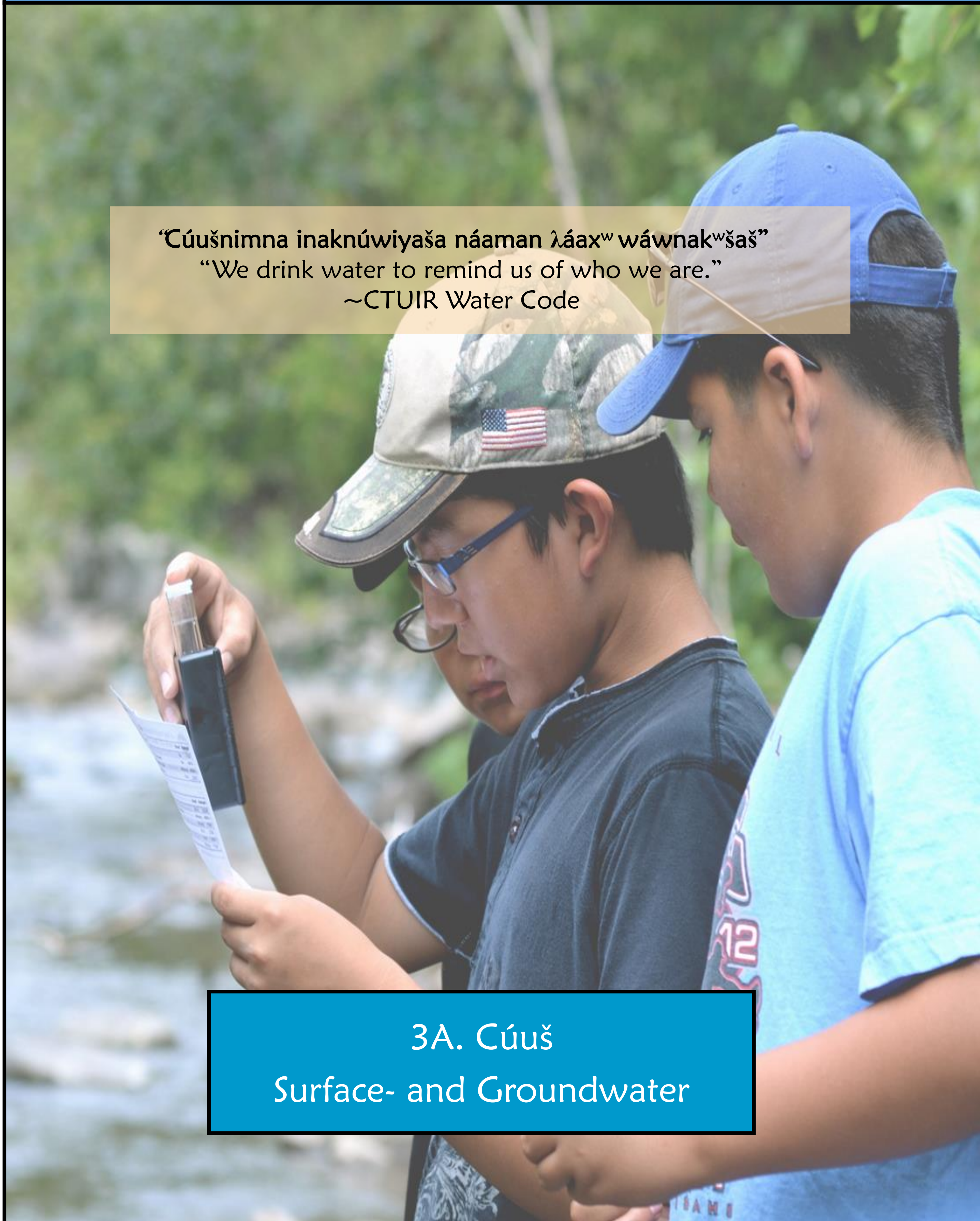
Chapter 3

Šapátunx̣wit

Impacts and Adaptation Goals

Chapter 3 : *Šapátunx̣wit* ~ Impacts and Adaptation Goals



"C̓úušnimna inaknúwiyaša náaman ƛáaxʷ wáwnakʷšaš"
"We drink water to remind us of who we are."
~CTUIR Water Code

3A. Cúuš
Surface- and Groundwater

Climate Impacts for **Surface Waters**

"Like the First Foods table settings, a functional Umatilla River would be dynamic throughout the annual cycle, yet consistent and reliable across decades. During winter, snowmelt water fills the main channel, causing the river to fill dry channels, inundate the floodplain, scour fine sediments from the streambed, and cut new channels with its high-energy flows.

During summer, flows recede and the river abandons some old channels for new channels. These seasonal patterns vary between wet and dry years. The native riverine and riparian communities are adapted to and depend upon these dynamic physical conditions for their growth and survival.

Thus, maintaining a functional Umatilla River for First Foods requires managing for the range of dynamic river conditions (and not simply static levels) throughout the year (Umatilla River Vision, 2011)." This section examines those impacts to waters that flow over lands.

"Water is the alpha, and it is the omega, the first and the last, beginning and end."
~Thomas Morning Owl, Umatilla Language Master Speaker

1. Unpredictable Snowfall

Warming winters will reduce the reliability of snowfall, and increase the percent of precipitation that falls as rain and as rain-on-snow events.
75-100% reduction in SWE into the 2080s over much of Ceded lands (Clifton et al, 2018) as seen in Figure 3A.1 (page 45).

2. Faster Melt of Winter Water

Unlike snow, warm winter rain increases runoff into rivers and streams immediately, resulting in winter flooding.
Increasing frequency of heavy precipitation events, measured as estimated 12% increase in the maximum daily precipitation into 2050 (Salathe et al, 2014) as seen in Figure 3A.2 (page 46).

3. Shifted Seasonal Hydrology

Peak flows of rivers and streams will shift from late spring to mid-winter, and increase chances of winter flooding. This can create a disconnection with aquatic ecosystem seasonal cycles.
15-30 day peak flow shift by 2050, 40-50 day peak flow shift by 2100 (Dalton, 2020) as seen in Figure 3A.3 (page 47).

4. Lower Summer Base Flows

Reduced opportunity for water infiltration reduces summer base flow in river and streams, creating ecological drought and higher water temperatures in summer months.
Small decreases of less than 10% for perennial streams , but some more sensitive regions are likely to experience a decrease of up to 30% by 2080 (Clifton et al, 2018) with **most severe impacts to Lostine, Minam, Imnaha, John Day, Grand Ronde, and Wenaha Rivers,** as seen in in Figure 3A.4 (page 48).

1. Unpredictable Snowfall

As climate change warms our winters in the Blue Mountains, the ability to accrue snow pack will be reduced, with the biggest impact predicted to affect mid-elevation mountain slopes. Grassy slopes that support the production of Root species and Big Game grazing, as well as within mid-elevation conifer forests will see the largest shifts.

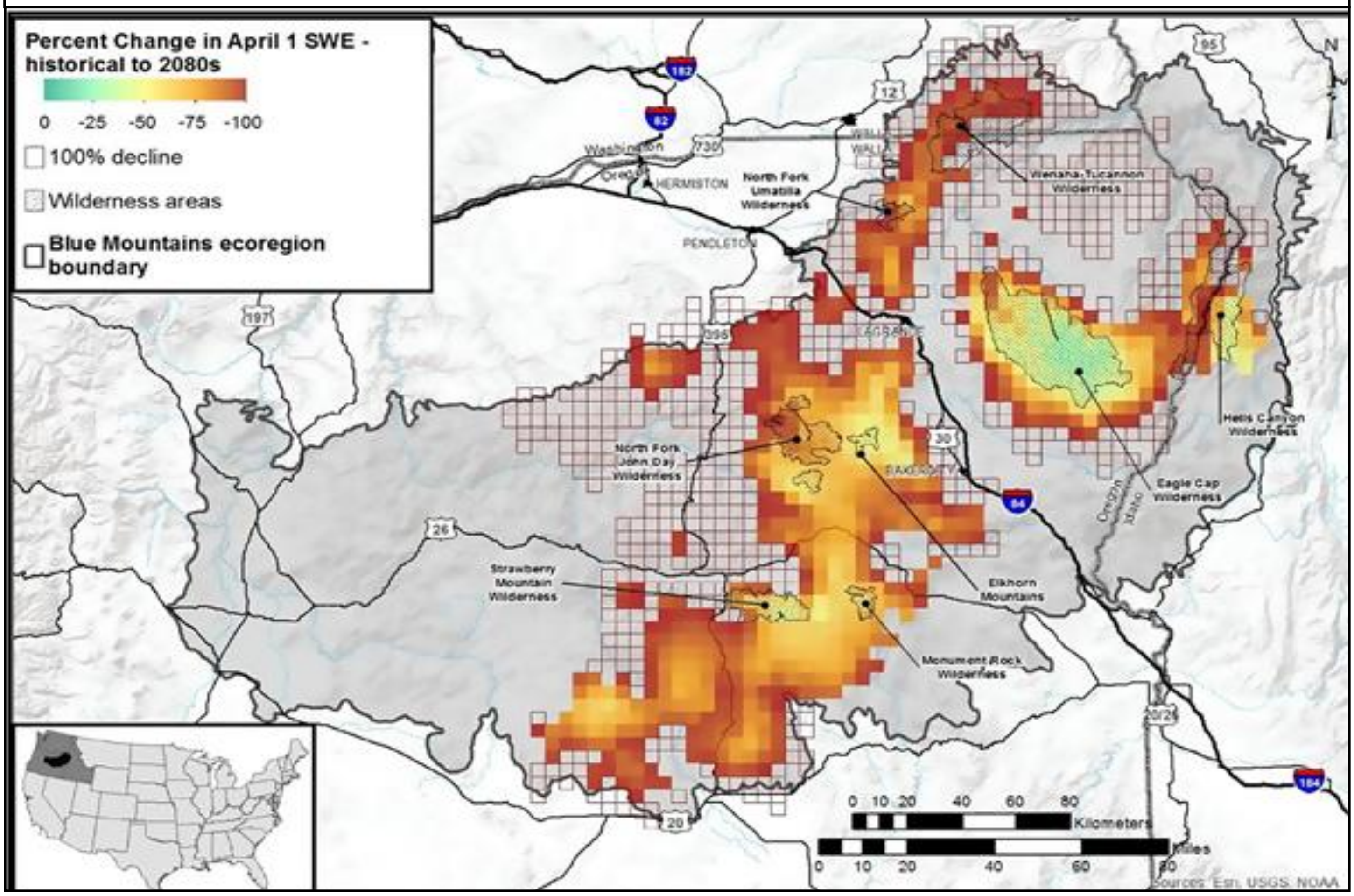
To measure of how much water is likely to be available for the coming water year, Snow Water Equivalent (SWE) is used to estimate the amount of water a current snow pack will be able to deliver.

Figure 3A.1 shows SWE for the Blue Mountain National Forests projected into 2080, under a 3˚C (5.4°F) of warming scenario. The color gradient shows the impact of changing SWE:

- Green indicates a 30% decrease in the potential to accumulate snow pack in those regions.
- Orange indicates a 50-70% decrease, and red indicating a 75-100% reduction.
- This projection anticipates locations which will experience the most sensitivity include the Strawberry Mountain, Monument Rock, Wenaha-Tucannon, and Hells Canyon Wildernesses, and at mid-elevations in the North Fork John Day, with **reductions estimated to be 75-100% in those management areas**.
- The Eagle Cap Wilderness is projected to experience the least impact, with roughly a 20% reduction being expected for that high elevation mountain range.

It seems that much of the Blue Mountains will lose its ability to store water predominantly as seasonal snow accumulation, thus land managers will need to consider how changing precipitation may create potential for runoff, soil destabilization, degradation to habitat, vegetation management strategies, and seasonal water availability.
(Credit: Clifton et al., 2018)

Figure 3A.1: Projected Change in SWE in Blue Mountain Forests



Gaps in Knowledge/Data/Policy:

- Effect of snow depth, soil moisture, and other atmospheric conditions and First Foods plant success;
- Magnitude and speed of shifts in precipitation patterns, and effects of intra– and inter-seasonal variability.

2. Faster Melt of Winter Water

River waters cycle seasonally: spring rain and snow melt contribute to high levels of water moving at a time when anadromous fish migrate back to their spawning grounds. As less winter snow falls, replaced instead by rain, this peak flow will become shifted earlier into the winter, and could cause a disconnect with fish migration and peak flow timing. Rain-on-snow (ROS) events are unique in this concern, because they compound multiple hazards:

- Rain is warmer than the snow that fell preceding, and melts the snow as it drains into river basins, increasing the magnitude of flooding effects.
- The snow also creates an impermeable barrier which prevents rain from infiltrating into the soil as it would on bare ground, resulting in additional water runoff potential.

Research conducted on soil types and snow covers typical of the Western U.S. estimate that a single ROS event increases the volume of flow in a river basin by 12% per event (Eiriksson, 2012). This means that a rain-on-snow event will cause rivers to flood by 12% more than if the rain fallen on bare soil. This greatly contributes to the magnitudes of flooding events during the winter season (Eiriksson, 2012).

Figure 3A.2 shows the modeling of frequency of heavy precipitation events for the Pacific Northwest measured over a 30 year average by the middle of the century under an A1B climate scenario (Salathe et al, 2014):

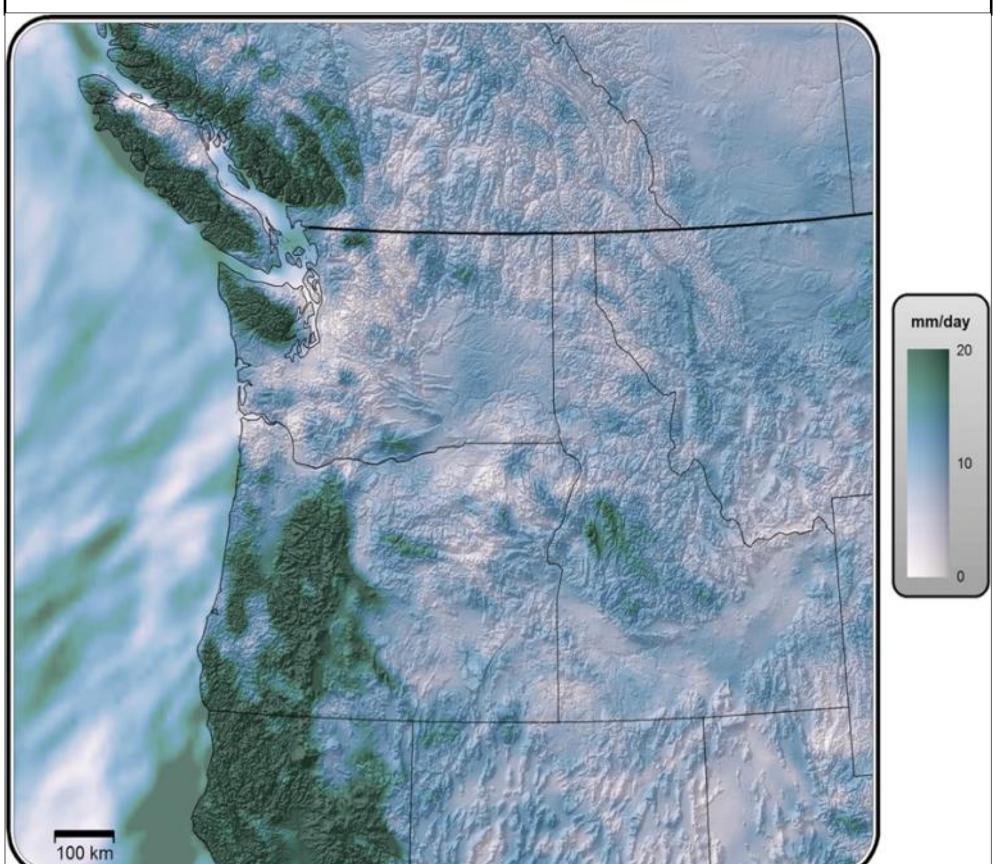
- An estimated **12% increase in the maximum daily precipitation into 2050 is anticipated across much of the Blue Mountains**, meaning that heavy precipitation events will become more frequent.

Through very elementary math, we can do some simple calculations about what this information means when considered together:

- If 30% of those heavy precipitation events are ROS events, then a 43% increase in river flow during winter can be expected.
- If 50% of heavy precipitation falls as ROS, then a 72% increase in winter river flow is projected.
- While extremely unlikely, if 100% of these events result in rain falling on snow, then a 144% increase in the magnitude of river flow is anticipated as a direct result of the type of precipitation falling, and the material that it is falling upon.

Increasingly frequent heavy precipitation events, as well as ROS events, will create a faster melt of snow pack that does manage to accumulate. Water managers should plan for flashier rainfall during all seasons but especially for flood events, with the potential for greater intra– and inter-seasonal variability.

Figure 3A.2: Projected Increase in Heavy Precipitation by 2050

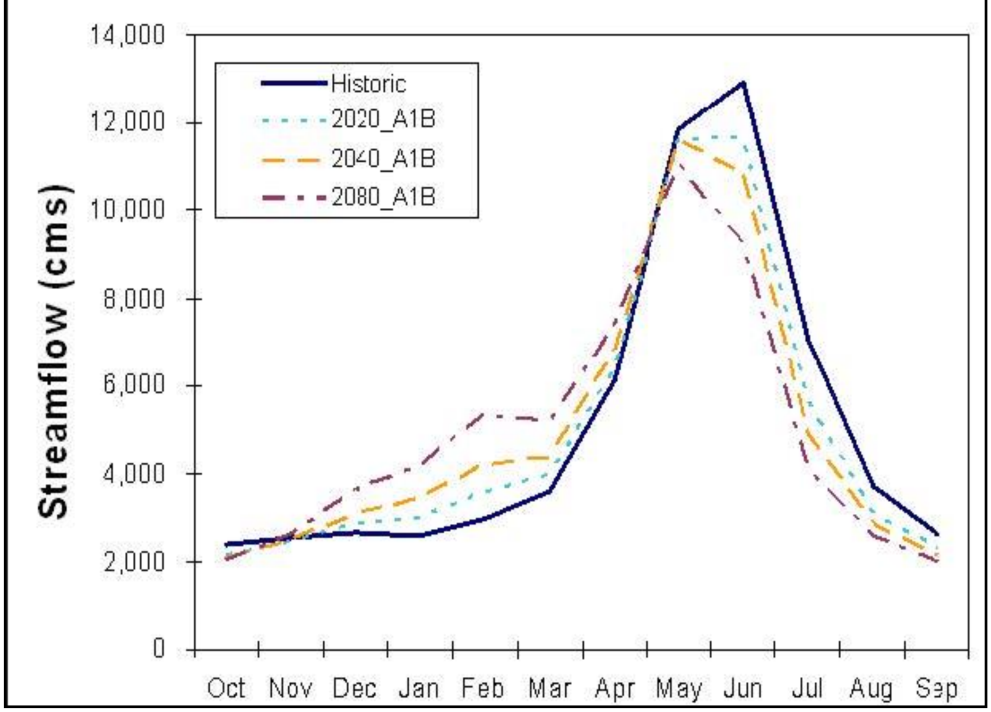


(Credit: Salathe et al, 2014)

Gaps in Knowledge/Data/Policy:

- Effect of land use on ROS erosion; how do different land use and management strategies affect topsoil erosion and overland flow into waterways.
- Effect of atmospheric rivers on precipitation patterns and seasonal variability.

Figure 3A.3: Streamflow Shifts for Mid and Late 21st Century



3. Shifted Seasonal Hydrology

"Hydrologic aspects of water quality within the Umatilla River Basin center on the flow regime (pattern of water discharge) in the river, which follows a distinctive seasonal pattern. Substantial flood pulses occur in late winter and early spring following rain-on-snow and warm "Chinook" winter wind events. Low flows occur in the summer when groundwater inputs and occasional rain events in the Blue Mountains maintain river base flows. Minimum flows observed in the dry months represent the approximate lower limit of discharge ranges necessary to sustain aquatic and riparian communities (Umatilla River Vision, 2011)." With warmer winters, flood pulses and peak flow will shift earlier into the winter, and could cause disconnection with seasonal fish migration timings.

Figure 3A.3 shows the projected change in peak flow measured at The Dalles Dam, OR, along the Columbia River, under climate scenario A1B (Hamlet et al 2010).

- Historic river conditions are shown in the solid black line, with peak flows typically during spring months (March to May).
- Light blue hashed line shows projections for 2020 are already displaying a shift in current conditions.
- Yellow hashed lines project 2040 conditions, where a second peak of flow is forming in winter.
- Red hashed line projects out to 2080, showing a definite second peak occurring February to March.
- This is an estimated shift of roughly 30 days earlier (from mid-June to mid-May), as well as a smaller peak from mid-January through February by 2080 (Hamlet et al 2010).
- Most recent modeling from the Climate Toolbox predicts a shift of roughly **30 days by 2040**, **40-50 day shift by 2070** under both high and low emissions scenarios, and **45-50 days under both by 2100 (**US Climate Toolbox, 2021) .
- Also anticipated is a reduction of peak magnitude of about 21,000 cfs for the high emissions scenario, all measured that The Dalles, Oregon.
- Other projections for McNary Dam on the Columbia River also project a 30-day shift earlier by 2070 (Dalton et al 2020) and a similar 30-day earlier shift for the Umatilla River measured at Pendleton, with peak flow moving from April to March (Dalton et al 2020).

With peak flows shifting over a month earlier into the spring, there are questions of whether aquatic animal species will be able to adapt their own lifecycles to accommodate for this shift, or if they will struggle to succeed. Resource managers will need to prepare for earlier high flows and wet ground conditions.

(Credit: Hamlet et al., 2010)

Gaps in Knowledge/Data/Policy:

- How First Foods migration patterns might be altered or impacted by these shifts;
- Changing energy generation and irrigation needs.

4. Lower Summer Base Flow

"Low flows occur in the summer when groundwater inputs and occasional rain events in the Blue Mountains maintain river base flows. Minimum flows observed in the dry months represent the approximate lower limit of discharge ranges necessary to sustain aquatic and riparian communities (Umatilla River Vision, 2011)."

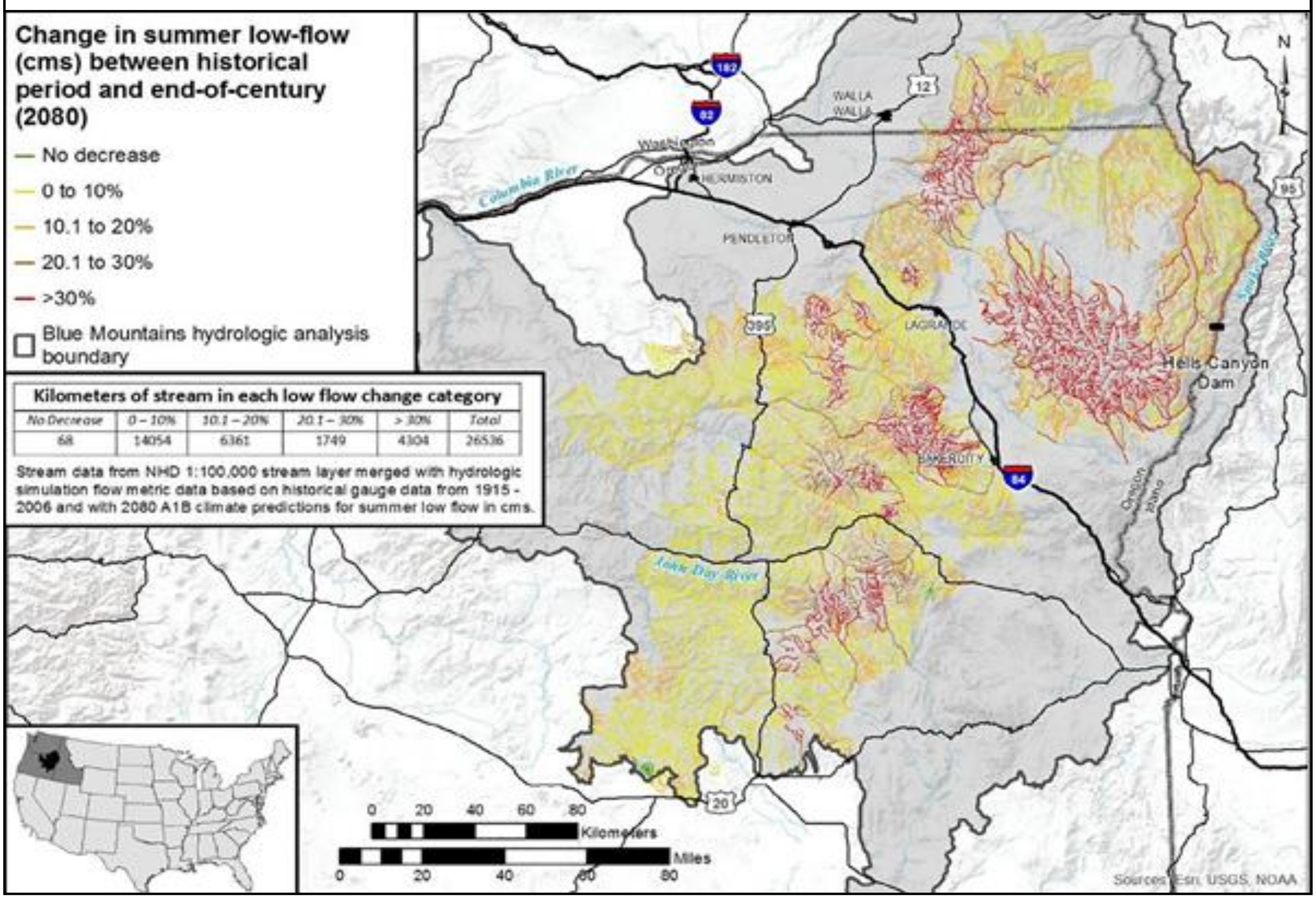
As peak hydrology shifts earlier into the winter, rivers that rely heavily on melting spring snow for summer flows will see a reduction in water storage capacity. This is likely to result in more intense periods of summer drought, and will increase the temperatures of the waters that do flow, secondarily concentrating sediments and pollution.

This will negatively impact the aquatic life that require consistent flows of cold, clear water, such as migratory salmon and lamprey, residential trout and sedentary freshwater mussels that are unable to rapidly migrate to better conditions.

Figure 3A.4 provides a projection of summer flow decreases to 2080 in the Blue Mountain National Forests under a 3˚C (5.4°F) of warming scenario:

- Streams marked in green will experience no decrease in summer flow; orange and yellow colors will likely see a 10-30% summer decrease.
- Streams in red will experience flow reductions of greater than 30% as compared to a historical average.
- In the Blue Mountains, we see that **roughly half of river basins in this region will see small**

Figure 3A.4: Reduction in Summer Stream Flow in Blue Mountains by 2080



- **decreases of less than 10% for perennial streams; this includes an estimated 14,054 miles of stream** (Clifton et al 2018).
- Some more sensitive regions such as the Wallowa Mountains, Elkhorn Mountains, Wenaha-Tucannon Wilderness are likely to experience a **decrease of up to 30% by 2080; this includes an estimated 4,104 miles of stream** (Clifton et al 2014).

It is likely that much of the Blue Mountain foothills will escape the most severe impacts since they are already predominantly rain-fed. The most severe impacts to summer flows for higher elevation river systems such as the **Lostine, Minam, and Imnaha Rivers, the North Fork John Day River system, and the Grande Ronde and Wenaha Rivers**.

These areas could be good locations to expand efforts to improve floodplain connection, for natural water storage in soils. Engineered options for water storage could also be explored: engineered wetlands and aquifer recharge storage projects could increase regional capacity to store plentiful water in winter months for release during summer months. Policy improvements could also be made to support the recognition of in-stream water needs and rights, and a reduction in consumptive water use throughout these heavily impacted and agricultural basins.
(Credit: Clifton et al, 2018)

Gaps in Knowledge/Data/Policy:

- Drought early warning system protocols and data collection; what are the ecological, health, and industrial trigger points of drought, and monitoring for these routinely.

Adaptation Goals for **Surface Waters**

A. Conservation of Water in River Systems

i. Natural Storage

"High-flow events provide temporary surface water connections between main channel and off-channel aquatic habitats, build and rearrange important channel and gravel-bar features across the floodplain thereby maintaining habitat diversity, enhance water movement… facilitating hyporheic water flux, and recharge the alluvial aquifer with water. A functional river, then, is dependent on the sufficient magnitude and frequency of flood events to maintain dynamic channel patterns and adequate water exchange rates between the channel and floodplain sediments (Umatilla River Vison, 2011)."

Short Term:

- **Quantify water storage and releases** as cold summer flows resulting from restoring floodplain connection and revegetation efforts.
- **Survey existing and potential restoration efforts to explore other potential locations on the UIR and across the basin** to create effective water storage with minimal continuing input.

CTUIR Water Resources staff routinely conduct stream surveys for surface water quality and quantity (pictured).

Long Term:

- **Prioritize healthy functioning river systems** for storing abundant winter flows which require minimal energetic input to operate, unlike engineered solutions.
- **Continue to implement Umatilla River Vision touchstone rehabilitation efforts** where opportunities arise.
- **Plan and actively facilitate the restoration of native beaver** (*Castor Canadensis*) within watershed restoration as appropriate per location and project phase.

ii. Engineered Storage

Engineered water storage systems already exist within the Umatilla River basin, and can be used as pilot examples for calculated winter water withdrawal and storage.

Short Term:

- **Explore research and monitoring of issues of chlorinated byproducts** like trihalo methane associated with deep aquifer storage water permeability in clay soils.

Long Term:

- **Invest in infrastructure designed to help artificially store water** during winter high flows for agricultural and municipal need. These could include (but are not limited to): water injection systems, infiltration pits, swales, rain water catchments, and permeable pavement, among others.

- **Develop and implement engineered wetlands and beaver dams** along tributaries that would be appropriate across the Umatilla Basin and other watersheds in CTUIR Ceded lands.

iii. Water Conservation Plan and Re-Use Initiatives

Reducing water demand overall will leave more in streams for fish and other First Foods needs. Water conservation initiatives can be enacted at a Tribal government, community, or family scale.

Short Term:

- **Develop a community-focused Water Conservation Plan** with specific strategies, goals, and monitoring procedures to quantifiably reduce water demand at an individual, family, government, and community scale.

- **Organize education and awareness campaigns for water conservation strategies** aimed at individuals and families, including knowledge sharing events, art and other creative engagement activities, youth projects, social media posts, and Confederated Umatilla Journal (CUJ) outreach efforts.

- **Investigate capacity to provide financial incentives or access to credit** to improve home and municipal buildings to reducing the consumptive demand of water resources to support water conservation.

Long Term:

- **Pursue investments in infrastructure to reduce water use**, or designs to recapture water; many buildings will require capital to implement upgrades or new facilities constructed to make more efficient use of water.

- **Expand use of native plants in landscaping** and reduce the acreage in turf grasses, like lawns, to reduce irrigation demand.

B. Expand Umatilla River Vision

i. Redirect Development Out of Current and Expanded Floodplain

"Managing the Umatilla River and floodplain to allow lateral inundation contributes to maintaining habitats for native riverine communities. Constraining high flows concentrates stream power (and energy to move sediments) within the main channel, resulting in an incised channel with faster flows (Umatilla River Vision, 2011)."

Relocating and decommissioning infrastructure in floodplains allows for greater reconnection opportunities.

Short Term:

- **Conduct climate-adjusted flooding magnitude visioning and mapping exercises**, with support from Federal Emergency

Management Agency (FEMA) and CTUIR Office of Information Technology (OIT) Geospatial Information Systems (GIS) program.

Long Term:

- **Develop urban and rural planning frameworks to prioritize removing, relocating, or restricting development in the floodplain zones.** This might mean creating policies that explicitly prohibit certain residential and industrial development in the floodplain. Tribal Planning Office (TPO) currently imposes some floodplain building restrictions, and would be involved in this process.

- **Advocate for restoration of river floodplains and implementation of the Umatilla River Vision across the CTUIR Ceded lands** to build non-Tribal understanding of the need for reconnection to preserve water quality and quantity.

Debris located in the river's expanding floodplain like vehicles (pictured) could be washed into the channel during high water events. (Feb 2020)

ii. Prioritize Riparian Property for Acquisition

"The spatial distribution of surface water across the floodplain drives the active and continuous exchange of water between the river channel and river gravels, as well as subsurface movement of river water through river gravels (Umatilla River Vision, 2011)." Land ownership on the UIR is a checkerboard and there are many private home sites and industrial operations located in the CTUIR watershed floodplains that could be acquired.

Short Term:

- **Develop a plan to acquire properties along riparian corridors** as properties come available for ownership transfer; see Ch 3F pages 234-235 for additional detail.

- **Advocate for expansion of state and federal resources dedicated to assisting Tribes with purchasing at-risk properties** within existing and expanded floodplains. FEMA operates these programs in many states, and opportunities could be expanded in Oregon and Washington.

- **Examine previous historic flooding events to anticipate where future problems with property developments are likely to occur**. These include the extraordinarily high flows of February and May 2020 and those from the past 60 years, including 2019, 1995, 1996, 1975, and 1965.

Long Term:

- **Support and expand riparian land acquisition priorities within CTUIR committees, commissions, plans and codes** to increase the resiliency of water systems through Tribal governance.

- **Develop or expand purchasing options for flood-damaged property acquisition**; 8-10 of these properties damaged in Feb 2020 were purchased by a joint CTUIR and Federal Emergency Management Agency (FEMA) program as a result of this flood.

C. Collaborate for Floodplain Reconnection & Restoration

i. Expand Restoration Scope and Develop Mutually Beneficial Evaluation Criteria

CTUIR is already engaged in restoration activities both on the UIR and in the traditional use area. Current efforts are concentrated on tributaries within reservation boundaries, but it is likely that supporting restoration efforts on the main channel of the Umatilla River will be necessary.

Short Term

- **Identify various watershed stakeholder groups**

whose interests align, and who recognize the need for action with mutually beneficial solutions around water conservation.

- **Collaborate with other regional land managers to form drought early warning and response systems, and water conservation plans** for agricultural and ecological drought conditions.

- **Develop additional technical guidance documents for First Foods land management support**, like the Umatilla River Vision, and the First Foods Upland Vision. These could be guidance support for agricultural, forestry, range, and other land management practices and training.

Long Term:

- **Advocate for prioritization of Indigenous knowledge for water management and conservation with municipalities and counties** in CTUIR Ceded and traditional use lands.

- **Support Indigenous and nature-based rights at state, national and international levels.**

D. Water Quality & Quantity Monitoring and Data Collection

"In addition to using conventional physio-chemical measures, evaluation of water quality in the Umatilla Basin must also include appropriate measure of biotic communities and hydrologic processes associated with high ecological health. To be successful, then, the First Foods paradigm must integrate the methods and means of water resource management into the concept of 'water quality.' Regardless of water physio-chemistry, water quality is low anywhere water is managed in ways that are incompatible with the ecological integrity (or "health") of the river (Umatilla River Vision, 2011)."

i. Support Existing Data Collection and Management Efforts

Many different agencies and entities, including CTUIR, contribute to water quality and quantity data collection throughout the Umatilla Basin and across the Ceded and traditional use areas.

Short Term:

- **Develop predictive models** that utilize CTUIR and other water data for use in tracking flow trends as they change over time.

- **Develop approaches to incorporate climate-shifted hydrologic modeling into existing CTUIR policy documents,** such as (but not limited to) the CTUIR Water Code, annual land leasing for irrigation, groundwater pumping and well permitting, and "total maximum daily load" (TMDL) water quality standards.

Long Term:

- **Continue to support Oregon and Washington water gauging stations** that contribute to CTUIR data collection, especially those located in the Umatilla and Walla Walla River basins.

ii. Pursue Additional Funding for Expanded Monitoring & Analysis

Actively pursuing additional grant and agency funding for data collection and analysis efforts will assist in planning.

Short Term:

- **Identify areas where gaps in data**

collection and relevant water and atmospheric condition information exist, and implement projects to address these gaps.

Long Term

- **Pursue opportunities for additional data collection stations at mid-elevation ranges in the Blue Mountains** to facilitate early warning of heavy precipitation and high flow/flooding events.

- **Develop, fund, and implement establishment of flooding and drought early warning protocols**, along with action trigger threshold values, and community response guidelines, and have these included future revisions of the CTUIR Emergency Operations Plan (EOP).

River-adjacent infrastructure, such as the Union Pacific Railroad line along Meacham Creek (pictured left), is threatened by flooding and also impedes floodplain reconnection.

- **Pursue additional support funding for data continuation and analysis** to improve understanding of surface and groundwaters connectivity, and how readily sources respond to water conservation and storage measures.

E. Water Administration, Modeling, and Management Strategies

"Privatized and extractive use of natural resources has environmental consequences for the Umatilla Basin, including the degradation of ecosystem processes that once supported the natural production and harvesting of First Foods for consumption by Tribal Members. Additionally, private land ownership and extractive resource use have created challenges to basin-wide management of resources necessary to sustain First Foods ("Saxu|Siwaala|Seewi'cs: River Mussels Through Time," 2015)."

How water is metered and used must be adaptive enough to respond to changing conditions. Water use on the UIR is regulated by the Tribal Water Commission (TWC) and by the Water Code policy.

i. Support Adaptable and Responsive Water Governance

Variability in seasonal conditions is a large part of the challenge climate change will bring. Building flexibility and responsiveness into systems governance will allow CTUIR to have appropriate contingency plans to address flooding and drought.

Short Term:

- **Support Tribal Water Commission (TWC) operation** in their ability to regulate water use on the UIR, and to provide a liaison capacity between stakeholders, Tribal Members and community, and the Tribal government.

- **Update CTUIR Water Code and other related water policy** to anticipate for changing seasonal conditions, and specify areas where adaptation are necessary.

- **Identify various water curtailment and conservation strategies** with the Tribal community, and develop a plan to implement and expand these efforts, and skills associated with implementation.

Long Term:

- **Develop and implement storm and overland water runoff capture strategies** to reduce water loss during heavy precipitation events.

- **Consider developing and implementing a progressive water use metering and pricing framework** rooted in earned income to reduce burden on lower income families.

ii. Build Capacity for Regional Water Governance

CTUIR is a leader in the Pacific Northwest region, and policies set by the tribe have a far-reaching effect. Improving the range of CTUIR decision-making power for water governance could improve water conservation efforts for the region.

Short Term:

- **Collaborate with DNR Energy and Environmental Sciences Program (EESP) to implement deep groundwater monitoring** and data collection in coordination with geothermal power generation fact-finding efforts, such as borehole drilling, among others.

- **Organize and facilitate a Tribal community conversation about the potential to develop a McKay Conveyance system** for consumptive use purposes to relieve stress on in-stream water needs.

- **Organize and facilitate updates to previous CTUIR water audits**, to collect water use information from Tribal facilities, and from volunteer usage reporting from UIR residents, and for water conservation planning efforts.

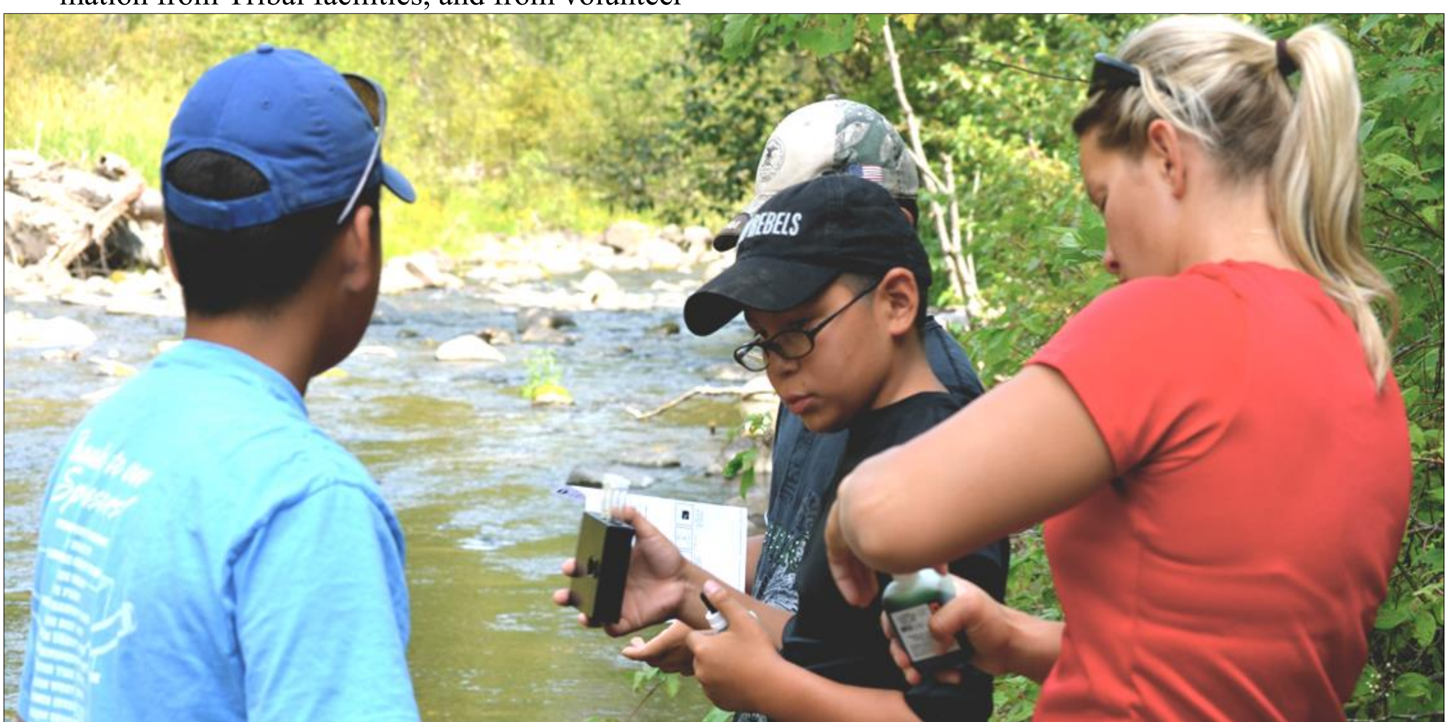
- **Expand and support "Place Based Planning" efforts to proactively plan for water needs**, and engage with additional stakeholders and outreach opportunities; Grande Ronde River Basin planning with DNR and Oregon Water Resources Department (OWRD) is a regional example of this work.

Long Term:

- **Develop legally defensible accounting methods for quantifying water conservation savings** in a protocol, as part of water conservation strategies to fortify in-stream water rights claims.

- **Develop a strategy for gray water treatment and landscape irrigation use**; Buffalo Peak Golf Course in La Grande, OR, is an example of how such waste water can be recaptured for use.

- **Support and expand regional and Tribal community outreach around water conservation**, to help families feel empowered to address reducing and changing water needs.



Community and youth education about watershed science and data collection strategies will improve the capacity of Tribal nations to monitor changing stream conditions. In turn, this will expand CTUIR's ability to maintain regulatory status and implement adaptations as necessary, in line with Tribal Water Commission guidance.

Measuring Success and Gaps in **Surface Water Adaptation**

How Do We Measure the Success of These Adaptations?

"Cúuš is tamánwit and we must teach and live tamánwit. We must share water with all living things. If we do not share, our greed will harm us. We must not look upon waqíšwit (life) as the šiyápu. We must take care of the water. Seven generations in the past we had good water. Seven generations in the future we must give back the same that was lent to us by Aniłá (the Creator); cold, clean water. So we think of fourteen generations of cold, clean, plentiful water. As we did seven generations back, so should we be able to do seven generations in the future, go to any stream or river and get cold clean water to drink (CTUIR Water Code, 2005)."

- **Connectivity via Umatilla River Vision Touchstones** (hydrology, geomorphology, connectivity, native riparian vegetation, and native aquatic biota).
- **Comprehensive Plan Objective 5.6.3:** To Protect, enhance, and restore functional floodplain, channel, and watershed processes to provide sustainable and healthy habitat for aquatic species of the First Food order (Comp Plan page 81 for benchmarks).
- **CTUIR Water Code Section 1.05. Statement of Policy B. Goals of Water Management:** The primary goals of water management are to conserve the quantity and maintain or improve the quality of water resources; protect and restore cold clean pure water consistent with the Tribal Water Quality Standards; maximize the beneficial use of water resources; promote diversity and protection of beneficial uses; promote the orderly economic development of the Reservation; and coordinate water use with land use and other planning on the Reservation (page 5);
- **CTUIR Water Code Section 1.05. Statement of Policy D. Use of Water without Waste**: In developing and utilizing water resources, water users shall appropriate water for beneficial purposes without waste. Regulations shall be developed and implemented to discourage the misuse or waste of water, and penalties shall be imposed on persons who misuse water or fail to cease practices that waste water (page 5);
- **CTUIR Water Code Section 1.05. Statement of Policy E. Water Conservation Required:** All official actions that allow persons to divert and use water resources shall be promulgated under the principle that the water user appropriates the minimum quantity of water required to accomplish the purpose of the diversion. To this end, standards and regulations shall be promulgated which require conservation in the allocation, use, and development of water resources and shall provide incentives for water users to practice water conservation (page 5);
- **CTUIR Water Code Section 3.07:** Water Quality Management Planning Goals and Objectives (page 42).
- **CTUIR Hazard Mitigation Plan (2021) Section 3: Hazard Identification and Risk Assessment**—Drought (page 74-78)
- **CTUIR Hazard Mitigation Plan (2021) Section 3: Hazard Identification and Risk Assessment**—Flooding (page 95-107)
- **CTUIR Hazard Mitigation Plan (2021) Section 4: Hazard Mitigation Strategy** (pg 192-208)
- Umatilla Basin Water Rights Settlement negotiations (ongoing).
- Tribal Water Commission (TWC) Annual Reports.
- WRP Annual Work Plans and Activities.

What Gaps in Knowledge, Policy, Capacity, or Education Exist?

- Changing supply of surface water in light of irrigation diversion like the Umatilla Basin Project;
- Sustained drought effects on water availability and surface water flow;
- Quantification of water conservation measures to be incorporated into water rights calculations;
- Responding to communities and stakeholder around water policy, use, and conservation.

Climate Impacts for **Groundwaters**

"Levels of groundwater and surface water are intricately linked as reductions in surface water levels may diminish groundwater levels (and vice versa)… Thus, management of extractive water consumption of both surface water and ground-water must consider the hydrologic regime of the river (Umatilla River Vision, 2011)."

Water stored in shallow aquifers is critical for summer base flow in streams, and many people rely on clean groundwater for household and drinking water needs.

Roughly 60% of surface waters in the Blue Mountains and 100% of UIR residential water supplies are fed by groundwater sources. Impacts to these vital contributions to future regional hydrology must be considered. In modern times, CTUIR has been able to maintain its groundwater supply, but more information is necessary to know how changes in climate will affect the recharge of these unique and essential systems.

"Management of extractive water consumption of both surface water and groundwater must consider the hydrologic regime of the river."

~Umatilla River Vision, 2011

5. Changing Potential for Storage

Wetter winters shift from snow to rain, reducing the potential for groundwater sources to be recharged in current quantities and strategies.

In the Columbia River basin, roughly 72% of the groundwater recharge occurs from diffuse mechanisms as permeability of precipitation, with 28% from irrigation recharge (Meixner, 2016) as seen in Figure 3A.5 (page 57).

6. Depletion of Groundwater & Surface Waters

Residential and municipal demands on freshwater will continue to draw from groundwater. If not managed in accordance with recharge capacity, groundwater sources will be depleted, and can have negative impacts on surface water base flows.

Overall, the study found that total Columbia Plateau ground-water recharge decreased, because the decrease in irrigation recharge (-37 mm) was larger than the increase in diffuse recharge (+6 mm) (Meixner, 2016) as seen in Figure 3A.6 (page 58).

7. Increased Potential for Contamination

Agriculture is a contributor to chemical groundwater contamina-tion, as pesticides and fertilizer can be leached into groundwater with heavy precipitation events. This increases potential for contamination.

Currently the Walla Walla River basin in Milton-Freewater experiences a 20% groundwater well contamination rate (ODEQ 2020) as seen in Figure 3A.7 (page 60). Rough projections anticipate this could **increase by 214 - 377% by 2050** (Li and Merchant 2017).

5. Changing Potential for Storage

Changing precipitation will alter the ways in which groundwater is recharged, especially in mixed rain/snow hydrologic systems like the Blue Mountains.

At higher elevations in the Blue Mountains, such as the Elkhorn or Eagle Cap Wildernesses, groundwater recharge is more likely to be driven by accumulation of snow pack in winter months. Lower elevations are more likely to rely on winter and spring precipitation in the form of rain absorbed into soil moisture.

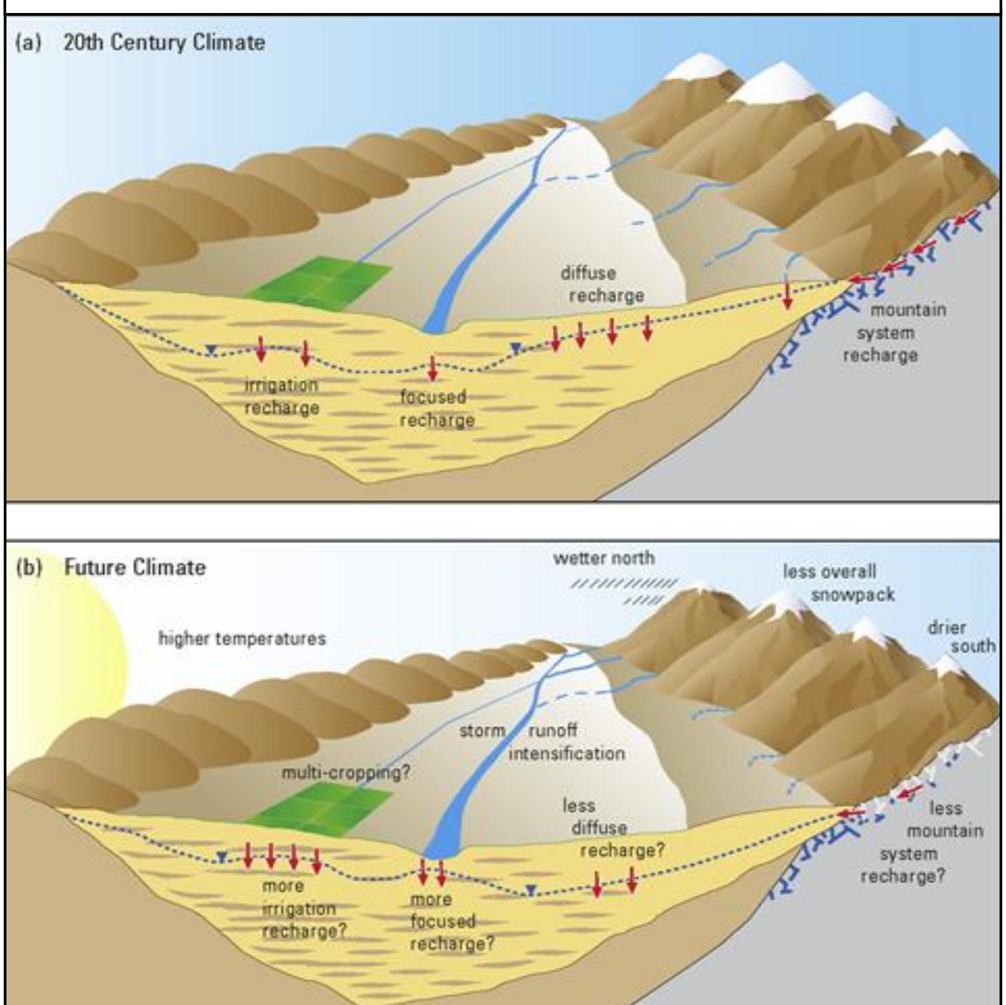
Figure 3A.5 illustrates the four major ways groundwater has historically been recharged, and how climate change is likely to alter those connections.

- In the **Columbia River Plateau basin, roughly 72% of the groundwater recharge occurs from diffuse mechanisms** (precipitation) as direct infiltration and percolation into the water table.
- The second largest contributor is from irrigation recharge, which is excess irrigation water as it percolates downward and enters shallow aquifers.
- Other forms of recharge include mountain systems recharge (MSR) at high elevations (usually headwaters), and focused recharge that occurs at ephemeral streams and other points such as hyporheic zones.
- Compared to the Columbia River, the **Spokane River Valley has a more diverse set of recharge mechanisms, with 57% coming from focused recharge at ephemeral streams and other hyporheic zones, 24% from mountain systems, and 16% from diffuse recharge;** the remaining 3% is from irrigation recharge.

For CTUIR Ceded lands, it can be approximated to include a combination of these two groundwater systems, though more detailed data collection is necessary:

- Columbia River Plateau groundwater systems, like the Umatilla and Walla River basins; and
- Mid-elevation mountain ranges like Laliik (Rattlesnake Mountain), North Fork Umatilla River, John Day and Wenaha-Tucannon Wildernesses, and the Wallowa-Whitman, Malheur and Umatilla National Forests should be looking to maximize rainfall infiltration into upland soils for diffuse recharge mechanisms.
- Higher elevation locations like the Elkhorn, Eagle Cap, and Hells Canyon Wildernesses are assumed to share groundwater system attributes similar to the Spokane River Valley system, could also benefit from diffuse recharge strategies. But greater potential comes from improving focused recharge along riverways, such as engineering wetlands and increasing stream

Figure 3A.5: Groundwater Impacts from Climate Change



meander and channel complexity.

Resource managers should develop research into specifying which recharge mechanisms exist for different watersheds across the CTUIR Ceded lands. (Credit: Meixner, 2016)

Gaps in Knowledge/Data/Policy:

- Fine detail knowledge of Columbia basalt hydrology and specific response to climate impacts.

6. Depletion of Ground and Surface Waters

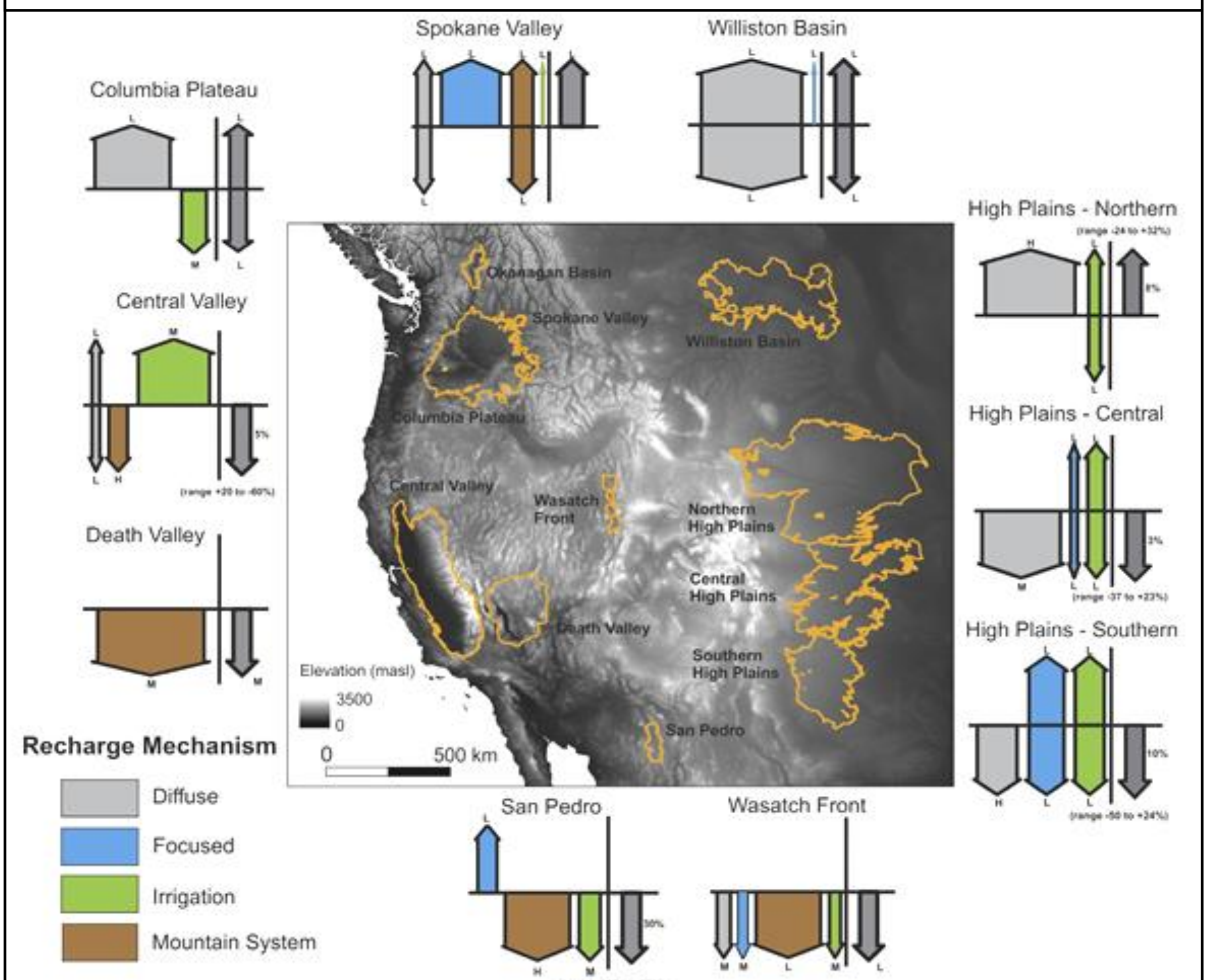
As reliability with natural groundwater recharge shifts, basins across the West will have different potentials for recharge due to their inherent geology. The geology and topography of the CTUIR ceded and traditional use lands is very diverse, and there is a lot of potential for different kinds of groundwater recharge mechanisms to be supported and enhanced.

While studies for the Blue Mountains groundwater have not been modeled, low elevations can be assume to be approximated by the Columbia River Plateau groundwater system, while higher elevations share groundwater system attributes similar to the Spokane River Valley system for the purposes of this plan.

Figure 3A.6 outlines the potential for each major river basin within CTUIR traditional use area for recharge with each of the different pathways to groundwater.

- Projections for different recharge mechanisms are estimated for different watersheds around the U.S. West. The size of the arrow indicates the magnitude of the change, while the direction (up/down) illustrates the direction this change is headed (increasing/decreasing). Diffuse recharge is shown as a gray arrow, focused recharge is shown as a blue arrow, irrigation recharge as green arrows, and mountain systems recharge as brown arrows.
- In the Pacific Northwest, simulated future diffuse recharge is projected to increase, as winter precipitation will be greater than needs of regional plants in cool months. This surplus of water as soil moisture can contribute to storage in permeable soils.
- However, in agricultural areas, irrigation recharge is likely to decrease, as crop plants will need much more water during growing seasons with increasing extreme heat (Meixner, 2016).

Figure 3A.6: Projected Shifts in Groundwater Recharge Capacity for Mid-Century



- For the Columbia Plateau system, the study found that **total groundwater recharge decreased, because the decrease in irrigation recharge (-37 mm) was larger than the increase in diffuse recharge (+6 mm)** (Meixner, 2016).

This study shows that even modest future increases in diffuse recharge could lead to an increase in total recharge across the whole Columbia River Plateau.

Within the Spokane Valley, focused Mountain System Recharge from upland tributary basins, and focused recharge from seasonal floodplain inundation and hyporheic exchange are the primary modes of groundwater recharge. In a climate shifted future, overall changes in recharge will hinge on whether the effects of warming — such as higher energetic needs from plants and animals— will outweigh the effects of increased precipitation.

- Focused recharge directly from rivers and associated reservoirs is expected to increase slightly given the close link between precipitation, river flows, seepage loss, and expected precipitation increases from warming temperatures.
- Knowledge of the properties of a basin's geology will help in adaptation planning to preserve the integrity and availability of groundwater resources.

Within the CTUIR's Ceded and traditional use lands, there are opportunities for diffuse groundwater recharge at low elevations including:

- Planting deep-rooting native or perennial grasses that facilitate soil moisture infiltration;
- Advocating for no-till agricultural dryland systems and long-term stable grassland ecosystems;
- Diverse crop rotations that retain soil health, water holding capacity, and increase soil carbon organic matter;
- Expanding flood zones to prioritize floodplain reconnection to facilitate greater opportunities for diffuse and focused recharge.

Within higher elevation systems, strategies that emphasize retaining soil moisture, increasing stream channel meander and decreasing water velocity strengthen focused recharge. First Foods habitat restoration, and strategically engineered wetlands can buffer ephemeral high flows would facilitate greater recharge in these high elevation mountain streams. Resource managers should proactively plan for greater ephemeral and runoff potential.
(Credit: Meixner, 2016)

100% of Umatilla Indian Reservation (UIR) residents rely on groundwater wells for home use. Drilling wells (pictured) is costly, and many well levels are dropping.

Gaps in Knowledge/Data/Policy:

- Specific infiltration potential for Columbia basalts, and effects of non-irrigated agriculture on storage potential

7. Increased Potential for Chemical Contamination

Nitrate and pesticide leaching into groundwater contaminates watersheds that sustain First Foods, especially in heavily agricultural areas. Agricultural crops require inputs like nitrogen fertilizers, irrigation, pesticides and herbicides, and farming creates situations for the potential over application of chemicals in response to changing seasonal conditions.

These inputs directly contribute to the generation of greenhouse gases, and chemical inputs like pesticides and nitrate fertilizers can leach into surface and groundwater through irrigation excess and heavy precipitation events. Farmland makes up over 80% of land use in Umatilla County, which is representative of much of the CTUIR Ceded lands.

Figure 3A.7 shows the locations of high pesticide concentrations in the Milton Freewater area of the Walla Walla River basin, sampled and reported in 2020.

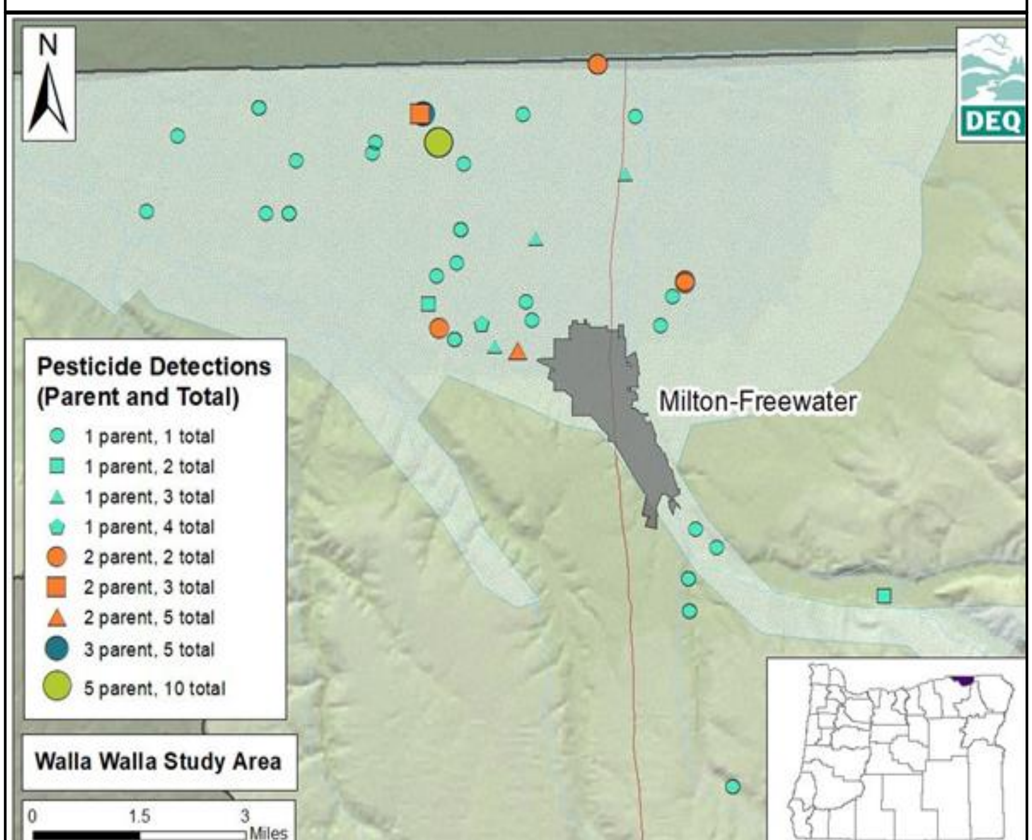
- The Environmental Protection Agency (EPA) has set the maximum contaminant level for nitrate at 10 mg/L for nitrate levels.
- Wells were sampled for the presence of various pesticide contaminants (labeled “parent” in the map legend) and their chemical byproducts. On the map these wells are indicated by the color and geometry of detected contamination. Low levels of contamination are indicated in light blue, moderate contamination in orange, and significant contamination in green.
- Within the Milton-Freewater area of the Walla Walla River, **20% of wells had nitrate concentrations above what are considered natural level (higher than 3 mg/L), and 1% was above the maximum contaminant level (10mg/L).**
- The lower Umatilla River basin has already reached nitrate contamination levels high to be classified as a “groundwater management area” and is referenced as the Lower Umatilla Basin Groundwater Management Area, or “LUBGWMA” in Oregon State.

Because of significant gaps in data collection, understanding how groundwater contamination will change requires a proxy estimate. Contamination modeling studies conduction in North Dakota agricultural watersheds may offer some insight on how changing precipitation affects groundwater quality.

- From **2000 to 2020, this study predicted a 1,885-1,072% increase in “vulnerable” watersheds, and a 645-2,143% increase from 2020 to 2050 under different emissions scenarios** (Li and Merchant. 2017).
- While North Dakota will see different climate challenges than CTUIR, this can serve as an extreme prediction for the potential of groundwater contamination under climate change projections.
- Using the findings of this study, quick back-of-the-envelope calculations indicate residential wells within CTUIR ceded lands could **increase 214 - 377% in contamination by 2050,** though there are many variables and assumptions in this prediction.

Additional monitoring, data collection and sampling, and predictive modeling for the Columbia River basin would help in understanding how contamination risks are changing.

Figure 3A.7: Areas of High Pesticide Detection in Walla Walla Wells (2020)



(**Credit: Oregon Dept of Environmental Quality, 2020)

<u>Gaps in Knowledge/Data/ Policy:</u>

- Monitoring and modeling of changing contamination risks and rates for CTUIR Ceded lands;
- Routine data collection for groundwater contaminants related to emission sources.

F. Create Opportunities for Infiltration

i. Restored Infiltration

"The spatial distribution of surface water across the floodplain drives the active and continuous exchange of water between the river channel and river gravels, as well as subsurface movement of river water through river gravels." (Umatilla River Vision, 2011)

Short Term:

- **Conduct community mapping exercises to identify opportunities to improve water infiltration** on the Umatilla Indian Reservation (UIR) and CTUIR Ceded lands; these could include natural, engineered, and behavioral strategies.

- **Support and advocate for education on benefits of wetlands and healthy river ecosystem function to diverse audiences**. Outreach to audiences should include (but not be limited to) Tribal families, youth and students, affiliation and partner organizations, and other regional non-Tribal private and public stakeholders.

Long Term:

- **Support and expand locations where wetlands and ephemeral streams exist to store excess water** and sequester it for the benefit of flood control, First Foods habitat, and water quality improvement. Opportunities could be located in areas affected by seasonal flooding or groundwater upwellings, such as along the Mission Creek Mission area.

ii. Engineered Infiltration

"When years with higher precipitation levels occur during the winter months resulting in a thicker snow pack at the higher elevation, sudden warming events have the potential to cause rapid melting of the snow pack and flooding in lower elevations. (CTUIR Hazard Mitigation Plan, 2016, 2021) Several municipalities and organizations within CTUIR's Ceded lands are building capacity for artificial storage, though these have a range of strategy and efficacy.

Short Term:

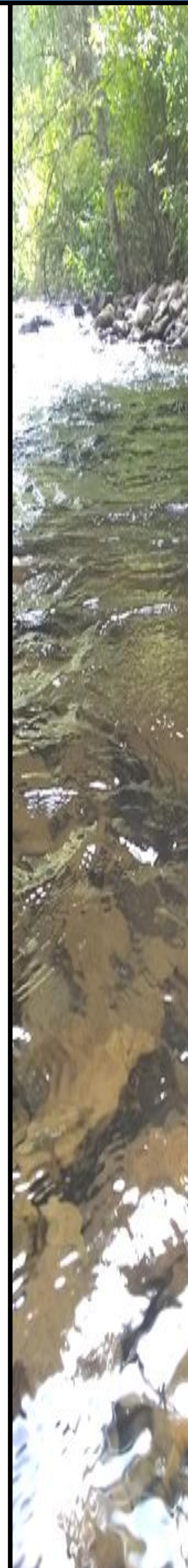
- **Examine regional water storage projects for community preference and feasibility**. Many locally are designed to serve primarily consumptive demands, and can have contamination and accumulation issues that need to be addressed. Examples include aquifer storage and recovery (ASR) with the City of Pendleton, and in Milton Freewater with the Walla Walla Basin Watershed Council.

- **Identify and inventory opportunities to improve groundwater infiltration for municipal/urban homes and communities locally**. These could include permeable pavement technology for sidewalks and roads, Rain gardens, bioswales, and compost operations, among others. Examples include aquifer storage and recovery (ASR) with the City of Pendleton, and in Milton Freewater with the Walla Walla Basin Watershed Council.

- **Identify and inventory opportunities to improve groundwater infiltration for municipal/urban homes and communities locally**. These could include permeable pavement technology for sidewalks and roads, rain gardens, bioswales, and compost operations, among others.

Long Term:

- **Upon completion, explore and research**



resiliency options related to the Umatilla Basin Water Rights Settlement, including potential for conveyance from McKay Reservoir, and other opportunities to convey stored water to the CTUIR homeland as appropriate.

G. Expand Groundwater Data Collection & Modeling

i. Support Existing Data Collection Efforts

Groundwater networks are highly complex, with some that interact across large distances, and others that are confined to their own geography. Knowing how groundwater sources are connected will allow for a more knowledgeable withdrawal and use planning, as well as locations where the most efficient areas of infiltration and exchange are for prioritizing restoration or artificial storage strategies.

Short Term:

- **Expand DNR Water Resources Program (WRP) pilot groundwater dating studies to examine recharge periods for select deep groundwater storage locations,** as an initial step towards determining the length of time it takes groundwater sources to recharge.

- **Continue and expand coordination between Tribal Planning Office (TPO) Environmental Health and Safety Specialist and WRP** to administer a broad set of codes that dictate the levels of contamination required to trigger advisories, and the protocols that are involved.

Long Term:

- **Support and expand CTUIR Dept of Natural Resources (DNR) WRP groundwater monitoring and data collection initiatives**, especially for the health and longevity of residential and industrial groundwater wells.

- **Identify gaps in water monitoring and management systems,** and where they could overlap and expand to improve CTUIR response to groundwater knowledge, modeling and monitoring.

CTUIR WRP staff monitor groundwater levels within the UIR. Well monitoring for water quantity and quality is done alongside Tribal Planning Office.

ii. Pursue Additional Funding for Expanded Monitoring & Analysis

Use of this water quality data for predictive planning could be expanded, and engagement with data from other basins in the traditional use area could be of guidance to adaptation planning efforts.

Short Term:

- **Actively pursue additional grant and agency funding for these data collection and analysis efforts,** especially as it could assist in the identification of climate-driven trends.

Long Term:

- **Expand capacity of water quality testing possible through the DNR Energy and Environmental Science Program (EESP)**, to include biological and chemical elements in its laboratory testing capability.

iii. Participate with Groundwater Contamination Efforts and Studies

Chemical contaminants are already a concern for the Umatilla River Basin as concentrations of nitrates from agricultural use throughout the watershed collect in the lower basin.

Short Term:

- **Participate with joint agency management efforts in the Lower Umatilla Basin Ground Water Management Area (LUBGWMA)** on groundwater contamination issues.

Long Term:

- **Expand and fund monitoring studies to provide information on how groundwater contamination rates are shifting** in response to land use and climate changes.

H. Opportunities for Regional Collaboration and Engagement

i. Outreach, Engagement, and Education

Watershed connection requires restoration and monitoring work to be done both on and off the UIR. Engagement of other entities as opportunities arise will expand the reach of the Umatilla River Vision.

Short Term:

- **Engage other public ate and private watershed stakeholders as project collaborators** where restoration and conservation goals align. Areas of contamination such as the LUBGWMA provide audiences and outreach opportunities for collaboration.

- **Support and expand Tribal participation with water education opportunities for all ages**. K-12 opportunities like Watershed Field Days, homeowner education about well, sewer, and septic services, and regional water conferences are examples of the kinds of educational opportunities available to pursue for water education.

Long Term:

- **Develop strategies within projects and work plans that empower communities around implementation of water conservation** and adaptation approaches. These might include community listening and visioning sessions, community science components to water monitoring initiatives, and providing incentives/financing assistance with infrastructure upgrades, among others.

- **Develop community-identified water use valuing systems to guide future decisions about water management**. These kinds of quantifiable valuing approaches could assist in communication of water conservation priorities across sectors.

ii. Leadership and Management

Communities and families have a role in preparing for changing water conditions. Providing education, access to services, and equipment necessary to be prepared is essential.

Short Term:

- **Continue, support, and expand CTUIR ability to apply "Treatment as a State" (TAS) status that promotes CTUIR as a leader in watershed quality and management;** this includes existing projects like the WRP TMDL water quality standards, the Umatilla Basin Project for irrigation supply and management, and consensus building innovations like the OWRD Place Based Planning project in the Grande Ronde Basin. See Ch 3G pages 273-274 for additional detail.

- **Incorporate CAP strategies** into CTUIR Annual Work Plans (AWPs), Board of Trustees (BOT) priorities, and other relevant Tribal governing documents, as well as developing measures of success relevant to each department and program.

Long Term:

- **Reduce groundwater pumping to levels supported by monitoring and demand.** Demand on groundwater supplies should be balanced with recharge potentials that vary in UIR locations.

- **Engage leaders at all levels in discussions of**

water management. Watersheds and floodwaters transcend human boundaries, and management requires leaders at different levels of jurisdiction to work cooperatively to address issues and find solutions.

Measuring Success and Gaps in Groundwater Adaptation

How Do We Measure the Success of These Adaptations?

" 'Cúušnimna inaknúwiyaša náaman ƛáaxw wáwnakwšaš' Water keeps all our bodies for us. Čúuš is a part of everything. It is within Natítayt, it is within Tiičám, and it is within Núsux (the salmon). It is essential for the survival of all life. Cold, clean, healthy water is the life blood of the land. We drink water to remind us of who we are. Cúuš cleanses and heals our bodies, "Płíx iwá čúuš" (CTUIR Water Code, 2005)"

- **Comprehensive Plan Objective 5.6.1**: To ensure that ground and surface waters are available to satisfy CTUIR Treaty Rights, the needs of CTUIR members, and the citizens of the Umatilla Indian Reservation (Comp Plan page 81 for benchmarks);
- **Comprehensive Plan Objective 5.8.2**: Quantify and adjudicate the CTUIR reserved rights to consumptive use of waters on the Umatilla Indian Reservation, to stream flows in the Umatilla River Basin, the Walla Walla River Basin, the Grande Ronde River Basin, the John Day River Basin, the Tucannon River Basin and to other areas with reserved water rights (see Comp Plan page 95 for benchmarks).
- **CTUIR Water Code Section 1.05 Statement of Policy F Groundwater Conservation**: Groundwater supplies are vitally important to the health and welfare of the citizens of the Reservation and to the progressive development of the Reservation economy. Development of water resources shall be controlled and regulated to prevent the depletion of aquifers and the overdraft of groundwater. Management of water resources shall protect and improve the quality of the groundwater resources (page 5);
- **CTUIR Water Code Section 1.05 Statement of Policy G Competition for Water:** Well Interference: Development of water resources shall be controlled and regulated to reduce or prevent well interference and competition for water between users (page 5);
- **CTUIR Water Code Section 3.07:** Water Quality Management Planning Goals and Objectives (page 42).
- **CTUIR Hazard Mitigation Plan (2021) Section 3: Hazard Identification and Risk Assessment**—Drought (page 74-78)
- **CTUIR Hazard Mitigation Plan (2021) Section 3: Hazard Identification and Risk Assessment**—Flooding (page 95-107)
- **CTUIR Hazard Mitigation Plan (2021) Section 4: Hazard Mitigation Strategy** (pg 192-208)
- Tribal Water Commission (TWC) annual reports.
- Water Resources Program Plan of Operations (1993), annual work plans, and completed activities.
- Umatilla Basin Water Rights Settlement negotiations (ongoing).
- Reduce groundwater pumping in vulnerable locations.
- Permit and allow new groundwater pumping only in places where recharge is proven.

What Gaps in Knowledge, Policy, Capacity, or Education Exist?

- Clear and detailed understanding of how long certain groundwater networks take to be recharged;
- Knowledge of how irrigation demand and management will change with changing climate conditions;
- Metering of consumptive water use for UIR residents and industries to establish conservation baseline measures;
- Coordinated water conservation outreach and voluntary management/monitoring participation;
- Impacts of engineered groundwater capture systems like ASR have on artisanal wells and sources.
- Tribal Member and community participation in monitoring and planning.

Water Adaptation Summary

Surface Water Adaptations

A. Conservation of Water in River Systems

B. Expand Umatilla River Vision

C. Collaborate for Floodplain Reconnection & Restoration

D. Water Quality & Quantity Monitoring and Data Collection

E. Water Administration, Modeling, and Management Strategies

Creating conditions for water conservation and storage buffer for water temperature and low flow impacts, and provide habitat for floodplain connection. Addressing opportunities for water recapture and understanding of unique hydrology will help develop adaptations that provide cold and clean water for all needs.

Measures of Success:

- Umatilla River Vision Touchstones (2011)
- CTUIR Comprehensive Plan (2010) Objective 5.6.3
- CTUIR Water Code (2005) Section 1.05 B, D, and E; and Section 3.07 for benchmarks.
- CTUIR Hazard Mitigation Plan (2021) Section 3: Drought (page 74-78), Flooding (page 95-107)
- Tribal Water Commission annual reports
- WRP Annual Work Plans and activities.
- Umatilla Basin Water Rights Settlement

Groundwater Adaptations

F. Create Opportunities for Infiltration

G. Expand Groundwater Data Collection & Modeling

H. Opportunities for Regional Collaboration and Engagement

Groundwater and surface waters are connected, and must be monitored and managed as such. Columbia basalts are unique in their groundwater behavior, and diverse locations have different recharge capacities. Understanding how these groundwater sources are affected at a local level is essential, and infiltration of high flows into shallow aquifers buffer for flood and drought.

Measures of Success:

- CTUIR Comprehensive Plan (2010) Objectives 5.6.1, and 5.8.2
- CTUIR Water Code Section 1.05 Statement of Policy F, and G; and Section 3.07 for benchmarks
- CTUIR Hazard Mitigation Plan (2021) Section 3: Drought (page 74-78), Flooding (page 95-107)
- Tribal Water Commission annual reports
- Reduce groundwater pumping in vulnerable locations
- Permit and allow new groundwater pumping only in places where recharge is proven

Chapter 3A References and Credits

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