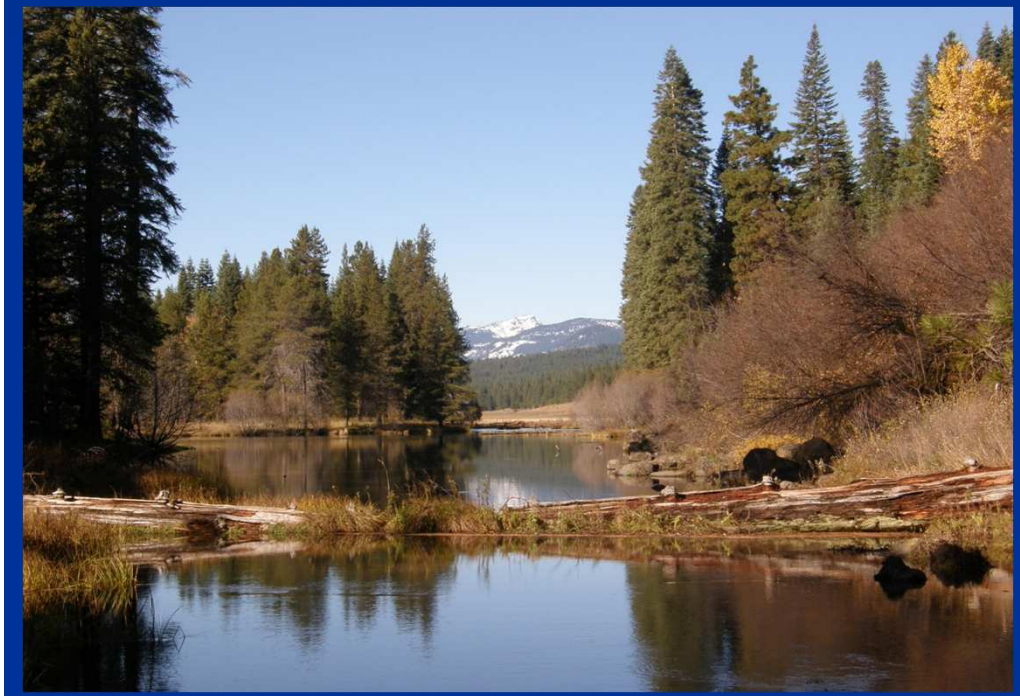
Groundwater Management in the Upper Klamath Basin, Oregon and California, USA:

Balancing the Benefits of Groundwater for Agriculture and Wildlife



Brian J. Wagner and Marshall W. Gannett
U.S. Geological Survey

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Acknowledgements

- Oregon Water Resources Department
- Klamath Water and Power Authority
- Bureau of Reclamation
- California Department of Water Resources

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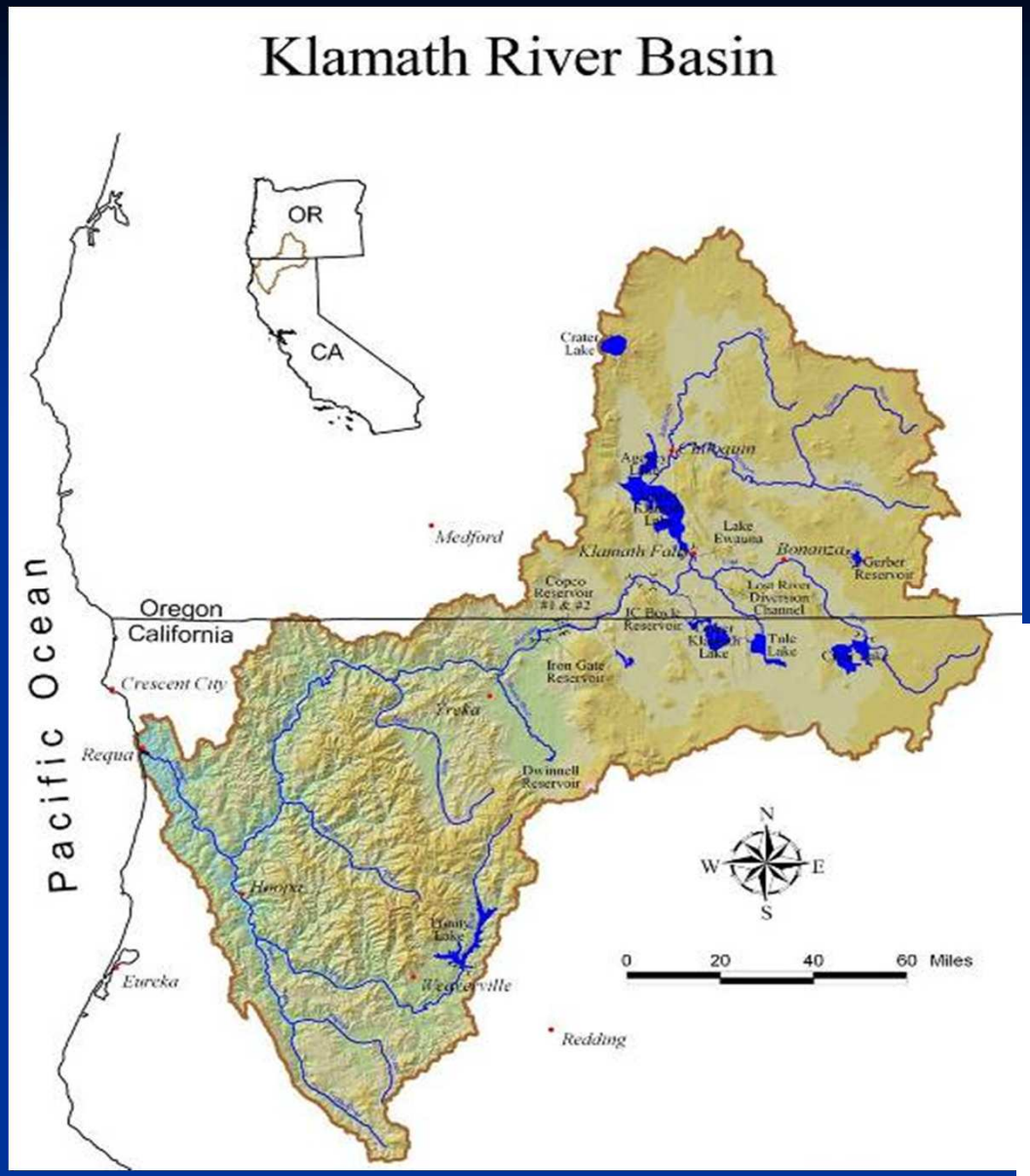
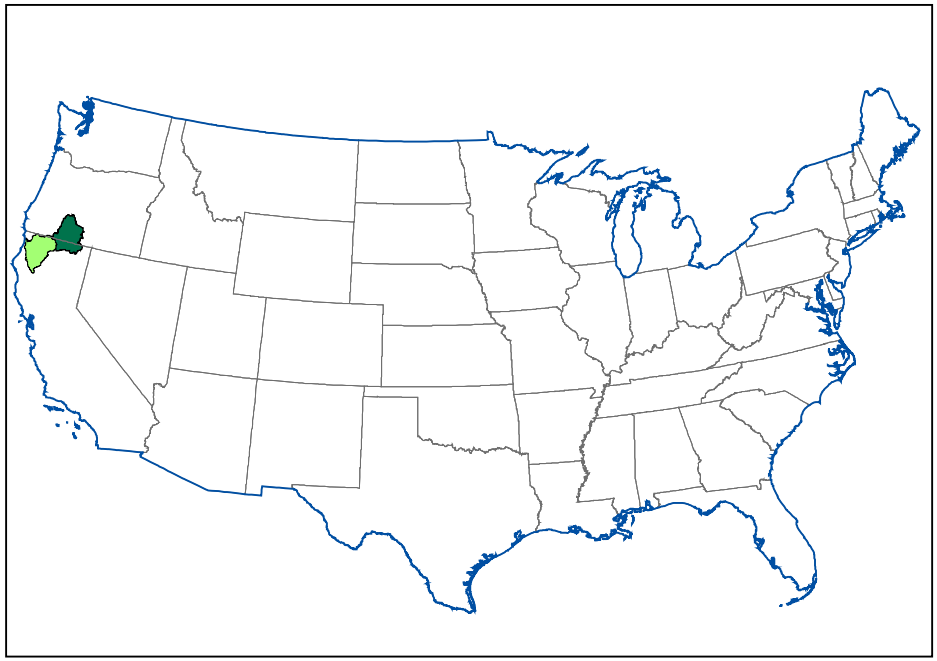


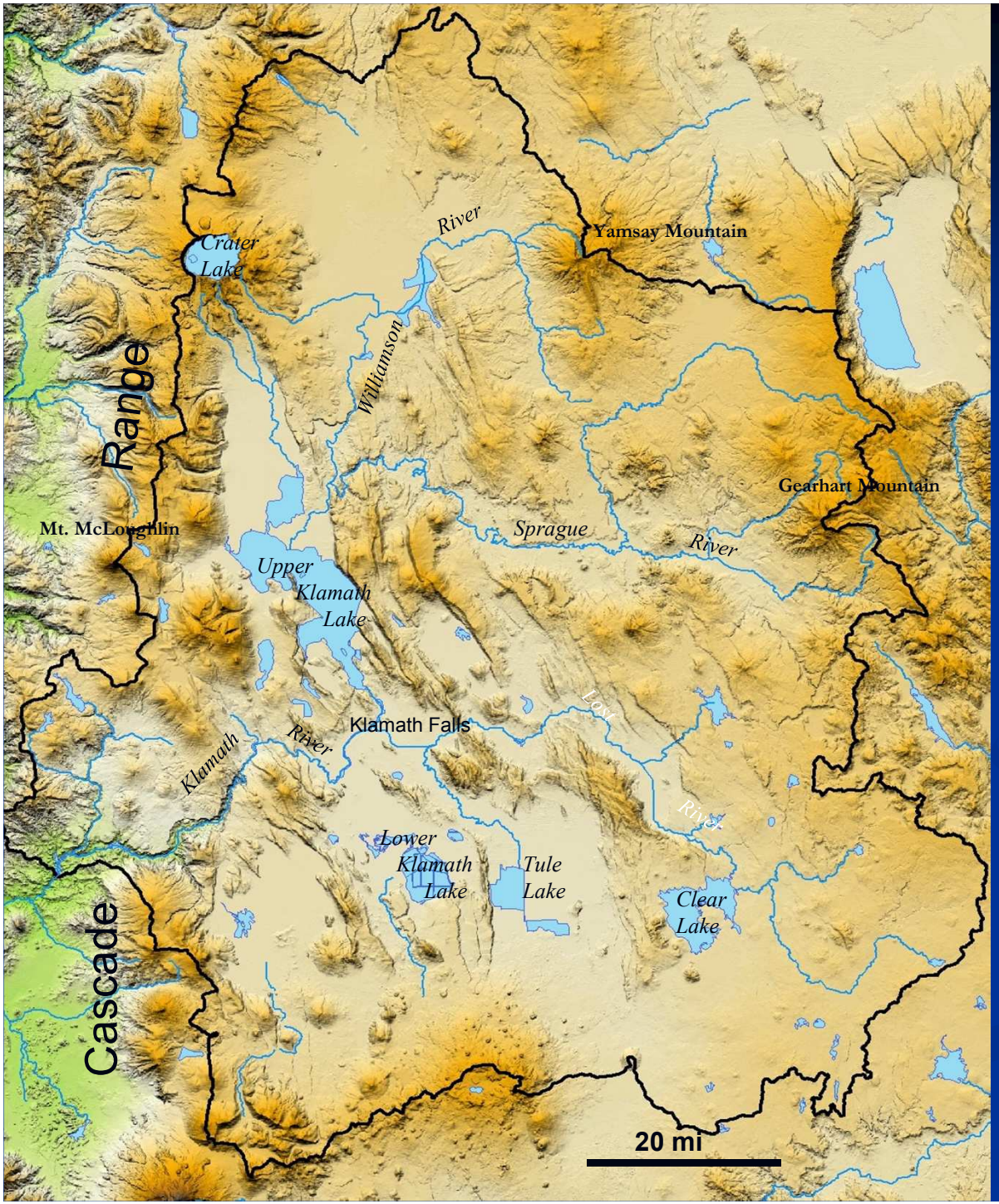
Klamath Basin

15,700 mi^2 total area

Upper Klamath Basin

8,000 mi^2 above Iron Gate Dam

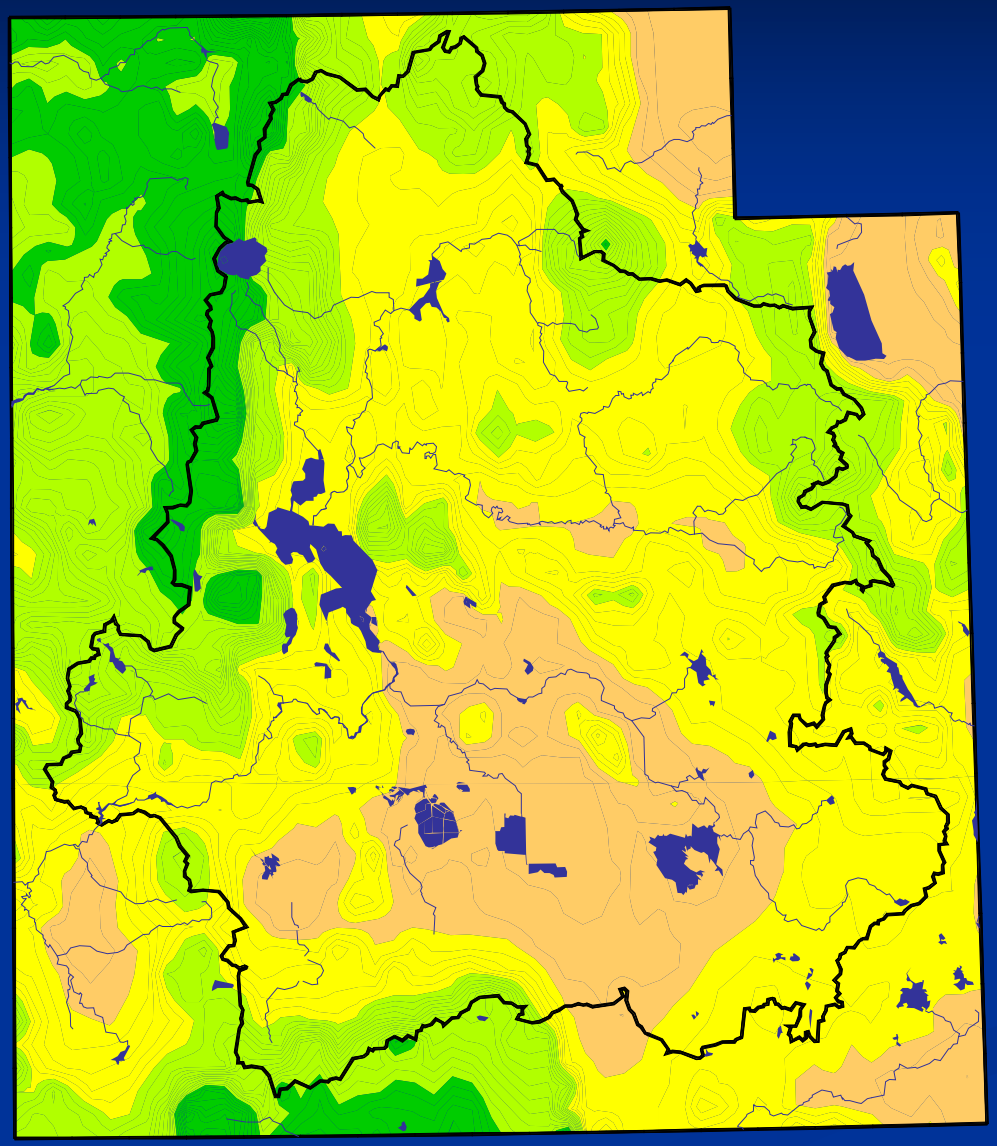




Overview

The physical geography of the basin is dominated by volcanic uplands and structurally-controlled sedimentary basins

Precipitation in the Upper Klamath Basin



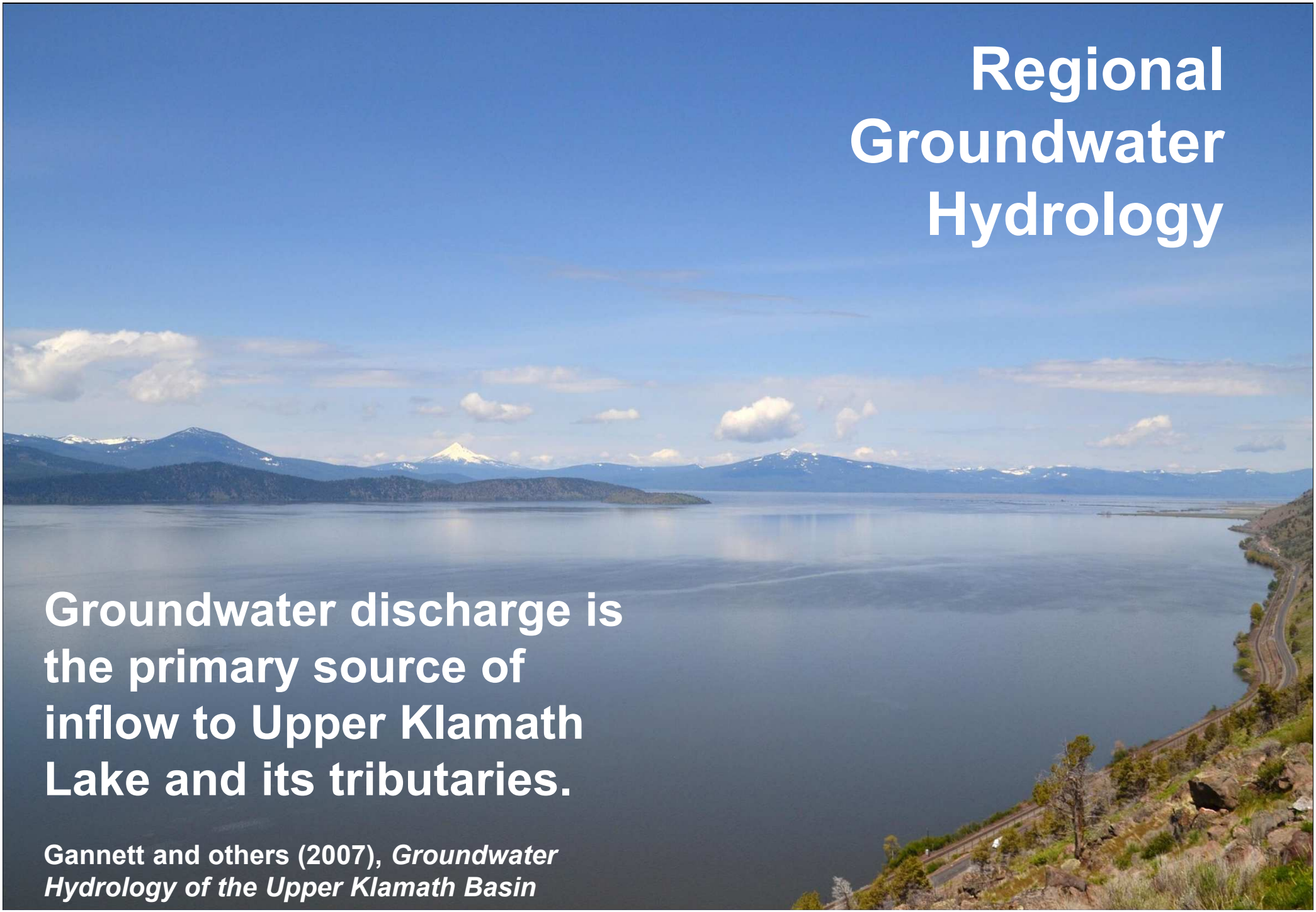
> 50 inches

25-50 inches

15-25 inches

< 15 inches

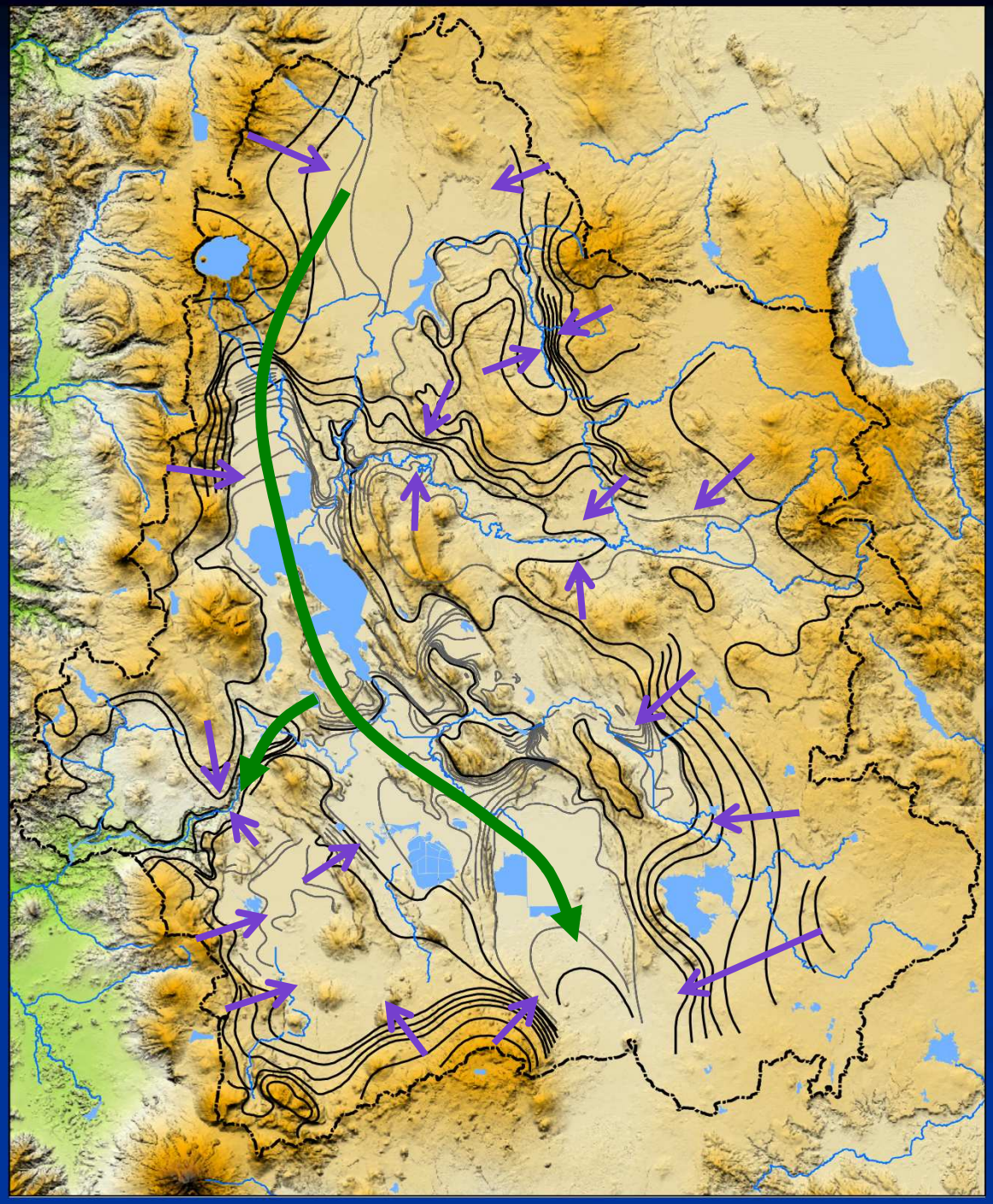
- Average precipitation is about 10 million acre-ft/yr.
- About 2 million acre-ft/yr enter the groundwater system.
- Mean annual discharge at Iron Gate Dam is about 1.5 million acre-ft/yr.



Regional Groundwater Hydrology

Groundwater discharge is the primary source of inflow to Upper Klamath Lake and its tributaries.

Gannett and others (2007), *Groundwater Hydrology of the Upper Klamath Basin*

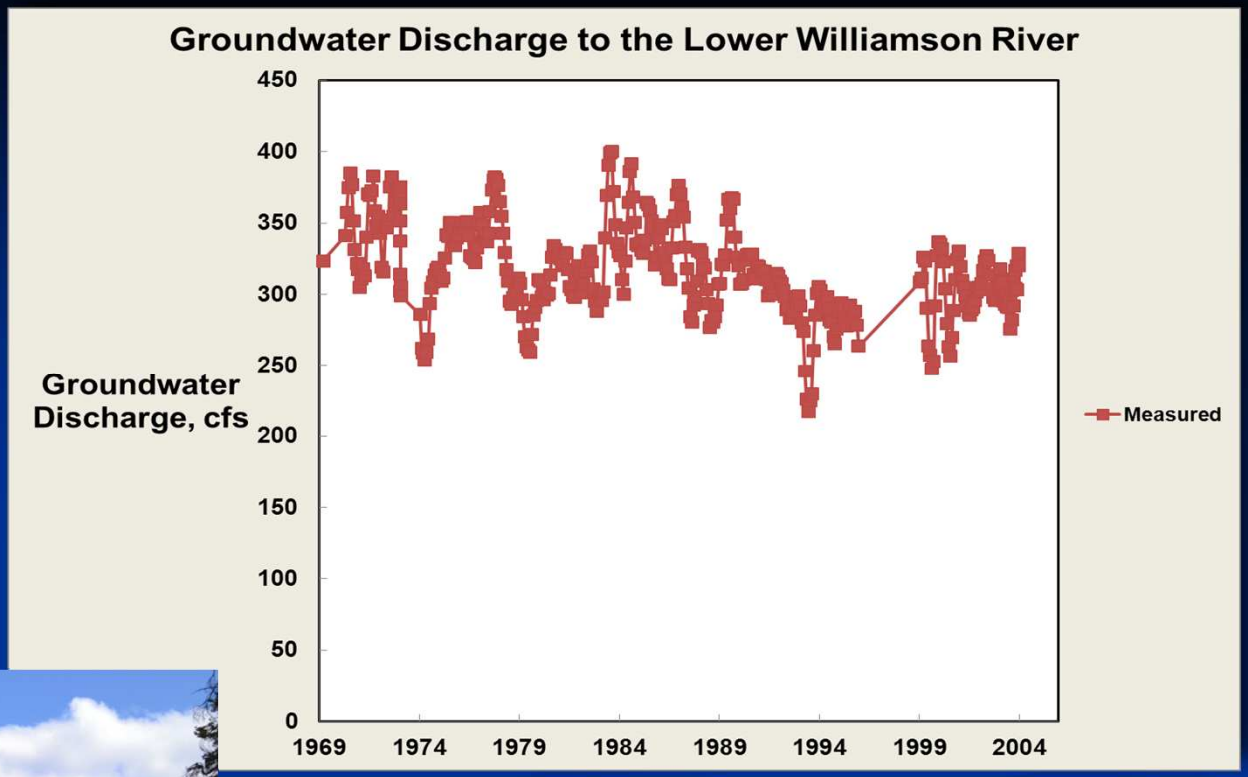


Groundwater Flow Directions

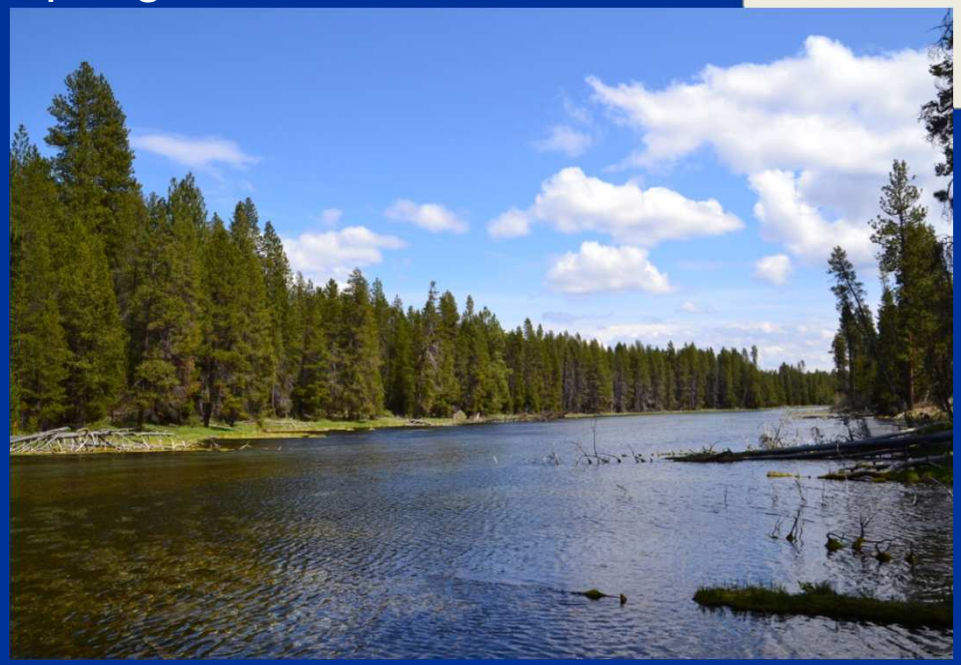
- From uplands toward basin interior
- Toward major stream valleys
- North to south regional flow

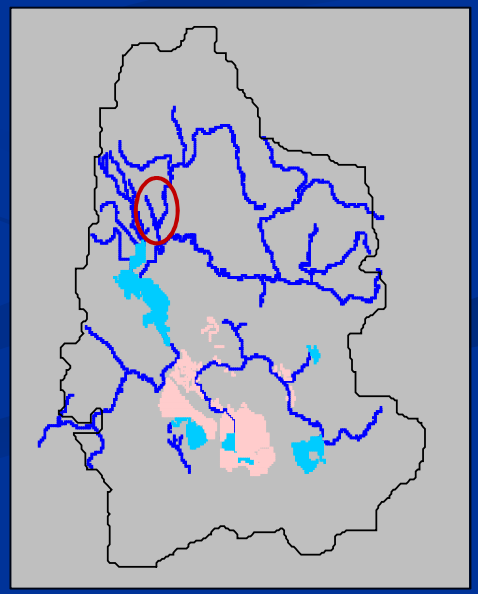
Black contours 100 ft
Gray contours 20 ft

Groundwater Discharge to Streams

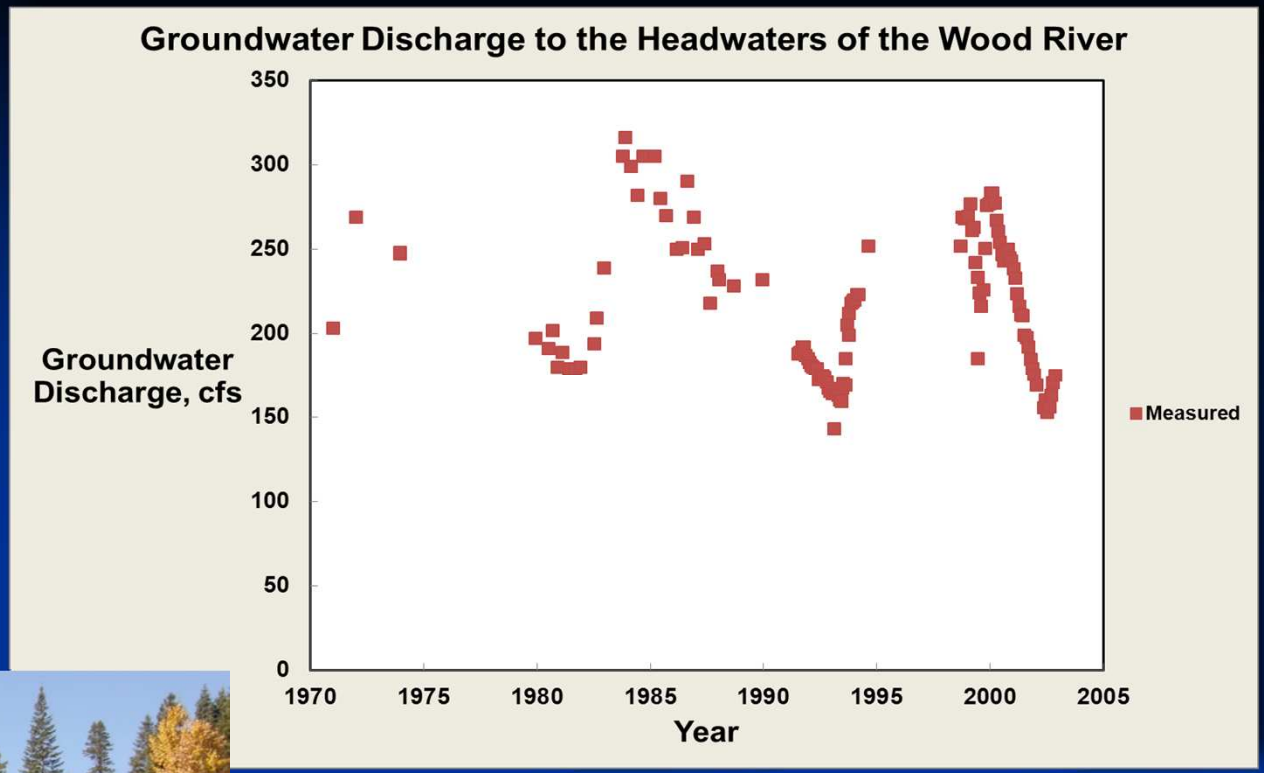


Spring Creek Headwaters

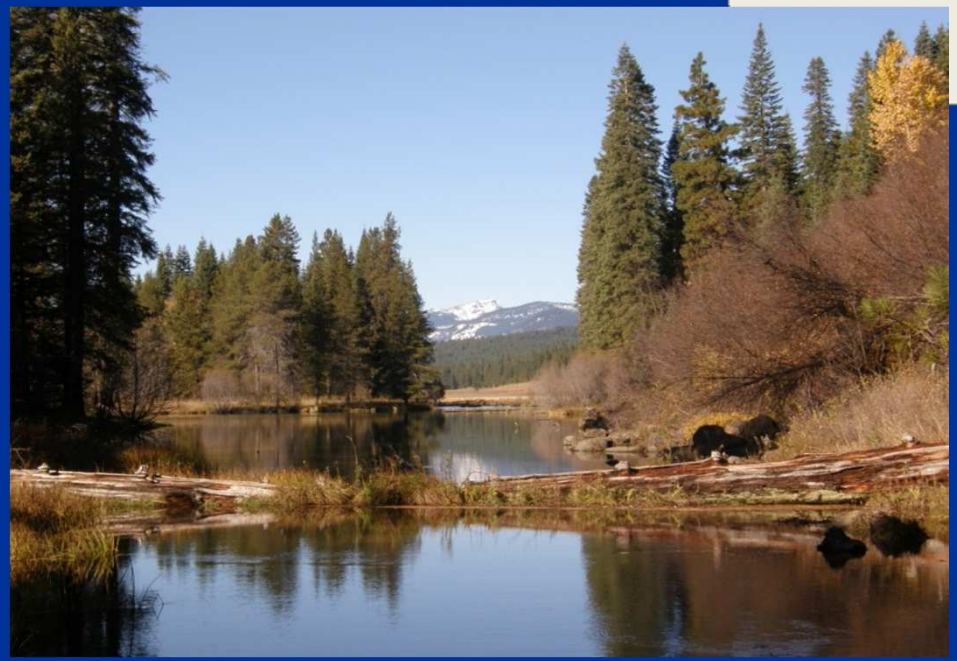


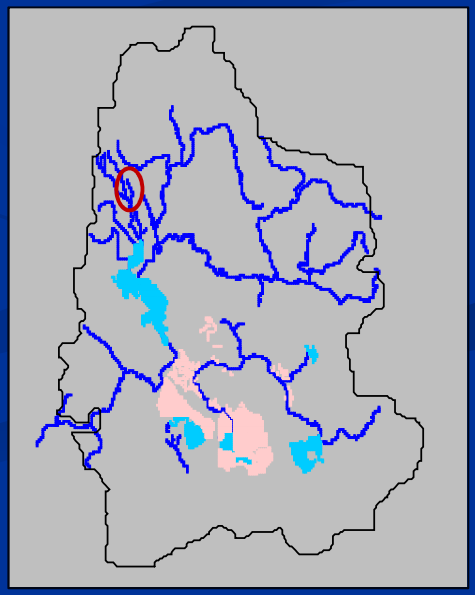


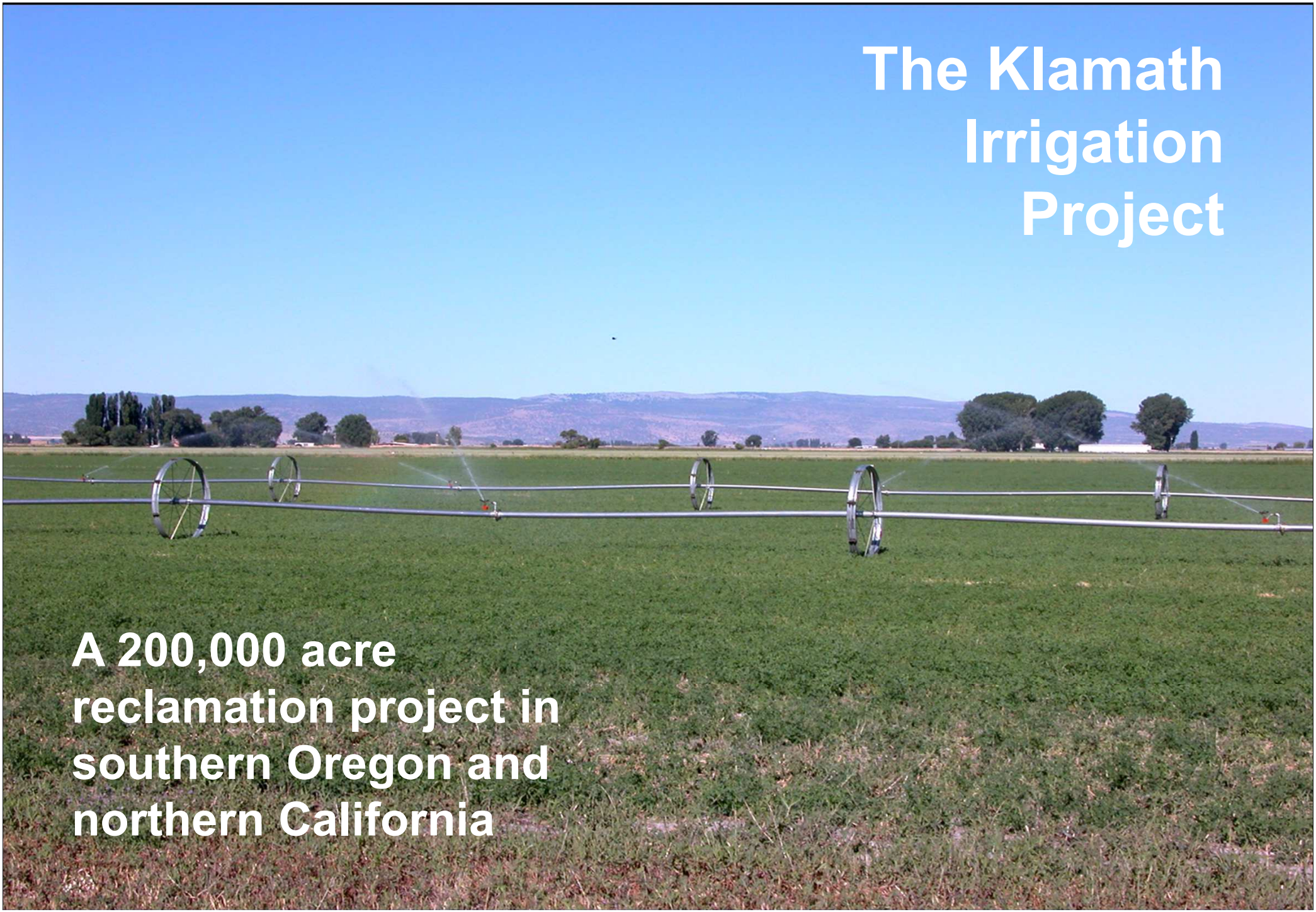
Groundwater Discharge to Streams



Wood River Headwaters



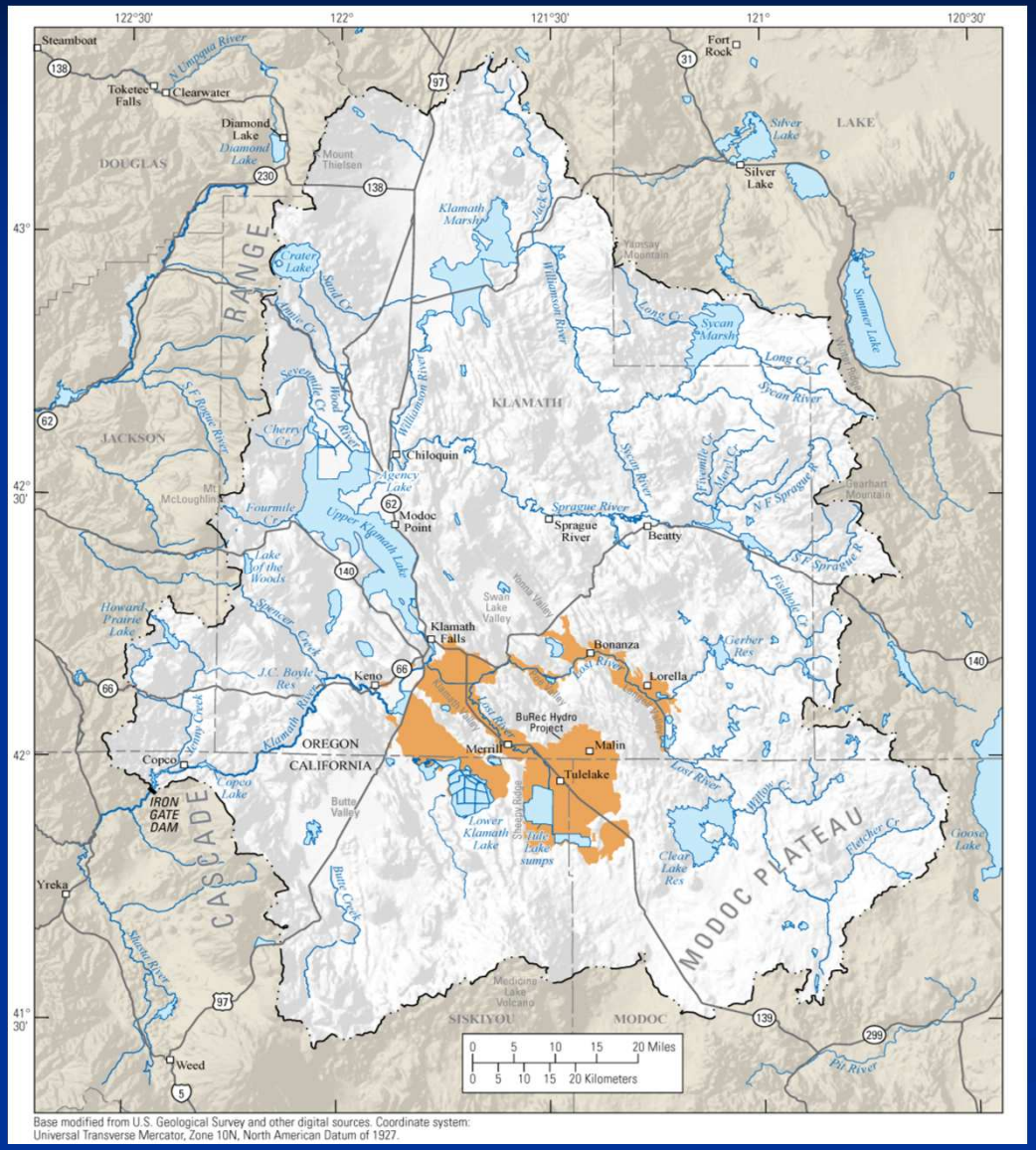



The Klamath Irrigation Project
A 200,000 acre reclamation project in southern Oregon and northern California

Klamath Irrigation Project

- 1905 – Project construction begins
- Homesteading begins in 1917 and ends in 1949.
- 1400 farms and 200,000 acres – primarily alfalfa, irrigated pasture, small grains, potatoes, onions.

Klamath Irrigation Project



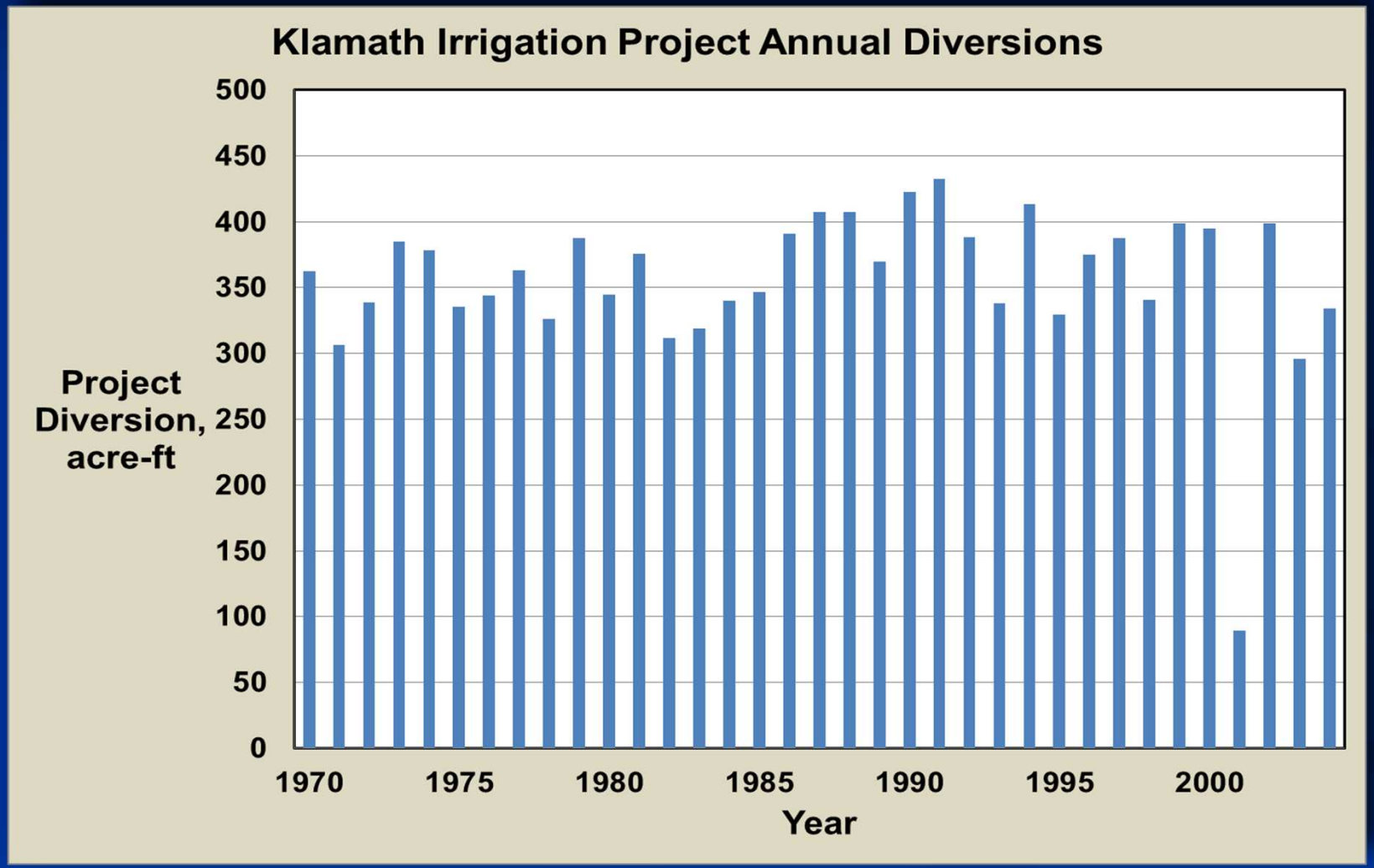
Shallow lakes and wetland complexes have been extensively reclaimed for agriculture.

The challenge is to balance the benefits of water for:

1. Endangered fish in Upper Klamath Lake and the Klamath River.

2. Reclamation project irrigators and wildlife refuges.

Klamath Project Annual Diversions from Upper Klamath Lake



Note: 1 acre-ft ~ 1200 m^3

Plenty of local links action ... Sports, B1 and B2

FRIDAY-SATURDAY

Herald and News

www.heraldandnews.com

Weather

Mostly cloudy , chance of snow showers. Highs near 40 Saturday.

Details, page B8.

April 6, 2001— No. 19,739 | Klamath Falls, Oregon | 50 Cents

No water for most farmers

Thousands of acres will go dry for benefit of fish

By JOHN BRAGG
H&N Staff Writer

Federal officials today announced that no water will be available from Upper Klamath Lake to supply farmers of the Klamath Reclamation Project.

However, Bureau of Reclamation officials said, about 70,000 acre-feet of water from other sources will be available for irrigation of lands on the east side of the project. That includes Horsefly and Langell Valley irrigation districts, according to Dave Solem, director of the Klamath Irrigation District.

H&N photo by Gary Thain

Hank's Marsh lies saturated on the east side of Upper Klamath Lake in this photo taken Thursday. Water in the lake will be conserved to keep marshes flooded this summer, while no water from the lake will be diverted for agricultural use.

made with the approval of Vice President Dick Cheney, who has been "personally

opinion from the National Marine Fisheries Service, released today, reflects the

U.S. Fish and Wildlife Service office in Klamath Falls, said the sucker opinion

"It provides us with the opportunity to operate the project without jeopardizing

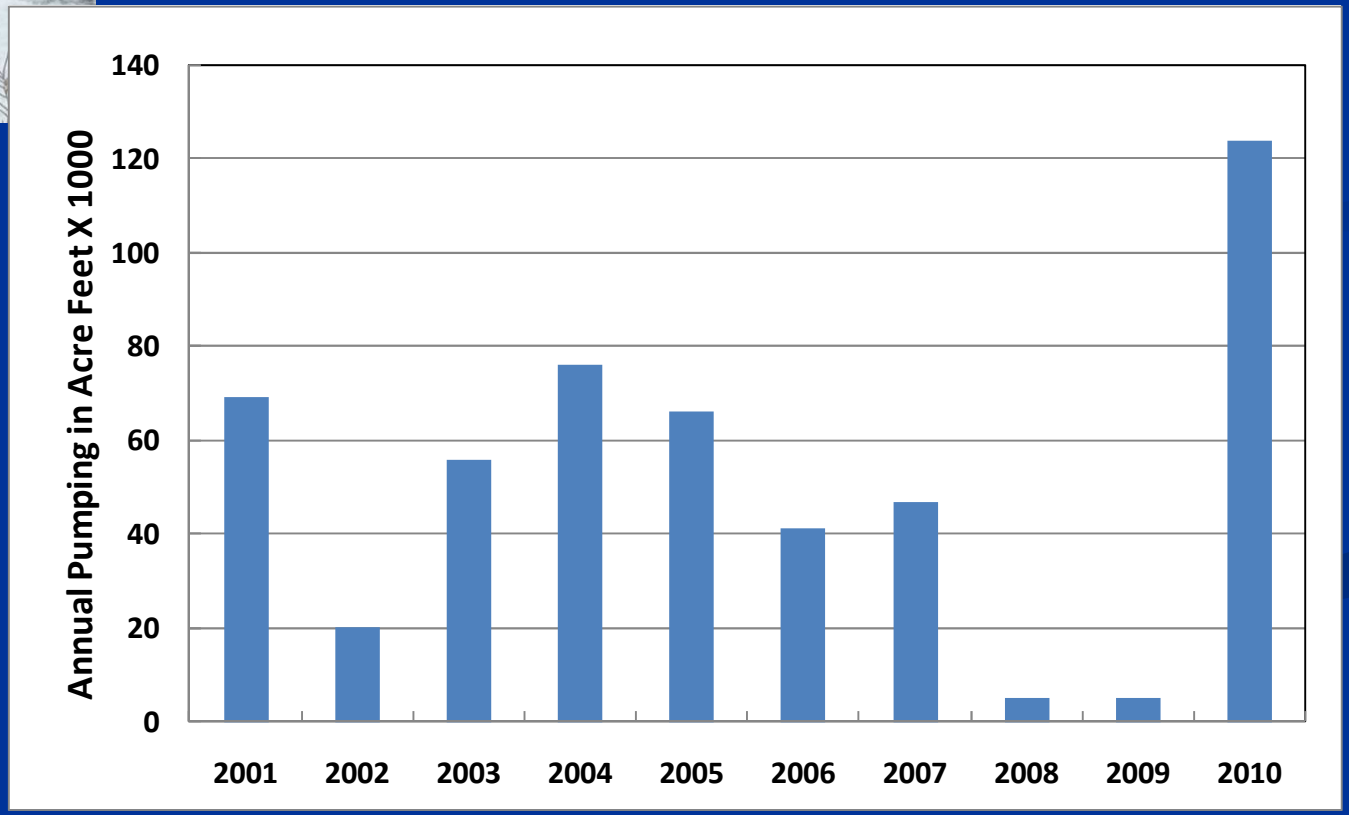
spokesman for Walden, said there was little to do now but try to minimize the damage.

The announcement included word from the Department of Agriculture that most crops in the affected area are eligible for crop insurance or other assistance, including "prevented planting" payments for farmers who purchased crop insurance before the drought was declared. Farmers should contact their crop insurance agents for details, Reclamation officials said.

Sen. Gordon Smith will be in Klamath Falls Saturday morning for a town hall meeting at 10:30 a.m. at the Shilo Inn. Afterwards he will have lunch privately with the Klamath Water Users Association and community leaders. Chris Mathews, Smith's spokesman, said the agenda for the meeting was not yet finalized.

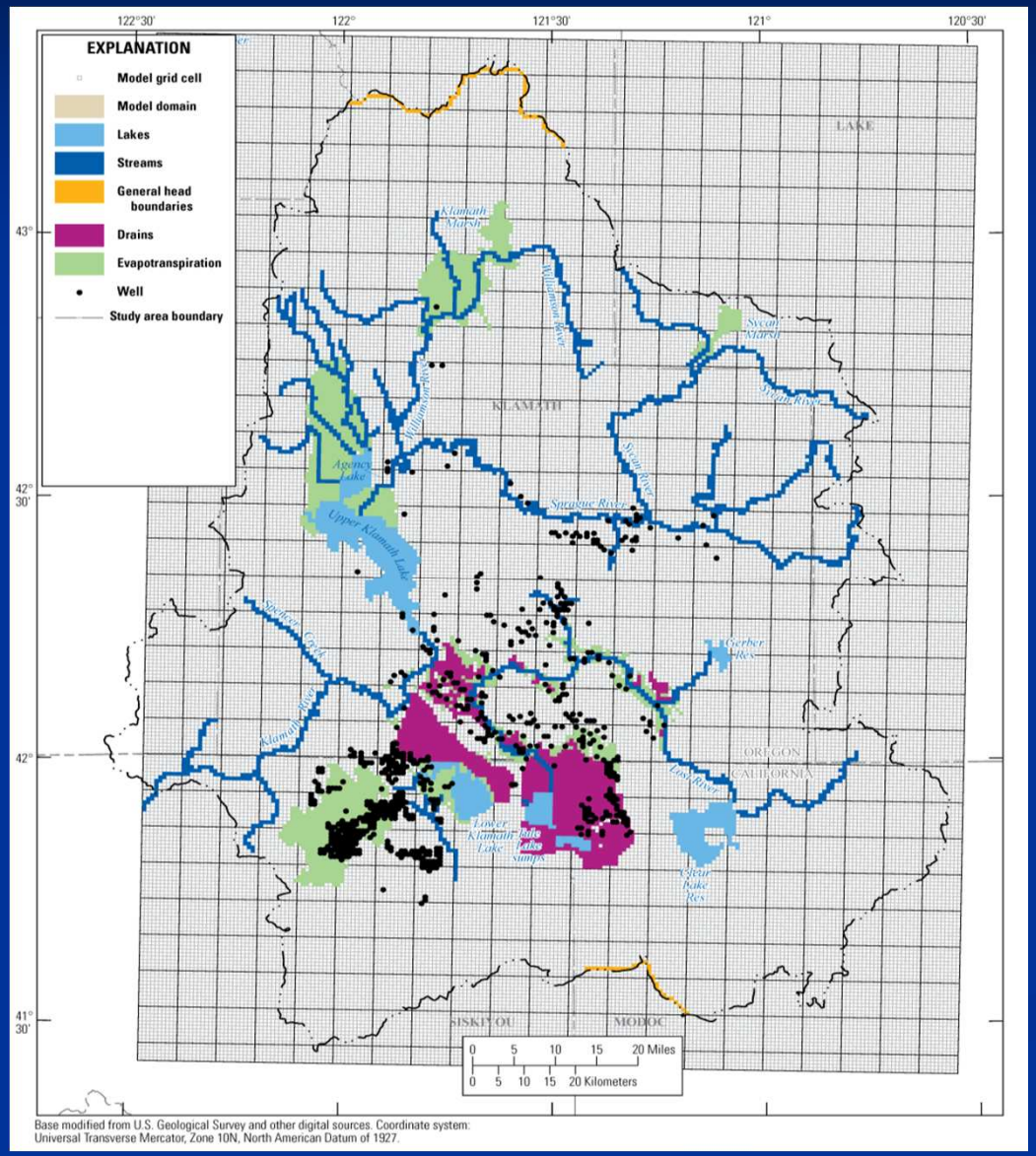
Don Russell, chairman of the Klamath Water Users

Supplemental Irrigation Pumping in the Upper Klamath Basin



Pre-2001 pumping in the basin was 150,000 acre-feet.

Upper Klamath Basin Groundwater Management Model



- **Fully incorporates all of the complexities of the groundwater system**
  - **Streams**
  - **Lakes**
  - **Drains**
  - **ET**
  - **Off-project pumping**

Gannett and others (2012), ***Groundwater Simulation and Management Models for the Upper Klamath Basin, Oregon and California***

Groundwater Management Model

- The groundwater management model links the upper Klamath Basin groundwater flow model with techniques of optimization.
- The management model uses a mathematical formulation of groundwater-development goals (objective function) and a set of constraints that limit those goals.
- The technique of sequential linear programming used to solve the nonlinear groundwater management problem.
- Sensitivity analyses allow us to evaluate the tradeoffs between management goals and constraints.

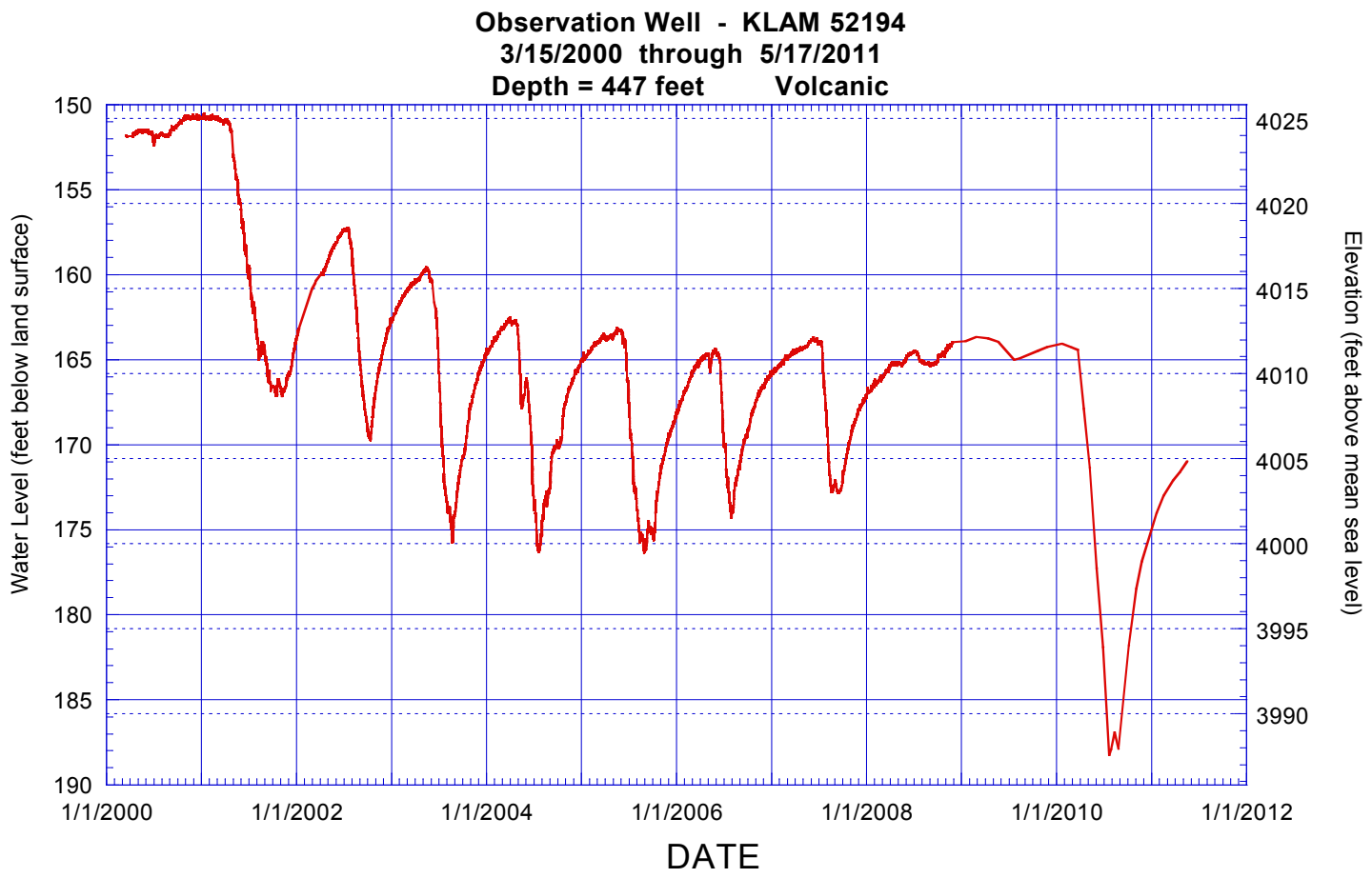
Basic Science Question

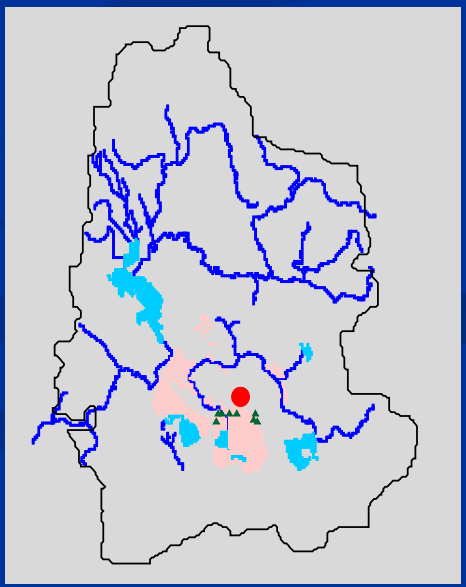
- How can groundwater be used as part of an overall water-management strategy in the upper Klamath Basin?
- We must account for and control adverse impacts to:
  - Aquatic habitat (KBRA).
  - Existing groundwater users (OWRD).
  - Klamath Project operation (KWAPA).

Klamath Basin Restoration Agreement

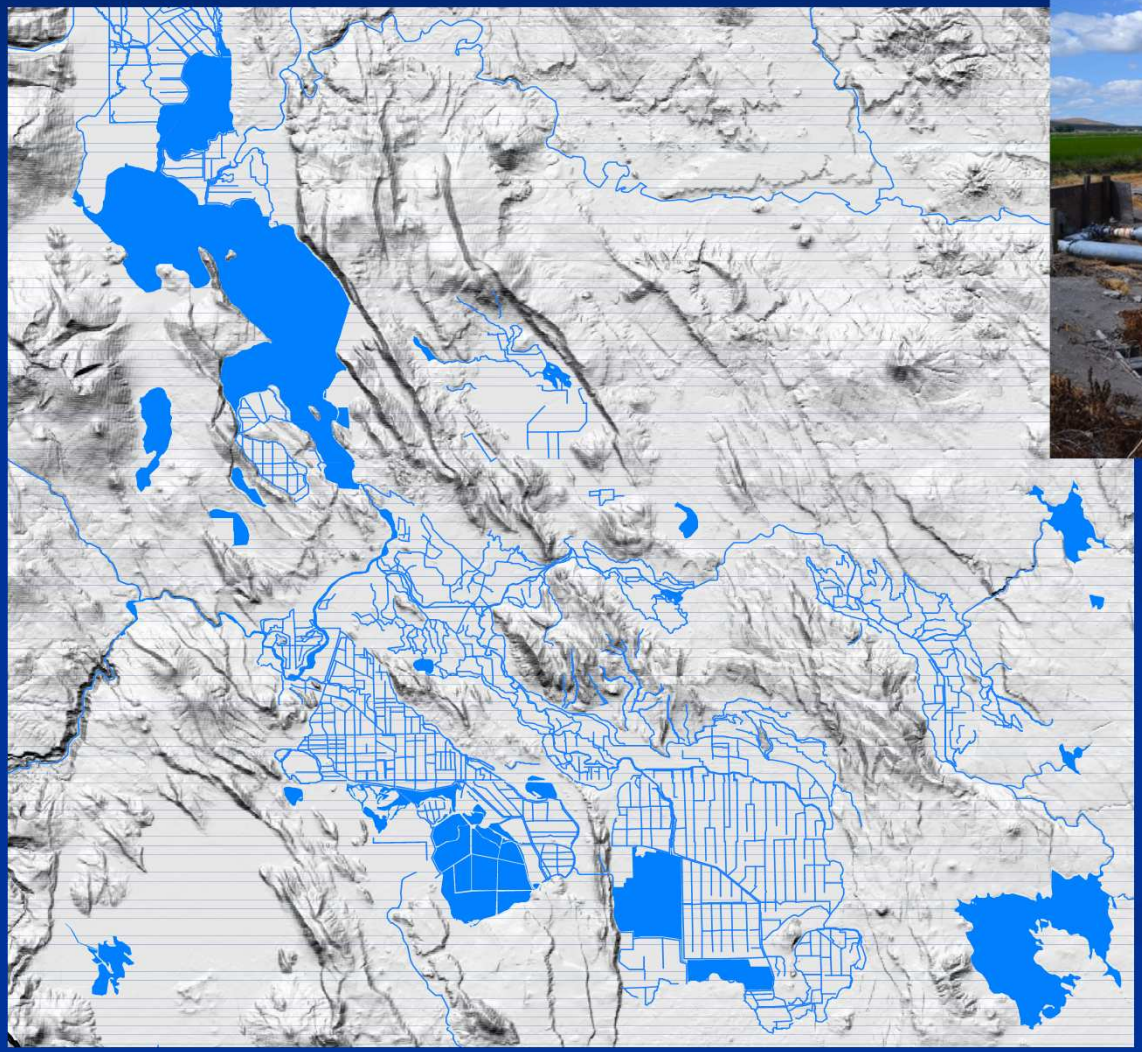
- Developed by a large group of stakeholders including Federal, State, and county agencies, Indian tribes, irrigators, ocean fishing and conservation groups.
- The goal is to restore fish habitat and populations in the basin and establish reliable water supplies for irrigation.
- Limits reductions of groundwater discharge to streams, springs, and lakes due to groundwater pumping to six percent of baseline.

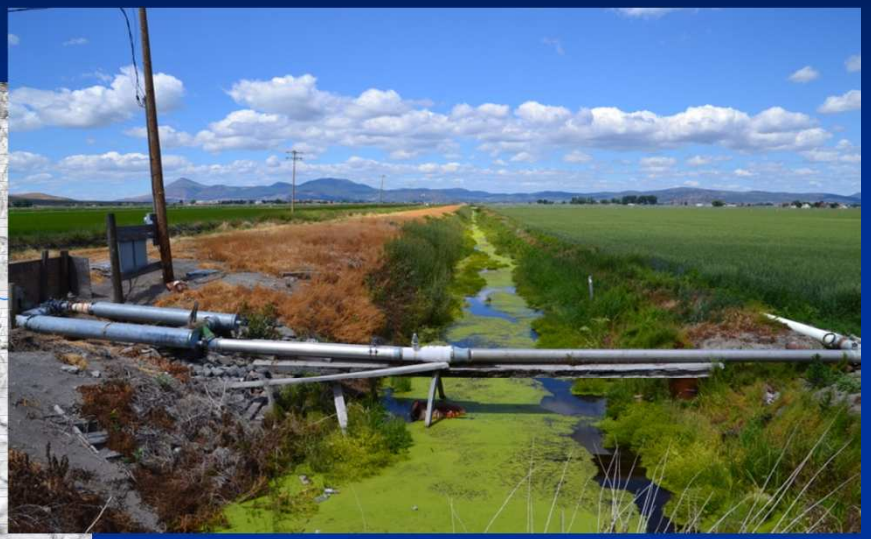
Water Level Trends in the Vicinity of the Klamath Reclamation Project





Pumping's Impact on the Klamath Irrigation Project





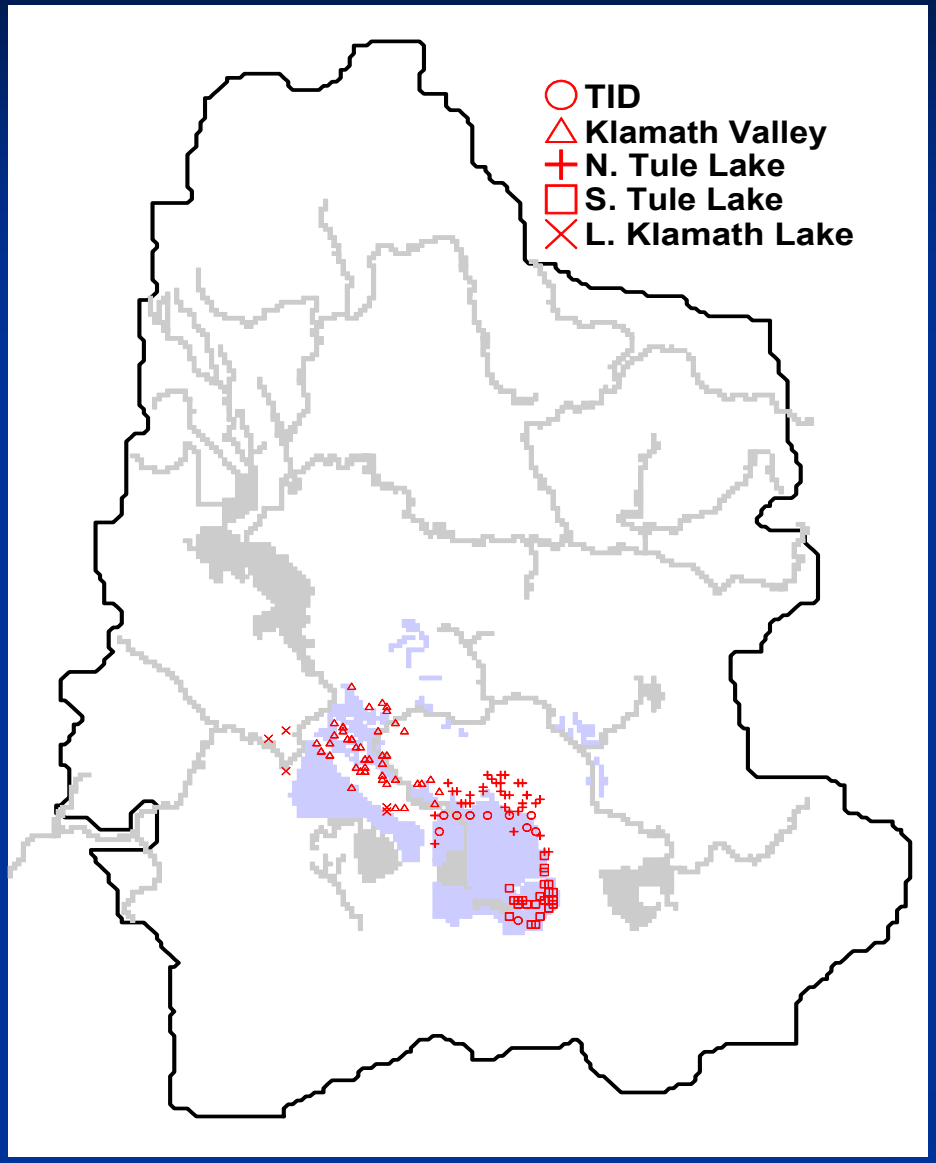
Project achieves high irrigation efficiency by recycling drain water.

Return flows also routed to Tule Lake and Lower Klamath Lake NWRs.

Groundwater Management Model – Variable Climate Simulation

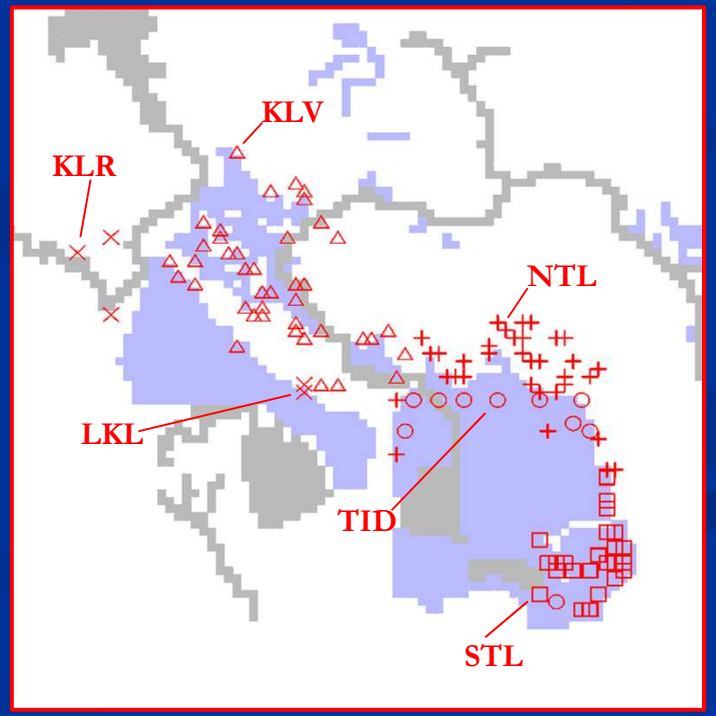
- **Objective:**
  - Maximize yield from supplemental wells
- **Decision Variables**
  - Volume and timing of pumping from 117 locations
- **Constraints:**
  - Limit impact on environmental flows
  - Limit drawdown (at a variety of time scales)
  - Limit impact on Project
  - Meet pumping demand (to the extent possible)
- **35 year management horizon, historical climate variation**

Supplemental Supply Wells

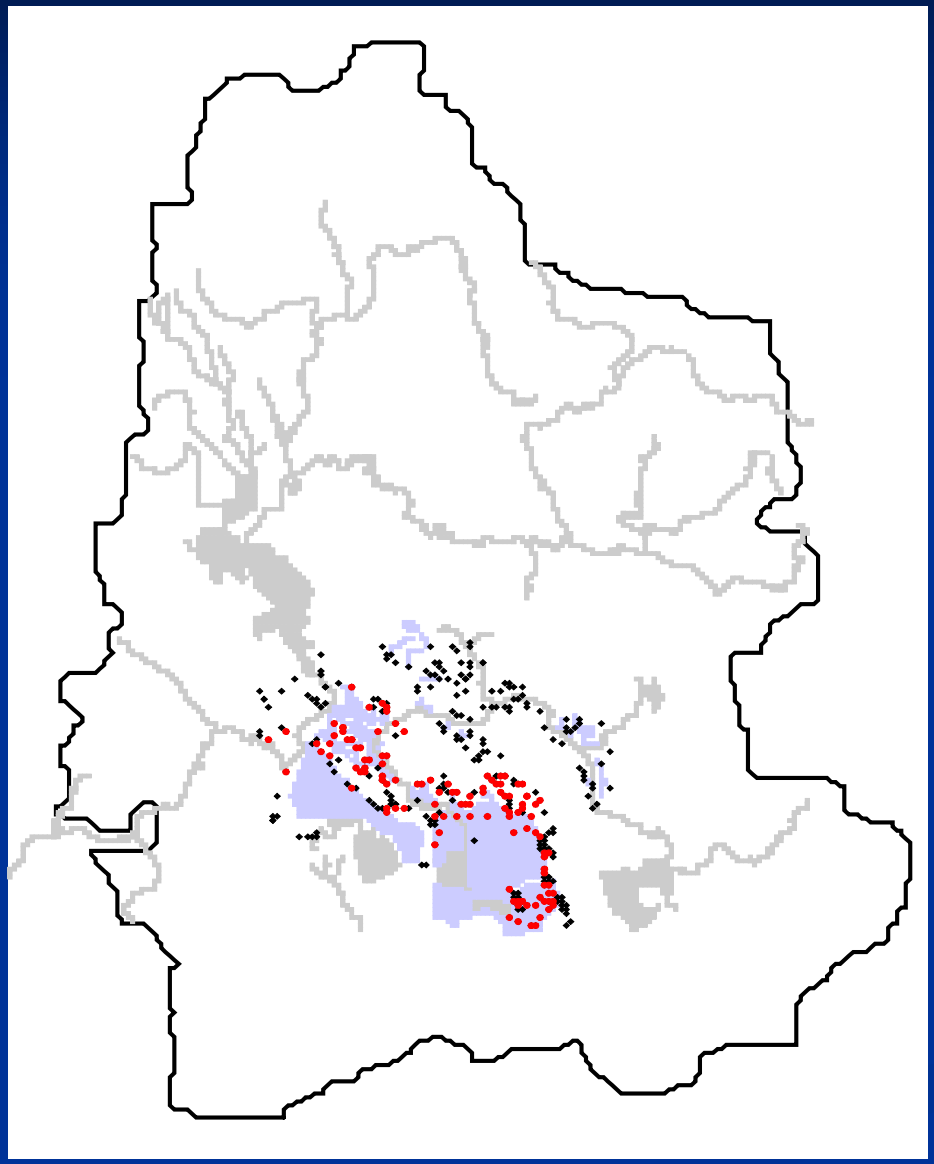


Wells grouped by geographic area:

- TID – Tulelake Irrigation District
- KLV – Klamath Valley
- NTL – Northern Tule Lake
- STL – Southern Tule Lake
- LKL – Lower Klamath Lake
- KLR – Klamath River

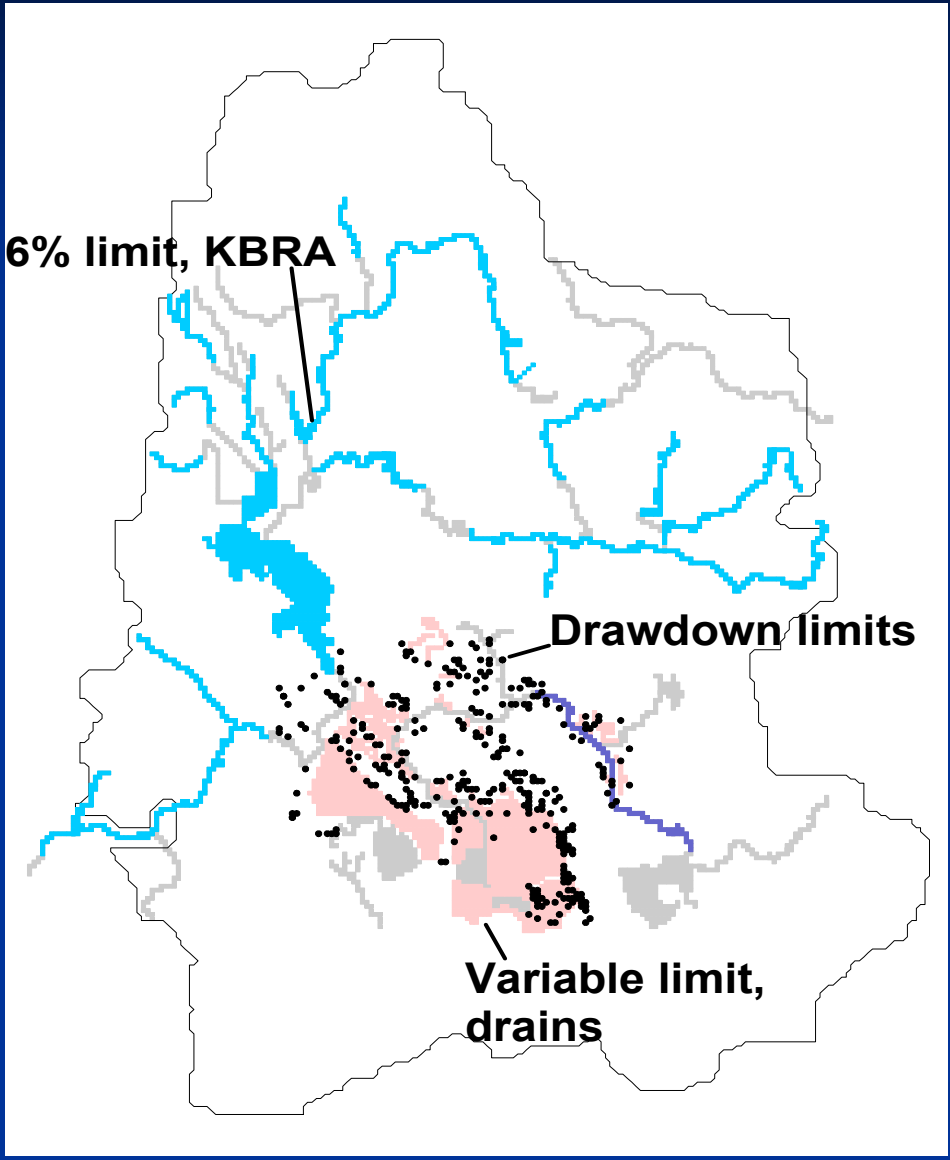


Limitations on Pumping



- Drawdown limitations at 337 locations.
  - Seasonal (max. 25 feet)
  - year-to-year (max. 3 feet)
  - 10-year (max. 25 feet)
  - Minimum groundwater level
- Locations of drawdown limitations include supplemental wells plus all wells within 6 miles of any supplemental well.

Limitations on Pumping

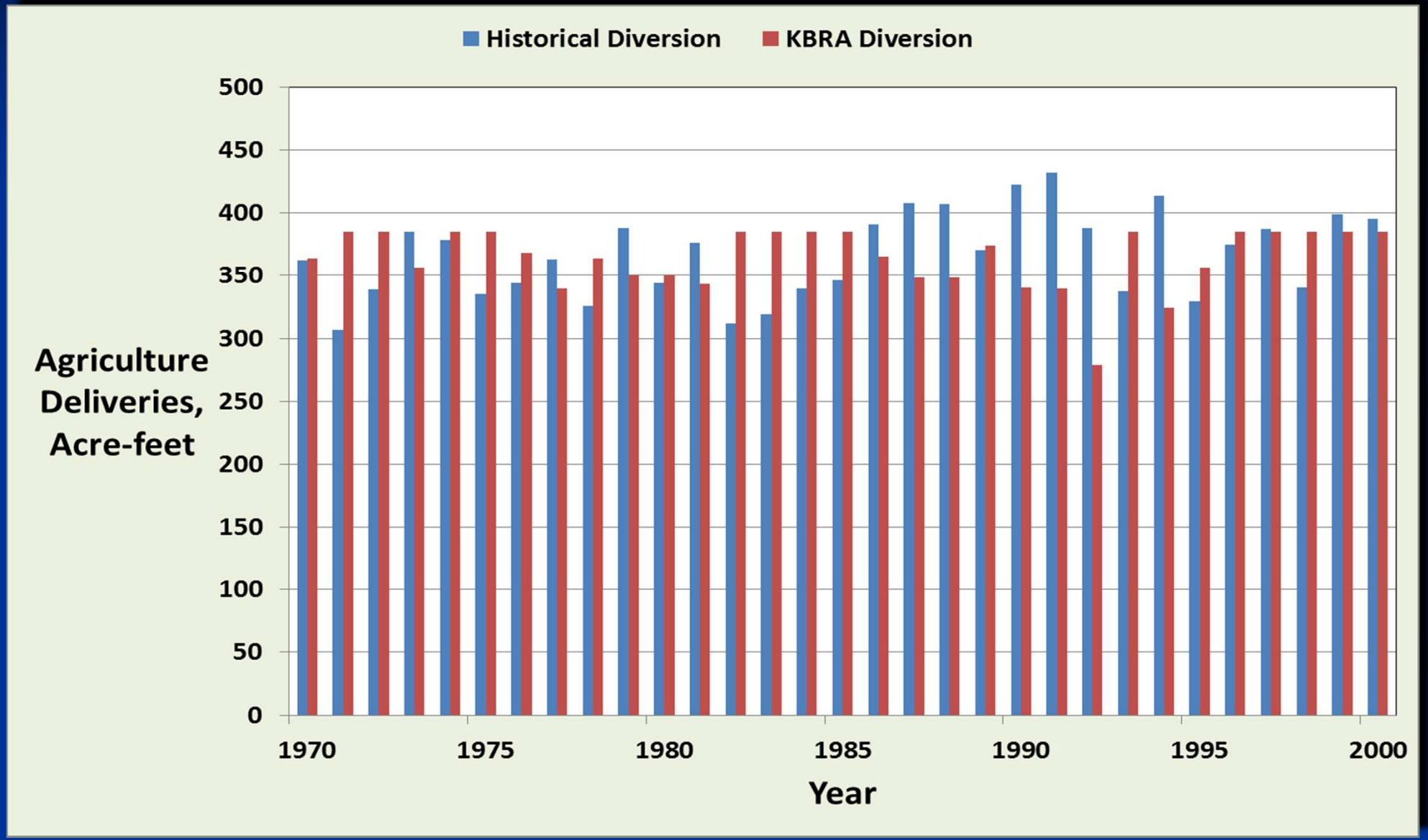


- Limitations on adverse impacts of pumping on surface water.
  - KBRA – 6% limit on reduction of groundwater discharge to streams and lakes.
  - Klamath Project – limit on reduction of groundwater discharge across Project's drain system.

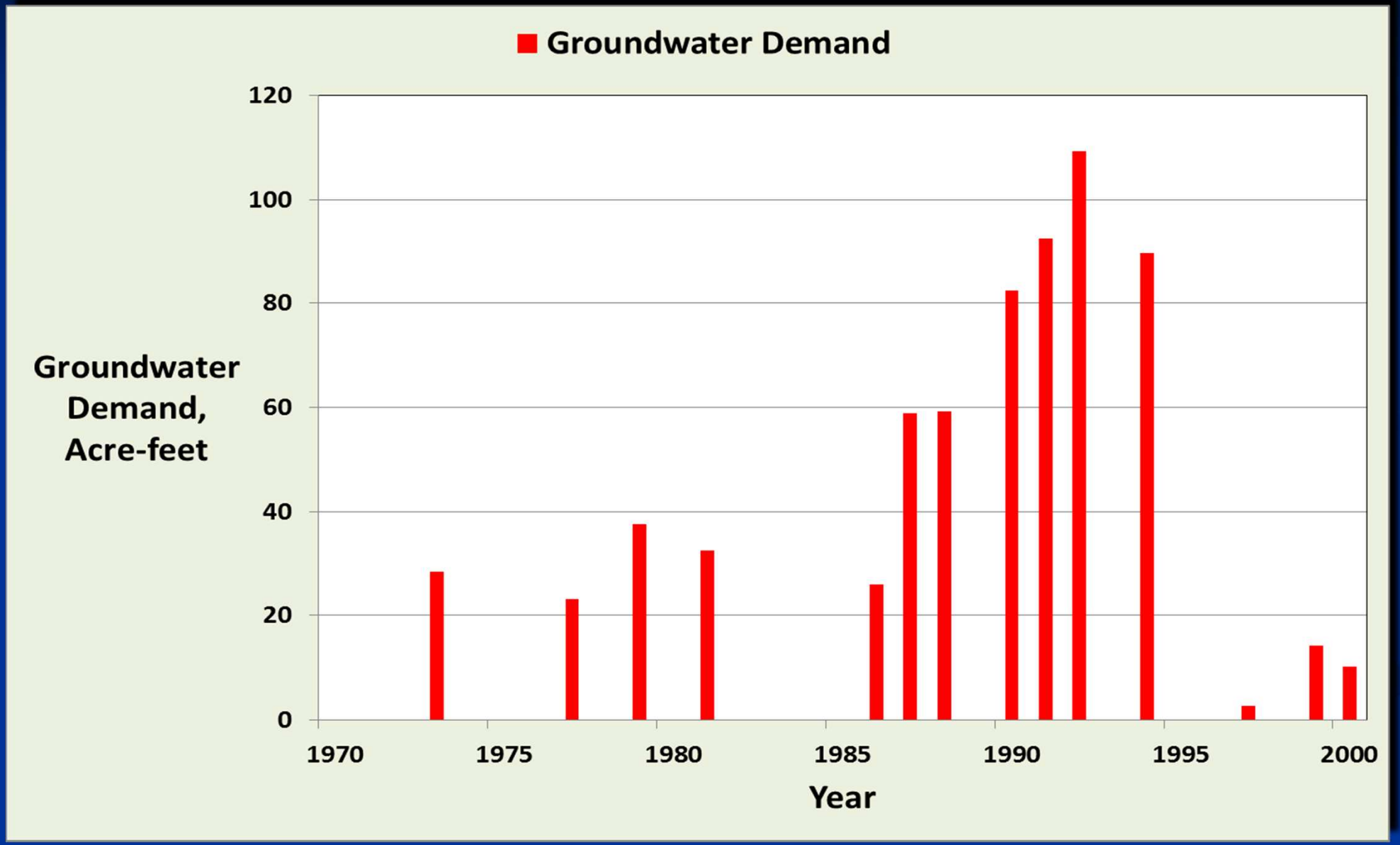
Klamath Basin Restoration Agreement: Allowable Diversions

- Diversion based on projected inflow to Upper Klamath Lake during irrigation season.
- Diversions range from 330,000 – 385,000 ac-ft.
- Dry year = Low diversion.
- Deficit ranges up to ~ 100,000 ac-ft.

Historical Water Use vs. KBRA Allowable Diversions



Groundwater Management Model



Groundwater Management Model Base Case Formulation

- Maximize $\Sigma(Q_{man,3} + Q_{man,4})$ } Objective

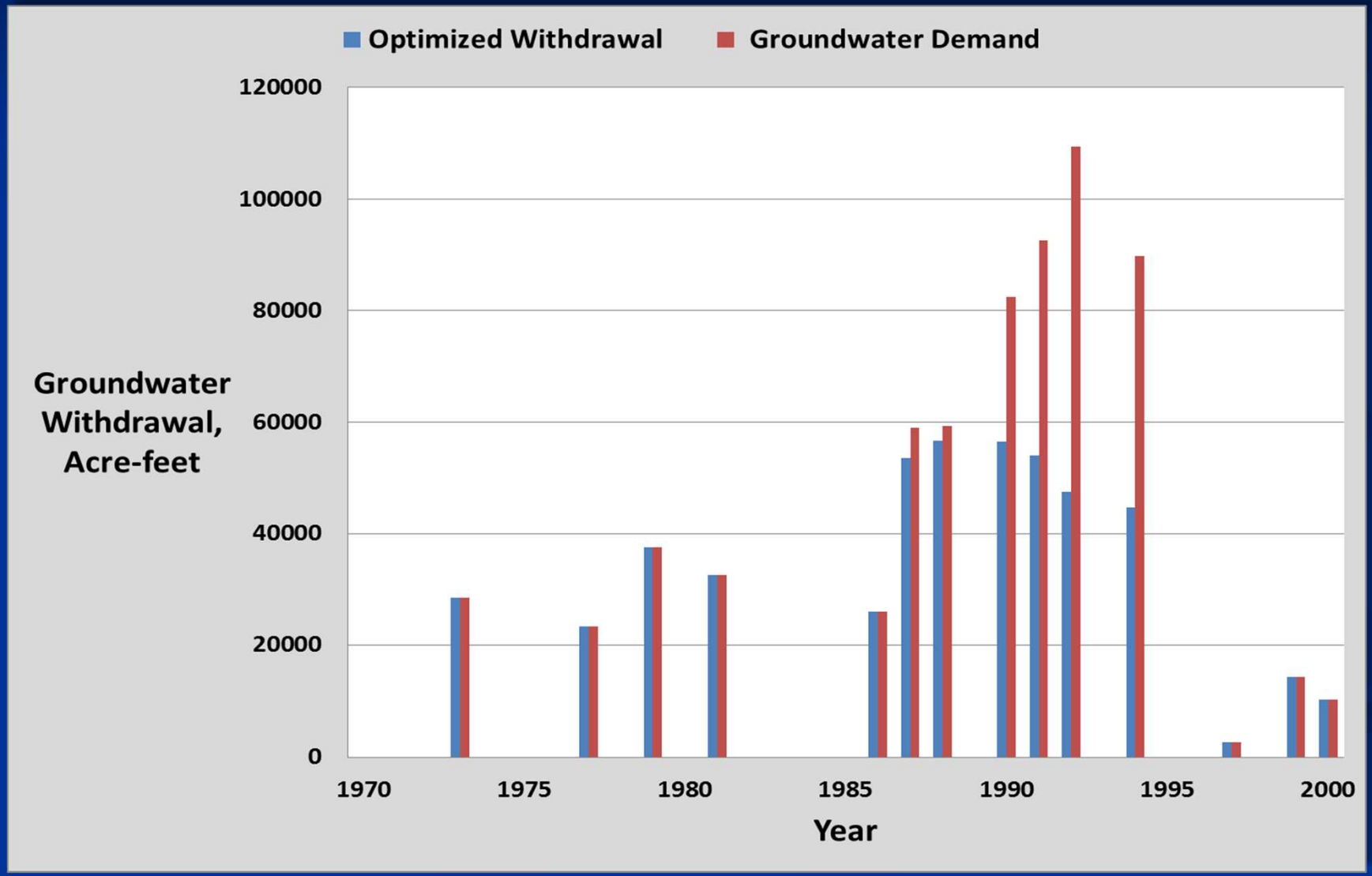
Subject to:

- $GWR_{Lk/Strm} \leq 6\%$ of Baseline
- $GWR_{Drain} \leq 20\%$ of Baseline
- $DD_{Seas} \leq 25$ FT
- $DD_{Y2Y} \leq 3$ FT
- $DD_{10Yr} \leq 25$ FT
- $\Sigma(Q_{man,3} + Q_{man,4}) \leq Q_{Dem}$

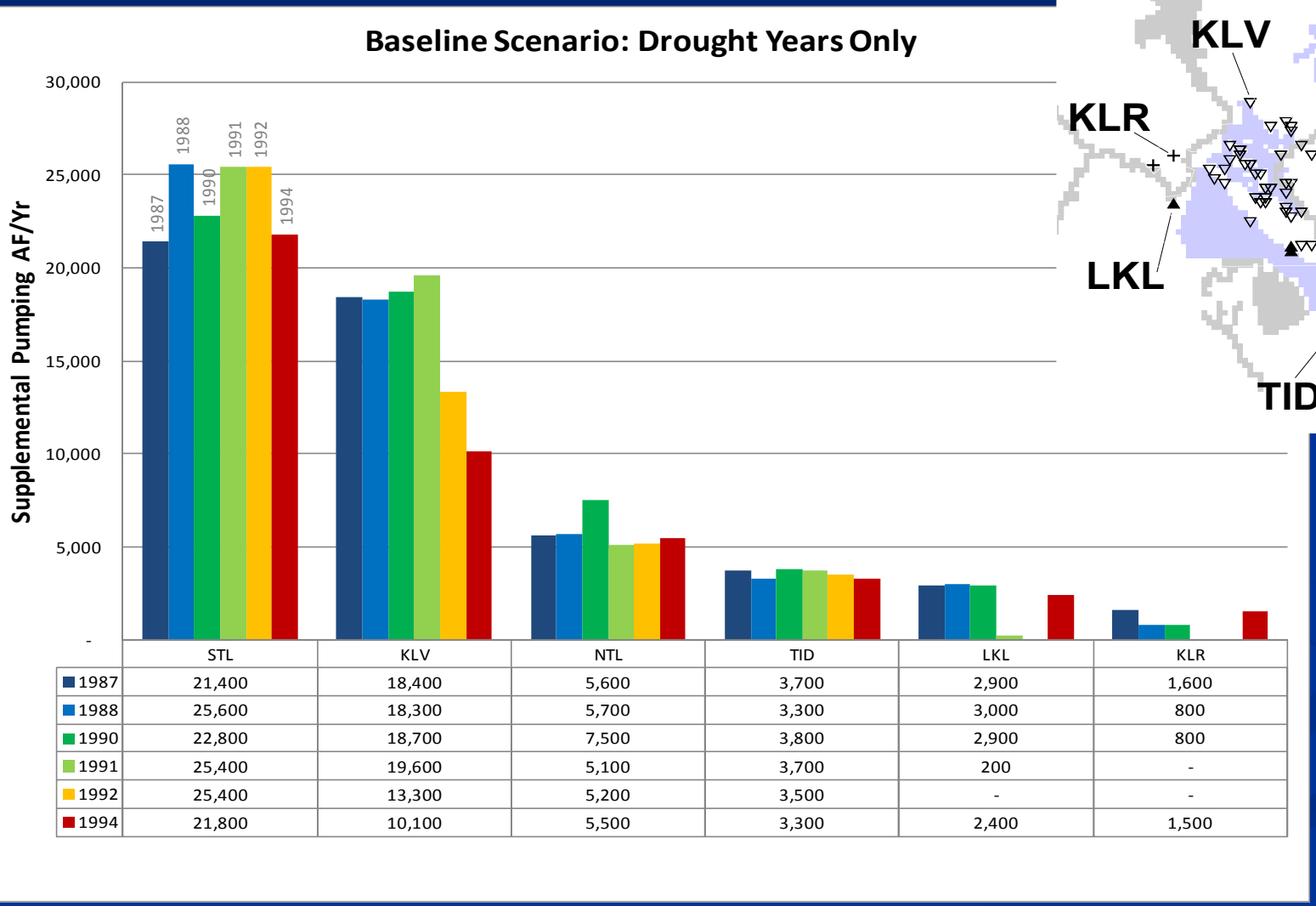
} Constraints

- $0 < Q_{Man} < Q_{Max}$ } Well limits

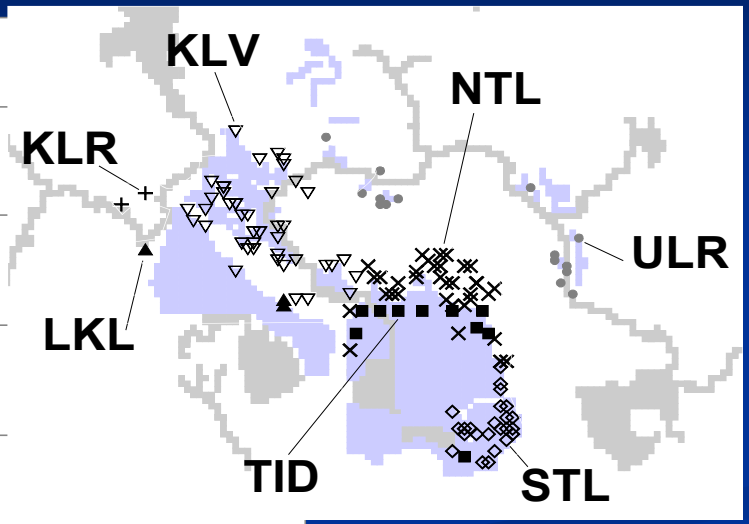
Groundwater Management Model: Base Case Results



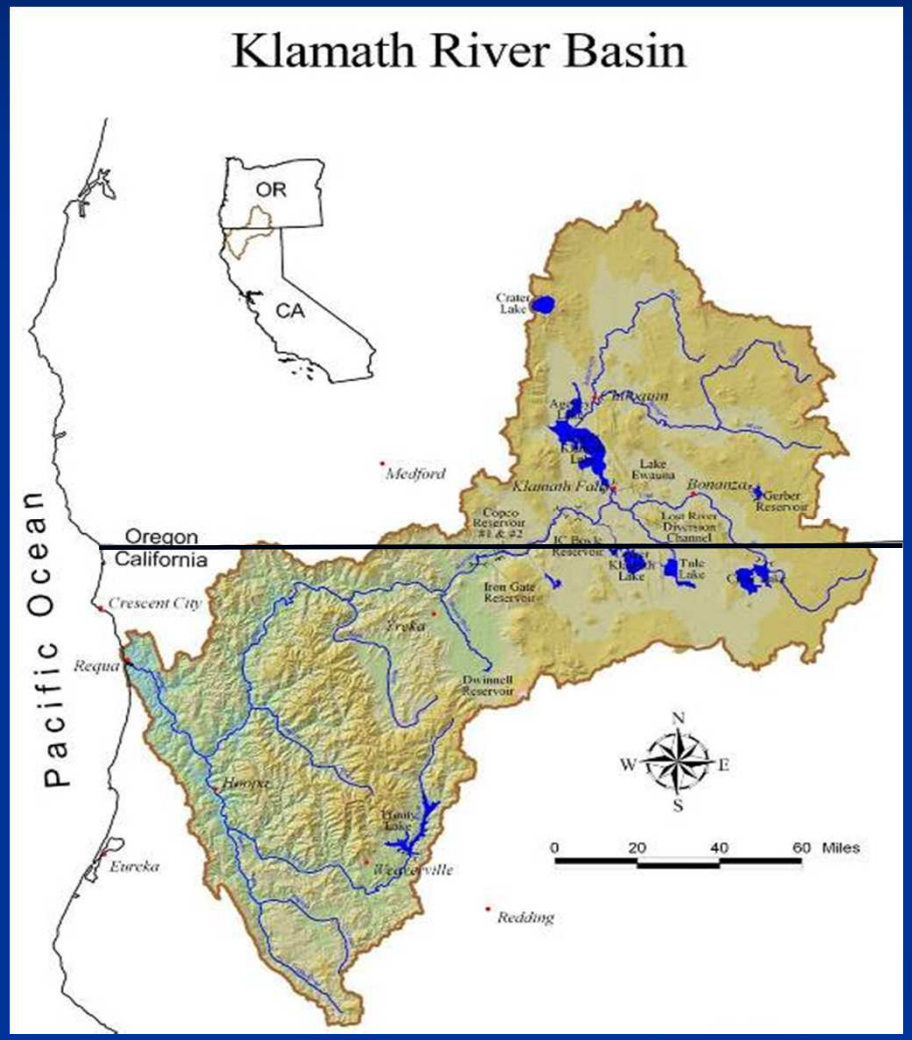
Groundwater Management Model: Base Case Results



	STL	KLV	NTL	TID	LKL	KLR
1987	21,400	18,400	5,600	3,700	2,900	1,600
1988	25,600	18,300	5,700	3,300	3,000	800
1990	22,800	18,700	7,500	3,800	2,900	800
1991	25,400	19,600	5,100	3,700	200	-
1992	25,400	13,300	5,200	3,500	-	-
1994	21,800	10,100	5,500	3,300	2,400	1,500



Groundwater Regulations in the Upper Klamath Basin



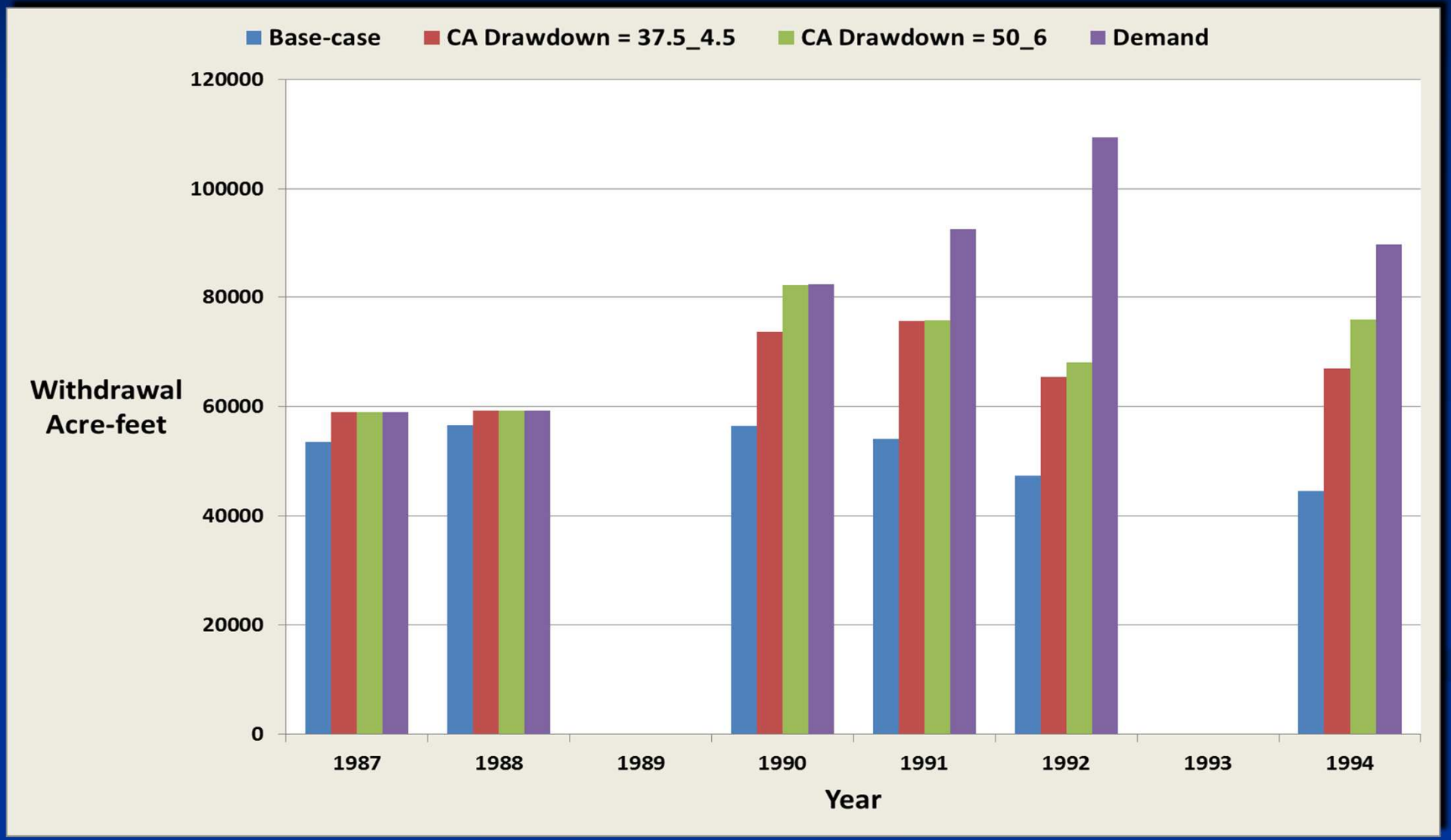
Oregon applies the *law of prior appropriation* – Limits adverse impacts to other groundwater users.

California portion of the Upper Klamath Basin has no limits on groundwater use.

Alternative Formulations

	DRAWDOWN LIMITS						DRAINS LIMIT	KBRA LIMIT	NOTES
	Seasonal		Y2Y		Decadal		Percent Baseline	Percent Baseline	
	OR	CA	OR	CA	OR	CA			
Base	25	25	3	3	25	25	20	6	
CA_1	25	37.5	3	4.5	25	25	20	6	
CA_2	25	50	3	6	25	25	20	6	
Drain_10	25	25	3	3	25	25	10	6	
Drain_05	25	25	3	3	25	25	5	6	
Add_cap	25	25	3	3	25	25	20	6	Additional pumping capacity
Back_pmp	25	25	3	3	25	25	20	6	Remove background pumping
Drought	25	25	3	3	25	25	20	6	1992 conditions in 1989 and 1993

Groundwater Management Model: Relaxed California Drawdown Limits



Summary

- Groundwater management model developed for the Upper Klamath Basin.
  - Identifies spatial and temporal patterns of sustainable groundwater development.
  - Controls impacts to environmental flows, drawdowns, and Klamath project operations.
- Results:
  - Impacts to important surface-water systems minimal.
  - Groundwater system will have difficulty meeting demand in extended dry periods.
  - Sensitivity analyses demonstrate the importance of improved information about constraint limits.

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Summary

- A significant increase in groundwater withdrawal is possible with relaxed drawdown constraints in California.
- Tightening the constraint that limits reductions in groundwater discharge to the Project drains can significantly reduce allowable pumping.
- Groundwater withdrawal under base case constraint limits can be enhanced with additional pumping capacity in select areas.
- Removal of background pumping can increase on-Project pumping.

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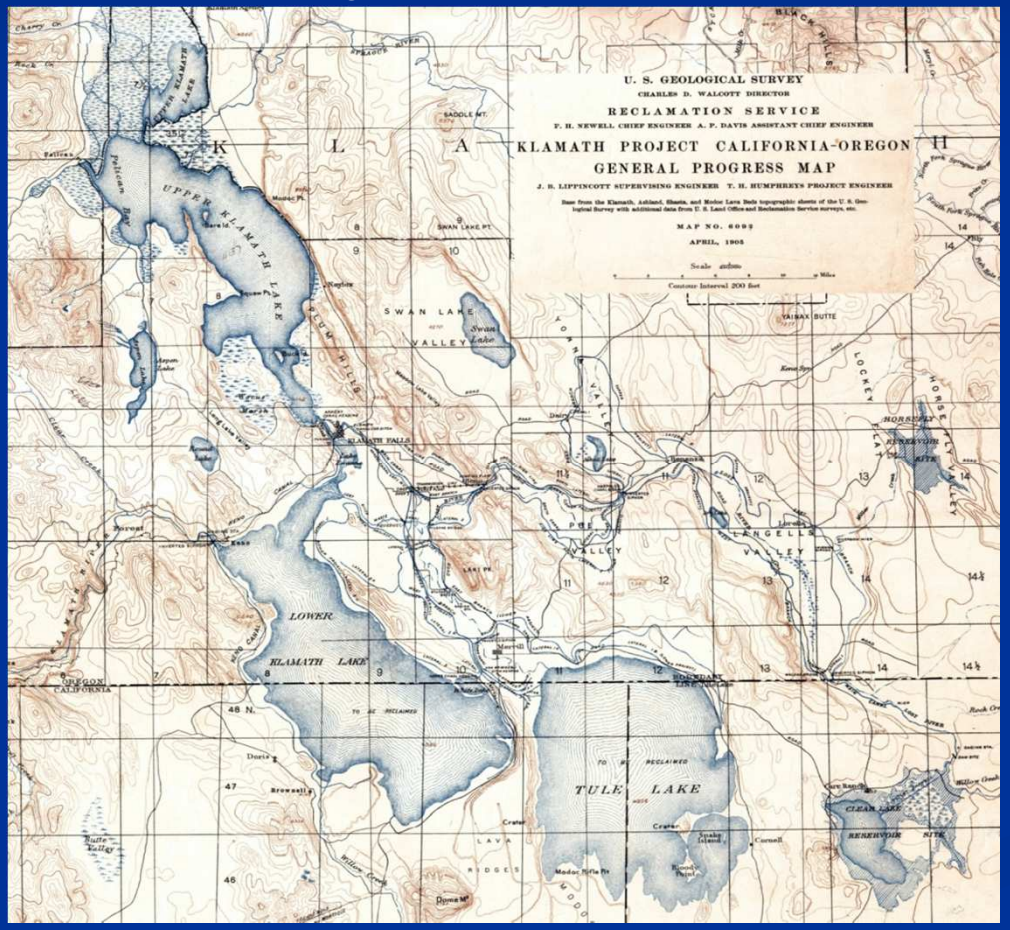
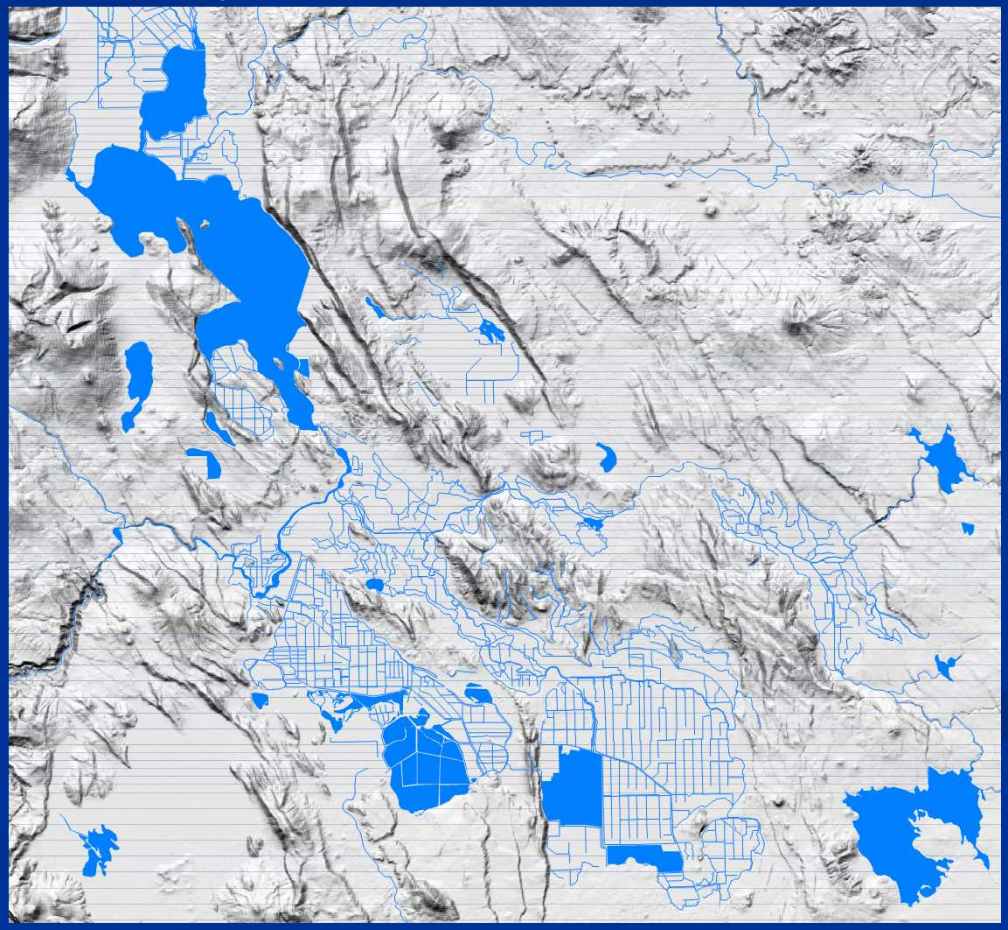
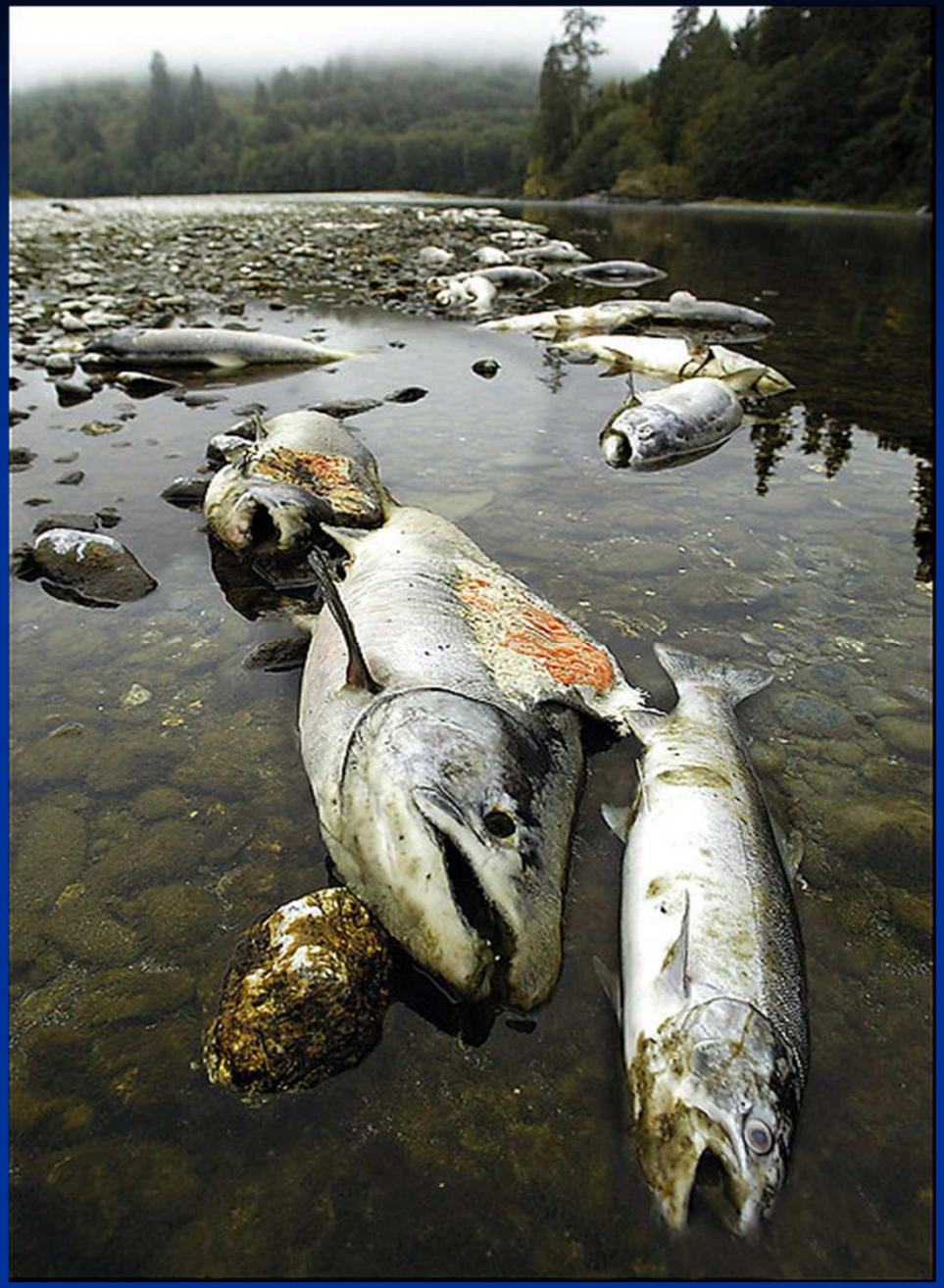
Upper Klamath Basin, Pre- and Post-Reclamation

1906 USGS Topographic Map



Basin Today





2002 Fish Die-off

- Estimated 35,000 salmon die
- Low flows in Klamath River due to irrigation diversions
- Higher than normal temperatures
- Large number of returning salmon