# How Water Moves Through Central Oregon

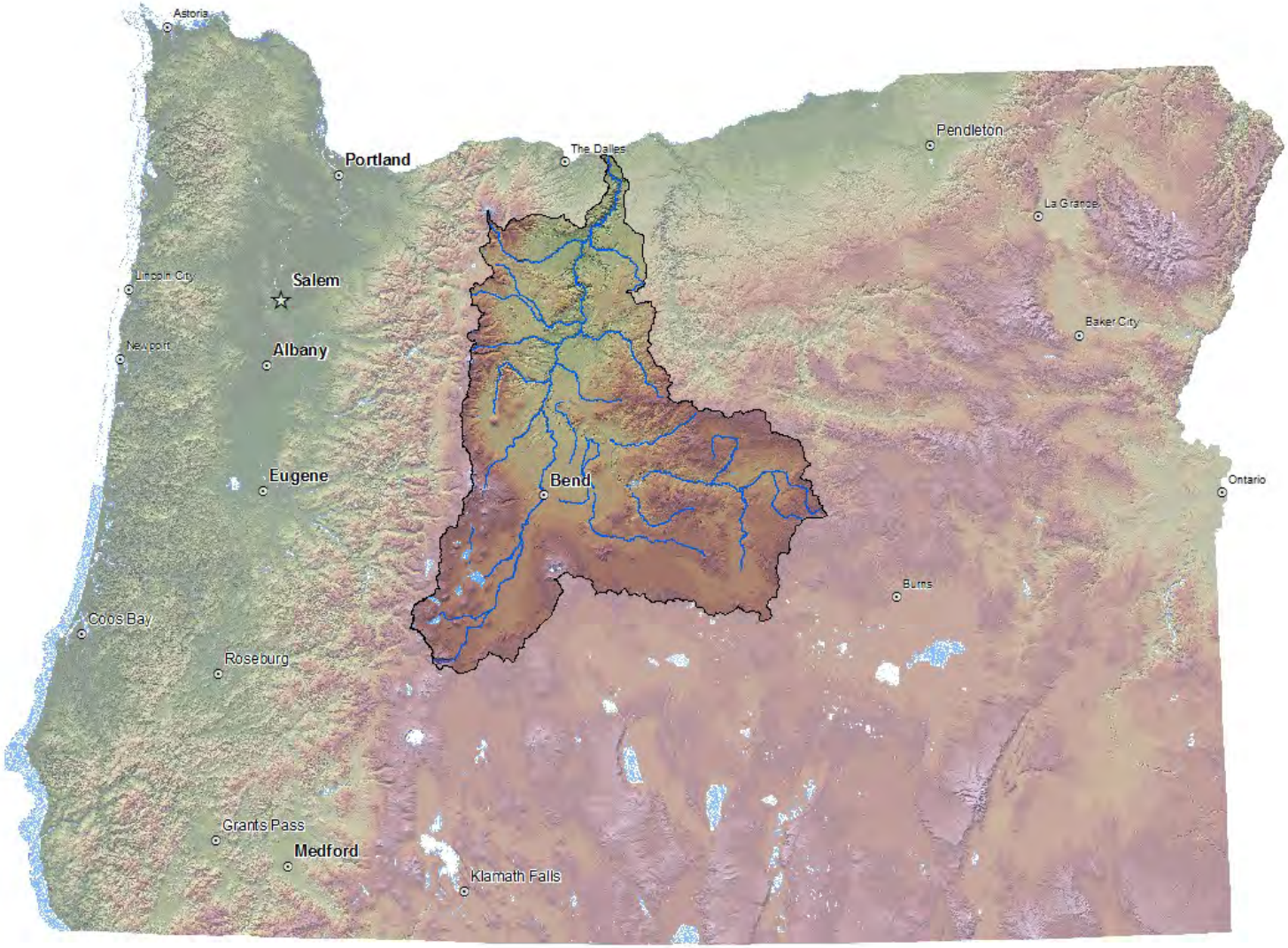
## *From Snowpack to Streams, Farms, and Faucets*

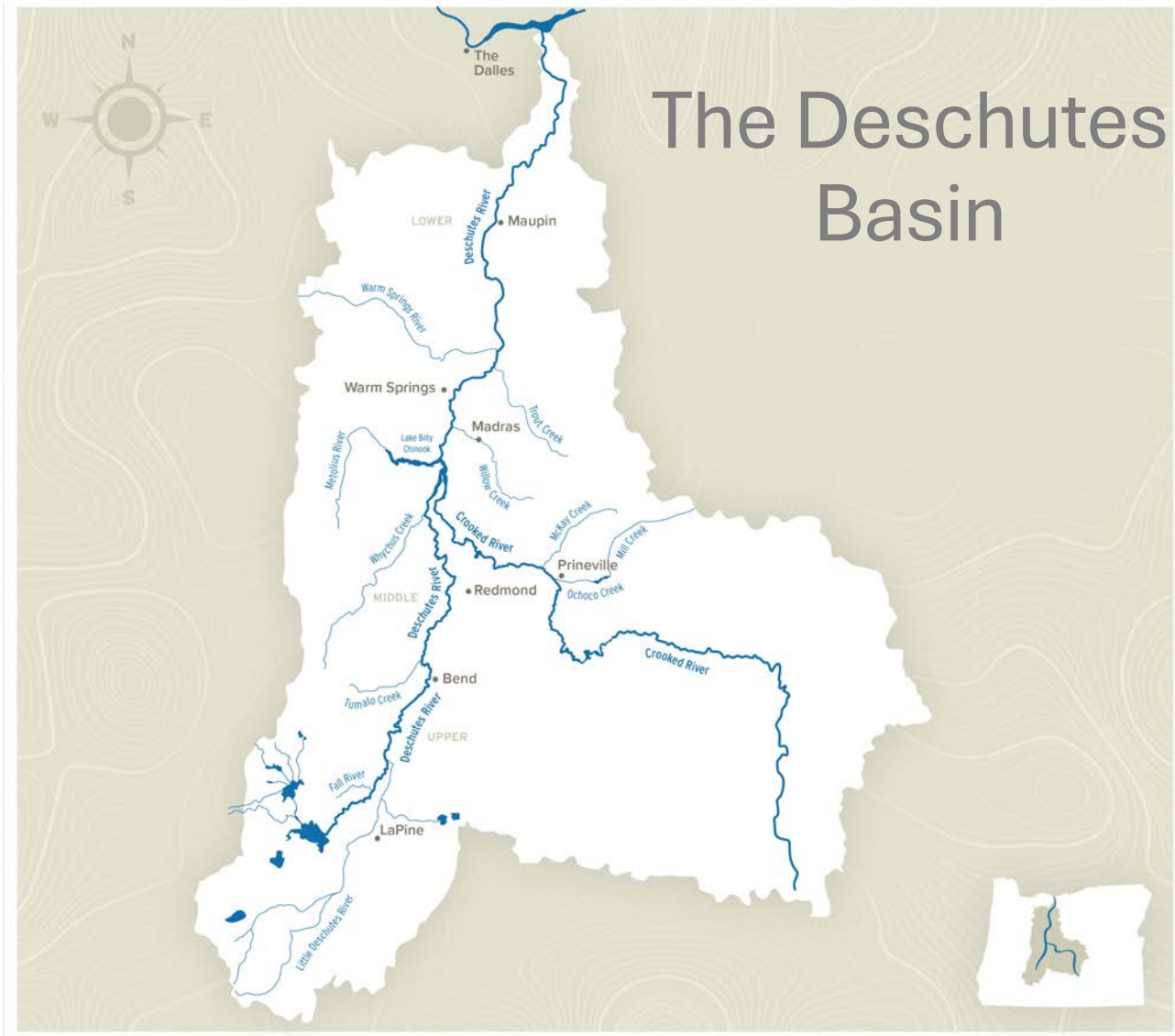
Zach Freed

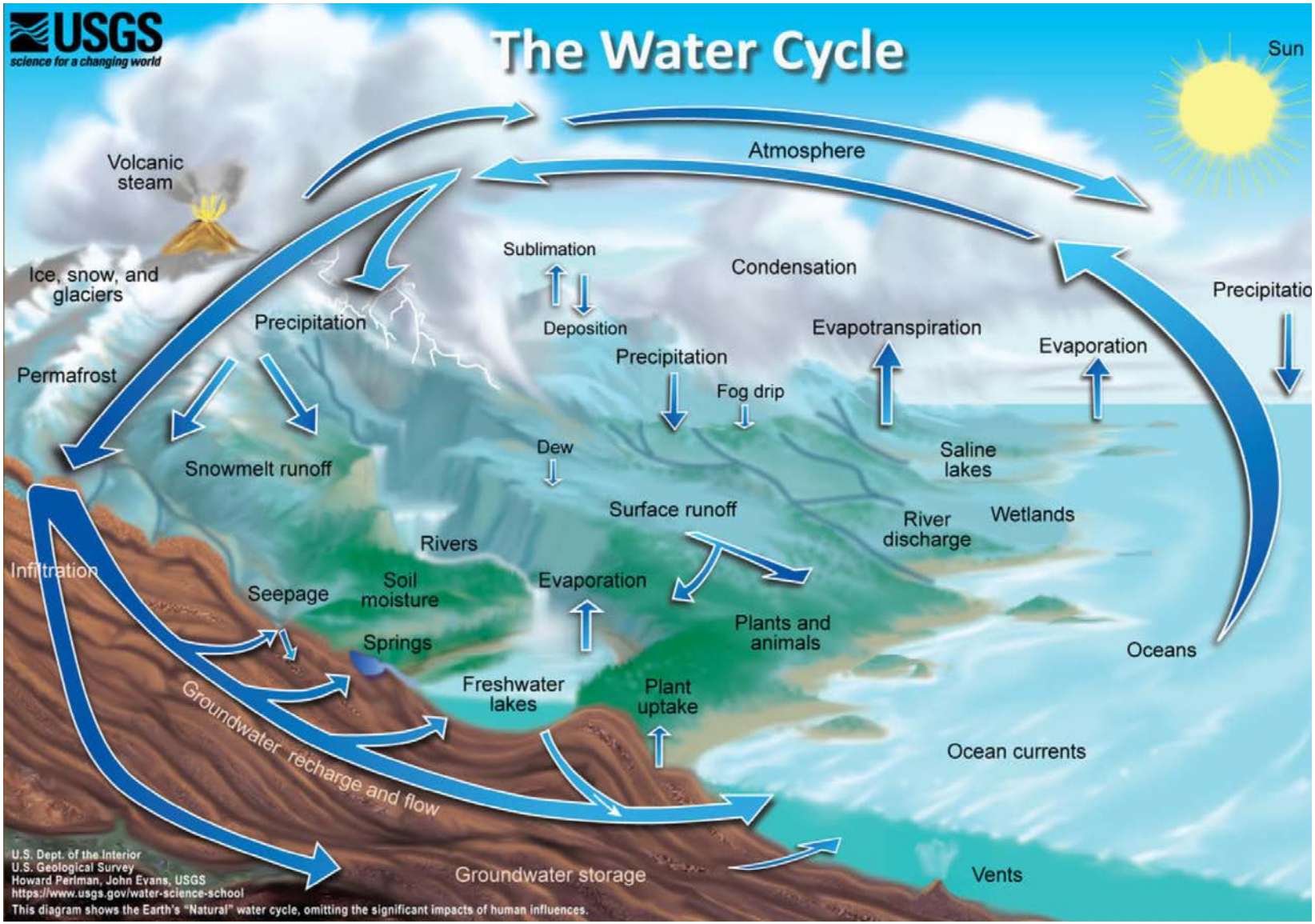
The Nature Conservancy

Lisa Seales

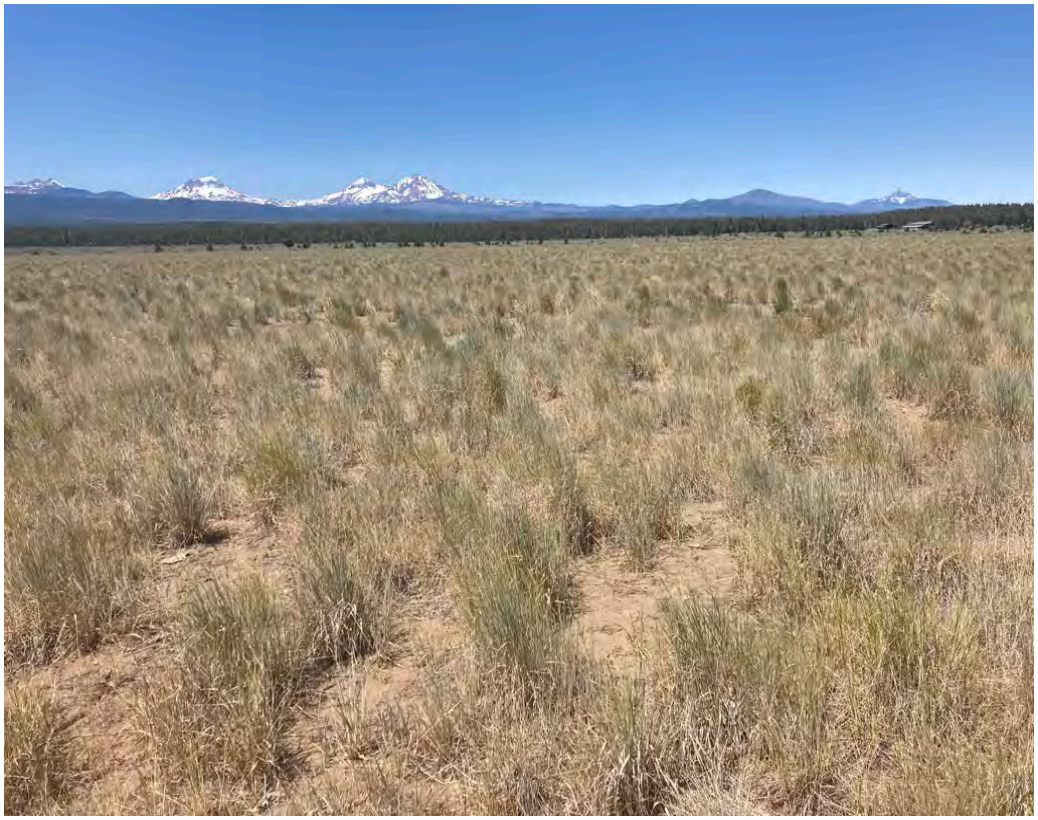
DESCHUTES RIVER CONSERVANCY


Astoria
Portland
The Dalles
Pendleton
La Grande
Lincoln City
Salem
Baker City
Newport
Albany
Eugene
Bend
Ontario
Burns
Coos Bay
Roseburg
Grants Pass
Medford
Klamath Falls

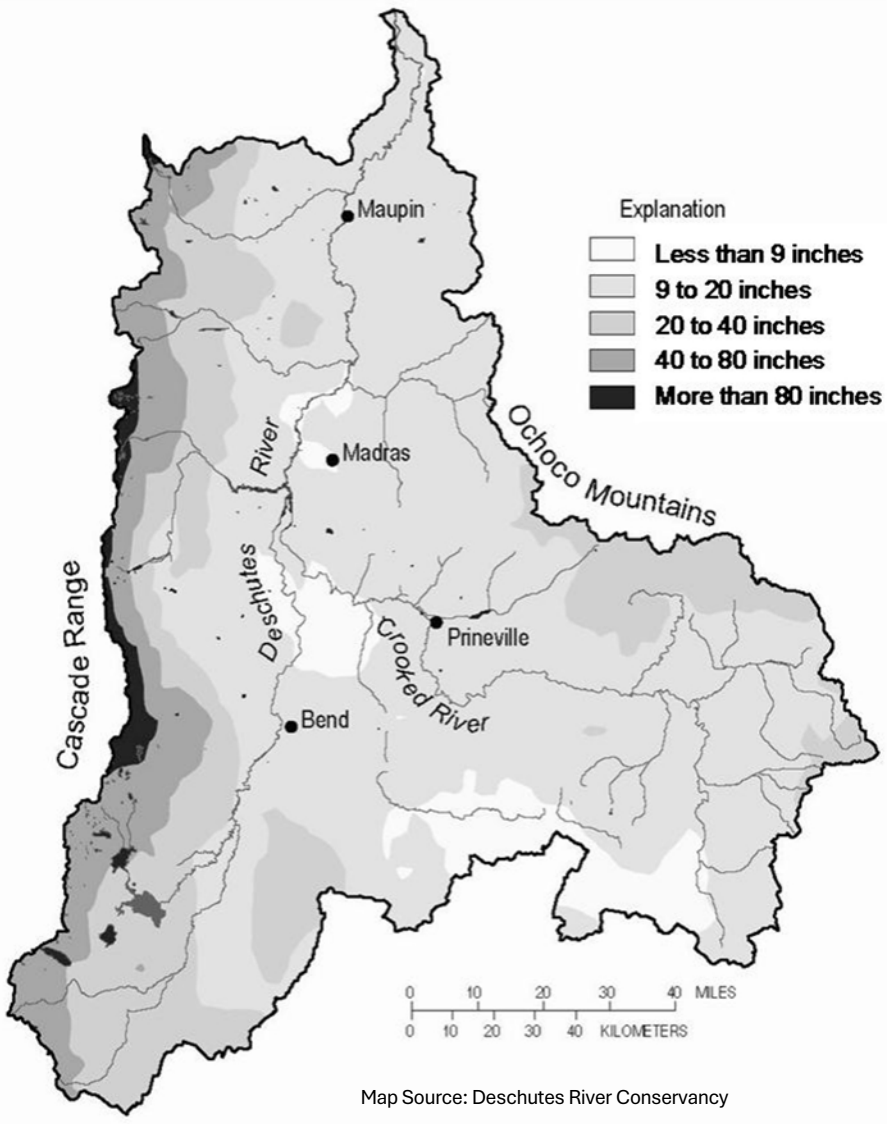

The Deschutes Basin
N
W
E
S
The Dalles
LOWER
Deschutes River
Maupin
Warm Springs River
Warm Springs
Madras
Trout Creek
Lake Billy Chinook
Metolius River
Willow Creek
Crooked River
McKay Creek
Mill Creek
Prineville
Ochoco Creek
Whychus Creek
MIDDLE
Deschutes River
Redmond
Crooked River
Bend
Tumalo Creek
Deschutes River
UPPER
Fall River
LaPine
Little Deschutes River


USGS
science for a changing world
The Water Cycle
Sun
Atmosphere
Volcanic steam
Ice, snow, and glaciers
Sublimation
Condensation
Deposition
Precipitation
Evapotranspiration
Evaporation
Precipitatio
Permafrost
Precipitation
Fog drip
Dew
Snowmelt runoff
Saline lakes
Surface runoff
River discharge
Wetlands
Rivers
Infiltration
Seepage
Soil moisture
Evaporation
Springs
Plants and animals
Oceans
Freshwater lakes
Plant uptake
Groundwater recharge and flow
Ocean currents
Groundwater storage
Vents
U.S. Dept. of the Interior
U.S. Geological Survey
Howard Perlman, John Evans, USGS
https://www.usgs.gov/water-science-school
This diagram shows the Earth's "Natural" water cycle, omitting the significant impacts of human influences.


The Source of Water

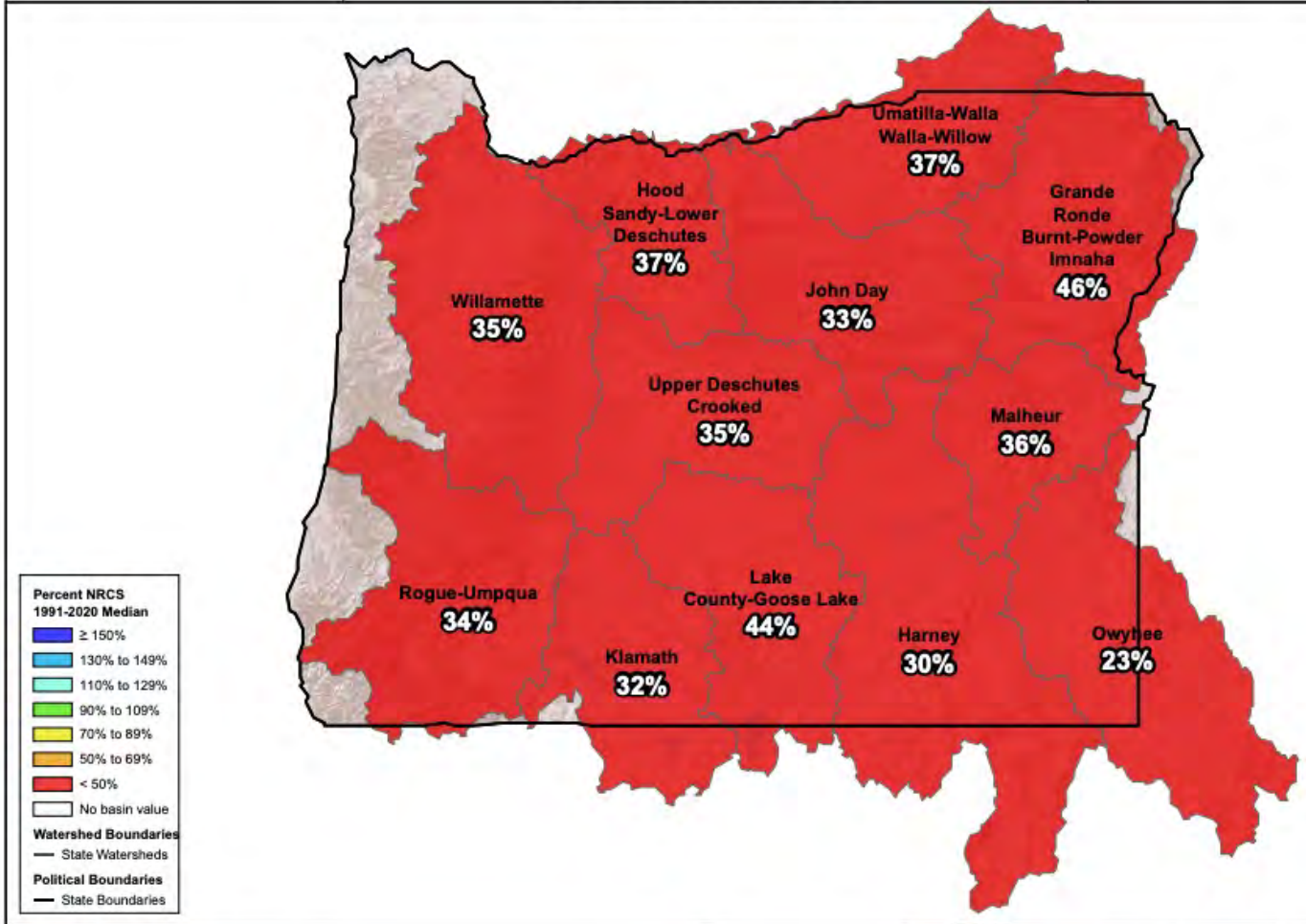


# Distribution of Precipitation




Map Source: Deschutes River Conservancy

| Snow Water Equivalent | Oregon SNOTEL<br>Percent NRCS 1991-2020 Median | February 22, 2026, end of day |
|---|---|---|

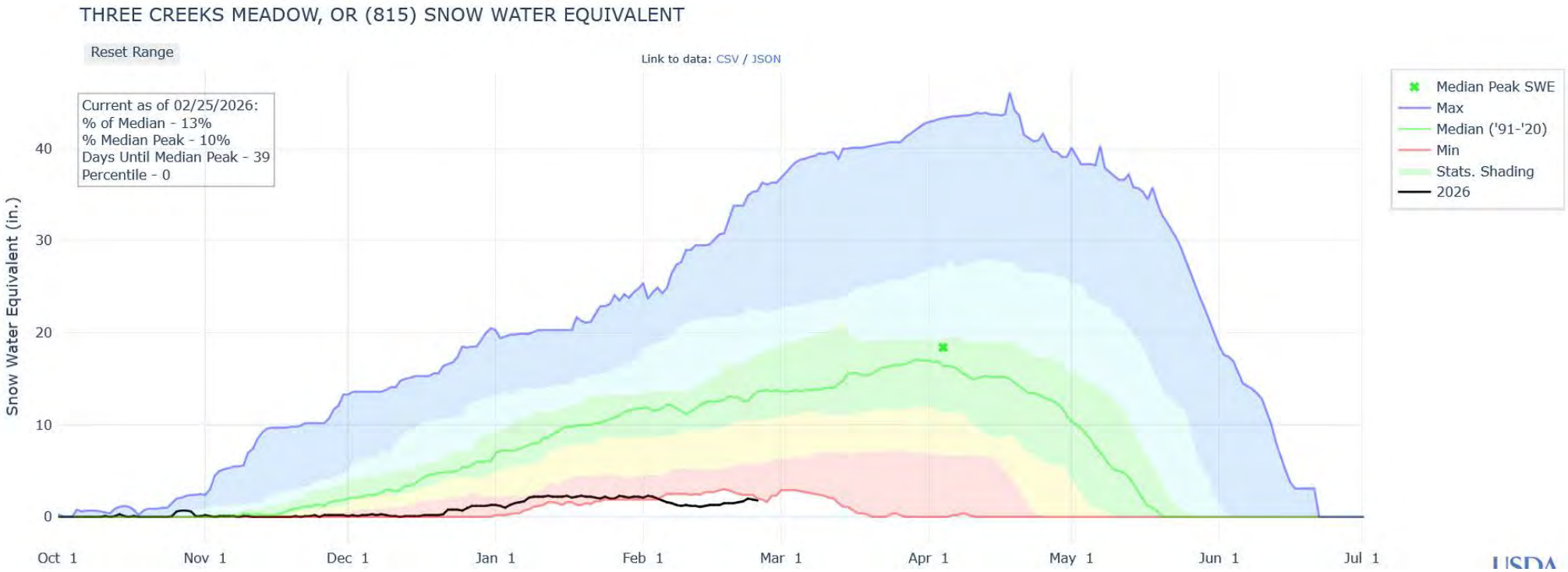



USDA Natural Resources Conservation Service
United States Department of Agriculture

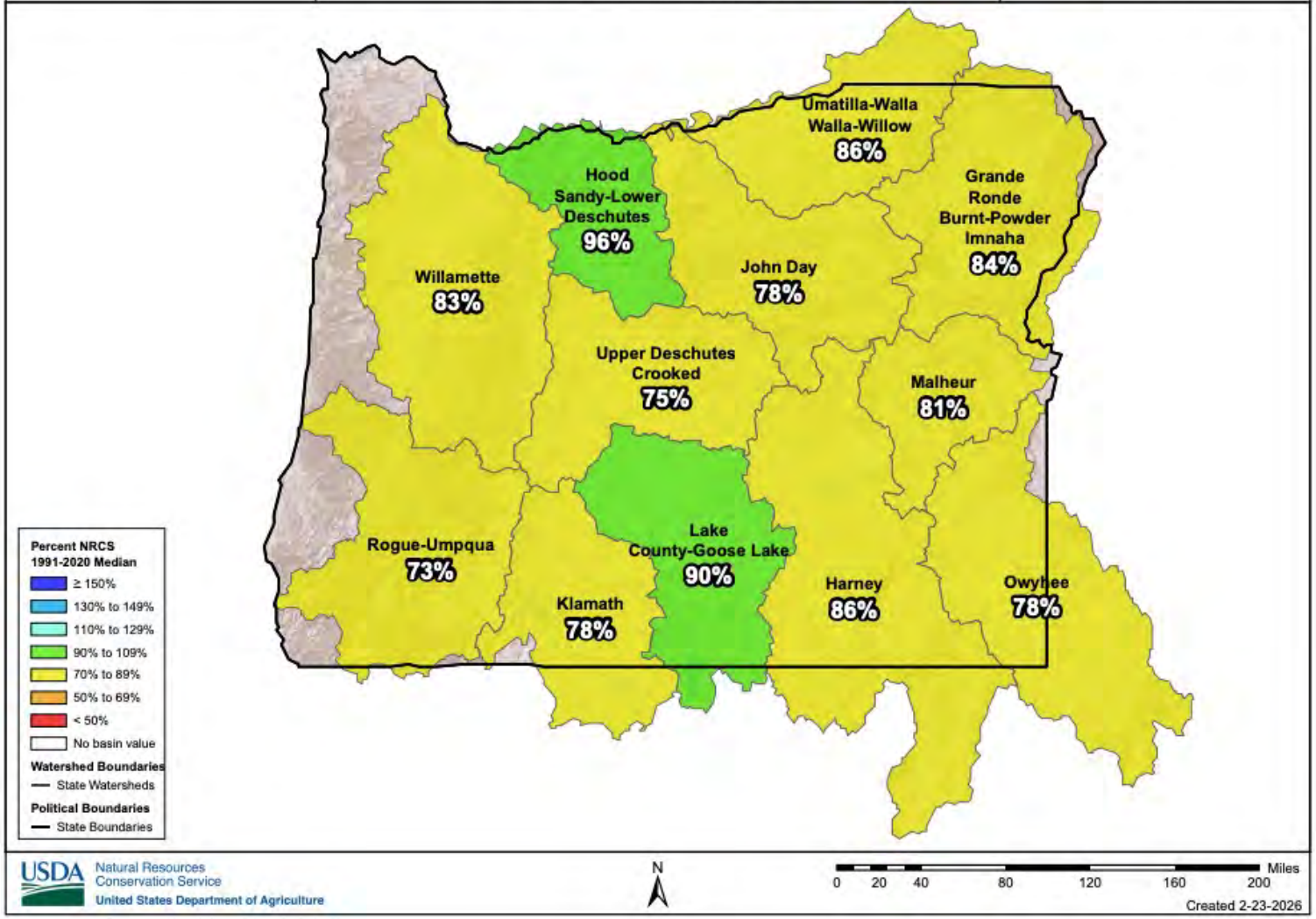
N

0 20 40 80 120 160 200 Miles

Created 2-23-2026


THREE CREEKS MEADOW, OR (815) SNOW WATER EQUIVALENT
Reset Range
Link to data: CSV / JSON
Current as of 02/25/2026:
% of Median - 13%
% Median Peak - 10%
Days Until Median Peak - 39
Percentile - 0
Median Peak SWE
Max
Median ('91-'20)
Min
Stats. Shading
2026
Snow Water Equivalent (in.)
40
30
20
10
0
Oct 1
Nov 1
Dec 1
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1
Jul 1

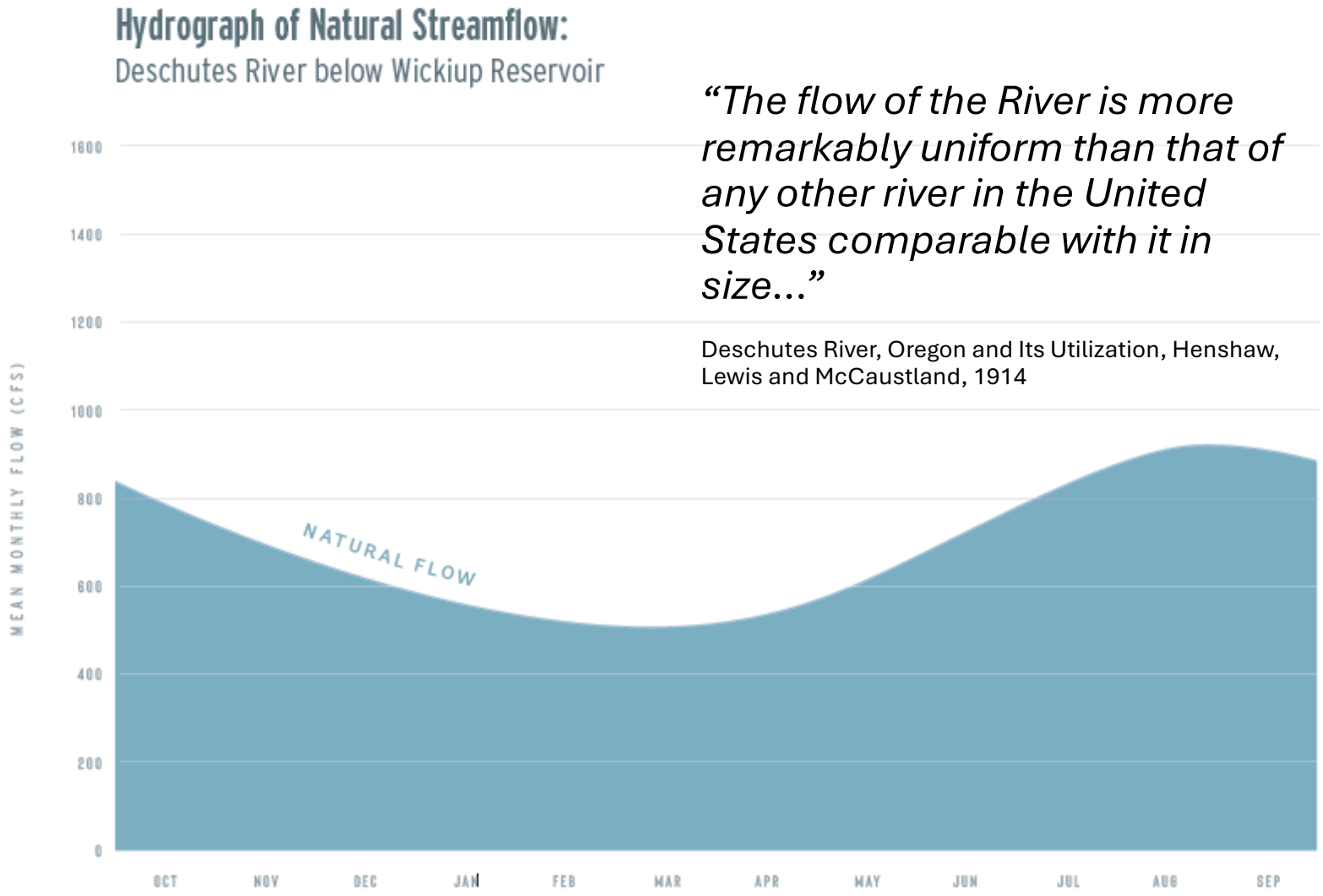
| Water Year to Date Precipitation | Oregon SNOTEL<br>Percent NRCS 1991-2020 Median | October 1, 2025 -<br>February 22, 2026 |
|---|---|---|




USDA Natural Resources Conservation Service
United States Department of Agriculture

Created 2-23-2026

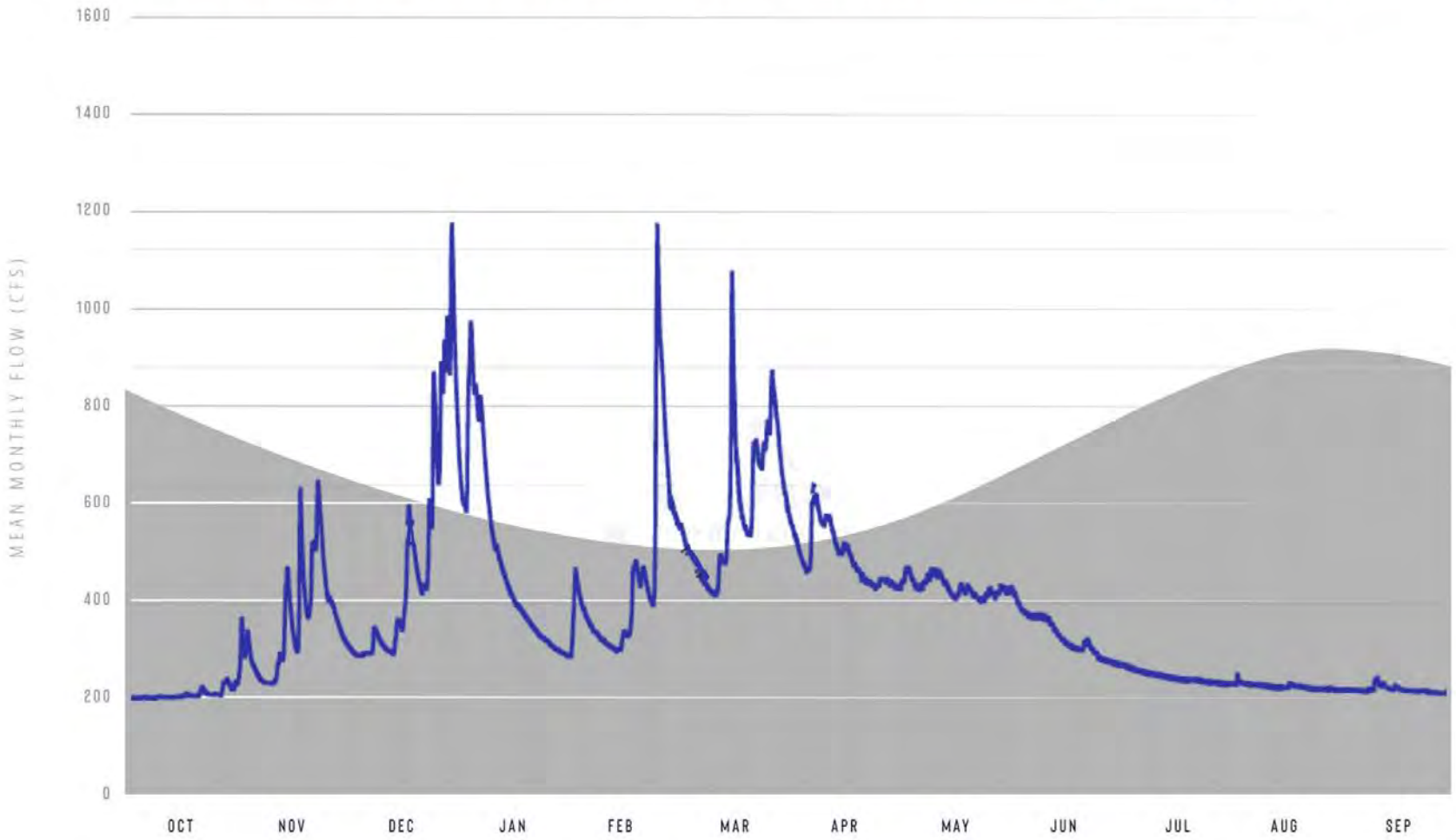
# The Pathways of Water

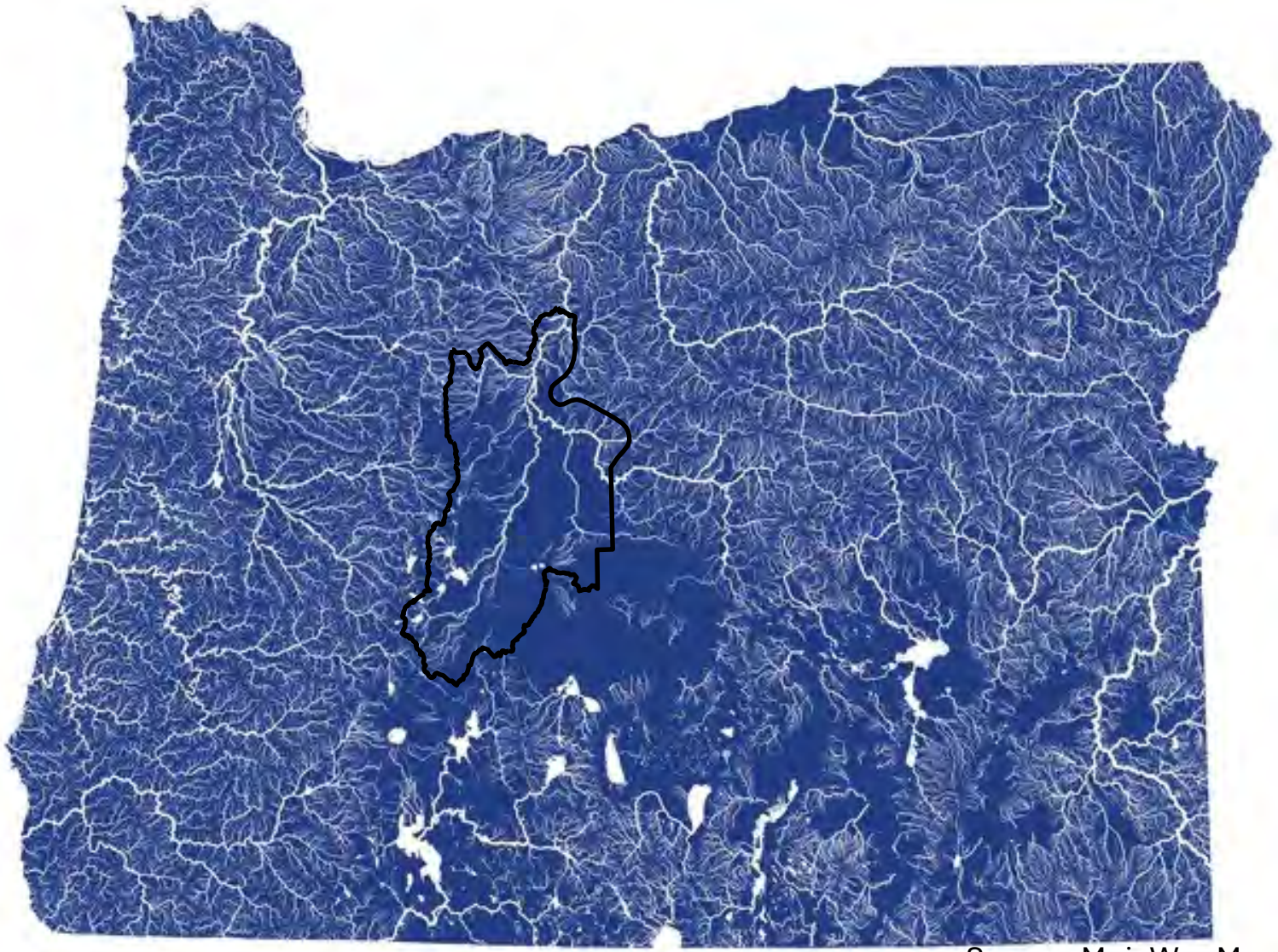



*"The flow of the River is more remarkably uniform than that of any other river in the United States comparable with it in size..."*

Deschutes River, Oregon and Its Utilization, Henshaw, Lewis and McCaustland, 1914

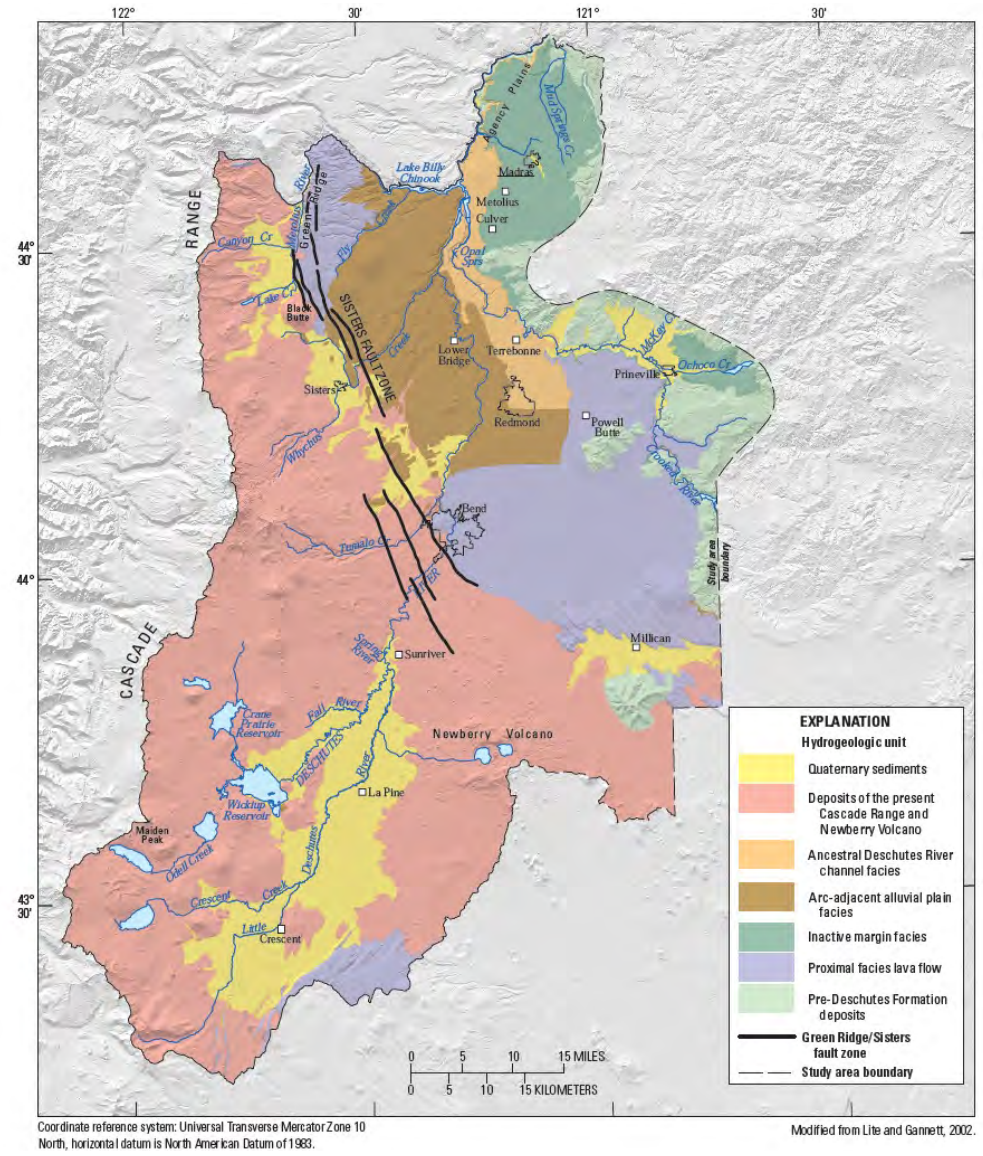
# Groundwater-Fed vs. Run-Off Driven Hydrograph:





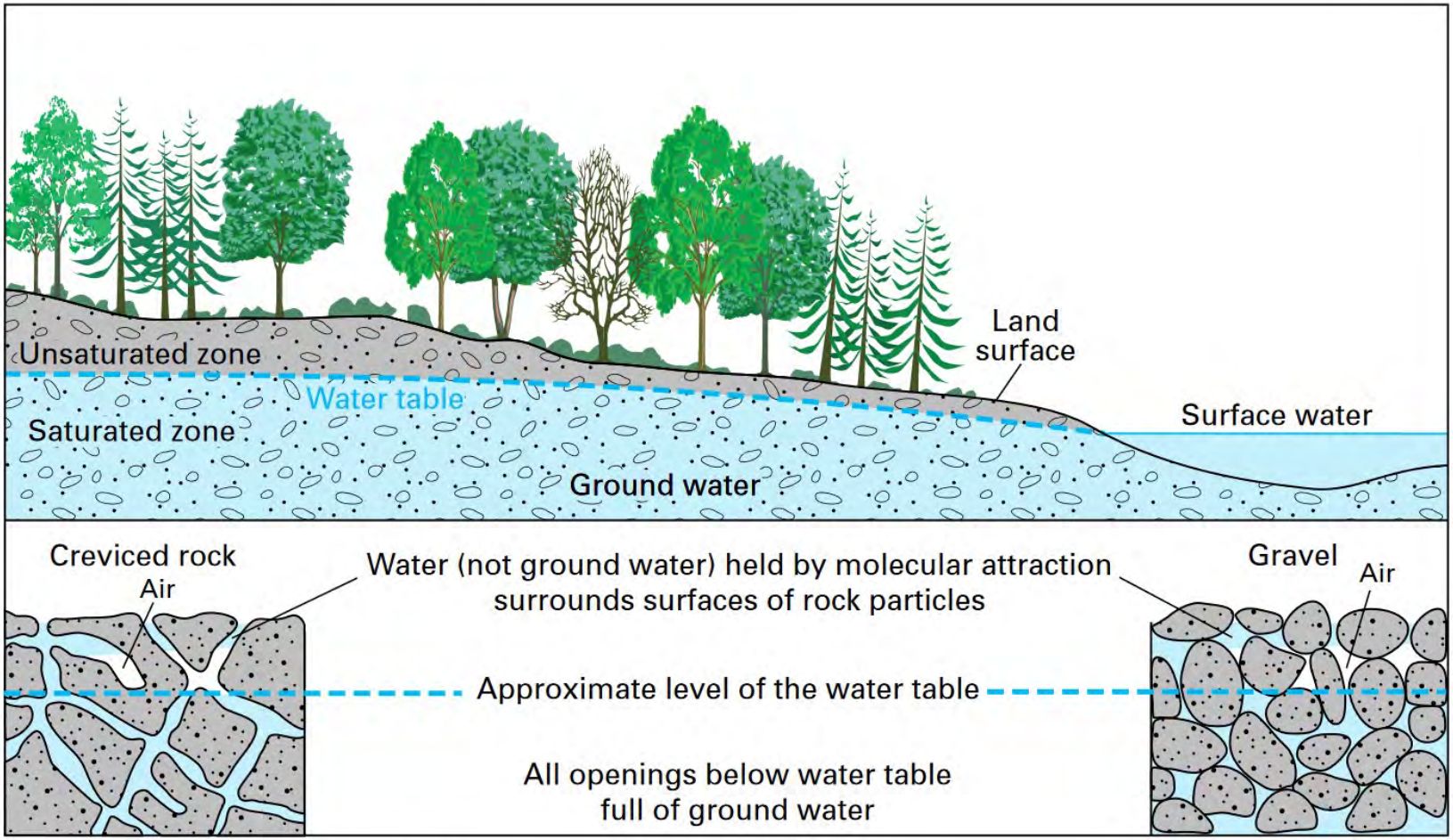
Source: Muir Way Maps

# Permeability




Source: Gannett, M.W., Lite, K.E., Jr., Risley, J.C., Pischel, E.M., and La Marche, J.L., 2017, Simulation of groundwater and surface-water flow in the upper Deschutes Basin, Oregon: U.S. Geological Survey Scientific Investigations Report 2017-5097, 68 p.

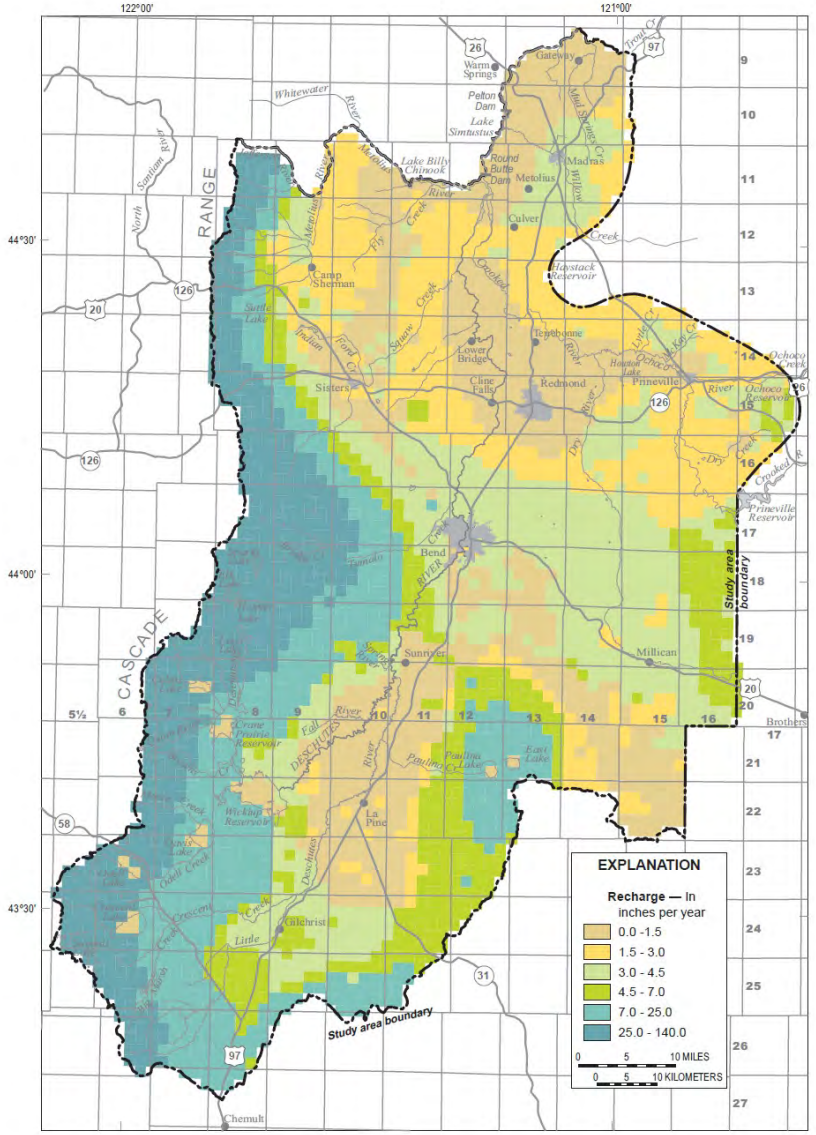
# What is Groundwater?




How ground water occurs in rocks.

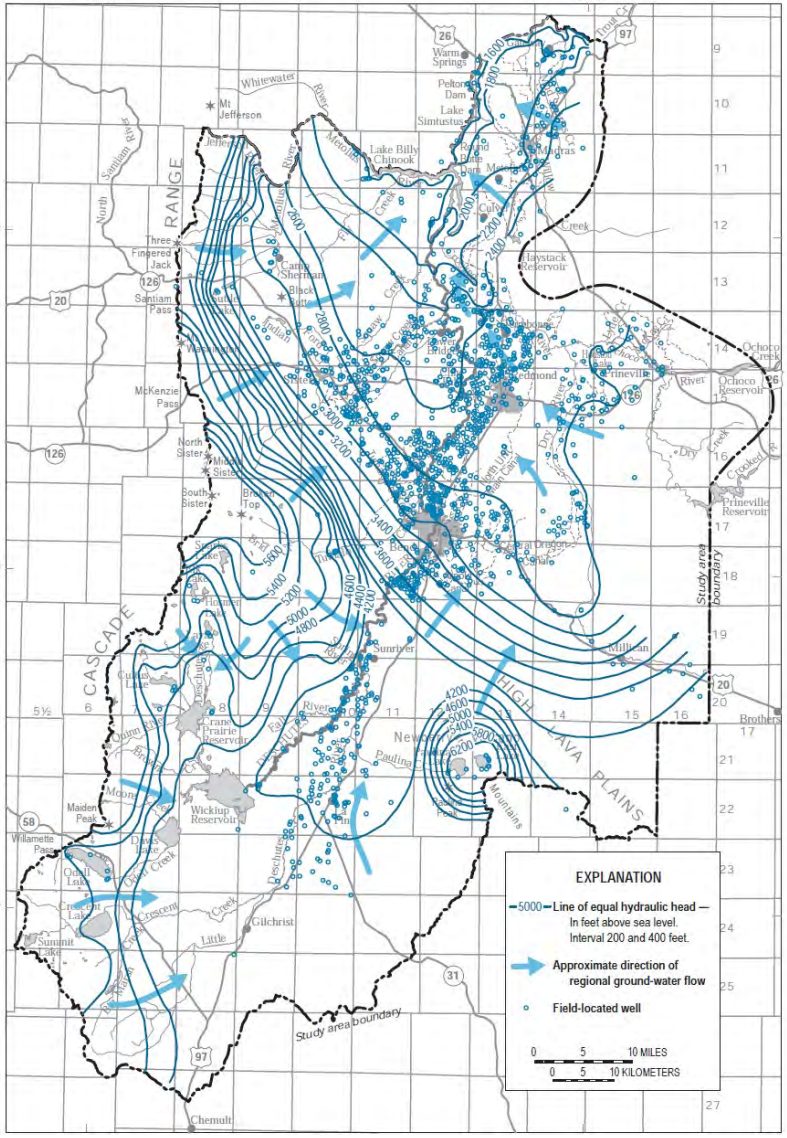
Source: USG Geological Survey
https://www.usgs.gov/media/images/groundwater-saturated-zone-soilrock-below-land-surface

# Recharge



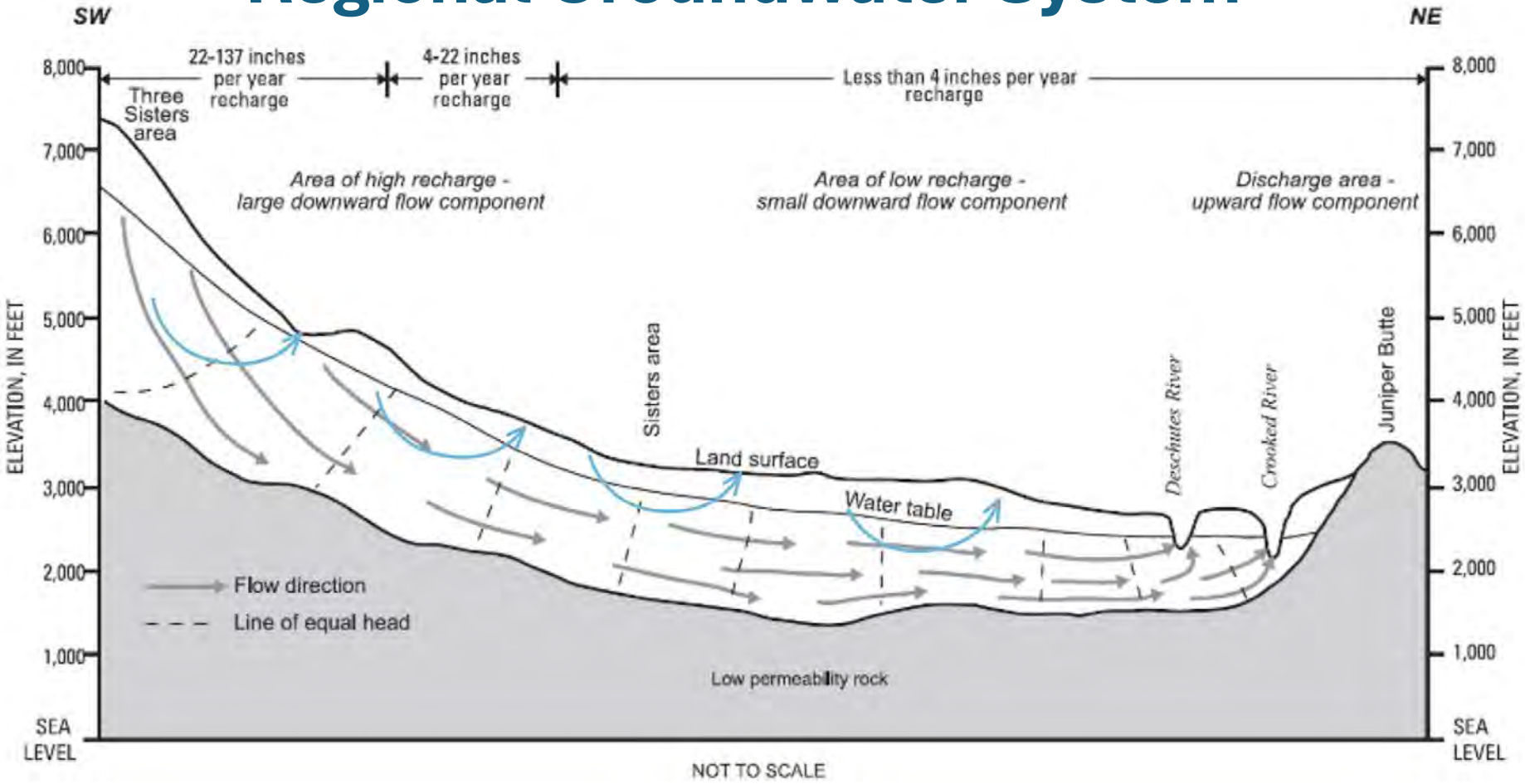

Source: Gannett, M.W., Lite, Jr., K.E., Morgan, D.S., and Collins, C.A., 2001, Ground-water hydrology of the upper Deschutes Basin, Oregon: U.S. Geological Survey Water-Resources Investigations Report 00-4162

# Flow Paths of Groundwater



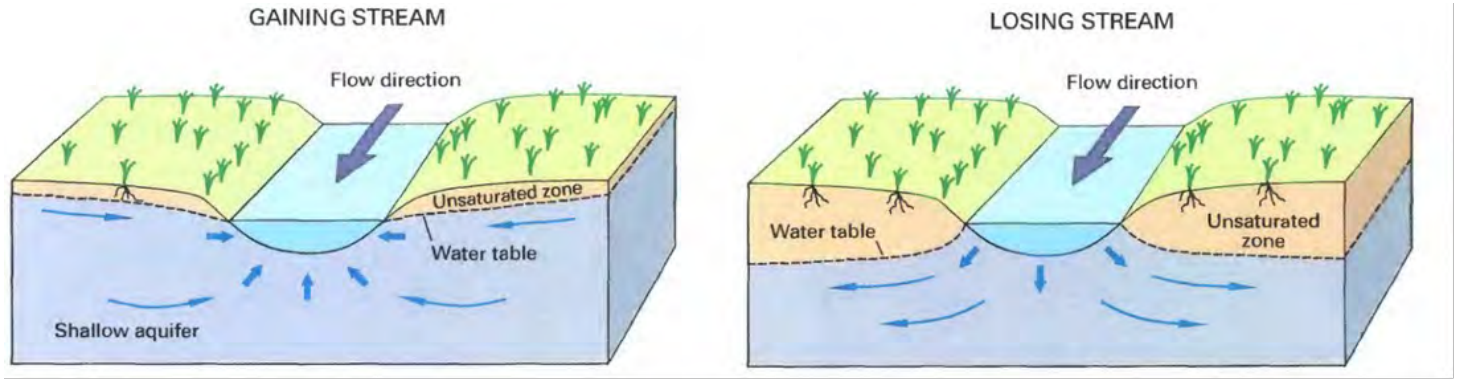

Source: Gannett, M.W., Lite, Jr., K.E., Morgan, D.S., and Collins, C.A., 2001, Ground-water hydrology of the upper Deschutes Basin, Oregon: U.S. Geological Survey Water-Resources Investigations Report 00-4162, 74 p.

# Regional Groundwater System




Adapted from: Gannett, M.W., Lite, Jr., K.E., Morgan, D.S., and Collins, C.A., 2001, Ground-water hydrology of the upper Deschutes Basin, Oregon: U.S. Geological Survey Water-Resources Investigations Report 00-4162, 74 p.

# Groundwater and Surface Water are Connected




Winter et al. 1999

# Gaining and Losing Reaches of the Deschutes

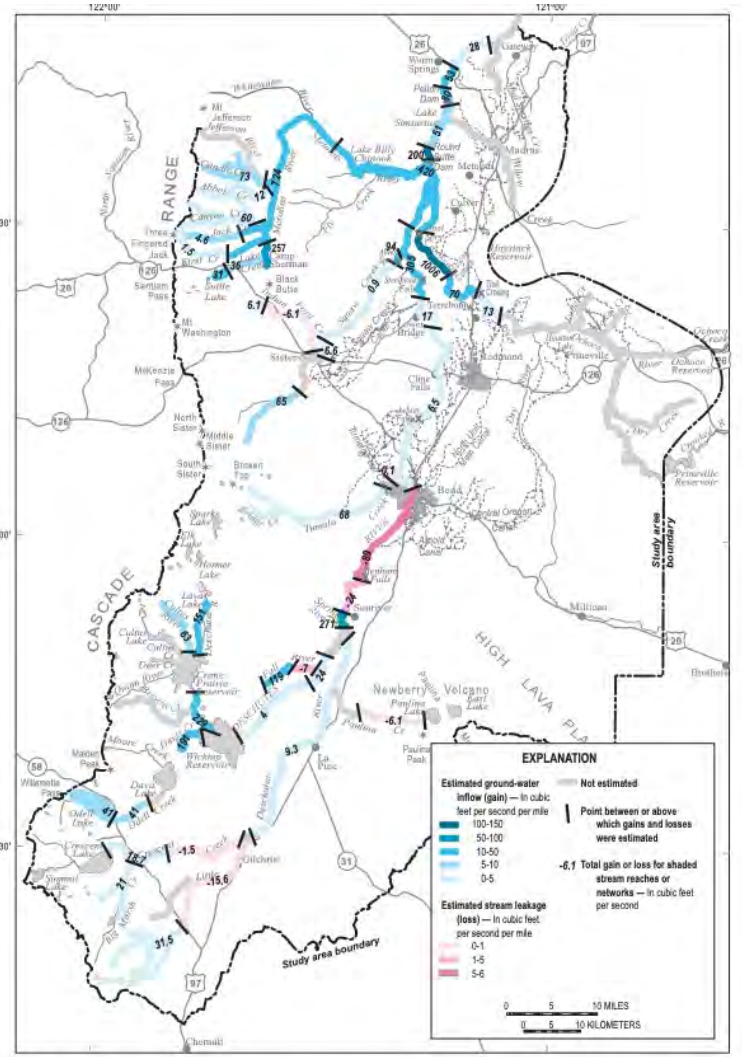
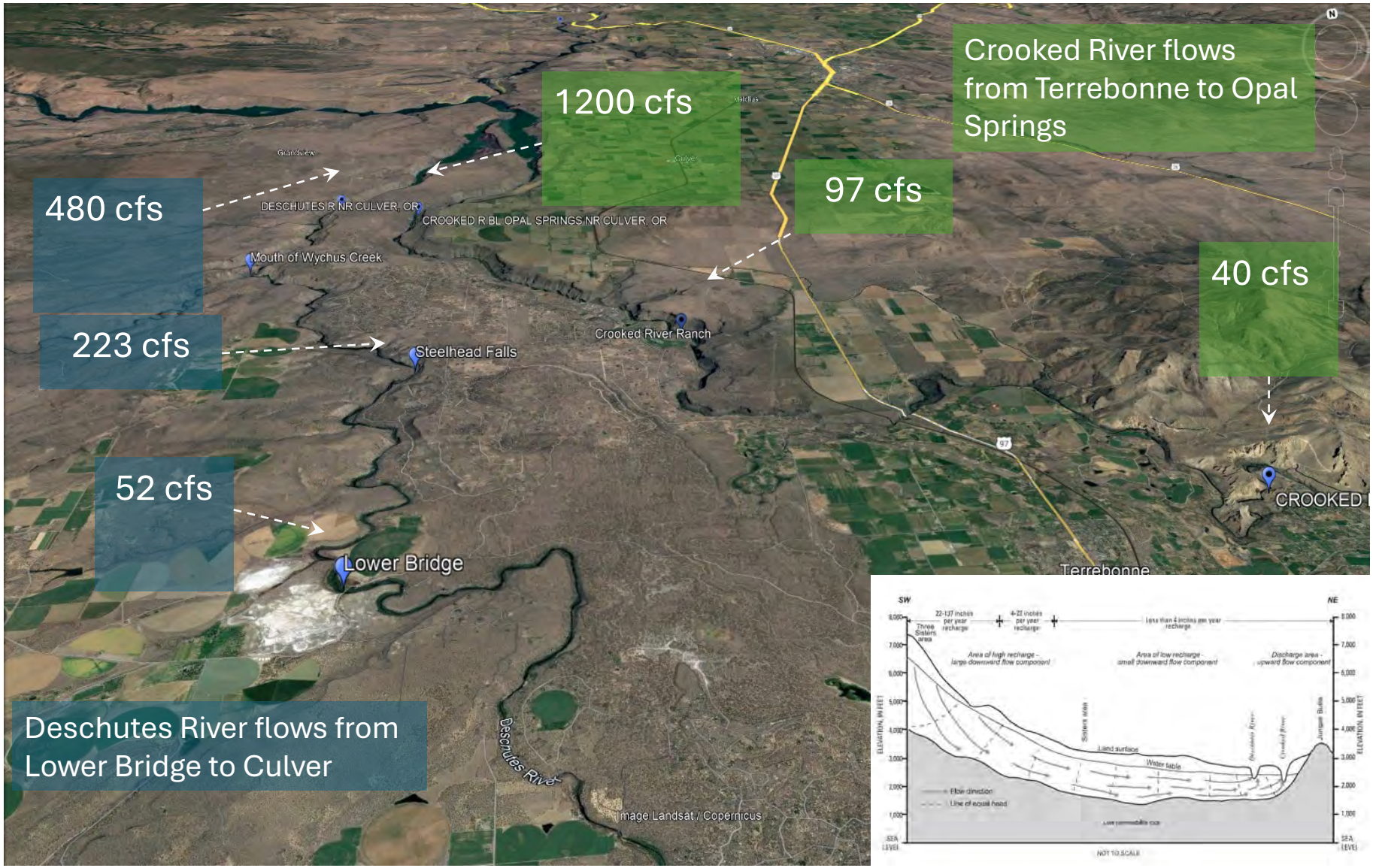


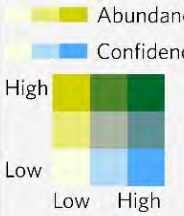

**Figure 12.** Estimated gain and loss flux rates and net gains and losses for selected stream reaches in the upper Deschutes Basin, Oregon.

Source: Gannett, M.W., Lite, Jr., K.E., Morgan, D.S., and Collins, C.A., 2001, Ground-water hydrology of the upper Deschutes Basin, Oregon: U.S. Geological Survey Water-Resources Investigations Report 00-4162


1200 cfs
Crooked River flows from Terrebonne to Opal Springs
480 cfs
97 cfs
40 cfs
223 cfs
52 cfs
DESCHUTES R NR CULVER, OR
CROOKED R BL OPAL SPRINGS NR CULVER, OR
Mouth of Wychus Creek
Steelhead Falls
Crooked River Ranch
Lower Bridge
Terrebonne
CROOKED
Deschutes River flows from Lower Bridge to Culver
Deschutes River
Image Landsat / Copernicus
SW
NE
Land surface
Water table
Flow direction
Line of equal head
NOT TO SCALE

# Oregon GDE Atlas 2022

## Distribution and Abundance of GDEs




**Orienting Features**

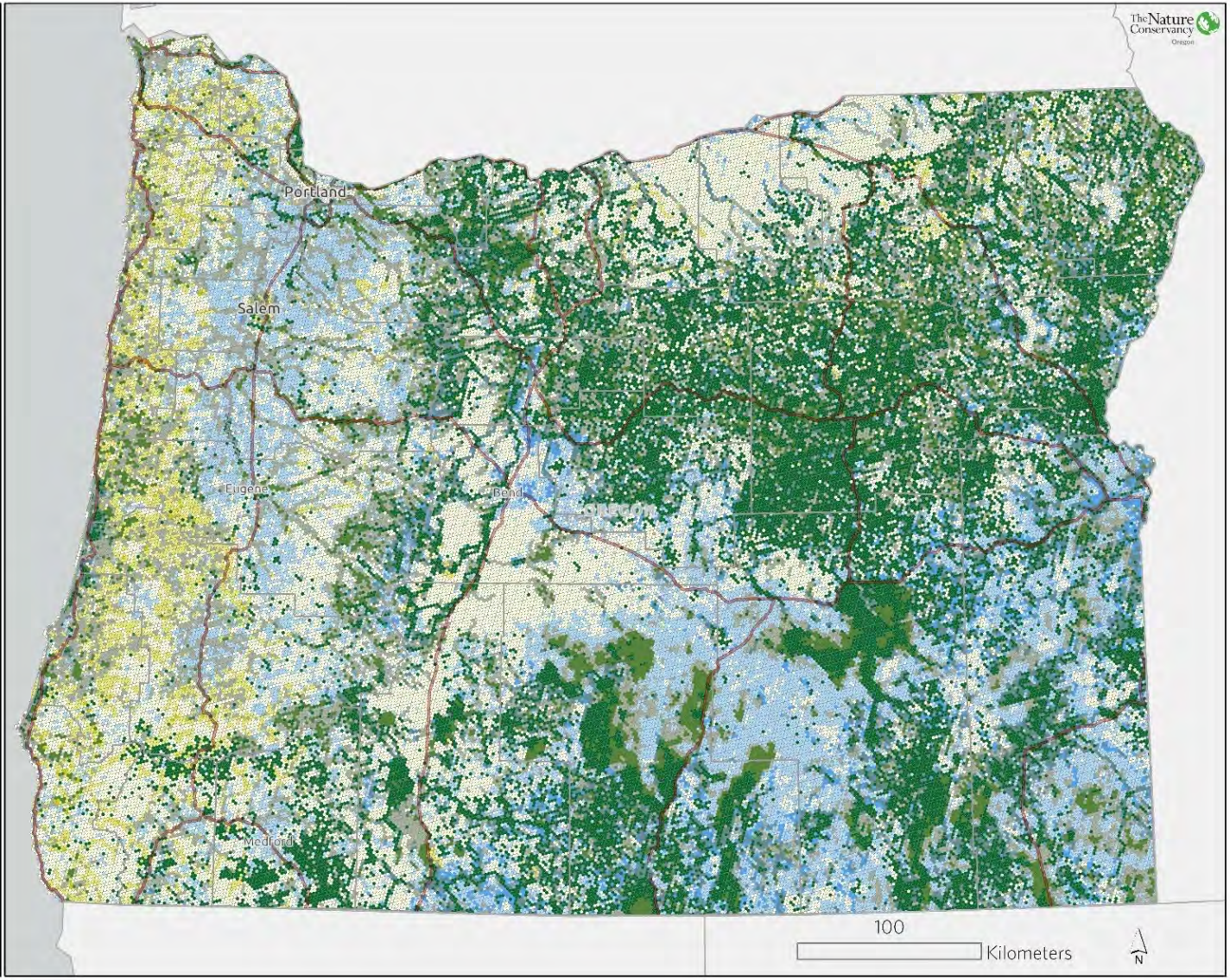
Highways

Counties

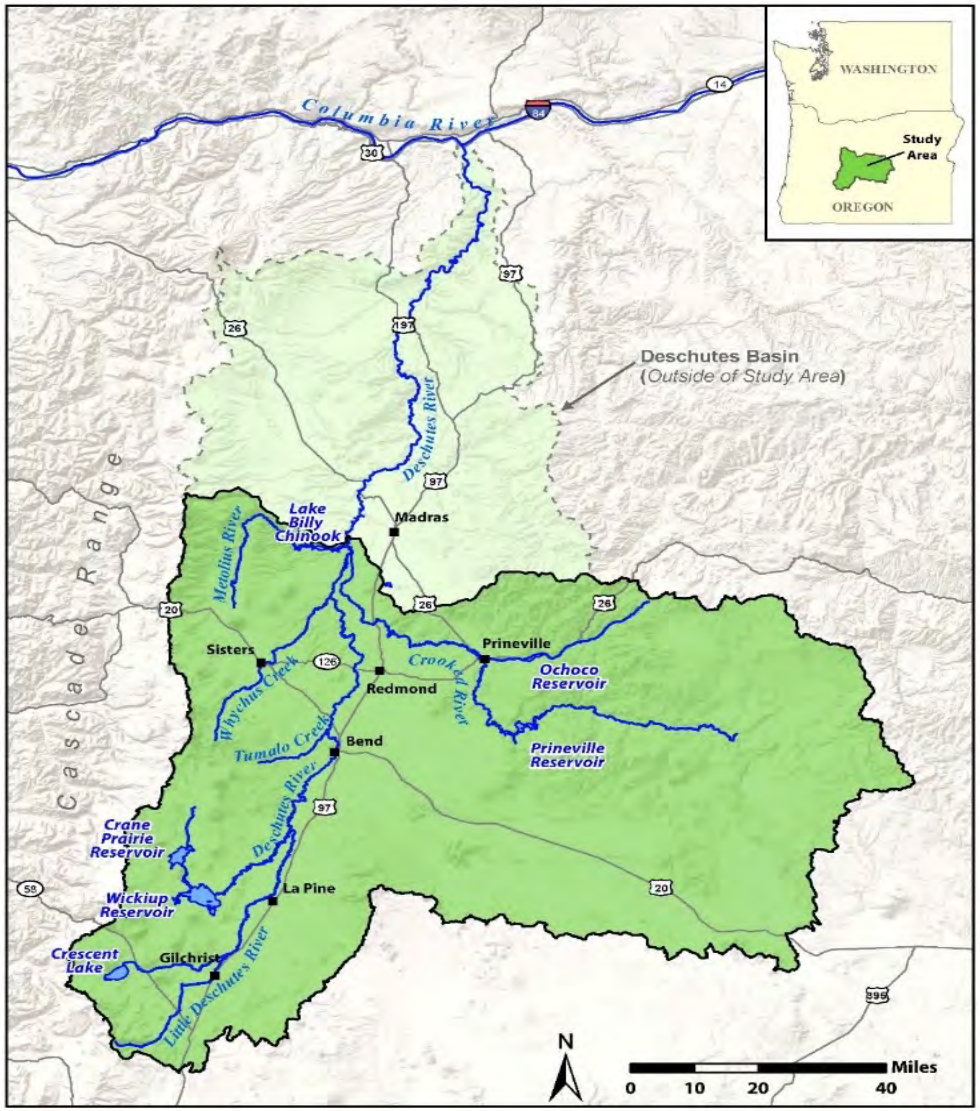
Groundwater-dependent ecosystems are unevenly distributed across Oregon. All five types of GDEs (springs, rivers, wetlands, lakes, and species) have been combined into a bivariate index of abundance and confidence. The abundance of different GDE types is standardized relative to their total distribution and summed. Confidence reflects the standardized sum of indicators across all GDE types.

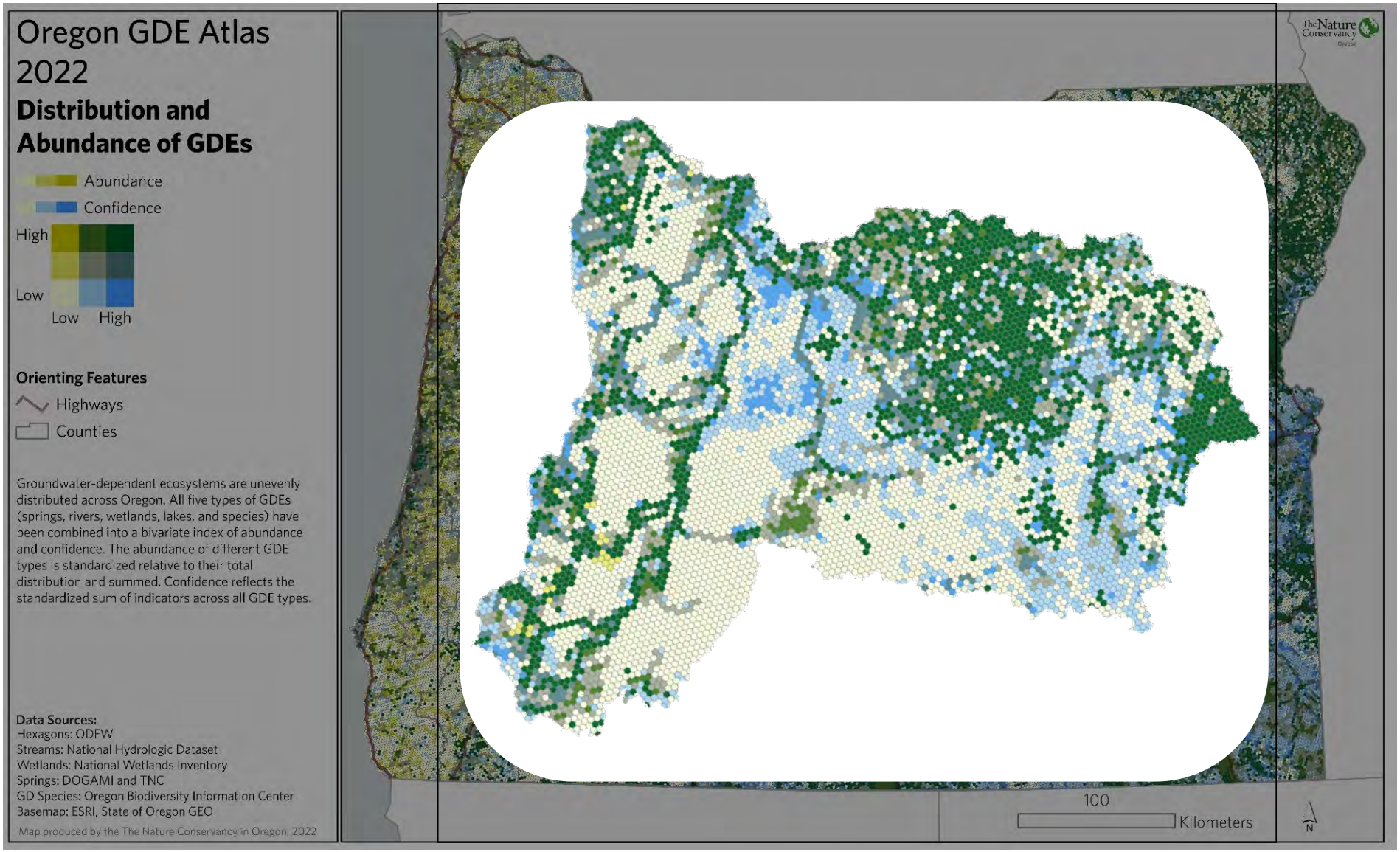
**Data Sources:**
Hexagons: ODFW
Streams: National Hydrologic Dataset
Wetlands: National Wetlands Inventory
Springs: DOGAMI and TNC
GD Species: Oregon Biodiversity Information Center
Basemap: ESRI, State of Oregon GEO

Map produced by the The Nature Conservancy in Oregon, 2022

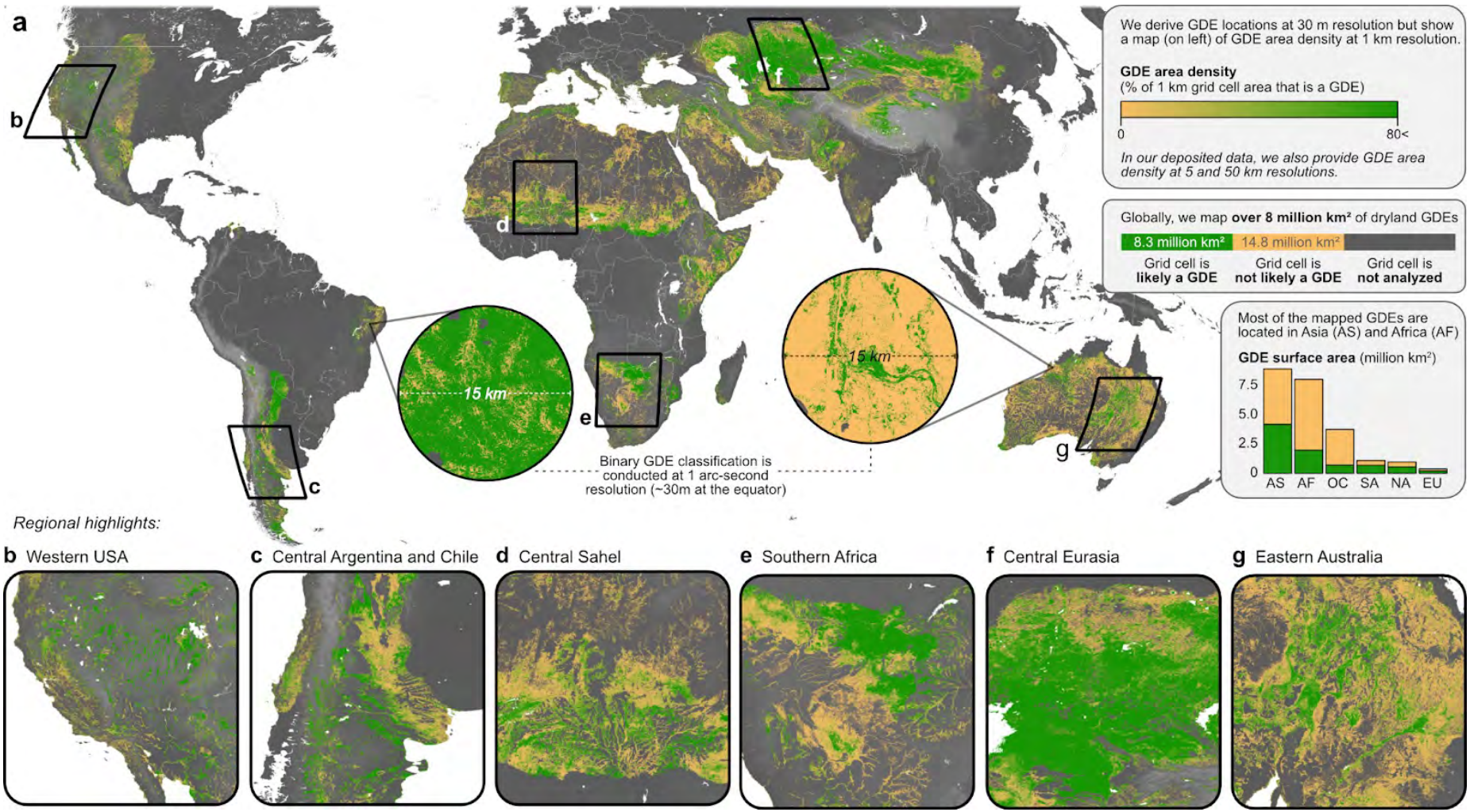



Freed et al. 2022


WASHINGTON
Study Area
OREGON
Columbia River
Deschutes Basin
(Outside of Study Area)
Deschutes River
Cascade Range
Lake Billy Chinook
Madras
Metolius River
Sisters
Whychus Creek
Tumalo Creek
Bend
Redmond
Crooked River
Prineville
Ochoco Reservoir
Prineville Reservoir
Crane Prairie Reservoir
Wickiup Reservoir
La Pine
Crescent Lake
Gilchrist
Little Deschutes River
N
Miles
0
10
20
40

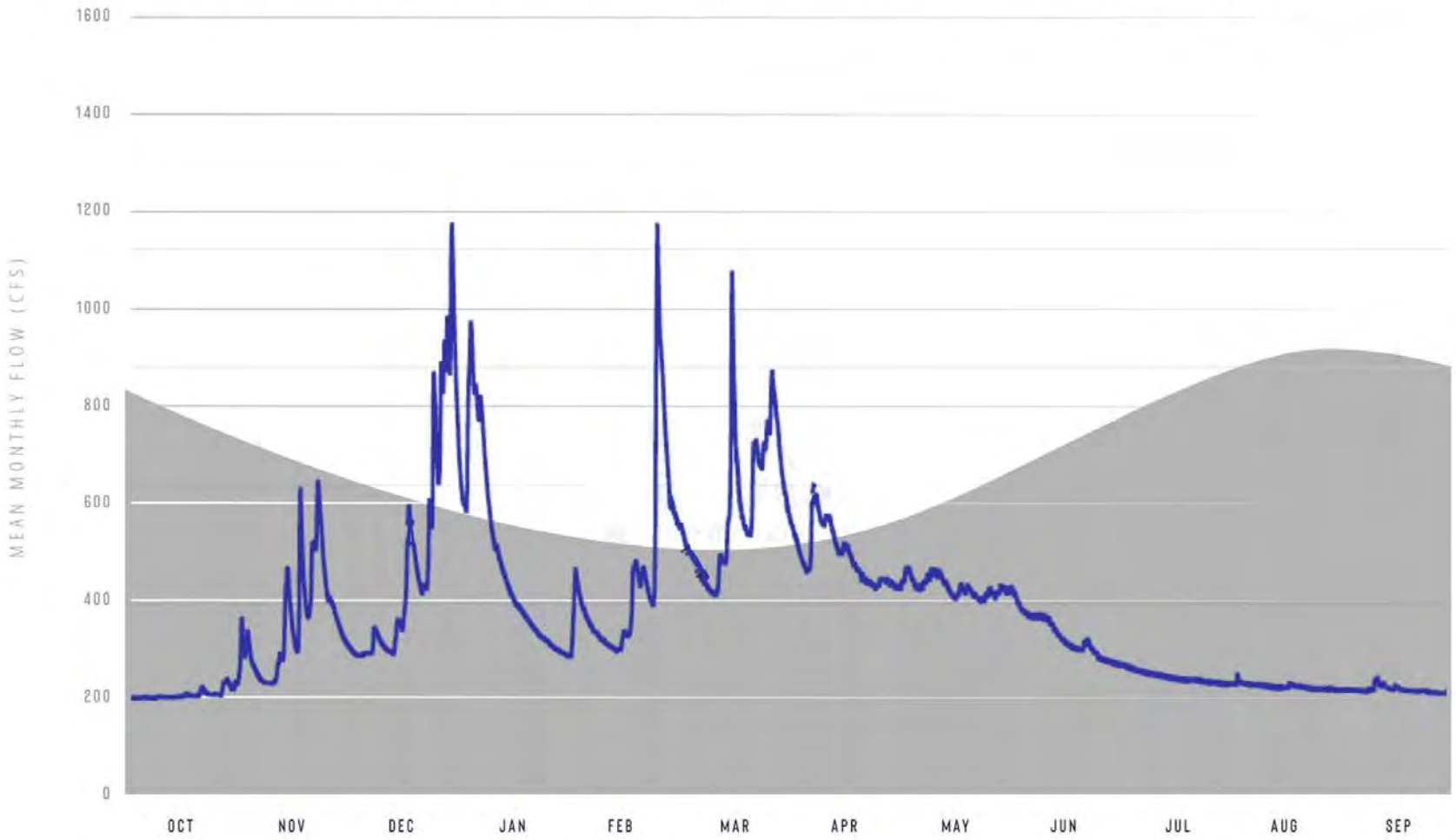


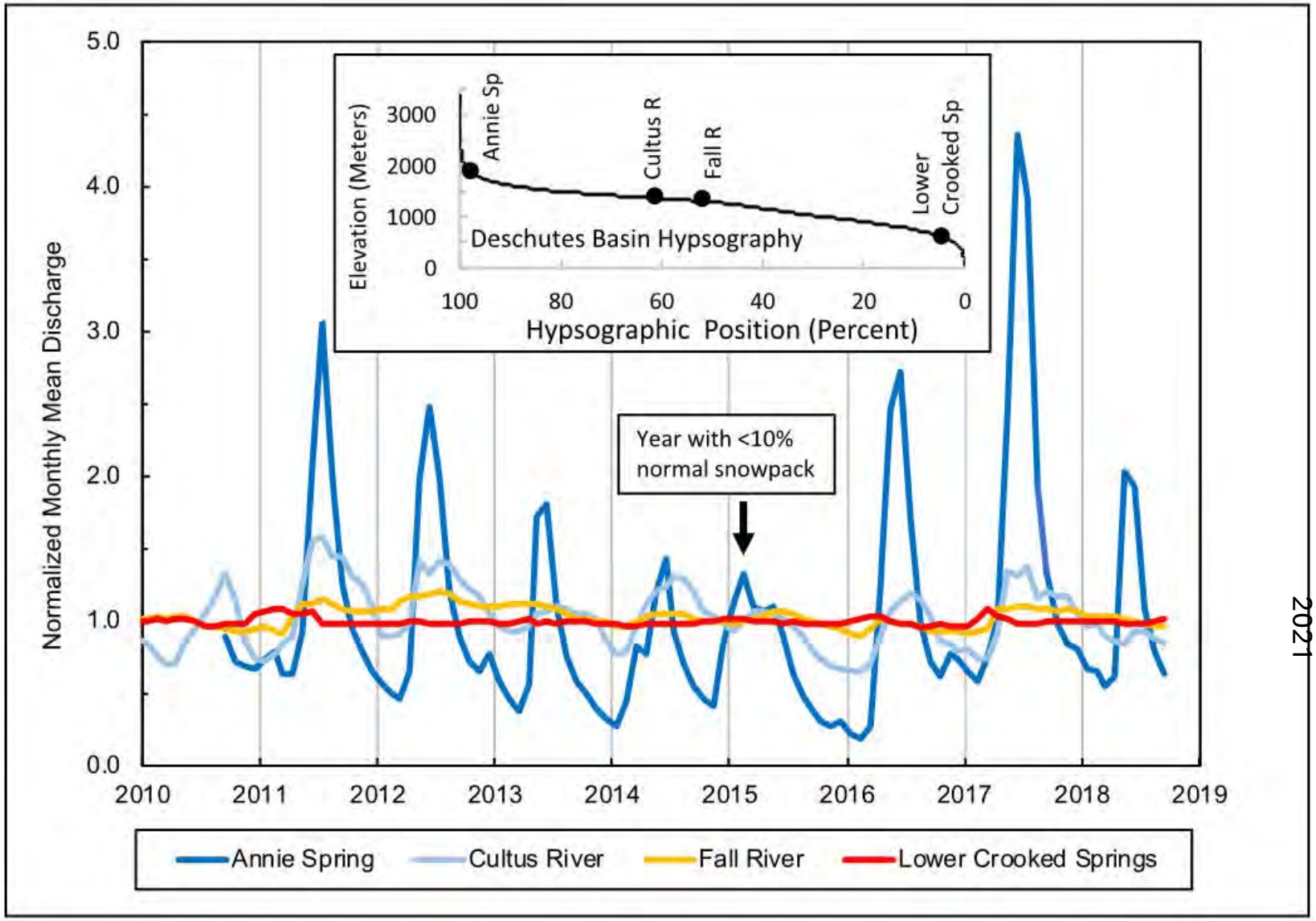

Freed et al. 2022




Rohde et al. 2024

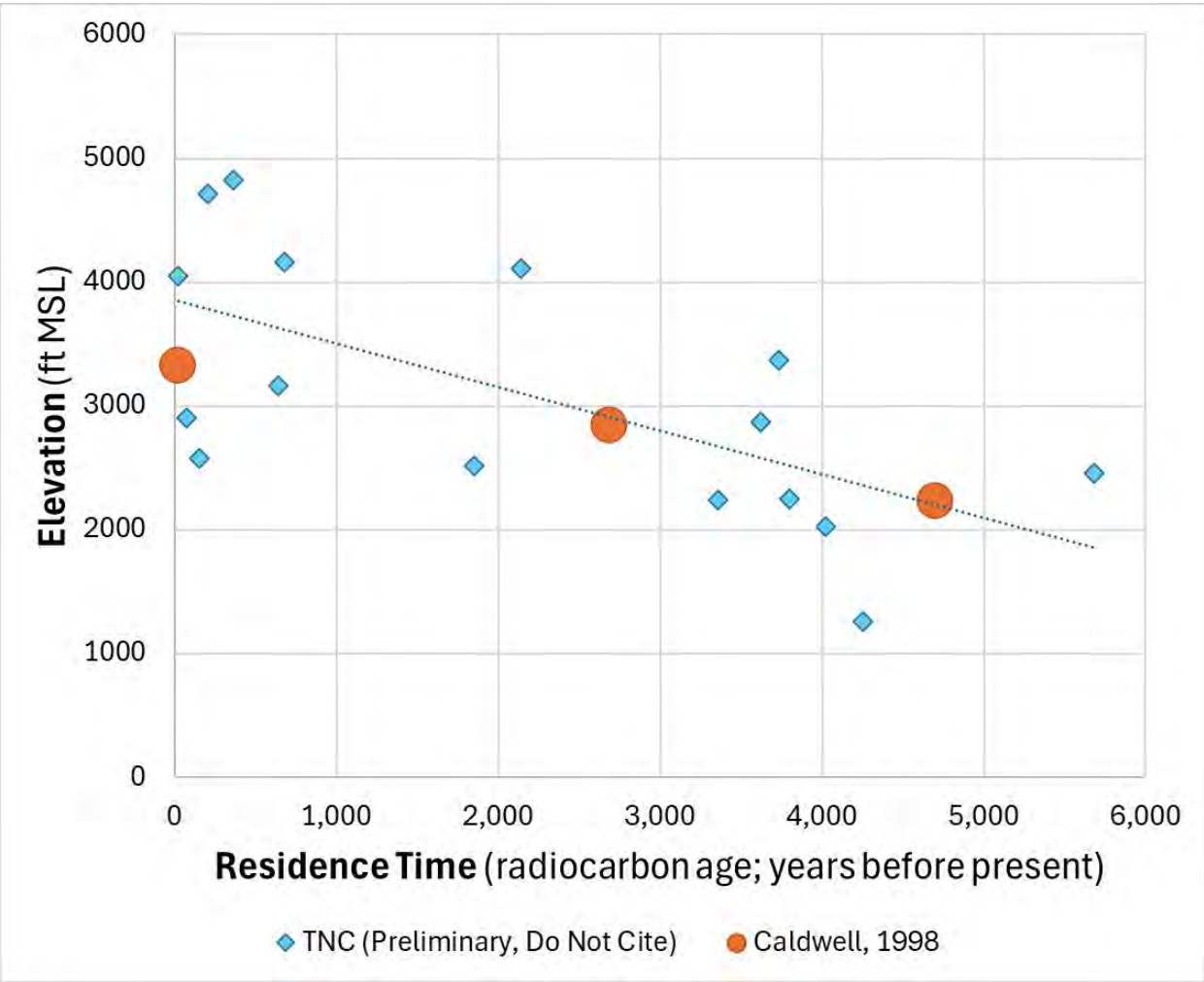
# Groundwater-Fed vs. Run-Off Driven Hydrograph:






Aldous & Gannett 2021

# Residence Time of Groundwater



# Hyporheic Zone

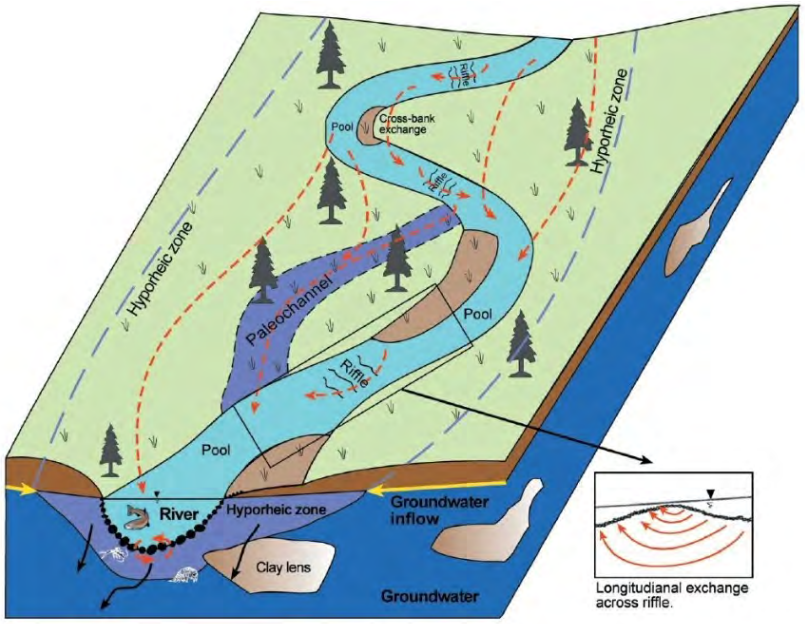
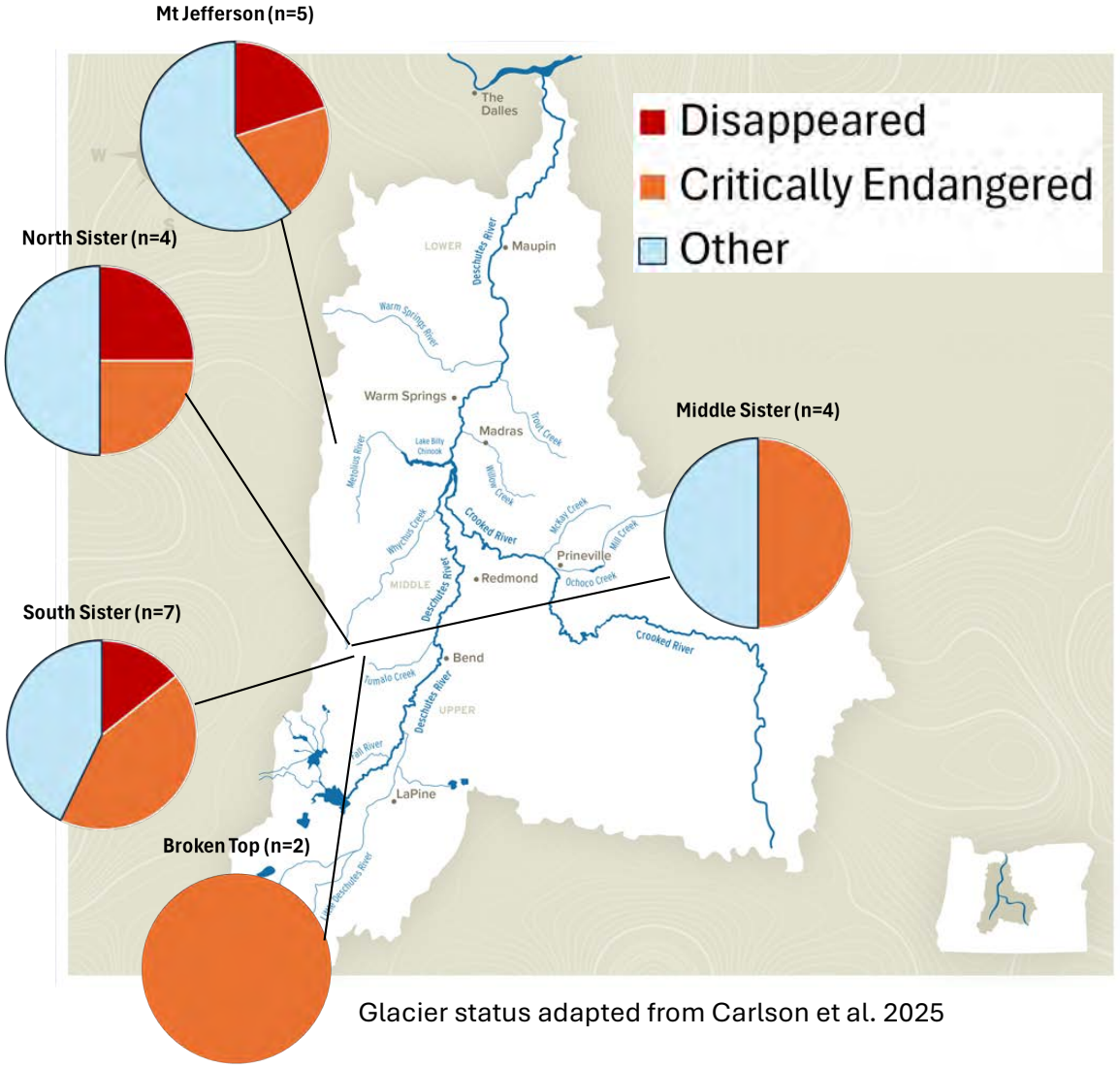



Illustration of the Hyporheic Zone, from D. Tonina and J. M. Buffington, 2009, Hyporheic Exchange in Mountain Rivers I: Mechanics and Environmental Effects. Geography Compass 3 (2009): 10.1111/j.1749-8198.2009.00226.x

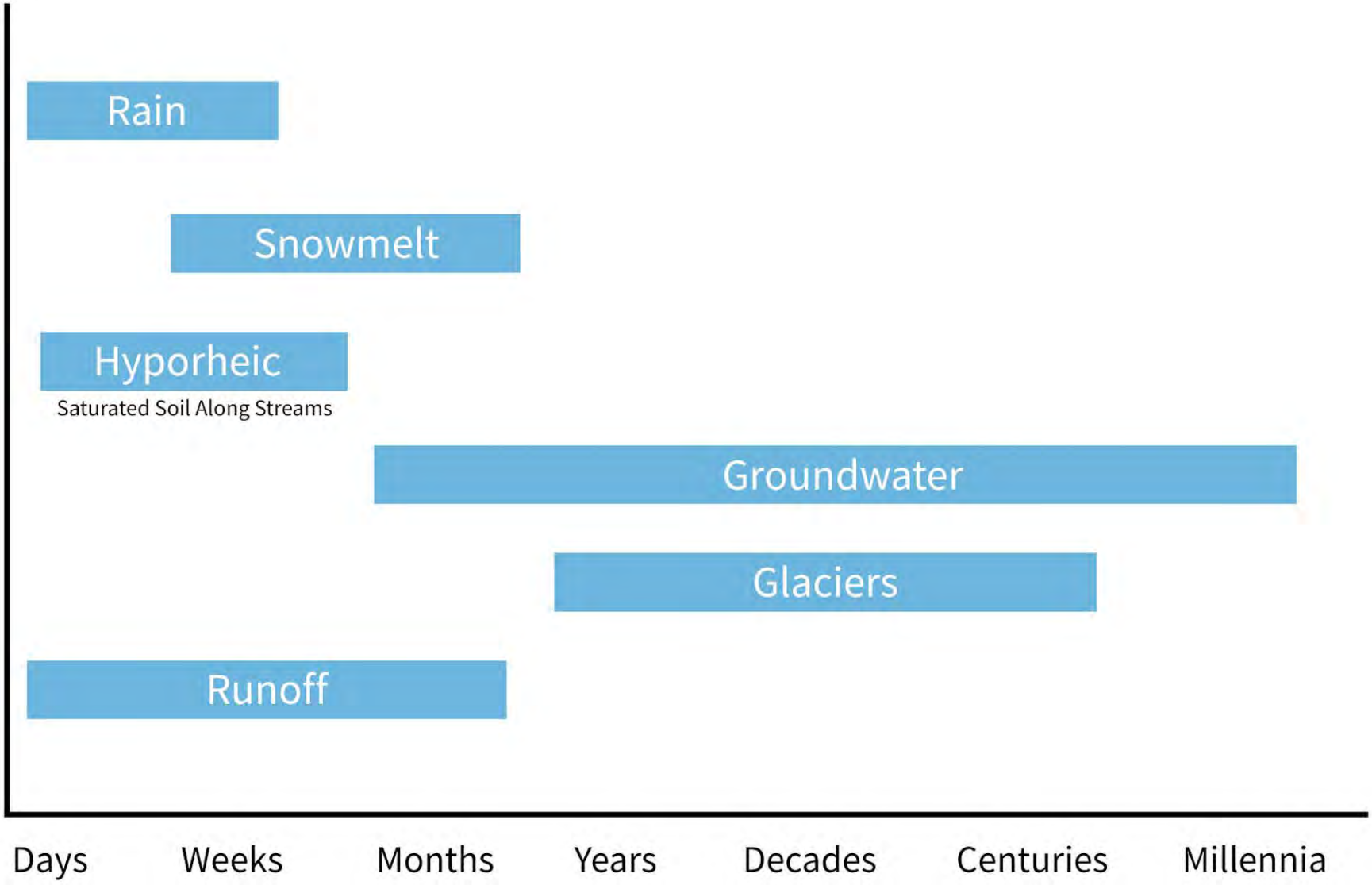

The hyporheic zone of Whychus Creek. Diagram: Land Trust (concept from Karen Jackson, Clemson University Cooperative Extension Service).

# Glaciers


The critically endangered Bend Glacier, Broken Top
*from* Carlson et al. 2025

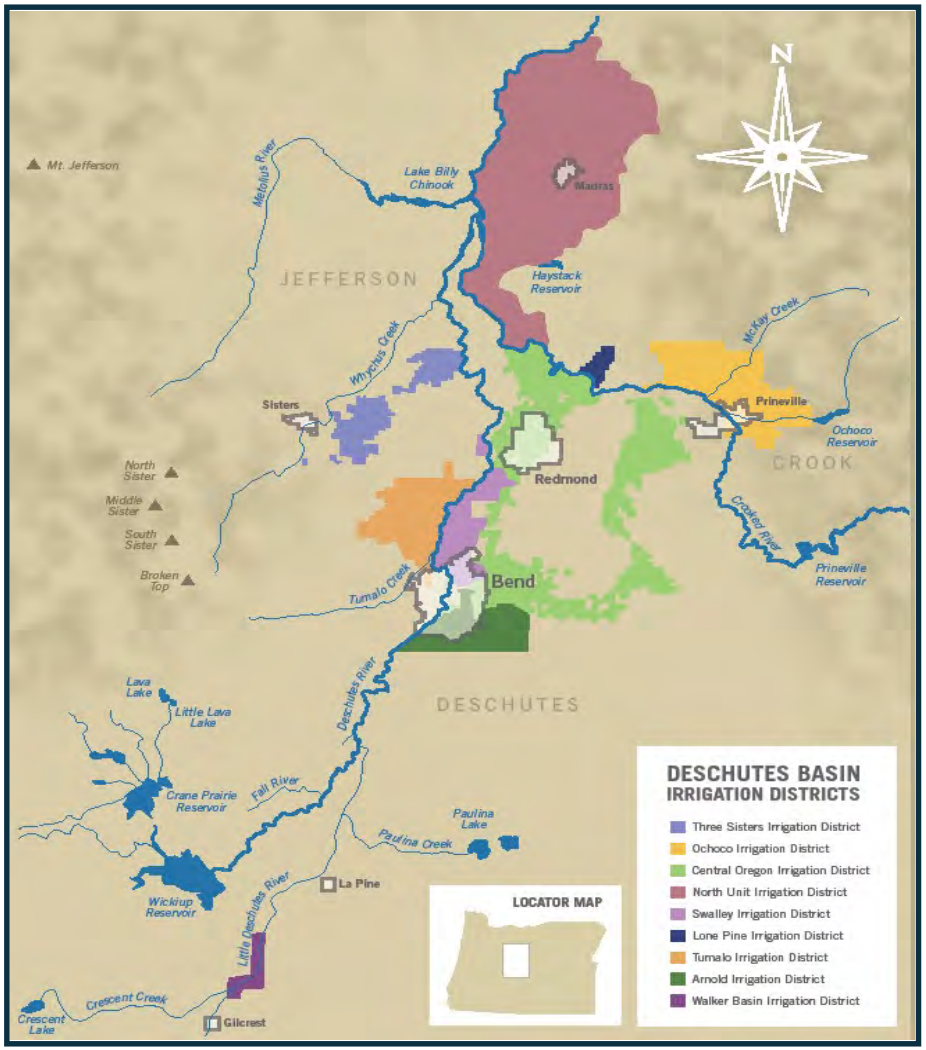



Glacier status adapted from Carlson et al. 2025


Rain
Snowmelt
Hyporheic
Saturated Soil Along Streams
Groundwater
Glaciers
Runoff
Days
Weeks
Months
Years
Decades
Centuries
Millennia

# Human-Altered Pathways

| District | Priority |
|---|---|
| Swalley | 1899 |
| Central Oregon | 1900 & 1907 |
| Lone Pine | 1900 |
| Tumalo | 1905 |
| Arnold | 1905 |
| North Unit | 1913 |
| Deschutes River | 1987 |



# Irrigation Canals in the Deschutes

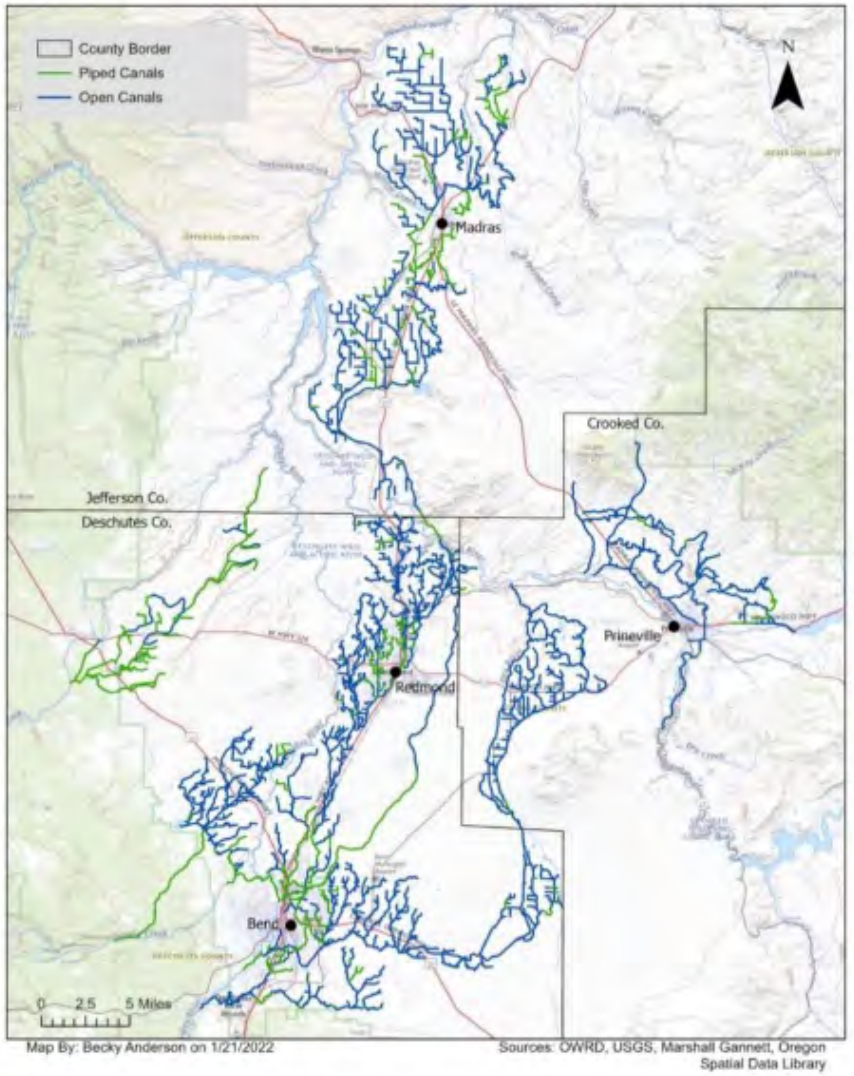
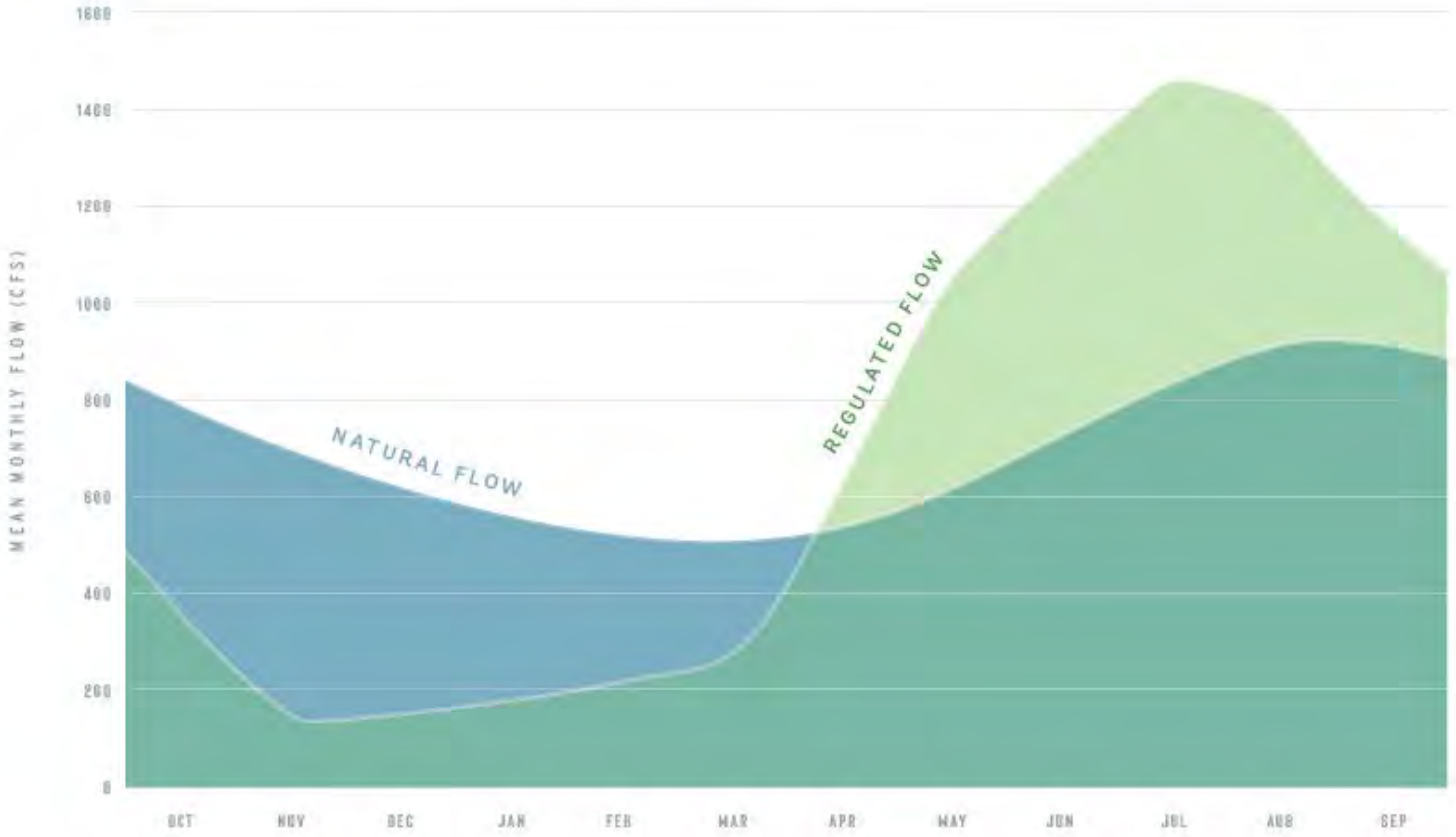
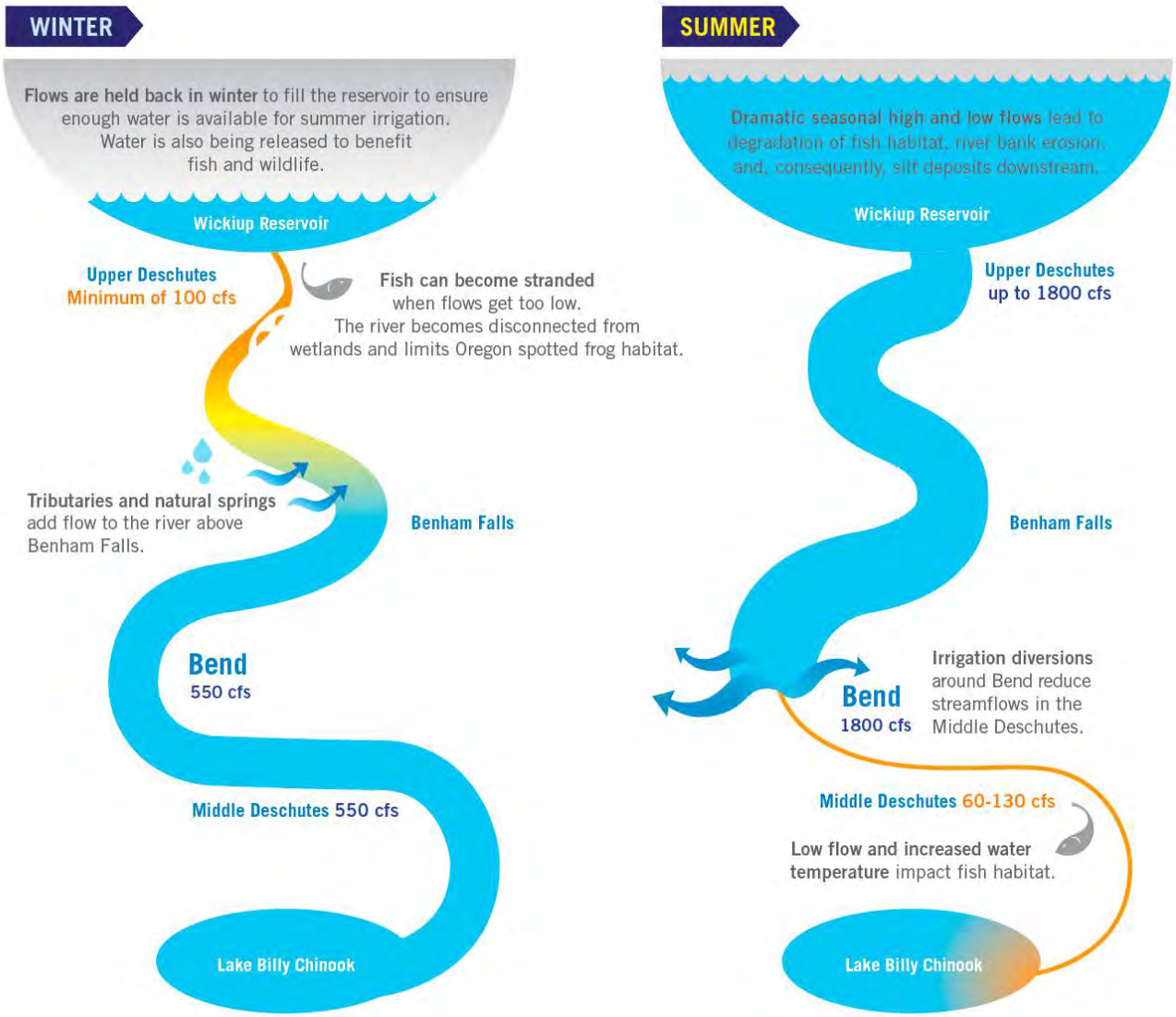



Figure 3: Irrigation canals in the Upper Deschutes Basin (as of 2018).

## Hydrograph of Natural and Regulated Streamflows:

Deschutes River below Wickiup Reservoir (1983-present)




WINTER
Flows are held back in winter to fill the reservoir to ensure enough water is available for summer irrigation. Water is also being released to benefit fish and wildlife.
Wickiup Reservoir
Upper Deschutes
Minimum of 100 cfs
Fish can become stranded when flows get too low. The river becomes disconnected from wetlands and limits Oregon spotted frog habitat.
Tributaries and natural springs add flow to the river above Benham Falls.
Benham Falls
Bend
550 cfs
Middle Deschutes 550 cfs
Lake Billy Chinook
SUMMER
Dramatic seasonal high and low flows lead to degradation of fish habitat, river bank erosion, and, consequently, silt deposits downstream.
Wickiup Reservoir
Upper Deschutes
up to 1800 cfs
Benham Falls
Bend
1800 cfs
Irrigation diversions around Bend reduce streamflows in the Middle Deschutes.
Middle Deschutes 60-130 cfs
Low flow and increased water temperature impact fish habitat.
Lake Billy Chinook

# Groundwater and Surface Water are Connected!

They are one source of water

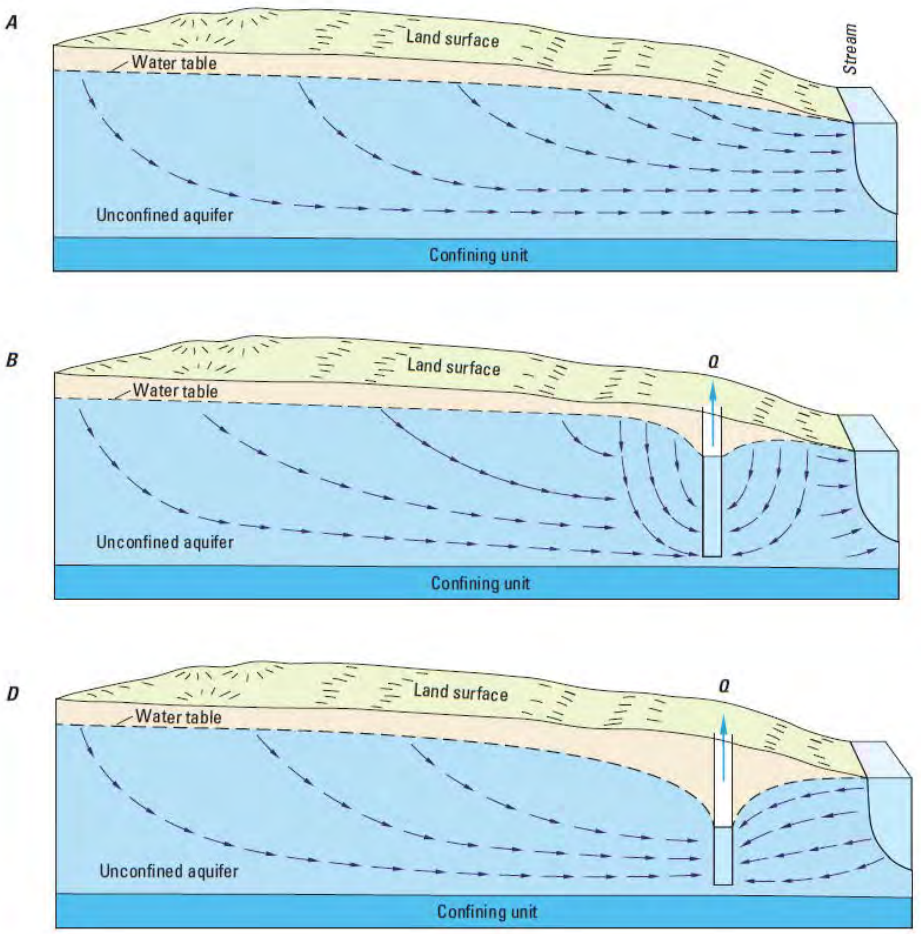
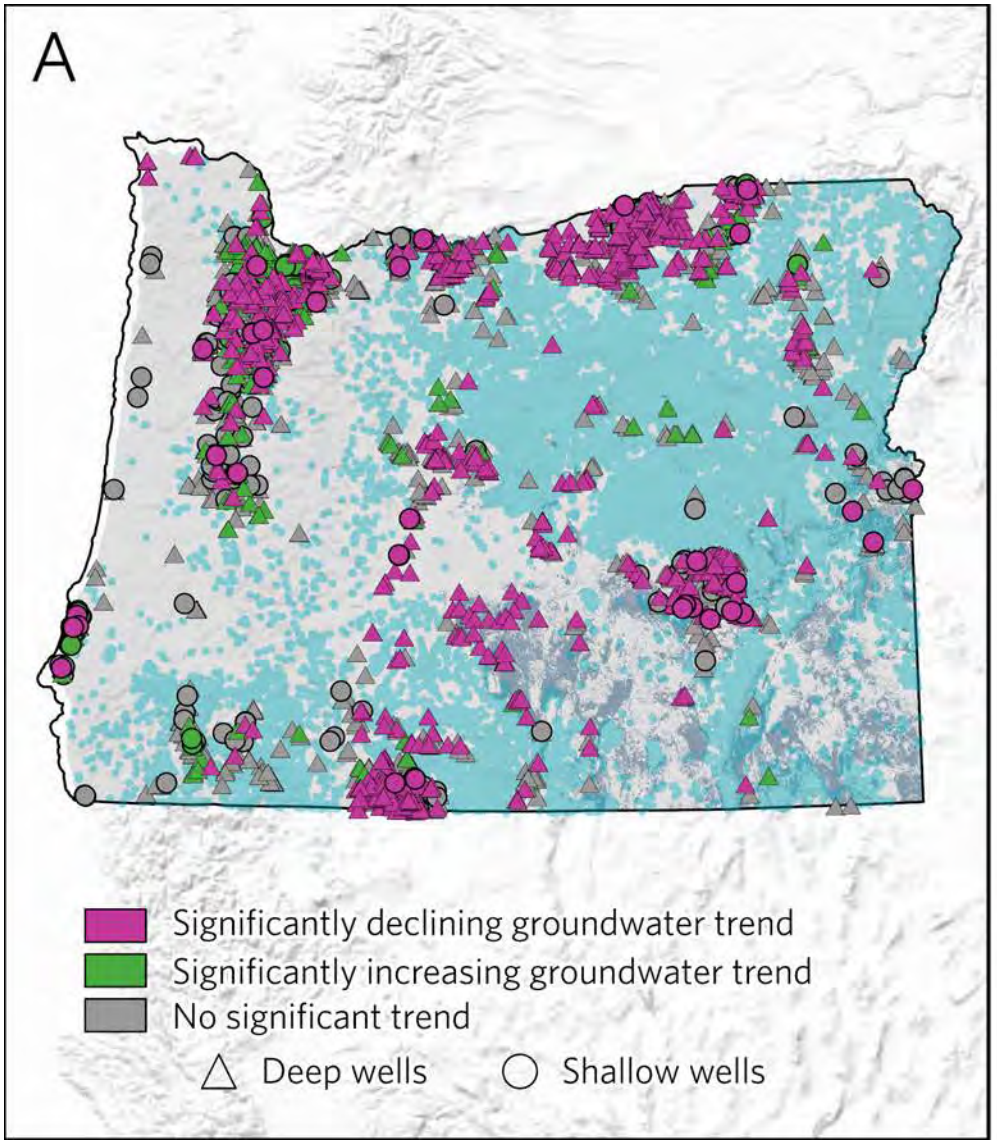
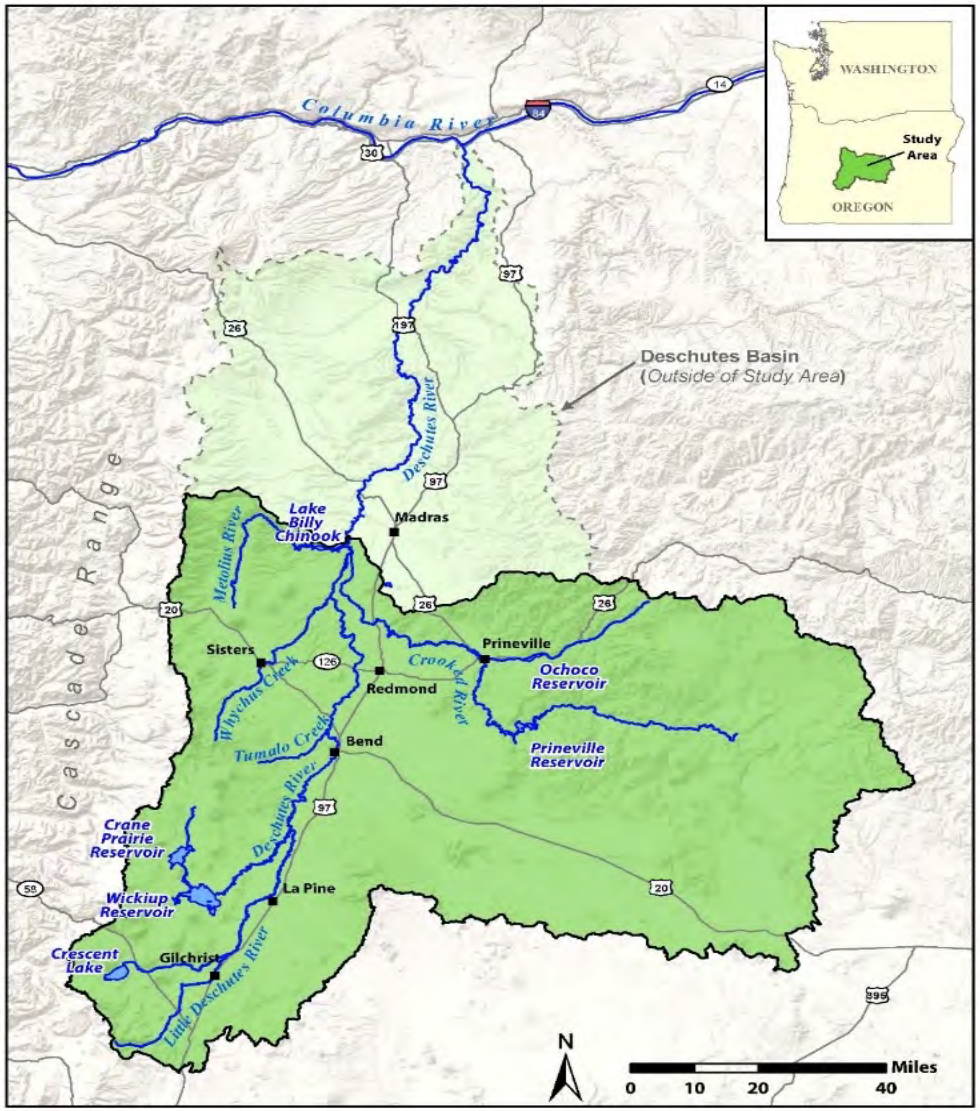
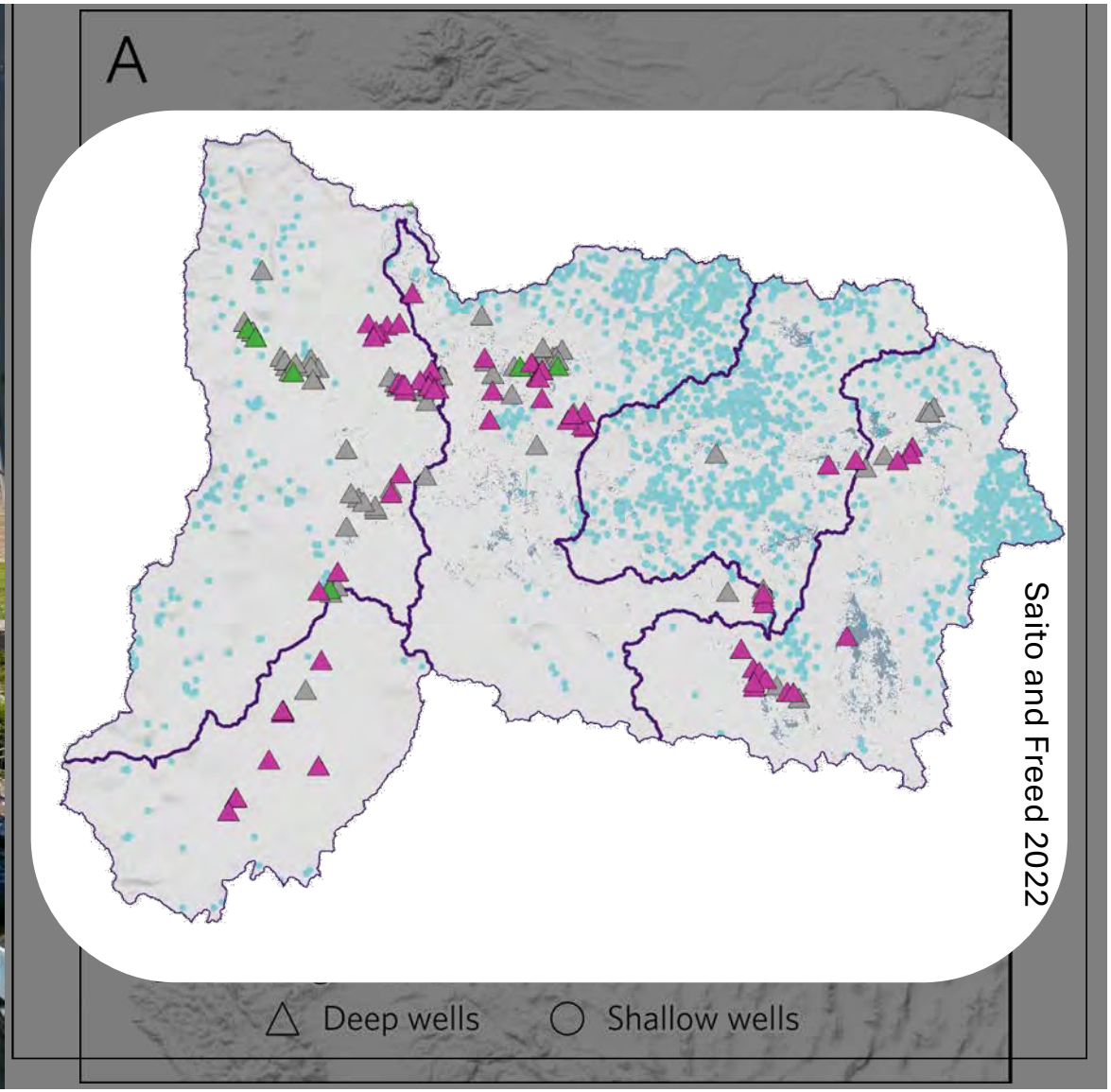



Image Source: Barlow, P.M., and Leake, S.A., 2012, Streamflow depletion by wells—Understanding and managing the effects of groundwater pumping on streamflow: U.S. Geological

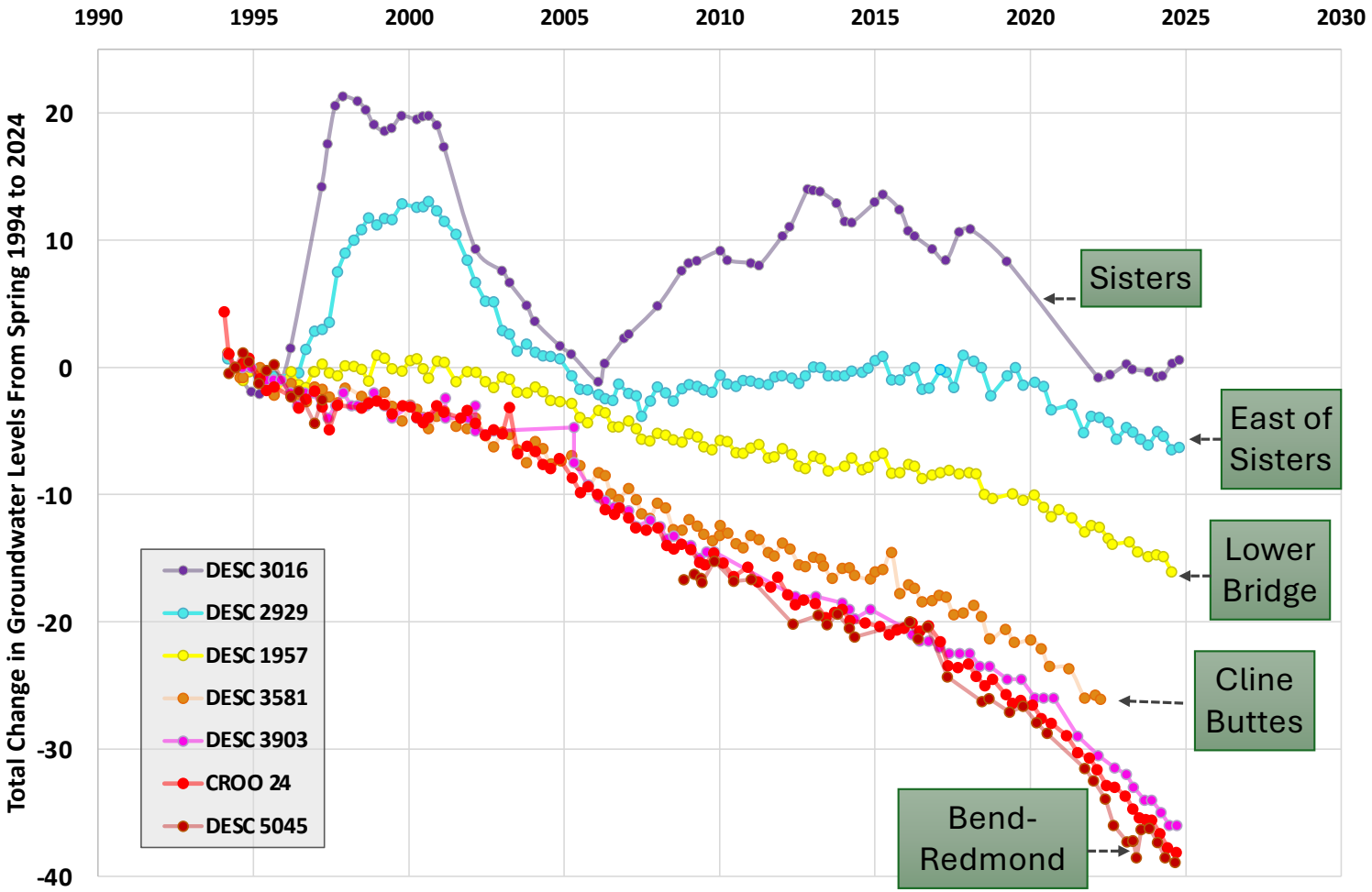



Saito and Freed 2022


WASHINGTON
Study Area
OREGON
Columbia River
Deschutes Basin
(Outside of Study Area)
Deschutes River
Cascade Range
Lake Billy Chinook
Madras
Metolius River
Sisters
Whychus Creek
Tumalo Creek
Bend
Redmond
Crooked River
Prineville
Ochoco Reservoir
Prineville Reservoir
Crane Prairie Reservoir
Wickiup Reservoir
La Pine
Crescent Lake
Gilchrist
Little Deschutes River
N
Miles
0
10
20
40

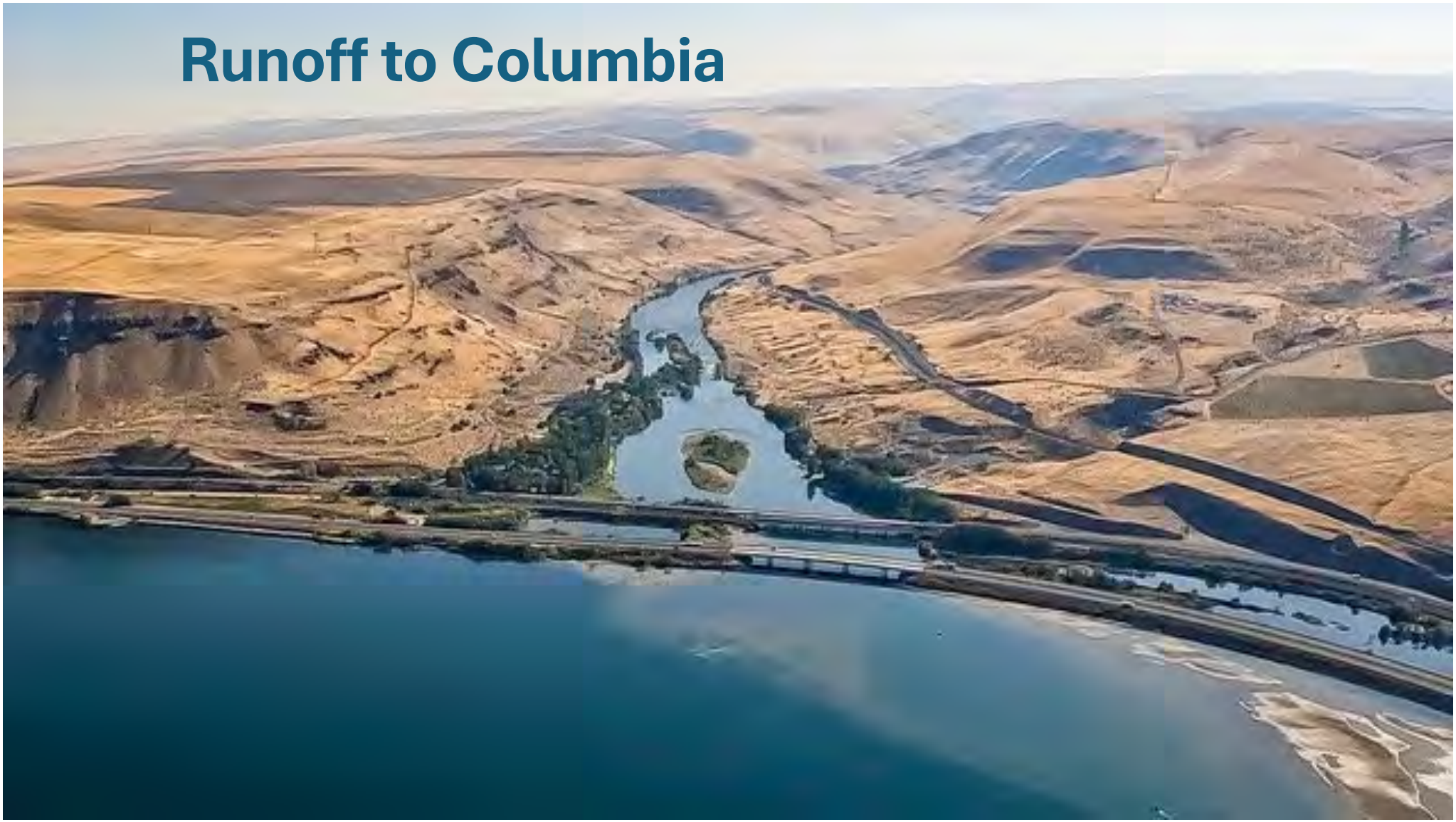

A
Saito and Freed 2022
Deep wells
Shallow wells

# Water Level Trends Across the Basin

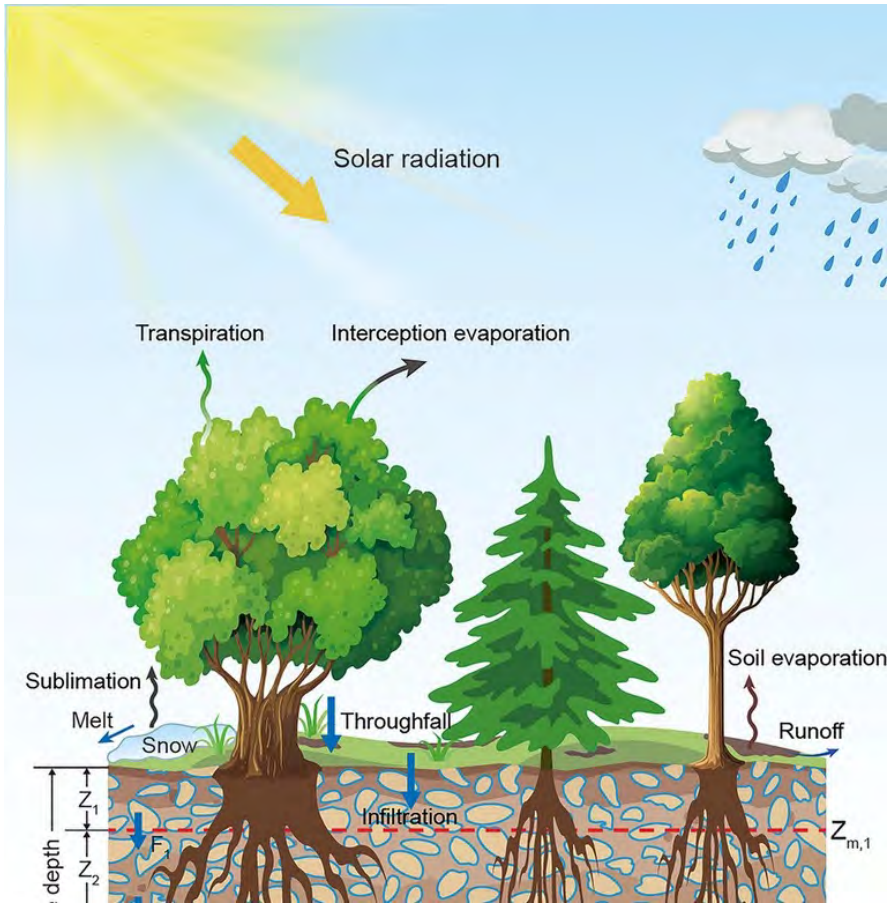


# The Fate of Water

# Runoff to Columbia



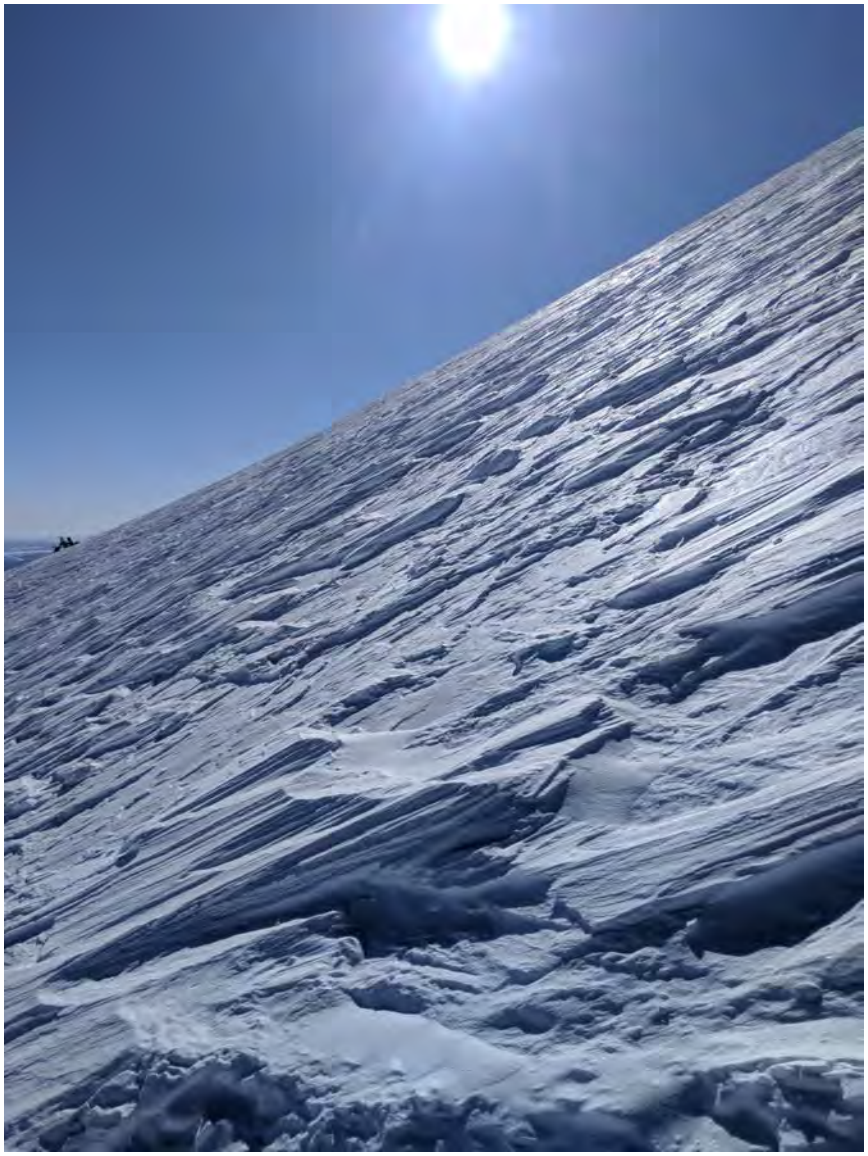
# Evapotranspiration



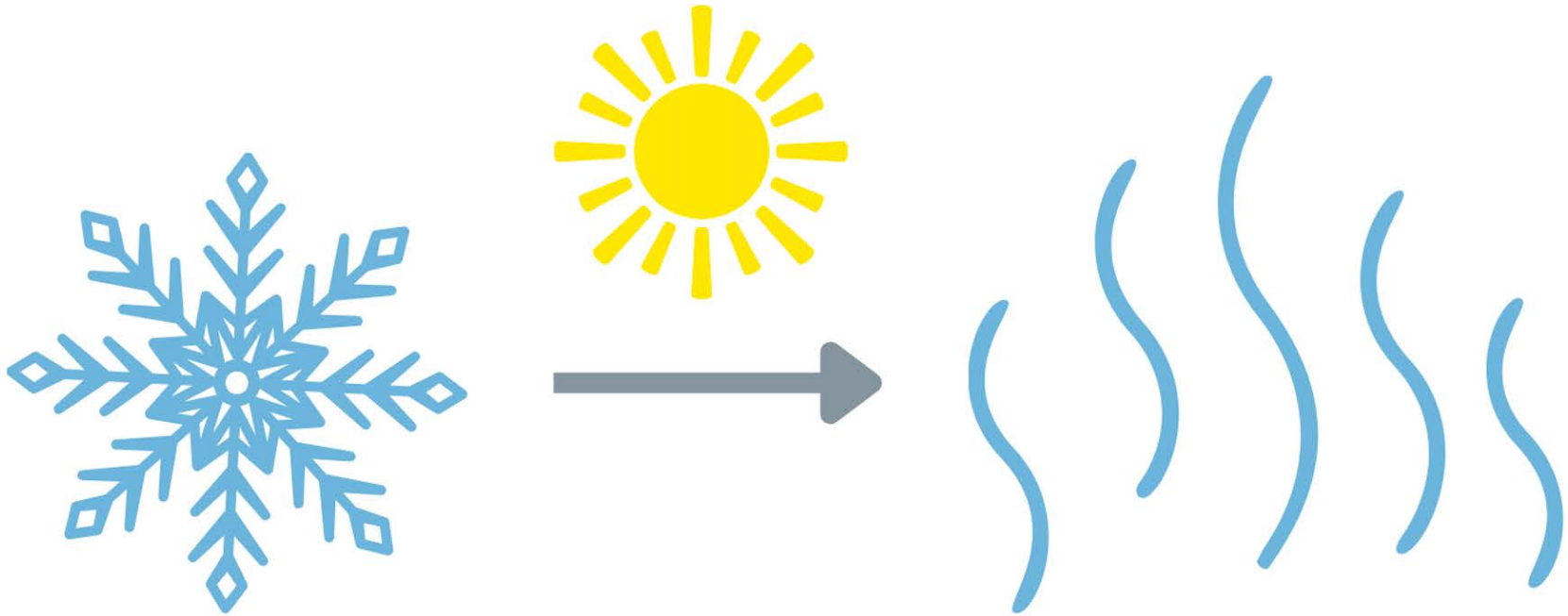

Zhang et al. 2024

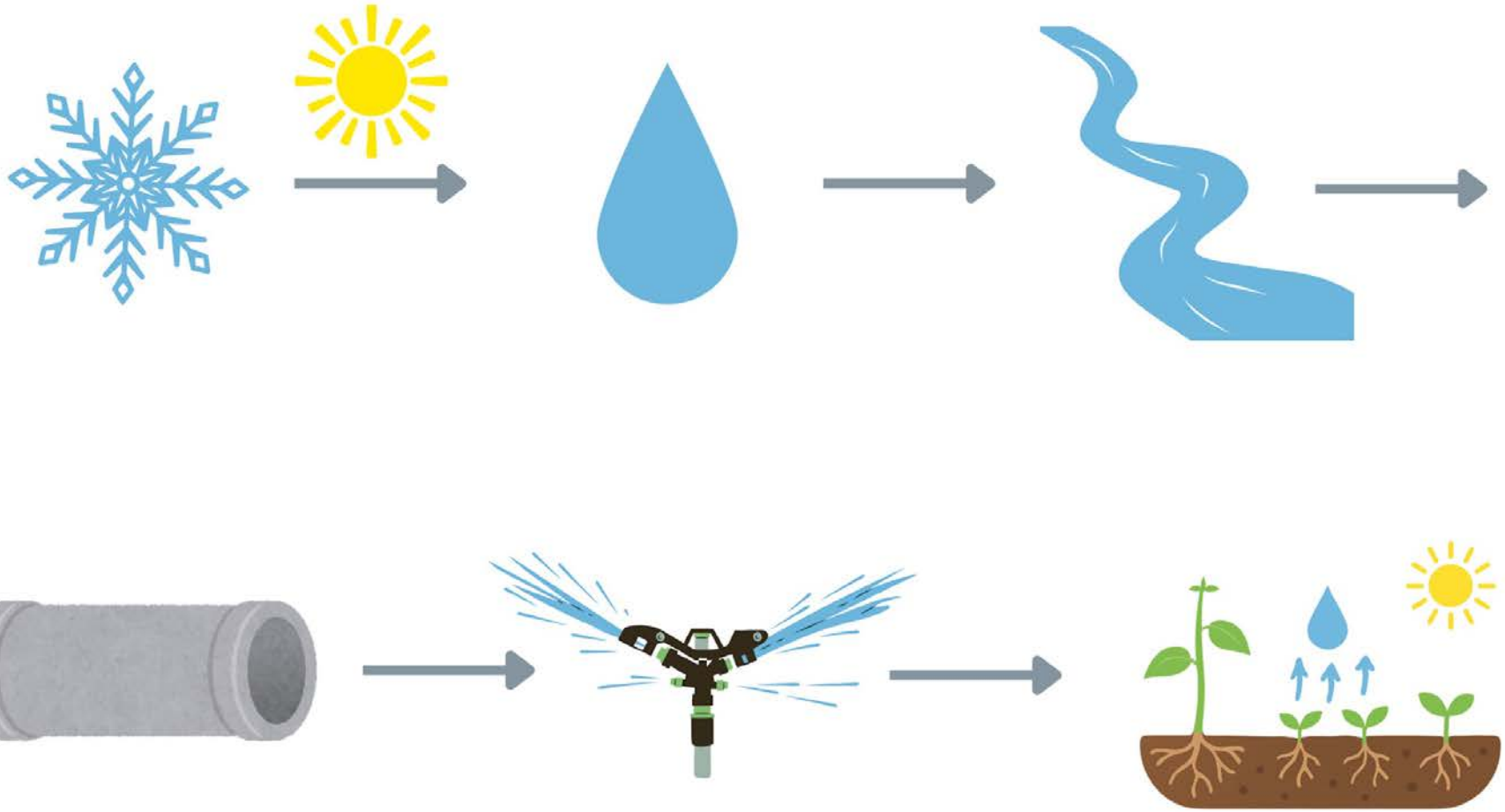
Photo: Z Freed

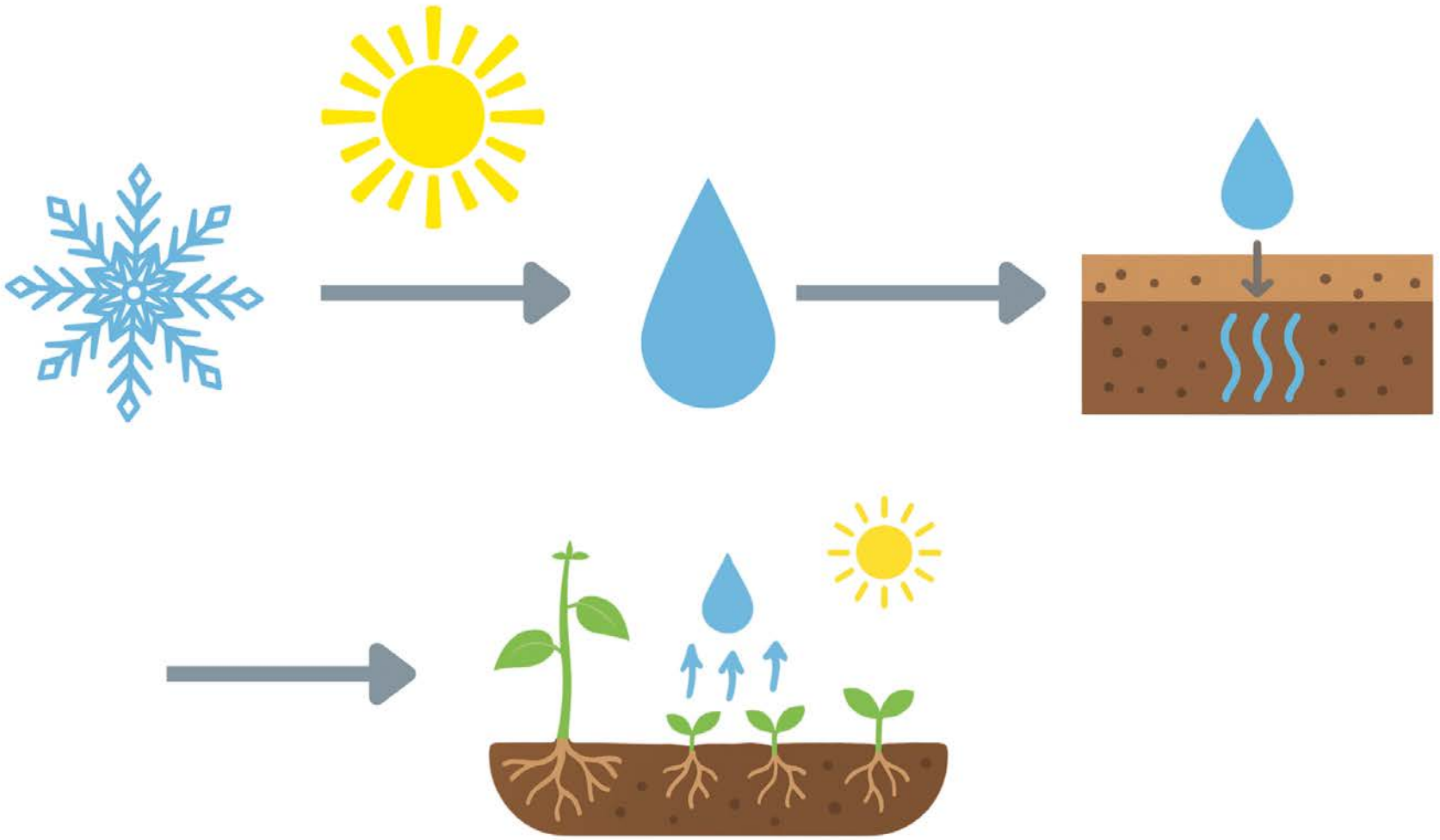
# Sublimation & Open-Water Evaporation

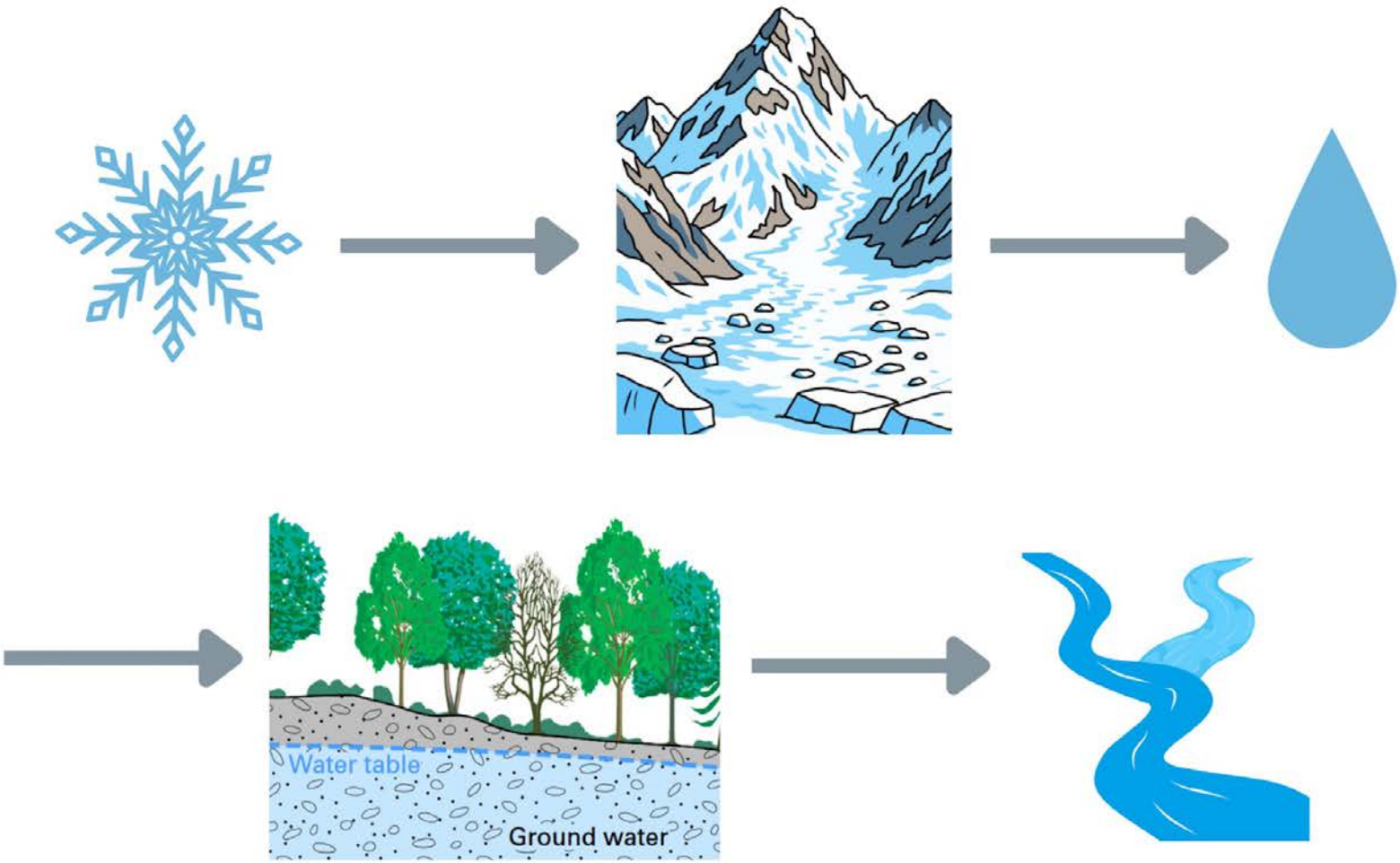


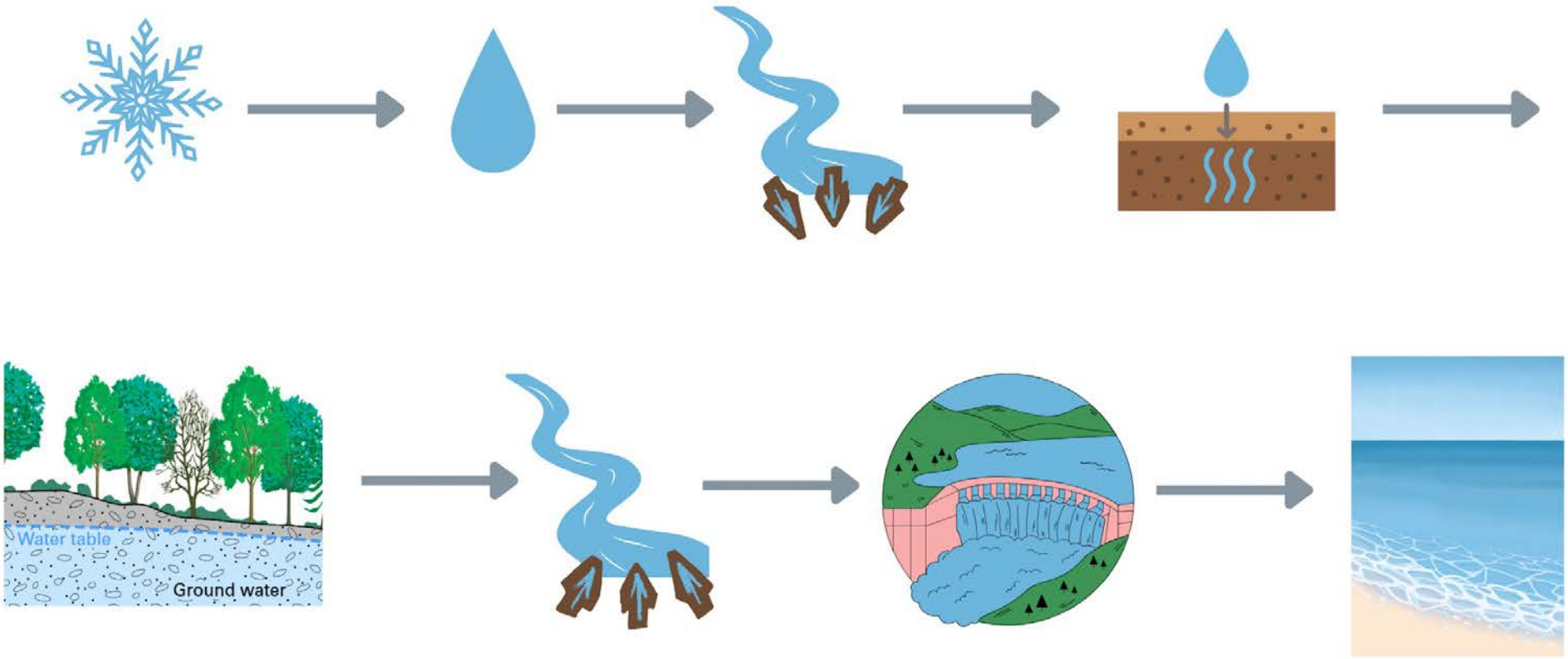
Photos: Z Freed



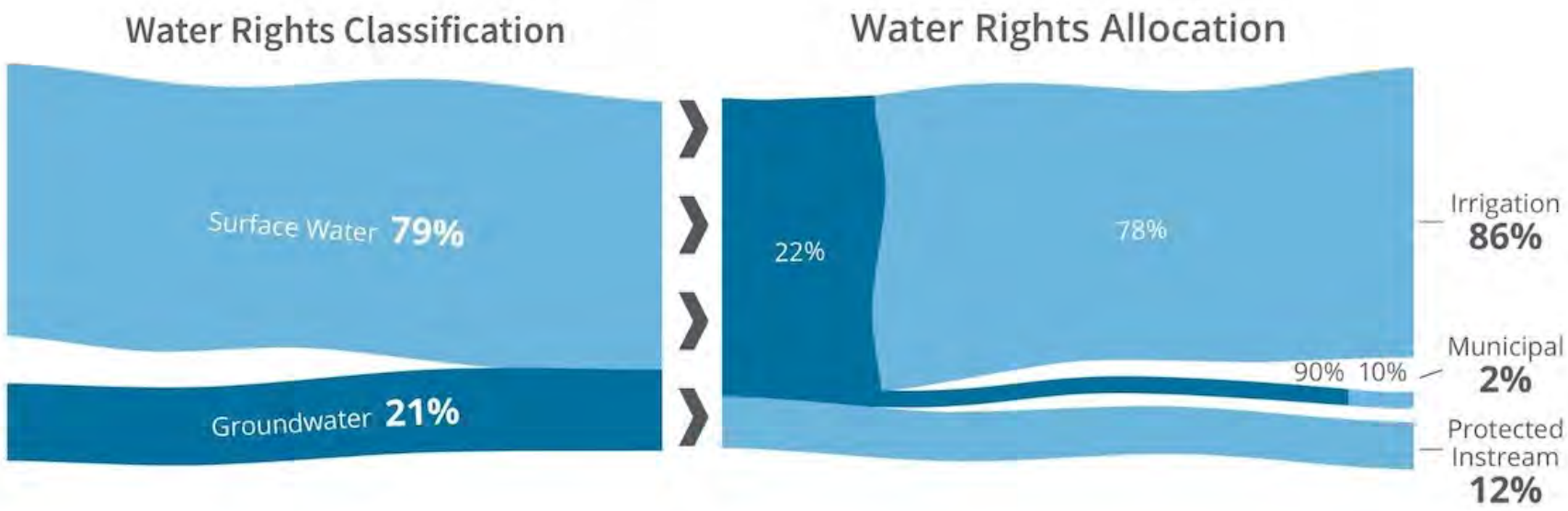





Water table
Ground water


Water table
Ground water

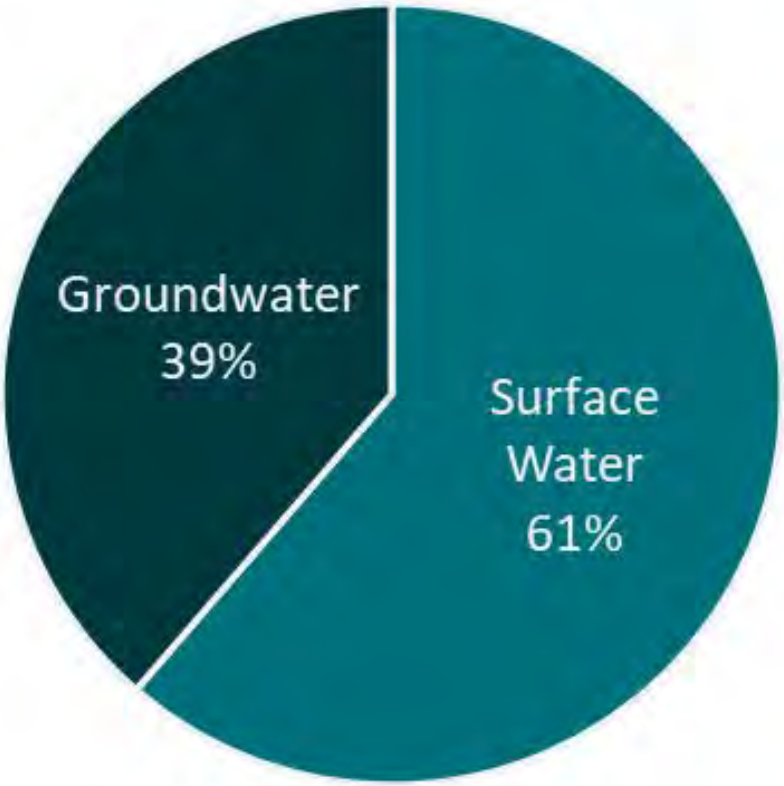
# Water Rights in the Deschutes Basin Above Lake Billy Chinook

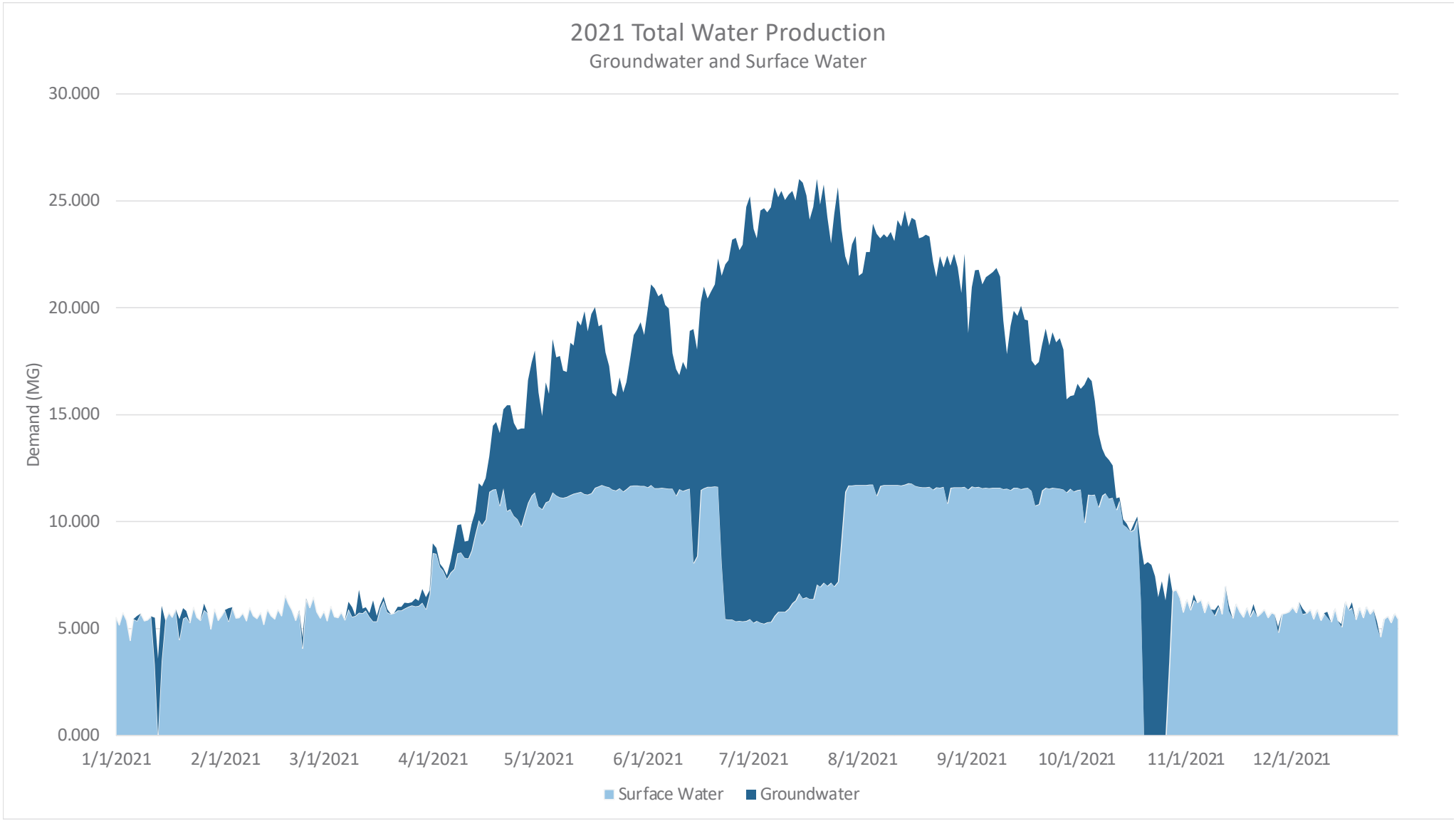



DESCHUTES RIVER CONSERVANCY

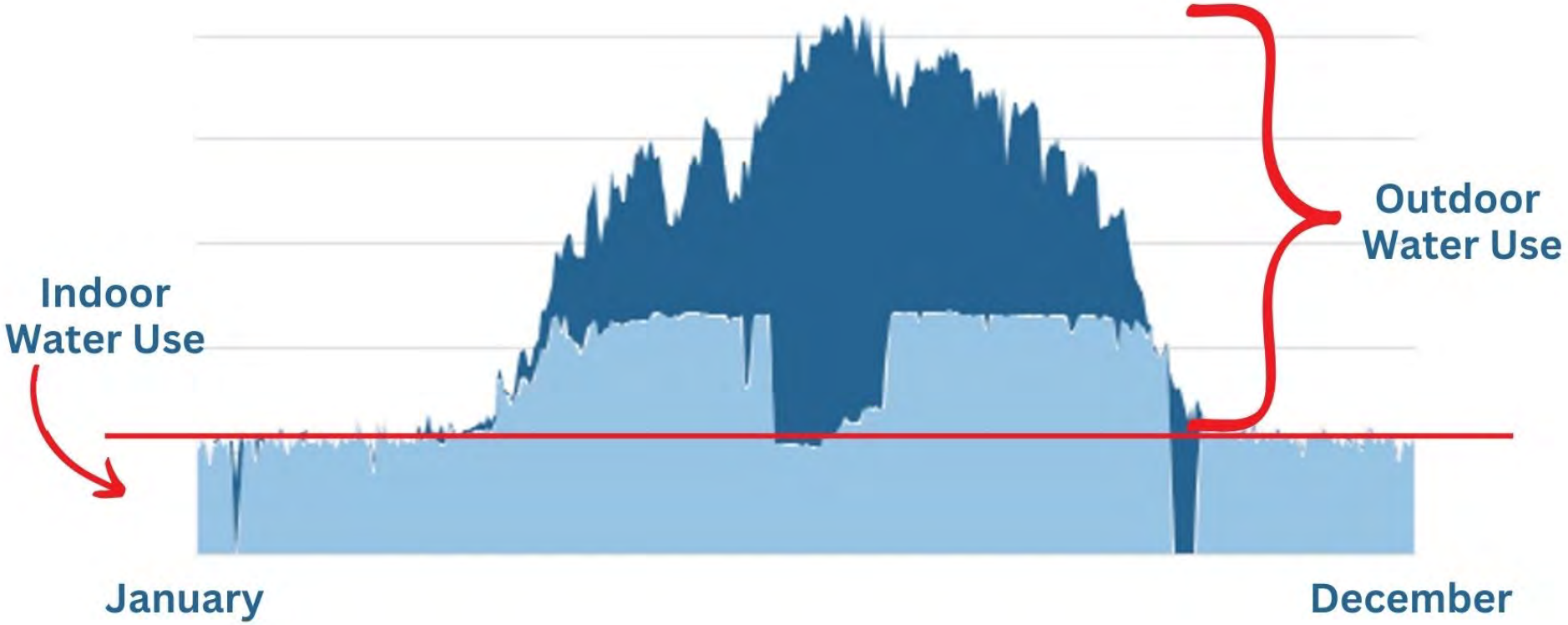
Source: Upper Deschutes Basin Study, 2018

# Bend's Dual Water Supply

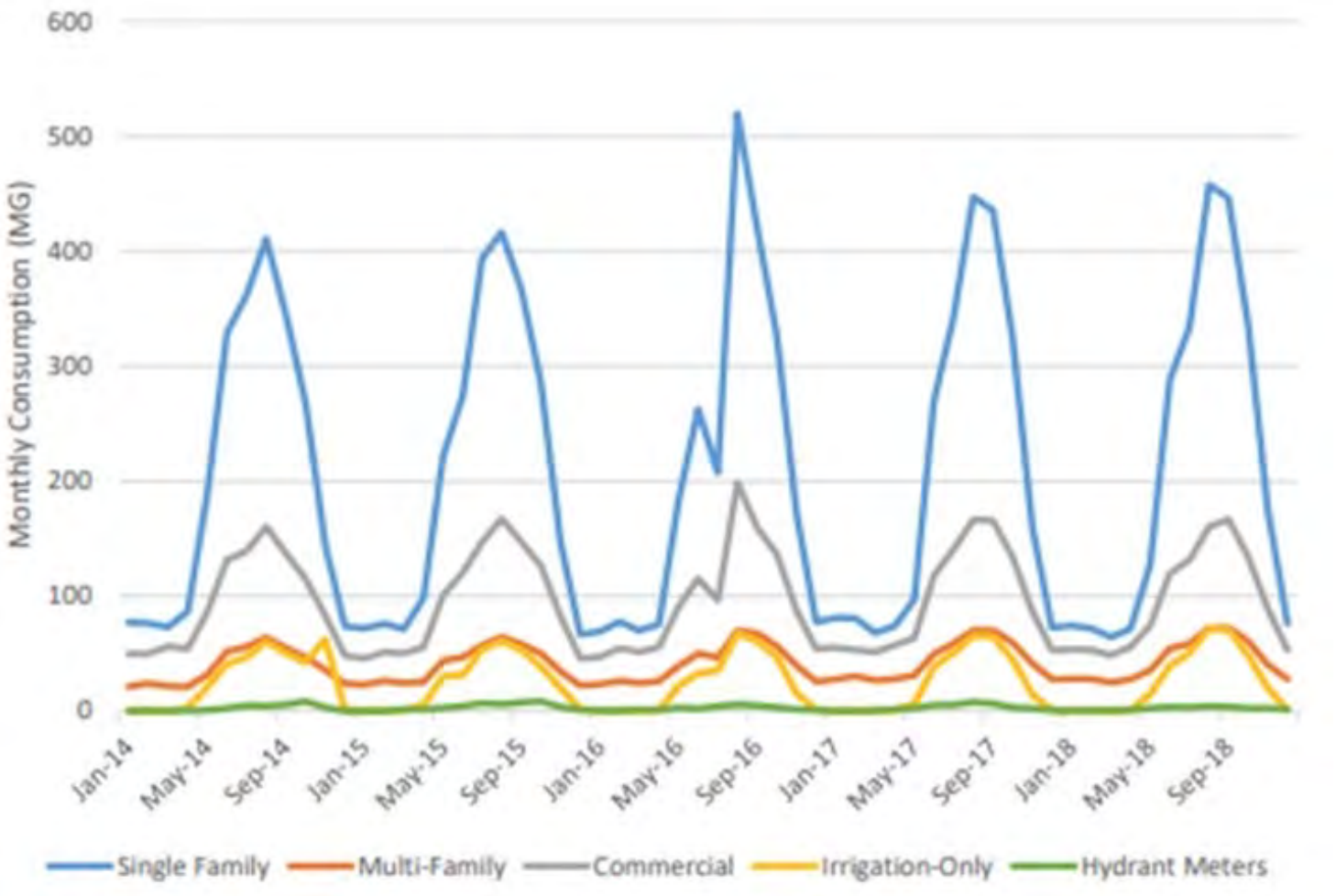



2021 Total Water Production
Groundwater and Surface Water
30.000
25.000
20.000
15.000
10.000
5.000
0.000
Demand (MG)
1/1/2021
2/1/2021
3/1/2021
4/1/2021
5/1/2021
6/1/2021
7/1/2021
8/1/2021
9/1/2021
10/1/2021
11/1/2021
12/1/2021
Surface Water
Groundwater

# City of Bend Water Use

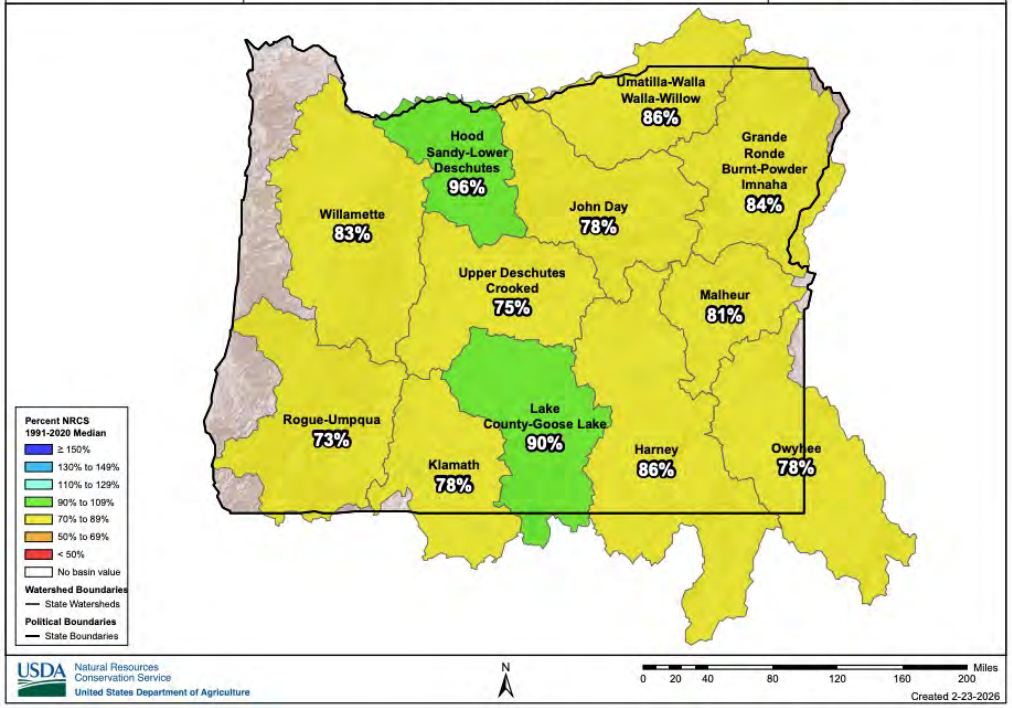


# Patterns of Customer Water Use



# Go Native! Lawns Suck....Water

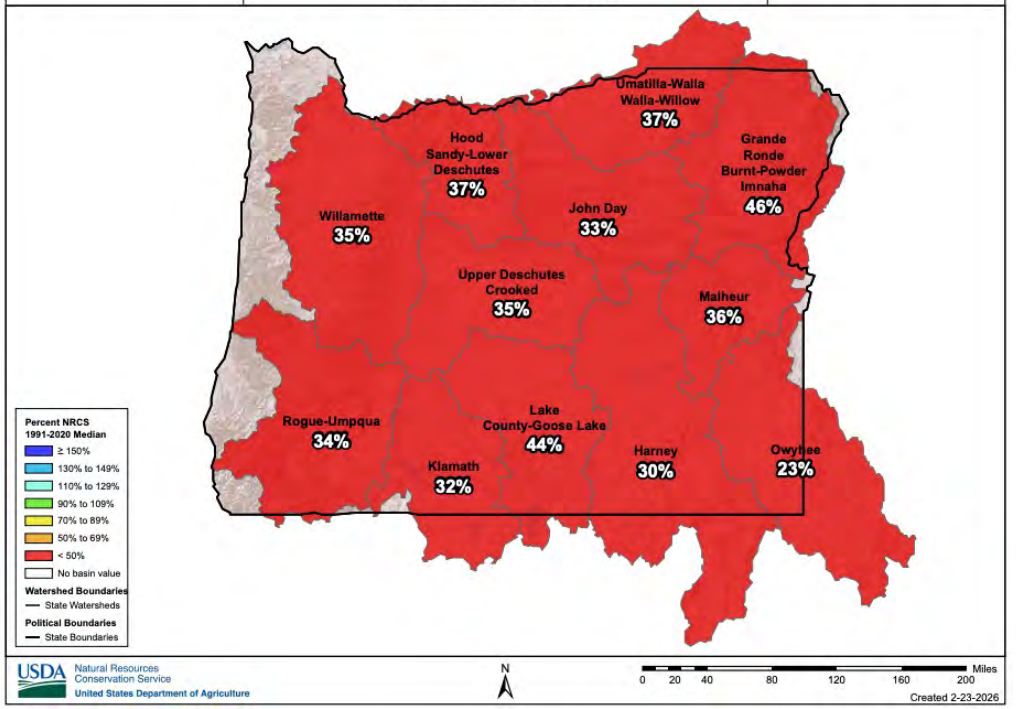
| Water Year to Date Precipitation | Oregon SNOTEL<br>Percent NRCS 1991-2020 Median | October 1, 2025 -<br>February 22, 2026 |
|---|---|---|




USDA Natural Resources Conservation Service
United States Department of Agriculture

Created 2-23-2026

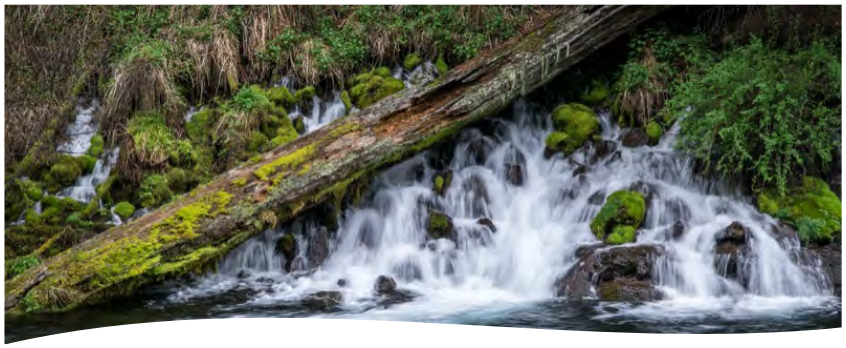
| Snow Water Equivalent | Oregon SNOTEL<br>Percent NRCS 1991-2020 Median | February 22, 2026, end of day |
|---|---|---|




USDA Natural Resources Conservation Service
United States Department of Agriculture

Created 2-23-2026

# Take Home Messages



- Precipitation is the only way water enters the basin
- Water exits the basin through:
  - Runoff
  - Sublimation/Open-Water Evaporation
  - Evapotranspiration
- Streams that are more groundwater dependent are more drought resilient
- Groundwater-dependent streams with long residence times will be the most buffered from drought and climate change