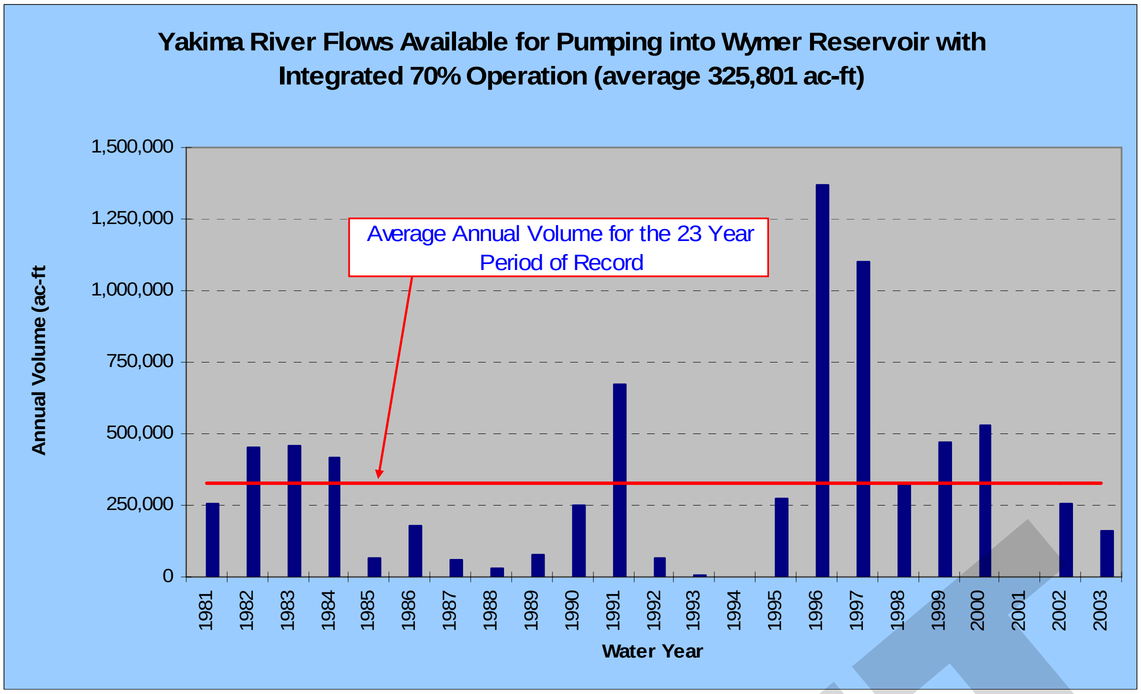

Figure 10. Annual Yakima River Flows Available for Pumping into Wymer Reservoir

Storage Contents

For the integrated operation studies, the emphasis is on meeting instream flow targets downstream of the dams (see table 9), Title XII flows, and the irrigation water supply goal. Specific criteria are not included in the simulated operations in an attempt to move the Yakima and Naches Rivers' flow regime toward the natural (unregulated) hydrograph. To do so would result in not meeting the irrigation water supply goal. Rather, the RiverWare model uses the integrated operation total water supply available (TWSA) to set the Title XII target flows. Additional flows resulting from increased TWSA of the integrated operations (as compared to the current operation) are then equated to a "block of stored water" which could be used for other fishery purposes, if desired (see table 12).

Table 9. Minimum Target Flows Used by the Model

River Location	Daily Flows (cfs)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tieton Dam	45	45	45	45	45	45	45	45	45	45	45	45
Bumping Dam	130	130	130	130	130	130	130	130	130	130	130	130
Keechelus Dam	80	80	80	80	80	80	80	80	100	100	80	80
Kachess Dam	15	15	15	15	15	15	15	15	15	15	15	15
Cle Elum Dam	220	220	220	220	220	220	220	220	220	220	220	220
Easton Diversion Dam	220	220	220	220	220	220	220	220	220	220	220	220
Naches River at Naches	Minimum of natural flow right or 450 cfs											
Parker				Title XII flows*								
*see table 1 for Title XII instream flows												

Bumping Lake Enlargement. Figure 11 shows Bumping Lake enlargement storage contents for the 23-year hydrologic period. The increasing line represents inflow available for storage being retained in the reservoir during the storage period beginning about November 1 with maximum reservoir contents usually occurring mid-June to early July. The decreasing lines are the reservoir releases during the storage control period resulting in the lowest reservoir contents occurring at the end of the irrigation season in October.

The operating emphasis of an enlarged Bumping Lake reservoir is on a carryover reservoir to improve the dry-year water supply available for proratable water rights. This results in major reservoir drawdown and minimum reservoir contents in the historical dry water years 1987, 1988, 1992, 1993, 1994, and 2001.

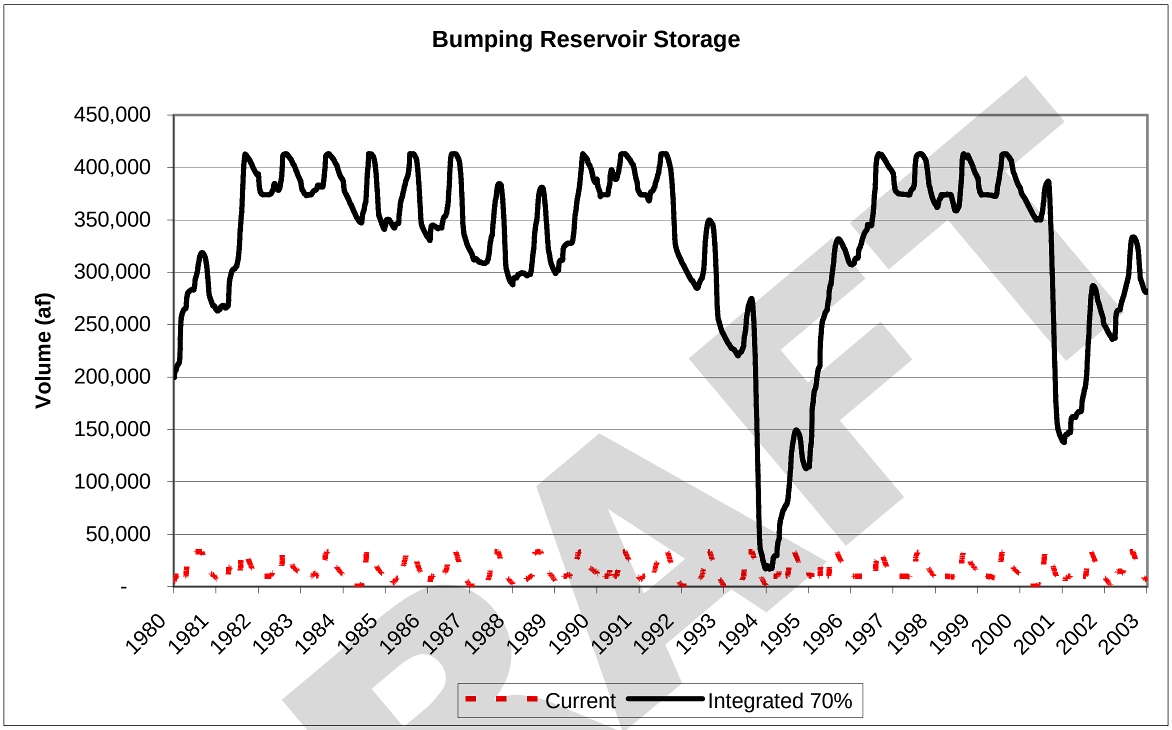

Figure 11. Bumping Lake Enlargement Contents for the Current Scenario and Integrated 70% Operation

Wymer Dam and Reservoir. Table 10 shows the monthly pumping to Wymer reservoir and the releases back to the Yakima River. For this *Yakima Appraisal Assessment*, the capacity of the Wymer pumping plant and the outlet works is 400 cfs.

Wymer reservoir is filled during the winter and spring months; releases are made in the dry years when stored water is required in meeting Title XII target flows at Sunnyside Diversion Dam. This operation, shown in figure 12, permits retention of stored water in the other Yakima Project reservoirs to improve the dry-year water supply available for all Yakima basin proratable water rights.

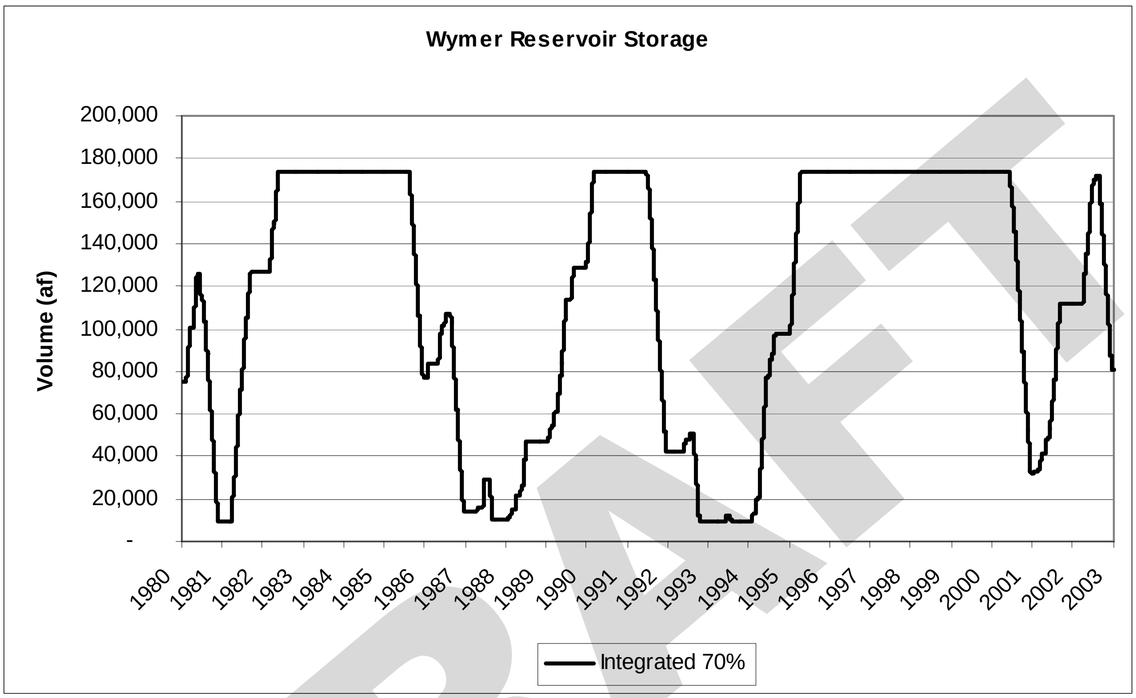

Figure 12. Wymer Reservoir Contents for the Integrated 70% Operation

Table 10. Inflows and Releases from Wymer Reservoir with Integrated 70% Operation

Water Year	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Annual Inflow	Annual Release
1981	0	14,853	10,709	11,901	13,796	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	0	51,259	116,904
1982	0	0	8,727	17,745	24,595	17,157	24,595	16,579	7,649	0	0	0	117,048	0
1983	0	633	21,319	11,208	Full	Full	Full	Full	Full	Full	Full	Full	33,160	0
1984	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1985	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1986	Full	Full	Full	Full	Full	Full	Full	Rel.	Rel.	Rel.	Rel.	Rel.	0	96,926
1987	6,557	0	0	0	13,959	6,245	2,901	Rel.	Rel.	Rel.	Rel.	Rel.	29,662	92,278
1988	0	0	0	1,286	0	13,744	0	Rel.	Rel.	0	0	0	15,030	19,563
1989	1,107	3,864	3,171	3,271	5,195	19,290	1,589	0	0	0	0	0	37,486	0
1990	946	5,984	7,143	11,165	19,471	21,721	136	11,085	3,399	0	0	3,151	84,200	0
1991	19,463	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	19,463	0
1992	Full	Full	Full	Full	Full	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	0	131,988
1993	0	0	0	0	3,919	1,606	3,208	Rel.	Rel.	Rel.	0	0	8,733	41,256
1994	0	0	0	0	143	2,750	Rel.	0	0	0	0	0	2,893	3,174
1995	444	9,022	4,603	22,215	23,911	8,515	10,346	8,696	1,143	0	0	0	88,894	0
1996	18,638	24,595	24,595	Full	Full	Full	Full	Full	Full	Full	Full	Full	67,828	0
1997	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1998	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1999	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
2000	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
2001	Full	Full	Full	Full	Full	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	0	141,795
2002	916	573	7,251	5,479	2,556	17,949	19,835	22,265	2,826	0	0	0	79,649	0
2003	0	0	4,823	17,668	18,670	15,969	2,792	Rel.	Rel.	Rel.	Rel.	0	59,923	80,926
Average	3,434	4,579	7,103	8,495	11,474	12,495	7,267	9,771	2,503	0	0	315	30,227	31,513
	Average Daily Inflow (cfs) by Month												**Average Daily (cfs)**	
Average	58	74	116	153	187	210	118	164	41	-	-	5	124	400

Integrated Total System Storage

Storage contents of the existing five major Yakima Project reservoirs with and without the addition of the three storage alternatives are shown in figure 13.

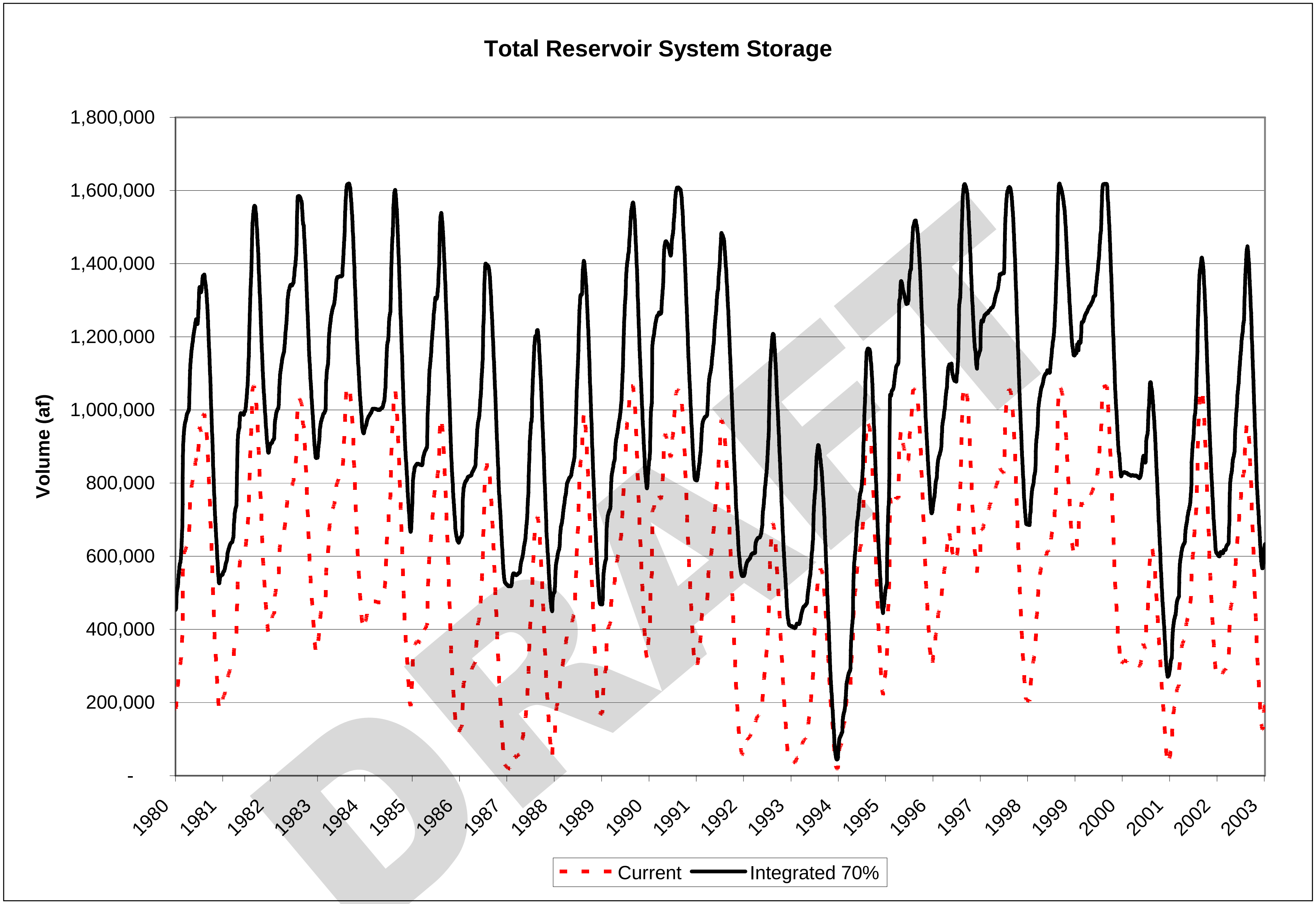

Figure 13. Total Reservoir System Storage - Integrated 70%

System Operation Results

Irrigation Water Supply

The 23-year average TWSA is 3,210,000 acre-feet with the integrated 70-percent operation as compared to the current operation TWSA of 2,850,000 acre-feet. With additional basin storage of 554,300 acre-feet,[7] and an operating plan that uses the additional storage capacity primarily as carryover, the 23-year average TWSA is increased by 360,000 acre-feet.

One-year droughts which follow two or more wet years could see a 30-percent improvement over the current operation proration level. This is demonstrated by drought year 2001, where the current operation proration level was 41 percent, and the integrated 70-percent operation proration level is brought up to 70 percent.

Irrigation water supply conditions are improved in the prolonged dry period, such as 1992-1994. The additional storage alternatives increased the amount of proratable water supply in 1992 and 1993 to not less than 70 percent. The 1994 proratable supply was increased to 66 percent; 4 percentage points less than the 70-percent irrigation supply threshold. It is estimated the 4 percent difference in supply amounts to about 50,000 acre-feet.

Wymer reservoir is filled by pumping from the Yakima River during the winter and spring months. Releases from Wymer reservoir were made during the dry years of 1987, 1988, 1992, 1993, and 2001. Only a minimum release was possible in 1994, because Wymer reservoir was empty in 1993, and there was little excess Yakima River flow in 1994 to pump.

Keechelus-to-Kachess pipeline would be used to capture runoff in only 1 year of the 23-year period—400 acre-feet in 1985. Current reservoir operations maximize carryover storage in Kachess, because it has the lowest inflow-to-total-storage ratio. This reservoir operation results in little benefit from the Keechelus-to-Kachess pipeline for storage augmentation, because, in wet years, Kachess fills from its own watershed. During dry years, there is not enough water in the Keechelus watershed to fill Keechelus reservoir, so no water is sent to Kachess Reservoir.

The Keechelus-to-Kachess pipeline does have a benefit of reducing flows in the Yakima River below Keechelus Dam, because flows can be routed by the pipeline from Keechelus Reservoir through Kachess Reservoir to the Yakima River during the summer months.

Table 11 shows the proration levels for the current and integrated operation studies using the Yak-RW model and the historical water conditions of water years 1981 through 2003. The proration levels generated by the Yak-RW model for the “current operation” are different than actually experienced in prorated years before 1995. This is because current-day operational criteria such as the Title XII instream target flows were implemented in 1995, and minimum

[7] Bumping Lake enlargement active capacity of about 413,000 acre-feet (used in the operation study) less 33,700 acre-feet for the existing Bumping Lake, plus Wymer reservoir active capacity of about 175,000 acre-feet = 554,300 acre-feet (413,000 – 33,700 + 175,000 = 554,300).

streamflow maintenance releases from existing Yakima Project reservoirs are input into the model for the entire 23-year period.

Table 11. Water Supply Conditions in Yakima Basin Above Parker and Water Supply Available for Proratable Entitlements

		April 1 TWSA (million af)		Proratable Supply (%)			
Water Year	Unregulated Runoff Volume (million af)	Current Operation	Integrated 70% Operation	Current Operation	Integrated 70% Operation	Integrated 50% Operation	Integrated 100% Operation
1981	3.57	2.48	2.86	95	91	91	100
1982	4.26	3.39	3.85	100	100	100	100
1983	3.96	3.33	3.89	100	100	100	100
1984	4.06	3.23	3.79	100	100	100	100
1985	2.80	2.74	3.27	100	100	100	100
1986	3.06	2.50	3.00	92	89	88	100
1987	2.64	2.26	2.82	65	70	69	100
1988	2.75	2.33	2.84	73	89	87	90
1989	3.10	2.66	3.10	98	100	100	100
1990	3.72	3.10	3.50	100	100	100	100
1991	4.02	3.01	3.57	100	100	100	100
1992	2.45	2.14	2.65	69	70	65	100
1993	2.36	2.07	2.57	54	72	75	74
1994	2.06	1.74	2.14	26	66	50	27
1995	4.15	2.90	3.07	100	100	100	100
1996	5.71	3.22	3.65	100	100	100	100
1997	5.70	4.50	4.99	100	100	100	100
1998	3.38	3.15	3.68	100	100	100	100
1999	4.63	3.99	4.49	100	100	100	100
2000	3.66	3.26	3.78	100	100	100	100
2001	1.77	1.81	2.34	41	70	50	84
2002	3.79	3.23	3.57	100	100	100	100
2003	3.06	2.56	2.97	97	92	92	100
Average	3.51	2.85	3.21				

Instream Water Supply

Title XII Instream Target Flows. Title XII instream target flows at Parker range from 300 cfs to 600 cfs, depending on the estimated TWSA "threshold level" (see table 1 on page 5). The addition of the three storage alternatives increases the "storage content" portion of the TWSA estimate and may result in moving the target flows from one threshold level to the next. When the TWSA estimate increases in the integrated operation studies, the instream flow threshold at Parker is increased. As unregulated flows fail to meet diversion demands and Title XII target flows, reservoir releases are required.

Table 12 summarizes the average increased flow rate (cfs) and the number of days at the increased flow rate, which would be provided from stored water resulting from the three integrated operation studies. Also shown is the volume (acre-feet) of the increase flow estimated to be provided from stored water. In some years, it may be possible to use this increased volume for other fishery purposes rather than for increased Title XII instream target flows.

Table 12. Increased Title XII Flows at Parker

Water Year	Average Increased Flow Rate(cfs) and Number of Days at the Increased Flow Rate			Volume of Increased Flow from Stored Water (acre-feet)		
	Integrated 70% Operation	Integrated 50% Operation	Integrated 100% Operation	Integrated 70% Operation	Integrated 50% Operation	Integrated 100% Operation
1981	200 (124 days)	200 (124 days)	200 (121 days)	49,000	49,000	48,000
1982	100 (71 days)	100 (71 days)	100 (71 days)	14,000	14,000	14,000
1983	100 (71 days)	100 (71 days)	100 (71 days)	14,000	14,000	14,000
1984	100 (91 days)	100 (91 days)	100 (91 days)	18,000	18,000	18,000
1985	300 (111 days)	300 (111 days)	300(111 days)	66,000	66,000	66,000
1986	200 (154 days)	200 (151 days)	200 (141 days)	61,000	60,000	56,000
1987	100 (141 days)	100 (151 days)	200 (15 days)	28,000	30,000	6,000
1988	100 (136 days)	100 (135 days)	- -	27,000	27,000	- -
1989	200 (118 days)	200 (118 days)	- -	47,000	47,000	- -
1990	200 (108 days)	200 (111 days)	100 (101 days)	43,000	44,000	20,000
1991	200 (98 days)	200 (98 days)	200 (98 days)	39,000	39,000	39,000
1992	100 (111 days)	100 (111 days)	- -	22,000	22,000	- -
1993	100 (96 days)	100 (96 days)	- -	19,000	19,000	- -
1994	- -	- -	- -	- -	- -	- -
1995	- -	100 (95 days)	- -	- -	17,000	- -
1996	200 (111 days)	200 (111 days)	200 (111 days)	44,000	44,000	44,000
1997	- -	- -	- -	- -	- -	- -
1998	300 (101 days)	300 (101 days)	300 (101 days)	60,000	60,000	60,000
1999	- -	- -	- -	- -	- -	- -
2000	200 (89 days)	200 (89 days)	200 (89 days)	35,000	35,000	35,000
2001	- -	- -	- -	- -	- -	- -
2002	200 (81 days)	200 (81 days)	100 (81 days)	32,000	32,000	16,000
2003	200 (121 days)	200 (118 days)	100 (134 days)	47,000	53,000	24,000

Streamflow Regimes**.** The instream flow water supply goal is to move the current flow regime of the Yakima and Naches Rivers to more closely resemble the natural (unregulated) flow regime.

To determine how well this goal is achieved for the integrated 70-percent operation scenario, five representative hydrographs (figures 15-19) and their associated flow characteristics were analyzed and compared to the current flow regime. This is summarized in table 14. This comparative approach was taken because a quantitative definition of what constitutes a normative flow regime for the Yakima basin as described by SOAC (1999) has not been determined.

The flows at the gauging stations shown below in table 13 were used to represent the flow regime for the corresponding stream reaches (see also figure 14).

Table 13. Gauging Stations and Stream Reaches

Gauge Station/Hydrograph	Reach Name	Stream Reach
Easton (RM 202.0)	Easton	Yakima River: Easton Dam (RM 202.5) to Cle Elum River confluence (RM 185.6)
Umtanum (RM 140.4)	Ellensburg	Yakima River: Cle Elum River confluence (RM 185.6) to Roza Diversion Dam (RM 127.9).
Bumping Dam outlet (RM 17.0)	Bumping	Bumping River: Bumping Dam (RM 17.0) to American River confluence (RM 0.0)
Naches at Naches River (RM 16.8)	Lower Naches	Naches River: Tieton River confluence (RM 44.6) to the Naches River confluence (RM 0.0)
Parker (RM 108.7)	Wapato	Yakima River: Sunnyside Diversion Dam (RM 103.8) to Granger (RM 83.0)

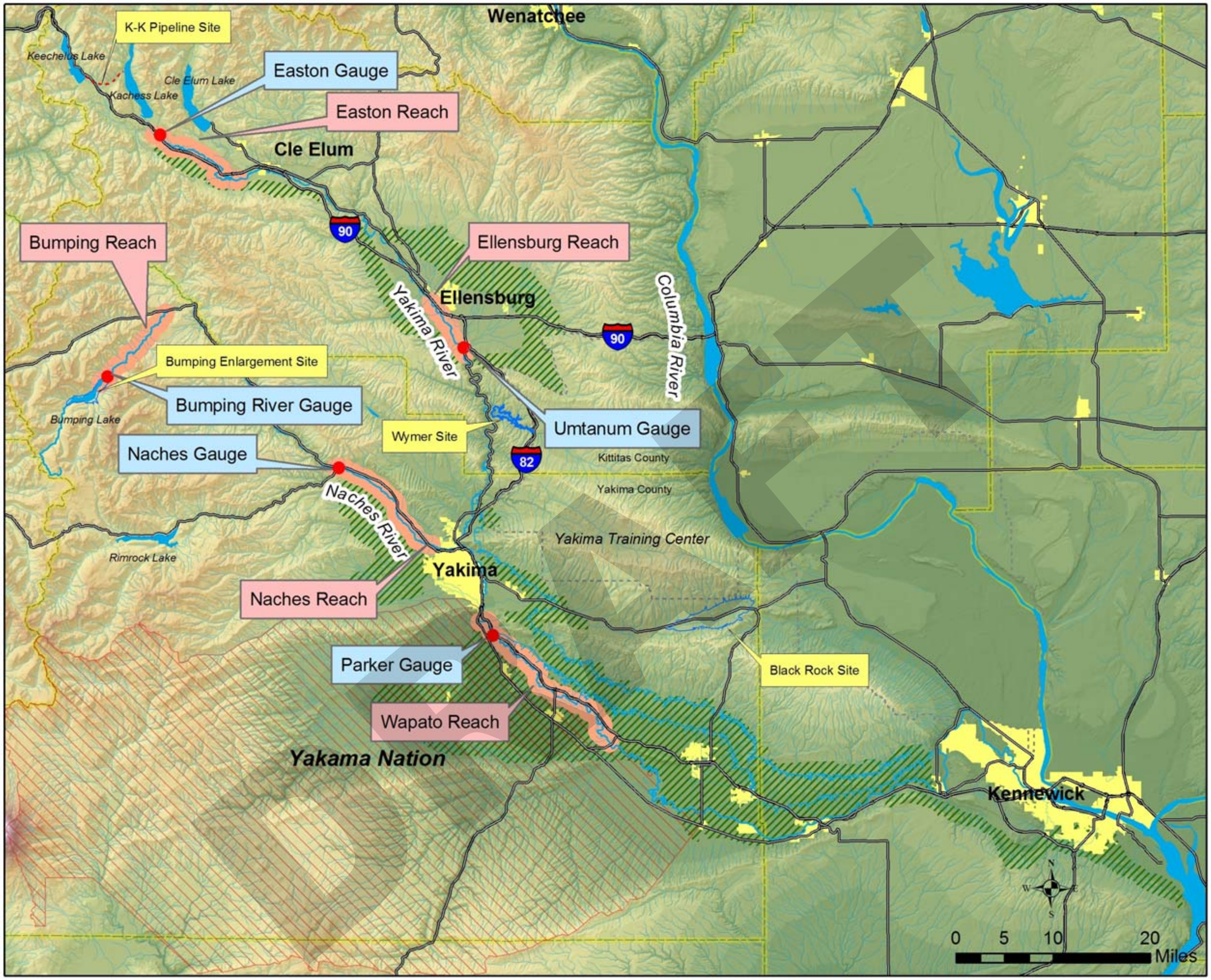

Figure 14. Stream reaches and gauges locations map

Hydrographs. The hydrographs show median monthly flows for the water years 1981 through 2003 for the natural (unregulated) scenario, the current operation scenario, and the integrated 70-percent operation scenario for the five stream reaches identified above. The median monthly flow is the flow which occurs 50 percent of the time for the respective month of the 23-year period of record. Note: This is not the average flow. The hydrographs follow the typical October 1 to September 30 water year. The Yakima basin irrigation season commences April 1 and ends October 15.

The hydrographs illustrate the three scenarios, which are represented by the following:

- Unregulated (black line)—Simulates the natural (unregulated) flow regime from 1981-2003. These flows represent the flow regime that would have happened without any storage reservoirs.

- Current (red line)—Simulates current river operations as described in the *Interim Comprehensive Basin Operating Plan* (Reclamation, 2002).

- Integrated 70-percent (green line)—Simulates the combined effect of Bumping Lake enlargement, Wymer dam and reservoir, and Keechelus-to-Kachess pipeline alternatives with the existing irrigation system and operations.

The vertical lines on the hydrograph represent variations of flow from the 75th percentile (top of the line) to the 25th percentile (bottom of the line). For example, the median flow was 285 cfs for the natural (unregulated) scenario in October at Easton; the 75th-percentile flow was 450 cfs, and the 25th-percentile flow was 157 cfs. The 75th-percentile flow of 450 cfs means that for all the daily mean flows recorded in the month of October for the 23 year period of record, 75 percent of these daily mean flows were less than 450 cfs.

A reach-by-reach discussion of the differences in flow regimes between the current and integrated 70-percent scenarios follows.

Easton, Yakima River (RM 202.0)
There was essentially no change in the flow regime between the integrated 70-percent and current scenarios for the Easton reach of the Yakima River (figure 15). The monthly median flows between the two scenarios were nearly identical, with differences only occurring in November, December and August, and never deviating more than ±50 cfs in monthly median flow. Similarly, there was no change in the eight qualitative hydrologic flow parameters for the integrated 70-percent scenario compared to the current scenario.

Desired improvements to the current operation to more closely mimic the natural (unregulated) hydrograph at the Easton reach would be:

- Spring peak flows of greater magnitude and, more importantly, better timing with the natural (unregulated) hydrograph, where flows begin to increase in April, peak in May, and decline in June.
- An increase in late fall and winter streamflows that allow for a more natural variation to the daily/weekly flows (opposed to a constant minimum flow).
- A decrease in summer flows.

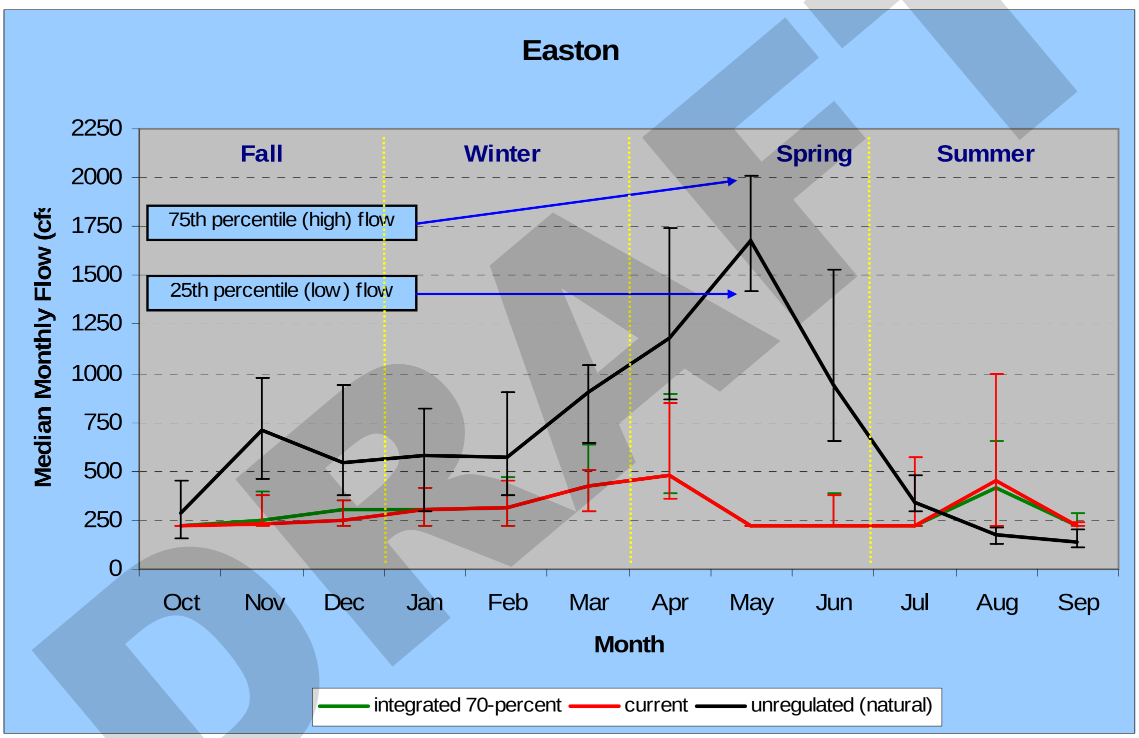

Figure 15. Representative Hydrograph at the Easton, Yakima River, Gauging Station (RM 202.0)

Umtanum, Yakima River (RM 140.4)
There was no significant change in the flow regime between the current and integrated 70-percent operation scenarios (figure 16). The greatest percent difference for any given month between the two scenarios was -10.8% (-179 cfs) (February). The percent difference in monthly

median flows between the integrated 70-percent and current scenarios is as follows: April, -8.7%; May, +6.5%; and June, +2.8%. Late fall and winter flows for both scenarios are generally within the natural (unregulated) 25th and 75th percentile flow criteria.

However, both operations create flows that significantly deviate from the natural (unregulated) hydrograph during the months of April, May, July, and August. The April-May deviation is due to filling the reservoirs (mainly Cle Elum) to full capacity during the snowmelt period. The July-August deviation is due to transporting irrigation water from Cle Elum Lake via the Yakima River to entities in the middle Yakima basin during the peak irrigation season. The integrated operation does not alleviate or significantly modify the operation that presently exists. The percent change in flow from August to September was -63.4% for the current operations scenario, and -60.7% for the integrated 70-percent operation scenario.

Desired improvements to the current operation to more closely mimic the natural (unregulated) hydrograph at the Umtanum reach would be:

- Timing that is more comparable to the natural (unregulated) hydrograph, meaning flows begin to increase in April, peak in May, and decline in June, with a somewhat greater flow magnitude in April and May.

- Reduced summer flows, especially in July and August that mimic closer to unregulated (natural) summer flow regime, and the elimination or significant reduction in the flip-flop operation.

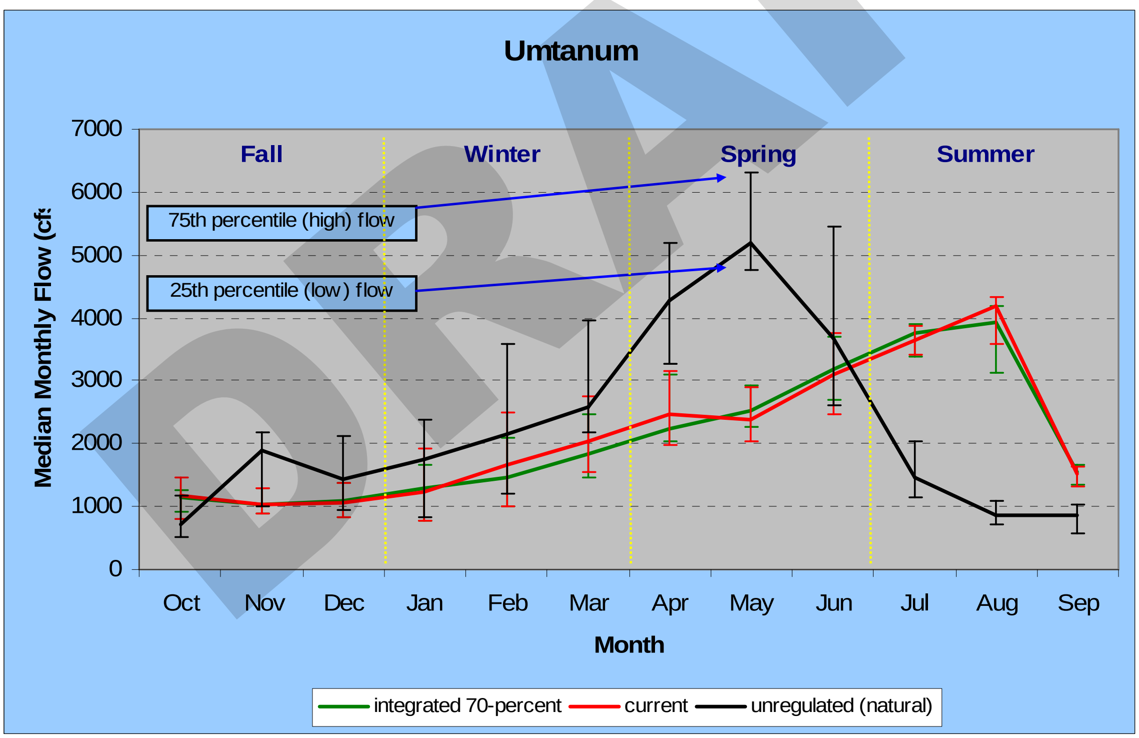

Figure 16. Representative Hydrograph at the Umtanum, Yakima River, Gauging Station (RM 140.4)

Bumping Dam Outlet, Bumping River (RM 17.0).
The current operation of the Bumping River mimics the natural (unregulated) hydrograph, with the exception of late summer flows (figure 17). The small capacity of the reservoir (33,700 acre-feet) allows the majority of flow in the Bumping River to pass in an unregulated manner, especially during the snowmelt period. In contrast, the integrated 70-percent operation scenario reduced spring flows in May -45.0% (-113 cfs) and June -65.9% (-365 cfs) and winter flows in January -12.8% (-20 cfs), and March -23.3% (-40 cfs) from the current operation. These reductions move the peak flow period to July and August instead of May and June. These reductions in winter and spring flows and the change in timing of the peak flows are due to water being stored in the larger reservoir.

The integrated 70-percent scenario August median flows increased 120.3% (264 cfs) and September median flows increased 85.0% (111 cfs) compared to the current scenario. The reason for increased summer flows is because additional stored water is available to meet irrigation demand in the lower basin, especially in water short years.

It should be noted that changes in the flows in the Bumping River will change flows at all locations below on the Naches and Yakima Rivers.

Desired improvements to the current operation to more closely mimic the natural (unregulated) hydrograph at the Bumping reach would be:

- Reduced summer flows, especially in July, August and September.

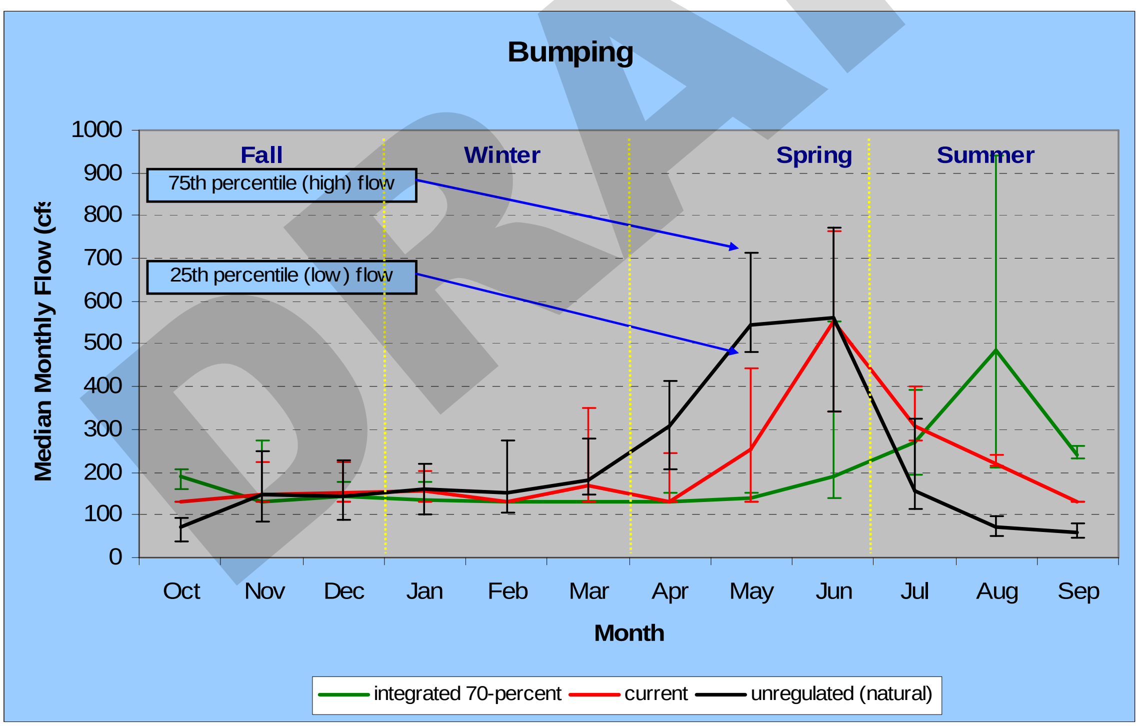

Figure 17. Representative Hydrograph at the Bumping Dam Outlet, Bumping River (RM 17.0)

Naches @ Naches River (RM 16.8).
The current operation scenario flow regime mimics the unregulated (natural) flow regime in the lower Naches Reach with the exception of August and September flows (figure 18). The integrated 70-percent scenario decreased spring flows in April: -1.9% (-34 cfs); May: -11.7% (-265 cfs); and June: -11.4% (-287 cfs) relative to the current operation scenario.

The integrated 70-percent scenario increased summer and fall flows in July: +12.9% (+150 cfs); August: +115.1% (+557 cfs); September: +8.7% (+157 cfs); and October: +53.4% (+315 cfs) relative to the current operation scenario. As previously mentioned for the Bumping River, the increase in summer flows is due to using the additional storage capacity in Bumping Lake Reservoir to meet irrigation demand in the lower basin, especially in water short years.

In August and September, the integrated 70-percent operation scenario changes the median monthly flows less than the current operation. This is based on the percent change in flows from August to September. The August to September flows increased 264% (484 cfs to 1760 cfs) for the current operation scenario, while the flows increased 84% (1041 cfs to 1914 cfs) for the integrated 70-percent scenario.

Desired improvements to the current operation to more closely mimic the natural (unregulated) hydrograph at the Lower Naches reach would be:

- Reduced summer flows in September to eliminate or significantly reduce the flip-flop operation.

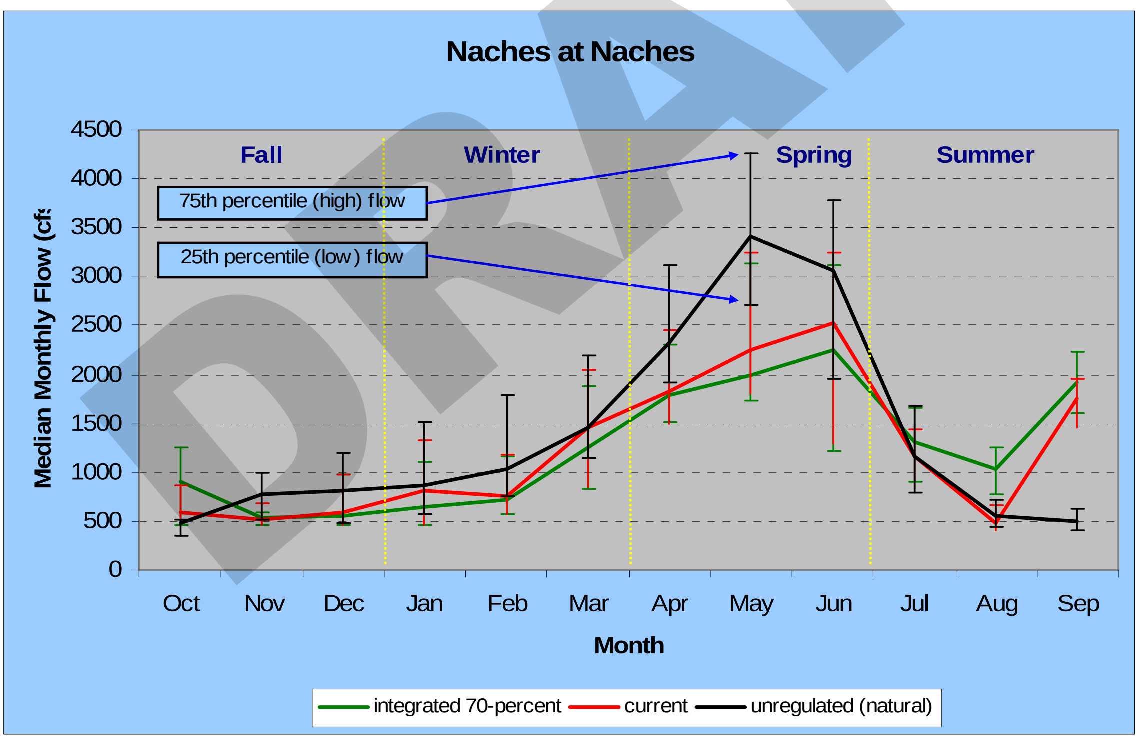

Figure 18. Representative Hydrograph at the Naches @ Naches River Gauging Station (RM 16.8)

Parker, Yakima River (RM108.7).
There was minimal difference in the flow regime between the integrated 70-percent and current operation scenarios for all seasons (figure 19). Both mimic the natural (unregulated) fall and winter flow regime pattern.

The spring and summer flow magnitudes are less than the natural (unregulated) flows for both the integrated 70-percent and current scenarios. The monthly median flow was reduced -2.8% (17cfs) in May and -35.7% (480 cfs) in June compared to the current operation. For both scenarios, peak flows occur in March at a reduced magnitude and steadily decline April through June, instead of peaking in May with much higher flows in April and June as in the natural (unregulated) scenario.

Summer (July-September) median flows do increase from an average of 313 cfs to 616 cfs (+96%) for the integrated 70-percent scenario compared to the current scenario. This increase is attributable to an average increase in the TWSA for the period of record, which increases the Title XII flows at Parker.

Desired improvements to the current operation to more closely mimic the natural (unregulated) hydrograph at the Parker reach would be:

- Improved timing in the spring seasonal flows, as well as increasing the flow magnitude.
- Increasing the magnitude of the summer seasonal flows.

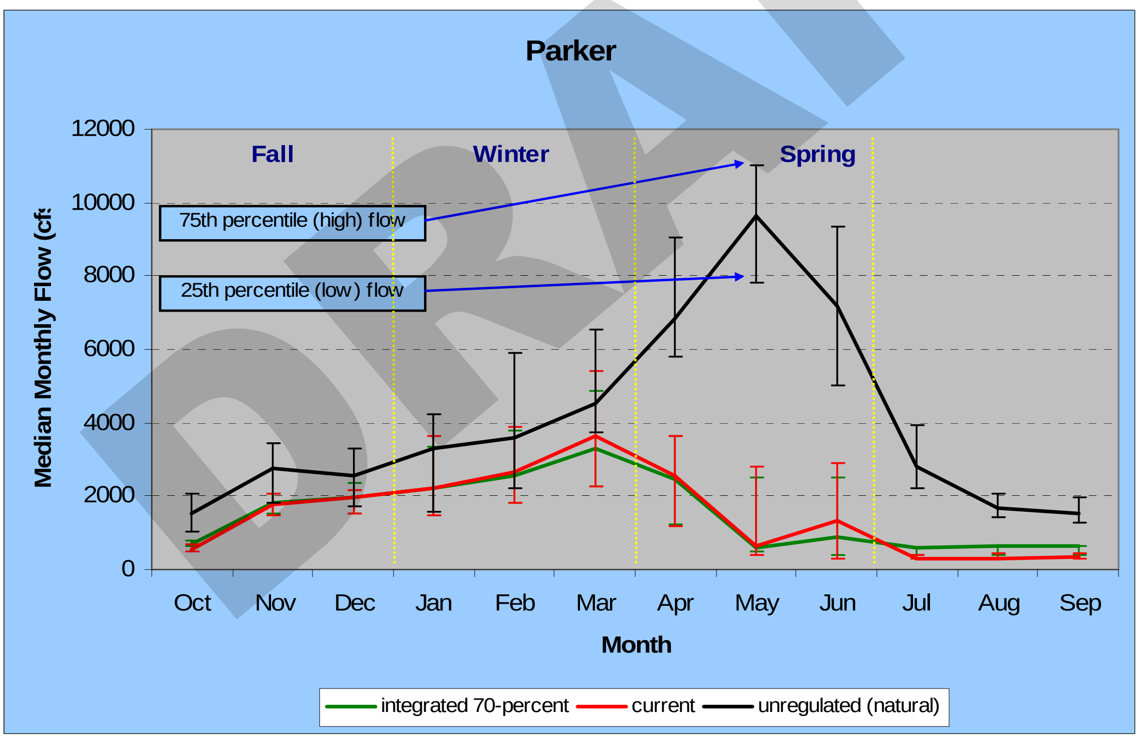

Figure 19. Representative Hydrograph at the Parker, Yakima River, Gauging Station (RM 108.7)

Hydrologic Flow Parameters.
The information presented in table 14 is derived from the Indicator of Hydrologic Alterations (IHA) model.[8] The IHA model has been used throughout the United States to evaluate river operations and impacts on the riverine ecosystem. The IHA model generates a set of descriptive flow statistics that describe the flow conditions of a particular scenario relative to the natural (unregulated) condition. The IHA model is a diagnostic tool that analyzes which flow parameters are within, or out of, criteria, compared to the natural (unregulated) condition.

Reclamation took the results of the IHA model, compiled it into eight hydrologic flow parameters (similar to IHA parameters), and separated them into three groups. These eight parameters were used in table 14 to show the relative effects of the integrated 70-percent operation scenario compared to current operations. The parameters and groups are shown below.

Group I - - Seasonal Magnitude.
The IHA model evaluates three flow ranges: middle flows (≥25th and ≤75th percentile of occurrence); high flows (>75th percentile of occurrence); and low flows (<25th percentile of occurrence) for a particular scenario relative to the natural (unregulated) condition. This comparison was conducted for each month. In Group I, there are 36 monthly flow parameters and 3 flow ranges for each month (12). These 36 monthly flow parameters were then organized by season; defined as follows: spring (April, May, June); summer (July, August, September); fall (October, November, December); and winter (January, February, March).

Reclamation used the IHA model to compare each of the 36 integrated 70-percent operation scenario monthly flow parameters to the corresponding current operation scenario monthly flow parameters. Reclamation then recorded whether each integrated 70-percent monthly flow parameter was better, worse, or showed no change relative to the corresponding current operation scenario monthly flow parameter. The results were summarized for each season and expressed as a percent of the number of monthly flow parameters that were better, worse, or no change, relative to the current operation scenario.

The “better,” “worse,” and “no change” categories for Group I and Group II shown in table 14 refers to the comparison of integrated 70-percent operation scenario flow parameters to the current operation scenario. The question being addressed is, “Did flow parameter X get better, worse, or didn’t change for the integrated 70-percent operation scenario, compared to the current operation scenario?”

Group II - - Magnitude-Duration.
Group II consists of 30 flow parameters, 15 for the minimum flow parameter, and 15 for the maximum flow parameter. Each minimum and maximum flow parameter is organized into the three IHA flow ranges: middle; high; and low, based on the percentile of occurrence as described above for the Seasonal Magnitude flow parameter. Thus, Group II is made up of six groups (i.e., minimum-IHA middle flow range, minimum-IHA high flow range, minimum-IHA low flow range; and maximum-IHA middle flow range, maximum-IHA high flow range, maximum-IHA low flow range) with five streamflow durations—1-day, 3-day, 7-day, 30-day,

[8] The Nature Conservancy developed the IHA software. The Nature Conservancy’s website (http://www.freshwaters.org/tools) provides a download of the software and supporting documents.

and 90-day. For example, within water year 1984, the model will calculate which 30-day period resulted in the highest or lowest average streamflow. There is no time element associated with these two parameters, meaning it is not known when this event occurred during the water year.

The analysis was conducted similar to that described for Group I, meaning each of the 30 integrated 70-percent operation scenario flow parameters was compared to the corresponding current operation scenario flow parameter. Results from the 30 comparisons were recorded as "better," "worse," or "no change." The results were summarized for the Minimum and Maximum flow parameters and expressed as a percentage in the better, worse, and no change categories.

Group III - - Peak and Base Flow Timing.
The Peak Flow and Base Flow parameters define Group III. The peak and base flows periods are defined by the natural (unregulated) peak and base flows. Peak and base flow timing was analyzed in two steps. Step one determined how many months did peak or base flows occur within the natural (unregulated) defined peak and base flow period. This was summarized in table 14, under Group III, for both the current operation and the integrated 70-percent operation scenarios. For example, the first occurrence in table 14 is for the Bumping gauge, for the Peak Flow parameter for the current operation scenario which reads, "2 of 3." This means for the current operation scenario, two out of a possible three months coincided with the natural (unregulated) peak flow period (April, May and June). The second step compares the Peak and Base Flow parameters between the current operation and integrated 70-percent operation scenarios for each gauge station. In the previous example, the current operation produced peak flows in 2 out of 3 months (i.e., "2 of 3"). The integrated 70-percent operation scenario for the Peak Flow parameter for the Bumping gauge station did not produce any peak flows in that period, which reads "0 of 3." This means that none of the integrated 70-percent operation scenario peak flow months coincided with the natural (unregulated) peak flow period. Therefore, compared to the current operation scenario, the integrated 70-percent operation scenario had two fewer months that coincided with the natural (unregulated) peak flow period. This results in a "worse" rating for this particular item.

Table 14. Summary of Hydrologic Flow Parameter Comparison Between the Current and Integrated 70-Percent Scenarios for the Bumping, Naches at Naches, Easton, Umtanum, and Parker Gauge Stations

			Bumping	Naches at Naches	Easton	Umtanum	Parker
	Hydrologic Parameters	**Change Category**	**Change in Scores**	**Change in Scores**	**Change in Scores**	**Change in Scores**	**Change in Scores**
Group I	**Seasonal Magnitude Parameters**						
	Spring (Apr-Jun)	Better	0.0%	22.2%	44.4%	22.2%	0.0%
		No change	0.0%	55.5%	55.5%	55.5%	77.8%
		Worse	100.0%	22.2%	0.0%	22.2%	22.2%
	Summer (Jul-Sep)	Better	11.1%	22.2%	11.1%	0.0%	0.0%
		No change	77.7%	33.3%	78.8%	77.8%	100.0%
		Worse	11.1%	44.4%	11.1%	22.2%	0.0%
	Fall (Oct-Dec)	Better	0.0%	33.3%	11.1%	22.2%	22.2%
		No change	33.3%	44.4%	78.8%	66.7%	77.8%
		Worse	66.7%	22.2%	11.1%	11.1%	0.0%
	Winter (Jan-Mar)	Better	0.0%	0,0%	33.3%	22.2%	0.0%
		No change	0.0%	55.5%	67.7%	55.5%	77.8%
		Worse	100.0%	44.4%	0.0%	22.2%	22.2%
Group II	**Magnitude/Duration Parameters**						
	Minimum Flows	Better	0.0%	40.0%	0,0%	0.0%	0.0%
		No change	6.6%	26.7%	86.7%	47.0%	100.0%
		Worse	93.3%	33.3%	13.3%	53.0%	0.0%
	Maximum Flows	Better	46.6%	6.7%	26.7%	6.7%	13.3%
		No change	6.6%	0.0%	73.3%	73.3%	33.3%
		Worse	46.6%	93.3%	0.0%	20.0%	53.3%
Conclusion			**Worse**	**Worse**	**No change**	**No change**	**No change**
Group III	**Peak & Base Flow Timing Parameters**						
	Peak Flow (typically Apr-Jun)	Current: Number of months within unregulated peak flow period	2 of 3	3 of 3	1 of 3	1 of 3	1 of 3
		Integrated 70%: Number of months within unregulated base flow period	0 of 3	3 of 3	1 of 3	1 of 3	1 of 3
		Net Change in Peak Month Timing	-2	0	0	0	0
	Base Flow (typically Aug-Oct)	Current: Number of months within unregulated peak flow period	2 of 3	1 of 3	1 of 3	1 of 3	2 of 3
		Integrated 70%: Number of months within unregulated base flow period	0 of 3	0 of 3	1 of 3	1 of 3	2 of 3
		Net Change in Base Month Timing	-2	-1	0	0	0
Reach Summary Conclusion			**Worse**	**Worse**	**No change**	**No change**	**No change**

The integrated 70-percent operation scenario shows no significant change in the flow regime of the Yakima River mainstem. In addition, the integrated 70-percent operation scenario moves the mainstem Naches and Bumping River flow regimes further away from a normative flow condition compared to the current operations.

Municipal Water Supply

The *Watershed Management Plan* indicates an additional 30,000 acre-feet will be needed for future (year 2020) municipal surface water needs in the Yakima basin. Currently, the cities of Cle Elum, Ellensburg, and Yakima are the major municipal water diverters.

Since the municipal surface water demand, by scale, is less in comparison to irrigation and instream flow use, the estimated increase in demand has not been included in the operation studies at this time. Future study would consider the needs, benefits, and allocation (water rights) to meet population growth if these Yakima basin storage alternatives proceed to the next phase of the Storage Study.

- END OF DOCUMENT -

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IN REPLY REFER TO:

UCA-1120
PRJ-1.10

MAR 14 2006

Mr. Louis Cloud
Chairman
Yakama Nation Tribal Council
P.O. Box 151
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Subject: Technical Information and Hydrologic Analysis for Yakima River Basin Alternatives for the Yakima River Basin Water Storage Feasibility Study

Dear Mr. Cloud:

On January 19, 2006, we sent for your review and consideration technical information of our hydrologic analysis of the three Yakima River basin storage alternatives (Bumping Lake enlargement, Wymer dam and reservoir, and Keechelus-to-Kachess pipeline) being considered in the Yakima River Basin Water Storage Feasibility Study (Storage Study). Subsequently, we met with stakeholders (Yakima Basin Joint Board, the Yakima System Operating Advisory Committee, the Yakima Basin Storage Alliance, the Washington Department of Fish and Wildlife, and the National Marine Fisheries Service) during February 3-17, 2006, to discuss this information and to obtain input to assist us in determining the Yakima River basin storage alternatives to include in the Plan Formulation Phase of the Storage Study.

The hydrologic analysis indicates that the three Yakima basin alternatives, operated in conjunction with the existing Yakima Project, would be able to supply 70 percent of the proratable (junior) irrigation water rights in dry years, except in the 1994 drought, when 66 percent of the proratable water rights would be available. The hydrologic analysis also indicates the flow regime of the Yakima and Naches Rivers is not moved in the direction of the natural (unregulated) hydrograph. The natural (unregulated) hydrograph is the template currently being used to evaluate the instream flow water supply goal. In the hydrologic analysis, we have assumed that the municipal water supply goal is achieved by these three alternatives. Additional work on the future municipal water supply needs will occur in the Plan Formulation Phase.

Our analysis showed that the current operational hydrograph of the Bumping and Naches Rivers mimics the shape of the natural (unregulated) hydrograph, and constructing a new larger Bumping Lake dam would move the flow regime even further from the natural (unregulated) hydrograph. In addition, a stakeholder pointed out that the potential new reservoir would inundate some bull trout spawning habitat on Deep Creek and about 1 mile of stream habitat in the Bumping River. Stakeholders indicated they did not think that Reclamation should consider the enlarged Bumping Lake in the Plan Formulation Phase of the Storage Study.

The integrated hydrologic analysis showed that constructing the Wymer dam and reservoir would not move the hydrograph in the Yakima River toward a natural (unregulated) hydrograph, but would help meet the Title XII target flows at the Parker gauge. Most of the stakeholders expressed the desire to analyze the Wymer reservoir feature again with different parameters to determine if there would be benefits to the fishery that may not be apparent using the natural (unregulated) hydrograph measurement of the benefit.

The modeling Reclamation has done on the Keechelus-to-Kachess pipeline indicates that the additional stored water supply would be negligible.

We heard concerns that the parameters used to indicate whether an alternative creates a return to a more natural (unregulated) hydrograph need to be better defined. For this phase of the Storage Study, those parameters are measured on a broad scale using average annual flows over a 23-year period. The concern was that this broad scale method of measuring parameters will not provide an accurate measurement of benefits to the threatened and endangered fishery in the Yakima River.

We will consider all the concerns we heard as we decide which alternatives should be analyzed in the Plan Formulation Phase of the Storage Study. We will continue to accept comments and or suggestions on this hydrologic analysis. The *Yakima River Basin Storage Alternatives Appraisal Assessment* is due to be released later this spring and will contain our recommendations on which, if any, of these three alternatives will be included in the Plan Formulation Phase of the Storage Study.

If you have any questions or comments, please contact Mr. Kim McCartney at 509-575-5848, extension 370, or at the address above. We are still available and willing to provide the stakeholder groups listed in this letter a presentation on the Hydrologic Analysis and answer any questions.

Sincerely,

/s/ Gerald Kelso

Gerald W. Kelso
Area Manager

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