Oregon
Kate Brown, Governor

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Integrated Water Resources Strategy

2017 Policy Advisory Group

September 14, 2016 Meeting Materials

Water Management and Conservation Plans

Background

Requirements for developing a water management and conservation plan (WMCP) went into effect in September 1994. The Water Resources Department administers this planning program, reviewing and approving plans for various entities. Some drinking water providers are required to develop a WMCP when obtaining a new water use permit.

When extending an existing water use permit, all drinking water providers that hold a municipal or quasi-municipal use permit are required are required to submit a WMCP within three years of approval of the extension, although there are some exceptions as outlined in OAR 690-315-0090.

A WMCP requirement can also be triggered as part of a loan through the Infrastructure Finance Authority or a capacity analysis through the Oregon Health Authority. Irrigation districts or other agricultural water providers can also develop a WMCP. These are voluntary through the Water Resources Department, although the Bureau of Reclamation has often conditioned contract water with a requirement to submit a WMCP to the Department.

Connection to the 2012 Integrated Water Resources Strategy

The Integrated Water Resources Strategy includes Recommended Action 10A, which calls for improving water use efficiency and conservation. This action includes developing an online clearing house of information, prioritizing agricultural water use efficiency, and conducting a water conservation assessment. It also includes expanding existing programs via outreach and participation in the state's allocation of conserved water program, and water management and conservation planning program.

Today, the Department has 128 active municipal Water Management and Conservation Plans. Active, in this context, means an approved plan that has not expired. The typical life span of a plan ranges from 5-10 years. There are 11 active agricultural WMCPs today.

Municipal WMCPs
128 active
21 first WMCP needed
20 updated needed
22 under review

Agricultural WMCPs
11 active
19 updated needed
2 under review

Elements of a Water Management and Conservation Plan

There are four main elements that need to be addressed in a Water Management and Conservation Plan.

- **Water supplier/system description** – this is where municipalities describe water sources, delivery systems, the efficiency of the system, current demands, and their set of customers.
- **Water conservation Program** – this section of the plan lays out actions to promote efficient water use. The State's water management and conservation planning program has been used by many water providers to successfully identify water conservation measures.
- **Water curtailment plan** – often referred to as the curtailment element of the plan, this is composed of a pre-defined water curtailment response to water shortage or other emergencies. In a drought, this acts as a response plan and guides messaging to customers.
- **Long term water supply** – the plan requires a projection of water demands for the next 20 years. If an entity plans to increase the diversion rate under an existing permit, then they are also required to look at alternative water sources, including conservation, to help meet demand projections.

Observations

There is a wide range of municipalities that are required to have a WMCP. These can be small homeowner associations, with as few as 25 connections, to a water system the size of Portland Water Bureau. To further encourage the use of this planning program, Department staff have proposed the idea of creating a "WMCP light" version. Such an approach may make it more suitable for smaller water providers that may currently lack capacity to develop or implement a WMCP. Such a plan could be particularly helpful during drought situations, such as that experienced in 2015.

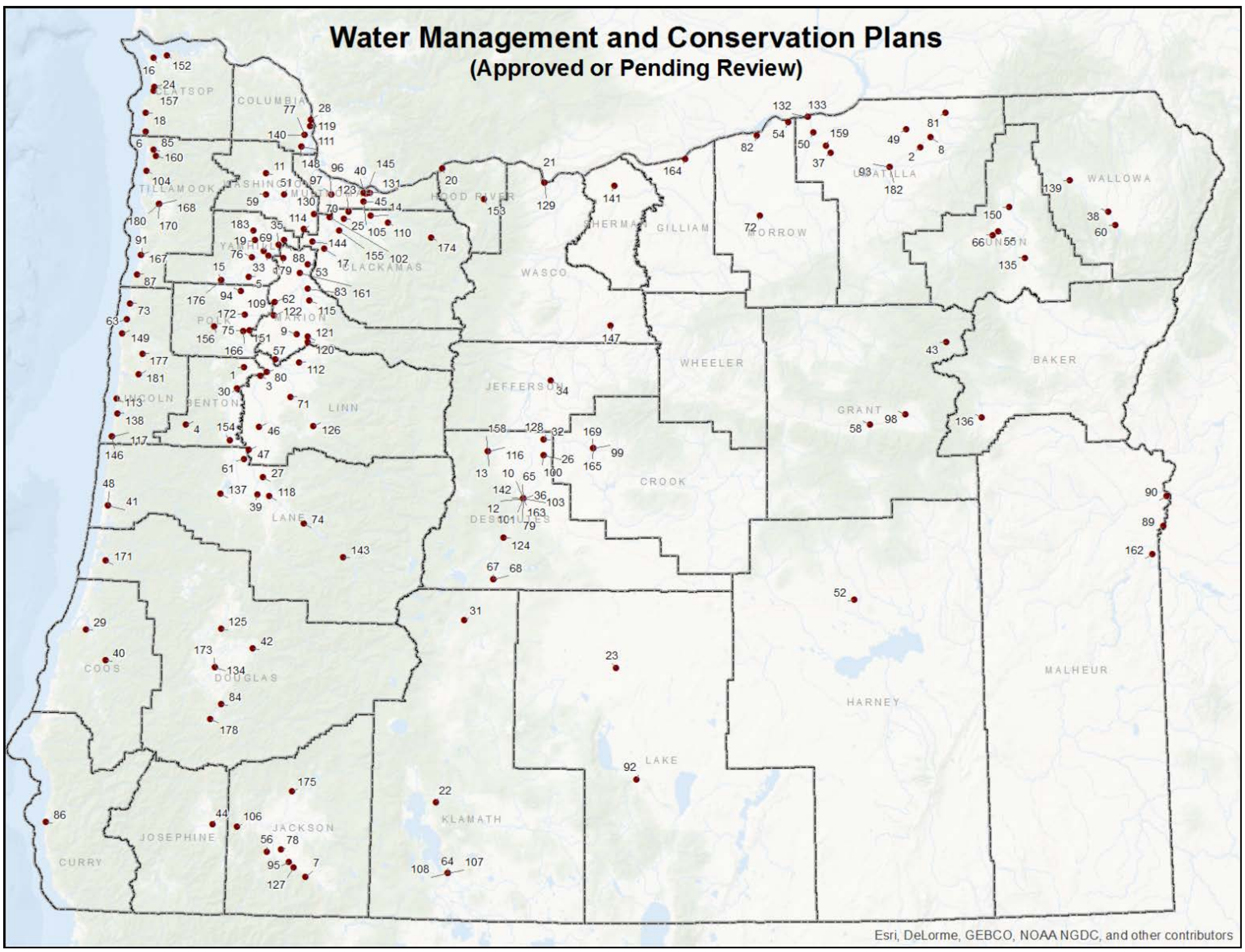
Additional Information

- Staff presentation to the Drought Task Force (August 1, 2016)
  http://www.oregon.gov/owrd/docs/HB4113/Oregon%27s_Water_Management_and_Conservation_Plans_Jaramillo.pdf

- Guidebook for municipal water management and conservation plans (March 2015):
  http://www.oregon.gov/owrd/docs/wmcp_guidebook.pdf

- Guidebook for agricultural water management and conservation plans (September 2007):
  http://www.oregon.gov/owrd/docs/Ag_guideboo_with_append_Sept_2007.pdf

Distribution of Municipal Water Management and Conservation Plans (September 2016)



Public Safety: Oregon's Dam Safety Program

Goal: Maintain Oregon's good dam safety record and ensure public safety.

Problem: Floods, earthquakes, internal erosion, and aging infrastructure are realities in Oregon. Many of Oregon's dams are old and cannot safely pass major floods. Older dams in Oregon were not designed to withstand a Cascadia earthquake. A number of pipes and concrete dams have worn out, with unknown potential effects. Oregon's dam safety laws, established in 1929, are outdated, making effective actions to improve public safety very difficult.

Solution: Modernize Oregon statutes and provide resources to better understand and improve the safety and resilience of Oregon dams. See observations below for specifics.

Dams at least 10 feet high and storing at least 9.2 acre-feet of water are subject to Oregon's dam safety program, managed by the Oregon Water Resources Department.

State Regulated Dams

Low Hazard Dams **736**
Failure is unlikely to cause major property damage or loss of life. These dams are inspected every 3 to 5 years.

Significant Hazard Dams **147**
Failure will damage properties but loss of life is unlikely. These dams are inspected every 2 to 3 years.

High Hazard Dams **77**
Failure will likely cause fatalities. These dams are inspected annually.

Total 960

Spillway outlet for dam above Silverton, safely passing flood flows

Of these high hazard dams,

- **37** are in satisfactory condition.
- **19** are in fair condition.
- **11** are in poor condition.
- **10** are in unsatisfactory condition.

Other states consider <u>any</u> unsatisfactory dams to be automatically unsafe unless there is a significant restriction placed on the maximum volume of allowable water storage.

Observations Regarding Oregon's Dam Safety Program:

Additional resources are needed to determine if dams have safety deficiencies. We need to identify dams posing the most risk to people and property, determine their condition and potential deficiencies, and note the likely vulnerabilities (e.g., flood, earthquake, etc.) at each specific dam. The result would be improved public safety and resilience of dams.

Statutes do not encourage cooperative actions with owners to improve the safety of their dams. Oregon statutes do not currently have a process for dealing with dams in poor or unsatisfactory condition. Rather, they set forth a process to enter immediately into enforcement. A more efficient means to improve conditions more quickly would be to allow the Department to work with a willing dam owner to bring the dam back into a safe condition.

Legal responsibilities of a dam owner are not defined in statute. While this term is used in statute (ORS 540.350), it is not defined. Owners should know what their responsibilities are, including the responsibility to keep the dam safe and take immediate action if the dam begins to fail and threaten people or property.

> "Ownership makes dams a unique part of the national infrastructure. While most infrastructure facilities (roads, bridges, sewer systems, etc.) are owned by public entities, the majority of dams in the United States are privately owned. A dam's owner is solely responsible for the safety and liability of the dam and for financing its upkeep, upgrade and repair."
>
> ~ Association of State Dam Safety Officials

Dam owners have not developed Emergency Action Plans (EAPs) for all dams rated high hazard. Nationally, EAPs are an accepted safety practice for dams, and are a major reason why loss of life from dam failures has decreased during the past 25 years. Current statutes contain no language that would require EAPs for existing high hazard dams. The Department can provide technical assistance for owners who need help developing EAPs.

The Department is not authorized to require monitoring on high hazard dams in poor or unsatisfactory condition. Remote monitoring can detect a potential problem before there is harm to people and property. The most important information includes current water level in the reservoir and any change in seepage flow through the dam. Many owners are already collecting and analyzing this information now, as it allows them to improve the performance and safety of their dams. Other owners have not taken this step.

There is no mechanism to pay for timely review of dam / reservoir plans and specification. There is currently an annual fee for the inspection and dam safety program assistance of existing dams, but no fee for the review of dam designs, construction inspections, and the related necessary correspondence with the dam owner and design engineer. When new designs are submitted, if there are other dam safety priorities, then review and approval can take several months or longer. Improved ability for the Department to conduct more timely reviews and to correspond with engineers, from preliminary to final design, would result in more certainty and consistency for dam owners and project engineers.

The Department does not have authority to act in an emergency. At present, the Department has no authority to direct an owner to take actions to prevent imminent dam failure. Such authority would allow the Dam Safety Program to direct specific actions, or to direct owners to engage an engineer to save the dam and protect people and property. It would also allow OWRD action on dams in imminent danger if owners are unavailable or unwilling. Actions could include opening valves; if caught in time, lowering reservoir levels will reduce stress on the dam and reduce its likelihood of catastrophic failure. This authority would also allow bringing in pumps or siphons, and emergency rock fill if it would help.

The state has no grant and loan program for the rehabilitation of deficient dams. Many owners do not have the financial resources to rehabilitate dams they own. This is especially true for dams that generate no income for the dam owner. Funding would allow owners to rehabilitate unsafe dams that still have value for the owner, or to provide funds for removal of dams that are not needed by the owner or that no longer have beneficial use.

> "Dams bring water, power, flood control, recreation, economic possibilities and many other advantages to people. But, people must understand that safe operation and maintenance is key to sustaining these advantages and avoiding potential disaster."
>
> ~ Association of State Dam Safety Officials

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Glossary of Flow-Related Terms

Adapted from *USGS Water Science Glossary* (2016) and *SB 839 Science Subgroup Report* (2014)

Natural Flow Terms

"Natural Flow""

- Flow in rivers and streams that would have occurred prior to man-made impacts or regulation.
- In unaltered environments, natural flow equals recorded flow. In affected systems, natural flow is a calculated value (WRD's Estimated Average Natural Flow) based on the recorded flows of contributing rivers, physical factors concerning the reach (for example, evaporation and channel losses), water diversions, consumptive use, and return flow.

"Seasonally Varying Flows" (previously "peak and ecological flows")

- The duration, timing, frequency, and volume of flows [that] protect and maintain the biological, ecological, and physical functions of the watershed.
    - A task force established methods for determining "seasonally varying flows" (SVF) that will be prescribed to certain storage projects awarded WRD grant funds under SB 839
    - The resulting matrix and narrative from the task force informed rule-making in 2015
    - The first grant cycle for projects that may trigger the SVF prescription occurred this year, with projects approved by the Water Resources Commission in May 2016.

Base Flows Terms

"Biological Base Flows" (= minimum or optimum flows)

- These flows are established as a lower protective threshold that provide biologically-necessary habitat for fish and other aquatic organisms.
- These flows are defined in order to be sufficient in volume for incubation, rearing, and spawning for key species over long periods of time.
- Minimum flows are designed to maintain production of key species whereas optimum flows are designed for enhancement of currently weakened fish populations.

"Hydrological Base Flows"

- This flow is the sustained flow of a stream (largely by groundwater discharge) in the absence of direct runoff.

Elevated Flow Terms

"Biological Triggering Flows"

- High or low streamflows that provide environmental cues for initiating upstream movement of adult fish and downstream movement of fry and juvenile fish.
- The timing or predictability of flow events can be ecologically critical because the life cycles of many aquatic and riparian species are timed to either avoid or exploit flows of variable magnitudes.

"Habitat Connectivity Flows"

- These flows connect side channels and other important off-channel habitats to the main channel.
- Many ESA- and State-listed species thrive in side channels and ponds that maintain a hydraulic connection with the main channel over relatively long periods each year.
- The timing and duration of connectivity flows should follow the shape of the naturally occurring hydrograph.

"Peak Flows"

- Peak flows are maximum instantaneous discharge for a given condition or location
- Peak flows occur less frequently, but at a greater volume than the average flow.
- They serve several functions including: ecological triggering flows that trigger key behaviors such as migration or spawning and geomorphic maintenance flows which help build and maintain overall ecological habitat

"Stream Channel Development and Maintenance Flows"

- These flows create or maintain stream morphology, channel form, physical habitat, and maintain healthy streamside vegetation. They are important for bank erosion/deposition, gravel bar formation, wood recruitment, prevention of vegetation encroachment in the channel, and maintenance of general channel form.
- These flows are higher flows and less frequent than flushing flows.

"Stream Channel Flushing Flows"

- These are regularly recurring streamflows with sufficient power to "flush" finer sediments (silt, sand) and organic matter from the interstitial spaces between larger gravel/cobble substrates, pools, and other slower-velocity rearing areas.
- These flows help to renew the spawning and incubation functions of the substrate and maintain the complexity of rearing areas.

"Stream Channel Forming Flows"

- These flows form and maintain side channels, scour floodplain surfaces, redistribute sediment, refill off-channel wetlands and oxbow lakes, and recharge groundwater storage in hyporheic and floodplain aquifers.
- They are often referred to as the bankfull flow, dominant flow, or effective flow.

For more information on Elevated Flows:

- ODFW published a document on elevated flows in September 2007 **(Calculating Channel Maintenance/Elevated Instream Flows When Evaluating Water Right Applications for Out of Stream and Storage Water Rights)**
- WRD released a White Paper: **Peak and Ecological Flow; a Scientific Framework for Implementing Oregon HB 3369**

Overview of Instream Water Rights
(ODFW's Perspective)

History

1) Prior Appropriation
   - Doctrine that underlies water law
     - First in time (putting water to use), first in right (to use water)
     - Junior users (later water right date) will be shut off to supply senior users (earlier water right date) in times of shortage
   - More recent water law considers water availability
     - Estimated natural flow minus existing water rights = water availability
     - Water must be available on an 80% exceedance basis (4 out of 5 years) to receive new surface water right
     - For storage rights, generally water <u>should</u> be available 50% of time (this is not law)

2) Minimum Perennial Streamflow Act of 1955
   - Established minimum stream flows sufficient to support aquatic life and pollution abatement
   - Mostly designated for major rivers and larger streams
   - Flow amounts often set lower than Oregon Game Commission recommendations and could be modified (reduced) as needed
   - Administrative Rule designation, not a true water right; failed to hold up against Certificated Water Rights in times of shortages

3) Instream Water Right Act of 1987
   - Instream flows officially recognized as a beneficial use
   - Established a process for applying for new Instream Water Rights
   - Applications filed by one or more of three state agencies: ODFW, DEQ, OPRD
     - Purpose: maintain and support public uses within natural streams and lakes, including, but not limited to, recreation, scenic attraction, aquatic and fish life, wildlife habitat and ecological values, pollution abatement and navigation
   - Created certificated water rights with legal status under the prior appropriations doctrine
     - Instream water rights cannot be modified, injured, or impaired
     - Instream water rights cannot take away or impair legally established senior water rights

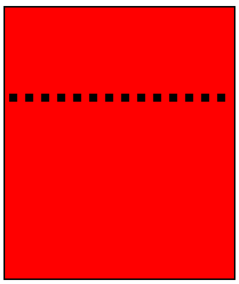
4) How many Instream Water Rights are there?
   - ~1,659 instream rights
   - 1,452 for fish and wildlife (from the 1990s)
     - 242 converted from Minimum Perennial Streamflows as is
     - 264 increased Minimum Perennial Streamflows
     - 946 applications from ODFW
   - Last estimate determined instream rights cover ~ 10% of total stream length in Oregon

Benefit of Instream Rights

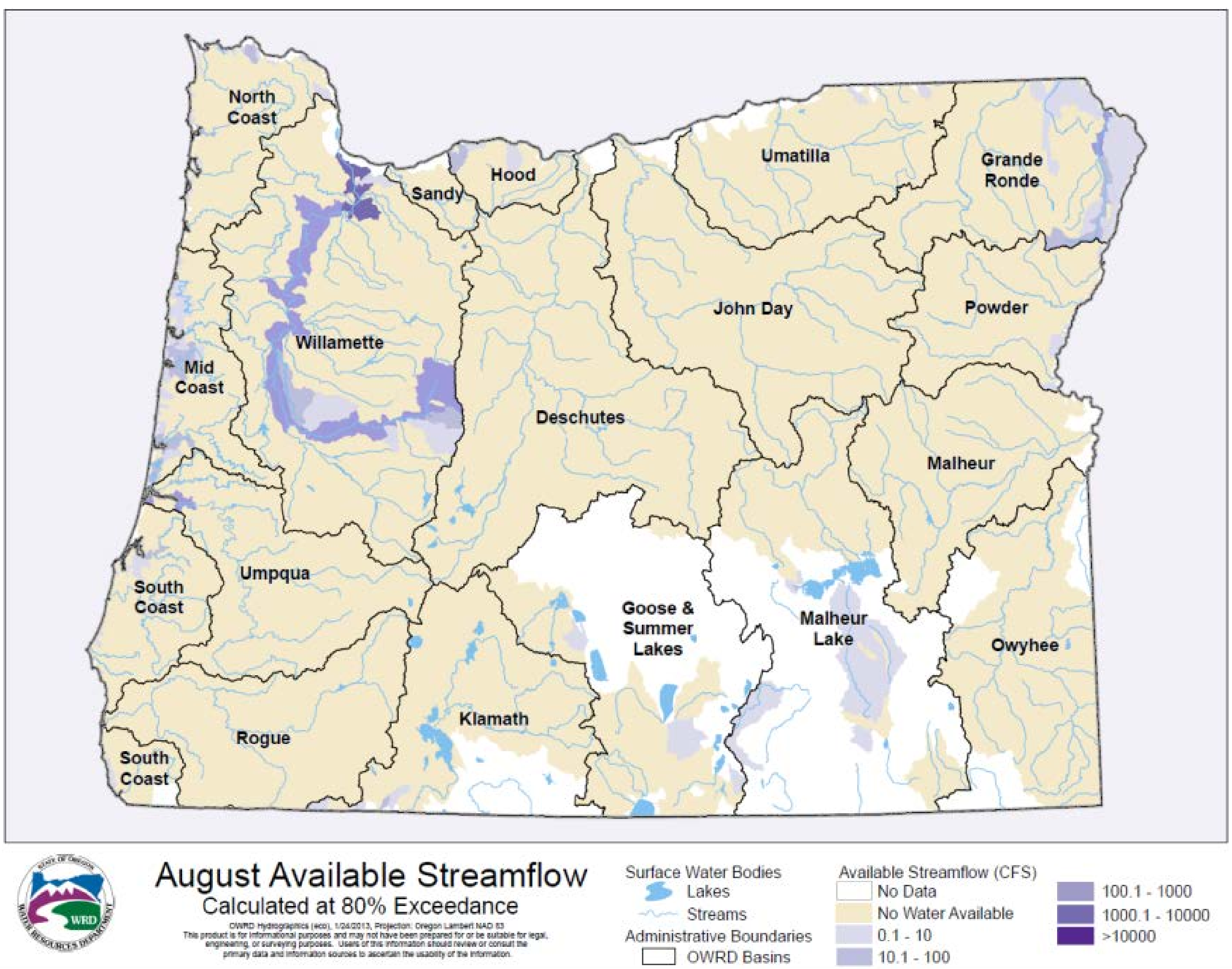
ODFW flow recommendations reflect best available information on the biological requirements of the fish present. As such, instream rights can be set at flow levels that naturally might occur in a stream rather than being limited to the water available in the stream like traditional out-of-stream allocations. Often these flow levels no longer exist during the summer and early fall because the water has already been allocated to senior users. In this instance, instream rights set goals for flow restoration for fish, wildlife, and their habitats (or water quality/recreation, in the case of applications submitted by DEQ or OPRD).

1) Why are Instream Water Rights important?
   - They place protection of instream flows on the same legal standing (under prior appropriation) as consumptive water rights
     - o As with all other water rights, they cannot be injured by a transfer unless there is a net benefit to the resource (mitigation to offset the impact is usually required)
   - They document how much water is needed to conserve, maintain, or enhance fish populations
   - They set goals for flow restoration efforts implemented by or in coordination with senior water right holders

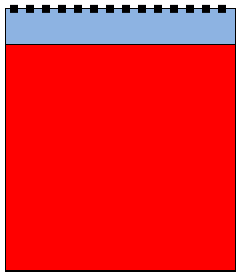
2) How do Instream Water Rights impact other water rights?
   A. All Water Allocated



- All water has been allocated in the basin
- **Majority of waterways during summer (see map)**
- Instream right sets goals for future
- Instream right has no effect on allocation or regulation (junior to all other water rights)
- Transfers may <u>not</u> injure the instream right unless they result in a net benefit to the resource

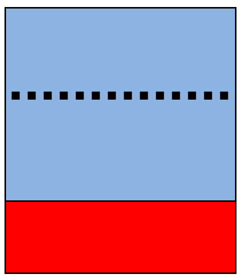


B. Most Water Allocated



- Most water has been allocated in the basin
- Instream right granted for remaining water
- No future allocations (for all or part of the year)
- Instream right has no effect on regulation (junior to all other rights)
- Transfers may not injure the instream right unless they result in a net benefit to the resource

C. Little Water Allocated (Highest Value)



- Little water has been allocated in the basin
- Water remains available to meet the instream right and allow for future allocation
- Future rights are junior to instream right and are regulated
- Transfers may not injure the instream right unless they result in a net benefit to the resource

What is Happening Now for Instream Flow?

- ODFW's policy is to apply for instream water rights on waterways of the state to conserve, maintain, and enhance aquatic and fish life, wildlife and fish and wildlife habitat to provide optimum recreational and aesthetic benefits for present and future generations of the citizens of this state.
- The long-term goal of this policy is to obtain an instream water right on every waterway exhibiting fish and wildlife values.
- ODFW is currently utilizing existing information to recommend flows for future instream water right applications
    - Outreach and notification of affected local governments will begin soon
- ODFW is working closely with OWRD staff to actively seek resolution of 62 protested instream water right applications that remain across the State (from the 1990s applications)
    - We are reinitiating discussions with protestants and actively developing plans to move forward
    - Discussion will result in Settlement (preferred alternative) or referral to Contested Case Hearings
- ODFW staff have been conducting instream flow studies (even prior to the IWRS adoption) as time, budgets, and partnerships allow
    - ODFW has developed a prioritized list of sites across the state for conducting new studies
    - Collection and processing of new data is time-consuming, taking two to three years to complete each stream reach
    - Current instream flow studies will provide data for future instream water right applications
- In addition to obtaining instream water rights, it is ODFW's strategy to engage landowners and senior water right holders in long-term solutions to provide for both instream and out-of-stream uses through voluntary measures.

2016 Oregon Pesticide Stewardship Partnership Program Update

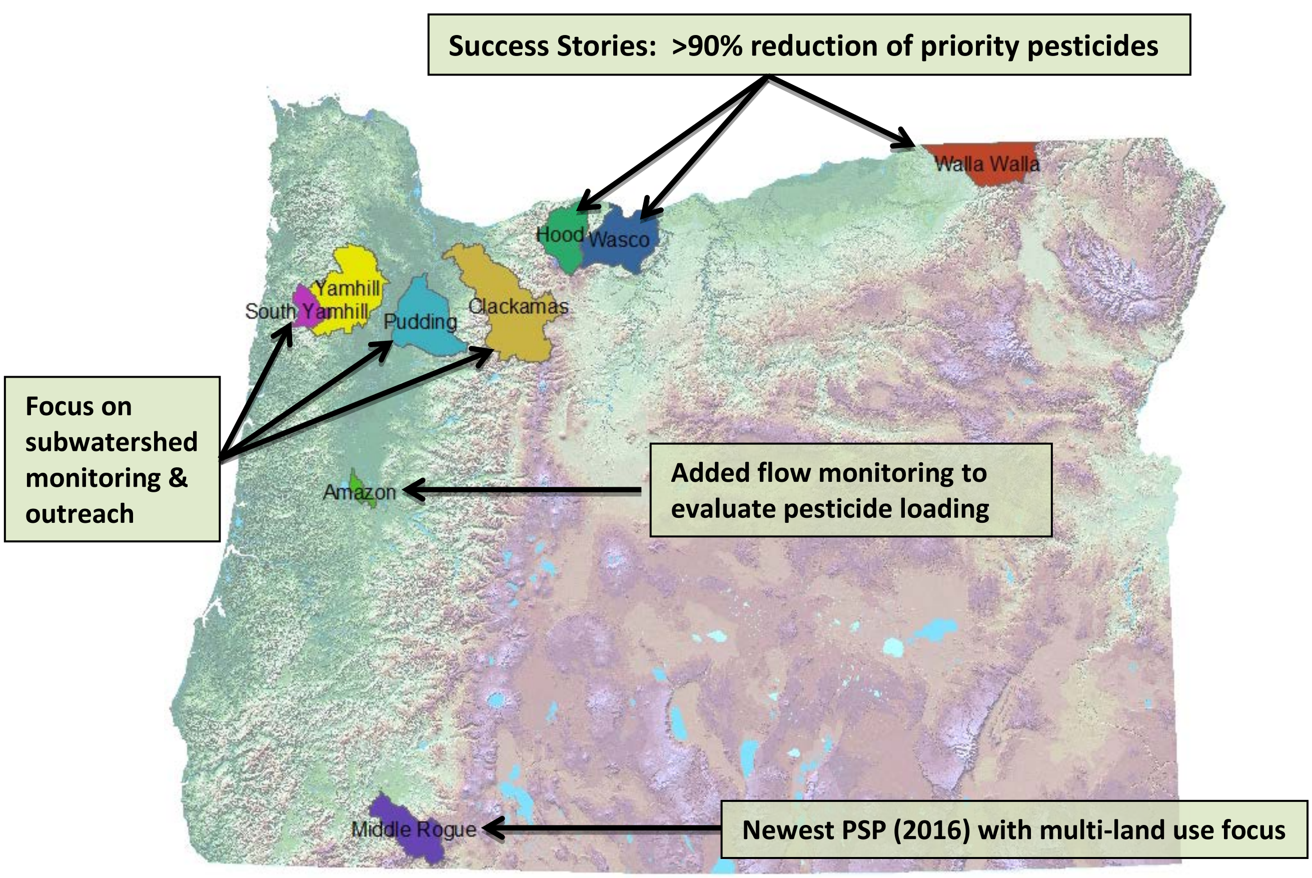
Background

Since 2000, Oregon has used a voluntary, collaborative approach called Pesticide Stewardship Partnerships (PSPs) to identify problems and improve water quality associated with pesticide use at the local level. An inter-agency state team partners with OSU Extension, soil and water conservation districts, watershed councils, grower groups, tribes, and other local organizations to conduct water monitoring and use the results to focus technical assistance and voluntary improvements in pesticide use practices. The PSPs were funded largely through federal grants and in-kind contributions from partners until 2013, when the state legislature allocated funding to ODA and DEQ to sustain and enhance the program. The inter-agency Water Quality Pesticide Management Team oversees the implementation of the PSP program, and guides these local partnerships through the interpretation of the monitoring data and other forms of technical support.

Connection to the 2012 Integrated Water Resources Strategy

The 2012 Integrated Water Resources Strategy included Recommended Action 12B, which calls for reducing the use of and exposure to toxics and other pollutants. This action includes several implementation activities, including supporting the state's Pesticide Stewardship Partnership Program.

Current PSPs in Oregon and Monitoring Approaches

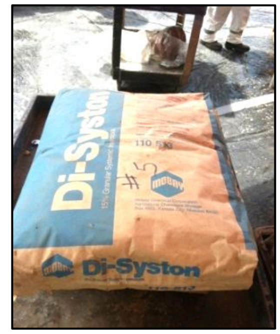


- Assessing "Phase II" Pilot Monitoring Options in **Middle Deschutes** & **South Umpqua**
- Limited stream bed sediment monitoring added and DEQ groundwater data evaluated
- Adding pesticides (e.g. Roundup) to laboratory analyses and scaling down in some areas

Pesticide Collection Events

Since 2014, pesticide collection events held throughout the state:

- Over **209,000 pounds** of unusable pesticides removed from watersheds
- **351** growers, forest land owners and commercial & institutional applicators participated
- Financial support also provided to local governments with collection facilities to hold their own events



Stewardship and Watershed Partner Technical Assistance

✓ 8 stewardship technical assistance grants have been awarded to watershed groups, SWCDs and Extension in PSP watersheds to:

- Implement commodity-specific integrated pest management programs (e.g., nurseries, Christmas tree growers, tree fruit).
- Conduct pesticide risk reduction outreach to multiple types of land uses.

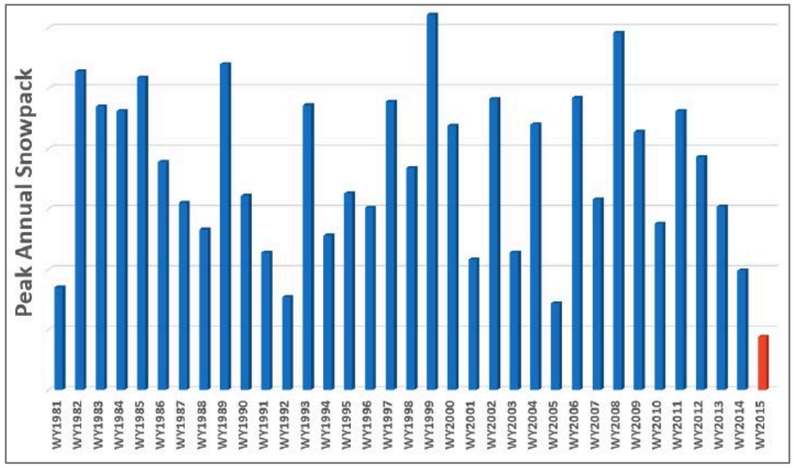
✓ Pesticide drift reduction equipment purchased for demonstration and training in multiple PSP watersheds

✓ Small PSP "partners grants" provided to watershed councils & SWCDs to support water sample collection and general outreach

Drought Chapter Project & Other Updates

Background

In 2015, Oregon experienced one of its most severe droughts on record, with state drought declarations in 25 of the state's 36 counties. Although winter precipitation levels were relatively average, it was Oregon's warmest winter on record, and snowpack was at a historic low. Snow melted earlier than normal, and there was less continuous runoff available during the summer months. Severe conditions continued throughout the year, as the state also faced its warmest and driest summer on record.



Peak Annual Snowpack, 1981 – 2015, Source: NRCS

Connection to the 2012 Integrated Water Resources Strategy

In July 2015, Governor Brown signed Executive Order 15-09 calling for several drought and climate-related actions. Among these, EO 15-09 directed agencies to address drought resiliency in the next version of Oregon's Integrated Water Resources Strategy.

This past spring, the Water Resources Department hired an intern, Rianne BeCraft, a master's student from Oregon State University, to gather and summarize information related to the 2015 drought. This summary will be used as the foundation of a drought chapter or section in the 2017 Integrated Water Resources Strategy. Information was collected by reviewing existing datasets, reports from various agencies, and media coverage, as well as by conducting several interviews with water providers, water users, recreation and conservation groups.

Comprised of three main sections, the drought summary includes:

1) A description of the physical and meteorological conditions of the 2015 drought (i.e., precipitation, temperature, snowpack, and streamflow), and a comparison of these conditions to the historic record and to those of other years of significant drought.

2) A summary of the effects of the 2015 drought, as well as examples of response strategies implemented by water providers and users to alleviate the impacts of drought.

3) A set of conclusions and recommendations based on the findings of the report.

Observations

Although there is substantial information on the conditions and projected impacts of Oregon's 2015 drought, very little information is readily available on the <u>actual effects of drought and the management responses</u> implemented. During the research process, it was especially difficult to find information on the impacts of the 2015 drought on municipalities, tribes, public health, and wildlife beyond fish.

Based on the findings of her analysis, Rianne has provided the following recommendations for state agencies and advisory members to consider:

- **Recommendation #1:** Convene representatives from agencies, tribes, and organizations that play a role in collecting information on drought impacts and responses to determine: a) priorities and a preferred format for summarizing the effects of drought and response strategies; and b) methods for coordinating and minimizing duplicative efforts around collecting, documenting, and compiling relevant information (e.g., water supply conditions, effects on sectors and local economies, emergency grant and loan programs).

- **Recommendation #2:** Prioritize water conservation, storage, and re-use such that the needs of water users and the environment can be met throughout the year.

- **Recommendation #3:** Increase government capacity for groundwater monitoring, and develop a long-term plan for sustainable groundwater management with clear objectives and metrics.

Other Updates

Drought Task Force – The Drought Task Force will hold its fourth meeting on September 15 from 10:00 – 3:00 pm at the Water Resources Department's office in Salem, Room 124A/B. Task force members have spent past meetings brainstorming and contributing proposals to improve drought response in Oregon. During tomorrow's meeting, members will evaluate and rank these proposals. The next scheduled meeting will be held on September 27, 2016, also at the Water Resources Department in Salem.

Drought Early Warning System for the Pacific Northwest - During the first PAG meeting held in March, Kathie Dello from the Oregon Climate Change Research Institute discussed an ongoing project, led by the National Integrated Drought Information System (NIDIS) and the National Drought Mitigation Center (NDMC). Working with regional stakeholders, NIDIS and NDMC are developing a Drought Early Warning System (DEWS) for the Pacific Northwest. One of the main project goals is to better connect drought planners, climatologists, hydrologists, and policy-makers throughout the region. Representatives from Oregon, Washington, Idaho, and Colorado will meet later this month to learn how neighboring states use various indicators and a series of triggers to direct response-related actions.

Additional Information

- Drought Task Force
  http://www.oregon.gov/owrd/Pages/HB_4113.aspx

- Pacific Northwest Drought Early Warning System
  https://www.drought.gov/drought/dews/pacific-northwest

OREGON WATER RESOURCES MONITORING STRATEGY

February 2016

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LIST OF ACRONYMS

ASR/AR	Aquifer Storage and Recovery/Aquifer Recharge
DEQ	Oregon Department of Environmental Quality
Department	Oregon Water Resources Department
IWRS	Integrated Water Resources Strategy
NRCS	Natural Resources Conservation Service
ODFW	Oregon Department of Fish and Wildlife
OWEB	Oregon Watershed Enhancement Board
RAFT	Rapid Assessment of Flooding Tool
STREAM Team	STRategic Enterprise Approach to Monitoring Team
USGS	U.S. Geological Survey

ACKNOWLEDGEMENTS

The development of this Monitoring Strategy was a cooperative effort among various staff at the Water Resources Department. In particular, the following people are gratefully acknowledged for their significant contributions in leading this effort and completing the Department's first Monitoring Strategy.

Mellony Hoskinson, Rachel LovellFord, and Ken Stahr led its development.

In addition, Brenda Bateman, Technical Services Division Administrator; Jonathan LaMarche, South Central Region Office; Rich Marvin, Surface Water Hydrology Section; Ivan Gall, Karl Wozniak, and Ken Lite, Groundwater Hydrology Section; and Alyssa Mucken from the Director's Office participated and contributed to the development of this strategy.

INTRODUCTION

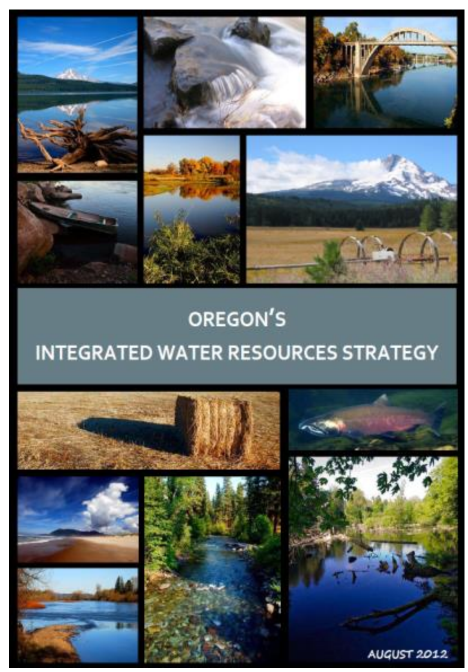
The vision of the Water Resources Department is to assure sufficient and sustainable water supplies are available to meet current and future needs. In order to properly manage Oregon's water resources to meet these needs, the Department must have a strategy in place and have the means for measuring both surface water and groundwater resources. A network of strategically placed stream gages and observation wells enable Department staff to collect valuable data about water resource conditions across the state at any given time. The challenge is to have a monitoring network design that adequately, efficiently, and effectively captures water resource data essential for proper management of the state's water resources. This strategy identifies the Department's monitoring priorities and recommends monitoring actions that will ensure the vision of the Department is being met.

Background

In 1988, the Department's groundwater section developed a framework as part of its Observation Well Network Review (Miller and Lite, 1988). The framework helped determine whether a proposed well was suitable for the state's observation well network and whether the resulting data would be valuable. A review form was developed and instructions and flow diagrams were provided to determine how to rank each proposed well in the network.

In 2008, the Department undertook a similar evaluation of its stream gage network. The purpose of this effort was to determine if the network met the needs of the Department, to identify "high value" stream gages, and to describe an optimum network, given staffing and budget constraints. As an initial step, the evaluation focused solely on distribution and regulation needs. The Department published its findings and recommendations in an open file report titled, *OWRD Stream Gaging Network Evaluation for Water Distribution* (LaMarche, 2011).

Integrated Water Resources Strategy



Oregon's Integrated Water Resources Strategy (IWRS), adopted by the Water Resources Commission in 2012, describes numerous coming pressures that may affect Oregon's water needs and supplies in the future. These include climate change, population growth, economic development, and changes in land use, among others.

Oregon's IWRS also calls on the Department to improve water resources data collection and monitoring methods (Recommended Action 1B). This Monitoring Strategy is a response to the IWRS, further strengthening the state's monitoring and data collection network.

Another IWRS action addressed by this Monitoring Strategy is Recommended Action 1C, "coordinate inter-agency data collection, processing, and use in decision-making." The Department's data collection standards were developed in coordination with the U.S. Geological Survey (USGS). The Department shares groundwater and streamflow data with several federal agencies, including the USGS, the Natural Resources Conservation Service (NRCS), the U.S. Army Corps of Engineers, and the U.S Bureau of Reclamation. The Department is also a member of

Oregon's STREAM Team (see inset), which is made up of several state agencies that monitor Oregon's waters, both quantity and quality.

Efficient Use of Resources

This Monitoring Strategy is designed to ensure that the Department is making the most efficient and effective use of funding and resources to build its monitoring network. The Department is designing its network around the monitoring needs of the state and providing staff and partners with much needed information to anticipate and adapt to coming pressures.

Monitoring Priorities

The Department has identified the following priorities for monitoring:

- Climate Change
- Extreme Events
- Groundwater
- Water Management
- Instream Needs
- Water Supply
- Partnering with Other Agencies (see STREAM Team box)

For each priority, the Department has identified recommended monitoring actions to meet the related data needs. These are described in further detail in the following pages.

STREAM Team

Oregon's STREAM Team is made up of many of the state's natural resource agencies which all monitor Oregon's water for various public purposes. 'STREAM' stands for *STRategic Enterprise Approach to Monitoring.* State agencies that make up this team include:

- Oregon Department of Agriculture
- Oregon Department of Environmental Quality
- Oregon Department of Fish and Wildlife
- Oregon Department of Forestry
- Oregon Department of State Lands
- Oregon Health Authority
- Oregon Water Resources Department
- Oregon Watershed Enhancement Board
- Oregon State University's Institute of Natural Resources

The STREAM Team facilitates collaborative decision making to support a healthy environment through coordinated planning, monitoring, and communication of water-related data and information among Oregon's natural resources agencies. One of the main goals of the STREAM Team is for each agency to develop an interactive monitoring strategy in support of collaborative decision making for water quality, water quantity, and ecosystem services. These strategies are designed to be used as communication tools among the agencies in managing the state's water resources.

MONITORING PRIORITIES

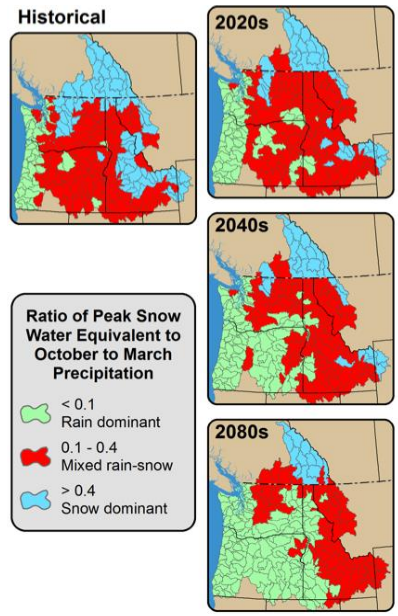
To fully understand and address each of the following priorities, the Department relies on monitoring data. Below, the Department has identified and recommended specific monitoring actions that should be taken in order to address each priority.

CLIMATE CHANGE

World renowned climate change research is taking place within Oregon's university system, and is helping the state prepare for a changing hydrologic regime. With a predicted increase in regional mean temperature of 3.3 to 9.7 degrees Fahrenheit by the end of this century, Oregon can expect to see the percentage of precipitation that falls as rain instead of snow to increase significantly (Mote, et al., 2014). Precipitation arriving as rain instead of snow may contribute to increased frequency and magnitude of high flow events, decreased summertime snowmelt run-off, and reduced recharge to groundwater aquifers.

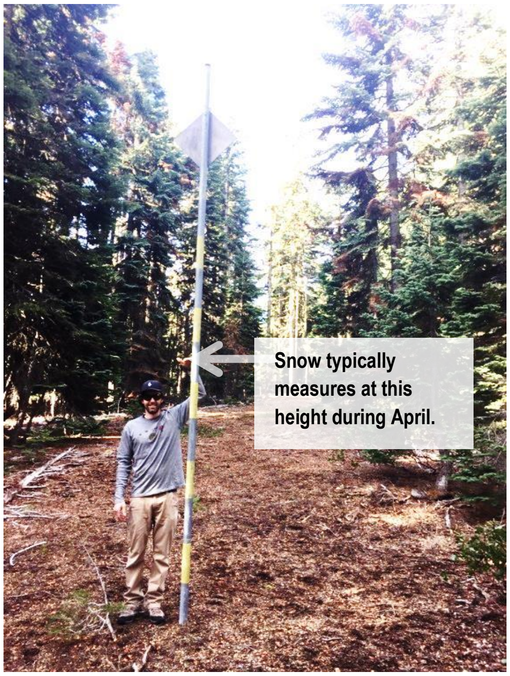
The state needs a monitoring network that is designed to capture data necessary to observe and quantify these shifts and changes. These data can provide water users and planners with the information needed to adapt and build resiliency within our water management systems.

Changes in snowpack over time (Hamlet, et al., 2013)



Recommended Monitoring Actions

- Identify basins susceptible to changing flow regimes (e.g., basins that receive a significant percentage of precipitation as snow) and establish gages to quantify the rate of change in the magnitude, frequency, duration, and timing of streamflow.
- Identify groundwater systems with areas of recharge within the rain-snow transition zone; monitor groundwater level responses to climatic impacts.
- Work with the USGS and other partners to support long-term, natural streamflow monitoring stations that have previously been used to assess climate impacts on water supplies (e.g., USGS Hydro-Climatic Data Network stations, Geospatial Attributes of Gages for Evaluating Streamflow stations).



Watermaster Travis Kelly at Mt. Ashland Ski Bowl Road Snow Course Site (April 1, 2015)

EXTREME EVENTS

FLOODS

Floods are common and widespread natural hazards in Oregon and increasing occurrences of floods are anticipated due to a changing climate (Mote, 2013). Changing land-use patterns, a growing population, and the occurrence of wildfires also contribute to the increasing impacts of floods. In Oregon, flooding generally occurs due to extreme precipitation events, rapid snowmelt, or rain-on-snow precipitation events. In the next few decades, extreme precipitation events may increase, but exact locations cannot be predicted with certainty.

Oregon Christmas flood of 1964

Gages that accurately capture high flow events help planners and engineers effectively plan for floods. However, not all stream gages accurately capture flood data. In some cases, the stream comes out of bank and the flow by-passes the gage. In other cases, there is not suitable cross-section in which to measure high flows. The Department needs more gages that effectively monitor floods and accurately capture high flow data. Such gages are used in the Department's Peak Flow Estimation Program and in real-time emergency response tools such as the Rapid Assessment of Flooding Tool (RAFT). RAFT is an interactive, near real-time tool developed by the Oregon Silver Jackets team that characterizes the severity of forecast flooding. Gages used for monitoring floods also play a key role in statistical flood frequency analysis (i.e., the frequency and impact of 10-year, 100-year, or 1,000-year floods). Combined with the Federal Emergency Management Agency (FEMA) floodplain maps, these gages can help communities respond to flood events in real time.

Recommended Monitoring Actions

- Identify gages that measure natural peak flows contained within channel and can be measured. Increase the number of high flow measurements or relocate these gages.
- Upgrade gages in flood-prone areas to transmit data in real-time for flood forecasting and early warning systems. Work with other state agencies and municipalities to identify at-risk areas.
- Identify watersheds within the RAFT program that would benefit from additional gages and/or additional measurements.
- Deploy temporary gages for real-time monitoring of high flow events.

DROUGHT

Drought conditions can result from low winter snowpack, a lack of precipitation, and warm temperatures. Oregon has a history of frequent, single-year droughts, particularly on the east side of the state. In 2015, some parts of Oregon were in year four of a multi-year drought, breaking historic records for the lowest observed snowpack and high summer temperatures. This provided water managers a glimpse into potential future water conditions in Oregon. Improved monitoring for low streamflows and groundwater levels is critical for both drought management and resiliency planning.

Stream gage on Fifteenmile Creek measuring 0.00 cfs. August 24, 2015

Water supply forecasts, such as those developed by the NRCS and the Northwest River Forecast Center, rely on stream gage data from rivers throughout the state. However, not all gages accurately capture low-flow events. In some cases, the stream should have an engineered control structure in place, such as a v-notch weir to focus flow so that it can be measured. Accurate low-flow measurements help to track water supplies for real-time distribution and allow for trend analysis and prediction of future low-flow events. Gages useful for tracking drought include those used to distribute water during low-flow periods (e.g., summer and fall), gages with high-quality records associated with the lower end of the rating curves, and gages used by other regulatory agencies that compute low-flow statistics.

Recommended Monitoring Actions

- Establish streamflow gages in locations that are vulnerable to low-flow conditions, to help with water supply forecasting.
- Establish water-level gages or inflow and outflow gages on reservoirs that provide water supplies or instream releases and that are also susceptible to short-term drought.
- Identify gages currently used for low-flow distribution and drought statistics; upgrade to near real-time, as needed.

WILDFIRE CONDITIONS

With recent fires in the Pacific Northwest, especially those of intense severity, expect to see extreme flash flooding conditions and debris flows during the fall and winter months following these fires. Other potential effects from wildfires include erosion and rapid run-off of precipitation due to decreased soil porosity. Watersheds under burned conditions may see the rate of streamflow increase by 10-100 times or more, compared to previously recorded high flows (Neary, 2003).

Recommended Monitoring Action

- Place traditional streamflow gages or rapid deployment gages in recently burned watersheds to track and send alerts regarding potential flash flooding and debris flows.

GROUNDWATER PROTECTION

GROUNDWATER LEVEL TRENDS

Monitoring groundwater levels provides valuable scientific data for hydrogeologic studies and informs the Department's decision-making with regard to permitting and conjunctive water management. The Department has a need for additional groundwater data and basin studies to better understand the capacity, location, and extent of Oregon's aquifers. These studies are also useful for assessing groundwater availability and quantifying surface water/ groundwater interactions.

Karl Wozniak and Aurora Bouchier, OWRD staff, near City of Sublimity, 2014

Recommended Monitoring Actions

- Construct dedicated observation wells in key aquifers around Oregon to expand and improve long-term groundwater level data collection; locate wells in areas of high groundwater demand, hydraulic connection between aquifers and streams, and groundwater recharge locations.
- Install data logging equipment in key observation wells to expand the continuous groundwater level data collection network.
- Estimate annual aquifer recharge rates for basins in Oregon, and compare aquifer recharge to aquifer discharge (via pumping wells, or discharge to streams and springs).

UNDERSTANDING SURFACE WATER / GROUNDWATER INTERACTIONS

Groundwater discharges to streams, springs, and rivers throughout the year, providing critical surface water flows during the dry months of the year. Groundwater and surface water are hydraulically connected at multiple scales, with the interaction controlled primarily by the geologic framework of the basin. Streams often gain flow from groundwater, but in some cases streams lose water into the aquifer. These exchanges can reverse seasonally or more frequently depending on the basin. Both groundwater level and stream discharge monitoring help Department scientists understand and quantify the stream-aquifer interaction. Oregon manages surface water and groundwater conjunctively, so a clear understanding of stream-aquifer interaction is key to protecting senior water rights. By coupling stream and aquifer monitoring in key basins, Department scientists will have a better understanding of these interactions.

Recommended Monitoring Actions

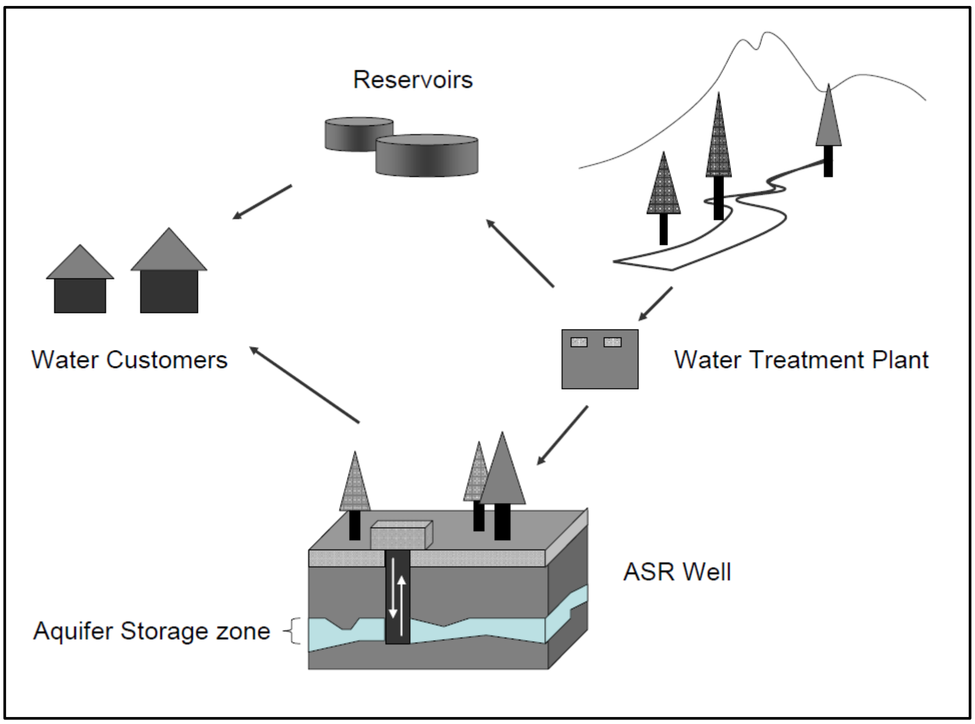
- Pair stream gages with observation wells in areas of stream-aquifer interactions.
- Target key basins for dedicated observation well installations to be monitored in conjunction with stream gages.
- Rank streams in Oregon based on the percent of annual yield contributed by groundwater. This ranking would provide a way to structure and prioritize long-term monitoring activities.

AQUIFER STORAGE AND RECOVERY & AQUIFER RECHARGE

In Oregon, the relatively wet climate during the winter months makes Aquifer Storage and Recovery (ASR) and Aquifer Recharge (AR) viable water storage techniques. During the summer dry season, water use typically peaks due to increased irrigation and municipal demand, while surface water supply is at its lowest. Many communities have surface water rights in the high flow winter months that are not fully utilized. ASR and AR can capture some of this flow and store it in aquifers to supplement dry season water supplies (Woody, 2007).

Recommended Monitoring Actions

- Construct dedicated observation wells in key basalt aquifers around Oregon to expand and improve long-term groundwater level data collection. Target wells in areas of potential ASR and AR projects with nearby surface water supplies.
- Expand continuous groundwater level data collection in key observation wells.
- Work with local water users to conduct ASR and AR feasibility studies for specific projects and water needs.



ASR system illustration. (Woody, 2007)

WATER MANAGEMENT

IMPROVE EFFECTIVENESS OF DISTRIBUTION AND REGULATION

The Department's watermaster corps is responsible for enforcing Oregon water laws in the field. In order to make effective and timely decisions, including calls for regulation of water, field staff need access to data that are accurate and up-to-date.

OWRD Watermaster Nikki Hendricks

Recommended Monitoring Action

- Place gages in locations that will help distribute water and validate regulation calls quickly. In particular, select reaches where regulation takes place frequently. Optimal sites may include areas near large water withdrawals or at specific locations named in water rights.

PREDICTING THE RESPONSE OF THE HYDROLOGIC SYSTEM TO DIVERSION / APPROPRIATION

Effective modeling can help determine the response of the hydrologic system to groundwater pumping and surface water diversions. The Deschutes Basin model, for example, developed in partnership with the USGS, demonstrates the effects of groundwater pumping on other wells in the system and also on streamflows. The sophisticated models used by the Department and its partners show how varying well depths and distances can affect other water users, while also affecting groundwater travel time and water quality.

Recommended Monitoring Actions

- Establish observation wells and stream gages in areas where groundwater basin studies will take place.
- Establish observation wells where the volume of requests for groundwater permits is high, and the number of recent groundwater-level measurements is low.

WATER AVAILABILITY

During the 1989 – 1991 biennium, the Department began to develop a Water Availability Program. The program uses computerized hydrologic models that include streamflow and run-off measurements to characterize the timing and volume of streamflow throughout the basin. This model is used by Department staff to determine the availability of water when conducting evaluations of new water use applications.

Recommended Monitoring Actions

- Establish natural flow stream gages in areas likely to see an increase in water development in the near future to adequately capture before and after conditions.
- Establish gages above diversions and impoundments in major streams (i.e., measure natural streamflow) throughout the state.
- Establish evapotranspiration measurements to improve water availability consumptive use estimates.

- Improve the resolution of the water availability model by establishing gages in regions of the state where stream gage density needs to be increased.

WATER USE DATA

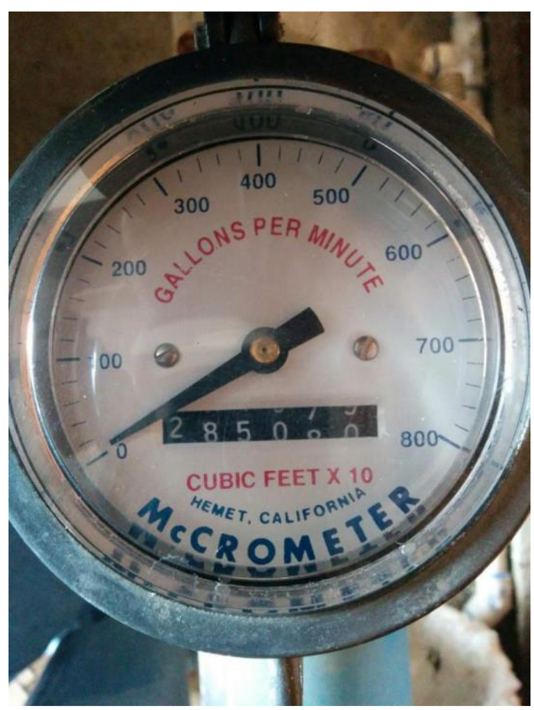
Water use information is critical for timely water management decisions, water resources planning, and hydrologic analyses. These data are often used to determine sustainable groundwater withdrawals or basin water budgets. Water use data differ from stream gage data collected at diversions in that they are self-reported by water users on a monthly basis. Totalizing flowmeters are typically installed to capture water use information at diversions or wells.

Water use reporting is required for approximately 23 percent of water rights in Oregon. Governmental entities, such as municipalities and irrigation districts, are required to track and report water use data. Since the late 1980's, some water permits have been conditioned to report monthly water use information annually to the Department. This Monitoring Strategy seeks to build upon already existing investments in the Water Use Reporting Program.

In 2000, the Water Resources Commission approved a strategic plan for improving water management statewide. The Plan focuses on measurement of diversions with the greatest impact on streamflows in areas with the greatest needs for fish. The Water Resources Department developed a statewide inventory of approximately 2,300 "significant diversions" within 300 high priority watersheds across the state. This represents about 10 percent of all the diversions in these watersheds, but accounts for about 50 percent of all water diverted in the state.

Recommended Monitoring Actions

- Coordinate the Water Use Reporting and Significant Points of Diversion programs.
- Establish quality assurance procedures to verify the accuracy of water use data.
- Monitor and report surface water diversions in high priority watersheds.
- Establish a water use reporting requirement for irrigation wells in declining or critical groundwater areas.
- Integrate the Water Use Reporting program with quasi-real-time water management.
- Utilize satellite-based remote sensing imagery to estimate consumptive use on irrigated lands.
- Collect groundwater use data from observation wells that are actively pumped.



Inline Totalizing Flow Meter

DAM SAFETY

Willow Creek Dam above the City of Heppner

Oregon's dam safety program pertains to dams that are taller than 10 feet and that hold more than 9.2 acre-feet of water. The program assigns hazard ratings, based on the density of population and property located below the dam. The program also assesses whether each dam is in satisfactory, fair, poor, or unsatisfactory condition. Water managers monitor the condition of local dams to guard against dam failures and downstream loss of life and property. Dam designs must include methods for determining if the dam is operating properly, and may include monitoring reservoir water levels to ensure the safe operation of a storage project. Regular inspections, coupled with monitoring capability and early warning systems, are critical to public safety and the success of Oregon's Dam Safety Program.

Recommended Monitoring Action

- Place gages to appropriately serve as early warning systems for high flow events that could indicate dam failures. Prioritize high hazard dams that have been evaluated as unsafe.

INSTREAM NEEDS

CHARACTERIZING INSTREAM NEEDS

In 1987, the Oregon Legislature recognized the protection of water instream as a beneficial use. The Water Resources Commission and the Department were directed to hold water in trust for recreation, pollution abatement, navigation, and the maintenance and enhancement of fish and wildlife populations and their habitats. To meet this directive, Department hydrologists must quantify the amount of instream flows needed to meet each beneficial use. Quantifying instream flow needs requires an understanding of the magnitude, frequency, duration, timing, and rate of change of streamflow.

Recommended Monitoring Actions

- Identify basins with sensitive, threatened, and endangered species (e.g., coastal tributaries) and install monitoring equipment to help characterize the suite of flows through these basins.
- Collaborate with other state agencies and watershed councils to monitor streamflow in order to support restoration and conservation activities.

Coho Salmon, Eagle Creek

PROTECTING A SUITE OF INSTREAM FLOWS

Instream water rights are enforced based upon priority date similar to consumptive water rights. There are a variety of tools available to protect water instream, from issuing instream water rights and designating scenic waterways, to authorizing instream transfers, and conditioning new permits. New instream protections often include some type of monitoring requirement.

Recommended Monitoring Actions

- Increase the number of stream gages with telemetry (real-time monitoring) in reaches with instream water rights.
- Increase the number of gages in streams where water has been transferred to instream water rights.
- Ensure there is a stream gage located at the mouth of each state scenic waterway.

WATER SUPPLY

MEETING FUTURE WATER DEMANDS

Oregon's water challenges are expected to intensify over time, driven by increases in population, changes in climate, and shifts in land use, and economic conditions. These drivers will affect water demands and water management practices across the state. In 2015, Oregon updated its water demand projections, which show a potential increase in total consumptive water demand by up to 15 percent before the year 2050 (OWRD, 2015). Both surface water and groundwater supplies will need to be monitored carefully to prevent further depletion of limited water supplies.

Irrigation in Central Oregon

In areas where surface water is fully allocated, groundwater is becoming a commonly used new source of supply. In a natural groundwater system, recharge is equal to discharge, with the net recharge equal to zero. In a groundwater system with pumping, understanding the balance between recharge and discharge is important for responsible management of the resource.

Recommended Monitoring Actions

- Establish stream gages and monitoring wells in watersheds with projected increased demand in locations that allow for tracking of the entire water distribution network.
- Employ the Department's Water Use Reporting Program to track demand over time.
- Use telemetry in wells to monitor actual groundwater use in each basin.

FORECASTING SEASONAL WATER SUPPLY

Gages that provide key information about streamflow patterns are crucial for accurately characterizing water supplies. Spring and summer forecasts utilize stream gage data from earlier in the year to predict the likely median streamflow at a site. These forecasts are based on historic streamflows, snowpack amounts, groundwater levels, and climate data. Gages that can be used to provide information for water supply forecasting include gages with a minimum of 20 to 30 years of record and gages that monitor natural streamflow.

Recommended Monitoring Actions

- Ensure communities in every basin have access to natural streamflow data from long-term, high-elevation gages, mid-level snow survey sites, and baseline groundwater levels.
- Participate with federal partners in the Jet Propulsion Laboratory's "Airborne Snow Observatory" (ASO) Program. ASO is a LiDAR-based system used to quantify snowpack conditions which will provide complete, accurate real-time water supply data for water management.

PARTNERING WITH OTHER AGENCIES

The Department partners with public and private sector entities to monitor and share data about Oregon's streams and aquifers. These partnerships help leverage limited state resources and serve as conduits for communication. Cooperative gages and wells have been identified by state and federal partners as useful for meeting various legal obligations and institutional needs.

DEVELOPING FLOW PRESCRIPTIONS

The state of science on instream flow needs has evolved greatly since the establishment of Oregon's Instream Water Rights Act in 1987. Although establishing new instream water rights is an effective strategy for protecting water instream, the state has other tools and options at its disposal as well. Under legislation passed in 2013, some storage projects funded through Oregon's newly created Water Supply Development Fund will be required to operate in a manner that protects diverse ecological needs. In order for both the users and the stream system to benefit, such projects will require thoughtful flow prescriptions, monitoring, and response programs.

Recommended Monitoring Action

- Work with Oregon Department of Fish and Wildlife, Department of Environmental Quality, and tribes to develop monitoring protocols in support of water supply development projects and requirements to protect seasonally varying flows.

MONITORING WATER QUALITY

Water quantity and water quality are inextricably linked. Decreased water quantity (streamflow and groundwater levels) impairs water quality; impaired water quality can have an effect on the accessibility and reliability of water supplies.

Water quality information, although generally outside of the regulatory responsibilities of the Department, plays a crucial role in water management decisions. The Department currently collects temperature data for partners who are monitoring watershed or stream health. The Department recently partnered with the Oregon Department of Environmental Quality (DEQ) to install water quality monitoring (temperature) devices at several stream gages and monitoring wells. These data are collected according to USGS standards and are publicly available through the Department's website.

Recommended Monitoring Actions

- Continue to work with DEQ to develop instrumentation deployment protocols at Department monitoring sites to support water quality monitoring programs.
- Increase the number of stream gages with reportable water temperature data to support DEQ, Oregon Department of Fish and Wildlife (ODFW), and other entities that might use the data. This includes linking the telemetered data sets with agency databases.

RESTORING AND CONSERVING HABITAT

The Oregon Watershed Enhancement Board (OWEB) funds millions of dollars of watershed restoration and conservation projects every year. Monitoring is a central component of OWEB-funded projects for project development reasons and for tracking effectiveness over time. Many local restoration and conservation partners operate long-term water quality and habitat monitoring networks in order to better understand baseline conditions and track trends in their watersheds. Baseline data, when compared to water quality or habitat standards, may trigger restoration or conservation activities. More recently, these groups have an increased interest in watershed characteristics that require continuous water quantity information. Essentially, monitoring streamflow conditions helps the state and its partners identify the most pressing restoration and conservation needs, ensures the effective use of funding, and confirms whether funding recipients have met their commitments.

Recommended Monitoring Action

- Work with OWEB to develop monitoring protocols for collecting and managing water quality and water quantity monitoring data.

Whychus Creek Watershed Restoration Project, 2011

EVALUATING THE MONITORING NETWORK

A well designed monitoring network provides accurate and reliable streamflow and groundwater level data for decision makers inside and outside the Department. This Monitoring Strategy provides a framework for evaluating the effectiveness of the Water Resources Department's current monitoring network of stream gages and observation wells.

In addition, this Monitoring Strategy identifies monitoring priorities and offers recommended actions to guide the design of the monitoring network in the future. It identifies desired site characteristics for effective monitoring of each priority and summarizes them into a succinct table format (see Table 1). This document also outlines next steps for evaluating the monitoring network. Included are a set of appendices identifying additional resources and tools that will be used for implementation.

The Department plans to evaluate current and potential monitoring sites for their effectiveness in meeting each of the priorities outlined in this Monitoring Strategy. In order to do this, however, the Department has additional work ahead. Evaluating current and potential monitoring sites starts by updating and adding site characteristics for each monitoring site in the database. Evaluating the network also means determining where there are gaps in the data and where the Department should place new monitoring sites[1].

Next steps for evaluating the monitoring network are:

1) Update and add new attributes for each monitoring site in a centralized database
2) Identify and rectify problematic sites
3) Solicit input from external partners on future monitoring locations
4) Evaluate current and potential monitoring sites
5) Determine gaps in monitoring data based on network evaluations

1) **Update and add new attributes for each monitoring site in the Department's database.** The Department has a list of about 40 different types of attributes for each of its stream gages and observation wells. Approximately 70% of these data have been filled in thus far. Department staff are working to update and populate 100% of these attributes. These attributes are primarily location related, such as latitude and longitude, county, and basin.

   One goal of the Monitoring Strategy is to capture even more precise information about Oregon's network of monitoring stations. For example, each gage record should reflect if the streamflow is natural or if there are diversions or impoundments upstream. In addition, we should note whether the site helps to characterize surface water/groundwater interactions. Refer to Table 1 to see the set of attributes associated with each monitoring priority. The Department is updating and adding these attributes to each monitoring station record in the database, improving its ability to query information.

2) **Identify and rectify problematic sites.** A number of monitoring sites have issues related to poor data quality, difficult access, or serious safety concerns. As Department staff update attributes

[1] One full-time staff member could coordinate and perform these network evaluations.

in the database, these sites will be flagged as requiring relocation, service, replacement, or removal.

Poor data quality can result when field conditions, equipment, methods, or lack of staff resources do not produce accurate or usable data. Equipment may not be properly calibrated, cleaned, or functioning, or methods may not meet Department and USGS standards. Access to monitoring sites may be physically hampered by items blocking the way such as wires, tree limbs, etc.

Some monitoring sites are in locations where new landowners may deny staff access to the site. Other sites are in remote locations surrounded by steep, slippery, or difficult terrain. Some of these sites can be accessed by all-terrain vehicles, while others can only be accessed by foot. Even locations close to urban areas can present safety concerns, with heavy traffic, dogs, vandalism, or unhealthy conditions posing serious threats.

Monitoring sites that are a cause for health or safety concerns and those yielding sub-standard data should be considered for removal or relocation within the network. Alternately, these problematic sites could be rectified by implementing different types of instrumentation and/or access.

3) **Solicit input from external partners on future monitoring locations.** The Department has a modest budget to establish additional monitoring sites. These new sites will be established first and foremost, in support of the Department's mission. However, the Department seeks input from other agencies and stakeholder groups, in areas of mutual interest. If a partner has specific monitoring needs, the Department would like to learn more. Department staff have developed a form for soliciting input on stream gage needs for outside agencies or groups (see Appendix B). This form has been used by members of the STREAM Team to provide recommendations for stream gage locations. As the Department moves forward in assessing its monitoring network, these needs will be incorporated into the process.

4) **Evaluate current and potential monitoring sites.** The Department will conduct evaluations of its monitoring network to determine whether or not monitoring sites are individually and collectively providing the data needed to support the monitoring priorities of the Department. For each monitoring site, the evaluations will determine the value of the information being collected at a particular location. In addition, the evaluations will determine the effectiveness of the network as a whole and identify areas for improvement.

5) **Determine gaps in monitoring data based on network evaluations.** Once the network evaluations and scientific studies for each monitoring priority are completed, the Department can determine where any data gaps and redundancies exist. These results will also show where there are high value monitoring sites and sites that need to be decommissioned.

TABLE 1. MONITORING PRIORITIES - SITE CHARACTERISTICS

OWRD's Surface Water and Groundwater Monitoring Priorities	Sample Monitoring Site Characteristics
Climate Change	
Tracking the immediate hydrologic effects of climate change	• Measures natural streamflow • Record is long term, year round • Data are transmitted in real-time • Located in snow-rain transition zone • Located in snow dominated or snow-and-rain dominated basin • Paired with snow level monitoring sites (i.e.; SNOTEL stations)
Tracking the long-term hydrologic effects of climate change	• Differentiates climate effects from land use trends • Record is long term, year round • Located in snow-rain transition zone • Located in snow or snow-and-rain dominated basin
Extreme Events	
Predicting and memorializing floods, debris flows, and inundation	• Serves as early warning indicator of high flows and debris • Gage rating curves provide accurate measurement of high flows • Contributes to statewide flood warning response (e.g., RAFT)
Predicting and memorializing short-term drought	• Measures flow in rain and snow dominated streams, reservoirs, and aquifers • Quantifies water supplies in drought susceptible streams and aquifers • Gage rating curves provide accurate definition of low flows
Predicting and memorializing long-term drought	• Record is long term, year round • Quantifies water supplies in in drought susceptible streams and aquifers • Measures natural streamflow and water levels
Monitoring post-wildfire conditions	• Tracks real-time streamflow in recently burned watersheds
Groundwater Protection	
Ensuring sustainable groundwater levels	• Record is long term, year round • Data are transmitted in real-time • Tracks water level in areas of groundwater recharge • Monitors water level in declining areas • Monitors water level in high demand areas without many records
Gaining a better understanding of surface water/groundwater interactions	• Installation of well is in conjunction with related stream gages • Monitors water level in basins with large annual surface water yield from groundwater
Supporting Aquifer Recharge & Aquifer Storage and Recovery	• Tracks water level in areas of current or potential ASR and AR projects, especially key basalt aquifers

Water Management	
Improving effectiveness of distribution and regulation	• Picks up timely and effective signals • Tracks points of diversion/appropriation, storage, outflows • Tracks significant points of diversion
Predicting response of the hydrologic system to diversion/appropriation	• Provides data to an existing or potential model • Fills in a geographic gap in a model • Monitors water level or streamflow in groundwater study basins
Determining water availability	• Fills in a geographic gap in the Water Availability Model • Measures natural streamflow • Measures return flow • Record is long term, year round
Supporting dam safety	• Provides early warning system for high flow events
Providing water use data	• Monitors use from surface water or groundwater diversions
Instream Needs	
Characterizing instream needs	• Identifies stream type (e.g., perennial, intermittent) • Record is long term, year round • Characterizes flow regime in stream with STE species
Protecting a suite of instream flows	• Monitors stream reach with instream water rights or instream transfer • Characterizes streamflow regime in basin with storage potential
Water Supply	
Forecasting water supply	• Measures run-off from high elevation watersheds • Measures snowpack and run-off at mid-level elevations • Measures baseline groundwater levels
Meeting future water demands	• Measures actual surface water and/or groundwater use • Tracks water use in basins with projected increased demand
Partnering with Other Agencies	
Developing flow prescriptions	• Measures streamflow variability
Monitoring water quality	• Measures water quality, in addition to temperature
Restoring and conserving habitat	• Measures floodplain connectivity and stream complexity • Documents relationship between sediment transport and streamflow • Documents relationship between habitat features and streamflow

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APPENDIX A

PROTOCOLS & PROCEDURES FOR ESTABLISHING SITES

The Department has policies and procedures in place for establishing new monitoring sites to protect archaeological and cultural resources and public and private property. These procedures include direction for obtaining property access and developing cooperative agreements. Protocols are being developed to outline specific steps the Department's staff will take in order to meet these requirements. In addition to these items, the protocols will also include agency guidelines for requesting a new gage installation or updating an existing one, equipment purchase agreements, and safety considerations for field-related work.

Archaeological and Cultural Resources Policy

The Department acknowledges the significance of archaeological, historic, and cultural resources and is committed to the protection and preservation of these resources. Oregon's State Historic Preservation Office (SHPO) within the Oregon Parks and Recreation Department (OPRD) is responsible for safeguarding and managing the state's archaeological and cultural resources. In coordination with SHPO and Oregon's federally recognized tribes, the Department established protocols for installing or maintaining gaging stations and monitoring wells. The Department has also established procedures for any inadvertent discoveries.

Property Access Agreements

Private Landowner: The Department has in place a process for obtaining Property Access Agreements, which must be signed by the property holder, and allow personnel access to private property. Activities covered include installation, operation, and maintenance, including site access for taking water level measurements. The agreement also ensures the security of the state's property, including gates and locks.

Public Landowner: The Department also has agreements with other governmental agencies for accessing public properties to establish and maintain stream gages, including taking periodic water level measurements. Such agencies include, but are not limited to, the Oregon Department of State Lands, Oregon Department of Fish and Wildlife, the U.S. Bureau of Land Management, and the U.S. Forest Service. The Department also has agreements with DSL on removal-fill permits and counties and Oregon Department of Transportation on right-of-way permits.

Gaging Station Cooperative Agreements

The Department's procedure is to establish cooperative agreements with entities interested in sharing gaging operation and maintenance responsibilities, including funding. These types of agreements outline the conditions for easements, maintenance, financial obligations, and operation of the stream gage. Sharing and use of the monitoring data is also outlined in the agreement.

APPENDIX B
SOLICITATION FOR INPUT ON STREAM GAGE NEEDS

Water Resources Department – Stream Monitoring Needs

The Department has a modest budget to establish additional streamflow measurement sites (gages). These new gages will be established first and foremost, in support of the Department's mission. However, the Department is also interested in seeking input from other agencies or stakeholder groups to potentially focus on areas of mutual interest.

If your agency or group has specific water monitoring needs in Oregon, the Department would like to know more about them. As the Department moves forward in assessing its stream monitoring network, these place-based needs will be considered as part of its decision-making process.

Contact Information	
Agency/Program	
Name/Title	
Address	
Phone Number	
Email	
Website	

1) Does your project focus on monitoring streamflow or water quality or both?

2) Is this a current monitoring project or a planned project for the future? (If a future project, please provide a date for when monitoring data would be needed.)

3) Please provide a description of the project/program and how the data would be used.

4) Describe the geographic area(s) of interest that your agency would like to monitor.

5) In addition to streamflow data, what other parameters are you interested in collecting?

6) Please provide us with any other pertinent information.

APPENDIX C
HISTORY OF WATER QUANTITY MONITORING IN OREGON

Monitoring streamflow and groundwater has always been critical to the management of the state's water resources. Although policy priorities for monitoring change over time, Oregon continues to rely on consistent monitoring to provide an accurate characterization of surface and groundwater. The Department's ability to conduct monitoring has largely been driven by the availability of resources. The extent to which the Department has met its monitoring objectives appears to be driven by four major factors: historical events driving the availability of resources; changes in agency statutes, policies, and approaches; state-wide budget availability; and local interest and financial participation.

The following narrative describes monitoring efforts by the Department over time including key events that shaped agency monitoring priorities and resources.

1900s. The initial priorities for monitoring for the state were to quantify surface water supplies, to support allocation, adjudication, and regulation. These three priorities remain fundamental to the Department's monitoring needs. In 1909, the Oregon Office of the State Engineer officially began registering water use. The State Engineer's office worked in partnership with the U.S. Geological Survey (USGS) to monitor water resources for municipalities, irrigation, and water-power works. During this decade there were 48 stream gages operating cooperatively by the state and the USGS, although the USGS exclusively performed the hydrographic work.

1910s. World War I (1914-1918) was the first time in history where a decrease in federal water resources monitoring occurred in response to international events. At the completion of the war, the USGS officially began using the State Engineer's office to conduct hydrographic work. During this time, state-level staff increased substantially. By the end of 1920, the State Engineer's office operated 85 gages cooperatively with the USGS.

1920s-30s. Severe droughts during the 1920s and 1930s focused national attention on water resources. Federal and state planning agencies recognized the need for additional hydrologic data, including climatic records, snow surveys, evaporation records, groundwater studies, and streamflow records. The federal government responded with an infusion of funding. By 1928, the State Engineer's Office was conducting snow surveys, while employing a new method of forecasting. This new forecasting approach quantified the status of water supplies for the upcoming season, allowing farmers to plant accordingly and manage stored water to supplement potential shortages.

During the 1920s and 1930s, the State Engineer's office also called for prudent use of groundwater, considering it essential to avoid aquifer depletion, unsustainable withdrawals, or excessive costs. This required accurate data to calculate estimates of sustainable yields. In 1927, the code for appropriation of underground water east of the Cascade Mountains was adopted, and by 1935, the USGS and the State Engineer's office were running a program to collect groundwater water-level measurements. A statewide, cooperative program was later born to inventory groundwater basins and to measure water levels in dedicated observation wells. State and federal agencies provided initial funding.

1940s. Although groundwater funding was diverted to the war effort during World War II, by 1946, cooperative investigations for both surface water and groundwater had resumed. A public information service began in response to 100 public inquiries on groundwater resources of the state. In response, the Department's watermaster corps was strengthened.

1950s. In the 1950s, the number of observation wells in the network rapidly increased. The Oregon Groundwater Act was passed in 1955, paving the way for the public appropriation of groundwater west of the Cascades. By 1958, 140 observation wells were being monitored and two critical groundwater areas had been designated, Cow Valley and The Dalles. Also in the 1950s, the State Water Resources Board was established to oversee water distribution across the state. By 1958, the state was monitoring streamflows at 308 gaging stations.

1960s. The year 1964 marked the beginning of state funding for assistant watermasters, who still play an important role in managing the state's stream gage network. Also in the 1960s, the observation well network had grown to around 150 wells and funds were made available to establish and maintain an observation well program. By the end of 1962, the well net had been expanded to 593 wells, a significant increase in such a short time. During the remainder of the decade, the number of wells had expanded to more than 800 and requests for additional staff were made to meet the increased workload.

Basic data collection must be expanded if a sound factual basis for groundwater controls is to be obtained. Increased uses of groundwater will continue to strain the capacity of our aquifers. The state must face the need for increased funding and immediate expansion of the investigation of surface and groundwater resources. The southwestern United States is already in need of outside water supplies and is looking to the Pacific Northwest. An expanded groundwater program must be initiated by the State Engineer soon, if we are to effectively answer our total water needs in the future.

(1966-1968 State Engineer Report)

1970s. By 1970, five critical groundwater areas had been designated due to groundwater development pressures. During this time, there was a significant increase in the number of public inquiries regarding groundwater. In 1975, the Oregon Legislature created the Water Policy Review Board and merged the State Engineer's Office with the State Water Resources Board to create the Water Resources Department. The national recession of the late 1970s drove agency budgets down, resulting in the start of a long-running stream gage record processing backlog. Record low flows of 1977 and 1978 were captured by gages around the state and resulted in the 1984 nomination of 75 streams for minimum flows by the State Fish and Game Board (now Oregon Department of Fish and Wildlife).

1980s. In 1985, the Water Resources Commission was established to take over the role of the Water Policy Review Board. The Instream Water Rights Act was enacted in 1987, granting authority to the Oregon Department of Fish and Wildlife (ODFW), Department of Environmental Quality (DEQ), and Oregon Parks and Recreation Department (OPRD) to apply for instream water rights. By the 1980'stream gaging station numbers had dipped and rebounded to around 275 gaging stations.

In 1988, the Commission adopted administrative rules governing groundwater interference with surface water, known commonly as the Division 9 rules. These rules guide the Department in making determinations regarding whether existing or proposed groundwater wells have the potential to cause substantial interference with a surface water supply and provides authority for controlling such interference. The Governor's Watershed Enhancement Board, established in 1989, granted funds to watershed restoration and enhancement activities across the state and was operated out of the Water Resources Department.

In the 1980s, the observation well net was reduced by 50 percent to eliminate unnecessary duplication of data and provide adequate time for the geophysical well logging program. Data from this program were used for groundwater management. Data sheets were completed and entered for the roughly 400 observation wells.

1990s. By 1990, overhaul of the statewide observation well network was about halfway complete. The existing wells on the net had been thoroughly screened to ensure the adequacy of each well for this purpose. The next step was to add monitoring sites where coverage was inadequate. Approximately 335 wells across the state were included as part of the state observation well network. That number gradually increased to about 350 observation wells by the year 2001. It was during this time that the Department developed key performance measures to track the network's growth.

Starting in 1990, the Department initiated the Water Availability program, developing an analytical tool for use in surface water allocation. In 1993, the Department discontinued many of its co-operative gage agreements with the USGS due to budget restrictions, bringing the total number of state-run gages to approximately 200 statewide.

Also in the 1990s, the Field Services Division organized in to five regions in order to better serve local water issues. These regions have largely determined the need and location of stream gages throughout Oregon. This also ushered in a new era of regulation with the Commission being permitted to issue civil penalties for violation of Oregon's water law. Stream gages and the careful tracking of water use became crucial to this new regulatory tool.

Significant improvements in computer systems allowed more timely tracking and comparison of stream gage data. Prior to this, all stream gage records had to be maintained on paper with computations later performed by hand. This was also the beginning of remotely accessed stream gage data.

ODFW applied for multiple instream water rights as well. During this time period many of the previously established minimum perennial streamflows were converted to instream water rights. The Department, which holds instream water rights in trust, continues to use the stream gage network to protect instream water rights today.

In 1997, the Oregon Plan for Salmon and Watersheds was adopted by the Oregon Legislature, in large part, to initiate a home-grown response to the listings of Coho and other salmon species under the federal Endangered Species Act. The Oregon Watershed Enhancement Board (OWEB) was established around this time and took over the funding role of the Governor's Watershed Enhancement Board for watershed restoration projects. Funds for monitoring to support such efforts also fall within OWEB's purview.

In 1998, the Hydrographics Section began working on a backlog reduction project to support the recently established water availability program, which required processing of approximately 500 water years of raw data.

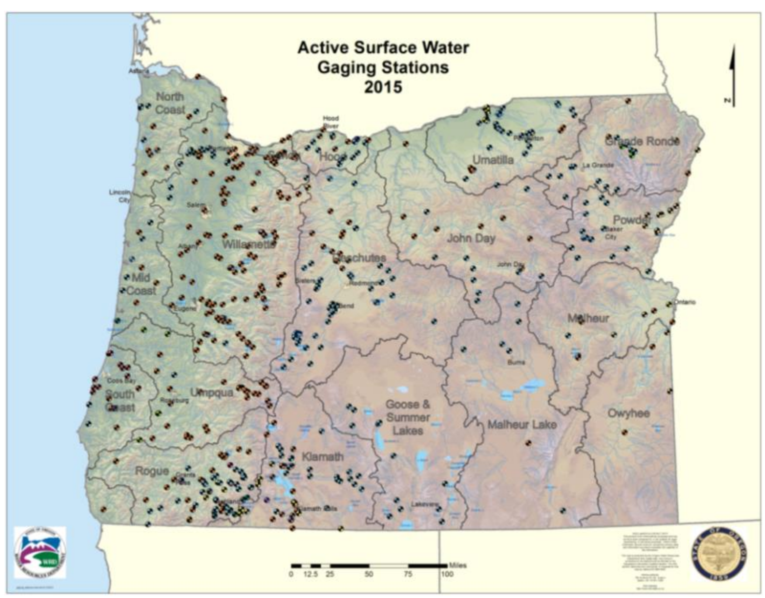
2000s. In 2002 and 2003, the Department worked with staff from the Oregon Progress Board to revise and update its key performance measures. The goal was to build a stronger link to the Department's mission. It was recognized that measuring streamflow and groundwater levels is essential to effectively managing these water resources. However, maintaining streamflow gaging stations and groundwater measurement sites is dependent on sufficient funding to operate stations and analyze and publish the data. Related key performance measures in existence today include:

> *Key Performance Measure #4* – Focused on streamflow gaging, this measure tracks the Department's progress toward increasing the number of state-operated or assisted gaging stations from the baseline year 2001. The baseline number of gaging stations is 215.
>
> *Key Performance Measure #5* – Focused on assessing groundwater resources, this measure tracks the Department's progress toward increasing the number of wells routinely monitored to assess groundwater resources from the baseline year 2001. The baseline number of wells is 350. There are challenges in maintaining the number of monitoring wells. Wells monitored by the Department are privately owned and access is commonly an issue. As property changes hands or other conditions change, some well owners have discontinued their participation in the State Observation Well Net.

The Department needs to ensure adequate budget and staff to maintain, collect, and analyze data from these important monitoring sites, and to continue providing publicly accessible data. Key to this success is an expanded network that includes dedicated sites with a long-term record.

Despite fluctuating budgets and the deep national recession of the 2000s, the number of monitoring stations has rebounded. An infusion of funding from the 2013 and 2015 Oregon Legislatures, discussed below, will help the state expand its programs and make significant progress on these key performance measures.

Present-Day Stream Gages. The Department operates more than 250 stream gages, of which about 80 percent are near real-time. The entire network shown on the accompanying map includes an additional 345 gages operated by cooperators, such as the USGS. The Department includes cooperators' gages as part of our network and utilizes the data collected at those sites in day-to-day operations and scientific studies.

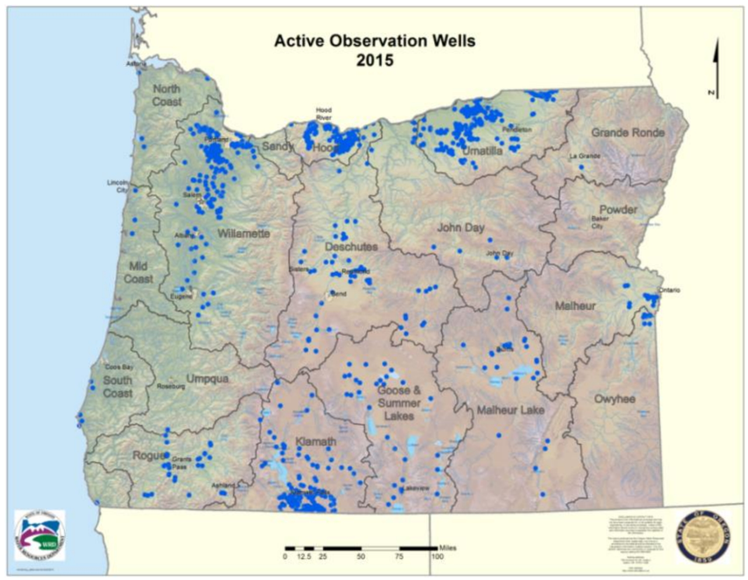


As part of the Upper Klamath Basin Comprehensive Agreement signed in 2014, the Department partnered with the

Klamath Tribes and the U.S. Fish and Wildlife Service to install several gaging stations within the Klamath River Basin. The gages will be used to monitor and assess streamflow conditions on a real-time basis in support of Tribal water rights. As of September 2015, six new gages had been installed in support of this effort.

The 2013 Oregon Legislature provided the Department with resources to install 16 new gages each biennium. This Monitoring Strategy will help ensure that will be installed in areas that provide the most benefit and data in support of our monitoring network objectives.

Present-Day Observation Wells. The Department currently has 370 state observation wells, 60 of which have continuous recorders installed. A well is considered part of the state observation well network if data are collected on a quarterly basis. However, the Department currently measures water levels in a total of about 1,100 observation wells across the state, some of which are project based wells.



The Department is actively installing new observation wells. The 2013 Oregon Legislature provided funding for new monitoring wells, groundwater studies, and staff. With this new funding, the Department has installed new monitoring wells in the Umatilla Basin, near The Dalles, Harney Valley in the Malheur Basin, and the Deschutes/Metolius area.

APPENDIX D
HYDROLOGY OF THE STATE OF OREGON

When designing a hydrological observation network, it is necessary to have as much knowledge as possible about the physical properties and the processes in the system involved (Netherlands Organization for Applied Scientific Research, 1986). Climate, hydrology, topography, and geology play a key role in understanding the interconnected water cycle of Oregon.

Precipitation. Oregon receives a majority of its precipitation in the winter. In general, Oregon has a rather mild, winter climate. The climate of the western third of Oregon is characterized by moderate temperatures, wet winters, and dry summers; about 78 percent of the annual precipitation occurs in the period October to March. The eastern two-thirds of the state, on the other hand, have greater extremes of temperature but somewhat less seasonal variation in precipitation. On the east side, about 65 percent of the precipitation occurs in the period October to March. (Phillips, 1969).

The Cascade Range, about 90 miles inland from the Pacific Ocean, lies parallel to the coastline and acts as a natural barrier to marine air masses and the prevailing westerly winds. This causes a significant statewide variation in annual rainfall. Average annual precipitation ranges from 200 inches in places in the Coast Range to less than 40 inches on the Willamette Valley floor in western Oregon and less than 10 inches in parts of north-central and south-eastern Oregon. Much of the precipitation falls as snow at altitudes above 3,500 feet, which is the approximate mean altitude of Oregon.

Precipitation does not all arrive at once, but in a series of storms or events. Each event elicits a unique combination of responses from the effected watersheds, including plant uptake, surface water runoff, and groundwater recharge.

Run-Off. Surface water runoff is relatively abundant in Oregon, but it is unevenly distributed with respect to location and timing. Major river systems drain the Coast Range, the Cascades, Klamath, John Day and Wallowa Mountains, and the terminal lake basins of the Great Basin. Each of these areas has a distinct topography and plant community, which interact with climate and geology to produce unique runoff patterns. Floods may occur every few years in the humid, western part of the state; although less frequent, floods are not unknown in the semiarid eastern region. Water shortages common to eastern Oregon can also occur in the humid western section, especially during typical dry summers. Some streams that lie almost side by side can differ markedly in their patterns of flow. Snow, and the period during which it melts, plays a major role in shaping annual hydrographs.

Recharge and Groundwater. In Oregon, most of the groundwater recharge occurs in the winter and spring months. This seasonal distribution of groundwater recharge results in a seasonal fluctuation of the water table. The magnitude of fluctuation is greatly dependent on the permeability of the underlying geologic formations. The occurrence of permeable rocks capable of absorbing and transmitting groundwater varies greatly from place to place in the state. Many of the geologic features of Oregon are of volcanic origin, but parts of the state have marine and continental sediments, metamorphic rocks, or unconsolidated deposits laid down by water, wind, or ice. The most permeable rock formations occur in the Cascade Mountains and are composed chiefly of young volcanic rocks.

They lie in a belt that receives relatively large quantities of recharge. The groundwater discharge from these rock formations create the many large springs that occur on both sides of the Cascade Mountains.

Coarse alluvial sediments were deposited along the eastern part of the Willamette River Valley by the swift streams flowing off the Cascade Mountains. These coarse-grained sediments form the high-production water bearing zones in the Willamette Valley. Slower moving streams flowing off the Coast Range deposited relatively fine-grained deposits along the western margin of the Willamette Valley. This difference in character of the alluvial sediments from one side of the Willamette Valley to the other accounts for the great difference in the availability of groundwater in these two areas.

In general, the Coast Range and Klamath Mountains are composed of extremely low-permeable rock units. Even though these areas receive large amounts of precipitation, the aquifers yield small supplies of groundwater.

Along the coast, there are many areas underlain by recent sand dune deposits. These areas absorb large quantities of water and are capable of producing large amounts of groundwater. Other parts of the coast are underlain by less-permeable marine terrace deposits which are composed of older beach deposits and which make up many of the aquifers along the southern coast.

In eastern Oregon, the central mountains are composed chiefly of relatively impermeable rock formations that are capable of yielding only small supplies of groundwater. Intermountain basins such as the Baker, Wallowa, and Grande Ronde Valleys often contain permeable rock formations and moderate natural supplies of groundwater. Much of the north-central part of the state is underlain by the Columbia River Basalt Group. These formations are of wide areal extent in both Oregon and Washington and are generally capable of yielding moderate to large supplies of groundwater. The deeper basalt aquifers do not recharge rapidly; mining this resource has led to significant declines in groundwater levels. Much of the basin and plateau areas of southeastern Oregon contain permeable rock formations, and where these formations contain water, they generally produce moderate to large amounts of groundwater.

Groundwater/Surface Water Interactions. Along with controlling rates of recharge to aquifers, the diverse geology of Oregon produce other variations in surface-water hydrology as well. For instance, the broad areas of pumice and young lava flows in the southern part of the Cascade Range (the Upper Metolius basin) have poorly developed stream systems because the highly permeable rocks at the surface readily absorb and retain rainfall. As a result, peak flows from rainstorm and snowmelt runoff are relatively low, but the discharge of groundwater through springs and seeps produces relatively large and sustained annual flows in Oregon's rivers and streams. By contrast, altered volcanic and marine rocks in parts of the Coast Range and some of the older rock formations in the Klamath and Blue Mountains have low permeability, allowing little infiltration of precipitation. Streams draining such areas respond rapidly to intense precipitation, and may recede to nearly zero during the drier months.

Between these two extremes are varying degrees of gradation. In places, surficial deposits allow a sizable amount of infiltration from moderate rates of precipitation, but reject a large part of precipitation from intense storms. This interaction among geography, geology, and climate is most evident in places where streams and groundwater directly exchange water. Groundwater/surface water interaction occurs in three basic ways: 1) streams gain water from inflow of groundwater via springs or seepage through the streambed; 2) streams lose water to groundwater by outflow through the streambed; or 3) they do both, gaining in some reaches and losing in others. Gaining streams represent locations where cooler groundwater emerges and contributes to a stable base flow, helping to sustain surface water during the summer months. Losing streams can act as a potential route of groundwater contamination, as polluted runoff enters streams that eventually percolate back into the ground. Stream reaches may seasonally shift between gaining and losing depending on the local water table and the rate and volume of precipitation and infiltration.

Vegetation. Evapotranspiration makes up a major part of the water cycle. During the rainy season, tree canopies intercept substantial amounts of water and slow the rate at which water seeps into the ground or runs off into streams. As the precipitation rates decrease and plants increase their rate of water use each summer, they can significantly influence surface and groundwater levels.

Conclusion. Together, the geology, topography, vegetation, and climate of Oregon produce a diverse system of water movement. Understanding this diversity is key to effectively managing Oregon's water resources.