



Science to Action:

Working Together to Build Resiliency at Lake Tahoe

Lake Clarity and Water Quality

Agenda

8:45 **Introduce Panel and Topic**

8:50 **Panel Presentations:** Past-Present-Future of Science + Management Partnerships

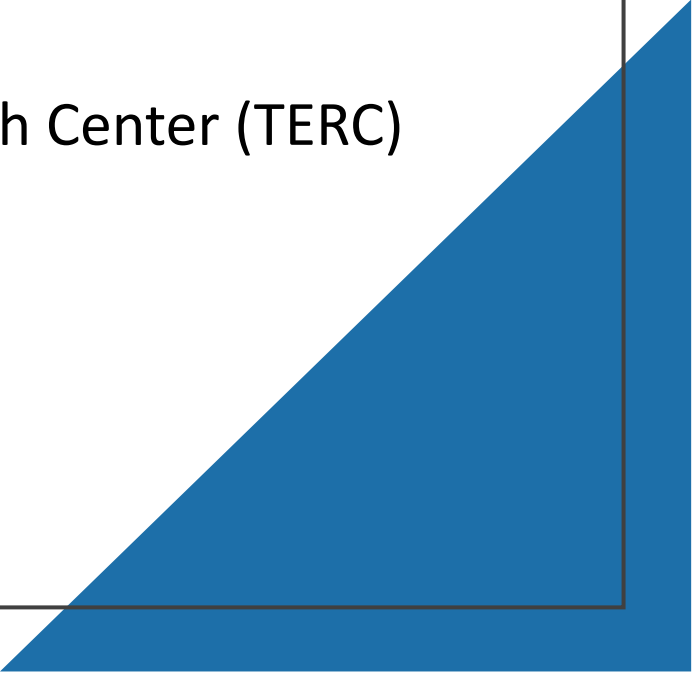
9:30 **Questions for Clarification**

9:40 **Small Group Discussion:** Priority topics in Science and Management

10:05 **Reports:** Key themes from small groups

10:30 **Final observations** and adjourn

Panelists

- Jason Kucknicki, Nevada Division of Environmental Protection (NDEP)
 - Dan Segan, Tahoe Regional Planning Agency (TRPA)
 - John Melack, UC Santa Barbara (UCSB)
 - Geoff Schladow, UC Davis Tahoe Environmental Research Center (TERC)
 - Facilitator: Heather Segale, UC Davis TERC
- 

Tahoe's Science Tradition

PHYSICAL STUDIES OF LAKE TAHOE.—I.

HUNDREDS of Alpine lakes of various sizes, with their clear, deep, cold, emerald, or azure waters, are embosomed among the crags of the Sierra Nevada Mountains. The most extensive, as well as the most celebrated, of these bodies of fresh water is Lake Tahoe, otherwise called Lake Bigler.

This lake, the largest and most remarkable of the mountain lakes of the Sierra Nevada, occupies an elevated valley at a point where this mountain system divides into two ranges. It is, as it were, engulfed between two lofty and nearly parallel ridges, one lying to the east and the other to the west. As the crest of the principal range of the Sierra runs near the western margin of this lake, this valley is thrown on the eastern slope of this great mountain system.

The boundary line between the States of California and Nevada makes an angle of about 131° in this lake, near its southern extremity, precisely at the intersection of the 39th parallel of north latitude with the 120th meridian west from Greenwich. Inasmuch as, north of this angle, this boundary line follows the 120th meridian, which traverses the lake longitudinally from two to four miles from its eastern shore-line, it follows that more than two-thirds of its area falls within the jurisdiction of California, the remaining third being within the boundary of Nevada.

area, is estimated to be about five hundred square miles. Probably more than a hundred affluents of various capacities, deriving their waters from the amphitheater of snow-clad mountains which rise on all sides from 3,000 to 4,000 feet above its surface, contribute their quota to supply this lake. The largest of these affluents is the Upper Truckee River, which falls into its southern extremity.

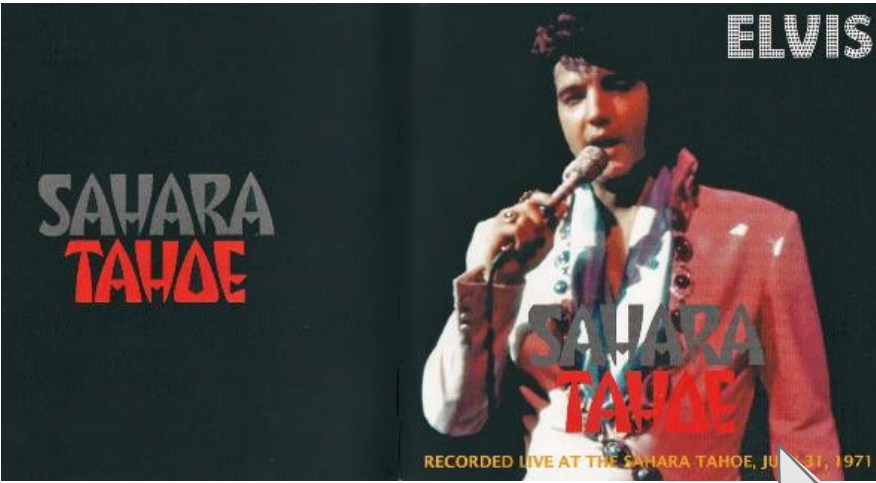
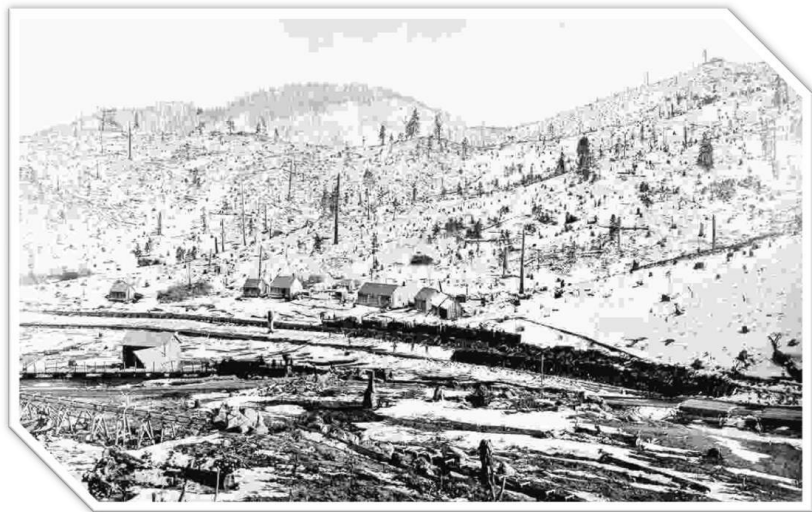
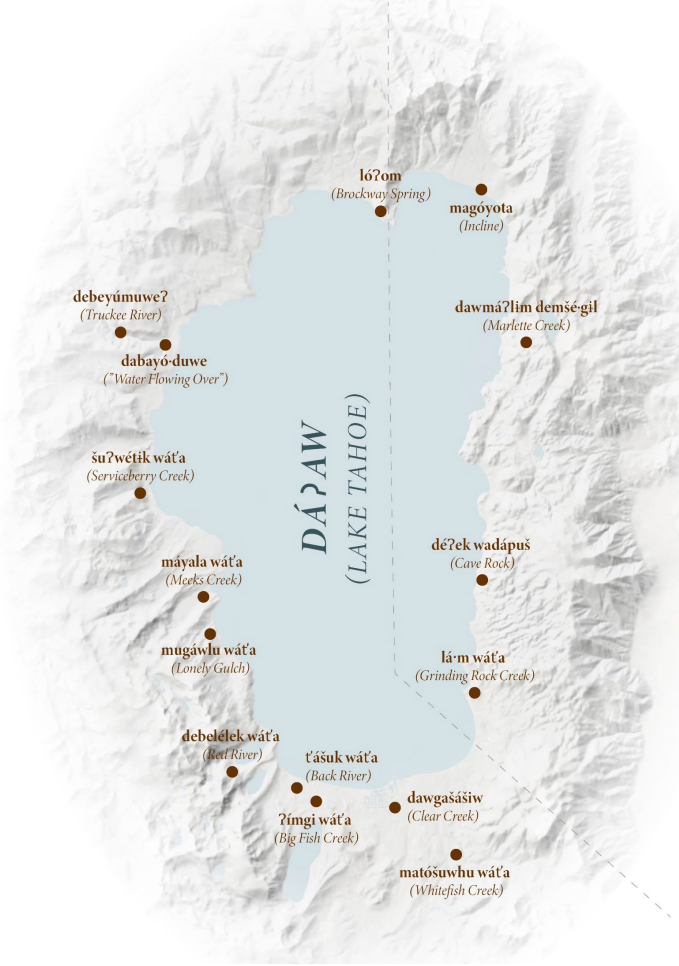
The only outlet to the lake is the Truckee River, which carries the surplus waters from a point on its northwestern shore out through a magnificent mountain gorge, thence northeast, through the arid plains of Nevada, into Pyramid Lake. This river in its tortuous course runs a distance of over one hundred miles, and for about seventy miles (from Truckee to Wadsworth) the Central Pacific Railroad follows its windings. According to the railroad surveys, this river makes the following descent:

	Distance.	Fall.	Fall per Mile
Lake Tahoe to Truckee.....	13 Miles	401 Feet	28.64 Feet.
Truckee to Boca.....	3 "	313 "	39.12 "
Boca to State Line.....	11 "	395 "	35.91 "
State Line to Verdi.....	5 "	211 "	42.20 "
Verdi to Reno.....	11 "	420 "	38.18 "
Reno to Vista.....	8 "	103 "	12.87 "
Vista to Clark's.....	12 "	141 "	11.75 "
Clark's to Wadsworth.....	15 "	186 "	12.40 "
Wadsworth to Pyramid Lake.....	18(?) "	187(?) "	10.39 "
Lake Tahoe to Pyramid Lake.....	102 "	2357 "	23.11 "

(5.) *Transparency of the Water.*—All visitors to this beautiful lake are struck with the extraordinary transparency of the water. At a depth of 15 or 20 meters (49.21 or 65.62 feet), every object on the bottom—on a calm sunny day—is seen with the greatest distinctness. On the 6th of September, 1873, the writer executed a series of experiments with the view of testing the transparency of the water. A number of other experiments were made August 28 and 29, under less favorable conditions. By securing a white object of considerable size—a horizontally adjusted dinner-plate about 9.5 inches in diameter—to the sounding-line, it was ascertained that (at noon) it was plainly visible at a vertical depth of 33 meters, or 108.27 English feet. It must be

Brief History

Traditional Washoe Places Streams, Tributaries, and Significant Places

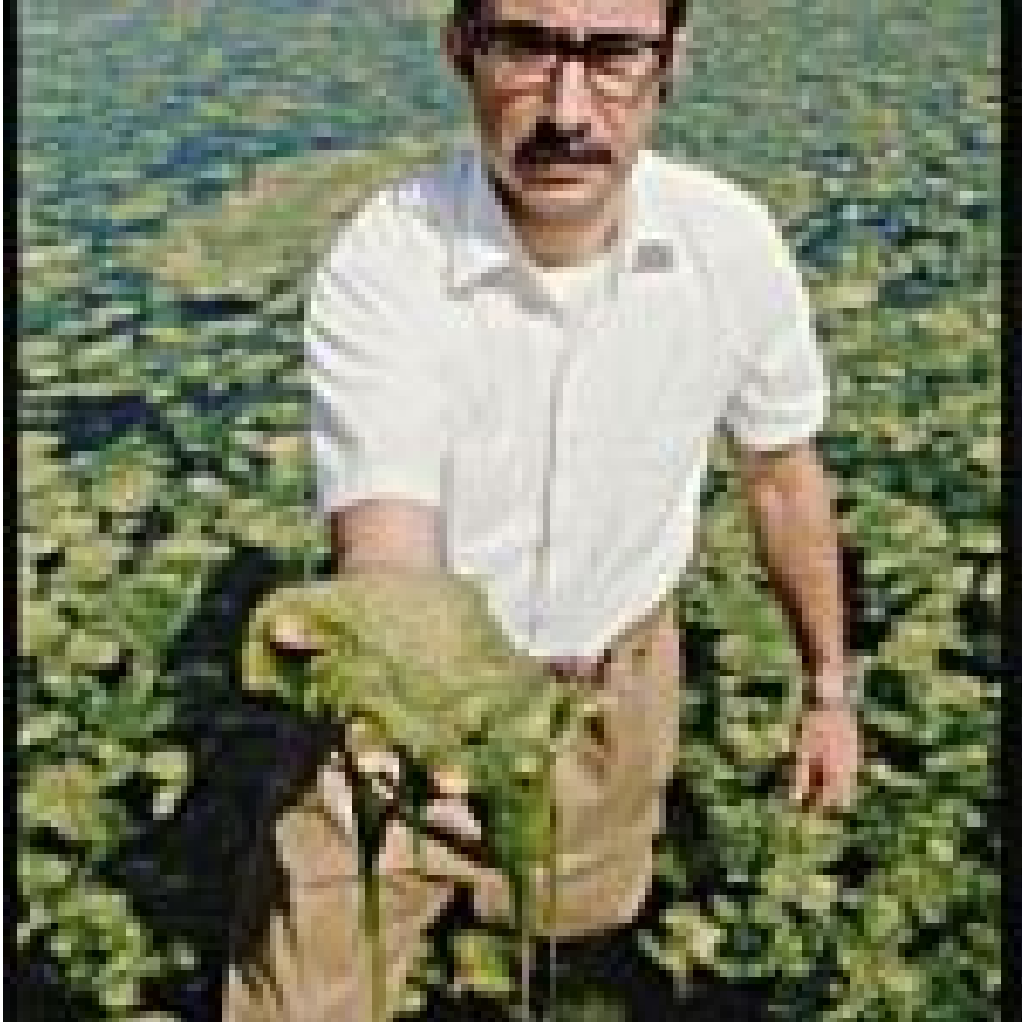


Pre-1850s

1850s

1960s

Environmental Impact



*“last spring (i.e. 1967) one could collect handful almost anywhere in the shallows, and waves piled up mats of the detached material along the shore. Marina owners looked into **green weed beds** from their docks during the entire summer, and the hulls of boats left in the water for long periods developed a slimy coating of attached algae.”*

– C. Goldman 1967

Wastewater Export

Porter-Cologne Act of 1969



Porter-Cologne Water Quality Control Act

Water Code Division 7 and Related Sections
(As amended, including Statutes 2022)

Federal Clean Water Act of 1972

FEDERAL WATER POLLUTION CONTROL ACT

(33 U.S.C. 1251 et seq.)

AN ACT To provide for water pollution control activities in the Public Health Service of the Federal Security Agency and in the Federal Works Agency, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

TITLE I—RESEARCH AND RELATED PROGRAMS

DECLARATION OF GOALS AND POLICY

SEC. 101. (a) The objective of this Act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. In order to achieve this objective it is hereby declared that, consistent with the provisions of this Act—

(1) it is the national goal that the discharge of pollutants into the navigable waters be eliminated by 1985;

(2) it is the national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved by July 1, 1983;

(3) it is the national policy that the discharge of toxic pollutants in toxic amounts be prohibited;

(4) it is the national policy that Federal financial assistance be provided to construct publicly owned waste treatment works;

(5) it is the national policy that areawide treatment management planning processes be developed and implemented to assure adequate control of sources of pollutants in each State;

(6) it is the national policy that a major research and demonstration effort be made to develop technology necessary to eliminate the discharge of pollutants into the navigable waters, waters of the contiguous zone and the oceans; and

(7) it is the national policy that programs for the control

Fifth Annual
Edition

7 SECTIONS
82 PAGES

TAHOE '68

TODAY'S PROGRESS . . .
TOMORROW'S SUCCESS

Rain

Sierra Nevada, occasional rain mostly north of Yosemite this evening with chance of more rain late Saturday. Mostly cloudy north.

Yesterday's high, 42; overnight low, 36. Barometer reading at 8 a.m.—30.14.

Tahoe Daily Tribune

Serving All Lake Tahoe — America's All-Year Playground

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Vol. 10 — No. 39 541-3880

SOUTH LAKE TAHOE, CALIFORNIA, FRIDAY, FEBRUARY 23, 1968

SEVEN SECTIONS

PRICE 20 CENTS

Reagan, Laxalt Hail Tahoe Agency

MESSAGE BY THE HONORABLE RONALD REAGAN GOVERNOR OF CALIFORNIA

The lands and waters of the Tahoe Basin represent a natural resource of incomparable value to the citizens of California, Nevada, and indeed, the entire nation. With the great increase in both population and leisure time, there is a real need for quality recreational areas. Lake Tahoe and the lands of the Tahoe Basin will serve a significant portion of the recreational needs of our citizens for many years.

The summer and winter recreational opportunities which are found in the Tahoe Basin distinguish it as a unique and valuable recreational asset. The basin is located within a four-hour drive of over three million people. It is a single day's drive for approximately 10 per cent of the total population of the United States, a great percentage of whom are residents of California.

The Tahoe Basin must be protected for this and for future generations. Governor Paul Laxalt of Nevada recently stated, "Every possible step should be taken by all parties involved to assure that Lake Tahoe retains its crystal clear quality and the beautiful basin not be destroyed by so-called progress." I endorse Governor Laxalt's statement without qualification. We will work together, citizens of California and Nevada, to preserve the priceless treasure that is Lake Tahoe.

The Tahoe Basin has been described by some writers as a polluted lake surrounded by ugly developments. Perhaps this is why people are surprised when they visit the region. Rather than the polluted waters and eroded landscapes which they were told to expect, they see the blue waters, clearer and purer than they imagined existed, set in a wooded forest backdrop of majestic snow-capped mountains.

"Truly," as Mark Twain described Tahoe, "the fairest picture the whole earth affords."

Compact Is Adopted By 37-2 Vote

CARSON CITY — It's now up to California to decide whether regional control over the entire Lake Tahoe basin will be established quickly.

The Assembly in the special session of the Nevada Legislature Thursday cleared SB9 authorizing the state to join California in a bi-state Tahoe Regional Planning Compact to prevent pollution of the lake's water, guard against overdevelopment around its shores and preserve the scenic beauty of all of the Tahoe Basin.

The bill passed 37-2 under emergency procedure.



THE HON. PAUL LAXALT



THE HON. RONALD REAGAN

MESSAGE BY THE HONORABLE PAUL LAXALT GOVERNOR OF NEVADA

Lake Tahoe is truly a "wonder of the world."

This phrase, though often used, indeed reflects what Lake Tahoe is to Nevadans and people throughout the world.

I think much credit is due to residents of the Lake Tahoe basin for their outstanding efforts in keeping Lake Tahoe beautiful and at the same time promoting the area as a most wonderful vacation spot.

However, we share concern with many that as the Lake Tahoe basin area expands, pressures for development will become increasingly heavy. To meet these pressures we are giving our wholehearted support to a regional agency which will join Nevada and California. The agency's primary function will be to assure proper development of the area.

We are confident residents of the Lake Tahoe area and landholders there will support reasonable programs designed to assure its proper development.

In addition, Lake Tahoe is an important part of the economy

LAND-CAPABILITY CLASSIFICATION OF THE LAKE TAHOE BASIN, CALIFORNIA-NEVADA

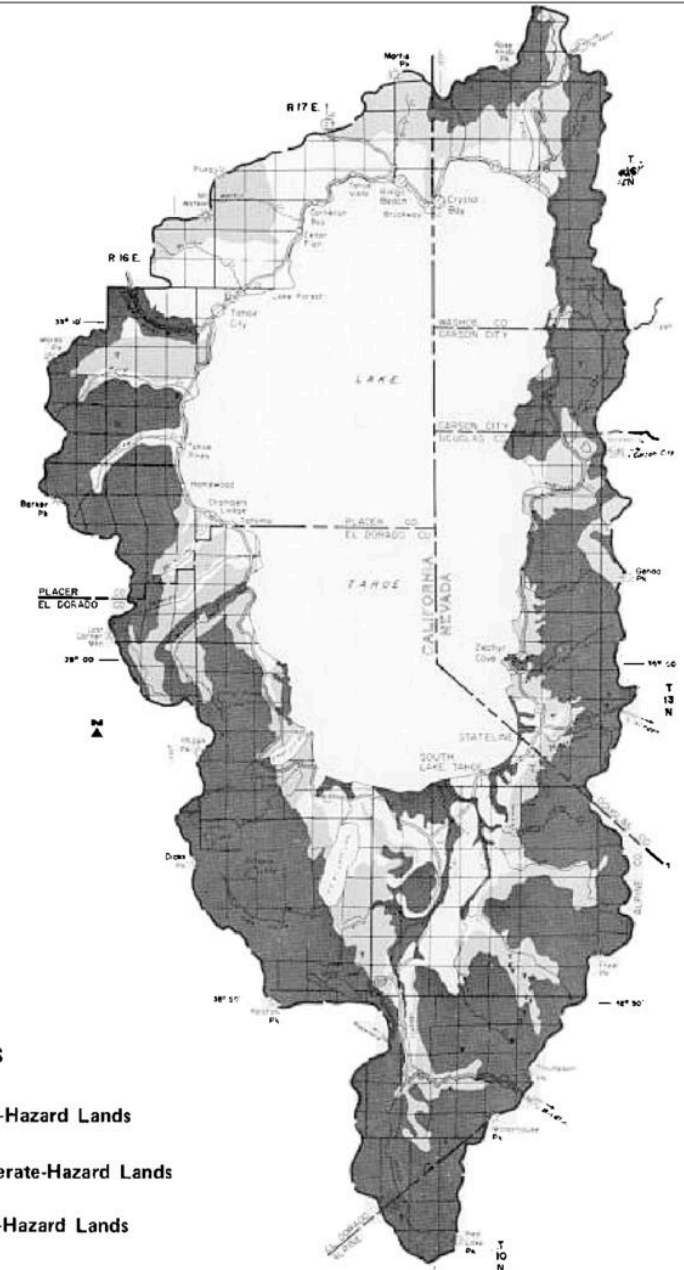
A Guide for Planning

ROBERT G. BAILEY



U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

Prepared in cooperation with the
Tahoe Regional Planning Agency



Continued Impact

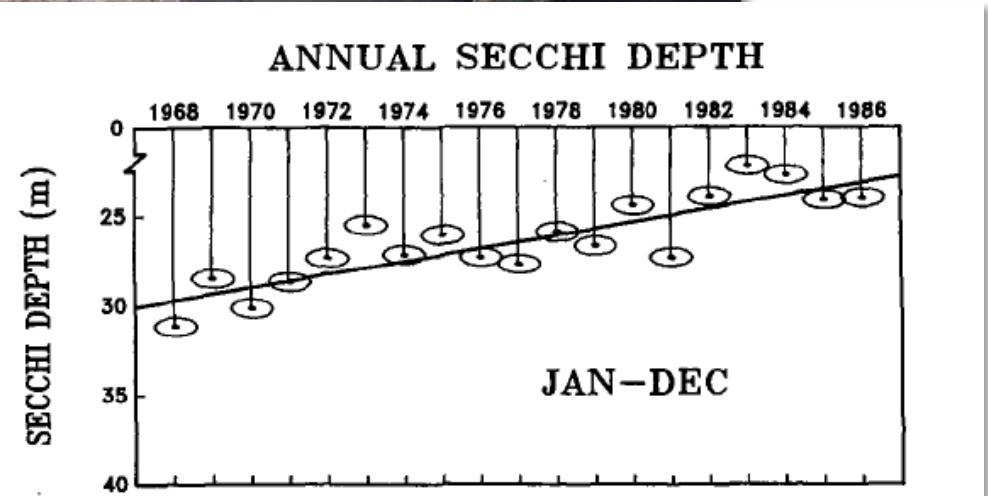
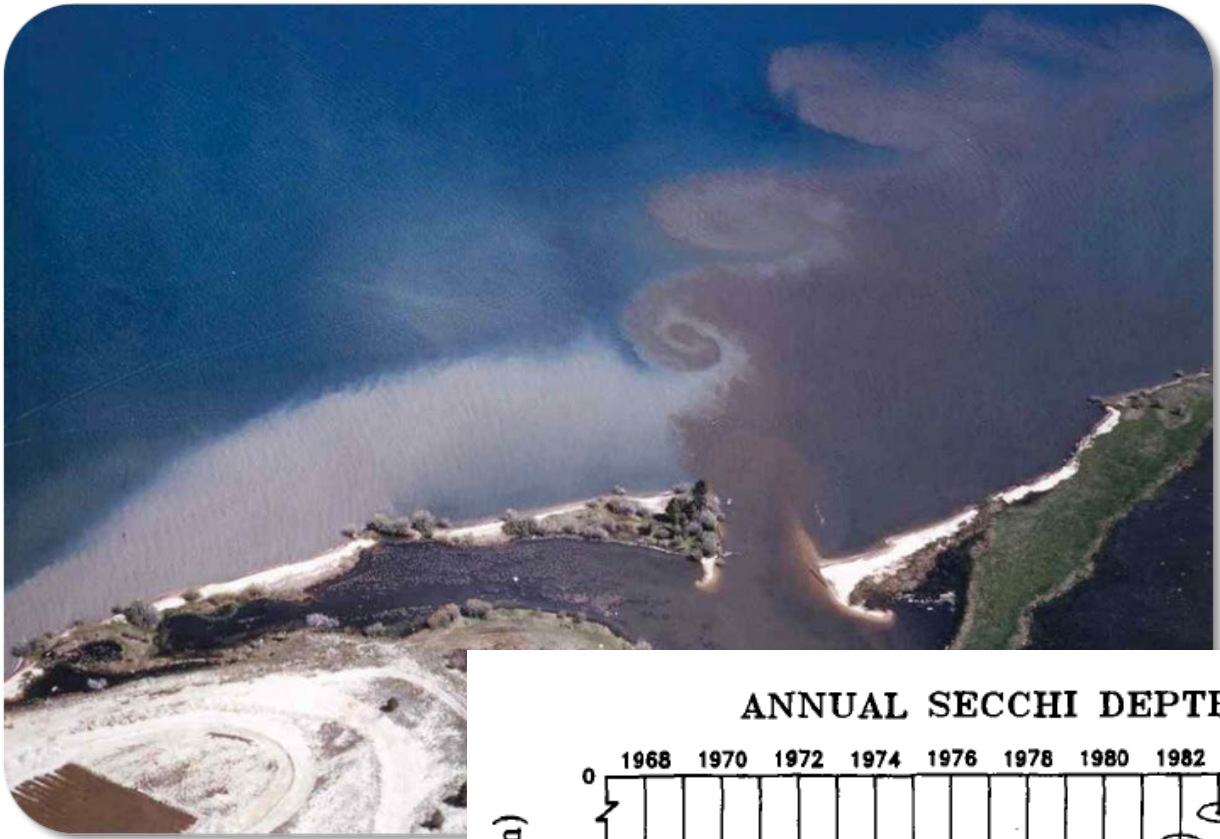
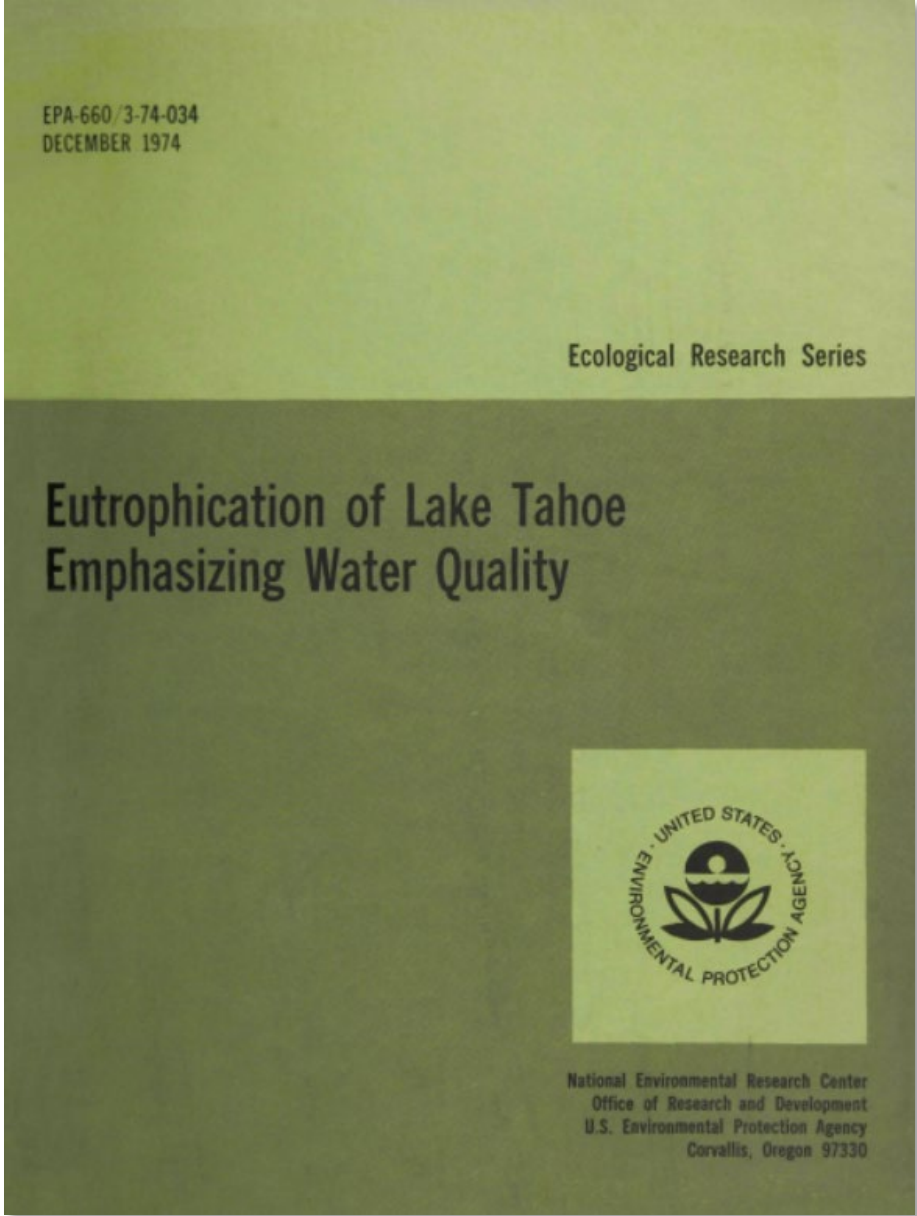


Fig. 10. Annual average transparency measured with a 20-cm white Secchi disk. Each point represents about 35 individual measurements. Dates where stormy, poor light conditions occurred have been eliminated from each year's average.

Regional Plan

REGIONAL PLAN FOR THE LAKE TAHOE BASIN

U U U U U

GOALS AND POLICIES



Adopted by the
TRPA Governing Board
June 25, 1987
Updated December 12, 2012
Amended April 28, 2021



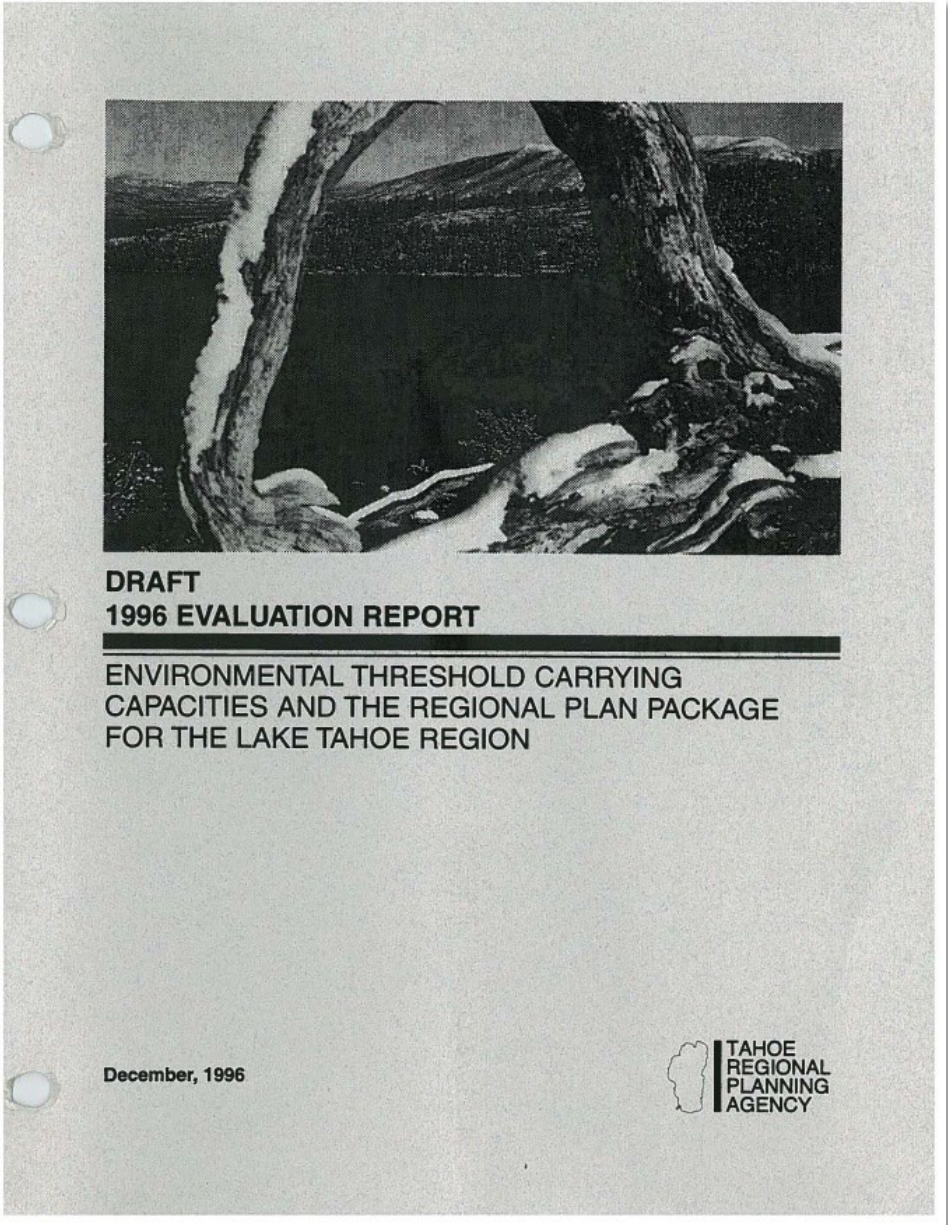
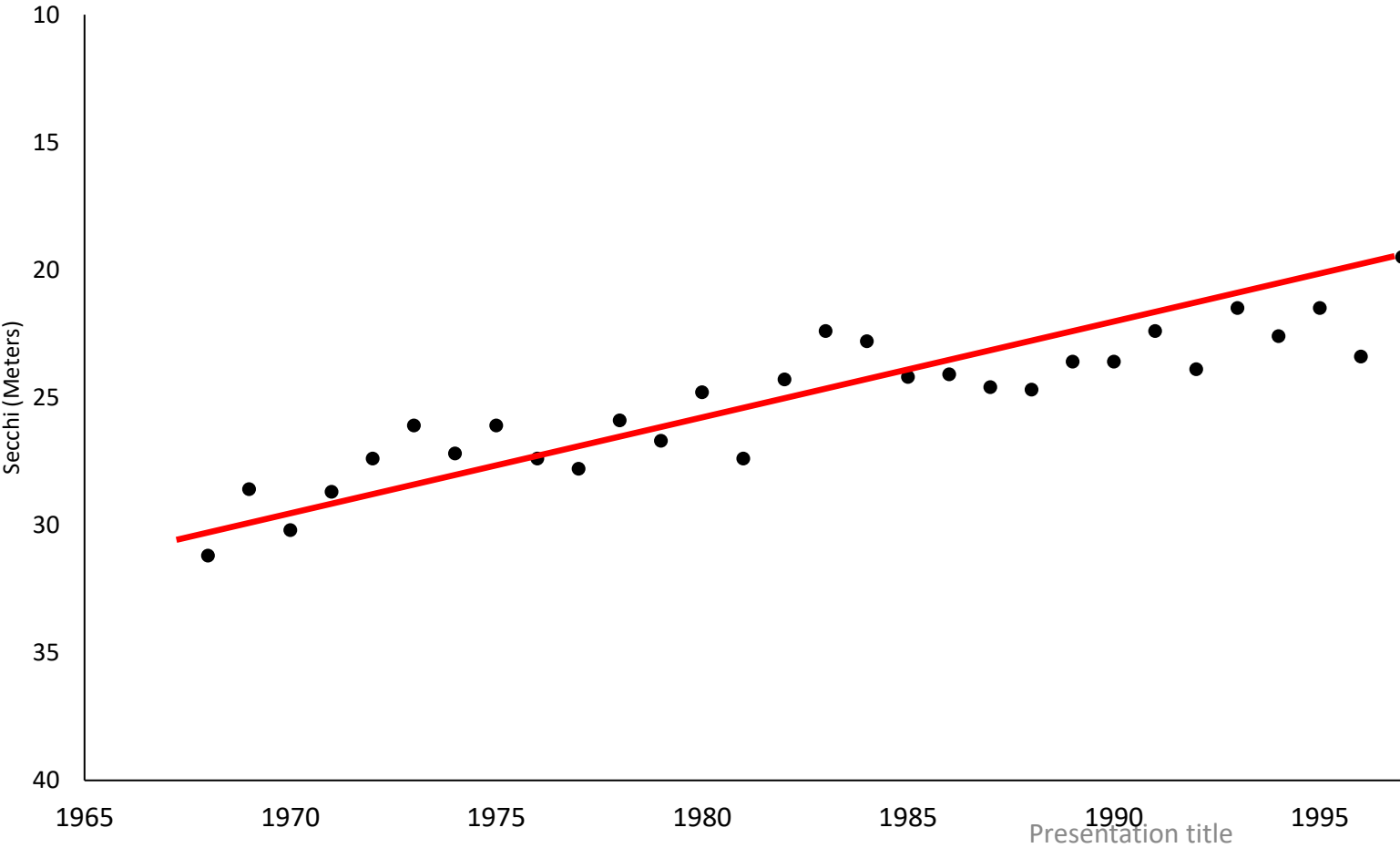
THRESHOLD STANDARDS
AND REGIONAL PLAN

TAHOE REGIONAL PLANNING AGENCY || *Lake Tahoe*

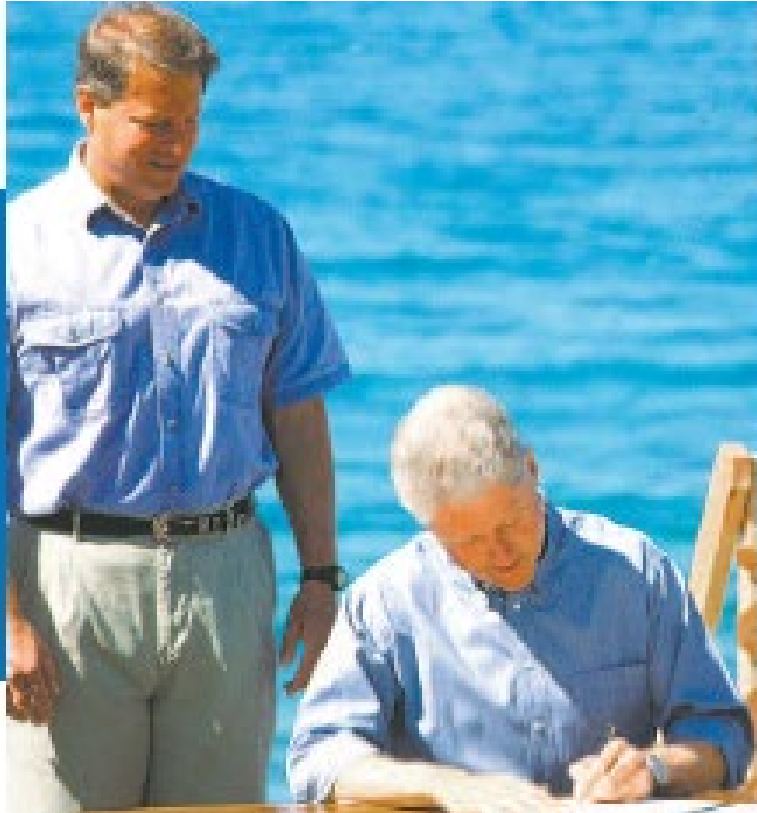


- Limits total development in the region
 - Homes
 - Hotel / Motel
 - Commercial Floor Area
- Ensures new development is consistent with environmental goals
- Incentivize redevelopment
- Walkable, Bikeable, Transit Friendly communities

1996 Threshold Evaluation



1997: Lake Tahoe Summit & Birth of the EIP



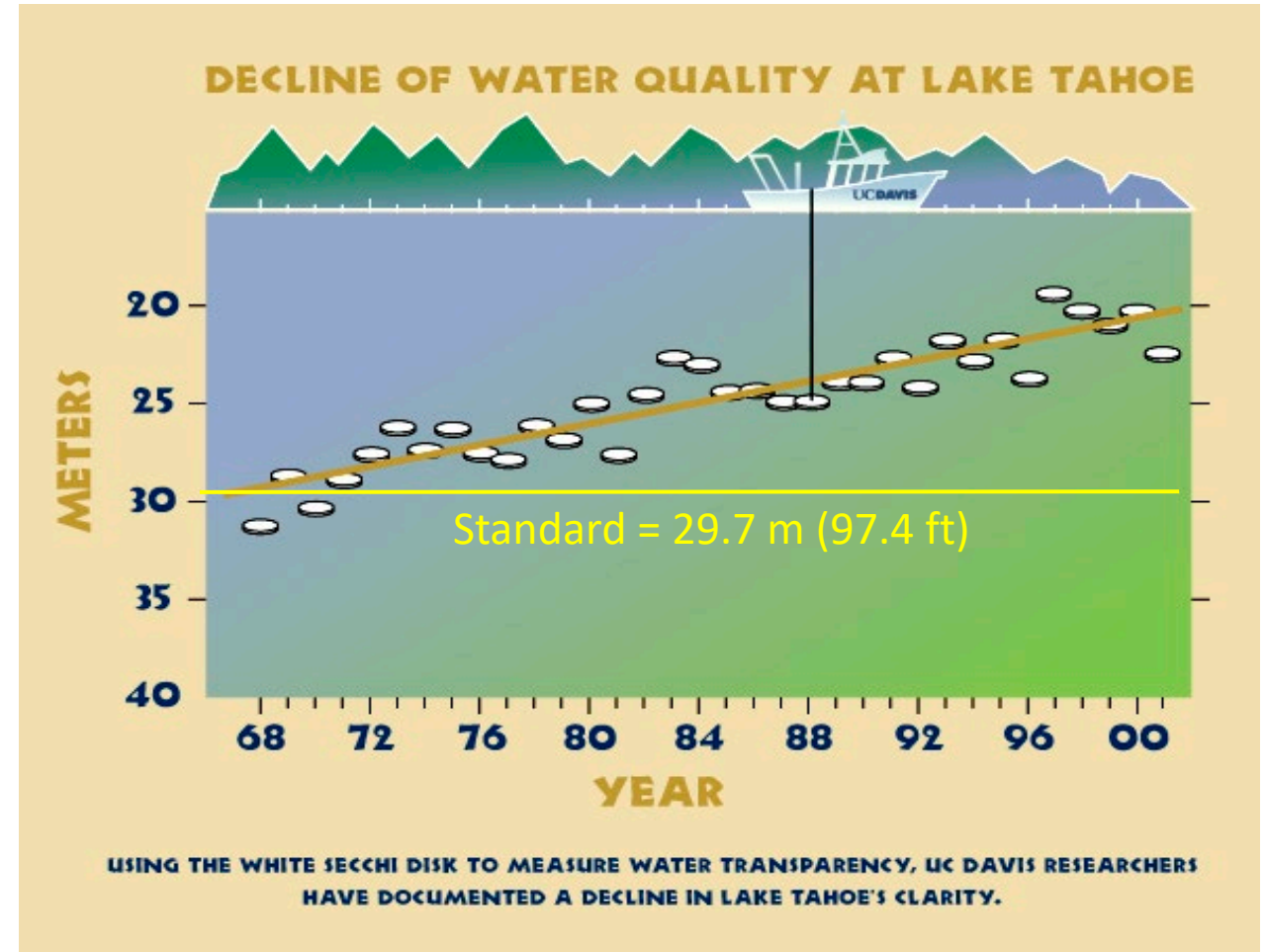
“We have a shared responsibility to build on our commitment at all levels to be sure the Lake and its environs are protected.”

President Bill Clinton, Lake Tahoe Presidential Forum, July 26, 1997

President Bill Clinton and Vice President Al Gore
at the 1997 Lake Tahoe Presidential Forum.

Lake Tahoe TMDL

- Initiated ~2000 by LWB & NDEP
- Goal: used best available science to better understand the pollutants and sources impacting clarity, and develop a cost-effective implementation strategy to restore historic clarity to Lake Tahoe



TMDL Phases & Key Questions

Pollutant - Source Analysis

- What pollutants are causing clarity loss?
- How much of each pollutant is reaching the lake?

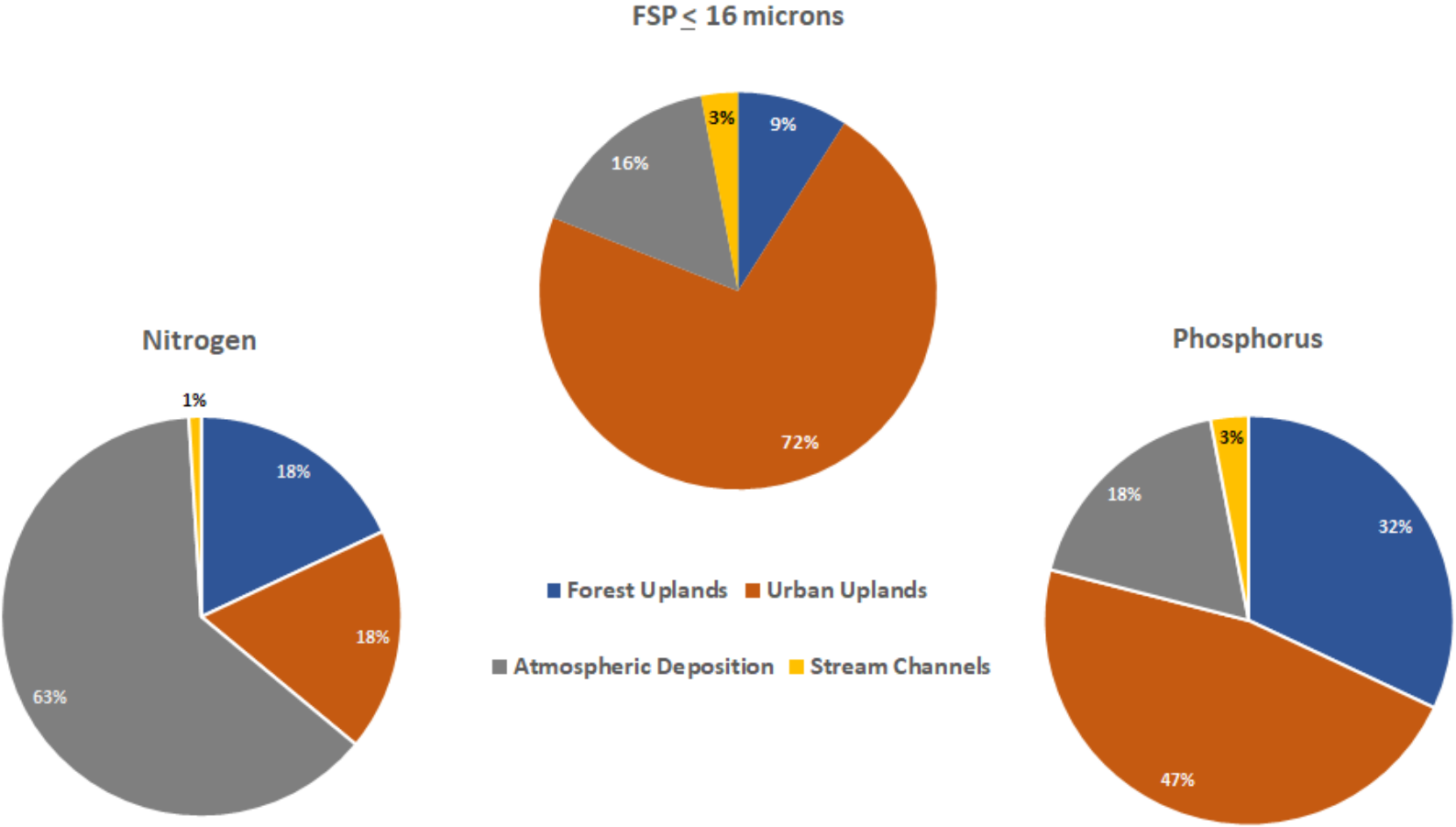
Load Capacity and Reduction Analysis

- What is Tahoe's pollutant loading capacity?
- What feasible options exist to reduce pollutants?
- What is the best strategy to meet clarity goals?

Progress Tracking, Assessment & Adaptive Management

- Are pollutant loads being reduced?
- Is clarity improving?
- How do we respond to new information and technologies?

TMDL Key Findings



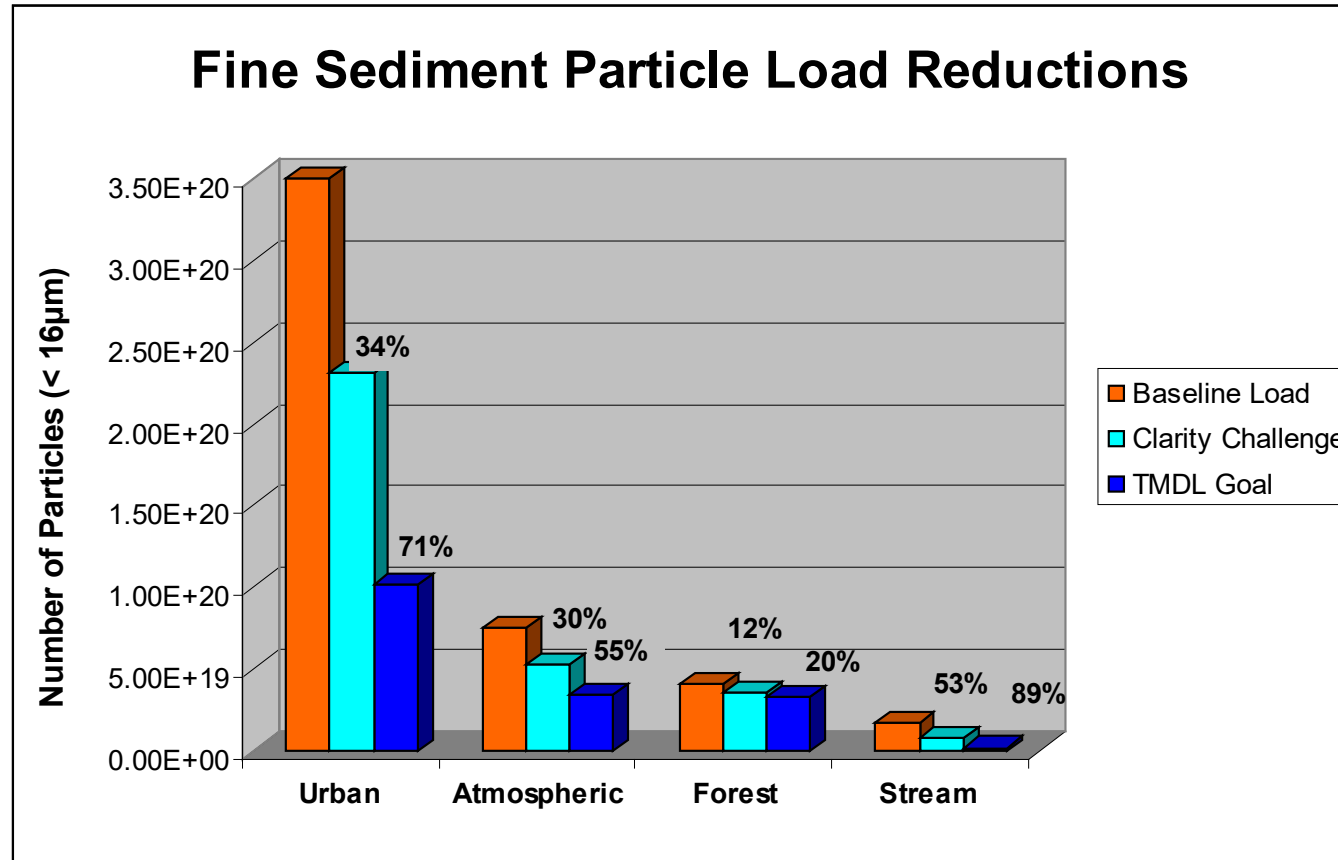
Source Distribution

TMDL Key Findings

Pollutant	Clarity Challenge	TMDL Numeric Target
Fine Sediment Particles (< 16 µm)	32 %	65 %
Phosphorus	14 %	35 %
Nitrogen	4 %	10 %

Load Reductions by Pollutant

TMDL Key Findings



Source-specific Pollutant Reductions

TMDL Progress



LAKE TAHOE TMDL PROGRAM 2023 PERFORMANCE REPORT

Guiding Efforts to Restore Lake Tahoe's Historic Clarity

Background

Lake Tahoe's loss of historic water clarity threatens its important role as a world-class tourist destination, an unparalleled opportunity for sustainable outdoor recreation, and a vital source of clean drinking water. The Lahontan Water Board and Nevada Division of Environmental Protection (NDEP) developed the Lake Tahoe Total Maximum Daily Load (TMDL) based on the best available science to guide efforts to reduce pollutants going into Lake Tahoe so that people may once again see to depths of nearly 100 ft.

To evaluate progress over a shorter timeframe, the 2011 Lake Tahoe TMDL Report set a Clarity Challenge target of 78 feet of clarity by 2031. Annual and multi-year pollutant load reduction goals have been established to help assess progress toward achieving the Clarity Challenge. Pollutants of concern include fine sediment particles (FSP), which scatter and reduce light from penetrating the water column, and the nutrients nitrogen and phosphorus which feed algal growth.

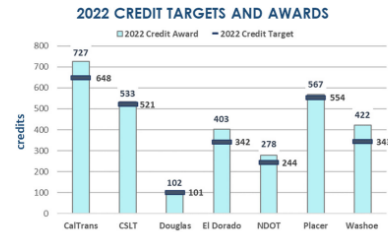
NDEP and Lahontan Water Board work together to track accomplishments, evaluate implementation progress and program effectiveness, and incorporate and respond to the latest science and information. As part of this adaptive management and continuous improvement system, the two agencies work closely with implementing partners to produce the annual Performance Report. This 2023 TMDL Performance Report highlights implementation accomplishments as of 2022, honoring the program's commitment to transparently track, report, and assess progress. For a closer look at the TMDL Program and data provided in this report, view the Lake Clarity Tracker at clarity.laketahoeinfo.org.

Urban Uplands Source Category

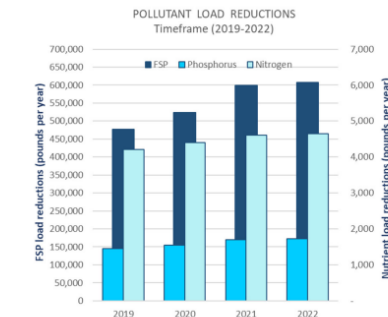
TMDL research shows FSP loads in urban stormwater must be reduced by one-third to meet the Clarity Challenge. Managing urban uplands is the greatest opportunity to control FSP pollution, as runoff from roads and other urban land uses accounts for over 70 percent of total FSP loading to the lake. Urban Implementing Partners – including the California and Nevada Departments of Transportation (CalTrans, NDOT); City of South Lake Tahoe (CSLT); and Douglas, El Dorado, Placer, and Washoe Counties – carry out controls such as roadway operations and maintenance, stormwater treatment facility construction and maintenance, and parcel-based best management practices (BMPs). These measures are registered through a comprehensive accounting system known as the [Lake Clarity Crediting Program \(LCCP\)](#).

Accomplishments

NDEP and the Lahontan Water Board award program credits to implementation partners that show ongoing effectiveness of controls. Credit awards are verified annually and compared against established targets, ensuring continued progress toward TMDL load reduction goals.

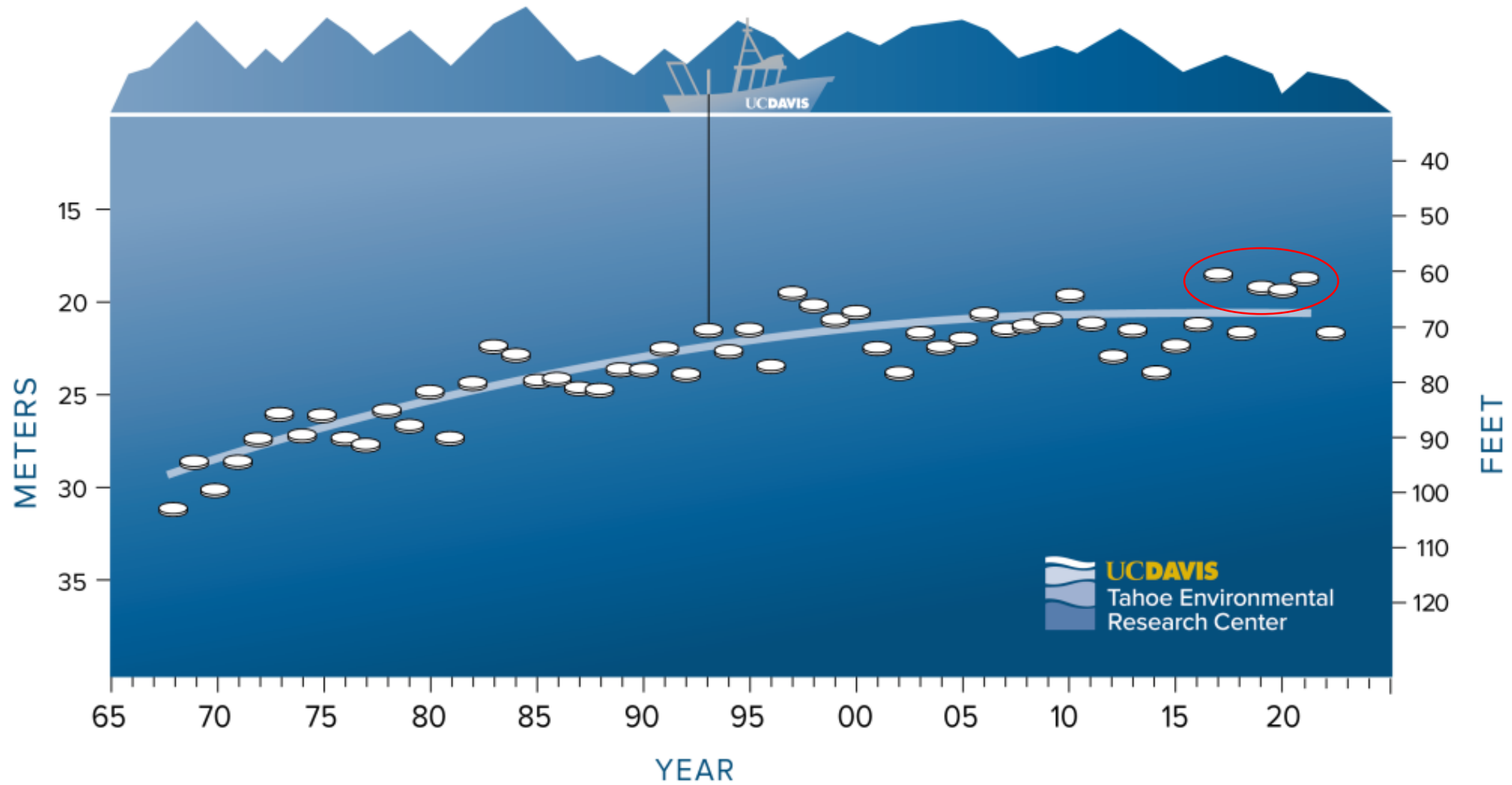


As of 2022, there were 45 active registrations in the [Stormwater Tools](#) platform. Thanks to these implementation partners, all urban uplands clarity credit targets were exceeded in 2022. In total, 3,032 credits were awarded to Urban Implementing Partners, far exceeding the target of 2,753. Because one credit is equivalent to 200 lbs./year of FSP reduced, FSP load reduction in 2022 reached nearly 608,000 lbs./year. Pollutant controls are also estimated to have reduced nitrogen loads by around 4,650 lbs./year, and phosphorus loads by 1,720 lbs./year.



- Assessment findings: urban load reduction targets and milestones continue to be exceeded and non-urban implementation remains on track
- However, recent annual clarity levels are the lowest on record (except 2023)

ANNUAL AVERAGE SECCHI DEPTH



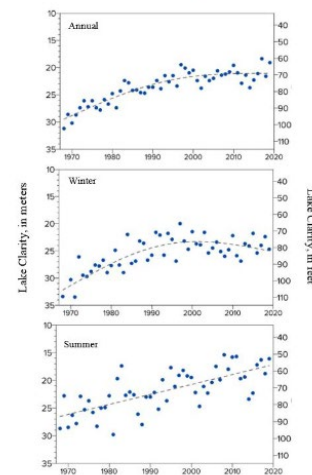
Agency-Science Coordination

- Since 2017, TRPA, NDEP, LWB and EPA have been coordinating with the Science Council to better understand why clarity is not tracking with implementation accomplishments

TSAC
TAHOE SCIENCE ADVISORY COUNCIL

Lake Tahoe Seasonal and Long-Term Clarity Trend Analysis

October 30, 2020



TAHOE SCIENCE ADVISORY COUNCIL

Lake Tahoe Clarity and Associated Conditions, 2022

Tahoe Science Advisory Council
Data Synthesis and Analysis Subcommittee



Alan Heyvaert, Ph.D.
Ramon Naranjo, Ph.D.
John Melack, Ph.D.
Shohei Watanabe, Ph.D.
Geoffrey Schladow, Ph.D.
Sudeep Chandra, Ph.D.

Key Findings from Recent Coordination Efforts

- Gaps in biology/ecology monitoring data limits ability to understand influence on system
- Further confirmation on the role and importance of climate change
- Validation of current implementation approach focused on particle reduction (inorganic, organic)
- Caldor Fire impact
- Data collection needs and recommendations to assess clarity conditions

Lake Clarity and Water Quality: Status of Science

John Melack

University of California, Santa Barbara

Major gaps in understanding ecology of lake

Modeling approaches

Key Factors Known to Impact Clarity

- Loading from watershed (particles and nutrients)
- Fine particles and small phytoplankton in water column
- Deep mixing
- Food web: interactions about aquatic organisms

Major gaps in understanding ecology of Lake

Abundance and distribution of all trophic levels from microbes to fish

Heterotrophic microbes

Autotrophic picoplankton and larger phytoplankton

Micro- and macrozooplankton

Fish

Benthic organisms

Major gaps in understanding ecology of Lake

Ecological processes

Phytoplankton and microbial productivity

Grazing and predation rates

Nutrient recycling

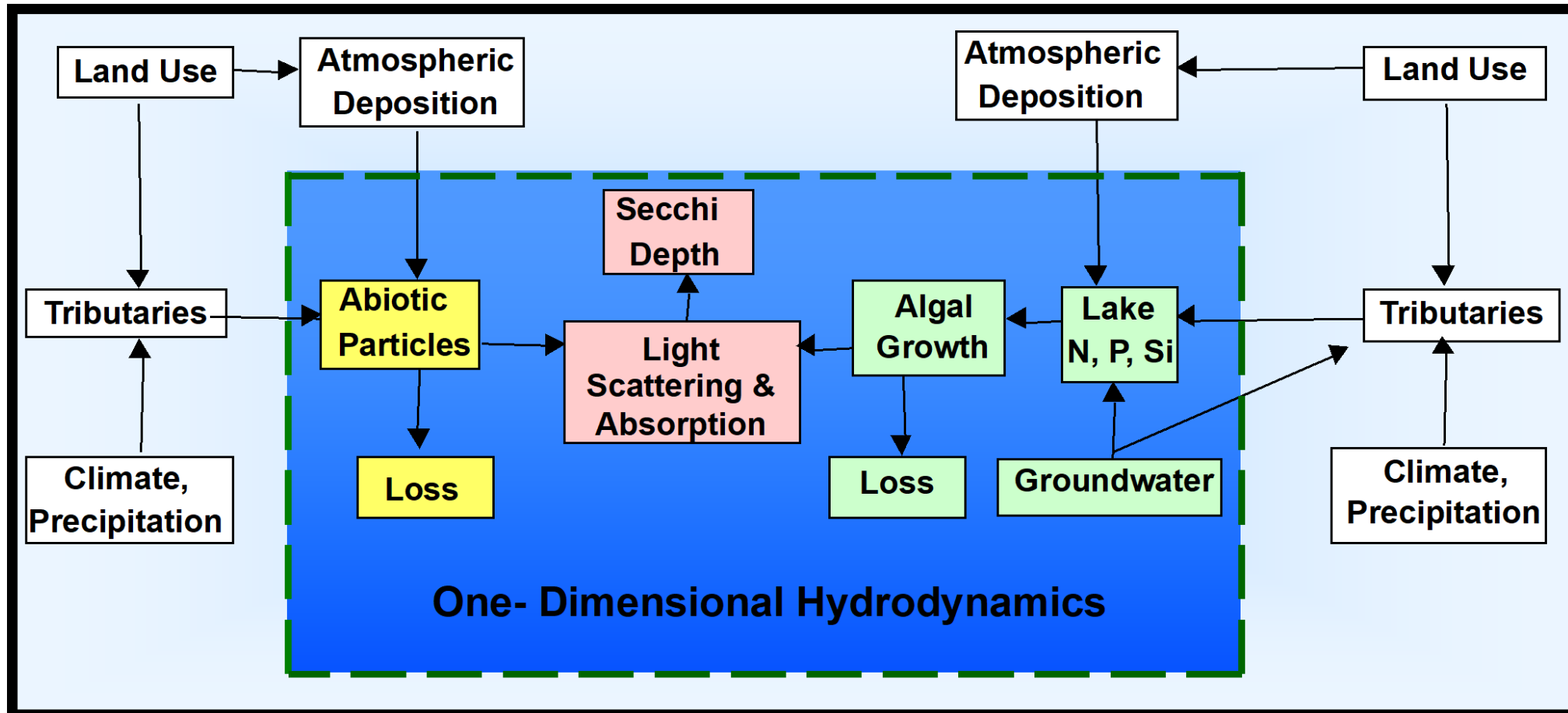
Modeling approaches

- Parametric simulation models
 - Hydrodynamic models well developed
 - Ecological models difficult, especially as predictive tools
- Empirical dynamic models
 - Require long-term data on relevant variables

Use and evaluation of models

depends on scientific and management issues of interest

Lake Tahoe clarity model – Schematic of parametric model



Empirical dynamic models (EDM)

EDM is an approach for analyzing ecosystem dynamics derived from theoretical work on the dynamical behavior of non-linear, coupled systems.

Applied to Lake Tahoe to test its ability to forecast clarity and related conditions based on time-series data spanning several decades available for Lake Tahoe.

Data used

Secchi depths: LTP – 1967 to 2020

Chlorophyll a: LTP – 1983 to 2020

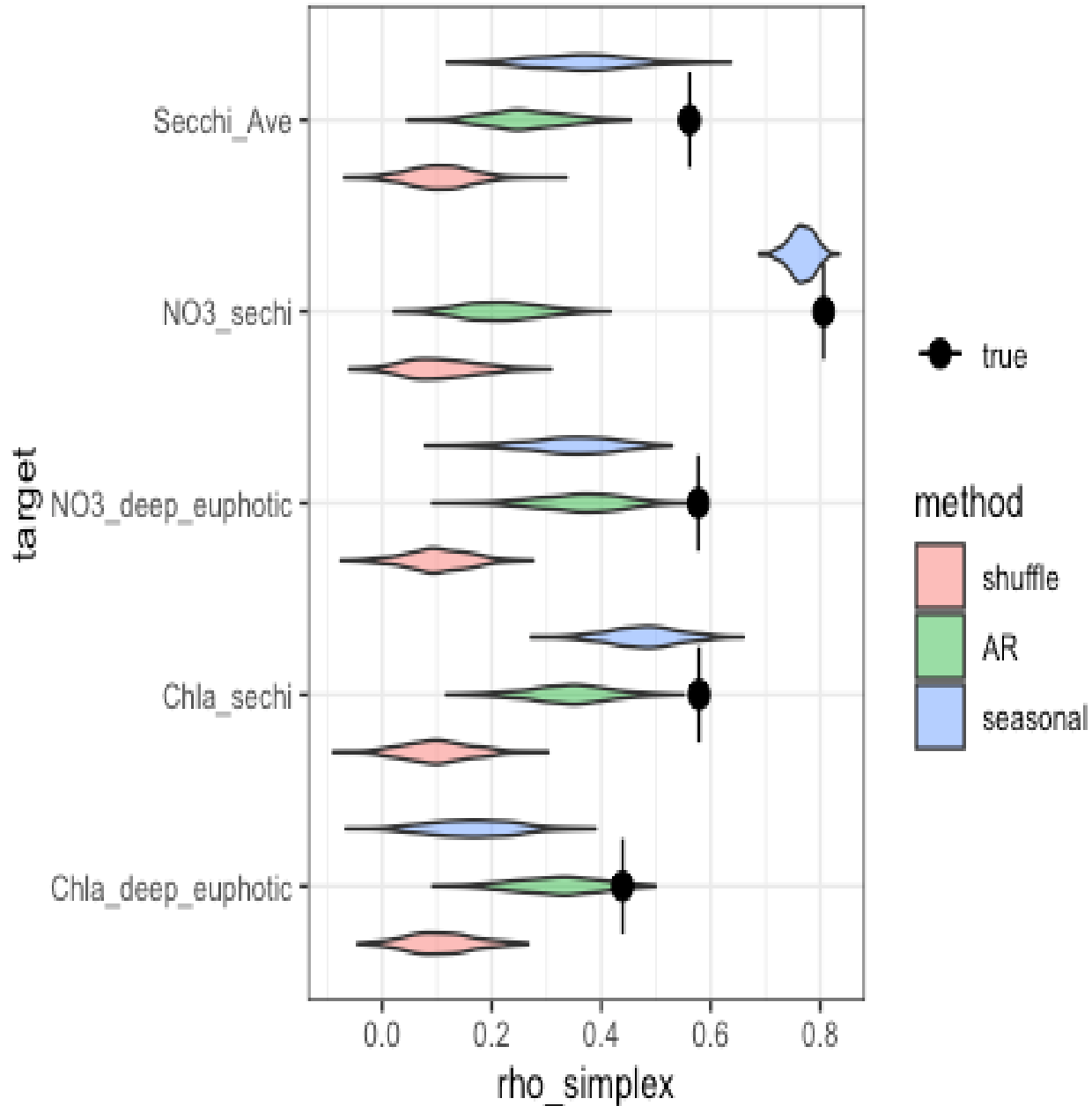
Nitrate: LTP – 1968 to 2020

Stream discharge: Upper Truckee, Blackwood, Ward

Precipitation and air temperature

Climate Indices: El Nino index

Null distributions of Simplex forecast skill



Forecast skill using EDM (black dots)

Shuffle - random shuffling of observations

AR - same autocorrelation with random changes through time

Seasonal - randomized deviations of long-term seasonal average

rho - Pearson correlation between observed time-series values and predictions

Conclusions and further analyses

High forecast skill using EDM for water quality variables (Secchi depth, chlorophyll-a, nitrate) using climatic drivers (stream discharge, precipitation, El Nino index) = solid evidence of complex, non-linear coupling among factors.

Further analyses

Link hydrodynamic modeling with EDM

Deyle et al. 2022. A hybrid empirical and parametric approach for managing ecosystem complexity: water quality in Lake Geneva under nonstationary futures. Proc. Natl. Acad. Sci. USA. 119, e2102466119. doi.org/10.1073/pnas.2102466119

Include time series of particles and plankton

Lake Clarity and Water Quality: Some Future Directions

S. Geoffrey Schladow

UC Davis Tahoe Environmental Research Center

Past Recommendations Have Included:

1. Measure more often
2. Measure more places
3. Measure smarter – using models to guide monitoring and experiments
4. Do it all

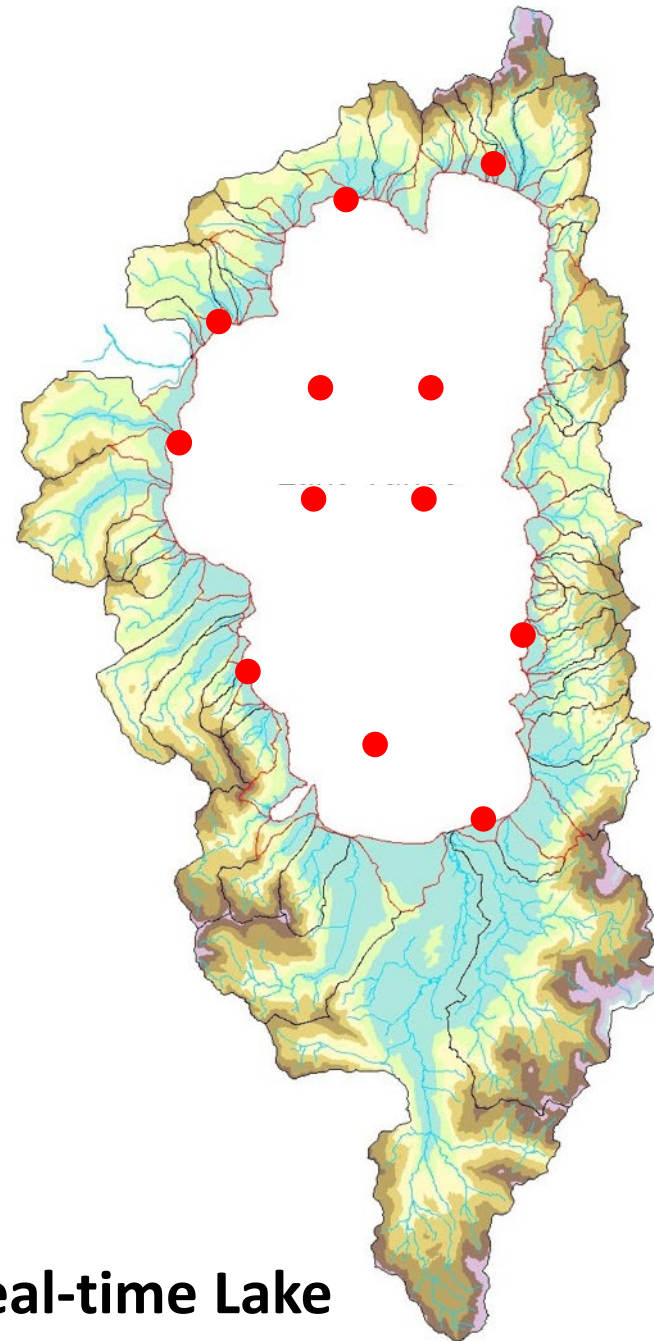
When will we achieve all that?



Surprise!! We already have the
infrastructure in place.

Beyond the 50-year long-term data record.

Real-time
Meteorological
Network

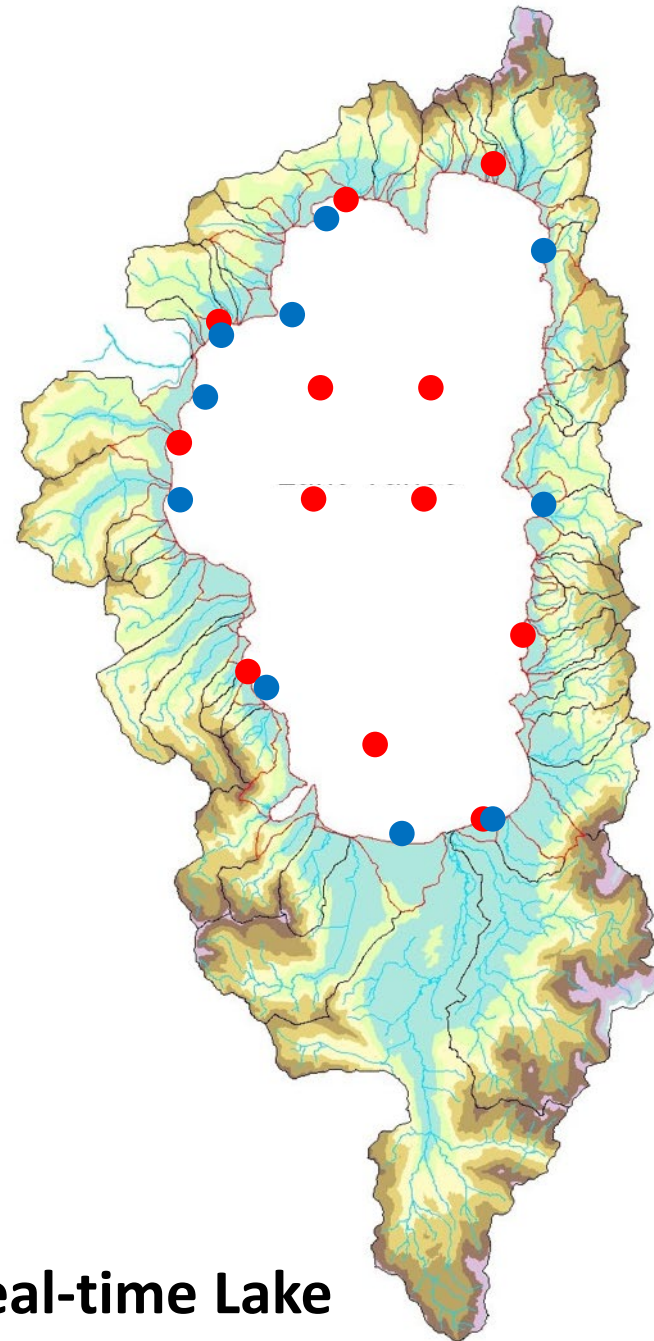
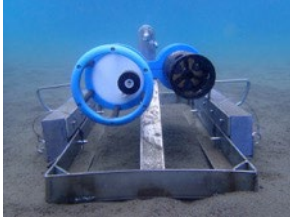


**Autonomous, Real-time Lake
Observatory**

Real-time
Meteorological
Network



Real-time
Nearshore
Network

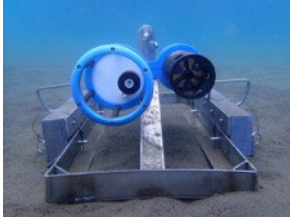


**Autonomous, Real-time Lake
Observatory**

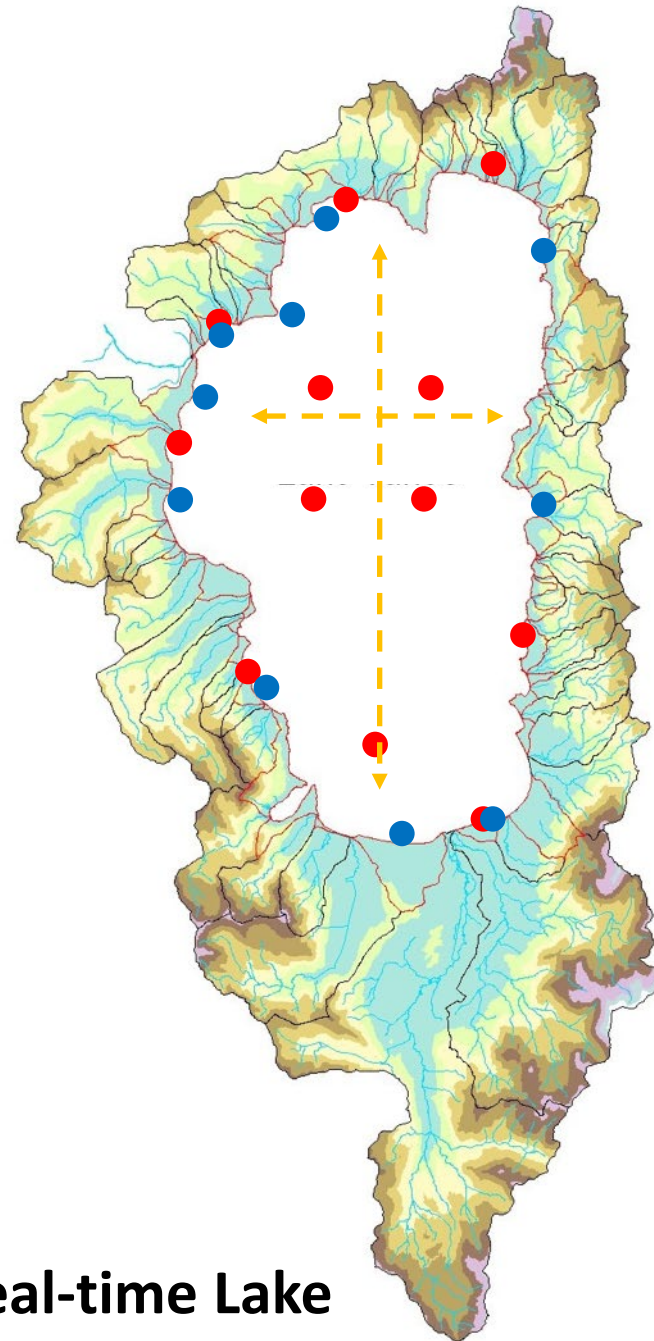
Real-time
Meteorological
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Real-time
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Gliders and
AUVs

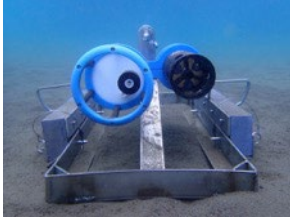


**Autonomous, Real-time Lake
Observatory**

Real-time
Meteorological
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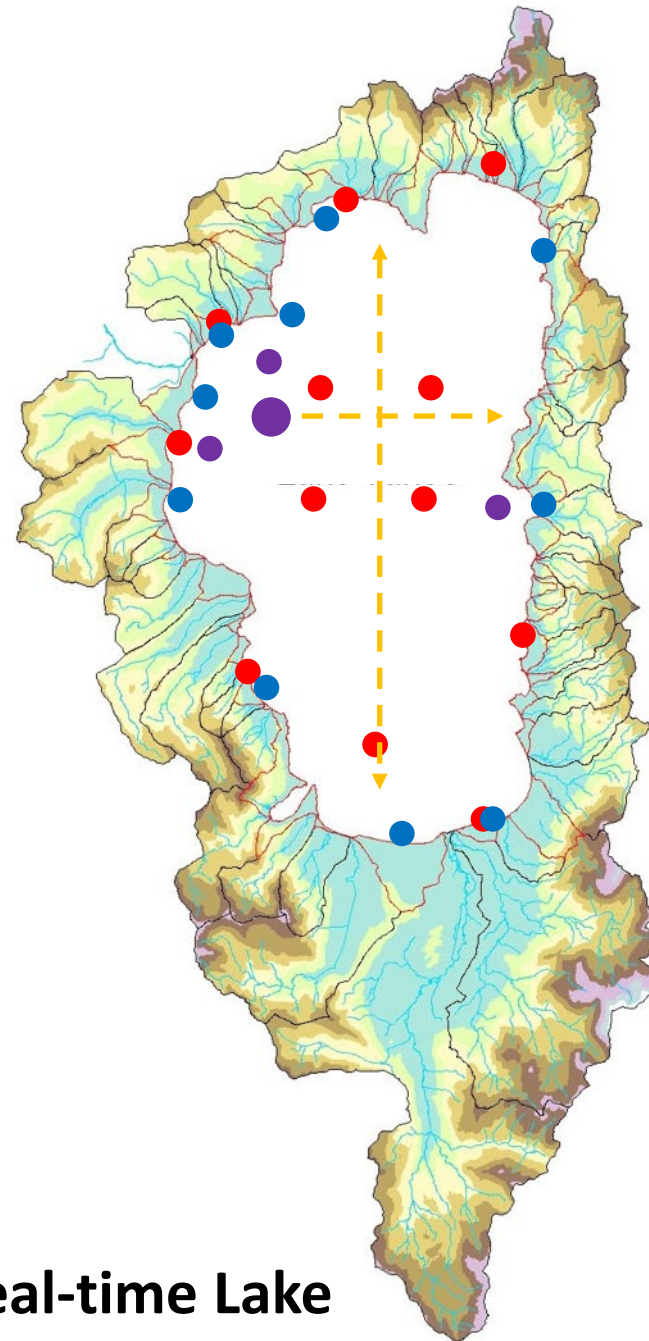
Real-time
Nearshore
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Gliders and
AUVs



Real-time
Lake Moorings

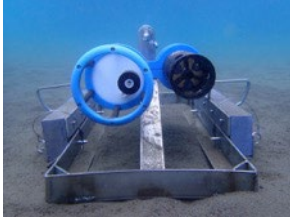


**Autonomous, Real-time Lake
Observatory**

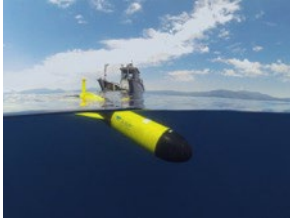
Real-time
Meteorological
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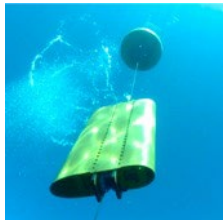
Real-time
Nearshore
Network



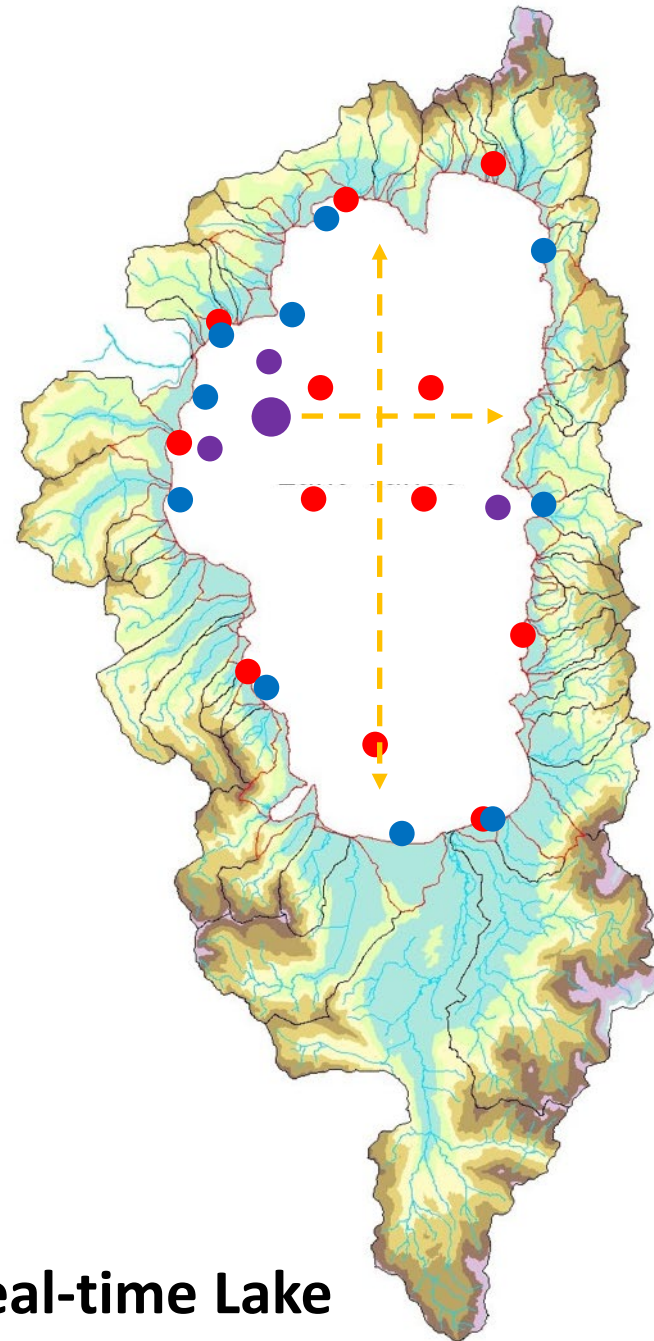
Gliders and
AUVs



Real-time
Lake Moorings



Coming March 2024

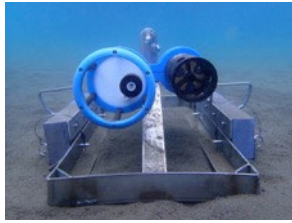


Autonomous, Real-time Lake Observatory

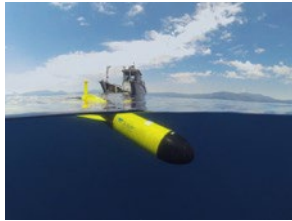
Real-time
Meteorological
Network



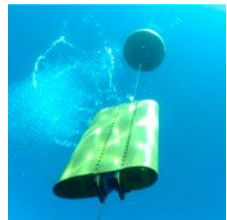
Real-time
Nearshore
Network



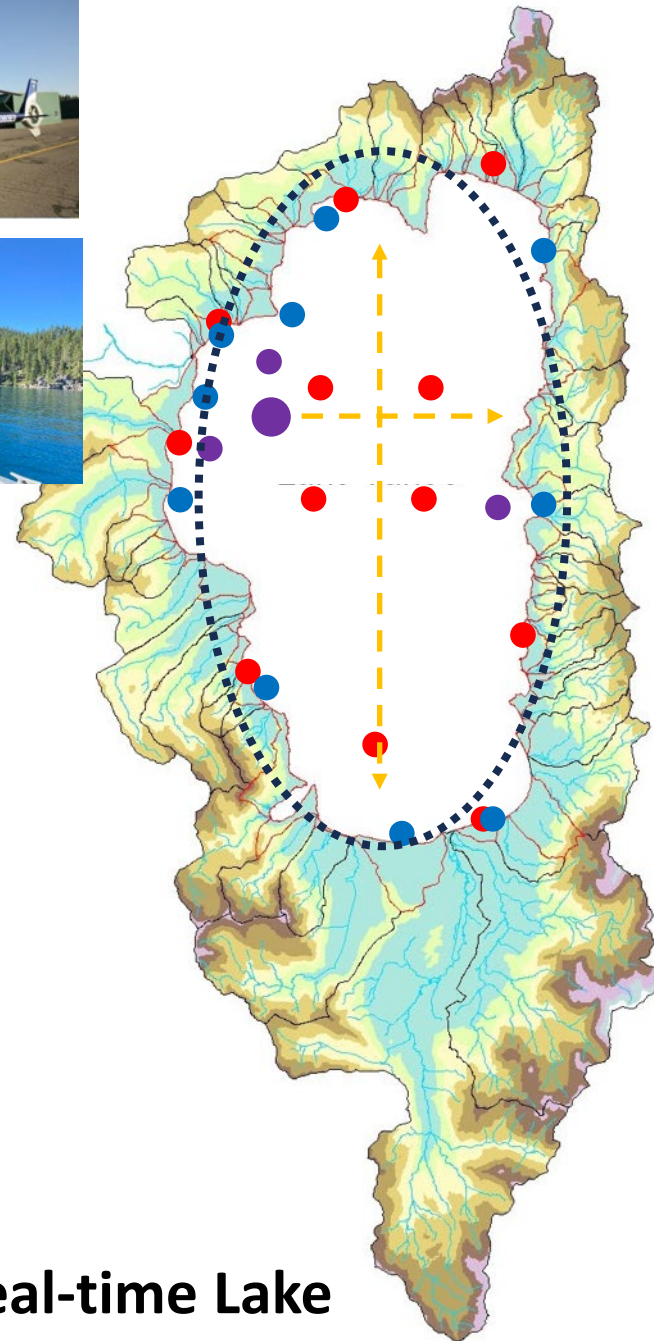
Gliders and
AUVs



Real-time
Lake Moorings



Aerial and
spaceborne
shoreline
surveys +
machine
learning

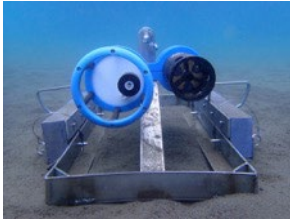


Autonomous, Real-time Lake
Observatory

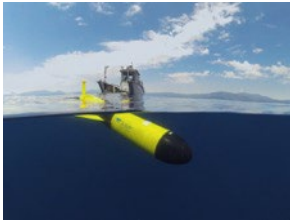
Real-time
Meteorological
Network



Real-time
Nearshore
Network



Gliders and
AUVs



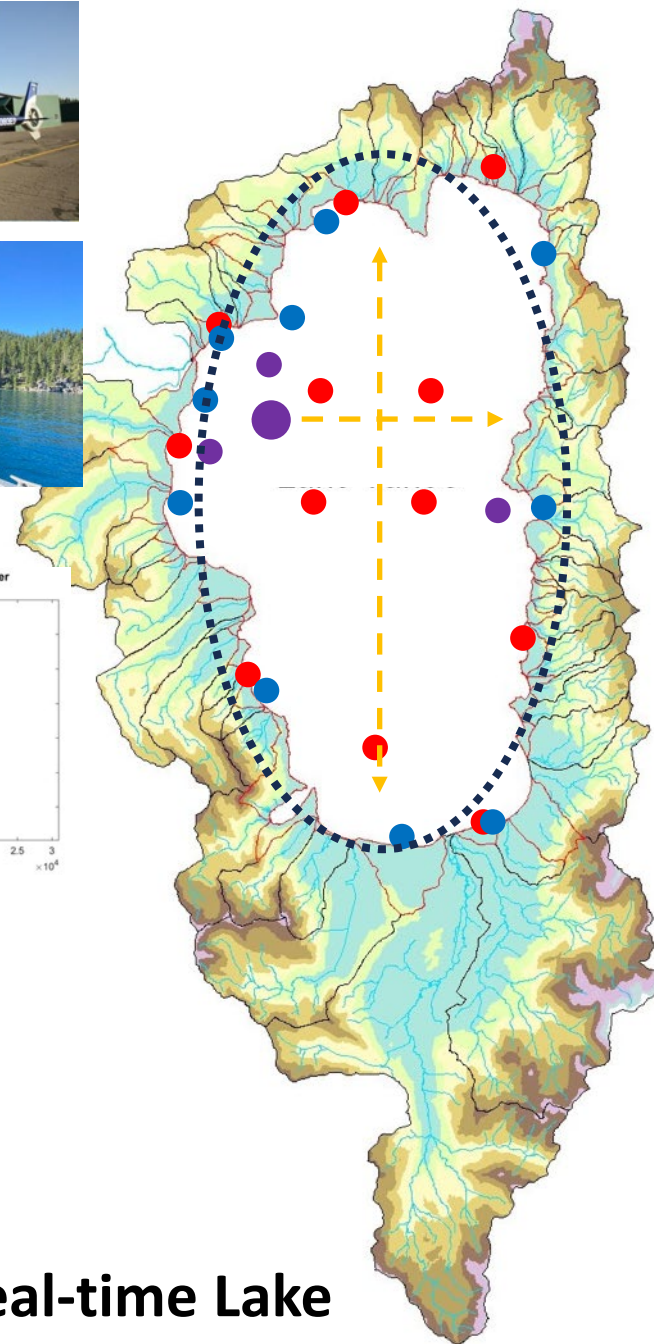
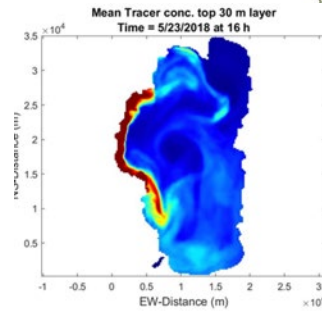
Real-time
Lake Moorings



Aerial and
spaceborne
shoreline
surveys +
machine
learning



3-D Lake
Model



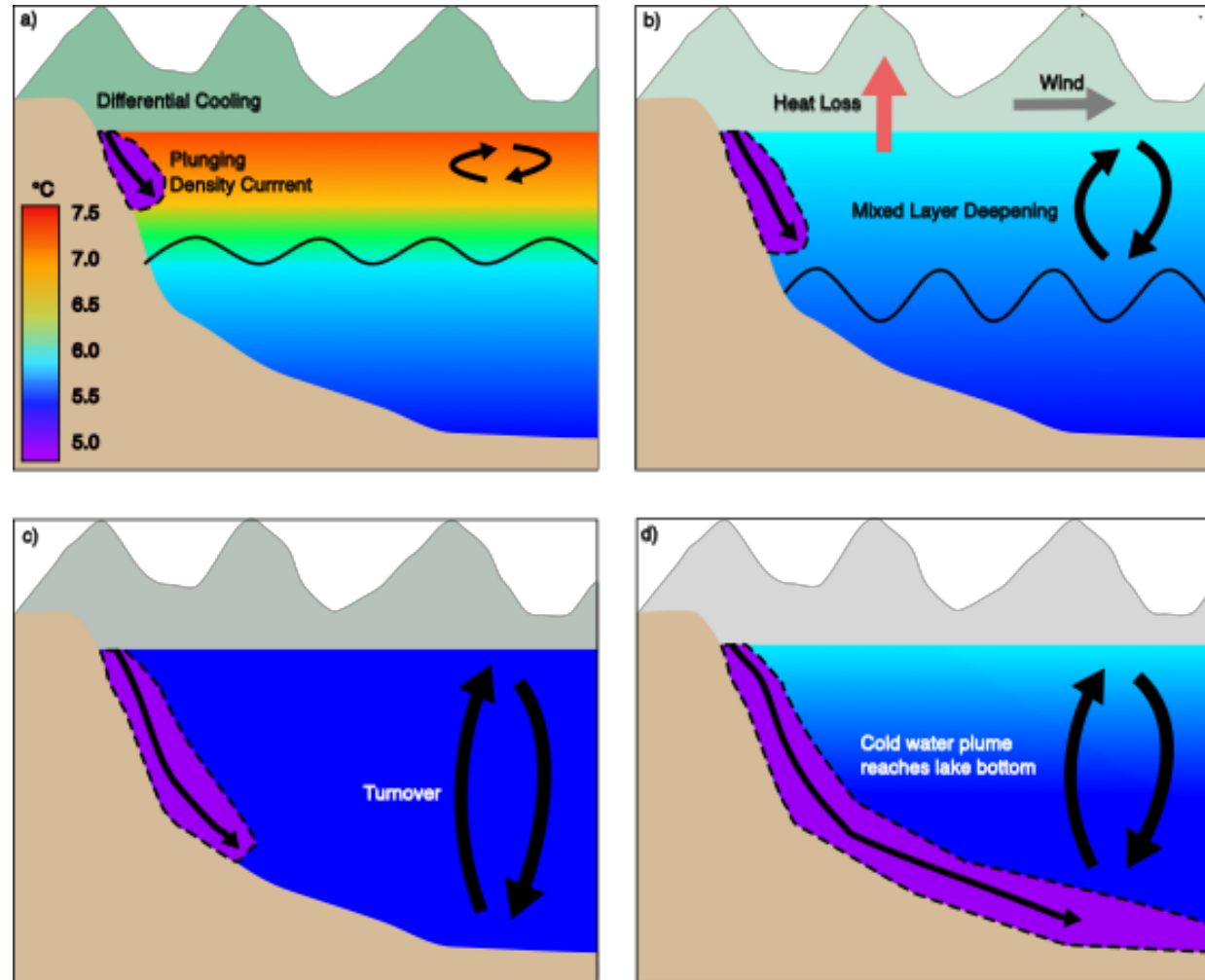
Autonomous, Real-time Lake
Observatory

An Example of How These Data
Types and Model Are Advancing
Our Understanding

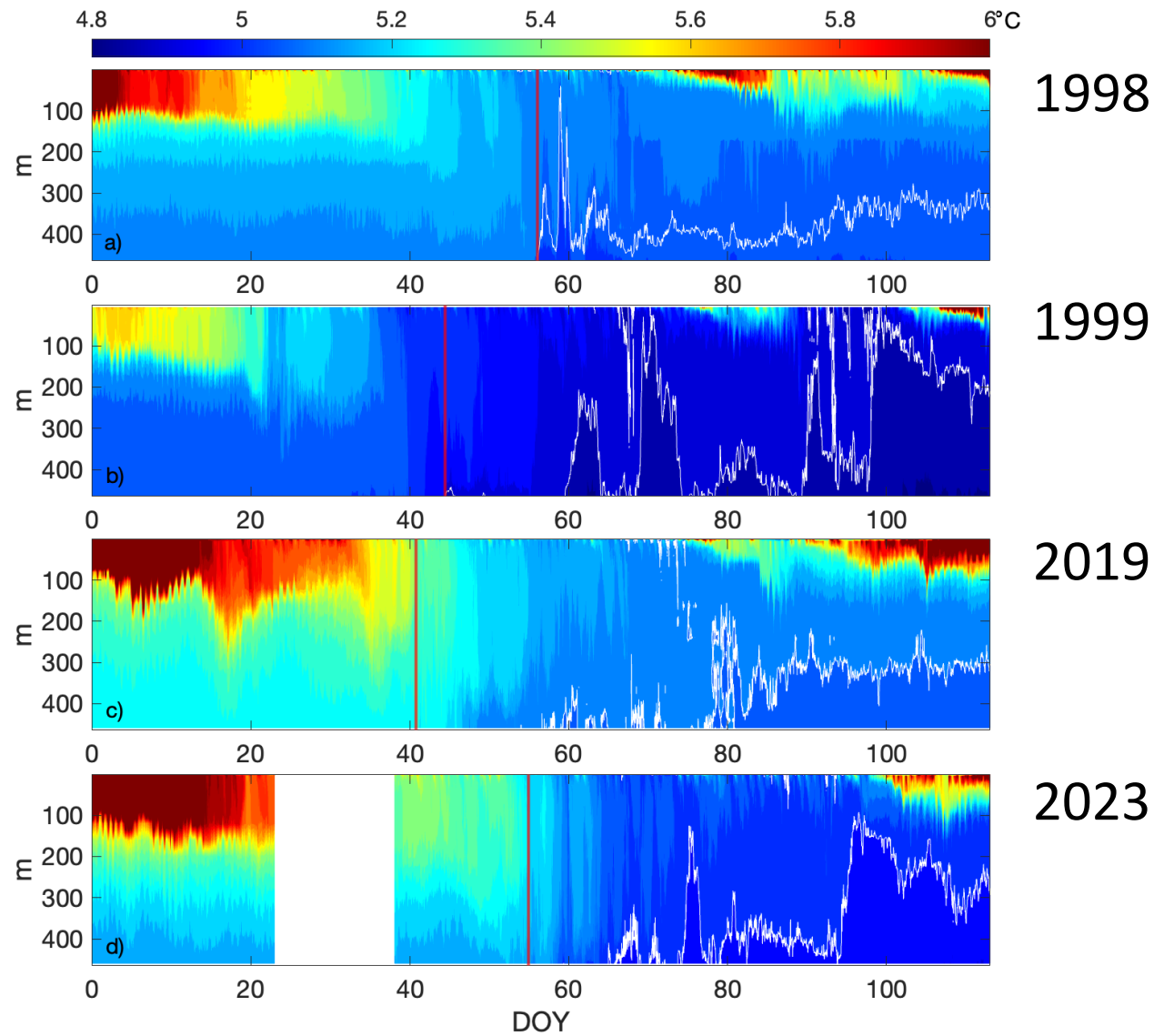
Deep Mixing is a Three-Dimensional Process

Used:

- Meteorological Network
- Nearshore Network
- Lake Moorings
- 3-D Model



Deep Mixing is a Three-Dimensional Process



Summary

- Key shift in recent years has been the recognition of the importance of “internal” lake processes
- Major knowledge gaps have been identified
- Expanded/new monitoring AND science can address physical, biogeochemical and ecological processes that govern Lake Tahoe’s clarity and water quality is continuing
- Models are an essential part of that understanding, especially for managers needing to know the impacts of actions
- For models, not necessary to know everything
- Model results, when compared to the data, can indicate the critical unknowns for a specific question, e.g. clarity, invasive species control, nearshore health, climate change impacts....

Resources / Recent Reports at

<https://www.taohesciencecouncil.org/water-resources>

- Lake Tahoe Clarity Analysis and Modeling Phase I: Biogeochemical and Ecological Modeling
- Seasonal and Long-Term Clarity Trend Assessment of Lake Tahoe, California–Nevada
- Lake Tahoe Clarity Analysis and Modeling: Empirical Dynamic Modeling
- UC Davis Tahoe: State of the Lake
<https://tahoe.ucdavis.edu/stateofthelake>

Small
Group
Questions

- Did anything stand out as new, surprising, or as an “a-ha moment?”
- What are the most pressing current issues for this topic?
- What are opportunities to advance science delivery?

Reports
from Small
Group
Discussion

- Did anything stand out as new, surprising, or as an “a-ha moment?”
- What are the most pressing current issues for this topic?
- What are opportunities to advance science delivery?



THANK YOU!

Please join us Friday to synthesize key themes and discuss how the Science Council can advance science delivery for healthy Tahoe systems!
