2011 Washington State Legislative Report

Columbia River Basin

Long-Term Water Supply and Demand Forecast

Submitted Pursuant to RCW 90.90.040 by:

DEPARTMENT OF ECOLOGY State of Washington in collaboration with WASHINGTON STATE UNIVERSITY

Washington Department of FISH and WILDLIFE

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The 2011 Columbia River Basin Long-Term Water Supply and Demand Forecast was prepared by Washington State University for the Washington State Department of Ecology.

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Definitions of Water Supply and Water Demand Terms Used in the 2011 Forecast

Surface Water Supply

Surface Water Supplies incorporate the impacts of operations of major reservoirs on the Columbia and Snake Rivers, as well as the major reservoirs in the Yakima. Thus, with the exception of Yakima (WRIAs 37, 38, and 39), water supplies at the watershed (WRIA) level are "natural supplies", without consideration for reservoirs. Supplies reflect supply prior to accounting for demands. They should not be compared to observed flows, which do account for demands through withdrawals for irrigation and other out-of-stream uses.

Groundwater Supplies were not modeled for the 2011 Forecast due to time and resource constraints. Addressing this limitation will be a major focus of the 2016 Forecast.

Historical Supplies indicate surface water supplies for 1977-2006. This time period was selected based on the available data as the most appropriate comparison point for the future period.

2030 Forecast Supplies indicate forecast supplies for the 2030s decade. Major reservoir operations are assumed not to change in response to changes in forecasted 2030 water supply. While this assumption may not be realistic, it was impractical to predict what management changes might occur.

Water Demand

Water Demands are derived under the baseline economic scenario unless otherwise noted. The baseline is defined to include medium domestic economic growth, medium growth in international trade, and no changes in water pricing or water supply capacity.

Agricultural Water Demand represents demand for water as applied to crops, often referred to as "top of crop". This includes water that will be used consumptively by crops, as well as water resulting from irrigation application inefficiencies (such as evaporation, drift from sprinklers, or runoff from fields). In comparing these demands to supplies, it is important to include additional water to account for conveyance losses, such as occurs when transporting diverted water in unlined channels.

This is a physical, rather than an economic definition, where the latter would reference the quantity demanded at specific prices. Agricultural water demand is forecasted under a projected crop mix that takes into account changes in domestic economic growth and growth in international trade. The land base in agriculture is assumed to be the same. The forecast does not incorporate improvements in irrigation efficiency or changes in crop mix that might be adopted by producers in response to limitations in water availability.

Water that is not consumptively used by crops (including irrigation application inefficiencies and conveyance losses) percolates through the soil and returns to the groundwater or surface water system. Non-consumptive return flows may be available to users downstream although the time-lags vary considerably both in time and location. Thus some of the upstream water demand will be counted towards supply downstream of the original place of use.

Conveyance Losses indicate water that is lost as it travels through conveyance systems (which can range from unlined ditches to fully covered pipes). These losses vary widely and are difficult to assess, but have been estimated to average about 20% basin-wide. Because of increased uncertainty associated with these estimates, conveyance losses have been treated and shown separately from "top of crop" demands.

Municipal Demand includes estimates of water delivered through municipal systems, as well as water delivered through self-supplied domestic systems. For those municipalities where data allowed, it also includes municipally-supplied industrial water. It does not include self-supplied industrial water use. Municipal demand also has a consumptive portion and a non-consumptive portion, which includes water that is lost within the municipal system through system leakages and water that returns for wastewater treatment. Together, the consumptive and the non-consumptive portion represent municipal diversion demand.

Instream Water Demand was incorporated into water management modeling through state and federal instream flow targets. Within WRIAs, the highest adopted state and federal instream flows for a given month were used to express current minimum flows for fish in both historical and 2030 forecast instream demands. State and federal instream flows along the mainstem were also compared to historical and future supplies.

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June 14, 2012

The Honorable Christine Gregoire, Governor
Honorable Members of the Washington State Legislature
Olympia, Washington

RE: Columbia River Basin Long-Term Water Supply and Demand Forecast

Dear Governor Gregoire and Legislators:

The Office of Columbia River (OCR) continues to aggressively pursue development of conservation and water supply projects to meet eastern Washington's economic and environmental needs. To support this mission, every five years, OCR prepares and submits to the Washington State Legislature a long-term water supply and demand forecast. The first forecast was released in 2006. I am pleased to submit to you the second "Columbia River Basin Long-Term Water Supply and Demand Forecast (Forecast)."

The Forecast's purpose is to help OCR effectively plan and implement water supply projects by better understanding where additional water supply is currently needed and where it will be needed in the future. The results will guide OCR in investing in capital infrastructure projects to meet both instream and out-of-stream needs.

To develop the 2011 Forecast, OCR contracted with Washington State University (WSU) to conduct the agricultural, municipal and industrial, and hydropower components of the Forecast. Climate change impacts were also considered and incorporated into the results, both on the supply and demand side. The Washington State Department of Fish and Wildlife developed a "Columbia Basin Instream Atlas" that reports on flows and fish life stages in eight critical basins.

Stakeholders played an important role in the Forecast's development. The Columbia River Policy Advisory Group, watershed planning units and the general public provided valuable input that helped the researchers refine the methodology. WSU's methods and models were peer-reviewed by four national experts in economic, modeling and regional water issues.

The results demonstrate that the state is unable to meet the current demand for instream and out-of-stream uses in eastern Washington. Water shortages exist in many watersheds, and regulation of out-of-stream uses in response to both senior water right holders and adopted instream flows is common. Adopted instream flows in watersheds regularly go unmet, with late summer being a time of particularly acute competition among fish, farms and people for the limited resource. Climate change and increased growth will bring additional pressure on these uses.

Nevertheless, the Forecast predicts a healthier future on which OCR has already begun to deliver. OCR has embarked on numerous projects that are already improving supply, with approximately 150,000 acre-feet already developed and another 200,000 acre-feet anticipated. With the money appropriated by the legislature, OCR is making progress on issuing new permits, improving flows for fish, converting declining groundwater users in the Odessa to surface water and reducing drought risk for interruptible water right holders. The Forecast is a valuable tool that will assist OCR in making smarter investments and help the state improve water supply for existing users, while meeting new growth needs.

Sincerely,

Ted Sturdevant, Director
Washington State Department of Ecology

Derek I. Sandison, Director
Office of Columbia River

Executive Summary

Since its establishment in 2006, the Department of Ecology's Office of Columbia River (OCR) has rapidly improved water supply for eastern Washington, with approximately 150,000 acre-feet (ac-ft) of water supply already developed and another 200,000 ac-ft in near-term development. Consistent with its legislative directives, OCR is developing a portfolio of diverse projects including modification of existing storage, new storage facilities, conservation piping and canal lining projects, transmission piping projects, and water right acquisitions. Every five years, OCR is required to submit a long-term water supply and demand forecast (Forecast) to the Legislature.

This 2011 Forecast was developed by OCR in collaboration with Washington State University (WSU) and the Washington Department of Fish and Wildlife (WDFW). The Forecast will help OCR strategically fund water supply projects by improving understanding of where additional water supply is most critically needed, now and in the future. The Forecast provides a generalized, system-wide assessment of how future environmental and economic conditions are likely to change water supply and demand by 2030. It also analyzes the impacts likely to occur if additional water is made available to users, though it does not consider the benefit-cost ratio of any individual project.

The Forecast evaluated surface water supply and demand at three geographic tiers: the entire Columbia River Basin, eastern Washington's watersheds and Washington's Columbia River mainstem. A general survey was carried out for the entire basin with in-depth analysis for the watersheds and mainstem. For the supply analysis, the Forecast focused on surface waters. It is recognized that groundwater supplies play a significant role in many parts of eastern Washington, but due to time, resource, and data constraints, groundwater supplies will be more comprehensively addressed in future forecasts. For this report, with the exception of the Odessa, it was assumed that demands met by groundwater supplies would remain groundwater in the future.

Using state of the art modeling techniques and economic scenarios, WSU evaluated the impacts of climate change, regional and global economic conditions and state level water management actions on surface water supplies and irrigation demands across the Columbia River Basin. At the basin level, these modeling results were supplemented with a survey of basin water managers across the region. To forecast water supplies, five different climate change scenarios, adapted for our study by the Climate Impacts Group at the University of Washington, were used.

On the demand side, irrigation demands were forecasted for roughly 40 primary Washington crop types over a broad range of alternative scenarios including climate change, economic scenarios, increased water capacity through development of water supply projects, and various cost recovery rates for water supply development. Municipal demand forecasting (including self-supplied domestic use) was forecasted in the Washington portion of the basin using data from county level population estimates from the Office of Financial Management, combined with data in water treatment plant and water system plans submitted to the Washington State Department of Health. For those municipalities where data allowed, industrial growth was also included. For hydropower demands, this report summarizes and incorporates existing planning efforts, supplementing with interviews.

For instream flow requirements, OCR compared the period of record historic flow data for dry, average and wet years to regulatory instream flow requirements for the Columbia River's mainstem and its major tributaries. Supplementing the work done by OCR, WDFW's "Columbia River Instream Atlas" (Atlas, Ecology Publication 11-12-015) assessed eight fish and low flow critical watersheds: Walla Walla, Middle Snake, Lower Yakima, Naches, Upper Yakima, Wenatchee, Methow, and Okanogan. One hundred eighty-nine stream reaches were evaluated for their potential to improve natural fish production through stream flow enhancement. Stream reaches were scored on three critical components: fish stock status and habitat utilization, fish habitat condition, and stream flow.

Surface Water Supply in the Columbia River Basin

Modeling forecast results for 2030 suggest that compared to historical (1977-2006) supplies:

- A small increase of around 3.0 (±1.2)% in average annual supplies will occur.[1]
- Timing changes will shift water away from the times when demands are highest. Unregulated surface water supply at Bonneville will decrease an average of 14.3 (±1.2)% between June and October by 2030, and increase an average of 17.5 (±1.9)% between November and May.
- Annual water supplies entering Washington are forecasted to increase for most rivers entering the eastern portion of the basin, and the direction of change is unclear for most rivers entering the northern portion of the basin.
  - Annual water supplies entering Washington will increase by approximately 3.7 (±1.3)% on average for the Columbia, Pend Oreille, Spokane, Clearwater, Snake, and John Day Rivers by 2030.
  - The direction of change for annual water supplies entering Washington is unclear for the Similkameen and Kettle Rivers, +1.4 (±1.9)% on average by 2030.

1 When discussing modeled supply and irrigation demand results, "average flow conditions" refers to the 50th percentile (middle) value under the middle climate scenario. "Average" by itself refers to the average value over all climate scenarios and flow conditions, and a 90% confidence interval around that average.

The regional survey of water managers throughout the Columbia River Basin was used to complement modeling results. Given that modeling assumed similar management in 2030, and did not anticipate large new water supply projects outside of Washington, in upstream portions of the Columbia River Basin, the survey was a useful tool. The survey revealed that efforts to improve flow or aquatic habitat conditions in portions of the Columbia River Basin outside of Washington state typically involve relatively minor changes to management of winter or peak flows at existing projects. Little definitive action is currently being taken to build large water infrastructure projects due to a lack of funding and willingness to pay for water. Overall, the results of the survey confirmed that the current upstream management scheme could be used for modeling.

The survey also indicated that a lack of regional and cross-jurisdictional communication hampers planning efforts. Improving communication may be a first step to creating more purposeful opportunities for partnership.

Annual surface water supplies within the Washington portion of the Columbia River Basin are expected to increase for most tributaries of Washington:

- Walla Walla (7.2 ±1.9%)
- Palouse (5.9 ±3.6%)
- Colville (9.5 ±2.8%)
- Yakima (4.4 ±2.3%)
- Wenatchee (5.9 ±1.8%)
- Chelan (5.8 ±1.5%)
- Methow (7.7 ±2.3%)
- Okanogan (4.3 ±2.4%)
- Spokane (6.6 ±2.2%)

Within the Washington portion of the Columbia River Basin, the Forecast shows a fairly consistent pattern in changes of surface water supply timing, with higher flows in late fall, winter and spring by 2030, and lower flows in the summer and early fall. Exact timing varies by watershed.

Cumulative Water Demands in the Washington State Portion of the Columbia River Basin

This section presents cumulative forecasted demands for the Washington state portion of the Columbia River Basin. These results should be understood within a likely context of increasing demands across the entire Columbia River Basin, particularly during summer low flow conditions.

Historical (1977-2006) out-of-stream diversion demands within the Washington state portion of the Columbia River Basin for municipal and agricultural irrigation water (excluding irrigation conveyance losses) were estimated to be in the range of 6.3 (±0.1) million ac-ft. Forecasted increases in water demands in eastern Washington for 2010 to 2030 are summarized in Table ES-1. The Forecast anticipates

- 170,000 (±18,000) ac-ft per year of additional *total* (ground and surface) water agricultural irrigation demand. This number assumes no change in irrigated acreage, and no additional water supply development. This number represents demands for surface and groundwater as applied to crops, plus the additional water needed to account for irrigation application inefficiencies.
- 430,000 (±14,000) ac-ft per year of additional *surface* water agricultural demand. This number includes new demands that will be met only by surface waters, and assumes that historical groundwater irrigation demands in the Odessa area will be new surface water demands in the future.
- 117,500 ac-ft per year in additional total diversion demands for municipal and domestic water.
- 500,000 ac-ft per year of unmet tributary instream flows, and 13.4 million ac-ft per year of unmet Columbia River mainstem instream flows, based on observed deficits during the 2001 drought year.
- No demand for new water storage for hydropower generation purposes.

Table ES-1. Forecast increases in demands by sector from 2010 to 2030 in eastern Washington.

Demand Type	Estimated Volume (acre-feet)	Source
2030 New Irrigation Demand[a]	170,000	WSU Integrated Model
2030 New Municipal and Domestic Demand (including municipally-supplied commercial)	117,500	WSU Integrated Model
Unmet Columbia River Instream Flows[b]	13,400,000	Ecology data, McNary Dam, 2001 drought year
Unmet Tributary Instream Flows[c]	500,000	Ecology data, tributaries with adopted instream flows, 2001 drought year
2030 New Hydropower Demand	0	WSU Surveys and Planning Forecast Review
Alternate Supply for Odessa	164,000	Odessa Draft Environmental Impact Statement (October 2010)
Yakima Basin Water Supply (pro-ratables, municipal/ domestic and fish)	450,000	Yakima Integrated Water Resource Management Plan (April 2011)
Unmet Columbia River Interruptibles	40,000 to 310,000	Ecology Water Right Database (depending on drought year conditions)

[a] Additional irrigation demands were modeled assuming an equivalent land base for irrigated agriculture, under a scenario of medium growth in the domestic economy, and medium growth in international trade. Acreage currently irrigated by groundwater in the Odessa was assumed to be new surface water demand in 2030, and thus is not reflected in changes in total demand, which includes both surface and groundwater. Increases in total demand are thus due to the combined impacts of climate change, and changes in crop mix driven by growth in the domestic economy and international trade.

[b] Unmet Columbia River instream flows are the calculated deficit between instream flows specified in Washington Administrative Code (WAC) and 2001 (drought condition) actual flows at McNary Dam.

[c] Unmet tributary instream flows are the combined deficits between current instream flows specified in WAC and 2001 actual flows at Walla Walla River near Touchet, Wenatchee River at Monitor, Entiat River near Entiat, Methow River near Pateros, Okanogan River at Malott, Little Spokane River near Dartford, and Colville River at Kettle Falls.

New irrigation and municipal demands do not include improvements in conservation, which could decrease the new demands that need to be met, but might also have complex impacts on return flows. For example, if all municipal and domestic users were able to conserve 10% of their water supplies by 2030, then new municipal demand might drop from 117,500 ac-ft to about 105,000 ac-ft. However, many municipal conservation techniques are non-consumptive in nature. For example, fixing leaky pipes and installing low flow showers and toilets reduce diversions, but with a corresponding reduction in water returned (via wastewater treatment plants or underground). Alternatively, some conservation measures, such as reducing lawn size, do reduce consumptive use. In addition, conservation is often less expensive than new water supply development.

In addition to these new demands by sector, other studies suggest several areas of unmet demand, some of which are not reflected in these totals. These other studies used different methods of calculating demand, and thus, should not be directly compared to the totals above.

- The draft Environmental Impact Statement for Odessa suggests a preferred alternative of supplying 164,000 ac-ft per year of surface water to current groundwater users in this area. This amount is not included in the total irrigation demands above, which shows changes in total (combined groundwater and surface water) demand between the historical period (which includes Odessa) and 2030.
- The Yakima Integrated Water Resource Management Plan suggests that 450,000 ac-ft per year will be needed for pro-ratable, municipal-domestic and fish needs. These demands overlap partially with the demands shown above.
- The Ecology Water Right Database indicates that in years in which the Mainstem Drought Program is run, there are 40,000 to 310,000 ac-ft per year of unmet needs by interruptible water users, depending on the drought year conditions. These amounts are currently unmet, so are not reflected in the numbers above.

Together, these current and new demands are likely to exacerbate water supply issues in some locations, particularly during the summer.

Water Demands in the Columbia River Basin by Sector

Agricultural Water Demands

The agricultural portion of the Forecast focused on irrigation water demands. The 2030 forecast of demand for irrigation water across the entire Columbia River Basin (seven U.S. States and British Columbia) was 13.6 million ac-ft under average flow conditions, assuming an equivalent land base for irrigated agriculture in the future (Table ES-2). The range of estimates was from 13.1–14.1 million ac-ft during wet and dry years, respectively (20th and 80th percentile).[2] This irrigation demand was roughly 2.5% above modeled historic levels under average flow conditions. Conveyance losses, that occur as water is transported through irrigation ditches and canals, were estimated separately.

Table ES-2. Top of crop agricultural demands under the baseline economic scenario (medium domestic economic growth and medium growth in international trade), excluding conveyance losses, in the Columbia River Basin in the historical and 2030 forecast period. Estimates are presented for average years, with range in parentheses representing wet (80th percentile) and dry (20th percentile) years.

	Historical (1977-2006) million ac-ft per year	**2030 Forecast million ac-ft per year**	**% Change**
Entire Columbia River Basin	13.3 (12.6-13.9)	13.6 (13.1-14.1)	2%
Washington Portion of the Columbia River Basin	6.3 (6.0-6.5)	6.5 (6.2-6.6)	2%

Seasonal timing of forecasted water supply and irrigation water demand is shown in Figure ES-1, with irrigation demands taking a larger proportion of water supplies in summer months by 2030. Instream, hydropower and municipal water demands will also need to be met from these water supplies.

2 On average, one in five years will be wetter than the 80th percentile, or drier than the 20th percentile.

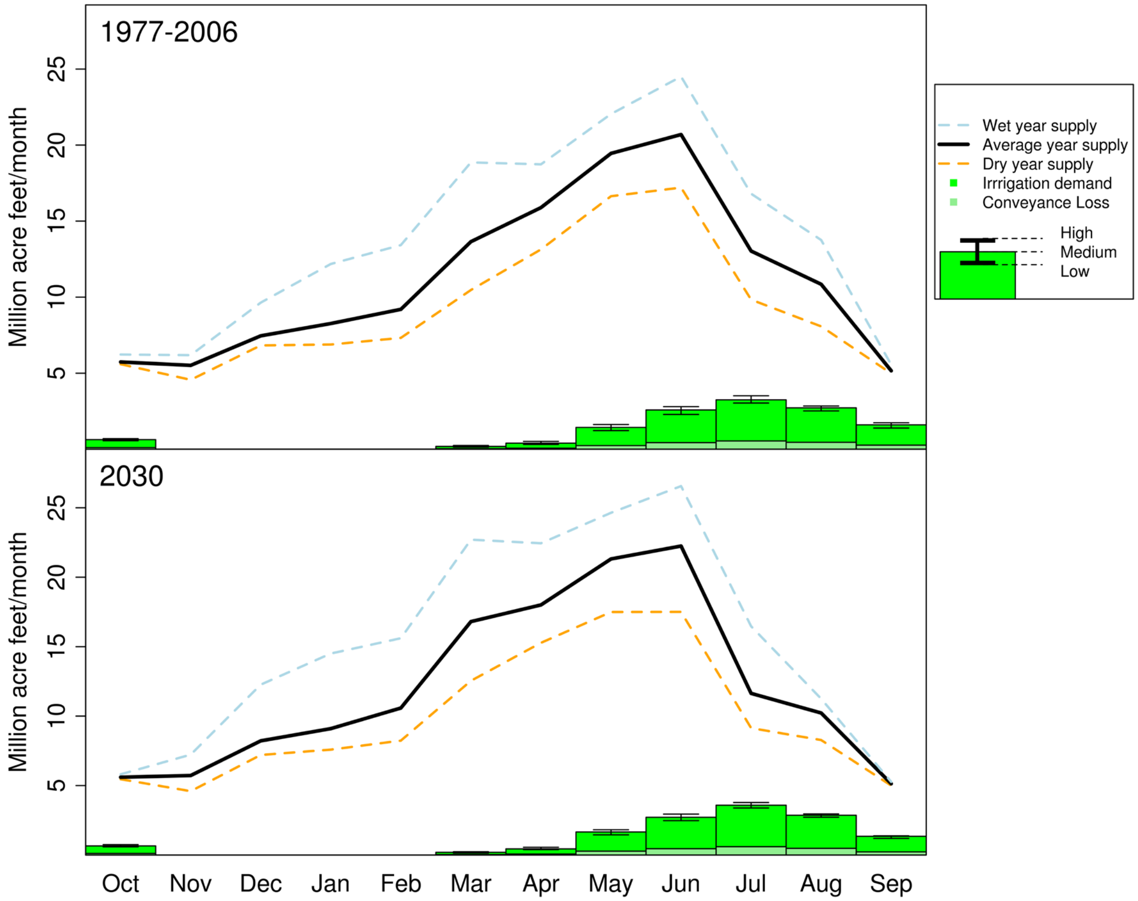


Figure ES-1. Comparison of regulated surface water supply and surface water irrigation demands for the historical (top) and 2030 forecast (bottom) periods under the medium-growth, medium-trade economic scenario across the entire Columbia River Basin, including portions of the basin outside of Washington state. Wet (80th percentile), dry (20th percentile), and average (50th percentile) flow conditions are shown for both supply and demand.

Within the Washington state portion of the Columbia River Basin, results were similar (Table ES-2):

- Forecast increases in irrigation water demand were an average of 170,000 (±18,000) ac-ft per year, roughly 1.9% above historical conditions, assuming an equivalent land base for irrigated agriculture, and a crop mix influenced by medium growth in the domestic economy and international trade.
- Considering only the climate impacts of temperature and precipitation variations on the irrigation demand, there would be a 3.7% increase in demand. When economic impacts resulting in a new crop mix are considered in addition to the climate effects, the increase in demand reduces to 1.9%.

Modeling under alternate economic scenarios was used to give information about the potential range of future water demands from irrigated agriculture, if growth in the domestic economy and international trade were higher or lower than anticipated.[3] Higher income growth leads to an expansion of high value crops like fruits and vegetables at the expense of low value crops. Similarly, stronger growth in exports has a disproportionate impact on higher value crops, although wheat and alfalfa are also sensitive to fluctuations in trade. Production patterns were generally more sensitive to assumptions about trade than to assumptions about economic growth. One exception was wine grapes where most of the growth in demand is expected to come from domestic consumers rather than international exports.

- The low, medium and high economic scenarios forecasted increases of 200,000 (±17,000) ac-ft, 170,000 (±18,000) ac-ft and 140,000 (±18,000) ac-ft over historical demands under average flow conditions within the Washington portion of the Columbia River Basin.
- These estimates assumed no change in the land base for irrigated agriculture, thus differences in the agricultural water demand between different scenarios were due to changes in crop mix and crop water demands under future climate conditions.

Additional scenarios considered the potential impacts of additional water capacity in specific locations corresponding to projects proposed by OCR. Under some scenarios, new water was provided at no cost to users, while in other scenarios, users were charged per unit fees to recover some development costs.

- The development of roughly 200,000 ac-ft of annual water capacity (the medium scenario considered) caused demand for irrigation water to increase by 46,400 (±640) ac-ft per year over baseline 2030 demands (under the medium economic scenario) in the Washington portion of the basin.[4]

3 Domestic economic growth was 1.3-1.8% under low and high scenarios, while international trade included scenarios of low and high growth in trade for specific crop groups (e.g. vegetables, wheat, etc.).
4 Under this water capacity scenario, 164,000 ac-ft was developed to meet current agricultural demand in the Odessa, with the rest serving new demands.

Municipal Water Demands

Municipal demands, including domestic and municipally-supplied industrial, are likely to increase throughout the entire Columbia River Basin over the next 20 years. By 2030, U.S. Census estimates show population growth in Idaho (25.6%), Oregon (26.2%), and Montana (5.6%). Although some new municipal demands will likely be met by deep groundwater supplies, others will likely come from shallow groundwater or surface water. These additional demands will likely reduce inflows into some parts of Washington. For example, an Idaho study of the Spokane River basin projected an additional demand on the river of 31 cfs by 2060.[5]

Within eastern Washington, the Forecast found that:

- Domestic and industrial diversion demands in rural and urban areas (excluding self-supplied industries) were forecasted to be 569,000 ac-ft per year in 2030, an estimated 26% increase over 2010. Consumptive demands are approximately 51% of this amount.
- Per capita water demands varied considerably throughout eastern Washington, with an average total demand (including system losses) of approximately 277 gallons per capita per day (gpcd).[6]

Instream Water Demands

Across the Columbia River Basin, the Forecast found that:

- Decreases in surface water supplies in summer and early fall may increase the challenge of meeting water needs for fish across the Columbia River Basin by 2030.
- Re-negotiation of the international Columbia River Treaty could change the amounts and timing of water available to meet instream needs in the Columbia River mainstem.
- Quantification of tribal water rights, while outside the scope of this Forecast, could also change surface water supplies for meeting instream demands in unpredictable ways.

5 31 cfs = 22,443 ac-ft/year
6 277 gallons per day = 0.429 cfs = 311 ac-ft/year

Within eastern Washington, the forecast of demand for water to support instream flows found the following:

- In many rivers in eastern Washington, stream flows are below state or federal instream flow targets on a regular basis, particularly in late summer. Surplus water exists in many of these same rivers at other times of year.
- Decreases in surface water supplies in tributaries in summer and early fall may lead to more weeks when instream flows are not met by 2030. This may result in a higher frequency of curtailment of interruptible water right holders in basins with adopted instream flow rules.
- An evaluation of fish, flows, and habitat in eight fish critical basins, available in the Atlas (Ecology Publication 11-12-015), will help target investments to maximize the positive impact on fish populations.

Hydropower Demands

Across the Columbia River Basin, the forecast of hydropower demands found the following:

- Demand for water storage to supply hydropower facilities is anticipated to remain unchanged in 2030. Utilities expect to be able to meet projected steady growth in peak winter and summer energy demands through conservation and integration of other energy sources, including those required under Washington's passage of Initiative 937.
- Several power entities are concerned that climate change and the possible renegotiation of the international Columbia River Treaty will affect hydropower generation capacity.

Water Demands in Washington State Watersheds

Surface water supplies and water demands were forecasted for each Water Resource Inventory Area (WRIA) in eastern Washington. Major results for each WRIA are presented at the end of this report. Cumulatively, the following results were found:

- The greatest concentration of current and future agricultural irrigation and municipal water demands are in the southern and central Columbia basin, including Lower Yakima (37), Lower Crab (41), and Esquatzel Coulee (36), as well as Rock-Glade (WRIA 31), Walla Walla (32), Lower Snake (33), Naches (38), Upper Yakima (39), and Okanogan (49). Irrigation dominates the demand for water in these WRIAs.

- Unmet demand due to curtailment of interruptible and pro-ratable water rights or insufficient water at the watershed scale was forecasted for Walla Walla (WRIA 32), Yakima (37, 38, & 39), Wenatchee (45), Methow (48), Okanogan (49), Little Spokane (55), and Colville (59).
- Unmet demand for surface water was forecasted for the Odessa due to existing groundwater declines in Palouse (WRIA 34), Esquatzel Coulee (36), Lower Crab (41), Grand Coulee (42), and Upper Crab (43).

Surface Water Supply and Demand on Washington's Columbia River Mainstem

Modeled historical and 2030 forecasted surface water supplies were compared to state-level instream flow targets and the Federal Columbia River Power System Biological Opinion (FCRPS BiOp).

- Under normal flow conditions, modeled regulated surface water supplies *prior to* meeting cumulative demands were close to Washington State instream flow regulations in fall/early winter at Priest Rapids Dam (both historical and 2030 forecast), and in July and August at Priest Rapids Dam and McNary Dam (for the 2030 forecast).
- Under normal flow conditions, modeled regulated surface water supplies *prior to* meeting cumulative demands were not sufficient to meet target flows under the FCRPS BiOp in April, July, and August at McNary Dam, and from November through January at Bonneville Dam. Imbalances were smaller in the 2030 forecast than the historical case for the late winter/spring months, and larger for the late summer.
- Along the mainstem, there are 379 interruptible water rights, the majority of which are agricultural surface water rights. These water users are particularly vulnerable to the potential impacts of water shortages.

Conclusion

Collectively, these results suggest that meeting water demands will be more challenging by 2030 as increased demands are placed on limited supplies. Solutions will require combinations of conservation, water banking/marketing, and new supplies based on groundwater and/or storage of water in peak runoff seasons.

For solutions requiring additional investment in water supply infrastructure, the Forecast's results suggest that at prices in the range of those currently being charged by the Office of Columbia River for new water it may be feasible to recover some or all water supply costs from new users without significantly decreasing the quantity of water demanded by users.

Projects associated with the medium water capacity scenario of an additional 200,000 ac-ft per year for out-of-stream uses were estimated to lead to total employment impacts (including indirect and induced effects) of 6,600 jobs. State and local tax impacts were estimated at about $37 million. These estimates do not subtract the jobs and taxes associated with production if land associated with the new capacity was previously under dryland cultivation. These estimates include economic activity generated from post-farmgate processing of agricultural products that occurs within Washington. While not quantified, it is recognized that maintenance of and improvement to instream flows would also have positive economic impacts on tourism and recreation, generating additional jobs and tax revenues.

This Forecast improves our understanding of future surface water supplies and instream and out-of-stream demands, and will serve as a capital investment planning tool to maintain and enhance the region's economic, environmental, and cultural prosperity. Future forecasts will build upon and expand this knowledge to include assessments of groundwater supplies, the Columbia River Treaty and other pertinent issues.

Meeting Eastern Washington's Water Needs

The Columbia River Basin is the fourth largest watershed in North America in terms of average annual flow, encompassing all or parts of seven western states and British Columbia. For thousands of years, the river has shaped the economy and lives of those who lived near it. Over the past two hundred years, the basin has been extensively developed for hydropower generation, irrigation, navigation, and flood control. The river is also managed for the protection of salmonid species listed under the Endangered Species Act, municipal and industrial supplies, maintenance of water supplies in accordance with tribal treaties, and recreation. This creates a myriad of competing demands. Reliable access to water is essential for existing and future regional economic growth and environmental and cultural enhancement. Seasonal variations in water supply and demand have resulted in localized shortages with increasing regularity due to population growth, climate variability and change, and increased implementation of regulatory flow requirements. The competing demands on the region's fresh water resources will only increase in the future, particularly in summer months when demands are high.

Irrigation near Kahlotus

Weber Siphon project in Grant Co.

Cornfield near Toppenish

The Office of the Columbia River

Recognizing that development of new water supplies for eastern Washington is a priority concern, the Legislature passed Chapter 90.90 RCW, directing the Department of Ecology (Ecology) to aggressively develop water supplies for instream and out-of-stream uses. The Office of Columbia River (OCR), formed as a result of this legislation, has a mission to develop water supplies for the following purposes:

- Addressing aquifer decline in the Odessa Subarea by replacing groundwater sources with surface water sources.
- Permitting new water rights.
- Securing water for drought relief.
- Providing water for instream flows to benefit fish.

Water supplies developed under this program are to support both instream and out-of-stream uses. For new storage projects, two-thirds of the supply developed must be allocated for out-of-stream uses and one-third for in stream uses. Since 2006, OCR has funded a variety of water supply projects consistent with the four legislative directives (Figure 1). With approximately 150,000 acre-feet (ac-ft) of water supply already developed and another 200,000 ac-ft in near-term development, OCR is rapidly improving water supply for eastern Washington.[7] OCR is developing a portfolio of diverse projects including modification of existing storage (e.g. Lake Roosevelt and Sullivan Lake), new storage facilities (e.g. Kennewick, Boise and White Salmon aquifer storage projects), conservation piping and canal lining projects (e.g. Red Mountain AVA (American Viticultural Area), Barker Ranch, Manastash, and Columbia Basin Irrigation District projects), transmission piping projects (e.g. Potholes Supplemental Feed Route and Weber Siphon), and water right acquisitions.

7 Developed water supplies have been constructed and Ecology is in the process of permitting new secondary water uses. Near-term refers to those projects that OCR is currently constructing, or is conducting the environmental review and permitting for the water supply.

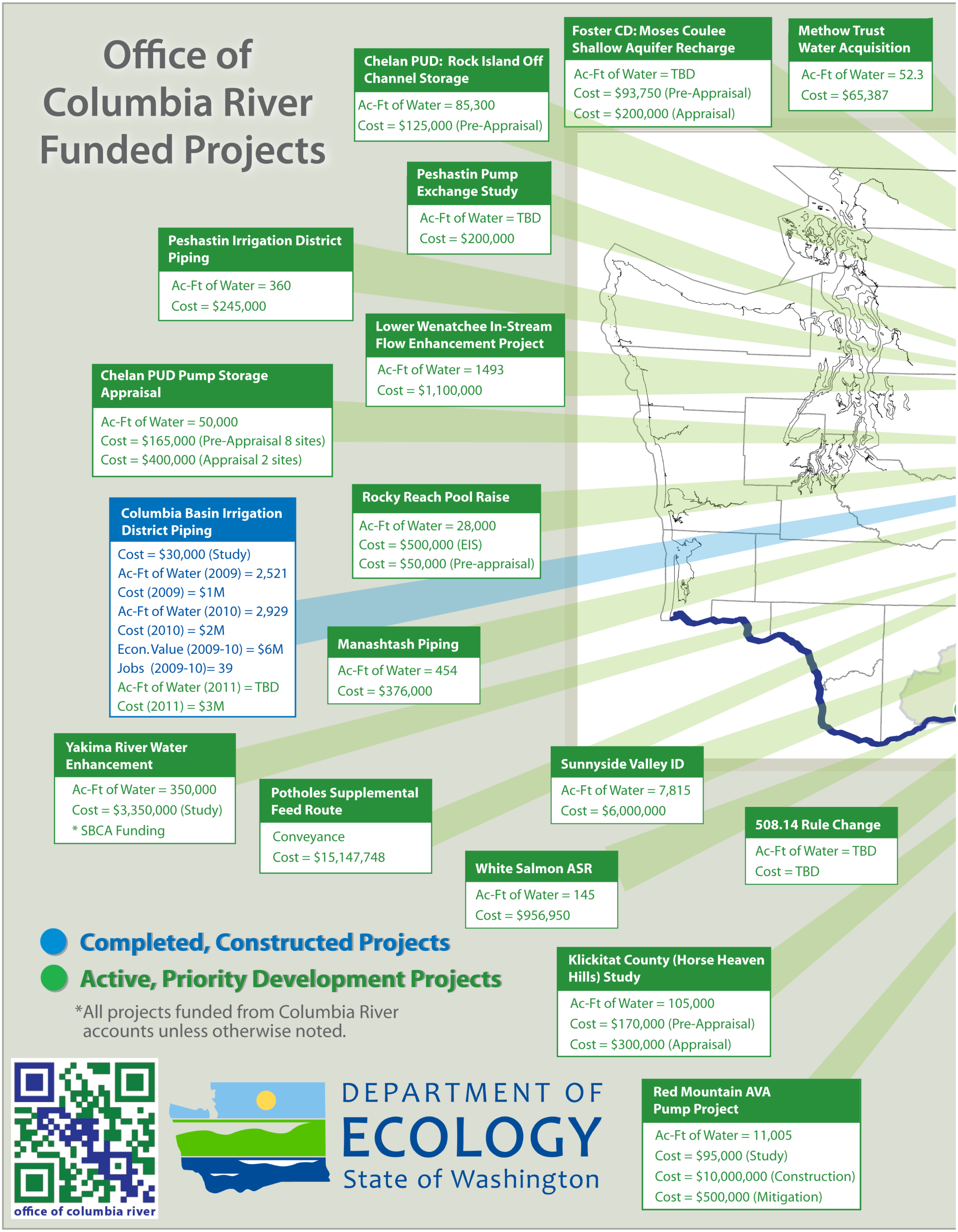


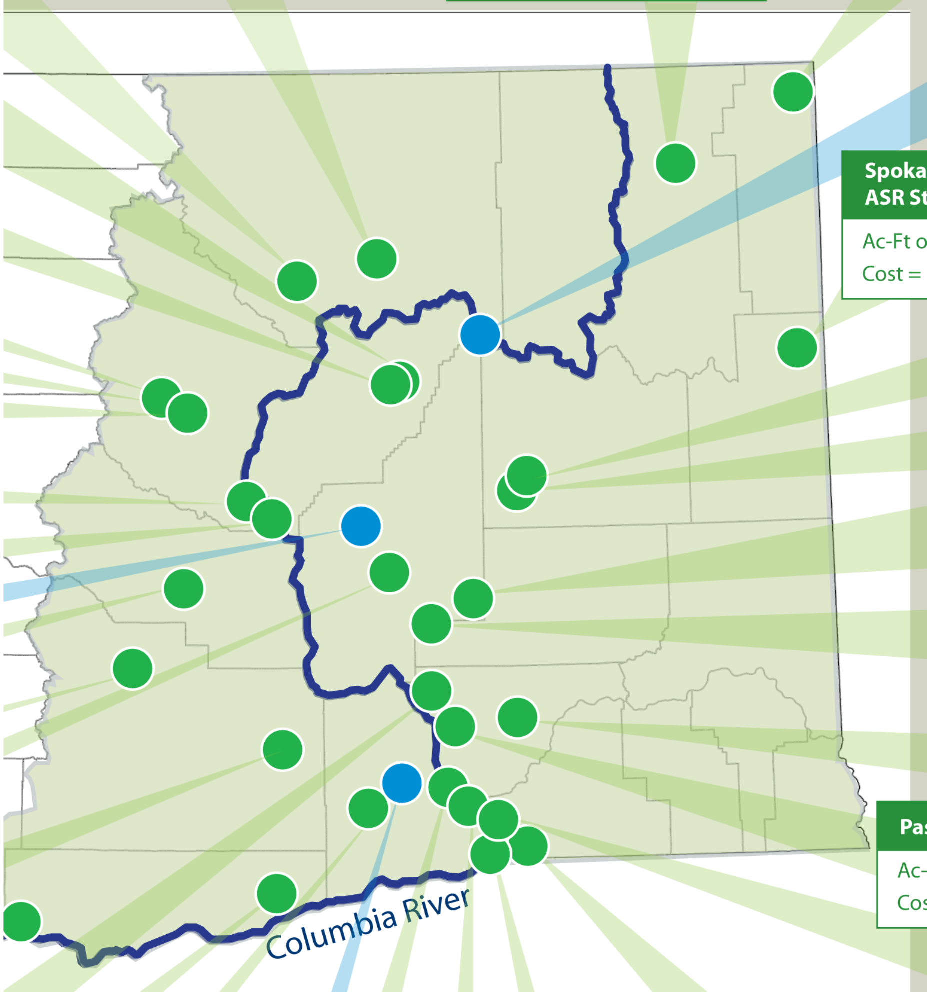
Figure 1. Projects funded by the Office of Columbia River

Goose Lake & 9 Mile Flat Water Storage (Colville Tribe)
Ac-Ft of Water = 4,750,000
Cost = $600,000 (Pre-Appraisal)

Mill Creek Storage Study
Ac-Ft of Water = 2,000-11,000
Cost = $125,000 (Pre-Appraisal)
Cost = $425,000 (Appraisal)

Sullivan Lake Water Supply
Ac-Ft of Water = 14,000
Cost = $14,000,000

Lake Roosevelt Incremental Storage Releases
Ac-Ft of Water = 132,500
Cost = $4,861,000 (+ $5.6M, annually)
Econ. Value = $3B (Muni/Industrial)
Jobs = 35,000 (Muni/Industrial)
Econ. Protected = $1.1B/yr (Odessa)
Jobs Protected = 784 (Odessa)
Econ. Protected = $9.5M/yr (Drought)
Jobs Protected = 140 (Drought)



Spokane-Rathdrum ASR Study
Ac-Ft of Water = TBD
Cost = $250,000 (Study)

Columbia Basin Groundwater Mgmt Area (GWMA) Study
Ac-Ft of Water = TBD
Cost = $1,000,000

Passive Rehydration (Lincoln County CD) Feasibility Study
Ac-Ft of Water = 300,000
Cost = $925,000 (Study)

Weber Siphon
Conveyance
Cost = $800,000

Odessa Subarea
Ac-Ft = 176,343 - 347,137
Cost = $8,223,469 (Study)
Cost = $841.6M - $3.314B (Construction)

Conservation Commission Irrigation Efficiencies
Ac-Ft of Water = TBD (Regional)
Cost = $ 2,000,000

Pasco Water Supply
Ac-Ft of Water = 5,000
Cost = $3,175,200

Port of Walla Walla Leases
Ac-Ft of Water = 4,769
Cost = $500,745

Boise Cascade ASR
Ac-Ft of Water = 1,657
Cost = $6,000,000

Kennewick ASR
Ac-Ft of Water = 318+
Cost = $2,250,000

Walla Walla Pump Exchange
Ac-Ft of Water = 30,000
Cost = $600,000 (EIS)
Cost = $40M (Construction)

Barker Ranch Canal Piping
Ac-Ft of Water = 6,436
Cost = $5,600,000
Jobs = 71
Econ. Value = $10,890,000

Franklin CD IWM Study
Ac-Ft of Water = TBD
Cost = $78,000 (Study)

Region-Wide Projects

Chelan PUD Columbia Treaty Model Review
Ac-Ft of Water = TBD
Cost = $20,000

Supply & Demand Forecast Report
Demand Forecasted = TBD
Cost = $1,000,000 (Study)

Aquifer Storage & Recovery Exploration
Ac-Ft of Water = TBD (Regional)
Cost = $ 1,750,000

Conservation Commission Retiming Pilot
Ac-Ft of Water = TBD
Cost = $1,000,000

SRB & Tribal Fisheries Project
Ac-Ft of Water = TBD (Regional)
Cost = $ 1,000,000

updated 12/5/2011

Long-Term Water Supply and Demand Forecasting

Every five years, OCR develops a long-term water supply and demand forecast (Forecast) and submits it to the Legislature. The Forecast provides OCR with a better understanding of where additional water supply is currently needed, and where it will be needed in the future. OCR uses the Forecast as a capital investment planning tool. The primary purposes of the Forecast are to provide a generalized, system-wide assessment (not project-specific) of

- How future environmental and economic conditions are likely to change water supply and demand.
- Where OCR can invest in water supply projects that have the greatest chance of meeting new demand and improving flows for fish.

Grapevines near Chelan

Cherries in Lower Yakima Valley

Fruit crates in Union Gap

The 2006 Forecast

In 2006, OCR contracted with Golder Associates and Anchor Environmental to conduct the first forecast, with WSU researchers providing a forecast of future agricultural demand. Based on 2004 U.S. Geological Survey estimates and estimates of public water system use provided by the Washington State Department of Health, estimates of water use in 2000 for eastern Washington were 467,432 ac-ft per year for domestic and industrial (public and self-supplied), and 3,288,740 ac-ft per year for crop irrigation and golf courses.[8]

Estimates of future agricultural demand carried out by Golder and Anchor that were based on an analysis of water rights applications suggested a nine percent growth in annual irrigation water demand of about 211,323 ac-ft over the twenty years from 2005-2025. WSU used vector autoregression (a method that captures changes and relationships between variable, time-based data sets) and a survey of expert opinion of future crop prediction and water use for major crops. WSU's Forecast suggested a largely stable picture for future agricultural acreage, though with a large expected range, from nearly one million acres to a decrease of 750,000 acres. The differences between Golder/Anchor and WSU results were a result of the different underlying data and the large amount of uncertainty in both estimates. Projected growth in domestic and industrial demand (public and self-supplied) was projected to be approximately 94,500–109,400 ac-ft per year over the twenty years from 2005 to 2025, depending on the methods used.

The 2011 Forecast

The 2011 Forecast updates and expands the 2006 Forecast by delving more deeply into water supply and demand issues. To develop the 2011 Forecast, OCR partnered with Washington State University (WSU) to conduct the agricultural, municipal, and hydropower components of the Forecast, and the Washington Department of Fish and Wildlife (WDFW) to conduct the instream demand component of the Forecast. This 2011 Forecast, described more fully in the "Overview of the 2011 Forecast," uses state of the art biophysical modeling techniques incorporating the impacts of climate change, future regional and global economic conditions, and state level water management actions.

8 Lane, R.C. 2004. Estimated domestic, irrigation, and industrial water use in Washington, 2000. U.S. Geological Survey Science Investigations report 2004-5015. 16 pp. Available online at http://pubs.usgs.gov/sir/2004/5015/.

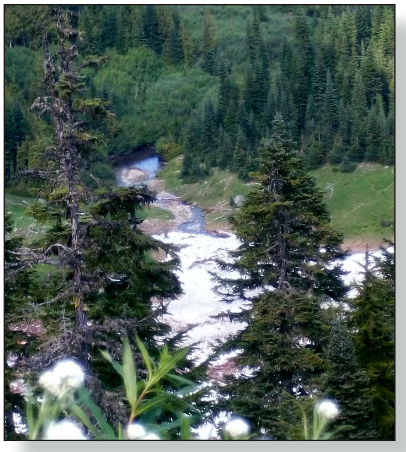
Bridge at The Dalles

Planned Improvements for the 2016 Forecast

The 2011 Forecast represents an initial effort to employ computer-based modeling to forecast water supply and demand. As such, it represents a major endeavor that OCR will use as a foundation for future forecasts. Improvements being considered for 2016 include the following:

- Incorporation of deep groundwater dynamics into water supply forecast. (Shallow subsurface/surface dynamics are captured in this 2011 report.)
- Adoption of new (AR5) climate model predictions.
- Full integration of economic and biophysical forecasting.
- Extension of economic analysis to cover the portions of the Columbia River Basin outside of Washington state.
- Development of non-agricultural demands.
- Development of economic modeling to include producer responses to water shortages beyond deficit irrigation.
- Extension of economic impacts analysis to include augmentation of streamflow.
- Expansion and update of the 2011 Columbia River Instream Atlas (Atlas).
- Inclusion of water supply and demand issues resulting from changes to the international Columbia River Treaty.

Climate Change and the 2011 Forecast



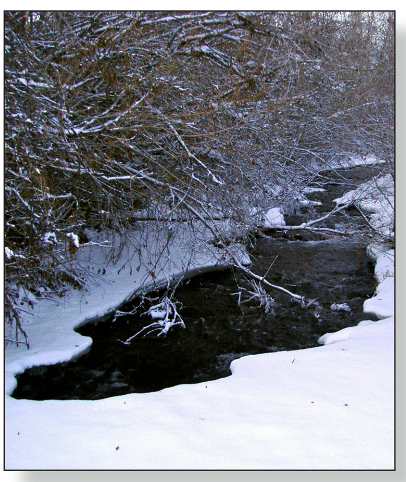
Melting snowpack into American River

Average temperatures are 1.5° F higher in the Columbia River Basin than they were a century ago, and are expected to increase by 2.5° F in the next 50 years.

The characteristics of the Columbia River Basin make it particularly sensitive to small changes in overall temperatures. Surface water flows in the Columbia River Basin are dominated by the temperature-sensitive cycle of snow accumulation and melting. During the winter, when the majority of precipitation occurs, snow accumulates in upper elevations of the basin, forming a "natural reservoir" that stores water during times when demands are relatively low. Melting snow subsequently provides peak yearly flows in the spring and early summer, with nearly 60% of the unregulated surface water availability occurring during May, June, and July. For most regions, this is followed by a low flow period in the late summer and early fall, until late fall flows increase due to rainfall. Operations of major reservoirs have attenuated the seasonal nature of the natural hydrograph, shifting a significant amount of water availability from the winter months to the drier summer months and reducing the seasonal pattern.

The climate in the Pacific Northwest is already changing. Average temperatures are about 1.5° F higher than they were a century ago, with more warming during the winter than at other times of year. Regional climate change projections suggest that these trends will intensify, with projected temperature changes in the range of 1 to 5° F over the next 50 years, and a best estimate of about 2.5° F.[9] This seemingly small amount of warming could fundamentally change the patterns of rain and snowfall in the Columbia River Basin. With more precipitation falling as rain during the winter, and earlier snowmelt, peak flows will likely be earlier, with longer and lower periods of low flows during the summer, when out-of-stream demands are highest and instream demands for hydroelectricity generation and fish are important. Reservoir management can compensate for some timing changes in areas of the basin with storage, though the overall level of storage in the Columbia River Basin is lower (as a percentage of annual runoff) than some other major river systems in the U.S.

Simultaneously, higher summer temperatures under climate change could change out-of-stream demands for water in complex ways. Irrigated crops and natural vegetation are likely to have higher evapotranspiration (loss of water through evaporation and plant transpiration) rates and thus need more water. Decreases in summer precipitation could also increase irrigation demand because irrigation demand is the crop water requirement beyond what is provided by rainfall. Some harvested crops may be planted earlier and reach maturity earlier, which could increase demands for some crops earlier in the season, but reduce demands later in the season. Meanwhile, higher summer temperatures could also cause an increase in domestic water demands.



Naneum Creek, Kittitas Co.

These temperature-driven changes in water supply and demand have the potential to seriously stress the Columbia River Basin water supply system, which was built to reliably deliver water under historical conditions. Climate change is thus incorporated as an important feature of this Forecast, to provide information that will help legislators, water managers, and agency professionals begin to plan for future conditions that will likely be different than what we have experienced in the past.

9 Mote, P., Salathe, E., Duliere, V., and Jump, E. 2008. Scenarios of future climate for the7Pacific Northwest. Climate Impacts Group, University of Washington. March 2008. Seattle, Washington, Climate Impacts Group. Accessible at http://cses.washington.edu/cig/

Overview of the 2011 Forecast

There is inherently a great deal of uncertainty in predicting changes in water supply and demand 20 years ahead. For example, water demand from agriculture could change significantly as producers respond to changes in a huge variety of factors, from domestic demand to input costs, to water availability and weather patterns, and to foreign trade in markets around the world. However, by analyzing three broad types of changes that may occur, it is possible to investigate the likely range of possible future water supply and demand:

- Biophysical factors, water availability and growing conditions for crops, among others.
- Economic factors,including impacts on agricultural water demand resulting from changes in domestic food demand and international trade.
- State-level changes in water management to increase water availability or recover the costs of developing new water storage capacity.

The 2011 Forecast is available in written and web-based formats. In addition to this Legislative Report, WDFW's "Columbia River Instream Atlas" (Ecology Publication 11-12-015) includes detailed assessment of 189 stream reaches in fish-critical WRIAs, and WSU's technical report (Ecology Publication 12-12-001) includes detailed methodology and complete results.

Stakeholder Input

Stakeholder input was essential to the development of the Forecast. WSU researchers presented initial modeling methods to the Columbia River Policy Advisory Group (PAG). This group represents a range of stakeholder interests and helps OCR identify and evaluate policy issues. Feedback from the PAG and watershed planning unit representatives was used to adapt WSU forecasting methods. To ensure that comprehensive and scientifically valid methods were utilized, an external peer review panel comprised of four national experts in economics, modeling, and regional water issues periodically reviewed and commented on WSU's work.

Watershed Planning Unit representatives and OCR's Policy Advisory Group provided input on the development of the 2011 Forecast.

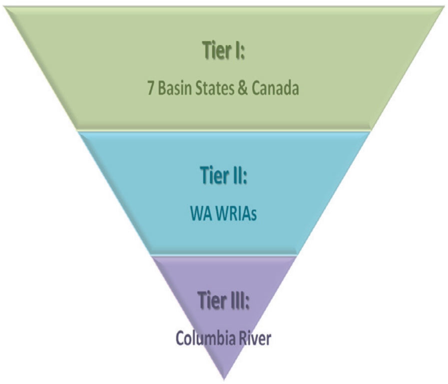
National experts in economic, modeling, and regional water issues peer reviewed the integrated modeling methods.

Preliminary results of the Forecast were presented to the interested public at three public stakeholder events in Wenatchee, Spokane and the Tri-Cities in early September 2011. A draft report was released at the end of September, with public comment accepted for 30 days. Based on feedback received at workshops, through on-line forums, and through the draft comment process, economic and biophysical modeling assumptions were fine-tuned and results were finalized.Comments received, and the responses to comments, are described in the "Summary of Responses to the Draft 2011 Legislative Report for the Columbia River Basin Long-Term Water Supply and Demand Forecast" (Ecology Publication 12-12-004).

Orchards and farms in northern Benton County

Forecast for Three Geographic Tiers

Supply and demand was forecasted at three tiers: the entire Columbia River Basin, the watershed level within Washington, and the Columbia River mainstem in Washington state (Figure 2). Specific objectives at each tier included the following:



Conceptual presentation of the three geographic tiers.

- **Tier I (Columbia River Basin).** Conduct an overview of planning efforts, regulations, water supply projects, and surface water supplies and demands in seven U.S. States and British Columbia. Estimate climate-induced changes in water entering Washington, and on surface water supplies within the state. Conduct a comprehensive analysis of demands within eastern Washington.
- **Tier II (Washington's watersheds).** Conduct an in-depth analysis of surface water supply and demand for eastern Washington's 34 Water Resource Inventory Areas (WRIAs), from the Canadian border to Bonneville Dam.
- **Tier III. (Washington's Columbia River mainstem).** Estimate climate induced changes in supplies with regard to the mainstem's legal, regulatory, and management schemes. Use the water supply forecasted for the Columbia River mainstem in Washington to estimate the portions of WRIA level demand that could possibly be supplied from the Columbia River.

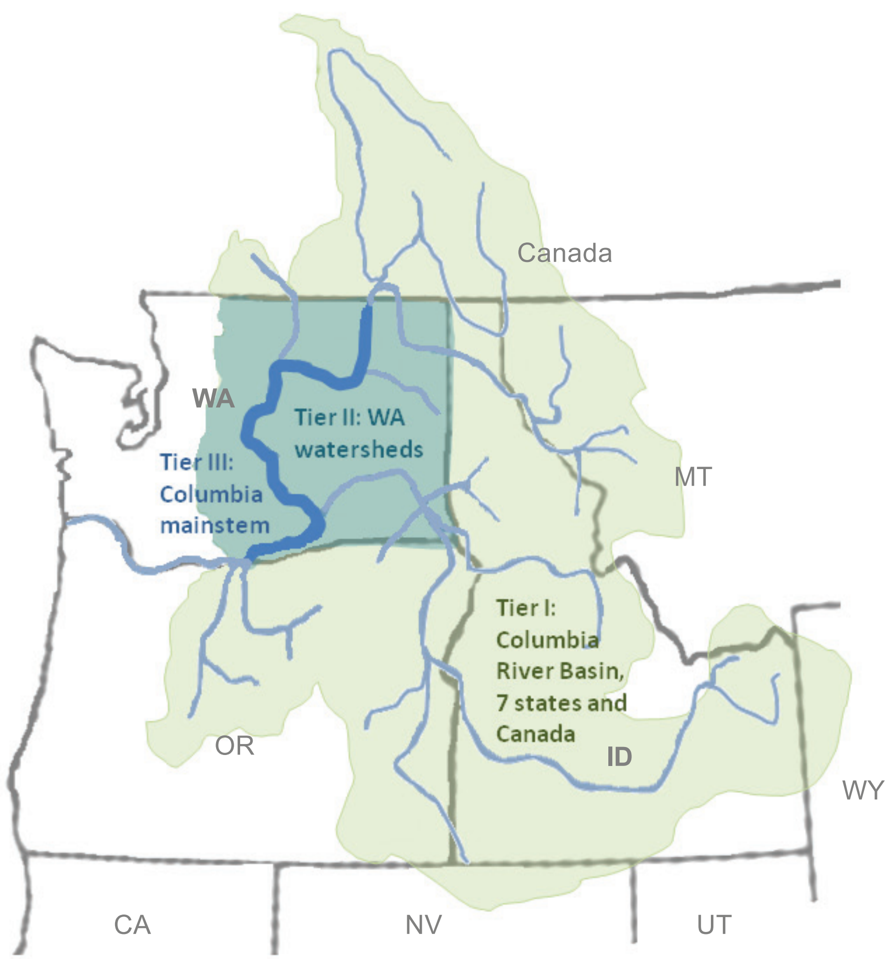


Figure 2. Long-term water supply and demand was forecasted at three tiers.

Instream and Out-of-Stream Elements of the Forecast

Four demand sectors were forecasted: agricultural, municipal, instream, and hydropower. WSU carried out integrated modeling of surface water supply and out-of-stream uses, and a review of hydropower planning projections. WDFW and Ecology's OCR carried out the instream portion of the Forecast. Each of these is described in more detail below.

Computer Modeling

Water supply and demand impact each other. Out-of-stream diversions reduce supply downstream, while water that is diverted, but that is not consumptively used (such as water that is lost through leaks in municipal systems), may return to the system and provide water supply downstream. WSU researchers thus simulated surface water supply and out-of-stream demands with an integrated computer model that simulated the relationships between water supply, climate, hydrology, irrigation water demand, crop productivity, economics, municipal water demand and water management at all three geographic tiers.

The Forecast's model integrated and built upon three existing models (Figure 3):

1. VIC: Variable Infiltration Capacity, a land surface hydrology model.
2. CropSyst: Cropping Systems Simulation, a cropping system model.
3. ColSim: Columbia Simulator, a reservoir operations model.

VIC modeling is used to simulate the effects of a broad range of climate change scenarios on regional water flow.

CropSyst modeling simulates soil water budgets, crop growth, and crop yield.

ColSim models reservoir operations on the mainstem Columbia and Snake Rivers.

The models allow researchers to project water supply and demand under a variety of climate change and economic scenarios.

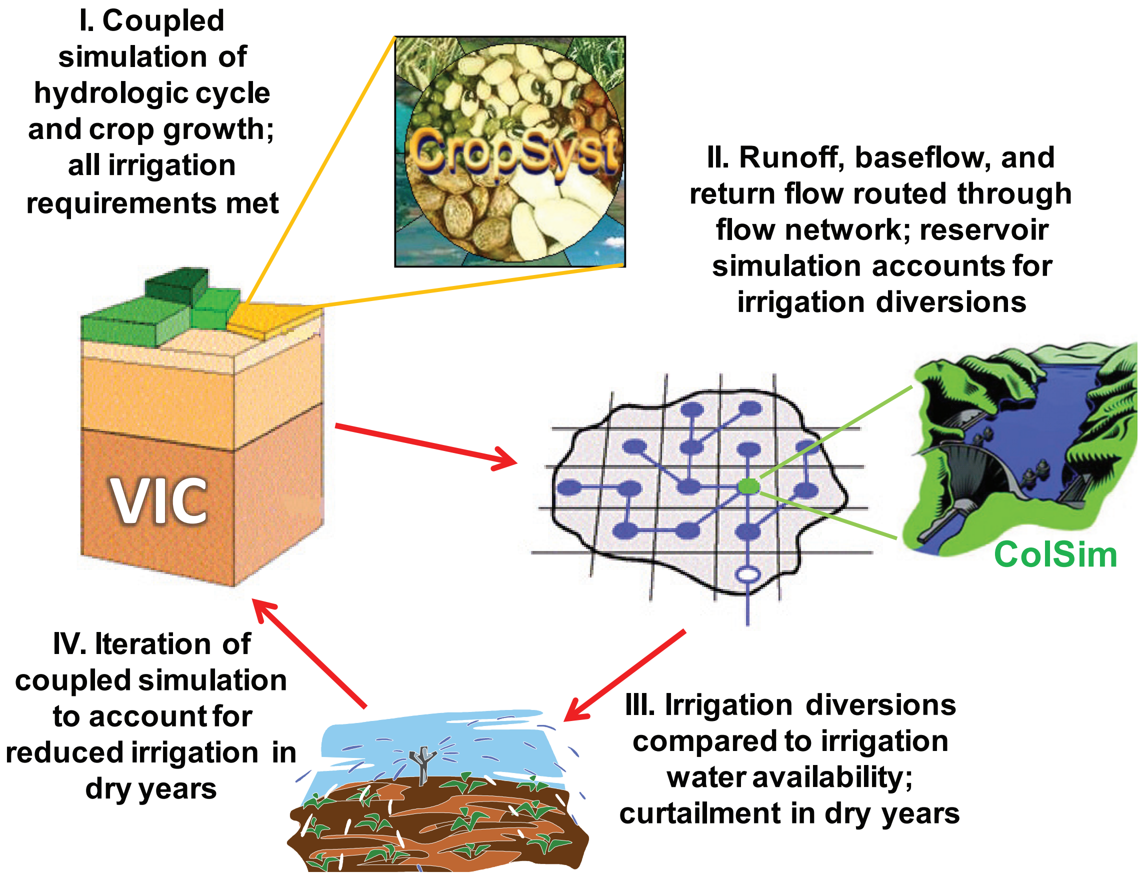
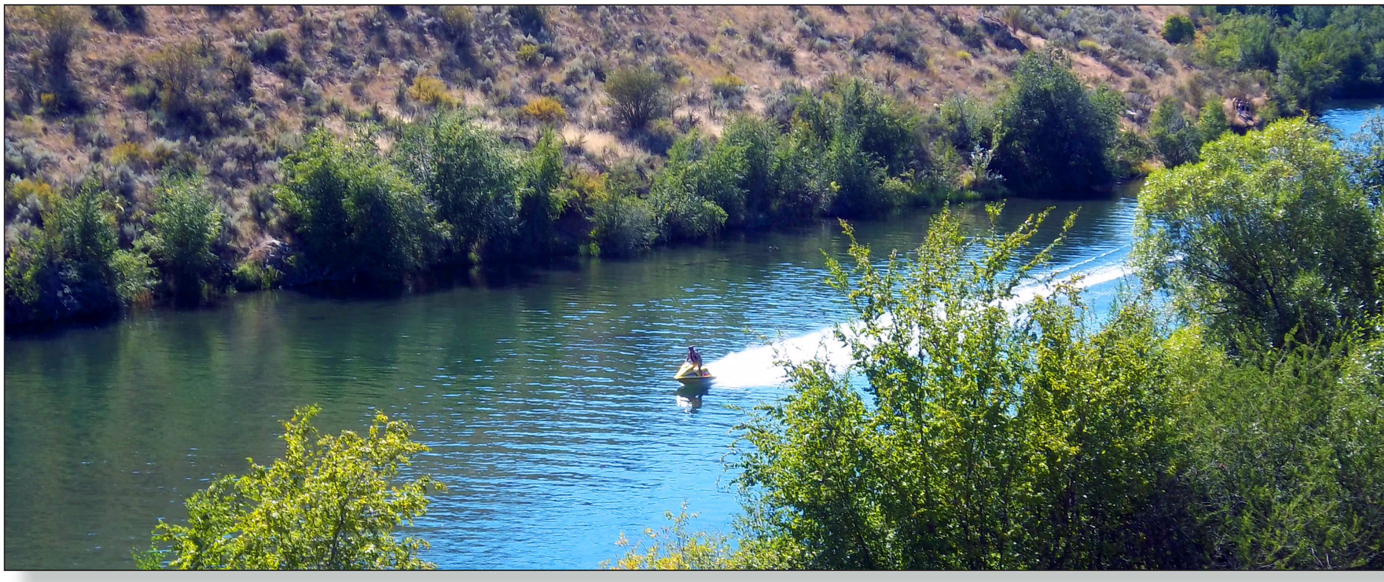


Figure 3. Biophysical modeling framework for forecasting surface water supply and irrigation water demand.



Entiat River

Each of these models has been used independently many times to simulate conditions in the Columbia River Basin. What is novel about WSU's approach is that VIC and CropSyst were integrated to exchange hydrologic and crop production information. For example, VIC informed CropSyst of daily weather and water supply; and CropSyst informed VIC of crop water needs and whether or not a particular crop was water stressed on any given day. This new model, termed VIC-CropSyst, used daily precipitation and temperature observations from across the basin for 1977-2006 to generate baseline simulations of present conditions for each location. To forecast future conditions, the model used daily weather information for the 2030s decade (referred to in this report as 2030) from five different climate change scenarios, representing a range of future greenhouse gas emissions and adapted for our region by the Climate Impacts Group at the University of Washington.[10]

Modeling Water Supply

For the supply analysis, the Forecast focuses on surface waters and shallow subsurface/surface hydrologic interactions, and does not analyze deep groundwater dynamics. It is recognized that deep groundwater supplies play a significant role in many parts of eastern Washington, and due to time, resource, and data constraints, deep groundwater supplies will be addressed in future forecasts.

Surface water supplies for our region reflect the current management of the existing reservoir system. The integrated VIC-CropSyst model was thus linked to reservoir and water use curtailment models that enabled evaluation of how a changing water supply might impact future reservoir storages and releases, irrigation application amounts, crop yields, and how frequently some groups of water users might be interrupted. The project did not model all dams in the Columbia River Basin, as there are more than 400 dams (both storage and

10 Modeling used downscaled climate projections from the A1B and B1 emissions scenarios, as developed by the Intergovernmental Panel on Climate Change (IPCC).

run-of-the-river) operated to meet a variety of purposes. Reservoir modeling captured operations of the dams shown in Figure 4, including the major storage dams on the Columbia and Snake Rivers, and the five major reservoirs in the Yakima Basin (Keechelus, Kachess, Cle Elum, Tieton and Bumping Lake). Dam management captured within ColSim included operations for power generation, flood control, instream flow targets, water storage, and stream flow regulation.

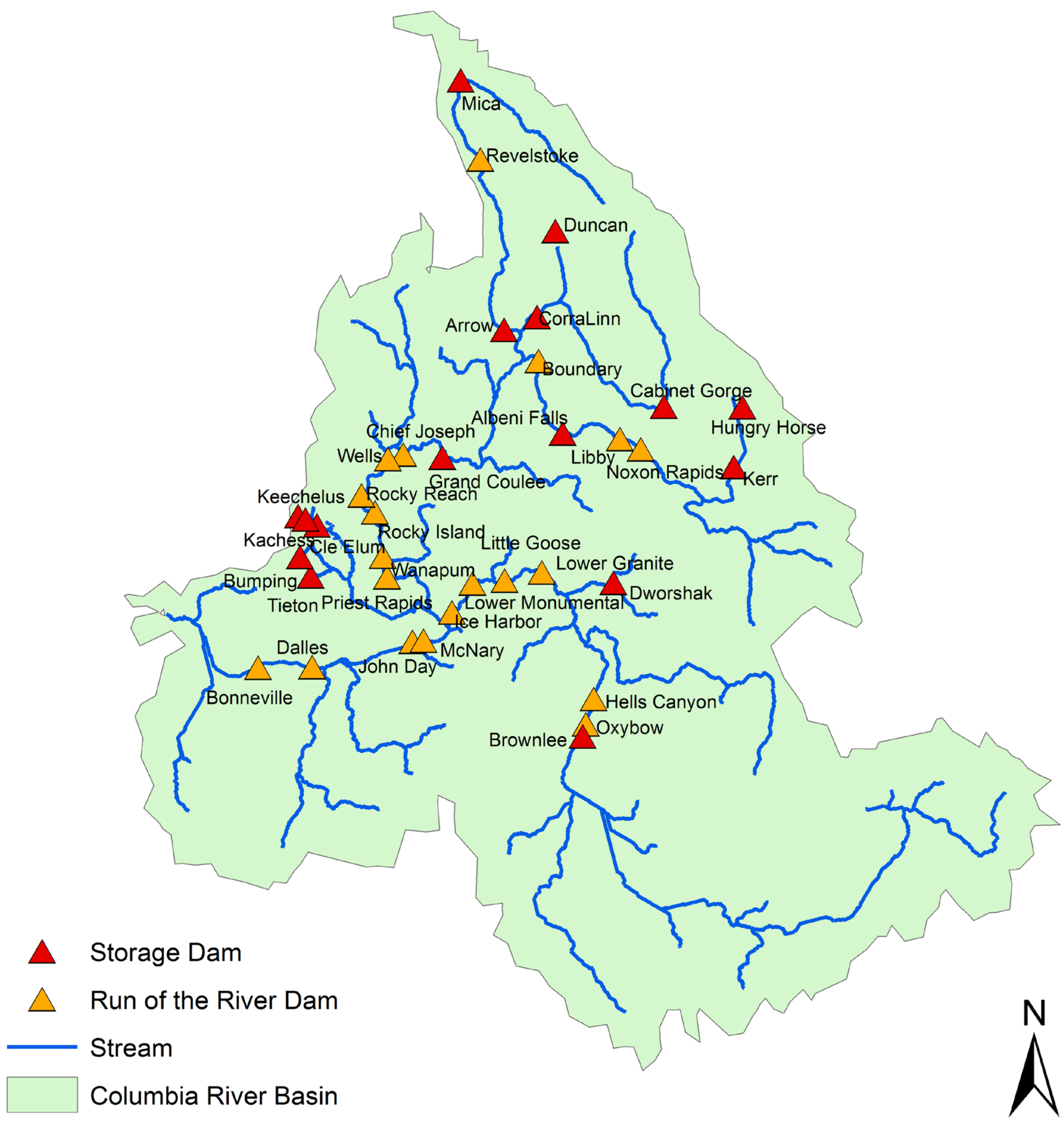


Figure 4. Dams incorporated in reservoir modeling.

The modeling effort assumed that dam management does not change going into the future. To better understand how changes in infrastructure and management could change the water supplies entering Washington state in the future, and to help interpret the modeling results, WSU surveyed basin water managers about water supply planning, project development, and water management, using a 29-question survey developed in collaboration with OCR.

Modeled Crop Groups

Major Crops
- Winter Wheat
- Spring Wheat
- Alfalfa
- Barley
- Potato
- Corn
- Corn, Sweet
- Pasture
- Apple
- Cherry
- Lentil
- Mint
- Hops
- Grape, Juice
- Grape, Wine
- Pea, Green
- Pea, Dry
- Sugarbeet
- Canola

Additional Vegetables
- Onions
- Asparagus
- Carrots
- Squash
- Garlic
- Spinach

Additional Pastures
- Grass Hay
- Bluegrass
- Hay
- Rye Grass

Lentil/Wheat Type
- Oats
- Bean, Green
- Rye
- Barley
- Bean, Dry

Berries
- Caneberry
- Blueberry
- Cranberry

Other Tree Fruits
- Pear
- Peach

Modeling Agricultural Water Demand

VIC-CropSyst focused on agricultural irrigation demands, as irrigation represents the majority of out-of-stream water use in the Columbia River Basin and is a prominent driver of Washington's economy.[11] Agricultural water uses other than irrigation, such as stock water, were not estimated for this Forecast. While these uses are important within some WRIAs, the magnitude of these uses basin-wide is small relative to consumptive use for crops. The U.S. Geological Service estimated that in 2005, within eastern Washington, stock water uses represented approximately 0.4% of out-of-stream water use, considering domestic, irrigation, stock water, aquaculture, industrial, and mining.[12] If stock water represents a significant proportion of water use in the future, it may merit additional attention in future forecasts.

To accurately simulate surface water supply and demand, the combined model needed accurate land use information for the entire Columbia River Basin, including upstream areas in other states and British Columbia. The historical simulation (1977-2006) used recent crop mix information from the United States Department of Agriculture (USDA) for areas outside of Washington, and from the Washington State Department of Agriculture (WSDA) for areas inside the state. The WSDA data were used in Washington because they were found to be slightly more precise for the Washington crop mix when evaluated against the USDA data layer. To capture the diversity of agriculture across Washington, nearly 40 groups of field and pasture crops, tree fruit, and other perennials were simulated. Because of the status of the Odessa groundwater area, all irrigated agriculture in this area that was served by groundwater in the historical period was assumed to need surface water in the 2030 forecast to grow irrigated crops.

Evaluation of the VIC-CropSyst irrigation water demand simulations was primarily based on observed diversion data at Banks Lake (serving the Columbia Basin Project irrigated area in central Washington). Based on 2008, 2009 and 2010 data, observed irrigation diversions from Banks Lake were in the range of 2.5 to 2.7 million ac-ft per year. The VIC-CropSyst simulated "top of the crop" demand for the period 1977 to 2006 for this area was on average about 2.2 million ac-ft. The difference of 14-22% between the simulation results and observed diversions could be attributed to conveyance losses (which are included in the observed data, but not in the VIC-CropSyst values, which measure "top of the crop" demand). These values are within a reasonable range of expected losses. The WSDA based irrigated acreage extent used by the model for this region (730,000) also agreed reasonably well with 670,000 irrigated acres that the Columbia Basin Project serves, though it may be a bit on the high side.

Lack of high quality metered diversion data was an impediment to doing similar evaluations of modeling results at the watershed scale. Some crop acreage and irrigation demand estimates are indicated in the watershed plans of individual

11 The U.S. Geological Survey estimated that agriculture represented 61% of out-of-stream water use statewide, considering municipal, domestic, irrigation, stock water, aquaculture, industrial, mining, and thermoelectric uses. Within eastern Washington, irrigation represented 82% of all uses except thermoelectric (which could not be separated regionally due to limitations in data presentation). Lane R.C. 2009. Estimated water use in Washington, 2005. U.S. Geological Survey Scientific Investigations Report 2009-5128, 30 p.

12 *Ibid.*

WRIAs, but these numbers have large uncertainties associated with them and are not appropriate for model result evaluation. This data gap needs to be addressed in the future.

Economic Analysis of Changes in Agricultural Production

Economic analysis was used to analyze historical changes in production and emerging trends within Washington, allowing for a forecast of how the crop mix is likely to change in the future in response to shifting economic and non-economic factors. Land use changes to predict movement of acreage into and out of agriculture were beyond the scope of this Forecast.

Within Washington, modeling captured the fact that over time, producers will respond to changes in the profitability of various crops resulting from changes in domestic economic growth and international trade flows. For example, over the last 20 years, Washington producers have begun to export increasing amounts of hay to meet a demand for hay in Asia, resulting from the growth in Asian meat and milk production to meet demand there. To carry out this analysis, the Forecast used low, medium, and high scenarios for domestic economic growth and international trade. These scenarios were based on statistical projections so that the medium scenario for domestic growth and international trade can be interpreted as the most likely future condition, while the low and high scenarios provide lower and upper bounds on what is likely to happen.

Domestic economic growth captured variation in the growth of the domestic economy and population, which impacts the amount of money households have to spend on goods. International trade captured variation in imports and exports of agricultural goods, which are an important source of demand for many crops in Washington. Approximately one third ($2.6 billion) of Washington's agricultural production is exported internationally. The trade analysis was based primarily on historical trends in international imports and exports at the state level for broad crop categories, including fruits, vegetables, and wheat, using data provided by the USDA. A detailed analysis was performed for specific crops such as alfalfa and wine grapes that were deemed to be particularly sensitive to assumptions made about changes in trade flows.

Due to resource limitations, it was not possible to model all the ways in which producers could adapt to a reduction in water availability. For example, some producers may switch into less water-intensive crops, particularly if curtailment becomes more regular in the future. In the long run, they may also increase irrigation efficiency by investing in more efficient irrigation infrastructure, or by investing in improved irrigation timing.

Our more simple approach was to try to capture how producers attempt to mitigate water shortages within a growing season by allowing for selective deficit irrigation of less profitable crops. This provides an upper bound on the negative impacts of reduced water availability on production and profitability. A more complex representation of producer decision-making is expected to be a point of emphasis for the 2016 Forecast.

The top countries that receive agricultural and livestock products from Washington ports are:

- *China*
- *Japan*
- *South*
- *Korea*
- *Canada*
- *Taiwan*

OCR is preparing to issue the first permits from the Lake Roosevelt Incremental Storage Releases Program. Water users will reimburse Ecology for the price ($35 ac-ft/year) the agency pays to lease the water from the Bureau of Reclamation. Ecology may consider whether local governments meet criteria for a lower cost recovery rate.

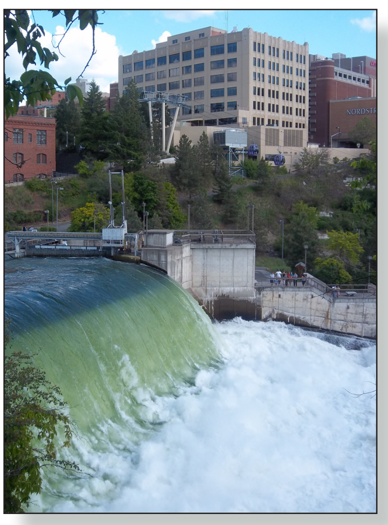
Economic Analysis of Changes in Water Capacity and Cost Recovery for Development Costs of New Water Capacity

A set of water management scenarios were developed to assess how increasing water availability would affect agricultural production and water use. Working from the baseline scenario of no added capacity, the Forecast examined the following possible water management changes:

Water tower in George

- Three different scenarios for water capacity enhancement, corresponding to approximately 100,000, 200,000, and 500,000 ac-ft of additional capacity at specific sites (at no cost to users for new water).
- Recovering direct costs of additional water capacity development at $25, $100 or $200 per ac-ft per year.

The consideration of additional water capacity was based on a list of specific conservation and storage projects currently being considered by OCR that would make additional water available for instream and out-of-stream uses. Details of the projects considered are provided in WSU's technical report (Ecology Publication 12-12-001). One important constraint relevant to the water capacity analysis was that most of the projects OCR is considering would provide water for drought relief or new permits. WSU assumed that any newly irrigated land would have approximately the same mix of crops as is present on nearby farmland, based on the fact that the extent of irrigated production in the Columbia River Basin is primarily constrained by water availability.



Spokane Falls

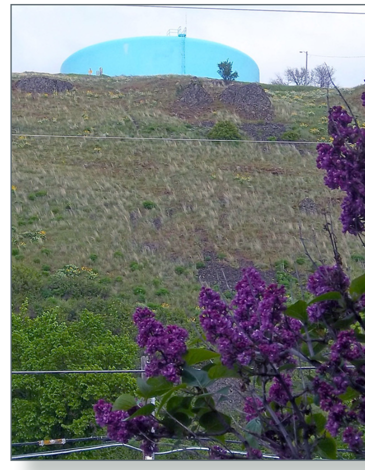
In addition to considering the impacts of additional capacity on water demand, WSU analyzed the economic impacts of additional capacity in terms of additional output, employment and tax revenue. The analysis used IMPLAN® data and software, a standard input/output model that captures the interlinkages between industries in our region. This specific package was chosen because it delineates between agriculture sectors by general crop types such as fruits, vegetables, and grains. Out-of-stream water allocated for newly irrigated land was accounted for on a project specific basis at the county level. New water was allocated to new irrigated crops based on the baseline future county-level crop mix for irrigated crops. The conversion of water into land was based on yields under future climate conditions.

The exploration of cost-recovery for the direct costs of developing water was structured to provide information about the potential feasibility of cost recovery strategies for supporting development of new water capacity. The analysis thus considered whether increases in prices would decrease the amount of water demanded by users or impact the total amount of cost recovery that could be expected. Potential changes in the costs of new water were considered on a crop specific basis. The analysis captured the fact that increased costs for water may prompt farmers to adopt new business practices. For example, they may choose to invest in more efficient watering systems, change their crop production choices, or make other changes to use less water.

Three possible prices that could be charged for cost recovery were explored. Existing projects in the region that have attempted to recover some development costs have charged in the neighborhood of $35 per ac-ft. The low price of $25 was considered to approximate this price point. The medium price, $100, was chosen to represent the high end of what has been observed in actual market transactions for agriculture in the region, while $200 was meant to represent a possible high price in the future. The total amount of cost recovery funds that could be expected was determined by discounting the stream of payments received over time into a single present value. Because this Forecast does not consider costs of specific projects it was not necessary (or possible) to directly deal with whether the prices would allow for complete recovery of costs, whether supply costs or economic costs.[13]

Forecasting of Municipal Water Demand

Municipal use represents a much smaller portion of water use than agriculture in the Columbia River Basin, but one that is important for supporting the continued prosperity of the region.[14] For areas of the Columbia River Basin outside Washington state, WSU reviewed existing municipal projections. Within Washington, municipal demand, including self-supplied domestic use and municipally-supplied industrial use, was forecasted and integrated with modeling.



Water reservoir in Colfax

Municipal forecasting in Washington state relied on data from water system plans submitted to the Washington State Department of Health from the one to three largest public water systems in each WRIA, scaled to a common analytical base year of 2000. This generally captured a majority of residents in a WRIA. For those municipalities where data allowed, municipally-supplied industrial growth was also included, and was assumed to occur at the same rate as population growth, based on the difficulty of accurately forecasting industrial use using other methods.[15] Self-supplied industries were outside the scope of this Forecast. These figures were used to compute an Average Daily Demand (ADD) in terms of gallons per capita per day (gpcd). In some instances, diversions were much higher because of system leaks.

Metro water in Kennewick

Using county-level population estimates obtained from the Washington State Office of Financial Management, city populations were counted in their primary WRIA, while projected county-level population growth outside of cities was distributed evenly by WRIA. Calculations of total WRIA water demand assumed that all people in the WRIA would use the average demand of nearby municipalities. Growth in rural demand will likely be met by groundwater supplies, but it was assumed that domestic wells would be shallow enough to impact surface water flows. Because municipal systems account for only about 10% of consumptive water use in the Columbia River Basin, economic scenario analysis (to explore the impacts of variations in economic growth and trade on water demand) was not carried out for the municipal forecasting.

Downtown Yakima

13 Supply costs normally include capital charges as well as operation and management costs, while economic costs also include opportunity costs.

14 The U.S. Geological Survey estimated that domestic uses (including public and self-supplied) represented 11% of out-of-stream water use statewide, considering domestic, irrigation, stock water, aquaculture, industrial, mining, and thermoelectric uses. Within eastern Washington, domestic uses represented 13% of all uses except thermoelectric (which could not be separated regionally due to limitations in data presentation). Lane 2009, *op. cit.*

15 Not all water supply plans include industrial use information; therefore, this could not be included for all WRIAs.

Consumptive use was estimated by examining the difference between water diversions and discharges at corresponding wastewater treatment plants, while recognizing the potential for significant discrepancies due to municipal inflow and infiltration. Evidence from other western locations shows that loss or addition of flow due to groundwater exchanges in aging wastewater collection systems can be significant. The Utah Division of Water Resources has traditionally estimated the fraction between winter (indoor) water diversions and wastewater discharges to be approximately 0.90 (Oregon uses 0.80-0.90),[16] but a study of 52 municipal systems in Utah found great variability in this ratio.[17] In our analysis, 28 of 34 WRIAs produced values where wastewater treatment plant discharges were less than diverted amounts, producing positive consumptive use values. The average of the 28 positive values was substituted for the six negative values when calculating consumptive uses.

Municipal demands were incorporated into modeling of water supply and agricultural water demand by withdrawing consumptive demands from the surface water system when water system plans or other evidence confirmed that municipal systems were supplied by surface water, or by groundwater in close hydraulic continuity with surface water supplies.

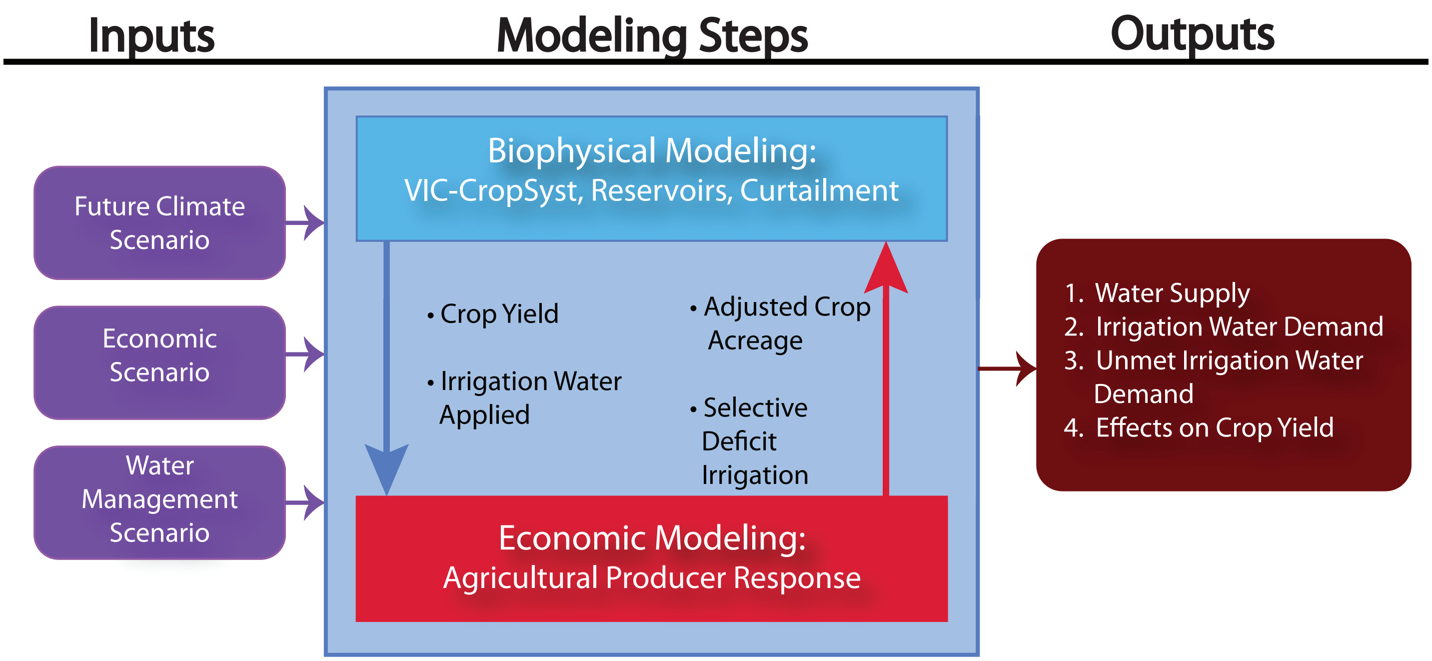


Figure 5. Integration of biophysical modeling (surface water supply, crop dynamics and climate) with economic and policy (human decision-making) modeling.

16 Cooper, RM. 2002. Determining surface water availability in Oregon. Open File Report SW 02-002. Oregon Water Resources Department, Salem, OR. http://www.oregon.gov/OWRD/WR/docs/SW02-002.pdf

17 Among the 52 municipal systems 63% suffered from excess infiltration or exfiltration, with 17 ratios greater than 1.0 and 16 ratios less than 0.70. The remaining systems averaged a supply/effluent ratio of 0.83 during the winter. Similar analysis of summer flows revealed a return flow ratio of 0.51 indicating nearly half the flow is used for outside irrigation. Hughes, TC. 1996. Consumptive use of municipal water supply. Utah Water Research Laboratory, Logan, UT. http://www.cachecounty.org/docs/water/docs//Consumptive%20Use%20of%20Municipal%20Water%20Supply.pdf

Model Outputs

An integrated overview of the modeling structure is shown in Figure 5. Instream demands were not determined within modeling, but were represented through the adopted state and federal instream flows which were assumed to be the same in the historical and future periods. Historical and forecasted municipal demands were included in the modeling framework by withdrawing the consumptive use portions from surface water availability.

The models were able to forecast a variety of potential impacts on a spatially distributed basis, including predicted surface water supply, total irrigation demand, unmet irrigation demand due to curtailment, and decreases in crop yield due to curtailment.

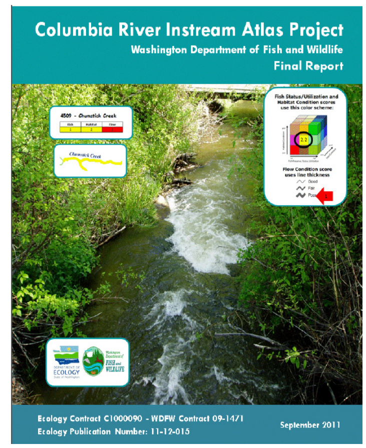
Forecast of Instream Water Demand

The waters of the Columbia River Basin support a variety of fish and other wildlife important to maintaining cultural, environmental, and recreational opportunities, including several ESA-listed threatened and endangered fish stocks (Table 1). Wildlife and fish (including both listed and non-listed species) help support a vibrant tourism, recreation, and fishing industry in the Columbia River Basin, one that plays a vital role in maintaining the rural economy. Recreational spending associated with fishing, hunting, and wildlife viewing was estimated to be $3.1 billion statewide in 2006, according to a study by the U.S. Department of Fish and Wildlife.[18]

While Ecology recognizes the value of all fish and wildlife, Chapter 90.90 RCW directs OCR to focus on salmonids. Across the Washington portion of the Columbia River Basin, OCR developed a comprehensive database of available historic flow data for each major tributary to the Columbia River. Using this data, OCR compared historic low, average, and high flow water years to state and federal minimum instream flow targets. This work was intended to improve understanding of

- How often minimum flow targets in fish critical basins are being met.
- How often water users subject to minimum flow targets are curtailed.
- Whether trends exist in the historic data relative to water availability, the shape of the hydrograph, or drought severity.
- Where opportunities exist to improve stream conditions by re-timing or re-locating water.

WSU's modeling also integrated quantitative instream flow requirements in the Washington portion of the Columbia River Basin. Within WRIAs, the highest adopted state and federal instream flows for each month were used to express current minimum flows for fish in both historical and the 2030 forecast. State and federal instream flows along the mainstem were also compared to historical and future supplies.



A component of the Forecast includes WDFW's "Columbia River Instream Atlas." The Atlas presents extensive data relevant to salmonid species in eight fish and low flow critical basins. One hundred eighty-nine stream reaches were evaluated for habitat and flow conditions, and fish status, distribution and utilization.

18 Numbers for eastern Washington were not available. U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. 2006. National survey of fishing, hunting, and wildlife-associated recreation. http://www.census.gov/prod/www/abs/fishing.html

In addition to this work that covered the Washington portion of the Columbia River Basin, OCR contracted with the WDFW to provide information on instream water demands for eastern Washington's eight fish and low flow critical basins:

- Walla Walla (WRIA 32)
- Middle Snake (WRIA 35)
- Lower Yakima, Naches, and Upper Yakima (WRIAs 37, 38, and 39)
- Wenatchee (WRIA 45)
- Methow (WRIA 48)
- Okanogan (WRIA 49)

Table 1. Fish stocks listed under the Endangered Species Act in Washington's Columbia River Basin.

ESA Listing Unit by region	Status
Lower Columbia River	
Southwest Washington/Columbia River Coastal Cutthroat	**Candidate**
Columbia River Chum	**Threatened**
Lower Columbia River Bull Trout	**Threatened**
Lower Columbia River Chinook	**Threatened**
Lower Columbia River Coho	**Threatened**
Lower Columbia River Steelhead	**Threatened**
Mid-Columbia River	
Mid-Columbia River Spring Run Chinook	**Not Warranted**
Middle Columbia River Bull Trout	**Threatened**
Middle Columbia Steelhead	**Threatened**
Touchet/Walla Walla (Oregon Recovery Unit) Bull Trout	**Threatened**
Snake Basin	
Snake River Sockeye	**Endangered**
Snake River Basin Steelhead	**Threatened**
Snake River Bull Trout	**Threatened**
Snake River Fall Run Chinook	**Threatened**
Snake River Spring and Summer Run Chinook	**Threatened**
Upper Columbia River	
Upper Columbia River Bull Trout	**Threatened**
Upper Columbia River Spring Run Chinook	**Endangered**
Upper Columbia River Summer and Fall Run Chinook	**Not Warranted**
Upper Columbia Steelhead	**Threatened**
Lake Wenatchee Sockeye	**Not Warranted**
Okanogan River Sockeye	**Not Warranted**
Northeast Washington Bull Trout	**Threatened**

The Atlas (Ecology Publication 11-12-015) presents WDFW's analysis of existing data, best professional knowledge, and new data for 189 stream reaches. Each reach was scored on three critical components: fish stock status and habitat utilization, fish habitat condition, and stream flow. This allowed for comparisons of stream reaches within each of the WRIAs. WDFW's results were at a finer geographic scale than WSU's modeling analysis, and were qualitative rather than quantitative. Thus they are presented independently in the Atlas. OCR will use the information in the Atlas, and consultations with WDFW staff, to identify and prioritize projects that benefit stream flows.

Forecast of Hydropower Water Demand

According to the Northwest Power and Conservation Council, the more than 75 major federal and nonfederal hydroelectric dams in the Columbia River Basin produce upwards of 15,000 annual average megawatts (MWa) of energy.[19] This relatively inexpensive source of power accounts for approximately 55 percent of the power generating capacity in the Pacific Northwest and on average provides about three quarters of the region's electricity. From a power generation perspective, the most significant of these dams are on the mainstem.

Power entities in the northwest regularly carry out extensive forecasting of electricity demand and power-generating capacity. For this Forecast, WSU reviewed existing projections across the Columbia River Basin with two specific objectives in mind:

- Find out whether regional and state level power entities felt that they would be able to meet anticipated growth in demand over the next 20 years.
- Determine the likelihood of any additional hydroelectric storage capacity being built within the Columbia River Basin over the next 20 years.

Available reports that were reviewed included those carried out by the Bonneville Power Administration (BPA), Northwest Power and Conservation Council (NWPCC), Avista, Idaho Power, Portland General Electric (PGE), and Grant County PUD. BC Hydro documentation was also reviewed, though long-term planning documents were general in nature. Reviews were supported with conversations with staff at public utility districts in Washington State and Avista Utilities.

Grand Coulee Dam spillway and power transmission lines

19 NWPCC. 2010. 6th Northwest Conservation and Electric Power Plan. Northwest Power and Conservation Council. http://www.nwcouncil.org/energy/powerplan/6/default.htm

Columbia River Basin: Tier I Results

Tier I, the Columbia River Basin, focused on a broad assessment of the basin as a whole, with in-depth analysis of the Washington portion of the basin. To accurately forecast Washington's water supply and demand, it is necessary to understand water supply and demand throughout the entire Columbia River Basin. The major water contributors are British Columbia, Washington, Idaho, Montana and Oregon, while Wyoming, Utah and Nevada are minor contributors by area (Figure 6). The amount and timing of water entering Washington state within the Columbia River Basin is highly impacted by existing infrastructure and management in British Columbia, Idaho, Montana, and Oregon.

Figure 6. Columbia River Basin

Throughout this report, WSU modeling results are presented using specific definitions of supply and demand, described in the box on page i at the beginning of this report.

Modeled Surface Water Supplies Entering Washington

Modeling results indicated a number of important changes in surface water supply entering Washington between the historical period (1977-2006) and 2030. These changes reflect the impacts of climate change (Figures 7 and 8):

- Annual water supplies for most of the eastern incoming rivers, including the Columbia, Pend Oreille, Spokane, Clearwater, Snake, and John Day will increase by 2030, an average of 3.7 (±1.3)%.[20]
- The direction of change for annual water supplies entering Washington is unclear, 1.4 (±1.9)% on average, for the Similkameen and Kettle Rivers.
- Within a season, surface water supplies entering Washington will generally increase by 2030 in late fall, winter and spring, and decrease in the summer and early fall. This pattern applies to both eastern and western portions of the basin, and is evident at most points where significant amounts of water enter Washington, including the Columbia River and the Snake River. The exact timing may vary somewhat by river.

Columbia River Basin Surface Water Supply and Seasonal Availability

The forecast of surface water supply and timing in 2030 for all areas of the Columbia River Basin upstream of the Bonneville Dam noted the following changes compared to the historical flows (1977-2006) (Figure 9):

- A small increase of around 3.0 (+/-1.2)% in annual supplies.
- Timing changes will shift water away from the times when demands are highest. Unregulated surface water supply at Bonneville will decrease an average of 14.3 (±1.2)% between June and October, and increase an average of (17.5 (±1.9)% between November and May.

20 When discussing modeled supply and irrigation demand results, "average flow conditions" refers to the 50th percentile (middle) value under the middle climate scenario. "Average" by itself refers to the average value over all climate scenarios and flow conditions, and a 90% confidence interval around that average.

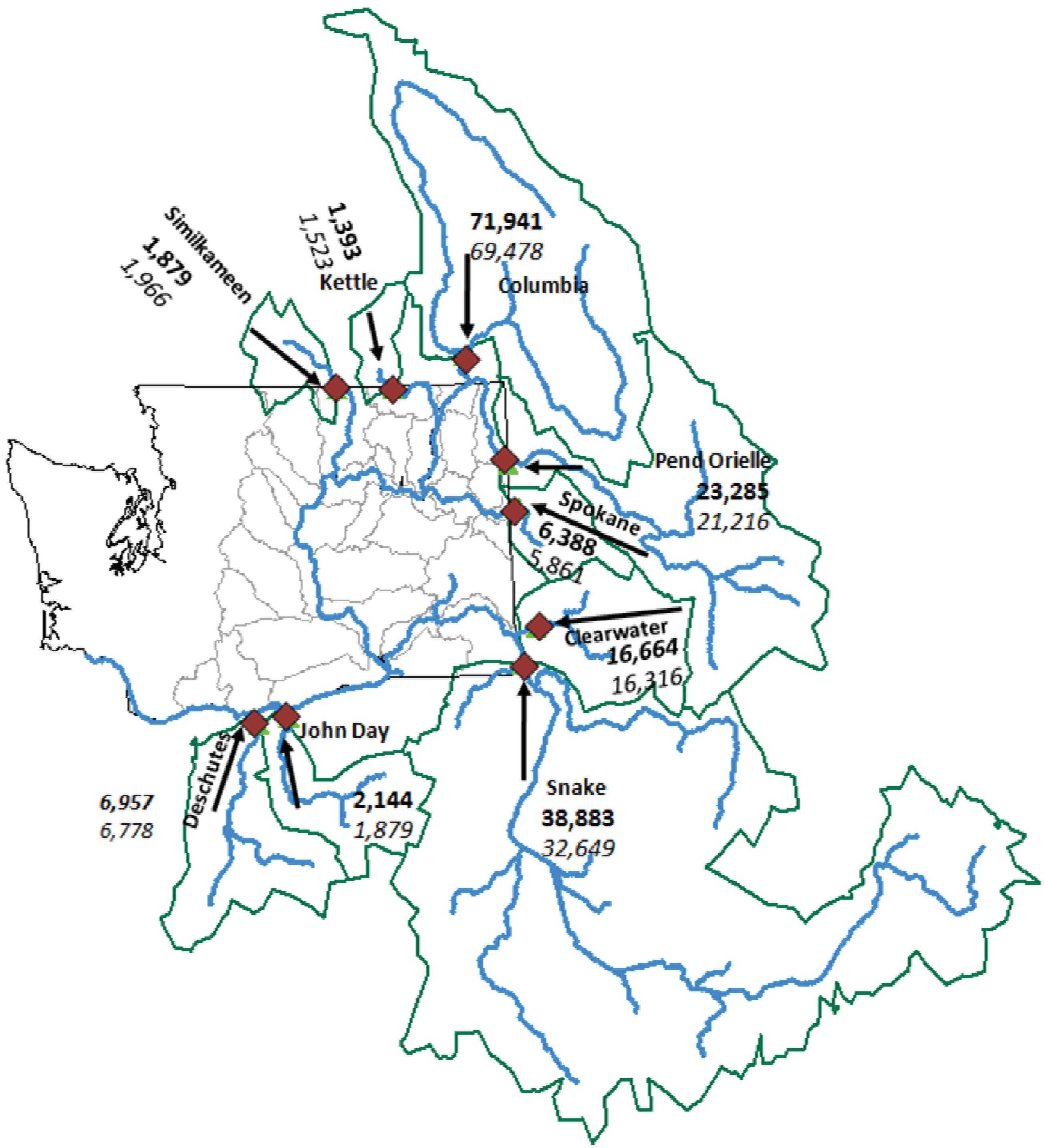


*Figure 7. Surface water flows for major tributaries upstream of the point where the rivers enter Washington state. Top number (**bold**) refers to 2030 forecasted water supplies for average (50th percentile) flow conditions and the middle climate change scenario, while the bottom number (italic) refers to historical (1977-2006) water supplies. All values are in cubic feet per second.*

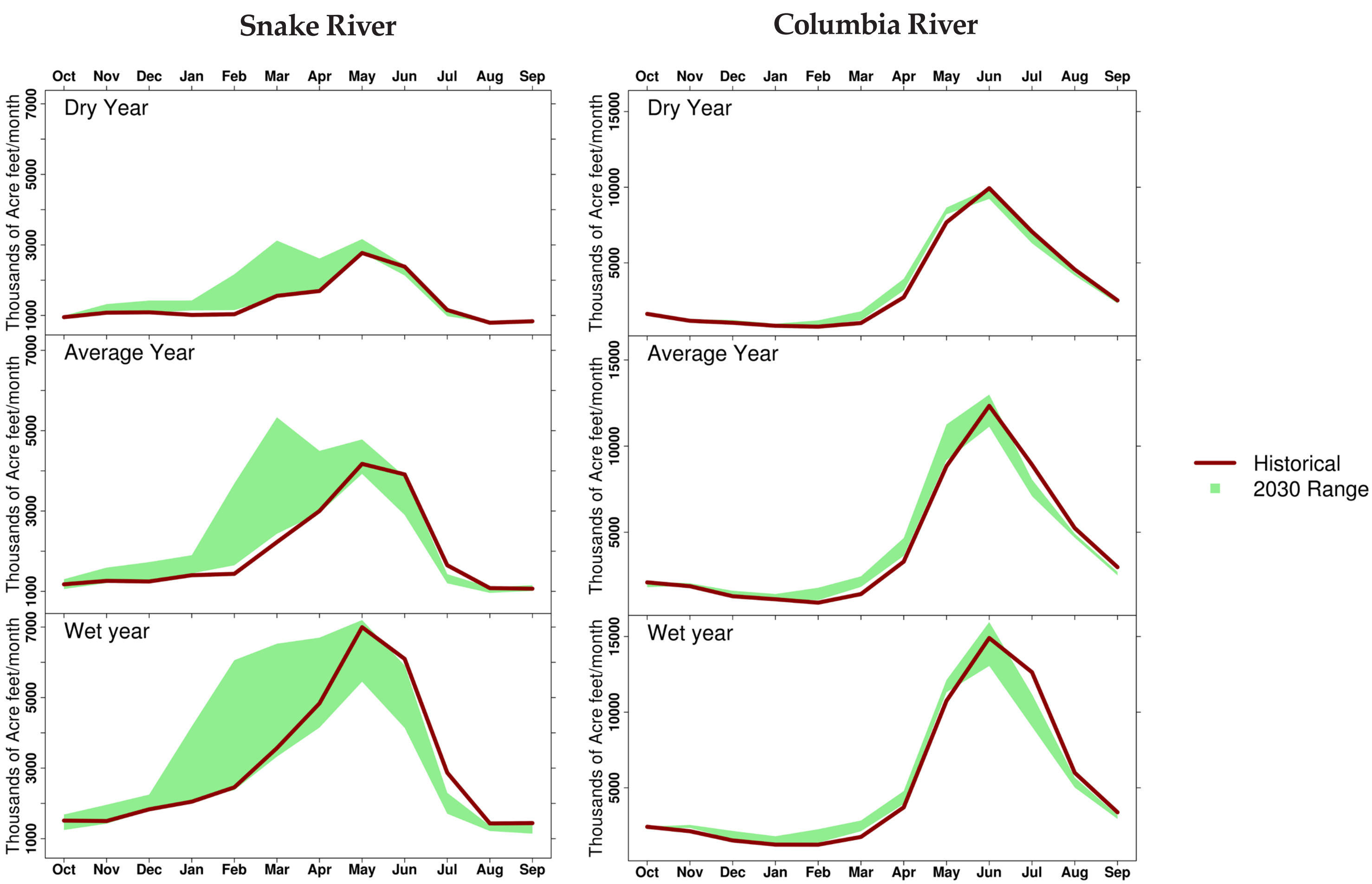


Figure 8. Historical (1977-2006) and 2030 forecasted regulated surface water supplies on the Snake and Columbia Rivers upstream of the point where they enter Washington state for dry (20th percentile, top), average (middle), and wet (80th percentile, bottom) flow conditions. The spread of 2030 flow conditions is due to the range of climate change scenarios considered.

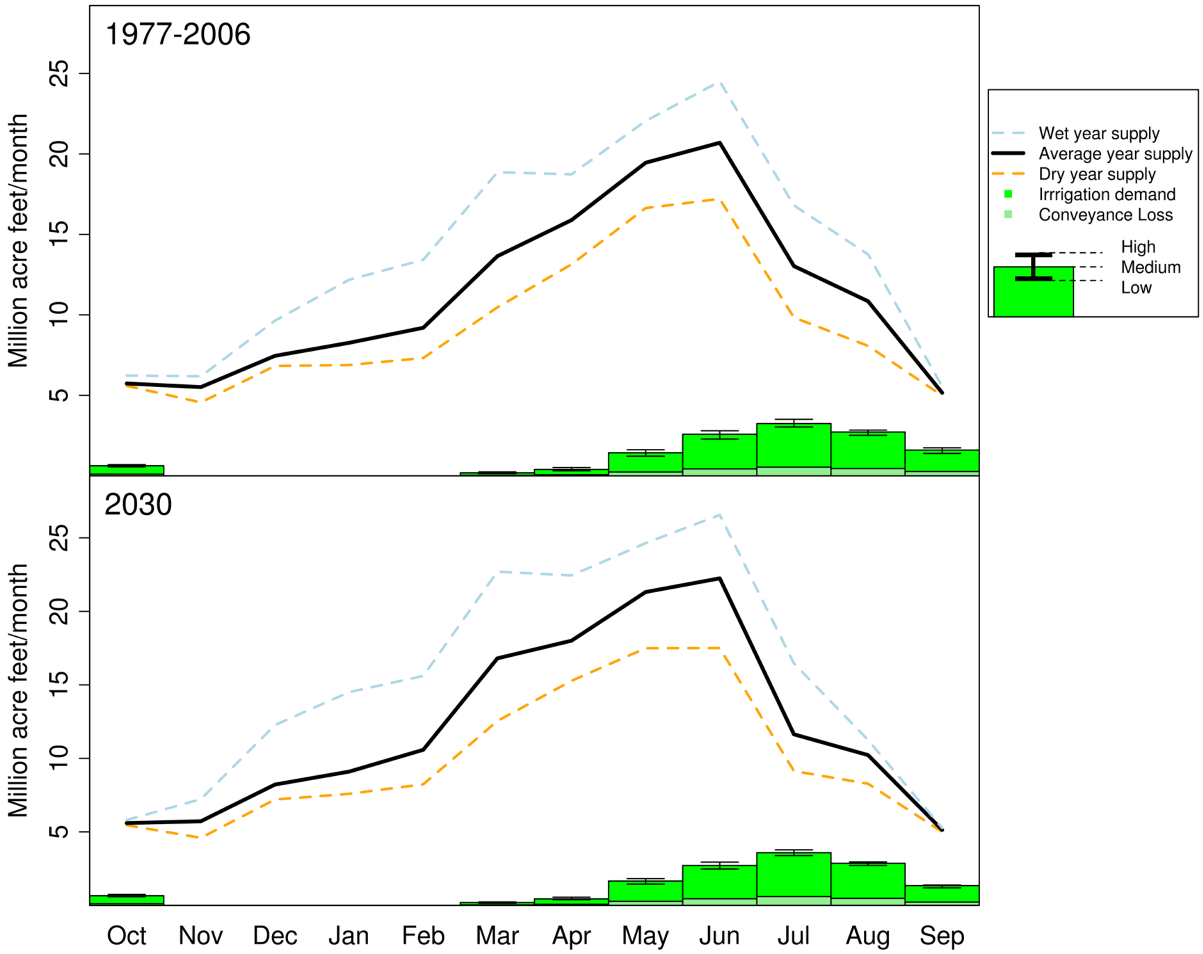


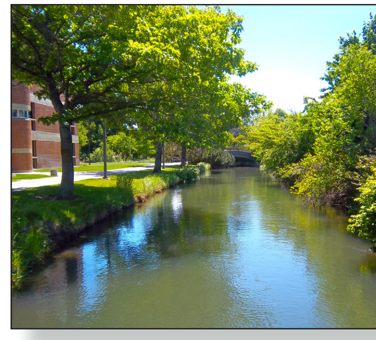
Figure 9. Comparison of regulated surface water supply and irrigation water demands for the historical (top) and 2030 forecasted (bottom) periods under the medium-growth, medium-trade economic scenario across the entire Columbia River Basin, including portions of the basin outside of Washington state. Wet, dry, and average flow conditions are shown for both supply (dotted lines) and demand (error bars).

Columbia River Basin Survey

In response to the survey, water mangers throughout the Columbia River Basin suggested that additional summer water is generally needed for future instream and out-of-stream demands. However, efforts to improve flow or aquatic habitat conditions in portions of the Columbia River Basin outside of Washington state typically involve relatively minor changes to management of winter or peak flows at existing projects, rather than new storage projects. Contributing factors include a lack of funding and willingness to pay for water. These types of minor changes to management of winter or peak flows would have limited impact on Washington's overall water supply. The survey results did not indicate a need for WSU's modeling team to dramatically alter flows entering Washington state in this Forecast.

OCR intended that the survey identify opportunities for future collaboration with out-of-state partners. No specific partnership opportunities were identified, but one underlying theme of responses was that a lack of regional and cross-jurisdictional communication hampers planning efforts. Thus, improving communication may be a first step to create purposeful partnerships.

Although not brought out directly in the survey responses, one important issue on the horizon that could dramatically alter the surface water supplies entering Washington state is the re-negotiation of the Columbia River Treaty between the United States and Canada. The 1964 Treaty provided for the construction of four dams in the upper Columbia River Basin that more than doubled the amount of reservoir storage in the basin: Libby in Montana, and Duncan, Keenleyside, and Mica in Canada. These four dams are operated to benefit downstream hydropower generation and flood control. According to the U.S. Army Corps of Engineers, the dams provide billions of dollars of benefits for the two countries. The Treaty has a 2014 opt-out clause that allows either country to notify the other that they intend to terminate the treaty in 2024. Since the treaty was originally ratified, the emergence of additional complex issues such as future needs for anadromous and resident fish, irrigation, recreation, municipal water supply as well as power and flood control has both sides examining whether or not new operating rules would provide additional benefits to both countries. If notification to terminate is given by either side in 2014, it could radically change the context in which OCR is working to meet water demands in the Columbia River Basin. This issue will be addressed in detail in the 2016 Forecast.



Irrigation Canal in Ellensburg

Berries at Spokane farmers' market

Tribal water rights may also have the potential to alter water supplies in the region. Quantification of these rights involves complex legal issues beyond the scope of the Forecast. Further quantification of these water rights could impact water supplies, particularly those available for meeting instream demands.

Columbia River Basin Agricultural Water Demand

The 2030 forecast of demand for agricultural irrigation water across the entire Columbia River Basin was 13.6 million ac-ft per year under average (50th percentile) flow conditions, with the range of low and high estimates under different weather conditions from 13.1–14.1 million ac-ft per year (20th and 80th percentile) (Figure 9). When compared to average historical (1977–2006) conditions, this represented an increase of 0.33 million ac-ft, or approximately 2.5% above estimated demands for the historical period of 13.3 million ac-ft per year (Table 2).

Table 2. Top of crop agricultural demands under the baseline economic scenario (medium domestic economic growth and medium growth in international trade), excluding conveyance losses, in the Columbia River Basin in the historical and 2030 forecast period. Estimates are presented for average years, with range in parentheses representing wet (80th percentile) and dry (20th percentile) years.

	Historical (1977–2006) million ac-ft per year	**2030 Forecast million ac-ft per year**	**% Change**
Entire Columbia River Basin	13.3 (12.6-13.9)	13.6 (13.1-14.1)	2%
Washington Portion of the Columbia River Basin	6.3 (6.0-6.5)	6.5 (6.2-6.6)	2%

These demand results should be thought of as the upper bound of "top of crop" water demand under the medium growth, medium trade scenario, assuming no change in the land base for irrigated agriculture. This is because the 2030 forecasted value represents water demand after changes in crop mix have occurred in response to changes in the domestic economy and international trade flows.As described more fully in the "Overview of the 2011 Forecast," constraints on water availability (including physical availability or regulatory curtailments) are assumed to result in deficit irrigation of nearby less profitable crops; other producer responses that would minimize the production impacts of water shortages are outside the scope of this Forecast. This would include strategies such as changes in crop mix to favor less water intensive crops, or investments to increase the efficiency of irrigation.

Okanogan River

Fruit stand near Methow River

Results for the Washington state portion of the Columbia River Basin are similar, suggesting that 2030 irrigation demands will be roughly 1.9% above historical. This change is due to a combination of two factors: climate change and changes in crop mix driven by the economic scenario considered. Considering the climate impacts of temperature and precipitation variations alone on the irrigation demand, there is a 3.7% increase in demand. When economic impacts resulting in a new crop mix are considered in addition to the climate impacts, the increase in demand reduces to 1.9%.

These changes in total irrigation demand do not include additional surface water demands that may result from the need to supply water to agricultural producers in the Odessa area who currently receive groundwater. These demands were treated as groundwater demand in the historical case, and surface water demands in 2030. In the 2030 forecast, this area represented 240,000 ac-ft per year of surface water irrigation demand.

Impact of Variations in Trade and Growth Predictions on 2030 Irrigation Water Demand in Washington

The irrigation demands presented above were run under a medium growth, medium trade scenario, reflecting 'most likely' future conditions. Low and high alternate scenarios captured the range of possible future economic conditions within Washington, considering both growth of the domestic economy, and growth in international trade in agricultural goods. Forecasting methods are described in the "Overview of the 2011 Forecast." Overall, the low, and medium economic scenarios forecasted an estimated 6.5 million ac-ft of average irrigation demand and the high medium scenario forecasted an estimated 6.4 million ac-ft of average irrigation demand within the Washington portion of the Columbia River Basin, assuming that the extent of irrigated acreage stayed constant (Table 3).

Table 3. Top of crop agricultural demands under the three economic scenarios (low, medium, and high), excluding conveyance losses, in the Columbia River Basin for the 2030 forecast period. Estimates are presented for average years, with range in parentheses representing wet (80^{th} percentile) and dry (20^{th} percentile) years.

	2030 Forecast Under Varied Economic Scenarios million ac-ft per year		
	Low	**Medium**	**High**
Washington Portion of the Columbia River Basin	6.5(6.2-6.6)	6.5(6.2-6.6)	6.4(6.2-6.6)

Over the range of scenarios considered, variation in assumptions about economic growth generally resulted in modest changes in production relative to the impact of international trade. Domestic economic growth was projected to be 1.6% per year in terms of real income per capita for the "medium" scenario, 1.3% under the low scenario, and 1.8% under the high scenario. In essence, domestic growth impacts water demand because more consumers with more money to spend on food places upward pressure on food prices, incentivizing producers to increase production. Population growth generally impacted all crops equally while income growth had a relatively larger impact on high value crops such as cherries and wine grapes. However, these changes still caused relatively small changes in total irrigation water demand. Although many of the crops most sensitive to changes in income are irrigated, including apples, wine grapes, and cherries, they each occupy 200,000 acres or less in Washington. This is a relatively small area compared to wheat, cropland pasture, and forage crops, which together account for more than 80% of all cropland in the state. Among these latter crops, non-irrigated acreage will not significantly impact irrigation water demand, although it may influence water supplies by impacting surface water runoff quantities.

Grant County sign

Grapes growing near Walla Walla

Variation in assumptions about international trade had a more significant influence on crop mix than assumptions about domestic economic growth, with greater influences generally for high-value crops. There was little variation in irrigated wheat production between the low and high scenarios, based on the expectation that export demand for wheat will remain fairly steady.[21] In contrast, fruit and vegetable production varied more between low and high scenarios, based on robust growth of export demand for these crops over the last decade.[22] In contrast to most fruit-based products, demand for Washington wine grapes and wine production is expected to be primarily dependent on growth in the domestic rather than foreign markets. For alfalfa, traditional exports to South Korea, Taiwan, and Japan are expected to stay at historic levels although there is some possibility that exports to dairies in other parts of Asia could become an important new demand center.

Impact of Additional Water Capacity Development and Cost Recovery for New Water Provision on Forecast 2030 Irrigation Water Demand in Washington

The baseline scenarios presented in this Forecast do not include any changes in water management. This was done to isolate the impact of changes due to larger market forces from those resulting from state level policy. It is also a prudent approach given the legal, political, and financial obstacles to changes in water management. As described in the "Overview of the 2011 Forecast," in comparison with that baseline, OCR asked for analysis of a number of scenarios that included development of approximately 100,000, 200,000, and 500,000 ac-ft of

21 Exports of Washington wheat have fluctuated around an average of $380 million for the last decade, and tend to spike when there are significant weather induced shocks to other major wheat growing regions. Climate change predictions suggest that weather-induced crop reductions could become more common in places like Russia and Australia, elevating the average level of Washington exports somewhat.

22 Fruit and vegetable exports fruit and vegetable exports have grown at approximately 5% per year for fruit and 3% for vegetables over the last decade, with simultaneous growth in domestic markets.

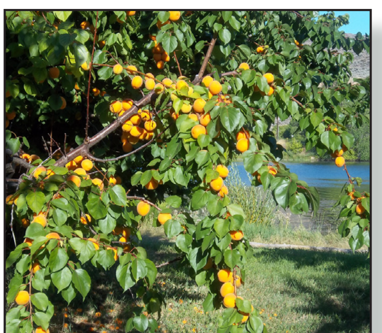
additional water capacity at specific locations in the state, and potential recovery of development costs at a variety of prices, including zero. In interpreting the results of this analysis, it is important to recognize that this Forecast does not include benefit-cost studies for any particular water development projects.

Vernita Bridge

Projects associated with the medium water capacity scenario of 200,000 ac-ft per year were estimated to lead to approximately 62,000 acres, including both newly irrigated lands, and replacement water for acreage in Odessa currently irrigated by groundwater. The economic impacts associated with production on this acreage would generate an estimated agricultural output of $169 million, or about $2,700 per acre. This estimate does not subtract the value of production if land were currently under dryland cultivation. Total economic impacts of the additional production were estimated with the Implan® economic input-output model to be an additional $120 million in indirect and induced effects.[23]

Methow River

The economic impact of this increased production was estimated to be 6,600 jobs, which included employment related to crop production and food processing industries. State and local tax impacts were estimated at about $37 million, with most of this coming from indirect business taxes, including taxes incurred in the ordinary operation of business (such as sales taxes, excise taxes, and property taxes).[24] The values of output and other estimated economic outputs are reported in current terms, reflecting the fact that the input-output model shows the current economy in terms of wages, production technologies, and many other factors. To put this into perspective, there are approximately 62,000 jobs in Washington directly related to crop production and almost half are in fruit farming. There are an additional 31,000 jobs in agricultural support activities and 12,000 jobs in relevant food processing industries.



Apricots in Okanogan County

Information on the disposition of agricultural production to specific processing industries is not generally available so it was necessary to make a few general assumptions to include processing industry impacts. According to USDA statistics about 18% of apple and cherry production enters into processing. Thus, 18% of new fruit production was assumed to be processed within the state, in the canning industry. For vegetables, potatoes, sweet corn, and onions constitute more than 90% of Washington's vegetable acreage. About 75% of potato production is allocated to the frozen food industry. Nearly all sweet corn production is processed. Data is not available for onions, though it is likely that less are processed. Combining all this information, it was simplistically assumed that 75% of the additional vegetable production would be processed within the state and that all of it went towards frozen foods (though in reality there is some processing in other industries such as snack food manufacturing). Additional wine grapes were assumed to be processed in Washington by the wine industry.

While not quantified, it is recognized that maintenance of and improvement to instream flows would have positive economic impacts on tourism and recreation, generating additional jobs and tax revenues.

23 This estimate included additional economic activity generated through backward linked industries, such as machinery repair and fertilizer sales, and spending throughout the rest of the economy that are impacted by additional household income.
24 Total taxes also included employer contributions to social insurance, proprietor income, indirect business tax, taxes on household income, and taxes on corporate profits.

Results for the low and high water capacity scenarios will be available in WSU's technical report (Ecology Publication 12-12-001).

Cost recovery scenarios considered various possible scenarios of prices that could be charged for new water capacity for cost recovery purposes ($25, $100, and $200 per ac-ft per year). These prices correspond respectively to the range of prices being charged for projects currently in development, a higher price that has been charged elsewhere for water projects, and a possible high price in the future. The total amount that could be generated for cost recovery purposes was determined by discounting the stream of payments received over time into a single present value. At low prices, agricultural producers are likely to use all water made available because their net revenue would still be greater by irrigating than under dryland production. At higher prices it is possible that not all of the water will be used.

OCR is currently developing many water supply projects at a cost recovery rate of less than $50 ac-ft per year. Examples include the Lake Roosevelt Incremental Storage Release Project and Sullivan Lake Water Supply Project.

As is typical for this type of analysis, results varied significantly depending on the assumption of the discount rate, which is usually based on either yields of long-term government bonds (low estimate) or on the rate of return on capital in private markets (high estimate). An assumption of a lower discount rate leads to a higher present value. Depending on whether the discount rate considered is 2, 4, or 6%, cost recovery from charging $25 per ac-ft for 200,000 ac-ft in perpetuity would be $250 million, $125 million or $83 million, respectively. Full results of the pricing scenarios analysis will be available in WSU's technical report (Ecology Publication 12-12-001).

Lake Roosevelt

Columbia River Basin Municipal Water Demand

Water tower in Ritzville

The forecast of municipal demand in Washington should be understood within the context of likely increases in demand throughout the Columbia River Basin. U.S. Census estimates show population growth over the next 20 years in Idaho (25.6%), Oregon (26.2%), and Montana (5.6%). Without concerted conservation efforts, population growth will certainly increase demands on water flowing into Washington state. Idaho has not released county-by-county growth projections, and it is difficult to predict which additional municipal demands will be met from deep groundwater supplies which would not impact surface water supplies. However, it is safe to assume that additional demands in Idaho will reduce inflows into some parts of Washington. A study of the Spokane River basin by the state of Idaho projected that they would place an additional demand of 31 cfs on the river by 2060.

WSU projected domestic and industrial diversion demands, excluding self-supplied industries, of 569,000 ac-ft per year in Washington in 2030, an estimated 26% increase over 2010 (Table 4). This increase of approximately 117,500 ac-ft per year compared to 2010 is driven by expected population growth. Per capita demands varied considerably throughout eastern Washington, with an average total demand (including system losses) of approximately 277 gpcd. These results are in line with a 2005 U.S. Geological Survey study of domestic water use, which estimated 285 gpcd.[25] Forecasting methods are described in the "Overview of the 2011 Forecast."

Table 4. Municipal diversion demands for the Washington state portion of the Columbia River Basin.

	2010 (ac-ft per year)	2030 Forecast (ac-ft per year)	% Change
Washington Portion of the Columbia River Basin	452,000	569,000	26%

Total consumptive demands for eastern Washington were estimated to be 291,000 ac-ft per year in 2030, compared to 232,000 ac-ft per year in 2010. This represents approximately 51% of the total diversion quantity, which may be high compared to other investigations, but nevertheless, represents an initial estimate. These amounts were distributed evenly throughout the year, with no attempt to account for seasonal variations in water use. Future analysis should examine monthly variations, and should also utilize the OFM's WRIA level population estimates to improve the assumed distribution of current and future populations by WRIA.

These estimates did not include the potential impacts of system repairs or conservation efforts on future demands. As an example of the impact this could have, eliminating system losses would result in a net savings of nearly 56,000 ac-ft per year currently and 70,000 ac-ft per year by 2030. Of equal importance is the potential impact of conservation practices. Reducing current demands by 10% would reduce current diversion requirements by 45,000 ac-ft per year and projected future diversion demand by 57,000 ac-ft per year and future consumptive use by approximately 29,000 ac-ft per year.

25 Lane 2009, *op. cit.*

Columbia River Basin Instream Water Demand

Forecast changes in surface water supply timing are likely to increase the challenge of meeting instream demands throughout the Columbia basin river system. Increases in out-of-stream demands within and outside of Washington by 2030 are also likely to make it more difficult to meet instream demands by 2030. Lower flows, particularly in the summer and early fall, could negatively impact threatened and endangered fish in the Columbia River Basin (Figure 10), as well as other fish important to the culture and economy of eastern Washington.

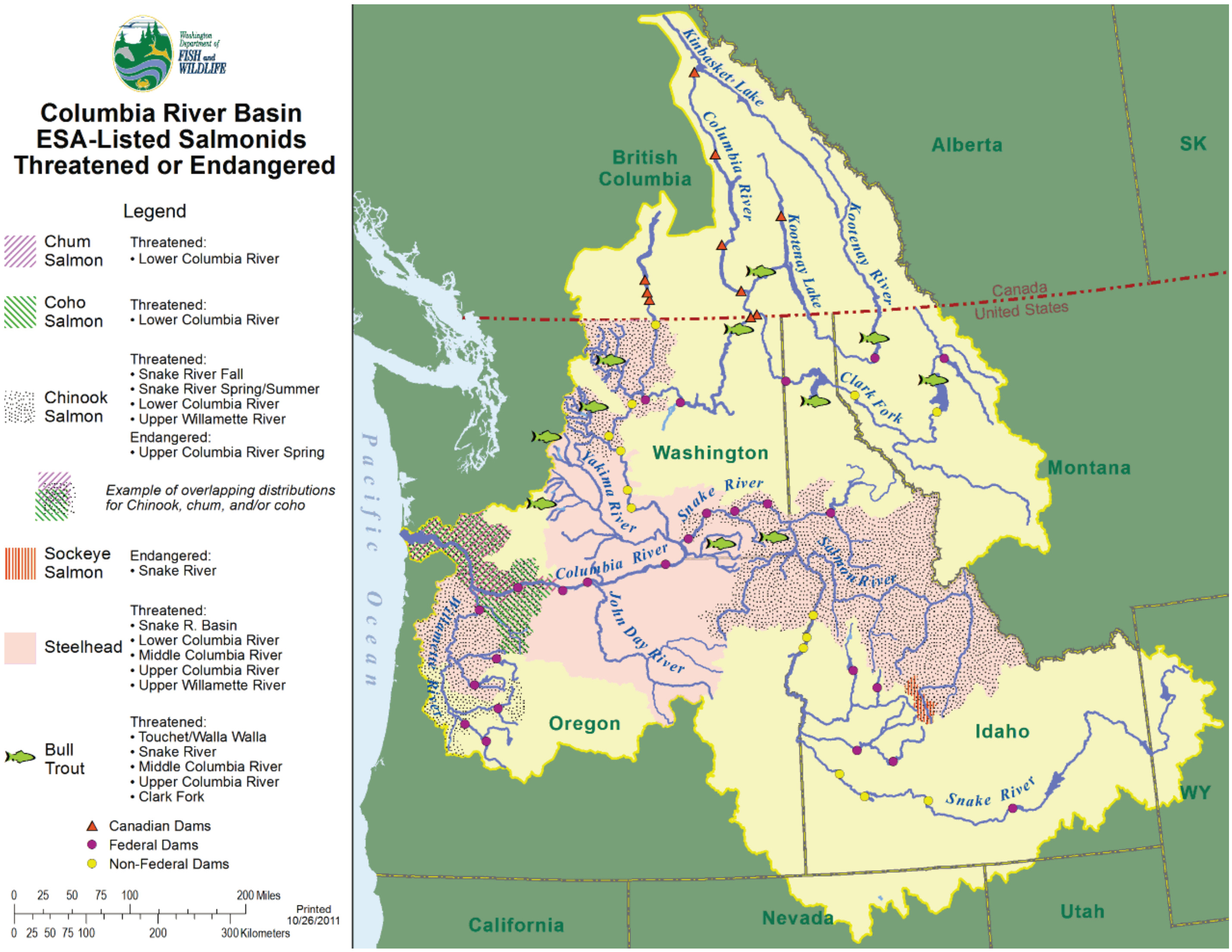


Figure 10. Distribution of fish listed under the Endangered Species Act in the Columbia River Basin.

Several factors have the potential to impact future water supplies for meeting instream demands in ways that are difficult to predict, and thus were not feasible to capture in this analysis. The possibility for re-negotiation of the international Columbia River Treaty and unquantified tribal water rights, both discussed with water supply results earlier in this section, could change the amounts and timing of water available to meet instream needs in the Columbia River mainstem.

As described in the "Overview of the 2011 Forecast," OCR's database of historical flow information provides site-specific information on historic flow levels, drought occurrences and how often instream flow rules are or are not met for tributaries to the Columbia River in Washington. For example, by graphing the 1963-2009 flows of the Wenatchee River at Monitor gauge (USGS # 1246200) (Figure 11) it is shown that

Chinook salmon

- Historic mean annual flows generally varied between 1.5 and 3 million ac-ft.
- Over the last 30 years, dry years (20th percentile or lower) occurred 6 times, with the worst stretch being 3 consecutive dry years in 1992-1994. During this same time period, the availability of water during dry years worsened (18% decrease).
- The instream flow rule is almost always met in average years except in late summer. In dry years, the instream flow is met in early summer and in the winter.
- The magnitude of unmet instream flows is small in this location. For example, in average years, the instream flow deficit for the entire year totals 2,000 ac-ft. The total annual deficit grows to 84,000 ac-ft in dry years.
- Water is available in-basin that could be used to address these instream shortages through OCR-funded projects (e.g. storage, conservation, or pump exchanges). At Wenatchee at Monitor, the annual amount of water surplus to instream flows during an average water year is 1.5 million ac-ft.

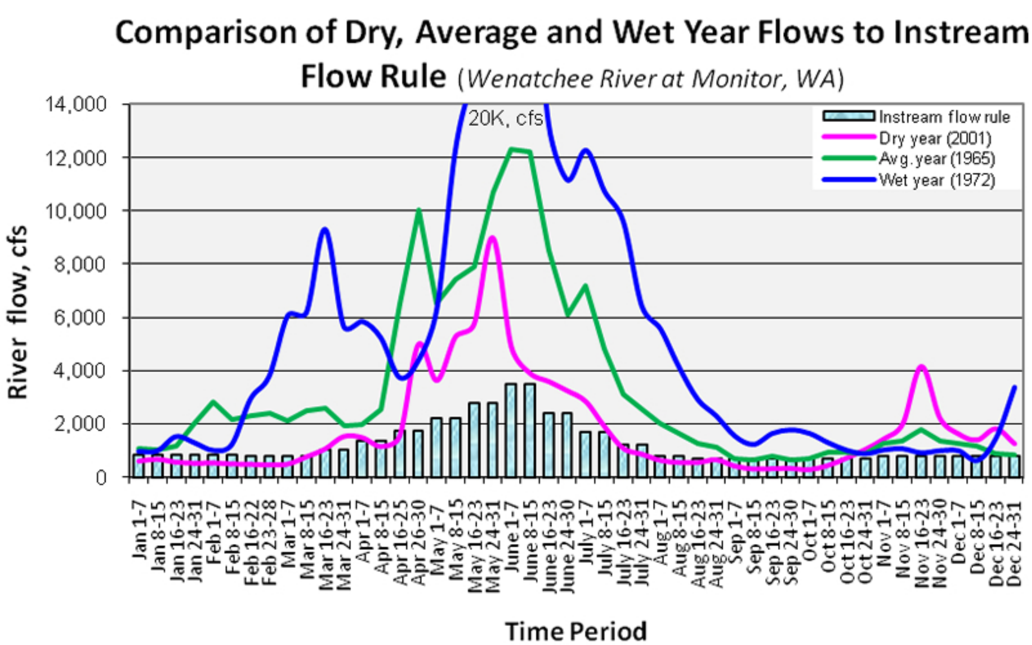


Figure 11. Comparison of actual (not modeled) historical flows (1963-2009) during dry (20th percentile), average (50th percentile), and wet (80th percentile) years to the instream flow rule for Wenatchee River at Monitor.

Columbia River Basin Hydropower Water Demand

As described in the section "2011 Forecast Overview," the hydropower demand forecast focused on a review of projections carried out by power planning entities throughout the Columbia River Basin. The Northwest Power and Conservation Council projected average electricity demand for the entire Pacific Northwest (inside and outside Washington state) of 25,275 MWa, roughly 6,000 MWa higher than in 2010 (range of 22,010-27,761 MWa).[26] Based on WSU's review of this and other regional documents, and interviews with several PUD officials and Avista, utilities throughout the U.S. portion of the Columbia River Basin expect to be able to meet projected steady growth in peak winter and summer energy demands through conservation and integration of other energy sources. New non-hydroelectric projects will likely be needed to meet other requirements such as those in I-937. Several power entities also mentioned concerns about the potential for climate variability (discussed in the section "Climate Change and the 2011 Forecast") and possible renegotiation of the international Columbia River Treaty (discussed with water supply results earlier in this section) to disrupt or reduce hydropower generation capacity.

I-937 requires that power-generating entities pursue Renewable Energy Certificates and other qualified renewable energy generation methods. Qualified methods do not include existing hydropower, except for new conservation and efficiency measures.

In the Canadian portion of the Columbia River Basin, B.C. Hydro expects that demands may grow as much as 40% across British Columbia. Conservation and transmission improvements are described as playing an important role in meeting this anticipated new demand. Beyond that, Site C Clean Energy Project (outside the Columbia River Basin, on the Peace River), if built, could provide up to 1,100 megawatts (MW) of capacity (450,000 homes). Additional capacity at Mica Dam on the Columbia River is anticipated to play a smaller role in meeting new demand; BC Hydro is currently working to add two new generation units (for a total of six). These additional units would not always operate, so although they will provide additional peak capacity of 1,000 megawatts, this is anticipated to serve only 80,000 homes.

It is unlikely that new storage reservoir projects will be needed solely to meet growing power demands within the next two decades.

Power entities in the Columbia River Basin feel that it is unlikely that new storage reservoir projects will be needed solely to meet growing power demands within the next two decades, though they may be needed to help meet growing future surface water supply demands. If additional storage projects are built for water supply purposes, pumping associated with the storage will likely create additional power demands, justifying the expansion or upgrading of hydroelectric facilities. It may also be feasible to generate power as an ancillary benefit at a new storage project, if one is built.

Bonneville Dam and power transmission towers

26 NWPCC 2010, *op. cit.*

Overview of Washington's Watersheds: Tier II Results

WSU's modeling provided a spatial analysis that allowed for forecasting for eastern Washington's WRIAs (Figure 12). Results for individual WRIAs are presented in the section "Forecast Results for Individual WRIAs." Four pages of results are included for each WRIA, comprising a summary of supply and demand results and information on the watershed's water management, water allocation and (for fish critical WRIAs) fish populations. The scale of modeling did not allow for presentation of results at the sub-WRIA level.

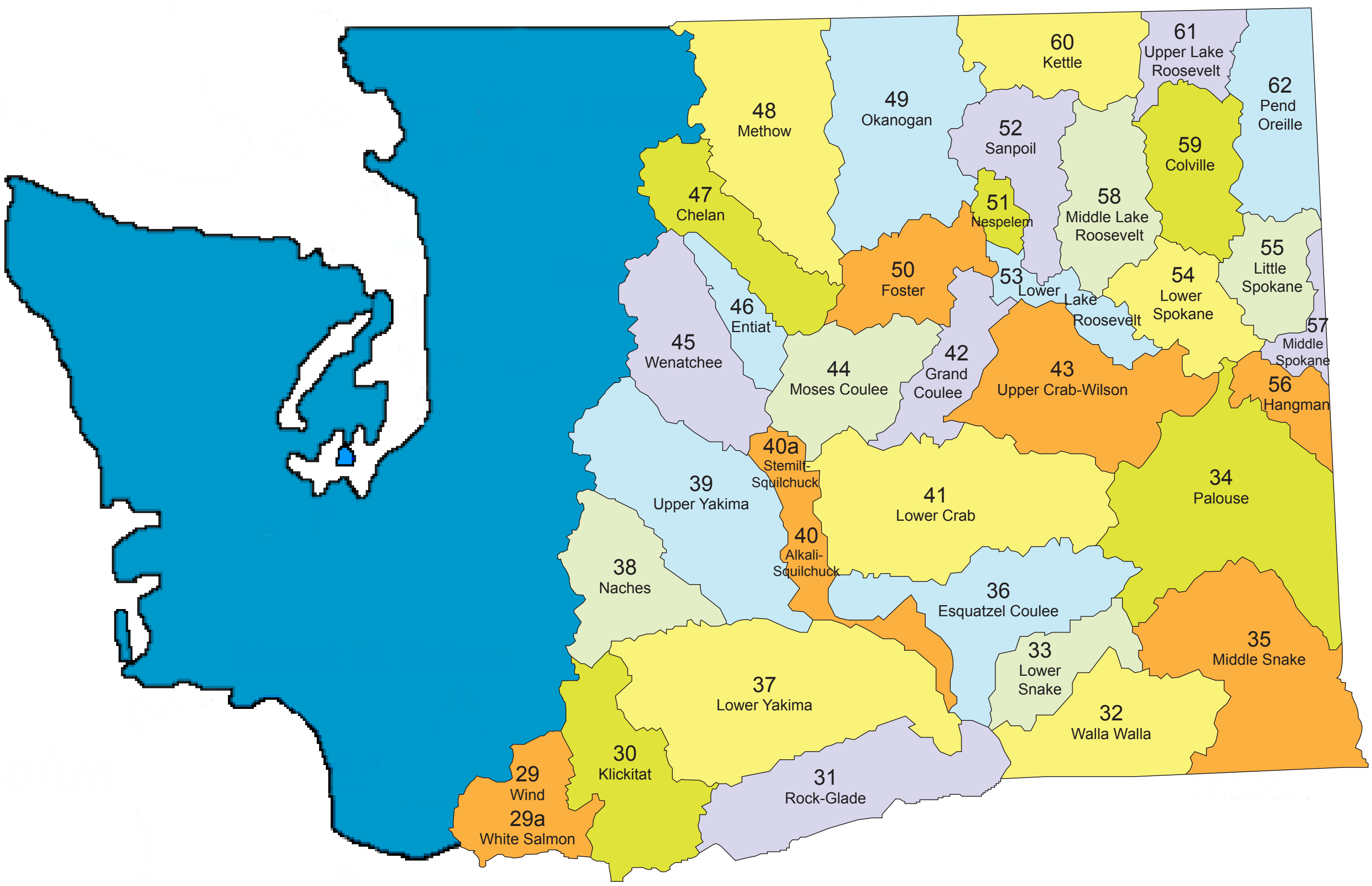


Figure 12. Water Resource Inventory Areas (WRIAs) in eastern Washington.

Definitions of water supply and demand are as described in "Definitions of Water Supply and Water Demand Used in the 2011 Forecast." It is also important when interpreting results to recognize that analysis of surface water supplies at the WRIA level focused on water supplies generated *within* the Washington WRIA. For this analysis, supplies exclude upstream areas that are outside Washington, as well as the mainstem Columbia and Snake Rivers. This was done because much of eastern Washington's water demands come from areas that cannot be hydrated by the Columbia River, but instead are supplied by the major tributaries.

In some watersheds that border the Columbia River, the mainstem supplies the majority of the water necessary to satisfy demands. In other watersheds, demands are met by supplies that come from upstream areas outside of Washington. Supplies on the mainstem are summarized in the section "Washington's Columbia River mainstem: Tier III Results." Supplies in areas outside of Washington state are summarized in the section "Columbia River Basin: Tier I Results," and in the discussion below.

Analysis of water supplies at the WRIA level focused on water supplies generated within the Washington WRIA. For this analysis, supplies exclude upstream areas that are outside Washington, as well as the mainstem Columbia and Snake Rivers. This was done because much of eastern Washington's water demands come from areas that cannot be hydrated by the Columbia River, but instead are supplied by the major tributaries.

Surface Water Supplies in Washington Watersheds

Flows leaving major tributary areas make sizeable contributions to the Columbia as it makes its way from the Canadian border to Bonneville Dam. Figure 13 shows flows (prior to accounting for demands) from major tributary areas, including the portions of tributary areas that extend upstream outside of Washington state.

Annual surface water supply within the Washington portion of the Columbia River Basin is expected to increase for most tributaries of Washington:

- Walla Walla (7.2 ±1.9%)
- Palouse (5.9 ±3.6%)
- Colville (9.5 ±2.8%)
- Yakima (4.4 ±2.3%)
- Wenatchee (5.9 ±1.8%)
- Chelan (5.8 ±1.5%)
- Methow (7.7 ±2.3%)
- Okanogan (4.3 ±2.4%)
- Spokane (6.6 ±2.2%)

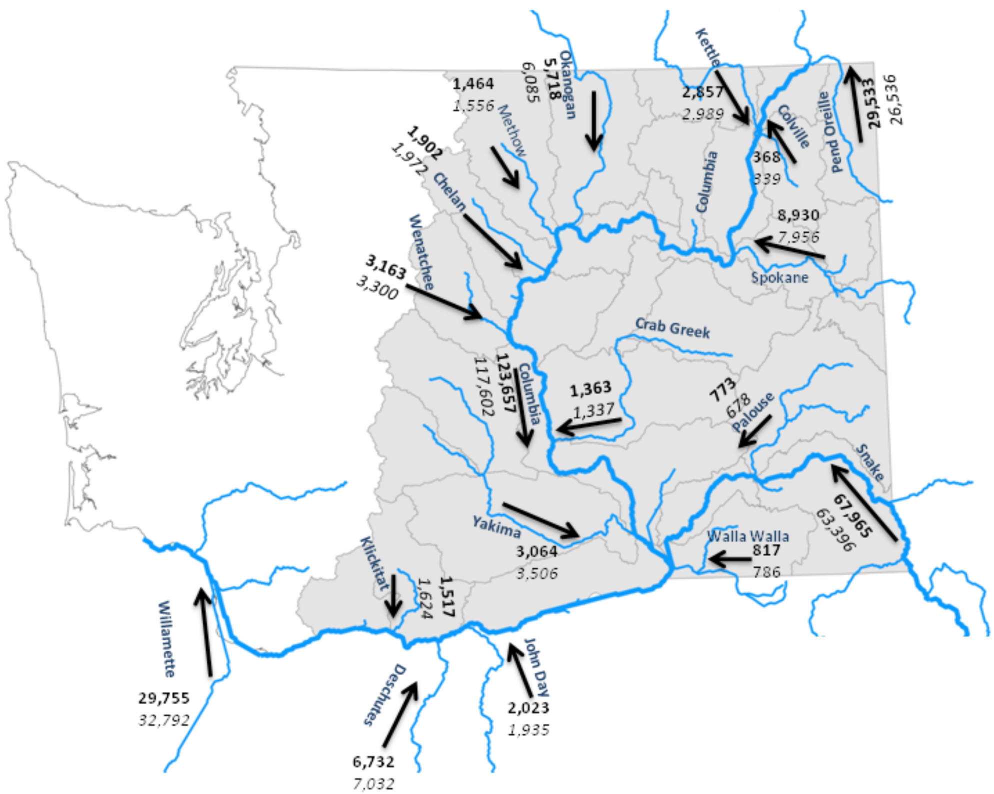


*Figure 13. Contribution of flows (prior to accounting for demands) from tributaries to mainstem Columbia River, including all areas of tributary basins that extend outside of Washington state. Top number (**bold**) refers to 2030 forecasted surface water supplies for average flow conditions. Bottom number (italic) refers to the historical (1977-2006) water supplies. All values are in cubic feet per second.*

Out-of-Stream Water Demands in Washington Watersheds

Forecast water demand for combined agricultural irrigation and municipal uses in 2030, including both surface water and groundwater demands, was concentrated within the southern and central Columbia Basin, including Lower Yakima (37), Lower Crab (41), and Esquatzel Coulee (36), as well as Rock-Glade (WRIA 31), Walla Walla (32), Lower Snake (33), Naches (38), Upper Yakima (39), and Okanogan (49) (Figure 14) These results are dominated by the impacts of irrigation water demand for most WRIAs. Changes in municipal demands are summarized in Table 5.

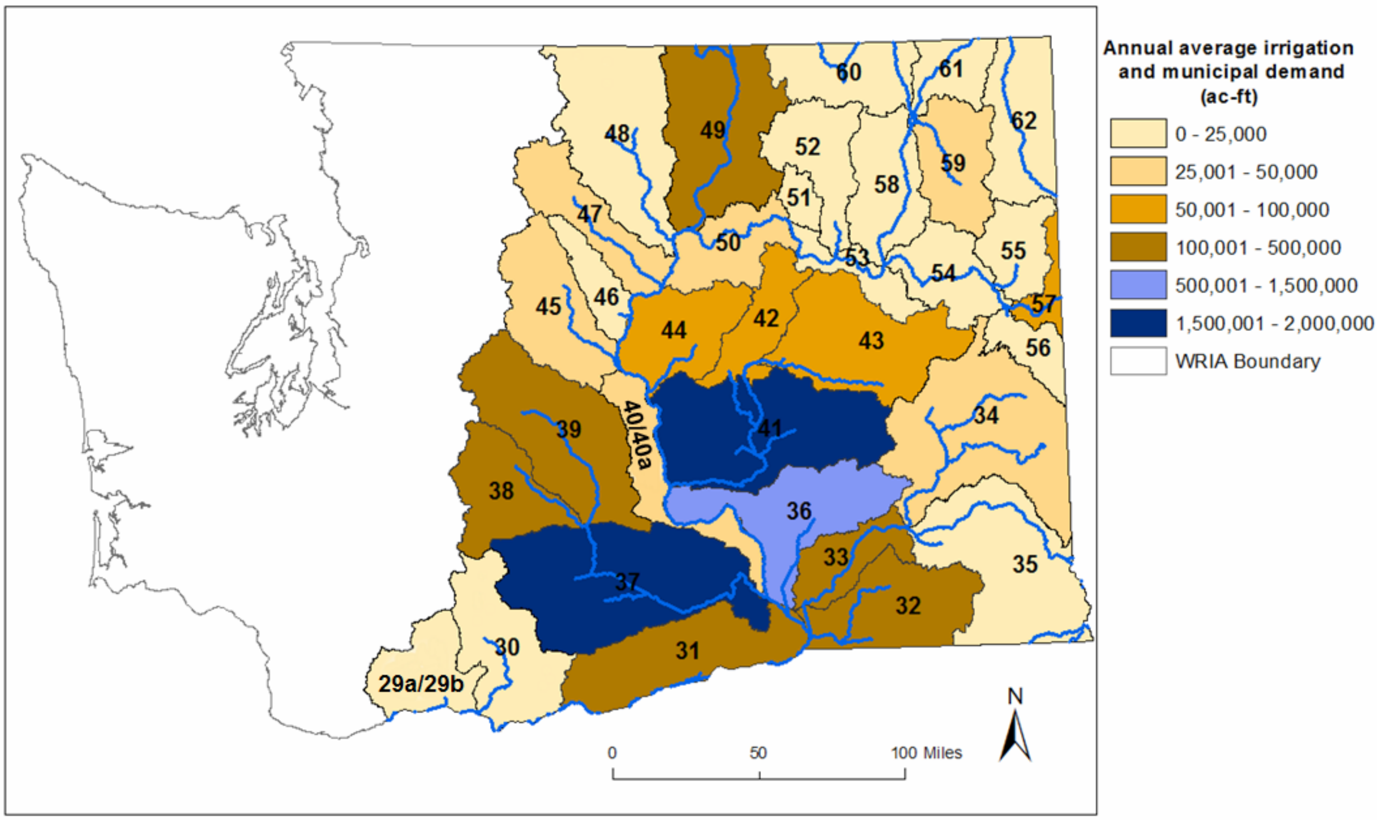
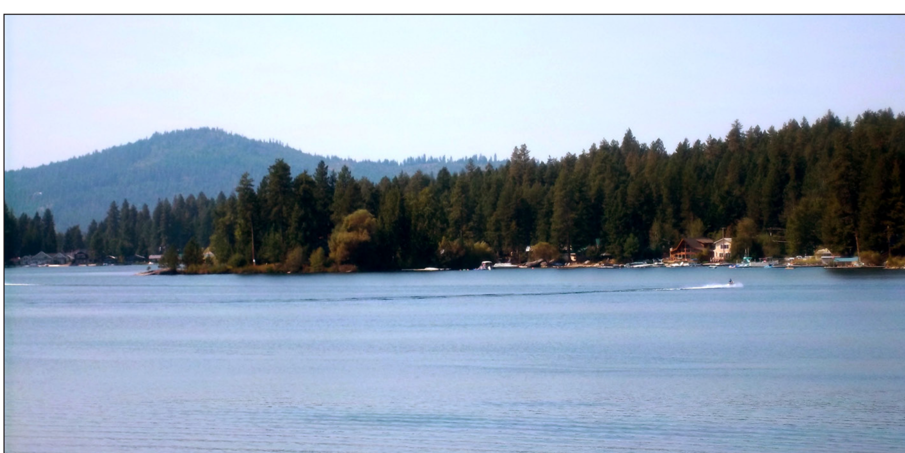


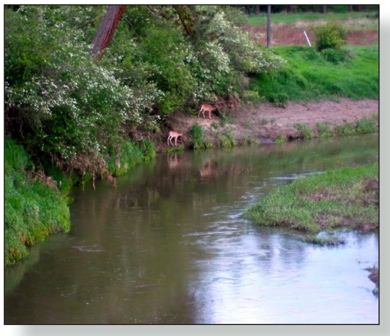
Figure 14. Total 2030 forecasted average annual surface water and groundwater demands for irrigation and municipal uses (including self-supplied domestic) by WRIA (in ac-ft per year).



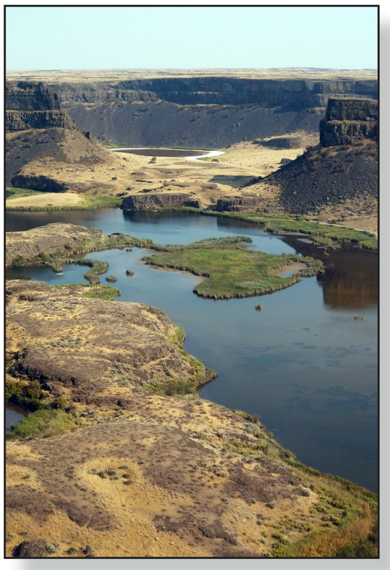
Diamond Lake

Table 5. Changes in municipal demand for WRIAs in the Columbia River Basin.

WRIA	WRIA Name	2010 Population Estimate	2030 Population Estimate	Population Increase 2010-2030 %	Change in Diversion 2010-2030 (ac-ft/year)	Change in Consumptive Use 2010-2030 (ac-ft/year)
29	Wind-White Salmon	10,710	23,564	120.0	1,961	351
30	Klickitat	23,275	28,003	20.3	2,383	791
31	Rock-Glade	93,685	104,313	11.3	1,836	615
32	Walla Walla	58,557	71,031	21.3	2,707	2,088
33	Lower Snake	65,377	76,115	16.4	2,755	291
34	Palouse	76,661	80,224	4.6	421	595
35	Middle Snake	26,344	29,699	12.7	1,630	1,215
36	Esquatzel Coulee	27,389	44,376	62.0	9,164	5,869
37	Lower Yakima	227,594	272,268	19.6	13,356	6,986
38	Naches	68,265	83,286	22.0	2,674	2,181
39	Upper Yakima	50,387	66,206	31.4	4,919	4,346
40	Alkali-Squilchuck	11,410	11,924	4.5	189	166
41	Lower Crab	74,527	95,981	28.8	12,377	6,286
42	Grand Coulee	16,214	15,389	-5.1	-223	-113
43	Upper Crab-Wilson	14,238	14,494	1.8	145	114
44	Moses Coulee	27,805	35,047	26.0	1,320	20
45	Wenatchee	50,530	65,673	30.0	5,284	2,137
46	Entiat	6,100	7,281	19.4	146	68
47	Chelan	14,701	19,419	32.1	1,164	478
48	Methow	11,975	14,362	19.9	835	264
49	Okanogan	22,583	27,544	22.0	1,767	635
50	Foster	11,453	14,121	23.3	851	490
51	Nespelem	1,198	1,358	13.4	45	3
52	Sanpoil	4,417	5,508	24.7	310	35
53	Lower Lake Roosevelt	4,367	5,435	24.5	421	238
54	Lower Spokane	76,440	101,152	32.3	6,329	1,467
55	Little Spokane	59,097	66,716	12.9	3,069	1,682
56	Hangman	56,051	61,374	9.5	701	316
57	Middle Spokane	254,751	342,462	34.4	29,201	12,779
58	Middle Lake Roosevelt	6,498	10,079	55.1	1,049	600
59	Colville	21,394	33,414	56.2	3,520	2,013
60	Kettle	4,518	6,286	39.1	518	296
61	Upper Lake Roosevelt	9,240	14,836	60.6	3,061	2,851
62	Pend Oreille	11,799	16,079	36.3	1,537	438
	TOTAL	**1,499,550**	**1,865,019**	**24.4**	**117,422**	**58,591**



Hangman Creek



Dry Falls

Instream Water Demands in Washington Watersheds

As described in the "Overview of the 2011 Forecast," WDFW ranked fish stock status and habitat utilization, fish habitat utilization, and instream flows in 189 stream reaches in Walla Walla, Middle Snake, Lower Yakima, Naches, Upper Yakima, Wenatchee, Methow, and Okanogan WRIAs. While independent scores for each reach generated a range of results, it was determined that great opportunity to improve salmonid production exists by pursuing water acquisition in smaller, lower elevation streams with good to excellent habitat.

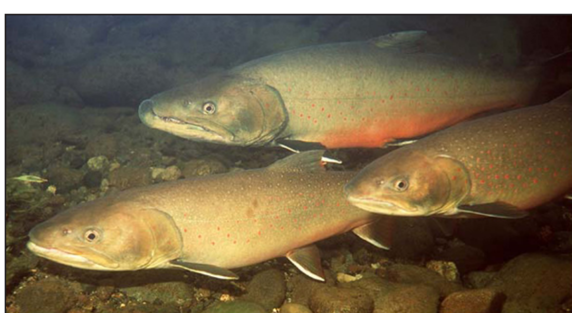
In addition, streams with good to excellent habitat in higher elevations or less populous areas are likely to benefit from flow augmentation, as are lower mainstems through which most stocks/species must migrate. Any flow augmentation could be helpful in salmonid restoration efforts, especially in smaller systems that have limited flow, in over-appropriated basins, or in combination with other recovery measures. Detailed results are available in the Atlas (Ecology Publication 11-12-015).

Unmet Demand in Washington Watersheds

The Forecast calculated unmet demand due to curtailment of interruptible and pro-ratable water rights for each WRIA for the historical period (1977–2006) and for the 2030 forecast. Water curtailment included interruptions in water use when instream flows are not met, in accordance with the relevant portions of the Washington Administrative Code (or for Yakima, the federal flow targets and pro-rationing system). Due to data and resource constraints, the modeling of unmet demand did not consider curtailment of one water user in favor of another more senior water right holder. Unmet instream flow demands are shown in the technical report.

Unmet demands due to curtailment of pro-ratable or interruptible rights, or to insufficient water to meet demands at the watershed scale were indicated for the historical period in the following WRIAs:

- Walla Walla (WRIA 32)
- Yakima (WRIAs 37, 38, & 39)
- Wenatchee (WRIA 45)
- Methow (WRIA 48)
- Okanogan (WRIA 49)
- Little Spokane (WRIA 55)
- Colville (WRIA 59)



Bull trout

Unmet demands were forecasted to impact additional WRIAs for the 2030 forecast. This group of WRIAs includes all watersheds that include land currently irrigated as part of the Odessa Sub-area. Within the Odessa, all lands that were irrigated by groundwater in the historical period (1977-2006) were assumed to have unmet surface water demands in the 2030 forecast, due to the existing groundwater declines. Unmet demands due to curtailment or unmet surface water demands in the Odessa were forecasted for the following watersheds:

- Walla Walla (WRIA 32)
- Palouse (WRIA 34)
- Esquatzel Coulee (WRIA 36)
- Yakima (WRIAs 37, 38, & 39)
- Lower Crab (WRIA 41)
- Grand Coulee (WRIA 42)
- Upper Crab (WRIA 43)
- Wenatchee (WRIA 45)
- Methow (WRIA 48)
- Okanogan (WRIA 49)
- Little Spokane (WRIA 55)
- Colville (WRIA 59)

Frequency and quantity of modeled unmet demands are described in more detail in the section "Forecast Results for Individual WRIAs."

Touchet River

Washington's Columbia River Mainstem: Tier III Results

The FCRPS Biological Opinion governs operations of dams that are part of the Federal Columbia River Power System, specifying flow targets and an adaptive management framework. The FCRPS BiOp aims to ensure that dam operations do not impede the recovery of endangered salmon and steelhead, is required by the Endangered Species Act, and has been the subject of continued litigation.

Flows on the Columbia River mainstem are a reflection of flows in upstream areas of the basin, including areas outside of Washington and tributary areas within Washington. Mainstem water supplies provide instream flows for migrating salmonids, hydroelectricity as part of the federal Columbia River Power System, and water to those in proximity to the river.

Supplies and demands are defined as described in the text box "Definitions of Water Supply and Water Demand Used in the 2011 Forecast." Because all demands exist within a watershed, the bulk of demand results are presented in the section "Washington Watersheds: Tier II Results." However, within the mainstem level, WSU did analyze the proportion of WRIA-level irrigation demand that is within one mile of the Columbia River mainstem.

Surface Water Supplies Compared to Regulatory and Management Schemes at Key Points along the Columbia River Mainstem

The Forecast compared modeled historical (1977-2006) and 2030 forecasted surface water supplies at Priest Rapids, McNary, and Bonneville Dams with Washington state instream flows (WA ISF), and the Federal Columbia River Power System Biological Opinion (FCRPS BiOp) (Figures 15 and 16). These two regulatory schemes were chosen because of their role in regulating interruptible water rights holders (in the case of the WA ISF) and managing federal dams and the Quad Cities[27] water permit (in the case of the FCRPS BiOp).

Palouse Falls

27 Kennewick, Pasco, Richland, West Richland

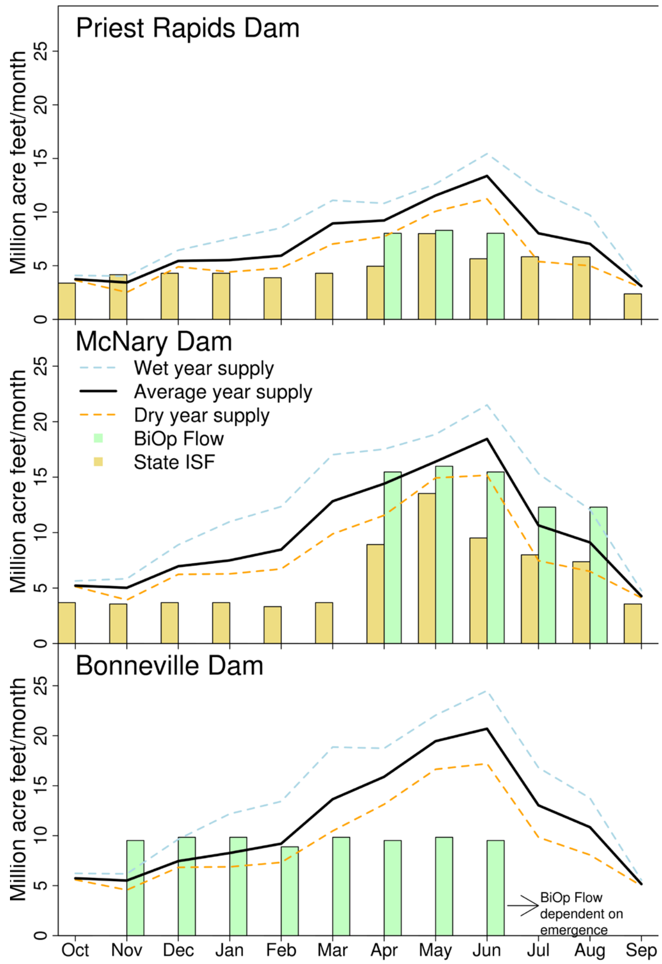


Figure 15. Historical (1977-2006) surface water supply at Bonneville, McNary, and Priest Rapids dams for low (20th percentile), average, and high (80th percentile) flow conditions. Also shown are the Washington state instream flow (ISF) and federal BiOp flow targets.

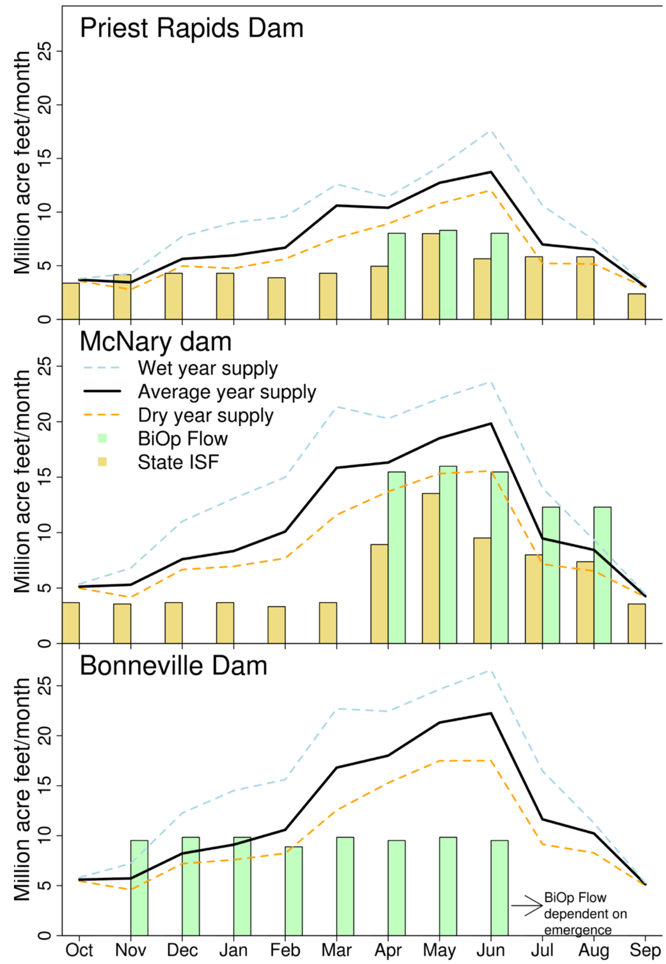


Figure 16. Forecast 2030 surface water supply at Bonneville, McNary, and Priest Rapids dams for low (20th percentile), average, and high (80th percentile) flow conditions. Also shown are the Washington state instream flow (State ISF) and federal BiOp flow targets.

Regulation of mainstem water users is not triggered unless the total forecasted on March 1st at The Dalles is less than 60 million ac-ft. However, on a month-to-month basis, under all flow conditions, forecasted (regulated) surface water supplies prior to meeting demands under average flow conditions were sufficient to meet Washington state instream flow targets in most months at most points along the mainstem. Under average flow conditions, the exception was November water supplies at Priest Rapids Dam, which did not meet state ISF targets.

Under dry flow conditions, in both the historical and 2030 forecast, August surface water supplies failed to meet state ISF targets at Priest Rapids and McNary. November water supplies at Priest Rapids were also below state ISF targets, under both normal and dry flow conditions.

Vineyards near Maryhill

Naches River

In contrast, water supplies prior to meeting demands were insufficient to meet BiOp flows in more months, in both the historical and 2030 forecast. Under normal flow conditions, at McNary Dam, historical and 2030 forecasted water supplies were below BiOp flow targets for July and August. Historical water supplies were also below BiOp flow targets for April. At Bonneville, both historical and 2030 forecasted water supplies under average flow conditions were below BiOp flow targets from November through January. Imbalances were generally smaller in the 2030 forecast than the historical case for the late winter/spring months, and larger for the late summer. Under dry flow conditions, there were even more months when surface water supplies failed to meet BiOp flow targets. Water supplies during dry flow conditions were below BiOp flow targets at McNary Dam from April through August. Under dry flow conditions at Bonneville, water supplies were insufficient to meet BiOp flow targets from November through February in the historical period, and in the 2030 forecast from November through January.

Proportion of WRIA-Level Demand along the Columbia River Mainstem

The Columbia River provides an important source of water supply for many WRIA water users within close proximity to the river. With additional infrastructure investments, mainstem water supplies could potentially meet even more of these WRIA-level demands. To give a sense of what portion of WRIA-level irrigation demand was in proximity to the Columbia River mainstem, a one-mile corridor on each side of the Columbia River was defined identifying all lands bordering the Columbia River. The corridor width was selected by OCR as a surrogate for detailed, project-specific analysis. It is possible that demands outside this corridor could be met by Columbia River supplies under some circumstances; however, evaluating all possible supply options was beyond the scope of the Forecast. Unfortunately, existing water rights data do not provide sufficient accuracy to confidently estimate what proportion of this amount is *already* being met by Columbia River mainstem supplies versus those that could be supplied via new projects. Lastly, the feasibility of serving specific areas with water diverted from the Columbia River was also outside the scope of this Forecast.

Both historically and in the 2030 forecast, more than half of the surface water irrigation demand was within one mile of the Columbia River mainstem for the following WRIAs (Table 6):

- Alkali-Squilchuck (WRIA 40)
- Moses Coulee (44)
- Foster (50)
- Lower Lake Roosevelt (53)
- Middle Lake Roosevelt (58)

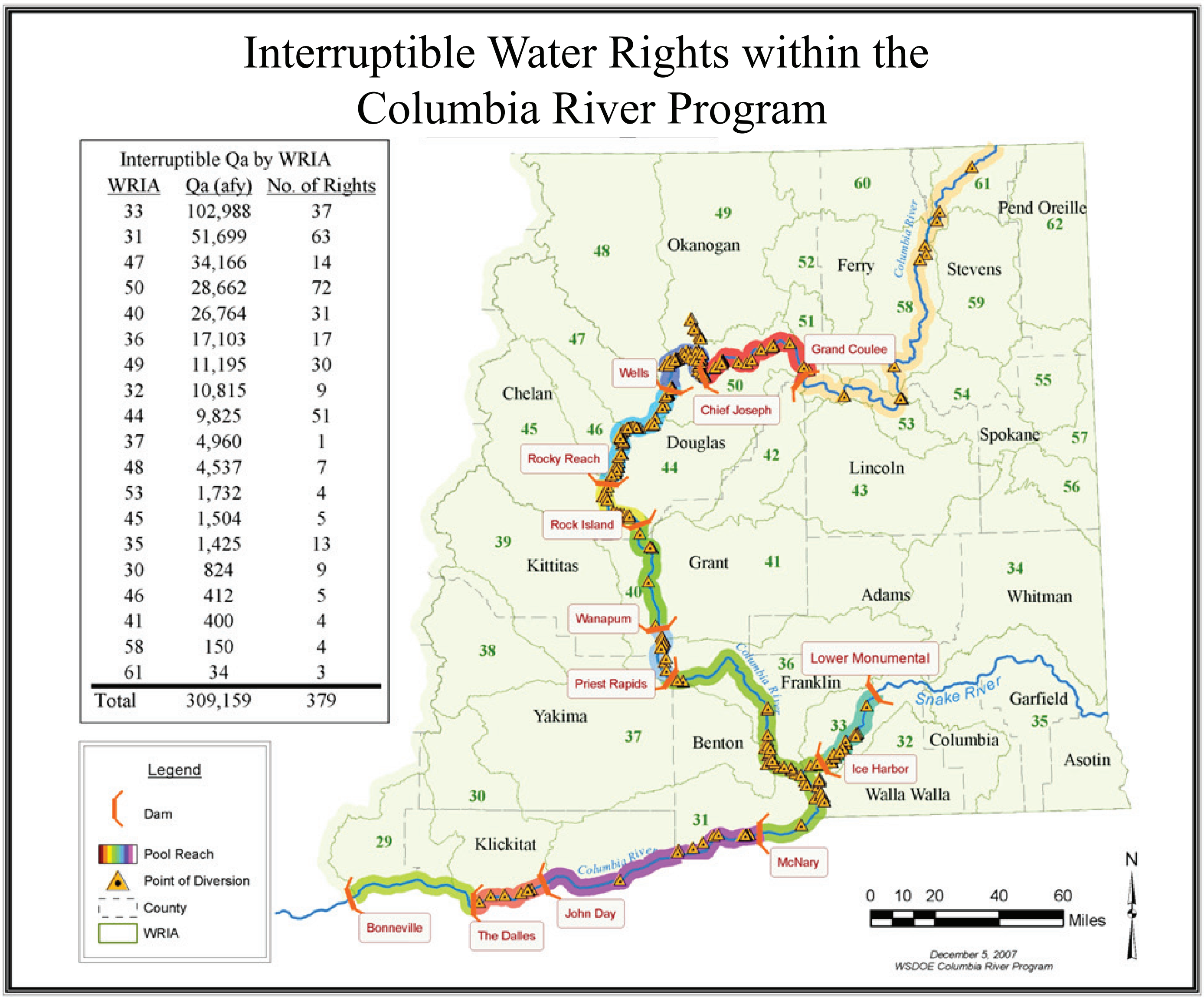
In addition, Esquatzel Coulee (36) and Lower Crab (41) each have more than 50,000 ac-ft per year of surface water irrigation demand within one mile of the Columbia River mainstem, although this does not represent a large proportion of WRIA-level irrigation demand, as there are large numbers of irrigated acres in both these WRIAs.

Table 6. Estimation of the average historical (1977-2006) and forecasted 2030 WRIA-level surface water top of crop irrigation demand (excluding conveyance losses) within one mile of the Columbia River mainstem.

WRIA	WRIA Name	Total modeled WRIA-level irrigation demand		Modeled WRIA-level irrigation demand within one mile of the Columbia River mainstem			
		ac-ft/year		ac-ft/year		As a percentage of WRIA-level demand	
		Hist	2030	Hist	2030	Hist	2030
29	Wind-White Salmon	6,237	6,600	290	298	5%	5%
30	Klickitat	17,616	18,284	0	0	0%	0%
31	Rock-Glade	401,521	395,150	87,118	87,900	22%	22%
32	Walla Walla	209,049	208,996	7,504	7,445	4%	4%
33	Lower Snake	159,315	163,629	0	0	0%	0%
34	Palouse	28,687	29,548	0	0	0%	0%
35	Middle Snake	1,523	1,579	0	0	0%	0%
36	Esquatzel Coulee	1,166,218	1,185,731	194,190	200,891	17%	17%
37	Lower Yakima	1,435,031	1,476,659	2,840	2,909	0%	0%
38	Naches	94,821	105,019	0	0	0%	0%
39	Upper Yakima	429,379	466,141	0	0	0%	0%
40	Alkali-Squilchuck	41,535	41,916	38,818	39,060	93%	93%
41	Lower Crab	1,824,122	1,829,532	83,342	84,668	5%	5%
42	Grand Coulee	96,813	95,847	0	0	0%	0%
43	Upper Crab-Wilson	84,196	83,931	0	0	0%	0%
44	Moses Coulee	55,869	61,384	36,049	40,707	65%	66%
45	Wenatchee	34,281	36,472	2,289	2,863	7%	8%
46	Entiat	1,726	1,793	0	0	0%	0%
47	Chelan	26,783	28,944	9,737	10,070	36%	35%
48	Methow	13,165	14,600	4,785	5,385	36%	37%
49	Okanogan	102,845	110,050	17,719	18,535	17%	17%
50	Foster	26,314	31,674	26,314	31,674	100%	100%
51	Nespelem	0	0	0	0	0%	0%
52	Sanpoil	230	245	0	0	0%	0%
53	Lower Lake Roosevelt	7,065	7,443	3,947	4,130	56%	55%
54	Lower Spokane	16,522	16,360	0	0	0%	0%
55	Little Spokane	4,449	4,629	0	0	0%	0%
56	Hangman	1,295	1,416	0	0	0%	0%
57	Middle Spokane	371	404	0	0	0%	0%
58	Middle Lake Roosevelt	1,942	2,089	1,674	1,782	86%	85%
59	Colville	26,719	29,970	0	0	0%	0%
60	Kettle	3,737	4,223	0	0	0%	0%
61	Upper Lake Roosevelt	1,220	1,386	549	616	45%	44%
62	Pend Oreille	0	0	0	0	0%	0%
	TOTAL	**6,320,598**	**6,461,645**	**517,167**	**538,932**	**8%**	**8%**

Curtailment along the Columbia River Mainstem

Water rights holders whose water use can be "interrupted" when flows fall below the levels specified by regulation are vulnerable to potential impacts of water shortages. Along the mainstem, there are 379 interruptible water rights (Figure 17), the majority of which are agricultural surface water rights. When The Dalles flow forecast is below 60 million ac-ft for April through September, these users may be required to stop using water in weeks when flows do not meet requirements. The highest total annual quantity of interruptible water is located in Lower Snake (WRIA 33), while Rock Glade (31), Alkali/Squilchuck (40), Moses Coulee (44), Okanogan (49) and Foster (50) include high numbers of impacted water rights holders.



Interruptible Qa by WRIA

WRIA	Qa (afy)	No. of Rights
33	102,988	37
31	51,699	63
47	34,166	14
50	28,662	72
40	26,764	31
36	17,103	17
49	11,195	30
32	10,815	9
44	9,825	51
37	4,960	1
48	4,537	7
53	1,732	4
45	1,504	5
35	1,425	13
30	824	9
46	412	5
41	400	4
58	150	4
61	34	3
Total	309,159	379

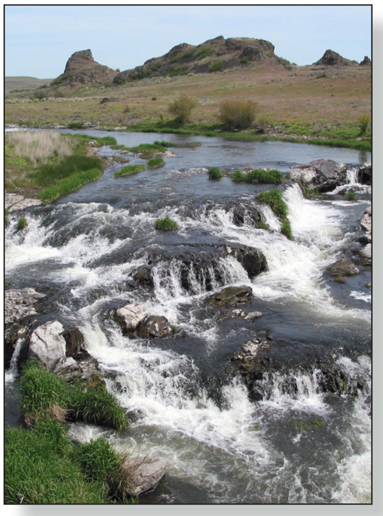
Figure 17. Amount of water associated with interruptible water rights along the 1-mile corridor within the Columbia River Program.

Significant Findings

Surface Water Supply in the Columbia River Basin

Modeling forecast results for 2030 suggest that compared to historical (1977-2006) supplies:

- A small increase of around 3.0 (±1.2)% in average annual supplies will occur.
- Timing changes will shift water away from the times when demands are highest. Unregulated surface water supply at Bonneville will decrease an average of 14.3 (±1.2)% between June and October by 2030, and increase an average of 17.5 (±1.9)% between November and May.
- Annual water supplies entering Washington are forecasted to increase for most rivers entering the eastern portion of the basin, and the direction of change is unclear for most rivers entering the northern portion of the basin.
    - Annual water supplies entering Washington will increase by approximately 3.7 (±1.3)% on average for the Columbia, Pend Oreille, Spokane, Clearwater, Snake, and John Day Rivers by 2030.
    - The direction of change for annual water supplies entering Washington is unclear for the Similkameen and Kettle Rivers, +1.4 (±1.9)% on average by 2030.



Rock Creek

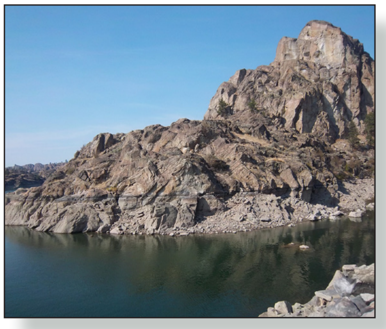
The regional survey of water managers throughout the Columbia River Basin revealed that efforts to improve flow or aquatic habitat conditions in portions of the Columbia River Basin outside of Washington state typically involve relatively minor changes to management of winter or peak flows at existing projects. Little definitive action is currently being taken to build large water infrastructure projects due to a lack of funding and willingness to pay for water. Overall, the results of the survey confirmed that the current upstream management scheme could be used for modeling. The survey also indicated that a lack of regional and cross-jurisdictional communication hampers planning efforts. Improving communication may be a first step to creating more purposeful opportunities for partnership.

Fishing on Lake Pateros

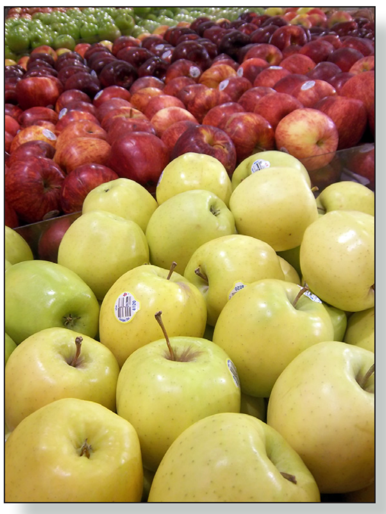
Annual surface water supplies within the Washington portion of the Columbia River Basin are expected to increase for most tributaries of Washington:

- Walla Walla (7.2 ±1.9%)
- Palouse (5.9 ±3.6%)
- Colville (9.5 ±2.8%)
- Yakima (4.4 ±2.3%)
- Wenatchee (5.9 ±1.8%)
- Chelan (5.8 ±1.5%)
- Methow (7.7 ±2.3%)
- Okanogan (4.3 ±2.4%)
- Spokane (6.6 ±2.2%)

Pond in Klickitat County



Banks Lake



Washington apples at the market

Orchards near Wells Dam

Within the Washington portion of the Columbia River Basin, the Forecast shows a fairly consistent pattern in changes of surface water supply timing, with higher flows in late fall, winter and spring by 2030, and lower flows in the summer and early fall. Exact timing varies by watershed.

Cumulative Water Demands in the Washington State Portion of the Columbia River Basin

This section presents cumulative forecasted demands for the Washington state portion of the Columbia River Basin. These results should be understood within a likely context of increasing demands across the entire Columbia River Basin, particularly during summer low flow conditions.

Historical (1977-2006) out-of-stream diversion demands within the Washington state portion of the Columbia River Basin for municipal and agricultural irrigation water (excluding irrigation conveyance losses) were estimated to be in the range of 6.3 (±0.1) million ac-ft. Forecasted increases in water demands in eastern Washington for 2010 to 2030 are summarized in Table 7. The Forecast anticipates

- 170,000 (±18,000) ac-ft per year of additional *total* (ground and surface) water agricultural irrigation demand. This number assumes no change in irrigated acreage, and no additional water supply development. This number represents demands for surface and groundwater as applied to crops, plus the additional water needed to account for irrigation application inefficiencies.
- 430,000 (±14,000) ac-ft per year of additional *surface* water agricultural demand. This number includes new demands that will be met only by surface waters, and assumes that historical groundwater irrigation demands in the Odessa area will be new surface water demands in the future.
- 117,500 ac-ft per year in additional total diversion demands for municipal and domestic water.
- 500,000 ac-ft per year of unmet tributary instream flows, and 13.4 million ac-ft per year of unmet Columbia River mainstem instream flows, based on observed deficits during the 2001 drought year.
- No demand for new water storage for hydropower generation purposes.

Table 7. Forecast increases in demands by sector from 2010 to 2030 in eastern Washington.

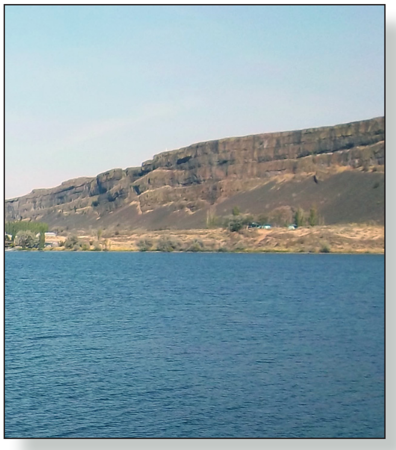
Demand Type	Estimated Volume (acre-feet)	Source
2030 New Irrigation Demand[a]	170,000	WSU Integrated Model
2030 New Municipal and Domestic Demand (including municipally-supplied commercial)	117,500	WSU Integrated Model
Unmet Columbia River Instream Flows[b]	13,400,000	Ecology data, McNary Dam, 2001 drought year
Unmet Tributary Instream Flows[c]	500,000	Ecology data, tributaries with adopted instream flows, 2001 drought year
2030 New Hydropower Demand	0	WSU Surveys and Planning Forecast Review
Alternate Supply for Odessa	164,000	Odessa Draft Environmental Impact Statement (October 2010)
Yakima Basin Water Supply (pro-ratables, municipal/domestic and fish)	450,000	Yakima Integrated Water ResourceManagement Plan (April 2011)
Unmet Columbia River Interruptibles	40,000 to 310,000	Ecology Water Right Database (depending on drought year conditions)

[a] Additional irrigation demands were modeled assuming an equivalent land base for irrigated agriculture, under a scenario of medium growth in the domestic economy, and medium growth in international trade. Acreage currently irrigated by groundwater in the Odessa was assumed to be new surface water demand in 2030, and thus is not reflected in changes in total demand, which includes both surface and groundwater. Increases in total demand are thus due to the combined impacts of climate change, and changes in crop mix driven by growth in the domestic economy and international trade.

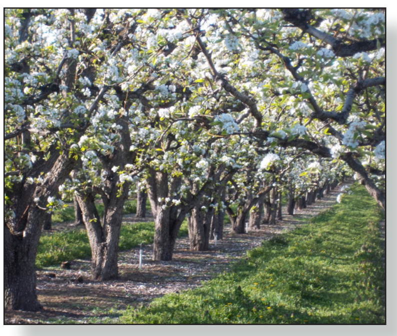
[b] Unmet Columbia River instream flows are the calculated deficit between instream flows specified in Washington Administrative Code (WAC) and 2001 (drought condition) actual flows at McNary Dam.

[c] Unmet tributary instream flows are the combined deficits between current instream flows specified in WAC and 2001 actual flows at Walla Walla River near Touchet, Wenatchee River at Monitor, Entiat River near Entiat, Methow River near Pateros, Okanogan River at Malott, Little Spokane River near Dartford, and Colville River at Kettle Falls.

New irrigation and municipal demands do not include improvements in conservation, which could decrease the new demands that need to be met, but might also have complex impacts on return flows. For example, if all municipal and domestic users were able to conserve 10% of their water supplies by 2030, then new municipal demand might drop from 117,500 ac-ft to about 105,000 ac-ft. However, many municipal conservation techniques are non-consumptive in nature. For example, fixing leaky pipes and installing low flow showers and toilets reduce diversions, but with a corresponding reduction in water returned (via wastewater treatment plants or underground). Alternatively, some conservation measures, such as incentives for reducing lawn size, do reduce consumptive use. In addition, conservation is often cheaper than new water supply development.



Lower Grand Coulee



Apple orchard in Yakima

In addition to these new demands by sector, other studies suggest several areas of unmet demand, some of which are not reflected in these totals. These other studies used different methods of calculating demand, and thus, should not be directly compared to the totals above.

- The draft Environmental Impact Statement for Odessa suggests a preferred alternative of supplying 164,000 ac-ft per year of surface water to current groundwater users in this area. This amount is not included in the total irrigation demands above, which shows changes in total (combined groundwater and surface water) demand between the historical period (which includes Odessa) and 2030.
- The Yakima Integrated Water Resource Management Plan suggests that 450,000 ac-ft per year will be needed for pro-ratable, municipal-domestic and fish needs. These demands overlap partially with the demands shown above.
- The Ecology Water Right Database indicates that in years in which the Mainstem Drought Program is run, there are 40,000 to 310,000 ac-ft per year of unmet needs by interruptible water users, depending on the drought year conditions. These amounts are currently unmet, so are not reflected in the numbers above.

Together, these current and new demands are likely to exacerbate water supply issues in some locations, particularly during the summer.

Water Demands in the Columbia River Basin by Sector

Agricultural Water Demands

The agricultural portion of the Forecast focused on irrigation water demands. The 2030 forecast of demand for irrigation water across the entire Columbia River Basin (seven U.S. States and British Columbia) was 13.6 million ac-ft under average flow conditions, assuming an equivalent land base for irrigated agriculture in the future (Table 8). The range of estimates was from 13.1–14.1 million ac-ft during wet and dry years, respectively (20^{th} and 80^{th} percentile). This irrigation demand was roughly 2.5% above modeled historic levels under average flow conditions. Conveyance losses, that occur as water is transported through irrigation ditches and canals, were estimated separately.

Table 8. Top of crop agricultural demands under the baseline economic scenario (medium domestic economic growth and medium growth in international trade), excluding conveyance losses, in the Columbia River Basin in the historical and 2030 forecast period. Estimates are presented for average years, with range in parentheses representing wet (80th percentile) and dry (20th percentile) years.

	Historical (1977-2006) million ac-ft per year	2030 Forecast million ac-ft per year	% Change
Entire Columbia River Basin	13.3 (12.6-13.9)	13.6 (13.1-14.1)	2%
Washington Portion of the Columbia River Basin	6.3 (6.0-6.5)	6.5 (6.2-6.6)	2%

Seasonal timing of forecasted water supply and irrigation water demand is shown in Figure 18, with irrigation demands taking a larger proportion of water supplies in summer months by 2030. Instream, hydropower and municipal water demands will also need to be met from these water supplies.

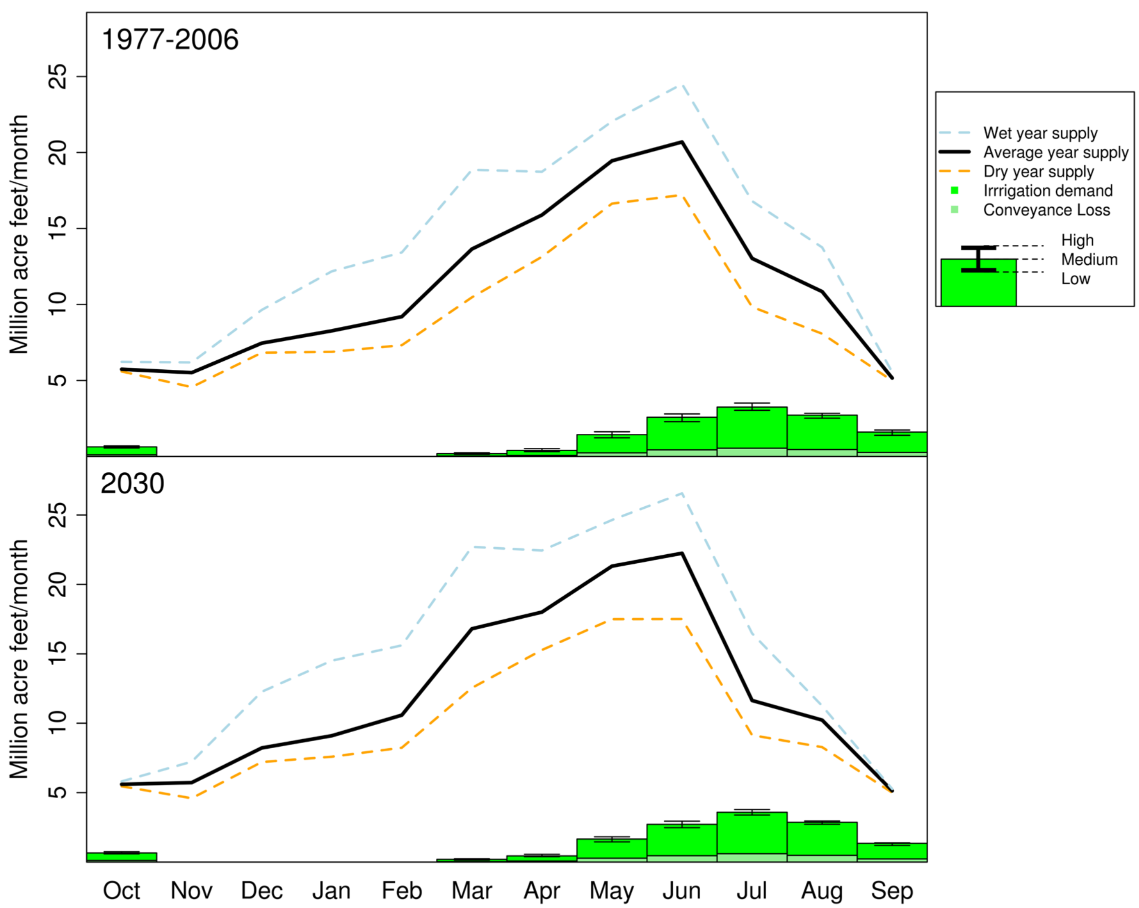


Figure 18. Comparison of regulated surface water supply and surface water irrigation demands for the historical (top) and 2030 forecast (bottom) periods under the medium-growth, medium-trade economic scenario across the entire Columbia River Basin, including portions of the basin outside of Washington state. Wet (80th percentile), dry (20th percentile), and average (50th percentile) flow conditions are shown for both supply and demand.


Downtown Leavenworth


Irrigation canal in Colfax


Sockeye salmon

Within the Washington state portion of the Columbia River Basin, results were similar (Table 8):

- Forecast increases in irrigation water demand were an average of 170,000 (±18,000) ac-ft per year, roughly 1.9% above historical conditions, assuming an equivalent land base for irrigated agriculture, and a crop mix influenced by medium growth in the domestic economy and international trade.
- Considering only the climate impacts of temperature and precipitation variations on the irrigation demand, there would be a 3.7% increase in demand. When economic impacts resulting in a new crop mix are considered in addition to the climate effects, the increase in demand reduces to 1.9%.

Modeling under alternate economic scenarios was used to give information about the potential range of future water demands from irrigated agriculture, if growth in the domestic economy and international trade were higher or lower than anticipated. Higher income growth leads to an expansion of high value crops like fruits and vegetables at the expense of low value crops. Similarly, stronger growth in exports has a disproportionate impact on higher value crops, although wheat and alfalfa are also sensitive to fluctuations in trade. Production patterns were generally more sensitive to assumptions about trade than to assumptions about economic growth. One exception was wine grapes where most of the growth in demand is expected to come from domestic consumers rather than international exports.

- The low, medium and high economic scenarios forecasted increases of 200,000 (±17,000) ac-ft, 170,000 (±18,000) ac-ft and 140,000 (±18,000) ac-ft over historical demands under average flow conditions within the Washington portion of the Columbia River Basin.
- These estimates assumed no change in the land base for irrigated agriculture, thus differences in the agricultural water demand between different scenarios were due to changes in crop mix and crop water demands under future climate conditions.

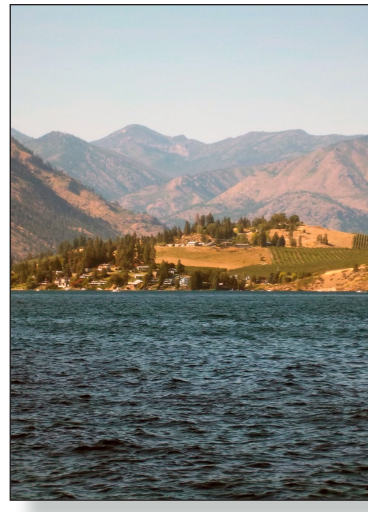
Additional scenarios considered the potential impacts of additional water capacity in specific locations corresponding to projects proposed by OCR. Under some scenarios, new water was provided at no cost to users, while in other scenarios, users were charged per unit fees to recover some development costs.

- The development of roughly 200,000 ac-ft of annual water capacity (the medium scenario considered) caused demand for irrigation water to increase by 46,400 (±640) ac-ft per year over baseline 2030 demands (under the medium economic scenario) in the Washington portion of the basin.[28]

28 Under this water capacity scenario, 164,000 ac-ft was developed to meet current agricultural demand in the Odessa, with the rest serving new demands.

Municipal Water Demands

Municipal demands, including domestic and municipally-supplied industrial, are likely to increase throughout the entire Columbia River Basin over the next 20 years. By 2030, U.S. Census estimates show population growth in Idaho (25.6%), Oregon (26.2%), and Montana (5.6%). Although some new municipal demands will likely be met by deep groundwater supplies, others will likely come from shallow groundwater or surface water. These additional demands will likely reduce inflows into some parts of Washington. For example, an Idaho study of the Spokane River basin projected an additional demand on the river of 31 cfs by 2060.[29]



Lake Chelan

Columbia River near Carson

Within eastern Washington, the Forecast found that:

- Domestic and industrial diversion demands in rural and urban areas (excluding self-supplied industries) were forecasted to be 569,000 ac-ft per year in 2030, an estimated 26% increase over 2010. Consumptive demands are approximately 51% of this amount.
- Per capita water demands varied considerably throughout eastern Washington, with an average total demand (including system losses) of approximately 277 gallons per capita per day (gpcd).[30]

Instream Water Demands

Across the Columbia River Basin, the Forecast found that:

- Decreases in surface water supplies in summer and early fall may increase the challenge of meeting water needs for fish across the Columbia River Basin by 2030.
- Re-negotiation of the international Columbia River Treaty could change the amounts and timing of water available to meet instream needs in the Columbia River mainstem.
- Quantification of tribal water rights, while outside the scope of this Forecast, could also change surface water supplies for meeting instream demands in unpredictable ways.

Within eastern Washington, the forecast of demand for water to support instream flows found the following:

- In many rivers in eastern Washington, stream flows are below state or federal instream flow targets on a regular basis, particularly in late summer. Surplus water exists in many of these same rivers at other times of year.
- Decreases in surface water supplies in tributaries in summer and early fall may lead to more weeks when instream flows are not met by 2030. This may result in a higher frequency of curtailment of interruptible water right holders in basins with adopted instream flow rules.

29 31 cfs = 22,443 ac-ft/year
30 277 gallons per day = 0.429 cfs = 311 ac-ft/year

- An evaluation of fish, flows, and habitat in eight fish critical basins, available in the Atlas (Ecology Publication 11-12-015), will help target investments to maximize the positive impact on fish populations.

Yakima River near Wapato

Hydropower Demands

Across the Columbia River Basin, the forecast of hydropower demands found the following:

- Demand for water storage to supply hydropower facilities is anticipated to remain unchanged in 2030. Utilities expect to be able to meet projected steady growth in peak winter and summer energy demands through conservation and integration of other energy sources, including those required under Washington's passage of Initiative 937.
- Several power entities are concerned that climate change and the possible renegotiation of the international Columbia River Treaty will affect hydropower generation capacity.

Pears near Wenatchee

Water Demands in Washington State Watersheds

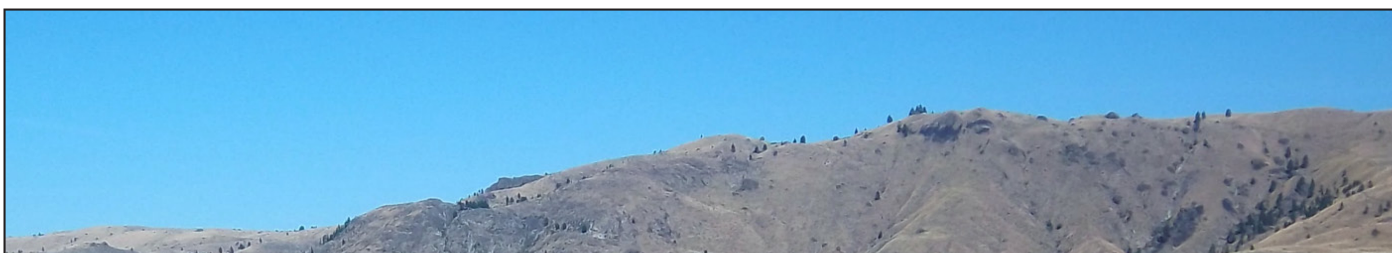
Surface water supplies and water demands were forecasted for each WRIA in eastern Washington. Major results for each WRIA are presented at the end of this report. Cumulatively, the following results were found:

- The greatest concentration of current and future agricultural irrigation and municipal water demands are in the southern and central Columbia basin, including Lower Yakima (37), Lower Crab (41), and Esquatzel Coulee (36), as well as Rock-Glade (WRIA 31), Walla Walla (32), Lower Snake (33), Naches (38), Upper Yakima (39), and Okanogan (49). Irrigation dominates the demand for water in these WRIAs.
- Unmet demand due to curtailment of interruptible and pro-ratable water rights or insufficient water at the watershed scale was forecasted for Walla Walla (WRIA 32), Yakima (37, 38, & 39), Wenatchee (45), Methow (48), Okanogan (49), Little Spokane (55), and Colville (59).
- Unmet demand for surface water was forecasted for the Odessa due to existing groundwater declines in Palouse (WRIA 34), Esquatzel Coulee (36), Lower Crab (41), Grand Coulee (42), and Upper Crab (43).

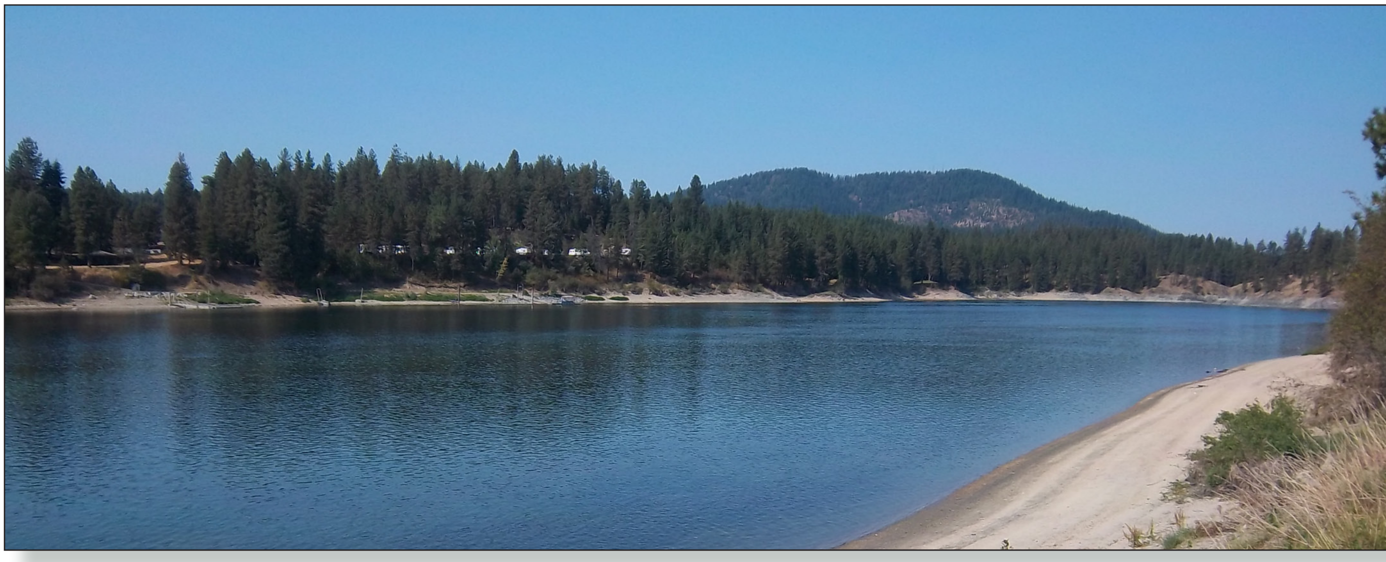
Surface Water Supply and Demand on Washington's Columbia River Mainstem

Modeled historical and 2030 forecasted surface water supplies were compared to state-level instream flow targets and the Federal Columbia River Power System Biological Opinion (FCRPS BiOp).

- Under normal flow conditions, modeled regulated surface water supplies *prior to* meeting cumulative demands were close to Washington State instream flow regulations in fall/early winter at Priest Rapids Dam (both historical and 2030 forecast), and in July and August at Priest Rapids Dam and McNary Dam (for the 2030 forecast).
- Under normal flow conditions, modeled regulated surface water supplies *prior to* meeting cumulative demands were not sufficient to meet target flows under the FCRPS BiOp in April, July, and August at McNary Dam, and from November through January at Bonneville Dam. Imbalances were smaller in the 2030 forecast than the historical case for the late winter/spring months, and larger for the late summer.
- Along the mainstem, there are 379 interruptible water rights, the majority of which are agricultural surface water rights. These water users are particularly vulnerable to the potential impacts of water shortages.



Columbia River near Chelan



Pend Oreille River

Conclusion

Collectively, these results suggest that meeting water demands will be more challenging by 2030 as increased demands are placed on limited supplies. Solutions will require combinations of conservation, water banking/marketing, and new supplies based on groundwater and/or storage of water in peak runoff seasons.

For solutions requiring additional investment in water supply infrastructure, the Forecast's results suggest that at prices in the range of those currently being charged by the Office of Columbia River for new water it may be feasible to recover some or all water supply costs from new users without significantly decreasing the quantity of water demanded by users.

Projects associated with the medium water capacity scenario of an additional 200,000 ac-ft per year for out-of-stream uses were estimated to lead to total employment impacts (including indirect and induced effects) of 6,600 jobs. State and local tax impacts were estimated at about $37 million. These estimates do not subtract the jobs and taxes associated with production if land associated with the new capacity was previously under dryland cultivation. These estimates include economic activity generated from post-farmgate processing of agricultural products that occurs within Washington. While not quantified, it is recognized that maintenance of and improvement to instream flows would also have positive economic impacts on tourism and recreation, generating additional jobs and tax revenues.

This Forecast improves our understanding of future surface water supplies and instream and out-of-stream demands, and will serve as a capital investment planning tool to maintain and enhance the region's economic, environmental, and cultural prosperity. Future forecasts will build upon and expand this knowledge to include assessments of groundwater supplies, the Columbia River Treaty and other pertinent issues.