7. Water Resources

7. Water Resources

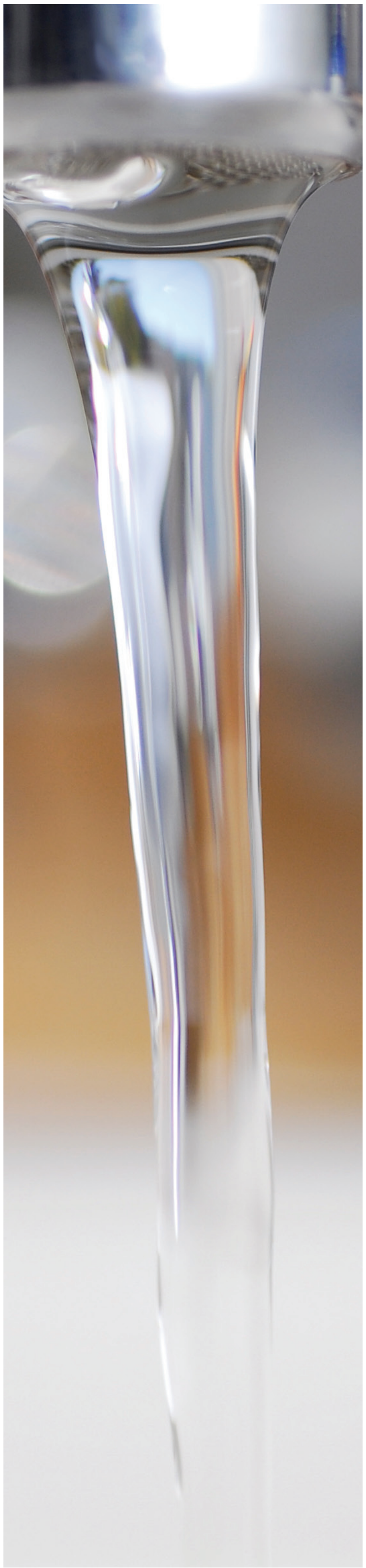
A reliable supply of water is vital for the communities, businesses, industries, ecology, and quality of life in Washington State. Washington communities rely to varying degrees on our snow-fed water supply to provide safe and clean drinking water. Our $2.5 billion irrigated agriculture industry, which helps drive the local and state economy, relies on water to irrigate crops. That same water also feeds rivers and streams that support salmon, a state icon and valuable commercial fishery. Washington's abundant hydropower resources supply two-thirds of the electricity for the state.

The impacts of climate change will intensify our current challenges in managing water resources in Washington. The state's water resources are already under stress from:

- Excessive water withdrawals.
- Increasing conflicts among water users and demands on water resources.
- Increasing water quality degradation.
- More frequent and intense droughts and floods.
- Loss of species, habitats, and ecosystems.

Climate change impacts will vary across different watersheds in Washington. More frequent and extreme precipitation events will likely strain our urban stormwater systems and increase the amount of polluted runoff flowing into Puget Sound. Flood risk will increase for some basins in the state, putting people and infrastructure in harm's way.

Climate change will increase the variability—widening the range—of future supply and demand of water. As climate change shifts the timing and volume of streamflow and reduces snowpack, lower flows during the summer will make it more difficult to maintain an adequate supply of water for communities, agriculture, and fish and wildlife. Lower summer flows and higher stream



temperatures will continue to degrade our water quality and place further stress on salmon.

Our current management systems for water are designed around past patterns of temperature and precipitation. Preparing for and adapting to the impacts of climate change will require new management approaches that take into account how future conditions are likely to change. Many initiatives are in place and partners are engaged in addressing these challenges and anticipating future needs, using approaches such as:

- Conservation and demand management.
- Technical innovations.
- Water transfers, markets, and water banks.
- Infrastructure improvements.
- Enhanced information systems and hydrologic forecasting.
- Water management and efficiency practices.

However, no single project or initiative can adequately address the challenges we face and the tradeoffs we need to make. Our region needs well-coordinated adaptation strategies at the state, local, and regional levels to improve resiliency, reduce risks, and increase water sustainability. Long-term integrated planning and investing in comprehensive actions at a region or basin level will help prepare Washington for future changing climate and balance our water management objectives related to:

- Water availability and demand.
- Water quality.
- Agriculture.
- Fish and wildlife.
- Flood and storm control.
- Hydropower.
- Navigation, recreation, and tourism.

Washington's quality of life depends on adequate, reliable amounts of clean water. The sections below describe the scientific understanding of the impacts of climate change on Washington's waters, followed by key strategies and recommended actions to protect these waters and lower risks to our communities and ecosystems.

Impacts of Climate Change on Water Resources

Climate change has already altered and will continue to alter the snowpack and streamflows in the western United States, affecting where, when, and how much water is available for all uses.[111] Projected climate change impacts include:

- Reductions in the amount of water naturally stored in snowpack and glaciers, due to rising temperatures and increasing winter runoff.
- Declining late summer streamflow, increasing demand for water, and more intense competition for scarce water resources.
- Increases in winter precipitation, posing additional challenges for managing reservoirs for flood control, fish, and hydropower.
- Reduced water quality due to lower late summer streamflow, warmer summer temperatures, and increased winter flooding.

1 Declining snowpack and loss of natural water storage

During the winter, when the majority of precipitation occurs, snow accumulates in upper elevations and forms a "natural reservoir" that stores water during times when demands are relatively low. As the climate warms, more precipitation falls as rain and less as snow, leaving less water naturally stored in snowpack and glaciers. The snow melts earlier in the spring, and less water is available to feed our streams in the late summer when demands for water are highest.

Widespread declines in spring snowpack have already occurred across the western U.S., especially since the 1950s.[112] Greater losses in snowpack have been observed in mid-elevation mountain ranges such as the Cascades, where sensitivity to changes in temperature is high. Snow is melting earlier, and peak runoff occurs from 1 to 4 weeks earlier across much of the western U.S. than in the 1950s.[113]

These patterns are expected to continue and further alter the hydrologic behavior of many watersheds in Washington. Spring snowpack across the state is projected to decrease 29 percent by the 2020s, 44 percent by the

[111] Hidalgo *et al*. (2009).
[112] Mote *et al*. (2005).
[113] Stewart *et al*. (2005)

2040s, and 65 percent by the 2080s (relative to the 1971-2000 average) under a moderate emissions modeling scenario (A1B). The low emissions scenario (B1) shows slightly less severe projected decreases of 27 percent for the 2020s, 37 percent for the 2040s, and 53 percent for the 2080s.[114]

2 Changes in seasonal streamflow

Increasing temperature, declining snowpack, and earlier snowmelt are expected to shift streamflow timing. The impact will differ by basin type (see Figure 4), however. Hydrologic modeling shows that:

- **Mixed rain- and snow-dominated basins**, such as the Yakima River, are likely to shift to rain-dominated basins. Peak streamflow will shift earlier in the spring and late summer streamflow will decline.
- **Snow-dominated basins**, such as the Columbia River, are likely to see reduced peak spring streamflow, increased winter streamflow, and reduced late summer flow.
- **Rain-dominated basins**, such as the Chehalis River, will likely see relatively little change in streamflow timing. However, they will likely experience higher winter streamflow, due to the potential for more winter precipitation.

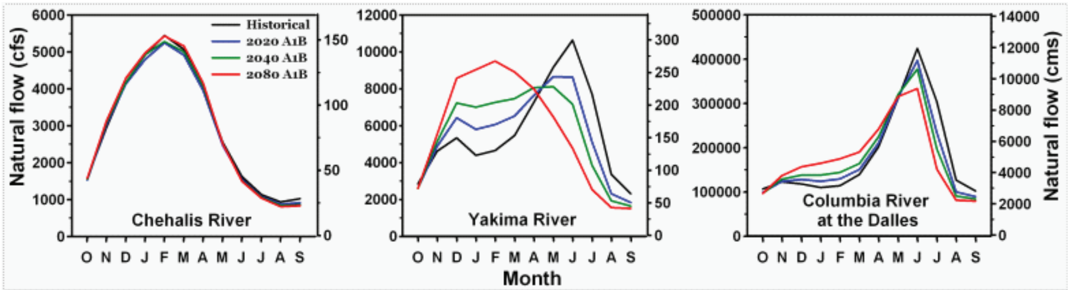


Figure 4. Projected average monthly streamflow for a rain-dominated watershed (Chehalis River), a mixed rain-snow watershed (Yakima River), and a snowmelt-dominated watershed (Columbia River). Hydrographs represent monthly averages of simulated daily streamflow for 1916-2006 and three future periods: 2020s, 2040s, and 2080s. (Elsner et al. 2010)

114 Elsner *et al*. (2010).

In the winter, average runoff is projected to *increase* by:

- 11 to 13 percent by the 2020s.
- 16 to 21 percent by the 2040s.
- 26 to 35 percent by the 2080s.[115]

In the summer, average runoff is projected to *decrease* by:

- 16 to 19 percent by the 2020s.
- 22 to 29 percent by the 2040s.
- 33 to 43 percent by the 2080s.[116]

Yearly precipitation changes are expected to be small overall. Seasonal patterns are expected to intensify, however, with most (but not all) models projecting more winter precipitation and less summer precipitation. Extreme precipitation events are also projected to increase in Washington. Future changes in precipitation due to climate change may be difficult to distinguish from natural variability, given the wide range of natural variability in annual and seasonal precipitation in the Pacific Northwest.

3 Higher drought risk and more competition for scarce water resources

Climate change is expected to increase the risk of summer water shortages and increase demand for water, which will intensify competition for water for both instream and out-of-stream uses.

Yakima Basin: Water shortages are projected to occur more frequently in the Yakima Basin, and the reservoir system will likely face difficulty supplying water to all users, especially those with junior water rights. The average production of apples and cherries could decline by approximately $23 million in the 2020s and by $70 million in the 2080s.[117]

Salmon in the Columbia Basin: Lower summer streamflow and higher stream temperatures will substantially reduce the quality and extent of freshwater salmon habitat.[118] By the 2080s, the duration of stream

[115] Relative to 1916-2006. Elsner *et al*. (2010).
[116] Relative to 1916-2006. Elsner *et al*. (2010).
[117] Stöckle *et al*. (2010).
[118] Mantua *et al*. (2010).

temperatures that cause thermal stress and migration barriers for salmon is projected to at least double and possibly quadruple for most streams in the interior Columbia Basin.

Hydropower: Summertime hydropower production is likely to decline by 9 to 11 percent by the 2020s. Meanwhile, summer demand for energy will increase significantly due to higher electricity needs from air conditioning as well as population growth.[119]

Puget Sound water supplies: Urban water supply systems in Puget Sound will collect less water in their reservoirs in late spring and early summer. Climate change impacts could result in water demand increases of as much as 12 percent by 2060.[120] Many of the region's water utilities have adapted in the past to fluctuations in water supplies and are actively implementing and planning long-term adaptations to respond to climate change challenges.

Small water systems and groundwater: Increased drought risk could alter drinking water supplies for small public, private, and independent water systems. Many communities in rural areas rely on groundwater, which could be affected by climate change. Reductions in spring and summer streamflow could limit surface water supplies, triggering heavier reliance on groundwater. On the "plus" side, warmer, wetter winters could increase the amount of water available for groundwater recharge.[121] The impacts of climate change on groundwater sources of supply are not well understood, however, and this area needs further study.

Forests: Drought stress is likely to reduce forest productivity in eastern Washington. The area of severely water-limited forests is projected to increase 32 percent by the 2020s and an additional 12 percent in the 2040s and 2080s.[122] Drought-stressed forests may be more susceptible to mountain pine beetle outbreaks.[123]

Wildfires: Warmer temperatures and reductions in summer precipitation will likely increase the areas burned by wildfire. Wildfires disrupt the watershed processes through erosion, warmer water temperatures, increased stormwater runoff, and loss of forest canopy. These changes will likely alter the soil's capacity to retain water and recharge aquifers.[124]

River navigability: Reductions in summer water levels could also affect the navigability of rivers and lakes in the region, although the risk is not well understood.

[119] Hamlet *et al*. (2010).
[120] Water Supply Forum (2009).
[121] U.S. Department of the Interior, U.S. Bureau of Reclamation (2011).
[122] Littell *et al*. (2010).
[123] Littell *et al*. (2010).
[124] U.S. Global Change Research Program (2009).

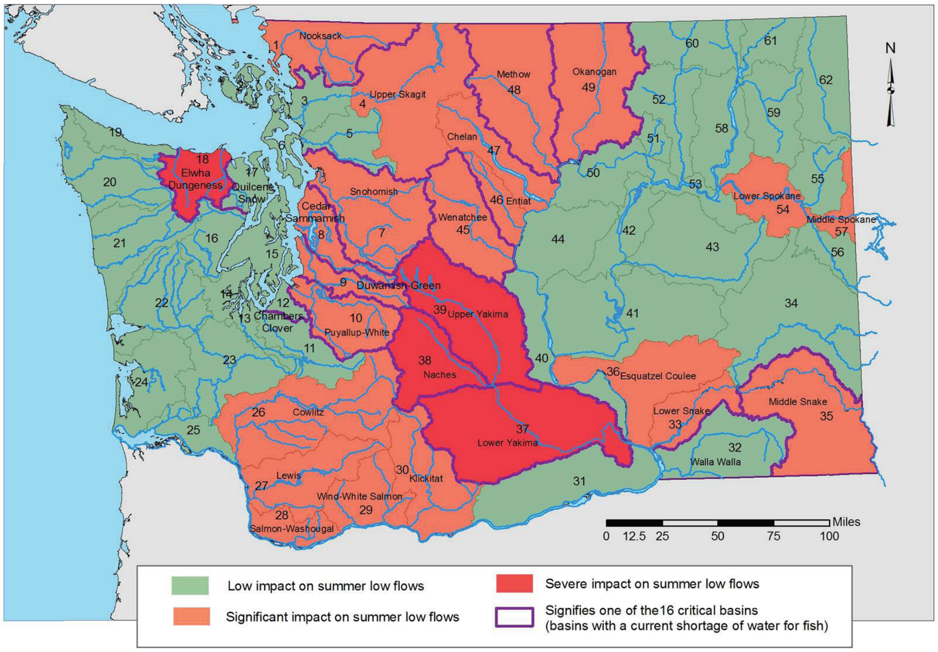


Figure 5. 2040 Projected climate change impact on summer flows by watershed. Climate change will intensify current water needs of people, fish, and farms in at least 45 percent of the state, shown in red on the map.

Source: Washington Department of Ecology

4 More severe winter flooding

Washington already faces challenges from severe flooding, and the damages can be very costly. Projected increases in winter runoff, increases in winter precipitation, and more intense precipitation will increase the frequency of flooding, particularly for mixed rain/snow-dominated basins sensitive to changes in temperature. For many large rivers near major population centers in western Washington, the magnitude of the 100-year flood under natural conditions is projected to increase by 20 to 30 percent by the 2040s (see Figure 6).[125] Low-lying, rain-dominated basins show modest increases in winter flood frequency due to projected increases in winter precipitation and extreme precipitation events.

Flood frequency east of the Cascades is typically driven by rapid spring snowmelt, particularly in snow-dominated basins. In general, snow-dominated basins are expected to experience

[125] Hamlet *et al*. (2010).

minimal changes in flood event frequency due to anticipated climate changes, and spring flood event frequency could decline in some eastern Washington basins because of declines in spring snowpack.

More frequent flooding poses challenges for managing reservoirs for flood control, fish, and hydropower production. More flooding will strain existing flood control infrastructure, such as reservoirs, dikes, levees, tide gates, and dams. Flooding, erosion, and rising snow/freeze-thaw levels increase the flow of sediment to lower elevations in watersheds, potentially changing the width and depth of stream channels. Low-lying buildings, roads, energy facilities, wastewater facilities, and other infrastructure in or near floodplains or along coastal areas will be at a higher risk of flood damage. The risk of erosion, landslides, and mudslides could also increase. In Puget Sound and lower elevation basins in the interior Columbia basin, winter flood risk will likely increase the risk of streambed scouring of spawning habitat.[126]

[126] Mantua *et al*. (2010).

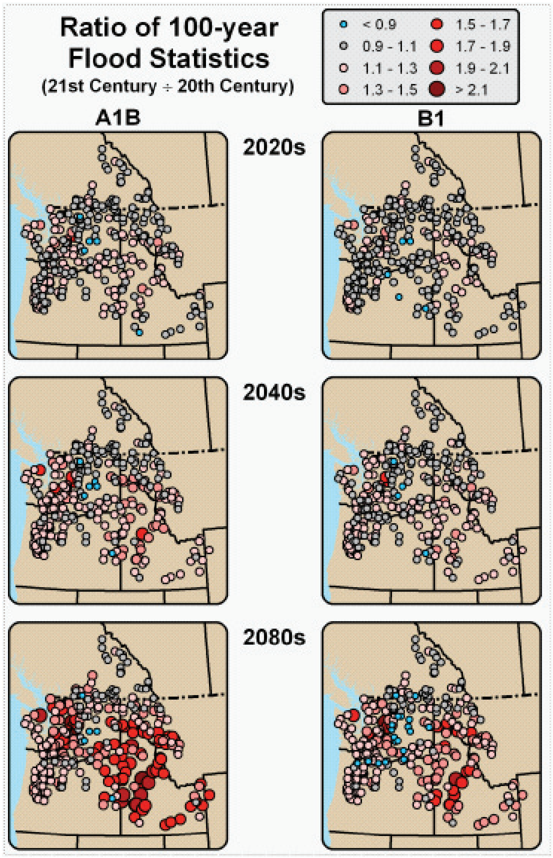


Figure 6. Maps of the ratio of the 100-year flood magnitude (future/historical) for three future time intervals, under two climate scenarios. (Higher ratios, shown with larger dots in red, indicate more intense flooding events projected for the future). (Source: Tohver and Hamlet 2010)

5 Declining water quality

Projected increases in temperature, winter flooding, and prolonged low summer flows will pose challenges for water quality. High runoff during the wet winter months will increase the flow of polluted runoff into waterways. Stormwater flows over the land and carries with it pollutants from the ground or paved surfaces, such as car oils, antifreeze, brake lining dust, pet and farm waste, fertilizers, and pesticides. Stormwater is the leading contributor to pollution of urban waterways in Washington, and this polluted runoff endangers sensitive species and habitats.

Winter flooding could also strain the capacity of urban drainage infrastructure and result in more frequent overflows. In coastal communities, marine water could inundate wastewater and stormwater systems and could discharge water into the streets from flooded storm drains.

Warmer and drier summers, and elevated stream temperatures could potentially impact the established water quality standards for rivers and streams and the effluent limits (amount discharge to the water body) set on existing wastewater treatment facilities.

Recommended Adaptation Strategies and Actions—Water Resources

Many water resources managers and users are already engaged in efforts to improve Washington's ability to respond to climate change. The recommended strategies and actions below are aimed at reducing climate risks and vulnerabilities, while accommodating non-climate demands of a growing population, ecosystem restoration, clean energy production, and protection from drought and floods.

Strategy D-1. Manage water resources in a changing climate by implementing Integrated Water Resources Management approaches in highly vulnerable basins.

Actions:

1. Ensure that long-range plans developed for highly vulnerable basins—including the Columbia, Yakima, and Walla Walla river basins—account for climate change impacts. Consider the risks and vulnerabilities to water resources and infrastructure, agriculture, forest, and other sectors. Integrate adaptation actions into basin plans to enhance water supply reliability, improve water quality, and improve instream flows and fish passage at existing reservoirs.

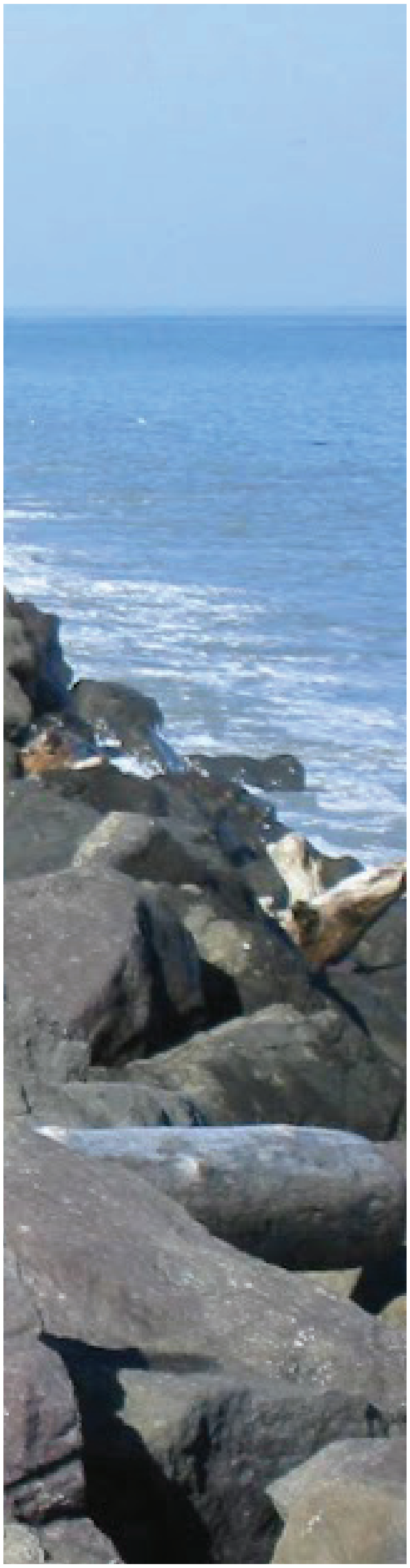
2. Promote broader recognition that an integrated approach is feasible and beneficial, by documenting lessons learned and conclusions from the implementation of integrated water resources management plans in the Columbia, Yakima, and other river basins.

3. Expand the models of the Columbia River Program, the Yakima River Integrated Water Management Plan, and the Walla Walla flexible water management system to other basins (such as the Dungeness and Wenatchee river basins), sub-basins, and aquifers, based on:

   - *Existing and emerging water management issues.*
   - *Need for integrated planning.*
   - *Community and stakeholder engagement.*
   - *Legal and institutional framework.*
   - *Capacity to develop and implement an integrated plan.*

4. Develop guidance for analyzing whether and how to incorporate projected climate information and adaptation actions into planning, policies, and investment decisions. The analysis would help state, local, federal and tribal governments and water organizations understand how changes in watershed hydrology, ecosystems, water quality, and species and habitat conditions in a given watershed may affect activities such as:

   - *Water allocation decisions.*
   - *Water delivery.*
   - *Water systems operations.*
   - *Water quality standards.*
   - *Stormwater and floodplain management.*
   - *Infrastructure safety.*
   - *Ecosystem restoration and species recovery.*
   - *Environmental preservation and restoration efforts.*



5. Incorporate climate change realities—recognizing that past hydrological data are no longer a reliable guide to project future conditions—into agency decision-making to:
   - *Approve new or change existing water rights.*
   - *Adopt instream flows for fish habitat and ecological purposes.*
   - *Decide whether water users are able to use their water rights for the amount allowed, when purchasing or banking trust water rights.*
6. Use the watershed-based framework created under Watershed Planning (RCW 90.82) to establish a well-coordinated water and land use policy that takes an integrated approach to planning. Such plans should reduce risks to rural and urban communities from extreme weather events (such as intensive flooding and frequent droughts).
7. Integrate climate change adaptation into ongoing efforts that address management of stormwater, wastewater, water quality, water reuse, and potable water demand—to ensure that planning decisions and investments made now are not increasing future vulnerability and causing unintended consequences. Require consideration of the impacts of extreme weather events in planning, siting, and designing of water, wastewater, and stormwater infrastructure and related facilities.

Integrated Water Resources Management in the Yakima Basin

Water shortages are a chronic problem in the Yakima River Basin. Demand for water to irrigate crops, provide drinking water and ensure salmon and steelhead survival is greater than available supply.

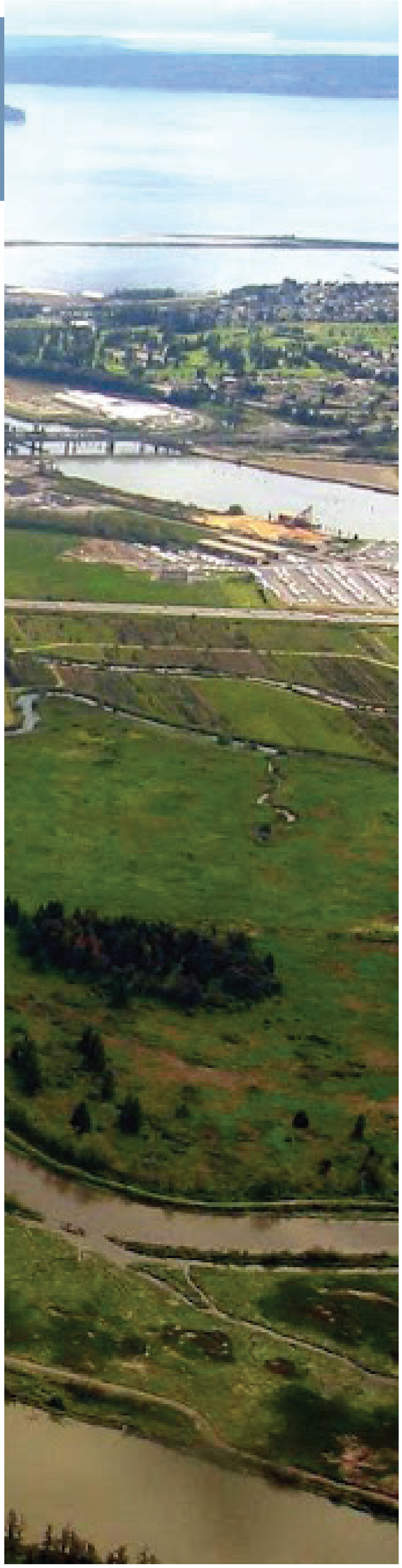
In 2009, Ecology and the U.S. Bureau of Reclamation brought representatives from the Yakama Nation, irrigation districts, environmental organizations, and federal, state, and local governments to develop a consensus-based solution to the basin's water problems. The group agreed upon a proposed approach to improving water management in the Yakima River Basin—an Integrated Water Resources Management (IWRM) plan.

The IWRM Plan, the most comprehensive effort to date in the Yakima Basin, includes seven elements: reservoir fish passage, structural and operational changes to existing facilities, surface water storage, groundwater storage, habitat and watershed protection and enhancement, enhanced water conservation, and market reallocation of water. The new plan has brought together once-conflicting water interests to support the plan.

Yakima River Basin Integrated Water Resource Plan:

www.usbr.gov/pn/programs/yrbwep/2011integratedplan/plan/integratedplan.pdf

Strategy D-2. Improve water supply and water quality in basins most likely to be affected by changing climate.



Actions:

1. Strengthen and increase the capacity of natural systems to respond to droughts, streamflow changes, and flooding by encouraging local governments to adopt land use policies and best practices. Examples include practices that reduce impervious surfaces to protect surface water quality, improve infiltration, and reduce stream erosion and sedimentation. These policies and practices would:
   - *Direct development away from vulnerable areas.*
   - *Decrease flood risk.*
   - *Expand the protection and restoration of prime agricultural and forest lands, aquifer recharge areas, wetlands, floodplains, and wildlife habitat and corridors.*
2. Encourage the state Department of Natural Resources and the U.S. Forest Service to develop and implement forest management practices that would improve water-holding capacity in watersheds and help protect water quality from increased temperature, erosion, and associated pollutants.
3. Support new surface and aquifer storage by capturing winter and spring runoff to make up for summer low flows, where feasible and environmentally sound; and increase storage capacity in existing reservoirs. Doing so could improve water supply reliability, and enhance instream flows, if and when stored water is released during low flow conditions.
4. Conserve water and support water reuse, retention, and infiltration by designing development sites to minimize water needs (such as drought-tolerant landscaping), retaining graywater and stormwater on site and using reclaimed water, and expanding adoption of low-impact development (LID).
5. Foster the development of climate-ready water utility initiatives. Highlight existing utility efforts to evaluate and incorporate climate information into planning, and support the development of peer-to-peer information sharing. Assist water and wastewater utilities,

along with stormwater and floodplain managers, in implementing climate change adaptation and mitigation strategies, with the goal of fostering more resilient water systems. Provide water system planners and operators with the knowledge, capacity, resources, and skills necessary to adapt to a changing climate and continue to fulfill their public health and environmental missions.

6. Support the development and delivery to water utilities of early-warning or rapid-response information, to address challenges and disaster risk to water systems from extreme climate events, such as devastating floods, droughts, fires, and storms.

7. Aggressively pursue reallocation and redistribution of water in critical basins, through water transfers, water transactions, water markets, and water banks with the goal of increasing streamflows for fisheries and improving habitat conditions.

8. Work with federal and local partners to improve the performance of existing water infrastructure, such as reservoirs, to respond to extreme events that may result from climate change and to improve local water supplies.

Columbia River Basin

A temperature-sensitive cycle of snow accumulation and melting dominates surface water flows in the Columbia River Basin. Average temperatures are 1.5°F higher in the Columbia River Basin than they were a century ago, and annual average temperatures are expected to increase by 2.5 °F in the next 50 years. This warming could fundamentally change the patterns of rain and snow in the Columbia River Basin. The changes in water supply and demand are important features of Washington State University's 2011 Forecast.

The forecast found that climate change will shift water availability away from the irrigation season when demands are highest. Water supply at Bonneville Dam is forecasted to decrease nearly 21 percent between June and October, while increasing up to 36 percent between November and May.

Current out-of-stream diversion demands for municipal and agricultural irrigation are projected to increase by 2030. This increased demand is likely to exacerbate water supply issues in some locations, and during the summer, will make it more difficult to meet all demands, including instream demands for fish. The forecast information will guide the state in developing a water management plan and in making strategic capital investments in water infrastructure to meet eastern Washington's environmental and economic needs.

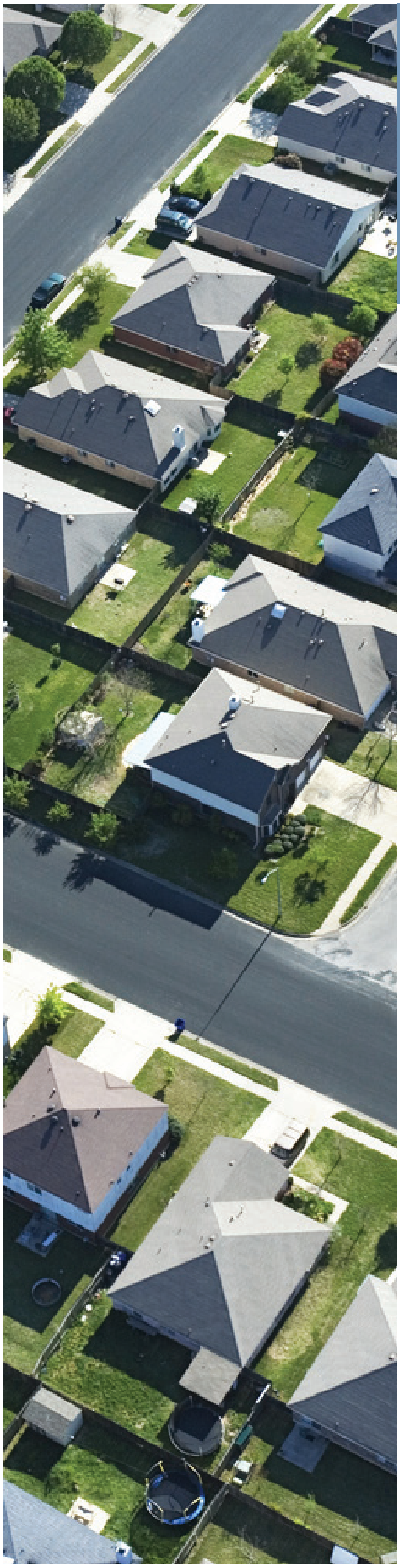
www.ecy.wa.gov/programs/wr/cwp/wsu_supply-demand.html

River Management Joint Operating Committee (RMJOC)

Climate change will alter how the Columbia River and its tributaries will be managed for flood control, power generation, and protection of endangered fish. The U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, and the Bonneville Power Administration began a climate change initiative in 2008.

In 2011, the three federal agencies produced the "Climate and Hydrology Datasets for Use in the River Management Joint Operating Committees' Longer-Term Planning Studies – Part IV Summary." The data sets show how climate change could alter hydrology and water supplies in the Columbia River Basin and how climate change could affect the operation of the Columbia River and its tributaries.

www.bpa.gov/power/pgf/ClimateChange/Final_PartIV_091611.pdf



Strategy D-3. Implement water conservation and efficiency programs to reduce the amount of water needed for irrigation, municipal, and industrial users and to improve basin-wide water supply.

Actions:

1. Adopt the most up-to-date water conservation technologies, water-efficient practices, and alternative water supplies whenever possible and where they:
   - *Provide the most beneficial and least costly way to decrease water demand across all sectors.*
   - *Reduce stress on existing water supplies.*
   - *Increase the benefits to aquatic ecosystems.*

   Because of the connection between water and energy use, new energy-efficient technologies may provide opportunities to reduce both energy and water use, along with greenhouse gas emissions.

2. Expand and accelerate improvements of irrigation infrastructure, starting with aging systems in basins most vulnerable to droughts and climate change. Local conservation districts and various funding agencies—such as the Natural Resources Conservation Service (NRCS), Ecology, U.S. Bureau of Reclamation (USBR), and the Bonneville Power Administration (BPA)—must continue to help irrigation organizations and landowners improve water delivery and distribution systems. These improvements can be done through projects such as:
   - *Lining ditches.*
   - *Piping.*
   - *Re-regulating reservoirs.*
   - *On-farm conservation.*
   - *Pump exchange (replacing water from one source with water from another).*
   - *Water use management projects.*

Climate Change in the Methow Valley

A team of USGS, local stakeholders, and consultants are looking at long-range water-related issues in the Methow Basin, anticipating changing climatic conditions. The major issues include water availability and providing riverine habitat for several endangered fish species.

The team is developing a decision analysis tool for water users and the public, interested in whether water will be available for irrigation in the future, whether the current fish populations can be supported with declining summer runoff, and whether there will be enough lowland snow to support the tourism industry of cross-country skiing. The tool will also enable decision makers and water managers to make more targeted decisions on specific restoration activities in the basin.

wa.water.usgs.gov/projects/methow/cc.htm

3. Expand and accelerate implementation of water conservation and efficiency standards for industries and businesses.

4. Expand the U.S. Geological Survey (USGS) and the National Weather Service (NWS) Methow Basin project—"Future Runoff Scenarios for Decision Makers for the Methow River, Washington"—to other watersheds to understand and quantify how hydrologic systems respond to land use, water use, and climate changes.[127] (This effort includes using the interactive web-based database being developed for the Methow.)

5. Expand and accelerate implementation of municipal water efficiency improvements to reduce amount of water used per person or household. Improvements could include:
   - *Water rate setting.*
   - *Water-smart landscape programs.*
   - *Rebates to install or upgrade water-efficient irrigation systems.*
   - *Regulations to reduce waste of water used outdoors.*
   - *Water-efficient development codes and policies for new development.*
   - *Rainwater harvesting from roofs.*
   - *Education and public outreach campaigns.*

6. Seek more reliable funding mechanisms to help water providers implement climate-ready plans and practices.

[127] USGS/NWS. *http://wa.water.usgs.gov/projects/methow/summary.htm*

Strategy D-4. Build the capacity of state, tribal, and local governments; watershed and regional groups; water managers; and communities to identify and assess risks and vulnerabilities to climate change impacts on water supplies and water quality.

Actions:

1. Provide local communities and watershed groups with water forecast projections using best available data, tools, and models to assess watershed vulnerability and determine priority risks that require a response. Provide examples of management strategies that will build resilient watersheds and communities.

2. Help watershed groups and communities identify vulnerable areas and assets at risk. Develop climate-readiness plans using approaches that would most sustainably and effectively prepare for and adapt to changes in the watershed.

3. Provide tools and incentives to watershed groups to implement watershed protection and restoration plans focusing on:
   - *Controlling stormwater on a regional or watershed basis.*
   - *Reducing flood peaks.*
   - *Reducing sedimentation.*
   - *Increasing recharge of aquifers.*
   - *Restoring instream flows.*

Climate Ready Water Utilities

Extreme weather events, sea level rise, shifting precipitation and runoff patterns, temperature changes, and resulting changes in water quality and availability contribute to a complex scenario of climate challenges that may have significant implications for drinking water, wastewater, and stormwater utilities.

Seattle Public Utilities (SPU) worked closely with the University of Washington's Climate Impacts Group to examine the effects of climate change on SPU's system performance and to project future changes in water supply and demand. SPU used this information to analyze a range of adaptation options and identified several "no-regrets" options that provide benefits regardless of the magnitude of climate change.

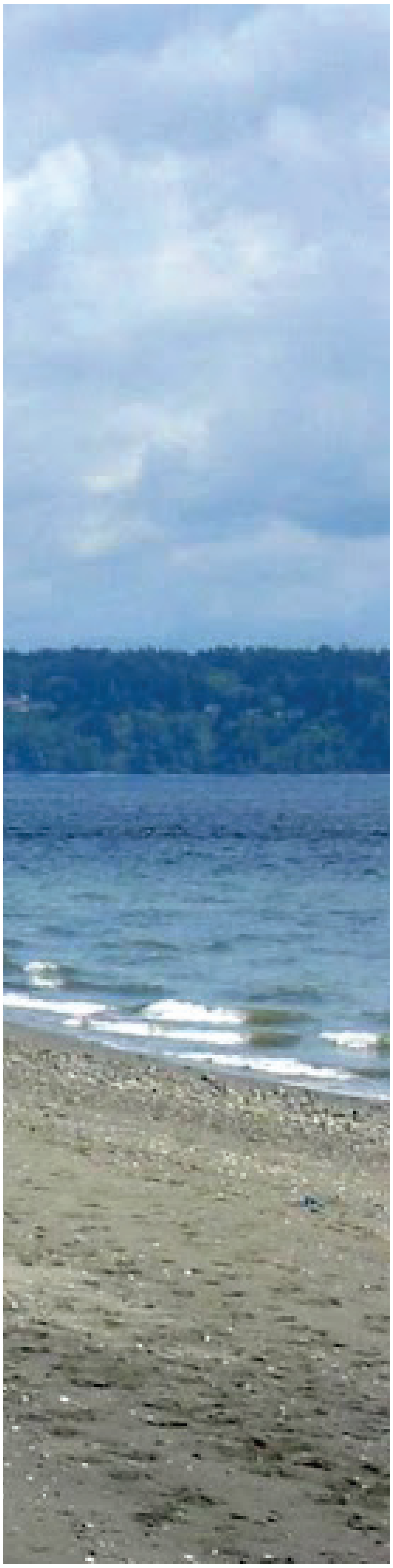
EPA's Climate Ready Water Utilities (CRWU) initiative provides resources for water utilities to adapt to climate change:

water.epa.gov/infrastructure/watersecurity/climate/

Climate Change Vulnerability Assessments: Four Case Studies of Water Utility Practices:

cfpub.epa.gov/ncea/global/recordisplay.cfm?deid=233808

4. Collaborate with the scientific community and water management entities to develop and disseminate best available data, information, and tools on:
   - *Hydrologic changes and hazards, such as extreme floods and droughts.*
   - *Projected impacts and risks of climate change on long-term water budgets and on ecological resources in a given basin.*
   - *Alternatives to respond to these changes effectively.*
5. Expand the central clearinghouse of data and case studies to support climate change and adaptation planning. Provide information and examples of effective strategies to prepare for climate impacts, including:
   - *Operational changes.*
   - *Engineering and design options.*
   - *Green infrastructure approaches.*
   - *New infrastructure investment.*
   - *Planning.*
   - *Land use controls.*
6. Inform utilities about the Climate Ready Water Utilities Initiative and tools such as the Climate Resilience Evaluation and Assessment Tool (CREAT). Support water utilities, working with the University of Washington's Climate Impacts Group (CIG) and the Climate Impacts Research Consortium (CIRC), to incorporate information on climate impacts into models used in water, wastewater, and stormwater systems planning and site design.



7. Continue to invest in improvements and expansion of online data-sharing systems to provide farmers, water utilities, and other customers with timely information on weather, soil conditions, crop water requirements, as well as water efficiency and conservation practices.

8. Improve information on water use by expanding use of meters and implementing methodologies using satellite imagery and other technologies.

9. Improve understanding of climate change impacts on water resources by supporting expansion and refinement of regional climate impact assessment tools and models developed by CIG, CIRC, U.S. Geological Survey (USGS), and other scientific entities. These tools are intended to cover climate change impacts on surface waters, groundwater recharge and groundwater availability and the interaction between climate, hydrology, and vegetation.

10. Explore cooperative work with regional Climate Science Centers, NRCS, USGS, CIRC, and the Climate Impacts Group. Continue and expand existing monitoring networks, such as streamflow gages.