# OKANAGAN RIVER:

## "ADAPTIVE MANAGEMENT SUCCESS STORIES"

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Adaptive Management for Large-Scale
Water Infrastructure Workshop
New Orleans, Louisiana
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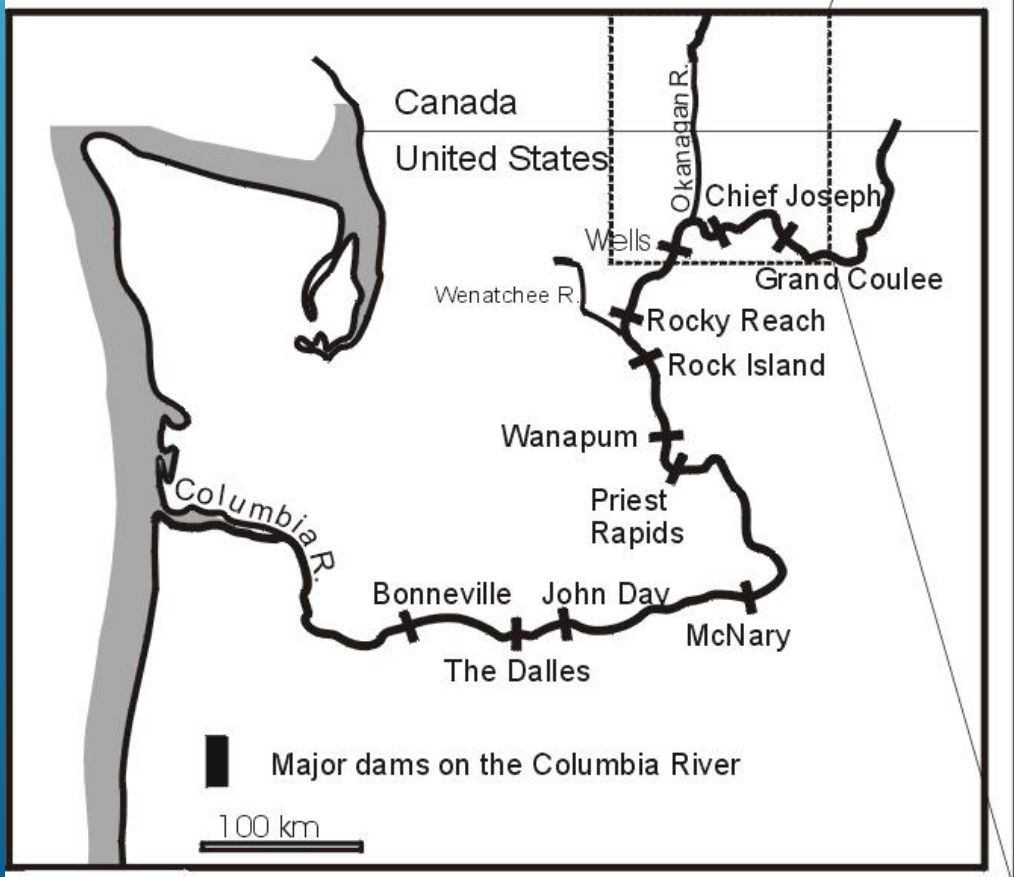
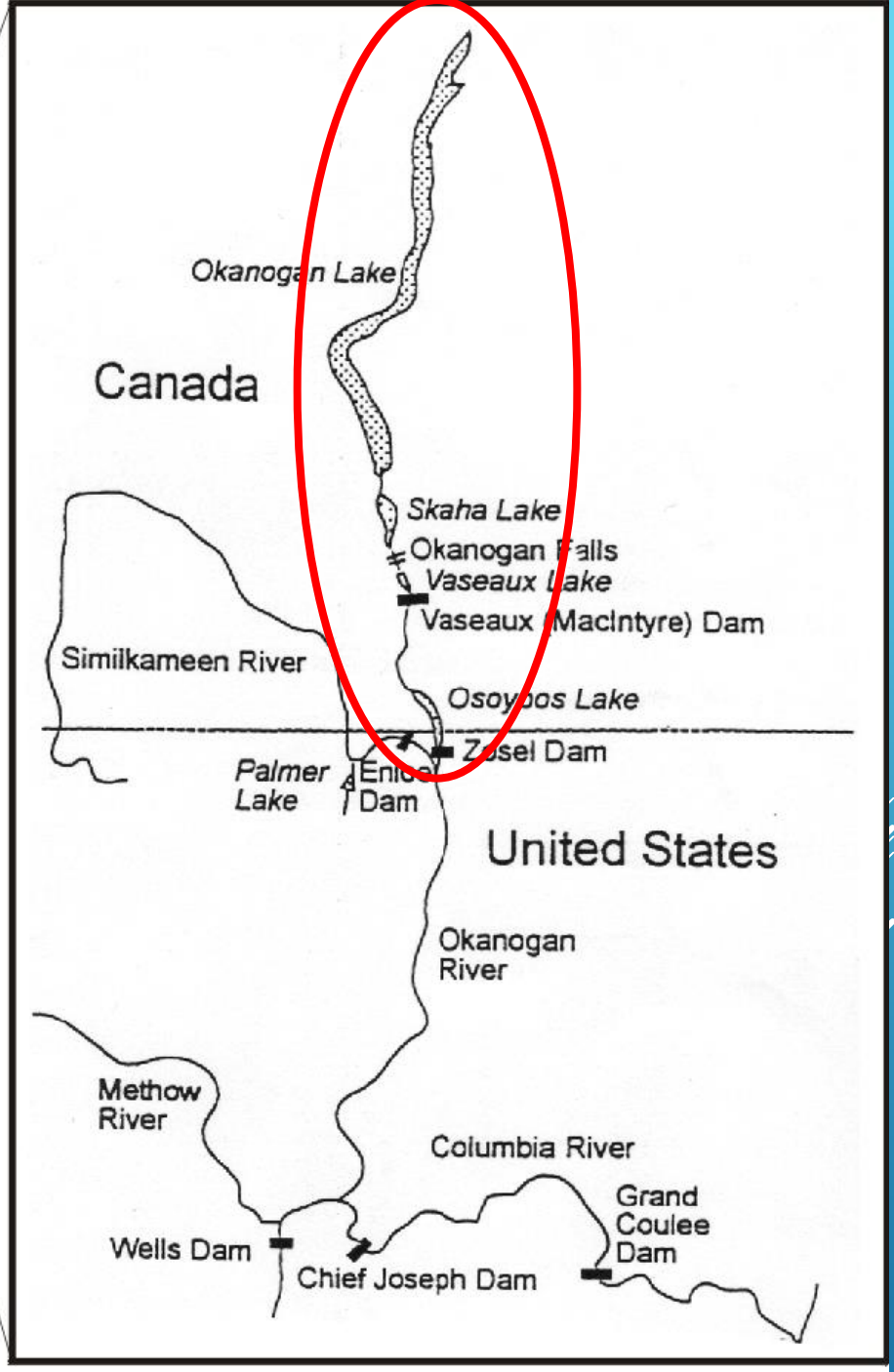
# PRESENTATION OUTLINE:

- Overview of Okanagan Watershed
- History of Okanagan Water Management Regulation
- AM Example 1:  Fish Water Management Tool
- AM Example 2:  Skaha Lake Experimental Sockeye Re-Introduction
- AM Example 3:  Renewal of IJC Order for Zosel Dam & Osoyoos Lake
- Summary of AM Success Stories

# LOCATION MAP



# OKANAGAN WATERSHED :

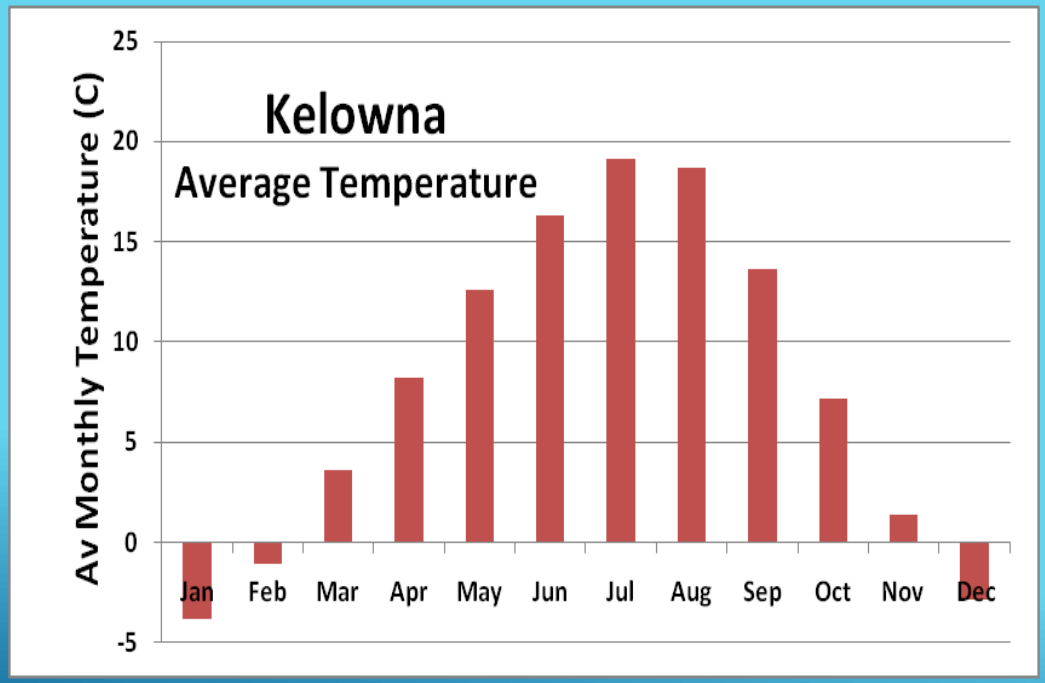
- Located in dry, southern interior of BC
- Tributary to Columbia River
- Drainage area = 8,200 $km^2$ (in Canada)

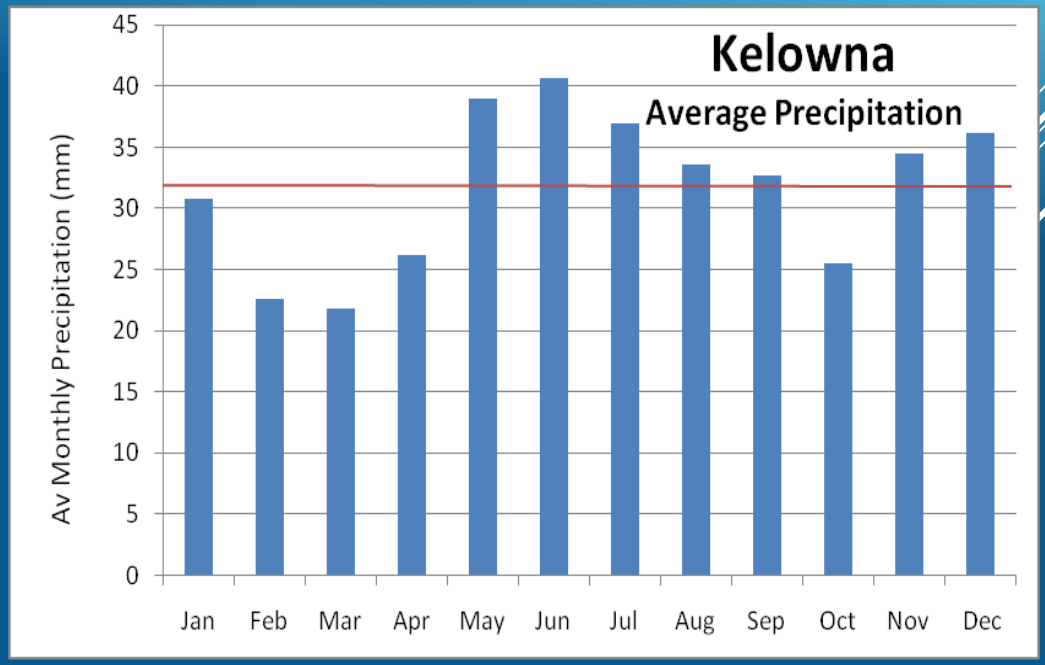
- 5 Mainstem Lks:
  - Kalamalka
  - Okanagan
  - Skaha
  - Vaseux
  - Osoyoos

# OKANAGAN CLIMATE

**Av. Monthly Temperature (range 25 – 79 º F)**

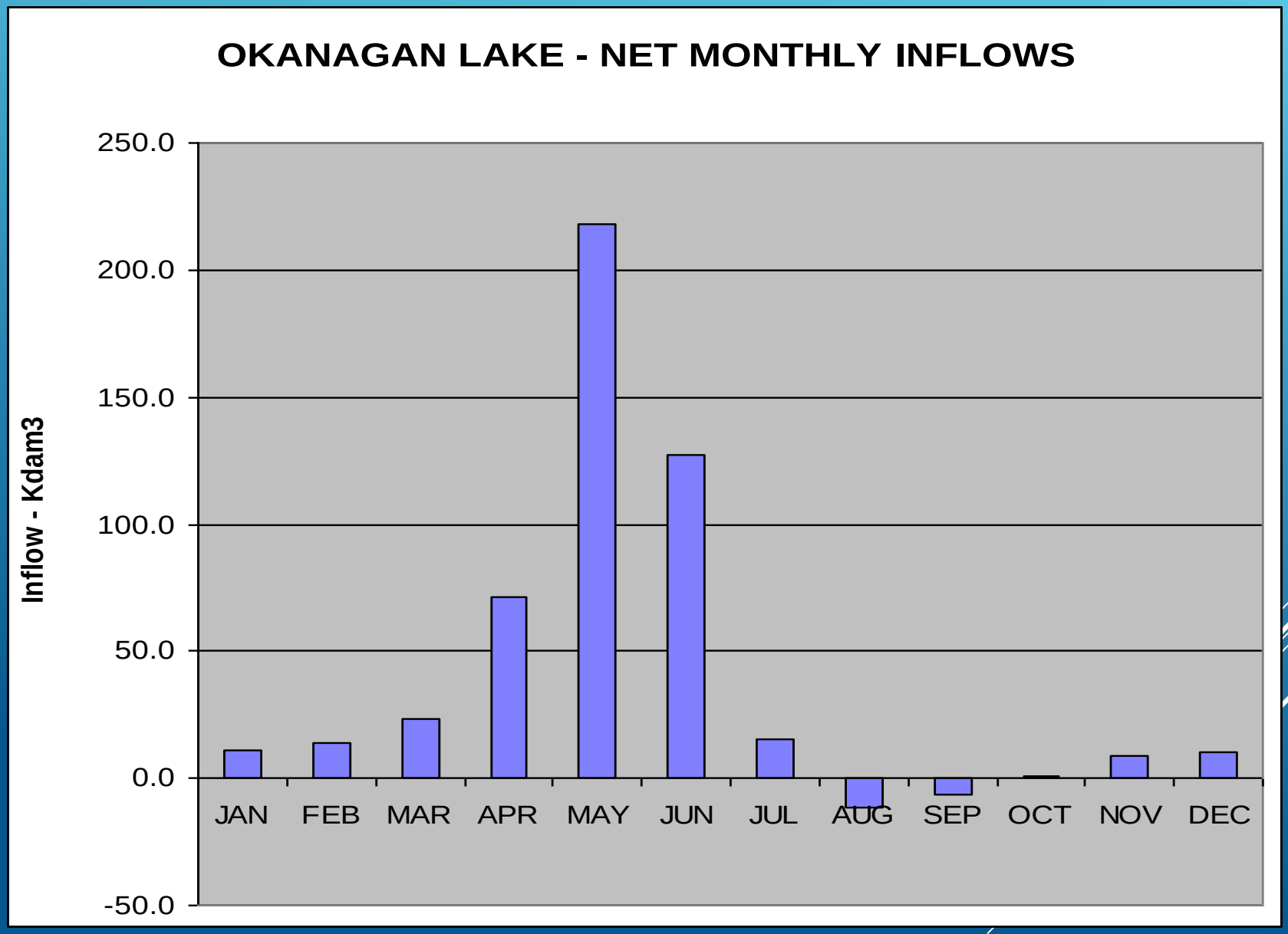
**Av. Monthly Precipitation (Mean Annual: ~ 15 in)**



# OKANAGAN HYDROLOGY

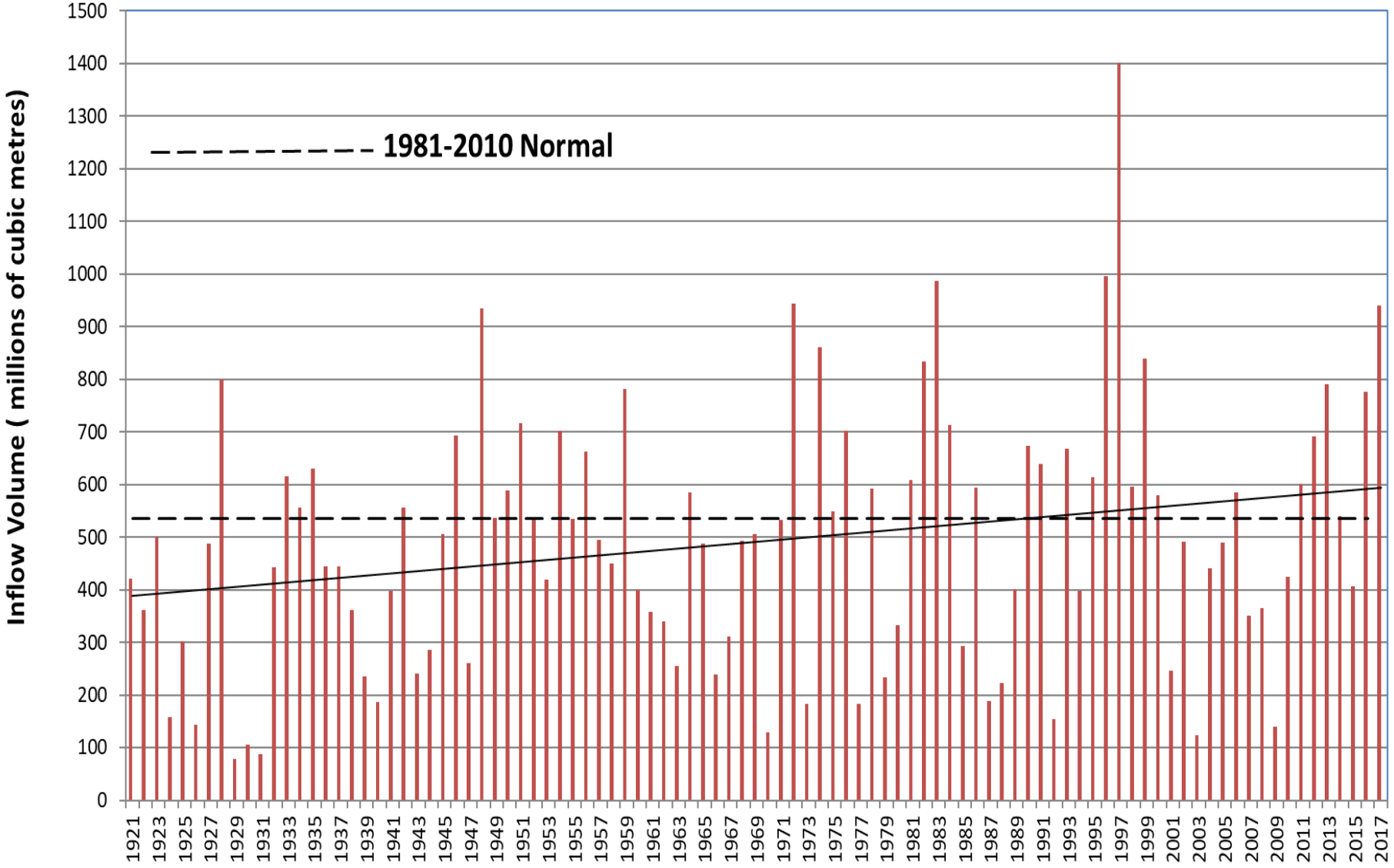
Annual hydrograph dominated by spring snowmelt


OKANAGAN LAKE - NET MONTHLY INFLOWS
Inflow - Kdam3
250.0
200.0
150.0
100.0
50.0
0.0
-50.0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

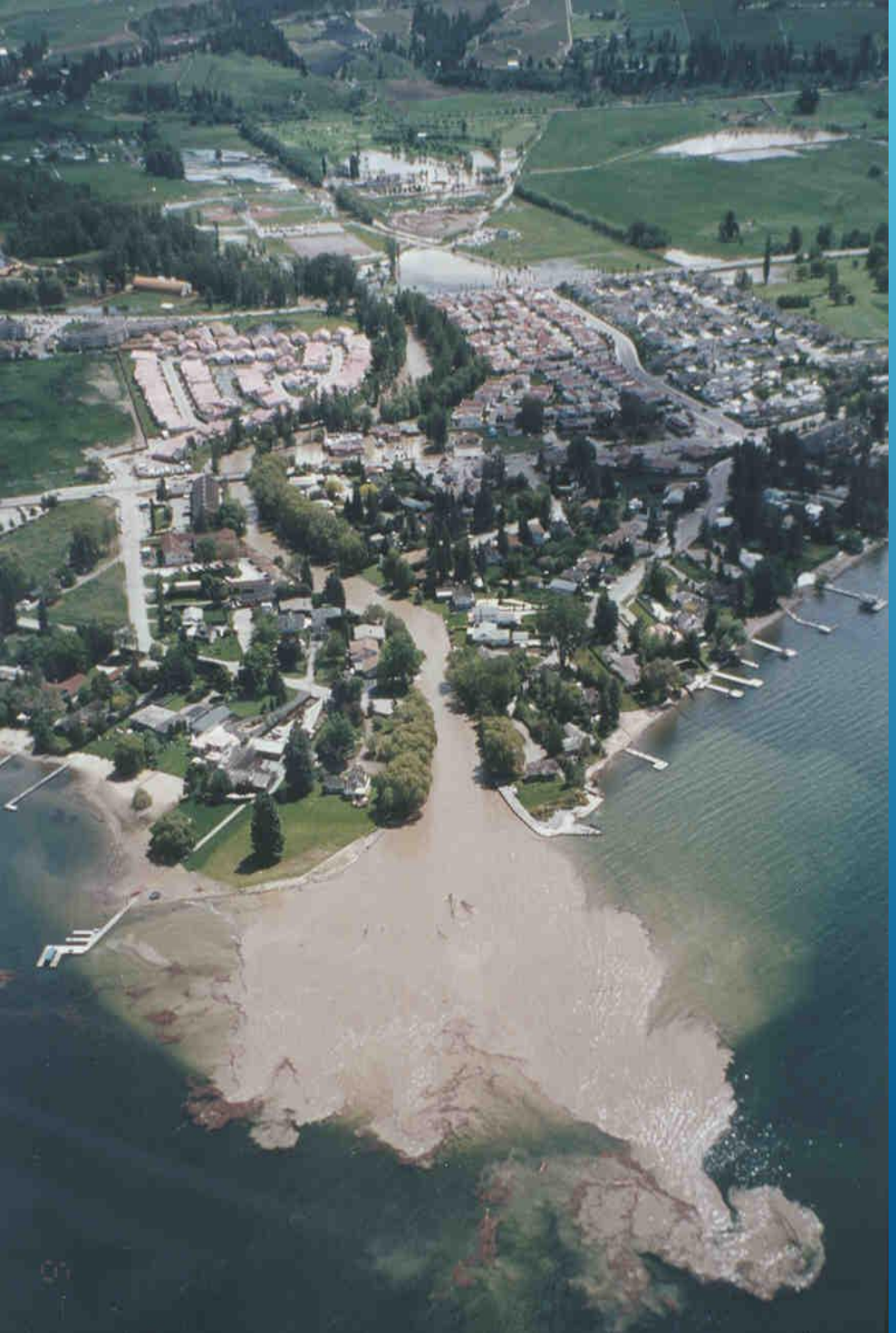
# Okanagan Lake

**Drainage Area: 6,090 km2 (2350 sq. mi.)**
**Surface Area:  341 km2  (132 sq. mi.)**
**Max. Depth:  245 m (804 ft.)**
**Residence Time:  50 - 60 years**
**Av. Outflow:  14.7 m3/s (520 cfs)**

# Okanagan Lake - Annual Net Inflow Volume (1921 - 2017)




**Source:** BC River Forecast Centre, Ministry of Natural Resource Operations

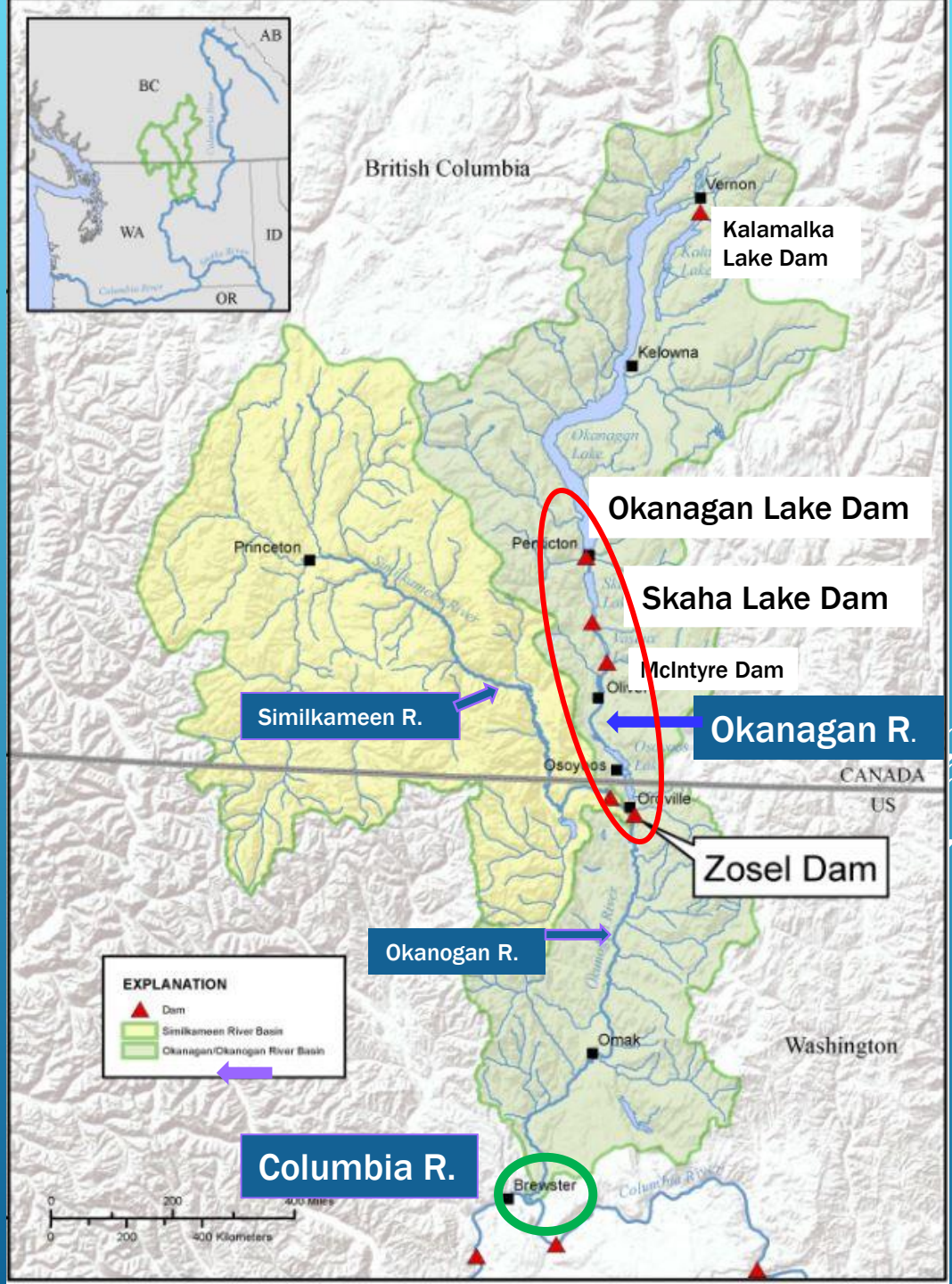


# VARIATION IN OKANAGAN LAKE ANNUAL INFLOW

Range of annual inflow volume :

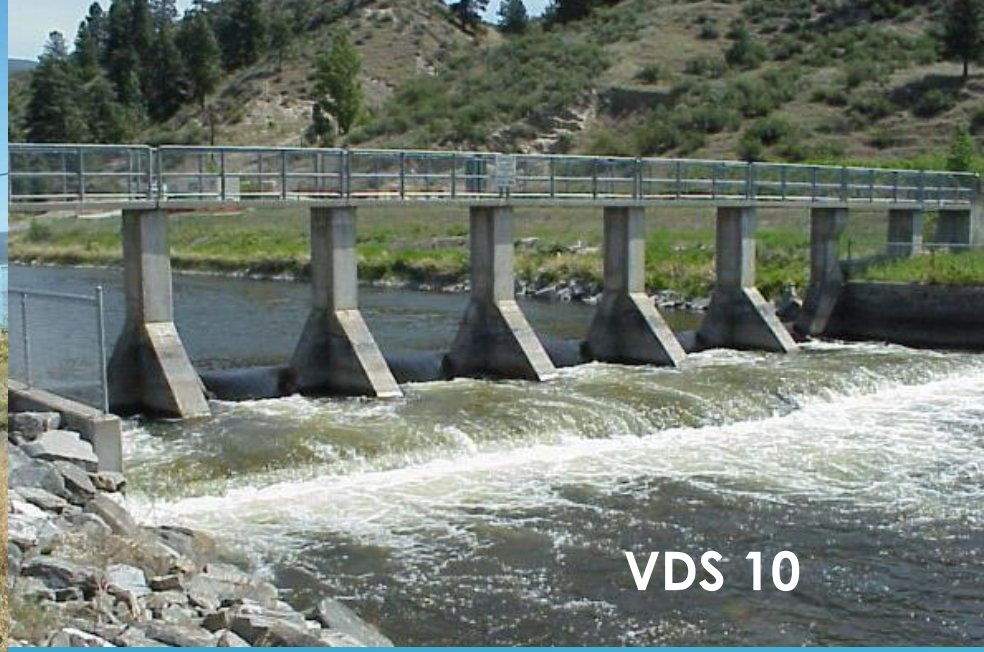
- 0.23 m to 4.12 m
- 78 to 1400 million $m^3$

# Okanagan Lake Regulation System (OLRS) & Columbia River

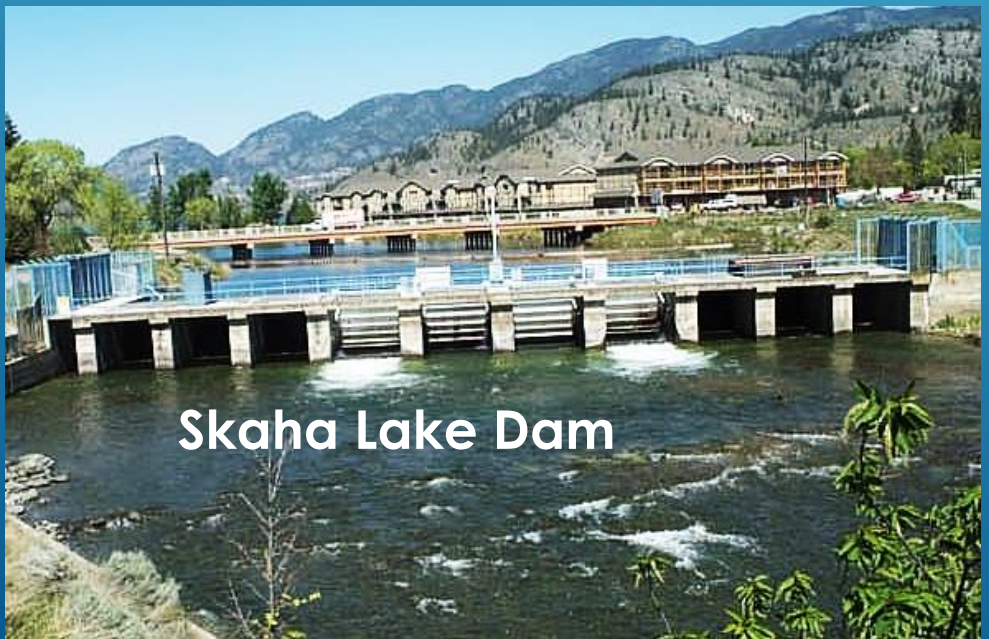


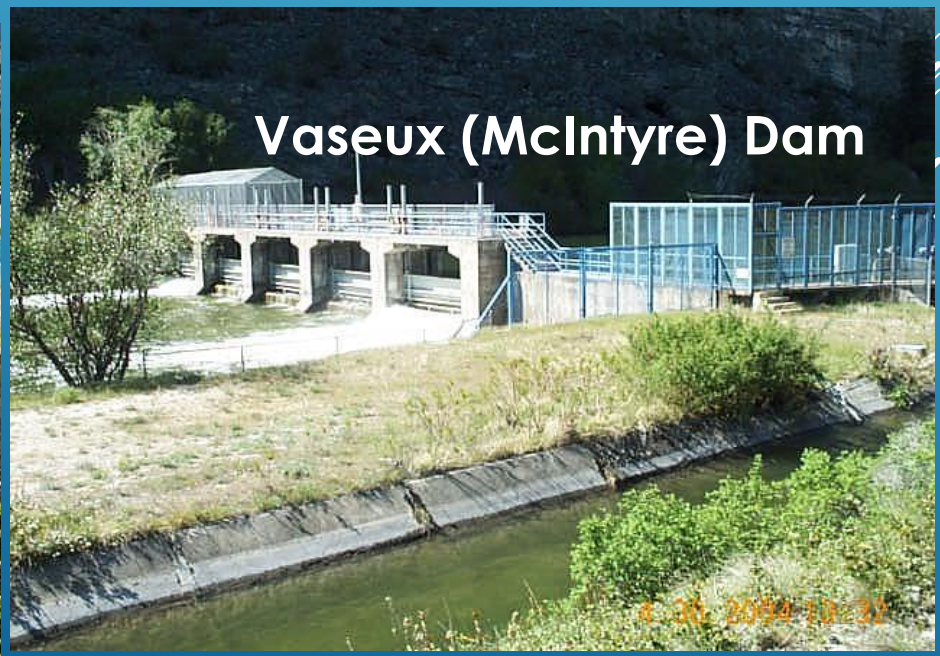
# OKANAGAN LAKE REGULATION SYSTEM (OLRS):

- Constructed in early 1950's in response to floods in 1940's
- Works: 4 dams
  - 38 km of engineered channel
  - 68 km of dikes
  - 17 vertical drop structures &
  - 5 sediment basins

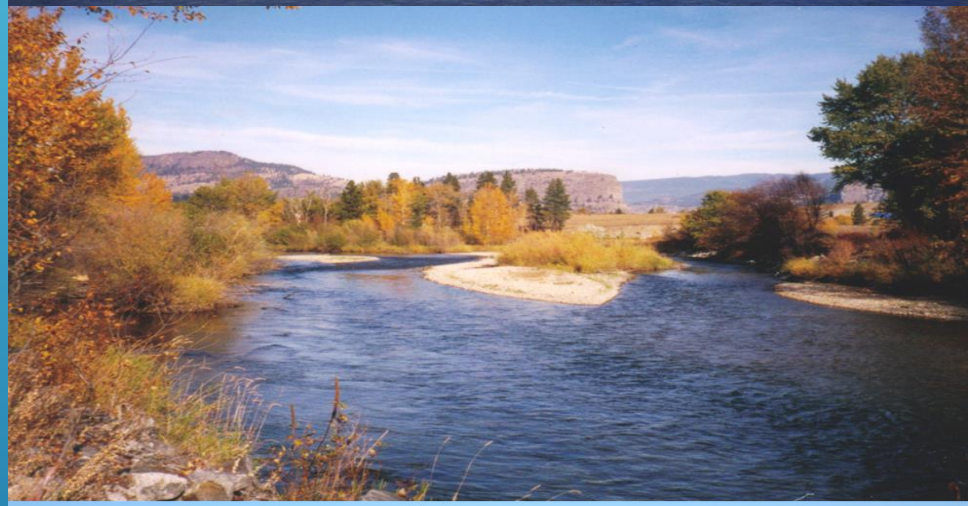

# OLRS Structures

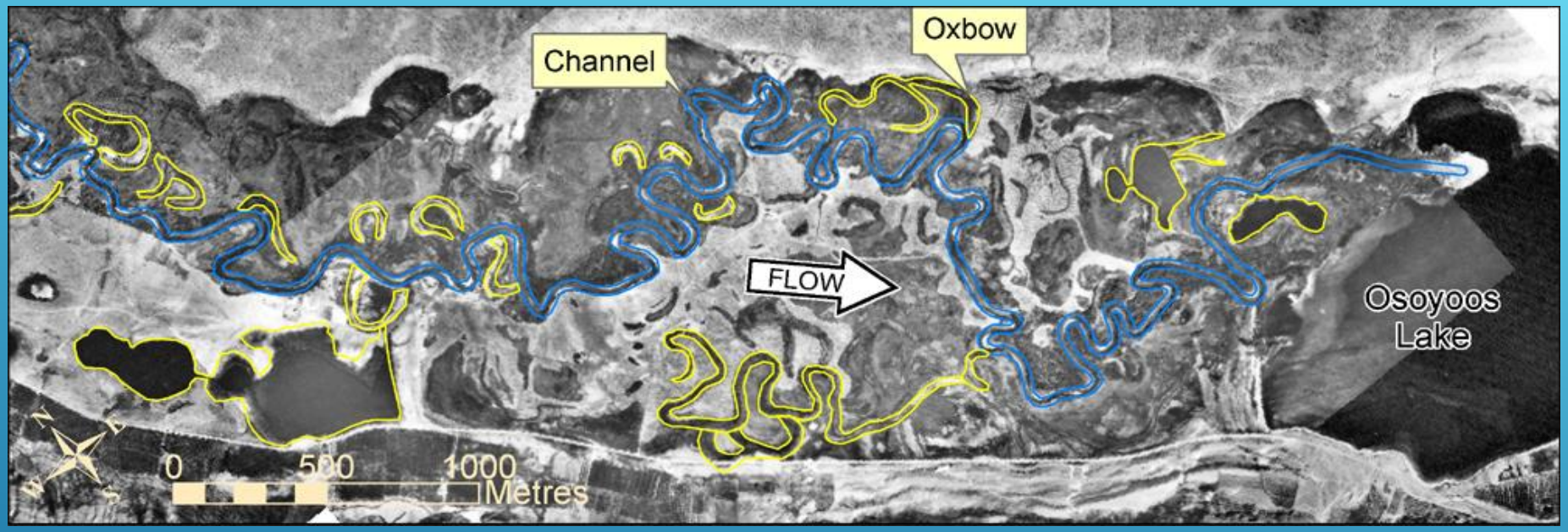


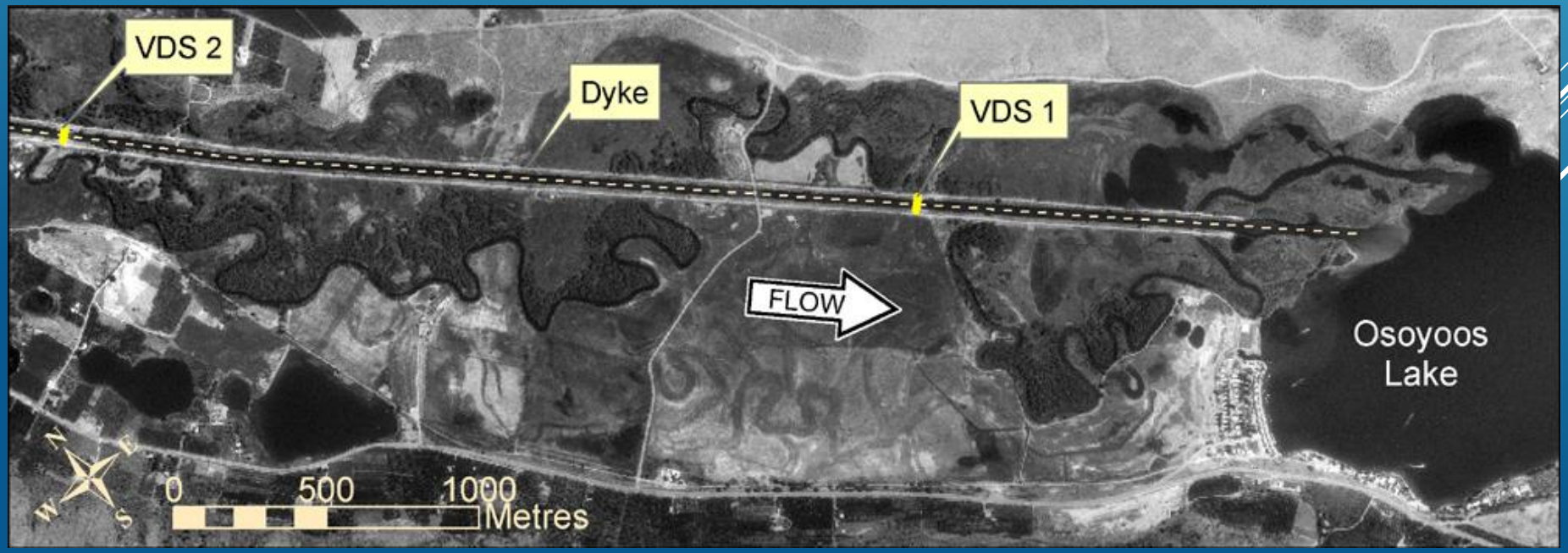
# Okanagan R. (Oliver reach)

- **30.4 km engineered channel (86%)**
- **2.1 km set-back dykes (~6%)**
- **2.8 km natural river (~8%)**






# OKANAGAN R. IN 1938 AND IN 1996

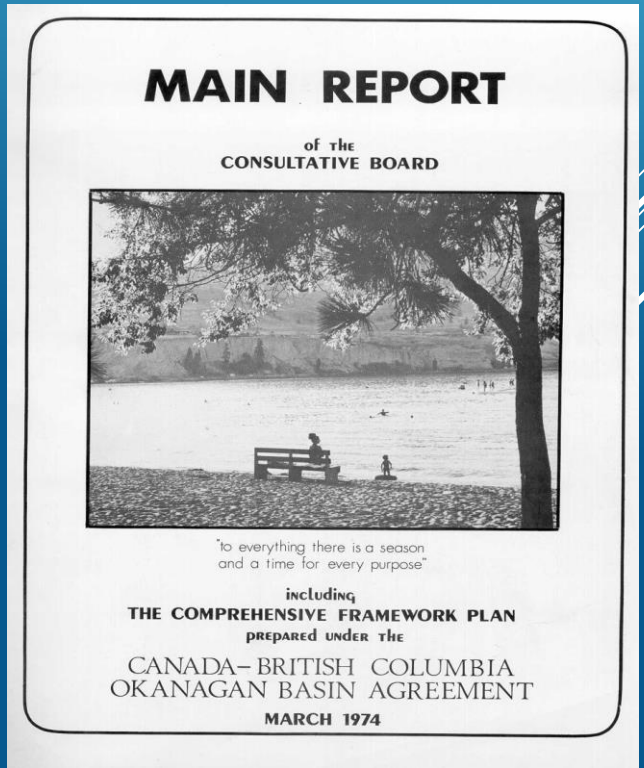


# Okanagan Water Management Operations

# OKANAGAN BASIN AGREEMENT:

In the 1970's the federal and provincial governments jointly undertook a multi-year planning process to develop a **Comprehensive Frame Work Plan** for managing the water resources of the Okanagan to **"achieved a desirable balance between the goals" of:**

- **Economic Development**
- **Environmental Quality**
- **Social Betterment**

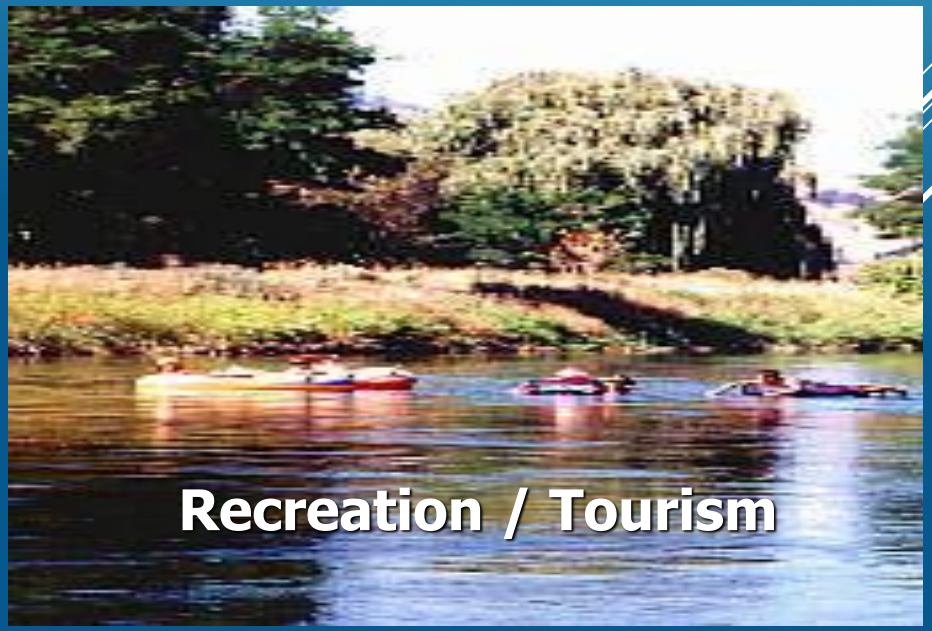


# OPERATIONAL IMPLEMENTATION OF THE OKANAGAN BASIN AGREEMENT:

- The OBA provides general operating targets & directions (i.e., target lake levels and river flows) to meet the multiple competing objectives of flood control, fisheries, water supply, recreation, navigation, tourism, etc. for each of the mainstem lakes and different sections of the Okanagan River
- Responsibility for managing and operating system assigned to engineering staff of the Province's Water Management Program.
- Operational decisions regarding lake levels and releases were based on OBA targets, inflow forecasts, past experience, "rules of thumb", and other WM annual operational considerations



# Operate to balance competing interests

# FRESHET INFLOW FORECASTS:

- Forecasts of freshet inflow volumes are made monthly throughout the winter and spring
- Forecasts models use fall & winter precipitation, mountain snow packs and over-winter lake inflow data.
- <u>Significant uncertainty in forecast volumes</u>

# WATER MANAGEMENT OPERATIONAL CHALLENGES:

- High natural variability of seasonal and annual inflows and demands
- Uncertainty of inflow volume forecasts
- Extreme weather events (rainfall, wind, etc.)
- Limited discharge capacities of dams
- Limited river channel capacity relative to instantaneous lake and river inflows

# WATER MANAGEMENT OPERATIONAL CHALLENGES (cont.)

- Need to accommodate competing economic (flooding, water supply), environmental (sockeye, kokanee) and social objectives at multiple locations and times of year
- Uncertainty of incremental impacts of changes in flows, lake levels and water temperatures on fish populations during various life stages (spawning, egg incubation)

# SOCKEYE 4- YEAR LIFE CYCLE:

**Year 1:**

- Eggs are laid in Oct/Nov
- Fry emerge in April/May & migrate d/s to lake

**Year 2 (May/June):**

- After spending 1 year in lake the smolts migrated d/s to ocean


**Years 2 ,3 &4:**

- Rearing in Ocean

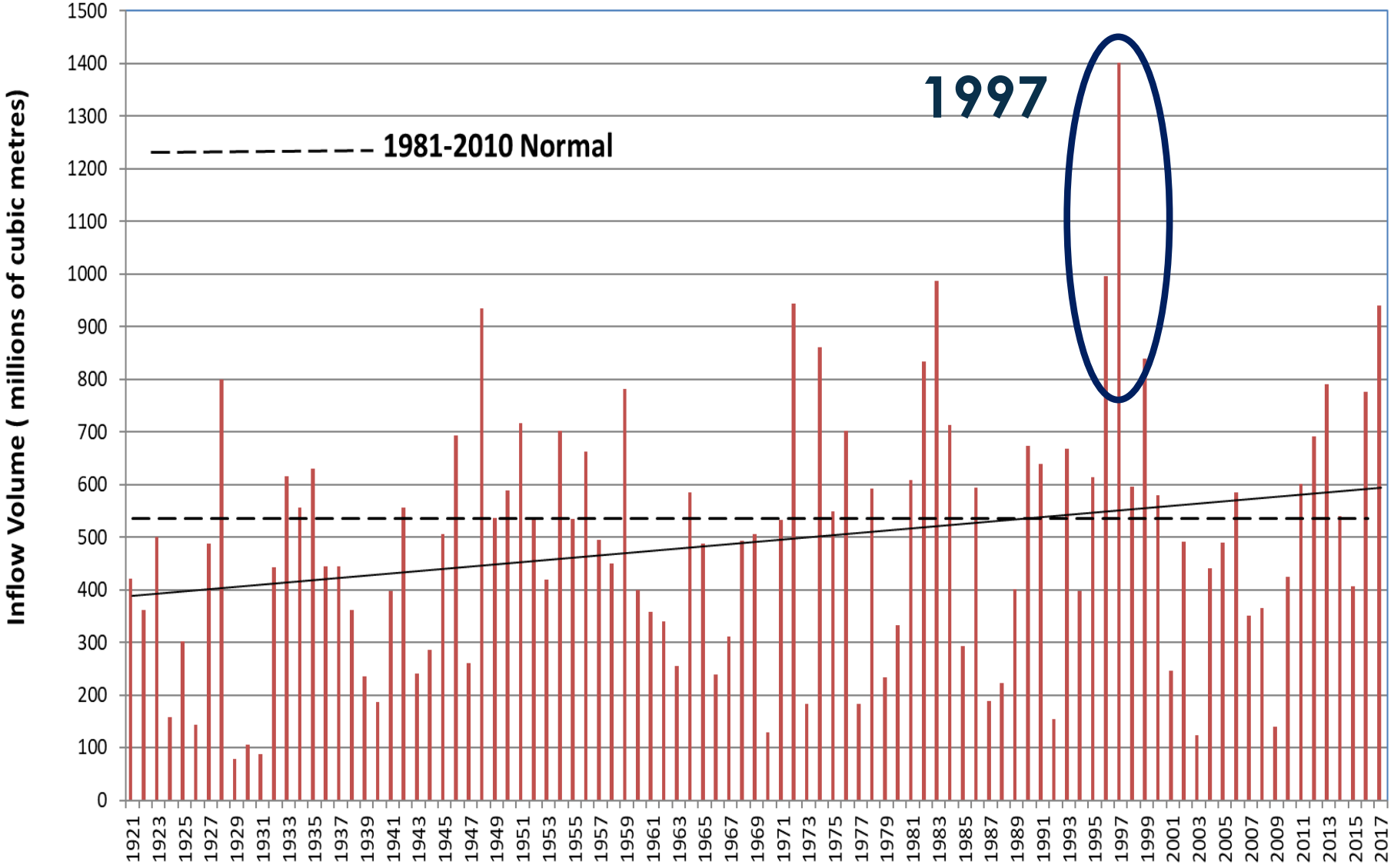
**Year 4:**

- Summer: Adults migrate u/s to lake
- Fall: When temp drop continue migration into river spawning areas to spawn.

# THE BEGINNINGS OF CHANGE:

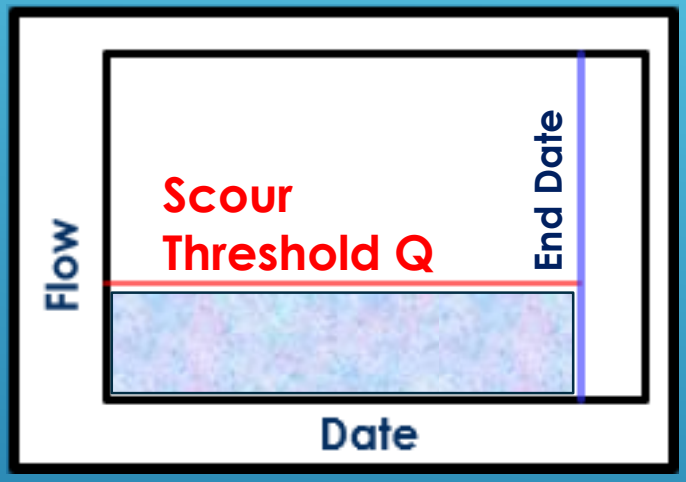
- Challenge of achieving the balance of water benefits in OBA, including maintenance of "fish friendly" lake levels and flows, had been given to local water managers with limited input from fisheries agencies.
- In the 1990's the Okanagan River was declared one of the most endangered rivers in Canada, largely due to serious declines in annual Okanagan sockeye returns (from over 200,000 to less than 10,000 returning adults).
- In Washington State, FERC requirements for greater mitigation of fish impacts of Columbia River PUD dams
- Greater interest and coordination amongst fisheries agencies and other interests on both side of border working  together to find solutions.

# Okanagan Lake - Annual Net Inflow Volume (1921 - 2017)

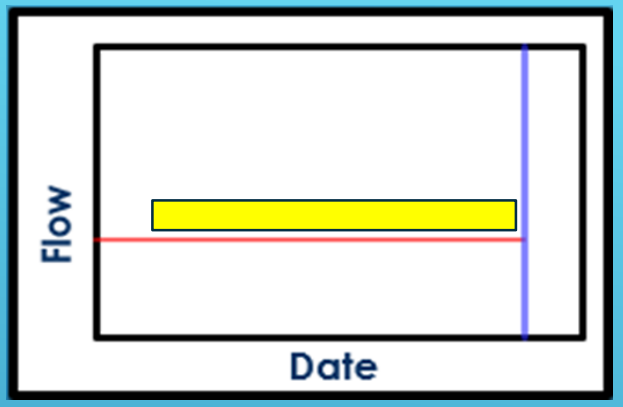



**Source:** BC River Forecast Centre, Ministry of Natural Resource Operations

# 1997 Sockeye Dilemma




A.

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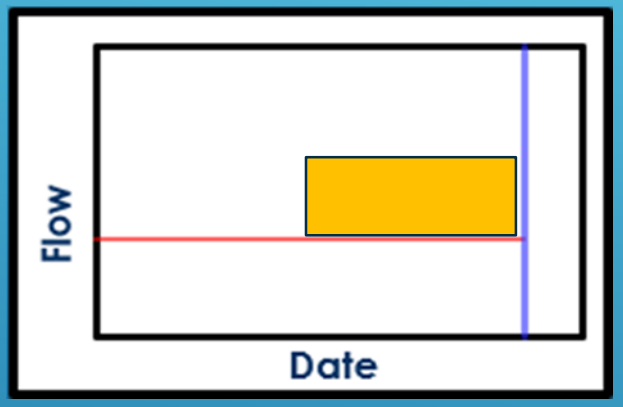


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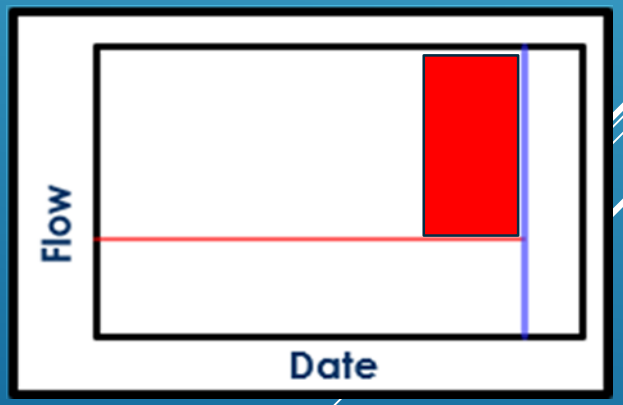



**Issues:**

1. Very high inflow early season forecast with high degree of uncertainty.
2. Unclear relationship between Q above "threshold" & degree of redd scour

# FORMING NEW PARTNERSHIPS:

In 1998 two key partnerships were formed.

1. The Canadian Okanagan Basin Technical Working Group, consisting of fisheries representatives from:
   - Canadian Department of Fisheries & Ocean
   - Okanagan Nation Alliance Fisheries Commission
   - BC Provincial Fisheries program

2. The Bilateral Okanagan Basin Technical Working Group, a transboundary partnership including the members of COBTWG plus USA representatives from:
   - Colville Confederated Tribes,
   - Washington State & County Fisheries agencies
   - Columbia River Public Utility Districts.

# THREE POTENTIAL AREAS WERE IDENTIFIED FOR FURTHER STUDY:

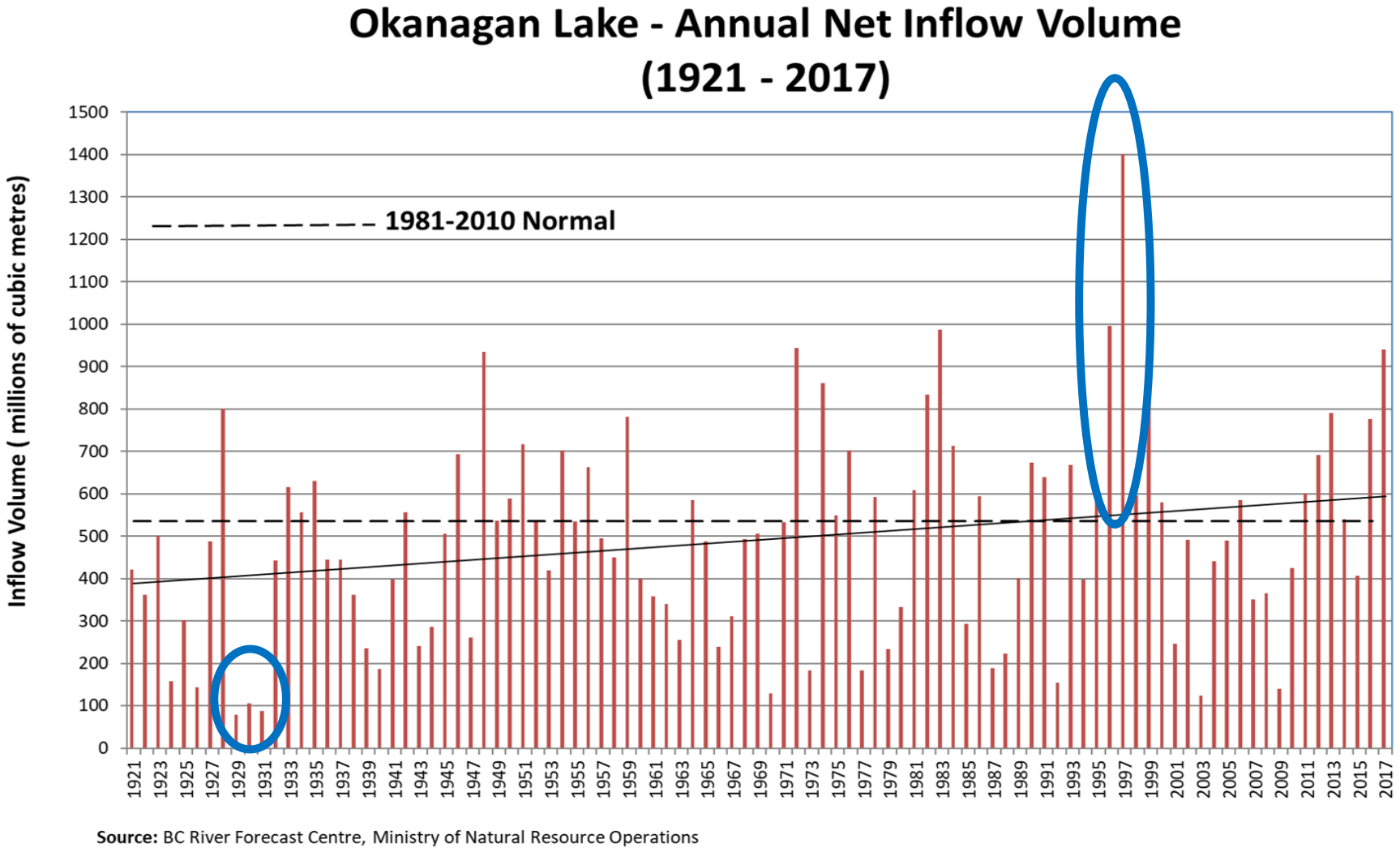
COBTWG, with support from BOBTWG, initiated a study to identify areas requiring action to address the decline in salmon.

1. Improving existing water management practices to reduce incidence of non-compliance events.
2. Reintroducing Okanagan sockeye salmon to their historic range.
3. Restoring instream fish habitat.

# ADAPTIVE MANAGEMENT EXAMPLE 1:

# OKANAGAN FISH-WATER MANAGEMENT TOOL

# *CHALLENGE 1:*
# LARGE VARIATION IN ANNUAL INFLOW




**Source:** BC River Forecast Centre, Ministry of Natural Resource Operations

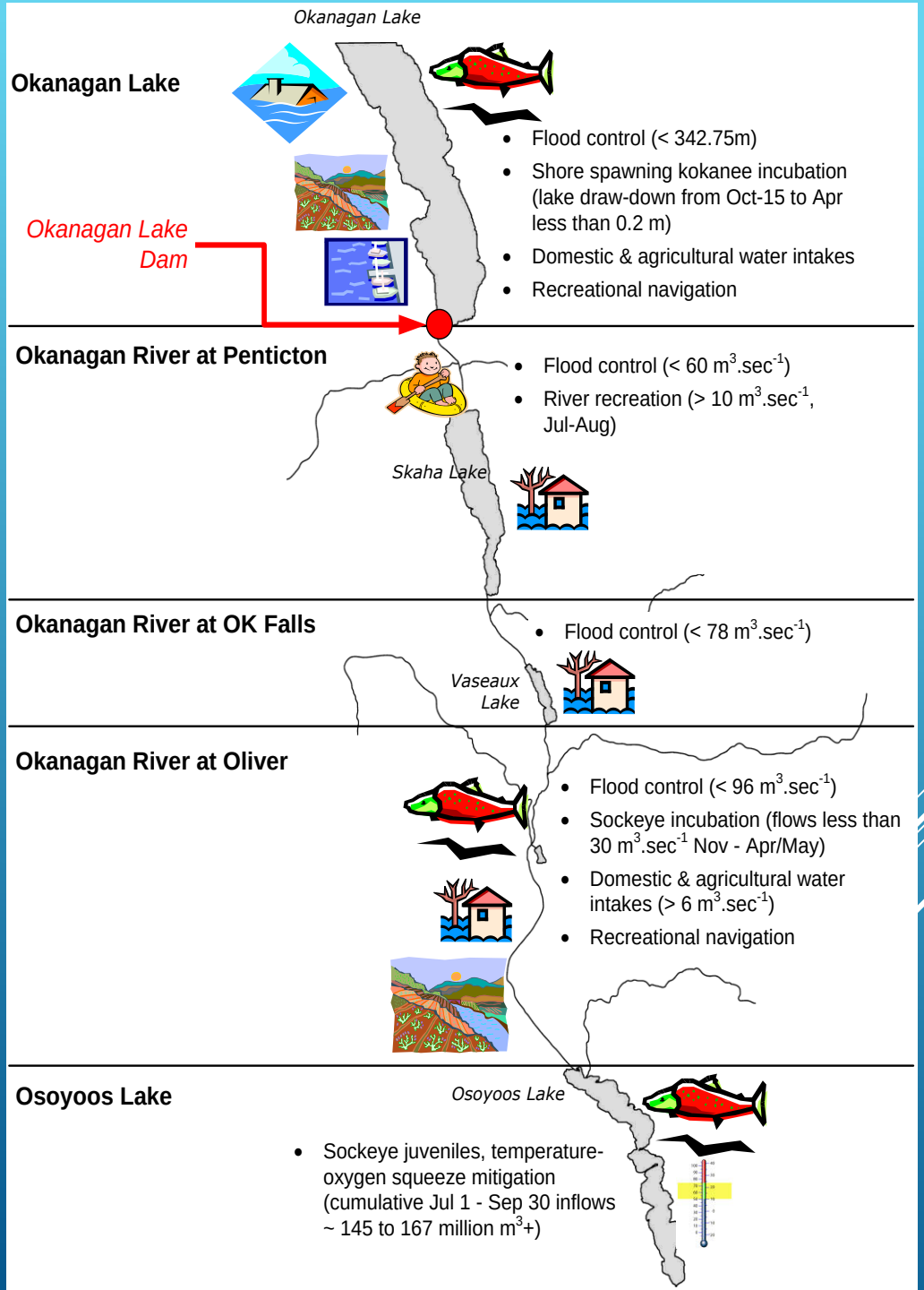
# *CHALLENGE 2:*

**WATER MANAGERS REQUIRED TO BALANCE *MULTIPLE* COMPETING OBJECTIVES & TRADE-OFFS**

**OVER SPACE AND TIME**

**ACROSS MULTIPLE ENTITIES**

**USING INCOMPLETE OR UNCERTAIN INFORMATION**



# CHALLENGE 3:
# LOW LEVEL OF TRUST BETWEEN PARTIES

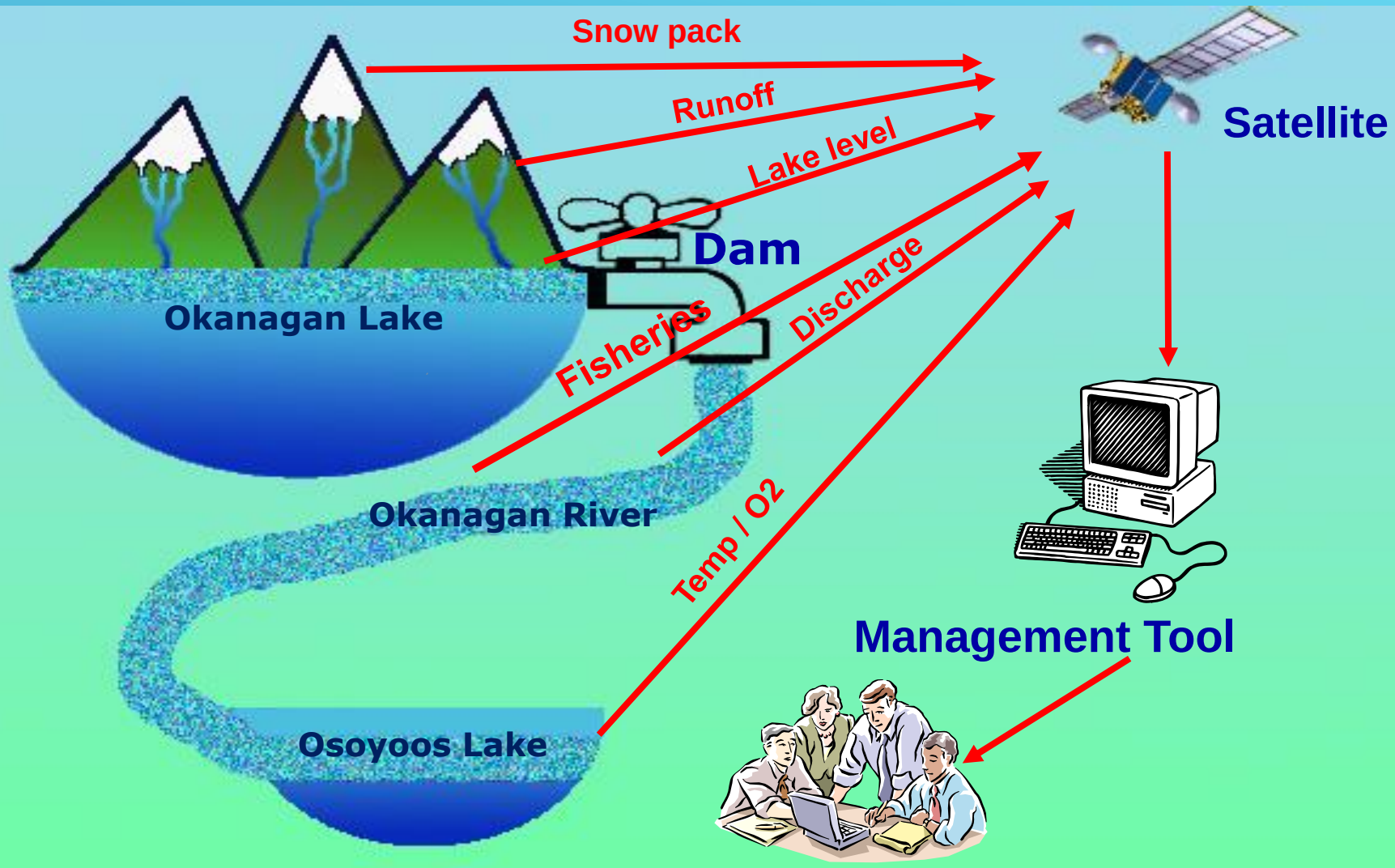
- Limited engagement between water managers and fisheries agencies & First Nations regarding operational decisions raised issues regarding lack of transparency and inclusion.

- Perceptions by fisheries agencies and FN that water managers might be giving human systems greater consideration than ecosystems and natural systems

# ASSEMBLING THE TEAM AND FUNDING:

- COBTWG met with water managers to better understand the issues and challenges facing WM and to solicit their commitment to work together to resolve challenges.
- A decision to collaboratively design, build & deploy an Environmental Decision Support System (EDSS) to provide real-time science-based fish and water management tools to improve the balance of WM decisions affecting both human and natural systems.
- In addition to "in-kind support" from team members, financial support for the EDSS was secured from Douglas County PUD who were looking for opportunities to meet their FERC fish mitigation targets.
- ESSA hired to facilitate EDSS design & development.

# OKANAGAN FISH & WATER MANAGEMENT TOOL



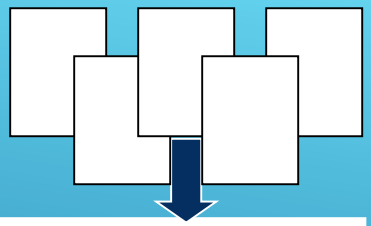
*Project Development & Field Work, 1999-2001*

*Spring, 2002*

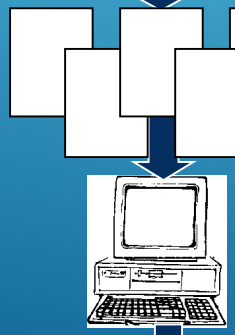
*Submodel Designs Summer 2002*

*Model Construction, Fall 2002-03*

*Model Revisions, Release, 2003-04*



Design Workshop



Review & Revision

Test Applications; Training

A M

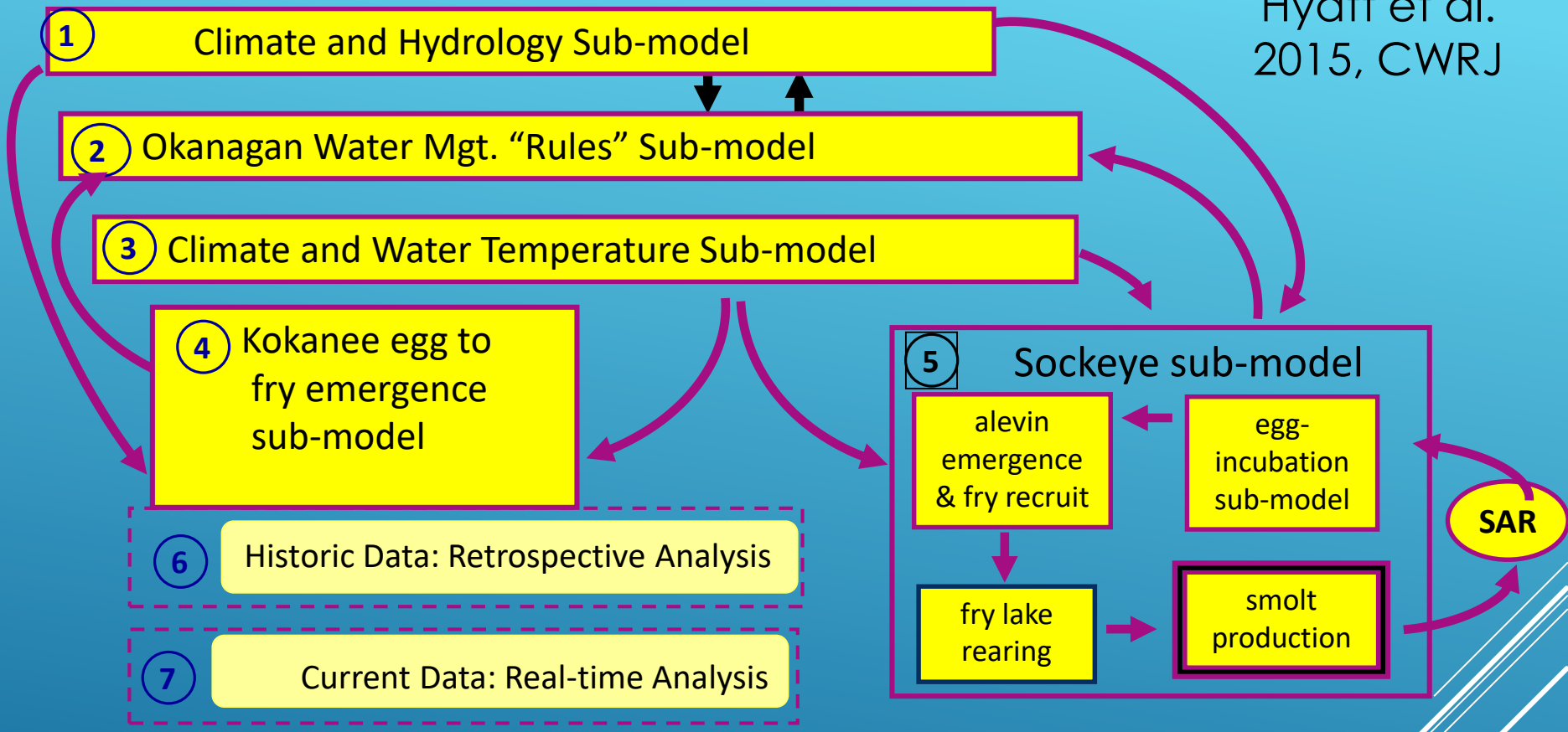
*2006-07*

Climate Change

*2005-now*

**Implementation**, Field Work

# FWMT Decision Support System




- **The FWMT System is a coupled set of 4 biophysical models of key relationships (among climate, water, fish & property) and a management rules model used to predict the consequences of water mgt. decisions for fish & other water users.**
- **FWMT may be used to explore water management decision impacts in an operational mode employing real-time data, a prospective-mode going forward or in a retrospective-mode looking back on historic water supply, climate & fish years.**

# WHAT IS THE "FISH WATER MANAGEMENT TOOL"?

- An Internet-accessible decision support system (hosted at ESSA),which incorporates real-time data (lake levels, flows, water temperatures, actual spawning dates, etc.) into a set linked hydrology and biological submodels
- Collaboratively developed and applied tool to support operational WM decision making
- Allows gaming and rapid trade-off analysis of potential release scenarios by the various fishery and water management agencies which supports transparent and inclusive in-season decision making
- Documents in-season decisions and learnings
- FWMT is updated periodically by working group based on field work, learnings, etc. (Adaptive Management loop)

# PROCEDURE FOR IN-SEASON USE..

*Agree on…*

**base case assumptions**

**PMs & hazard thresholds**

**Inflow Estimates**

*Individual analysis…*

**Best dam release policy, point of view "x"**

*Group analysis…*

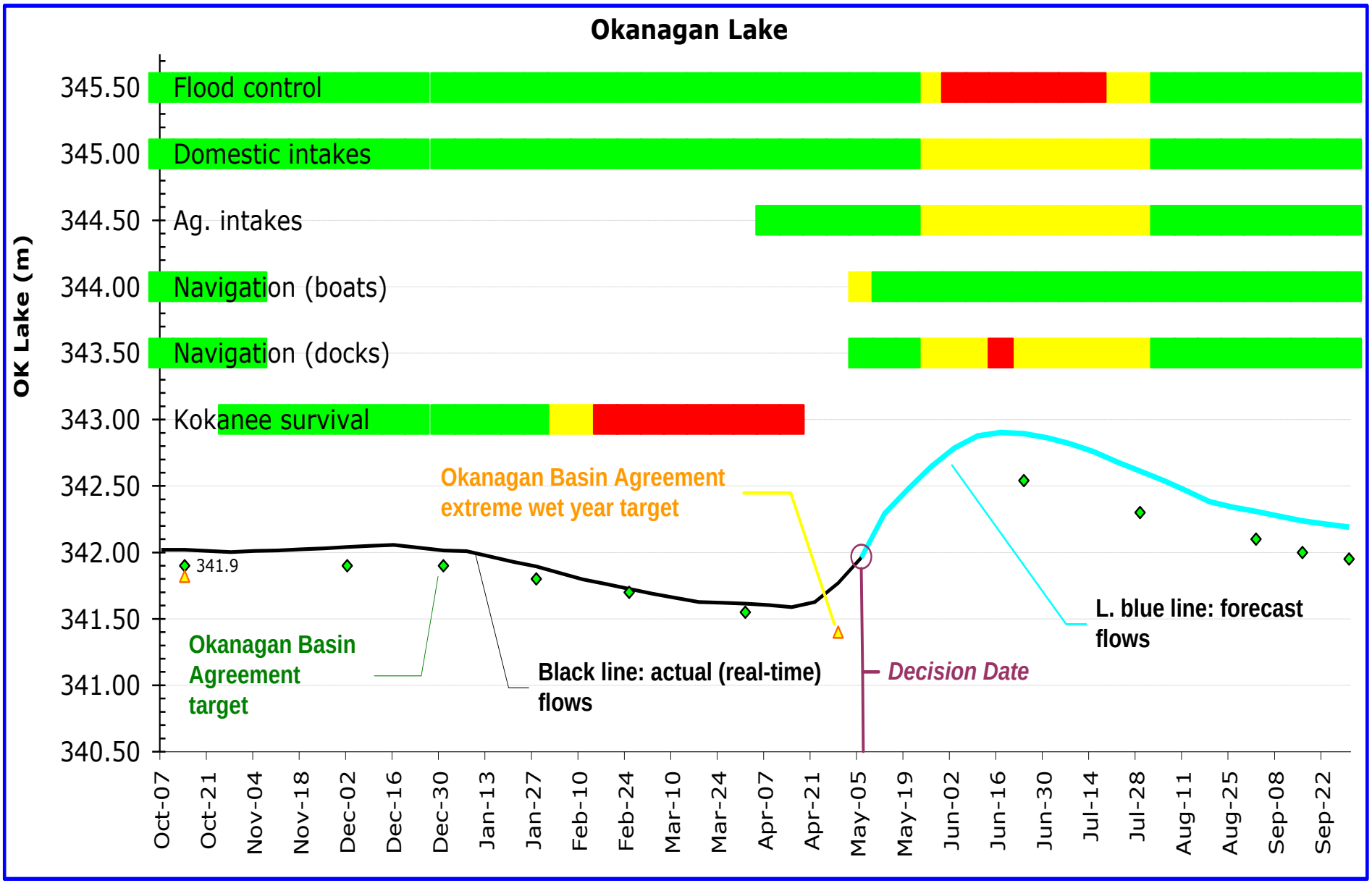
**Multiple objectives**

**Scientific Uncertainty**

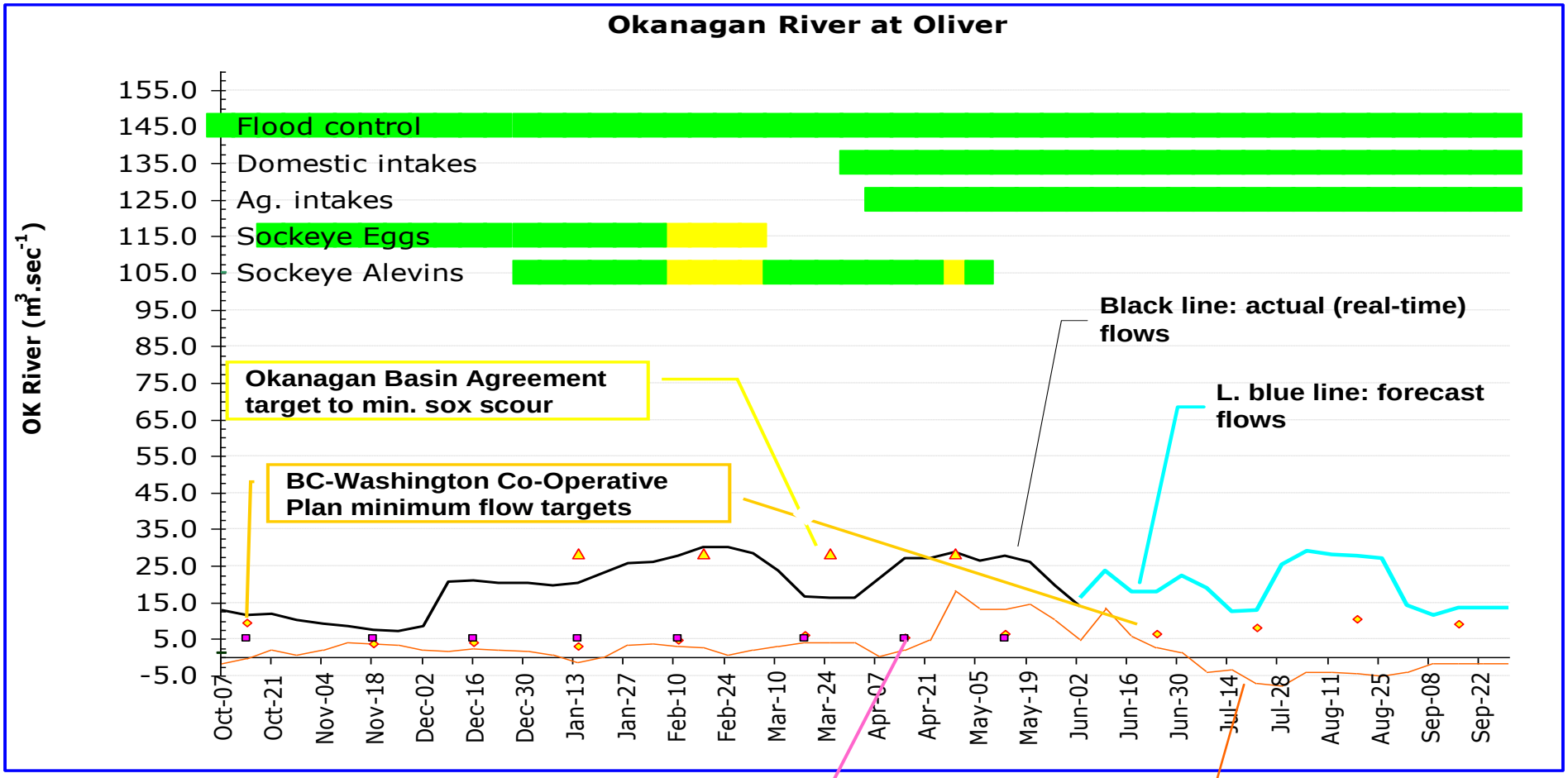
**Value differences**

**Optimal Policy** (decision point)

# SAMPLE FWMT OUTPUT: OKANAGAN LAKE



# SAMPLE FWMT OUTPUT: OKANAGAN RIVER AT OLIVER



# FWMT Retrospective Analysis (Test of benefits):

**If OKFWM had been used between 1974 and 2003:**

- **What release decisions would have been made?**
- **How might this have changed the abundance of sockeye?**

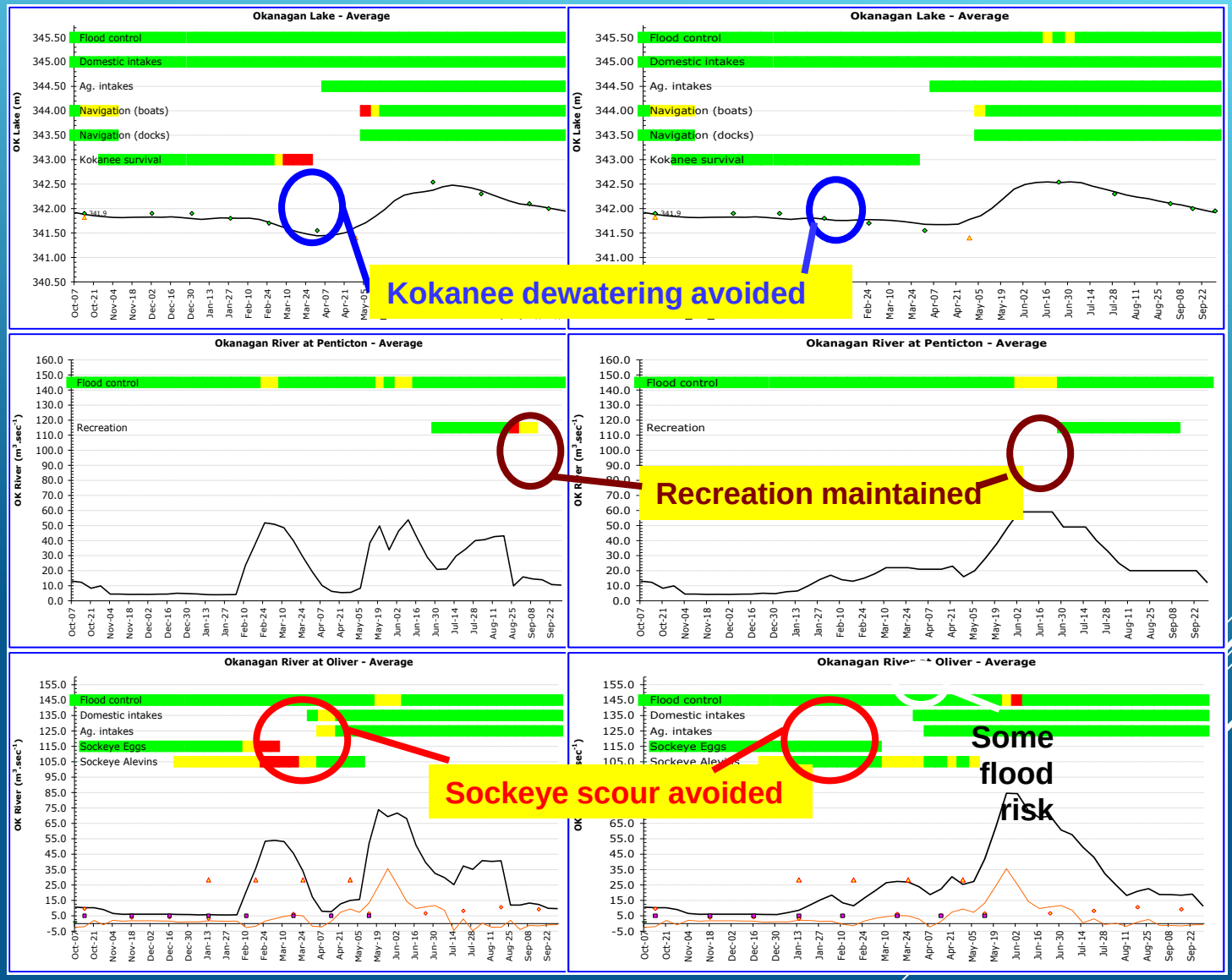
1991 Actual

1991 with FWMT

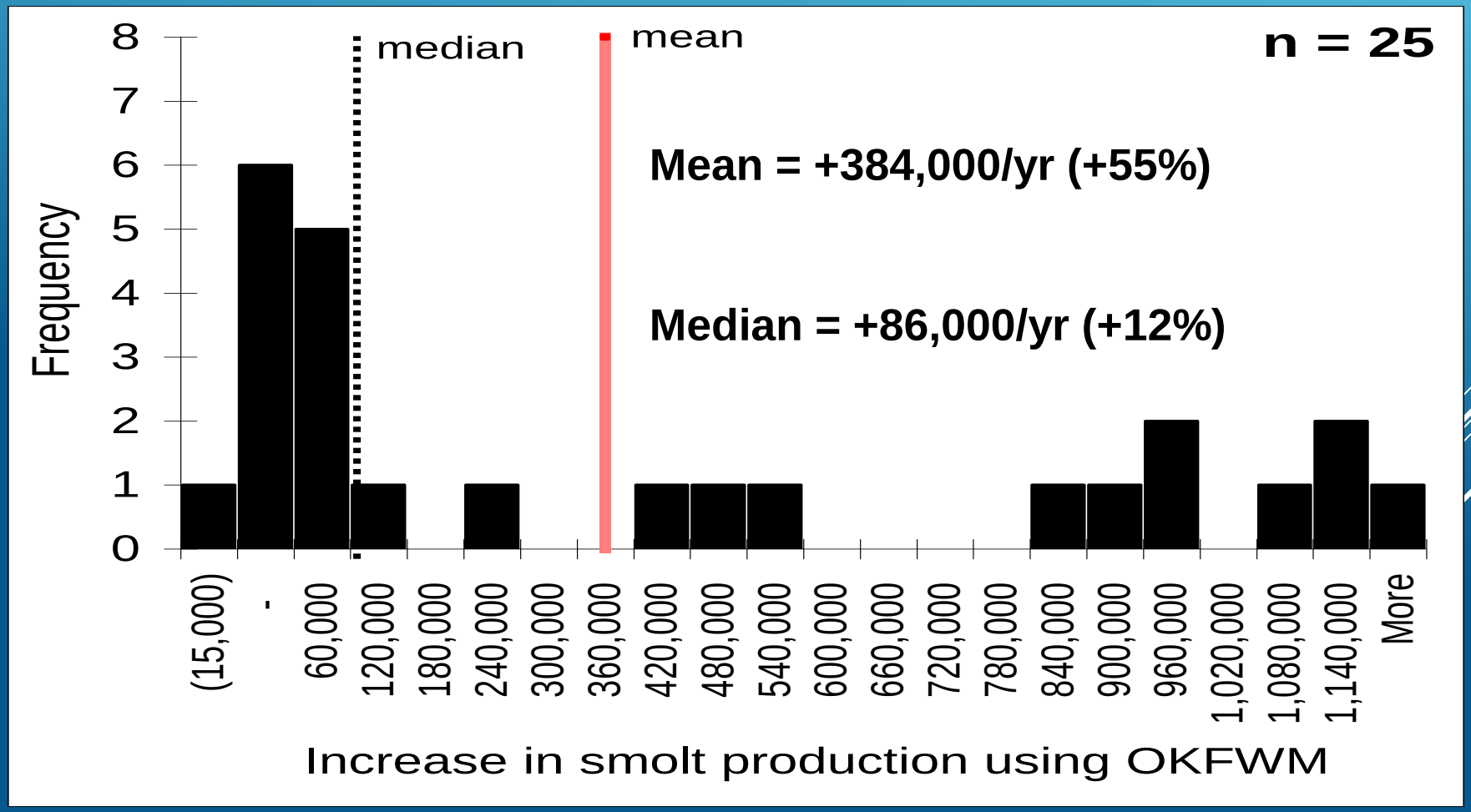
Lake Level

Dam Release

D/S River Flow



# 1974-2003 RETROSPECTIVE ANALYSIS:
## PREDICTED INCREASE IN SOCKEYE SMOLT PRODUCTION WITH FWMT VS. ACTUAL WATER MANAGEMENT

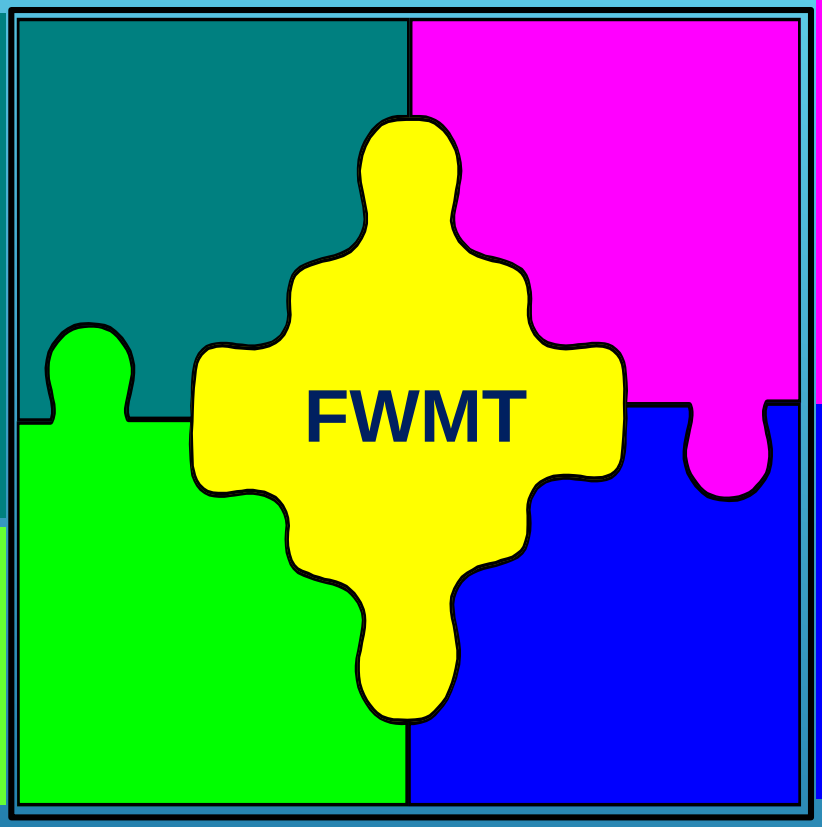


# STRENGTHS OF THIS APPROACH

**Efficiently integrates current expert understandings of hydrology, Sockeye, Kokanee, & impacts on people.**

**Expandable**

**Real time data allows response to unexpected stochastic events**

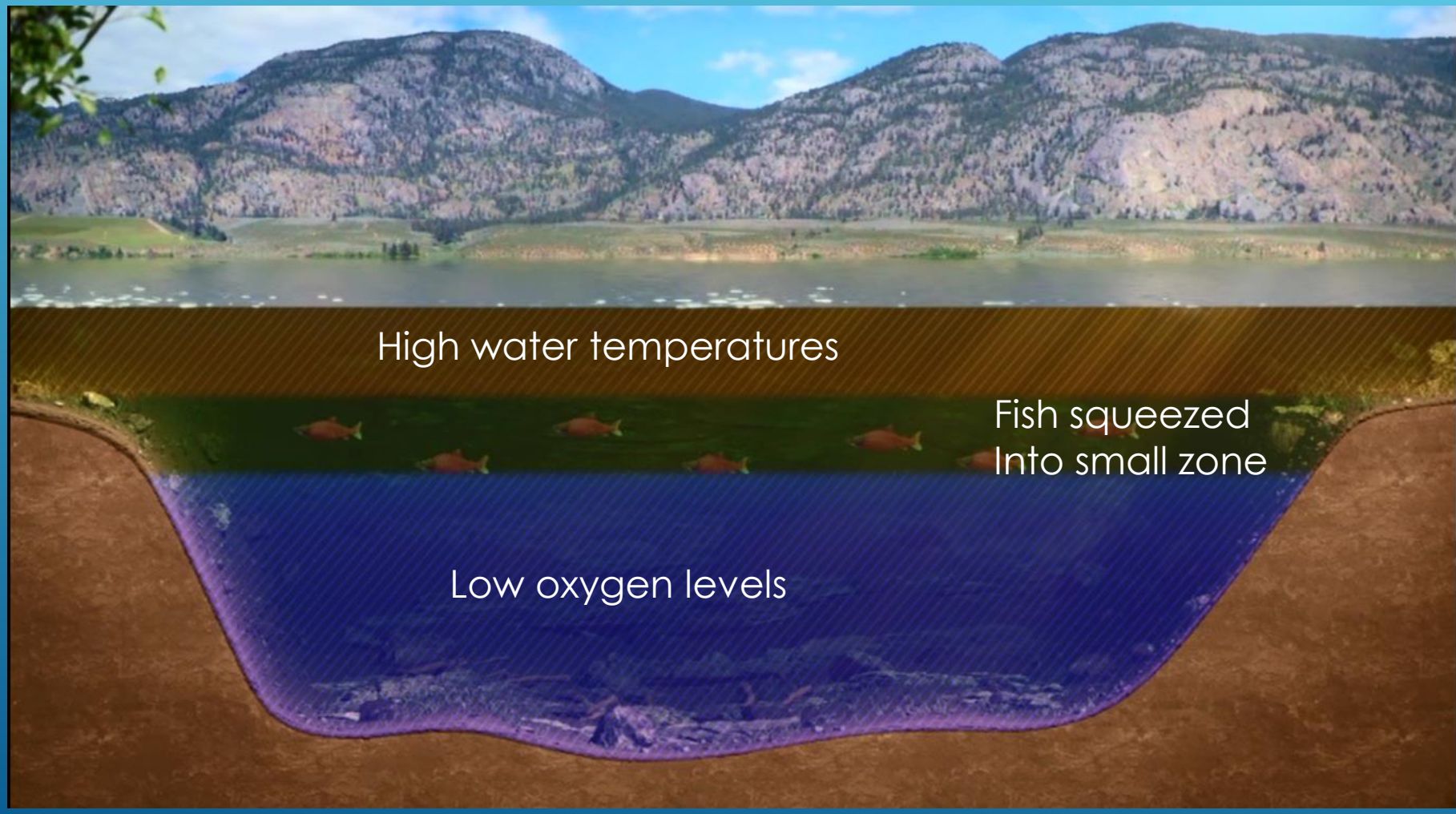



**Helps structure collaborative dialogue on multiple objectives & tradeoffs**

**Web-accessible model, trials, parameters, data, decisions**

**Training a new generation of collaborative water & fish managers in MOE, DFO, Okanagan FN**

# POST IMPLEMENTATION SUBMODEL: TEMPERATURE / OXYGEN SQUEEZE IN OSOYOOS LAKE



# FWMT SUCCESSES:

- Provided a solution to inability of operators to effectively use the full range of quantitative relationship and incoming information to support balanced WM decisions.
- Increased understanding and appreciation by fish biologists and water engineers of each other's objectives
- Created higher levels of trust and transparency between fish biologists and water managers
- Elevated level of ongoing, multi-party engagement in regulation to achieve an improved balance of both human system and natural system objectives.
- Helped overcome collaboration barriers arising from dispersed locations of advisors
- Has made a significant contribution to the ongoing recovery of salmon returns without compromising other WM objectives.

# ADAPTIVE MANAGEMENT EXAMPLE 2:

## SKAHA LAKE EXPERIMENTAL SOCKEYE SALMON RE-INTRODUCTION PROGRAM

# OKANAGAN FIRST NATIONS

Okanagan salmon are very significant to Okanagan FN's culturally, ceremonially and as a traditional food source.

FN's were strong champions within COBTWG for restoring the indigenous range of Okanagan sockeye; including Skaha and Okanagan Lakes.

Range limited by small irrigation dam constructed in 1950's created a barrier to sockeye upstream migration

# AN ADAPTIVE MANAGEMENT APPROACH TO RESTORING RANGE OF OKANAGAN SOCKEYE

- In 1997 FN and other fish agencies collaborated to develop a comprehensive approach for restoring the range of indigenous salmon while continuing to balance other ecosystem and resident fish objectives.
- Due to concerns over then depressed kokanee runs in Okanagan Lake a decision was made that before premenant re-introduction occurred it should first be tested experimentally in Skaha Lake.
- Financial suppot for experiment obtained from Grant and Chelan PUDs, and Canadian government
- 2000 - 2003: risk assessment and project design


- 2003 – present: Hatchery sockeye fry have been stocked into Skaha Lake annually on an experimental basis

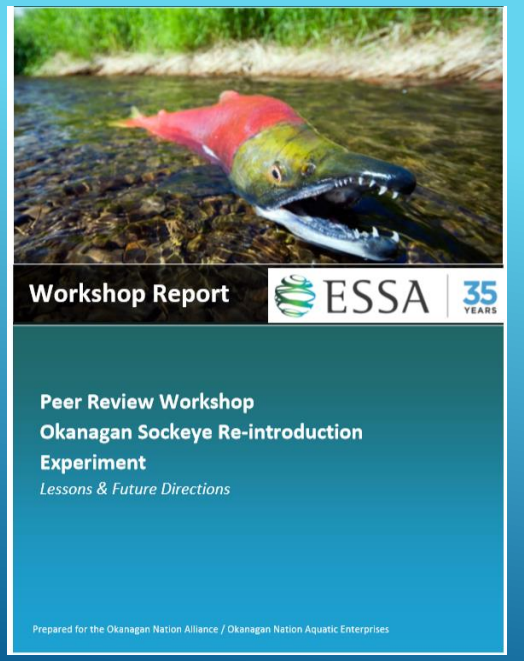
# KEY MANAGEMENT GOALS FOR SKAHA LAKE EXPERIMENTAL RE-INTRODUCTION STUDIES:

- Restore sockeye to historic range with in Okanagan
- Determine whether Skaha Lake sockeye could be produce in sufficient numbers to meet PUD's smolt production requirements.
- Determine the effects of hatchery-reared kokanee may have on Skaha Lake kokanee
- Assess potential negative impacts on Osoyoos Lake sockeye from genetic introgression and disease transmission
- Assess carrying capacity of Skaha Lake for sockeye and/or kokanee

# April 2014 Peer Review Workshop

As part of the Adaptive Management approach a workshop of 30 fish biologists was held to share and review the experiment's findings to identify areas of consensus & conclusion, and others requiring further study, and to determine next steps.

Follow-up actions from the workshop included:



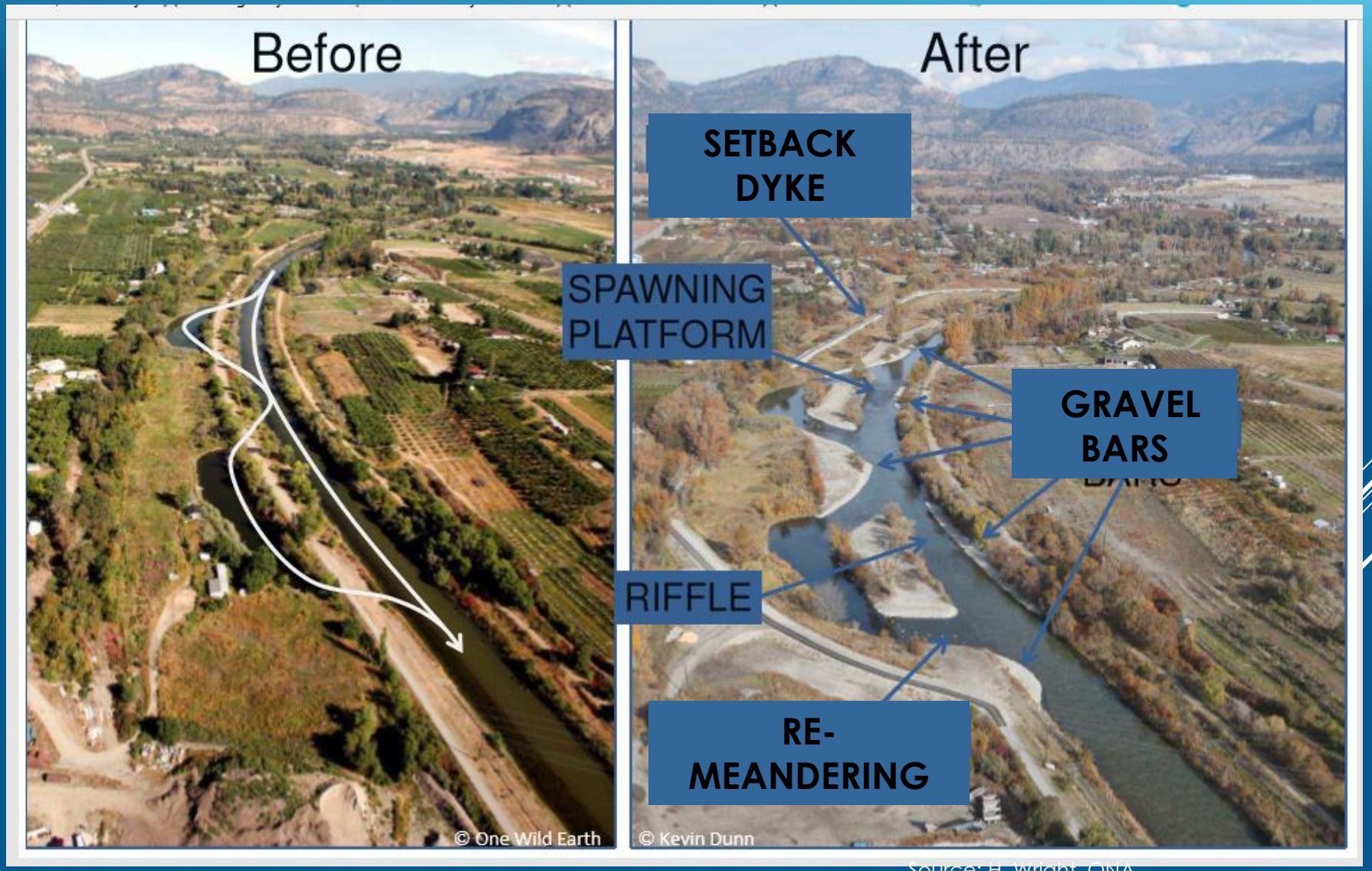

- Re-establishing fish passage into Skaha Lake to extend the available sockeye range to include Okanagan River d/s of Okanagan Lake Dam
- Construction of a new fish hatchery in Penticton to expand hatchery program
- Constructing new spawning beds in river in Penticton.
- Continuation of a number of the monitoring programs to further inform a future decision regarding Okanagan Lk re-introduction

# OKANAGAN RIVER RESTORATION INITIATIVE – RESTORING HABITAT AND RANGE

**While the re-introduction experiment in Skaha Lake was taking place, a number of changes have been made to remove downstream barriers and restore habitat.**

**Backwatering an existing drop structure by adding a series of riffles to add complexity to an otherwise uniform channel.**

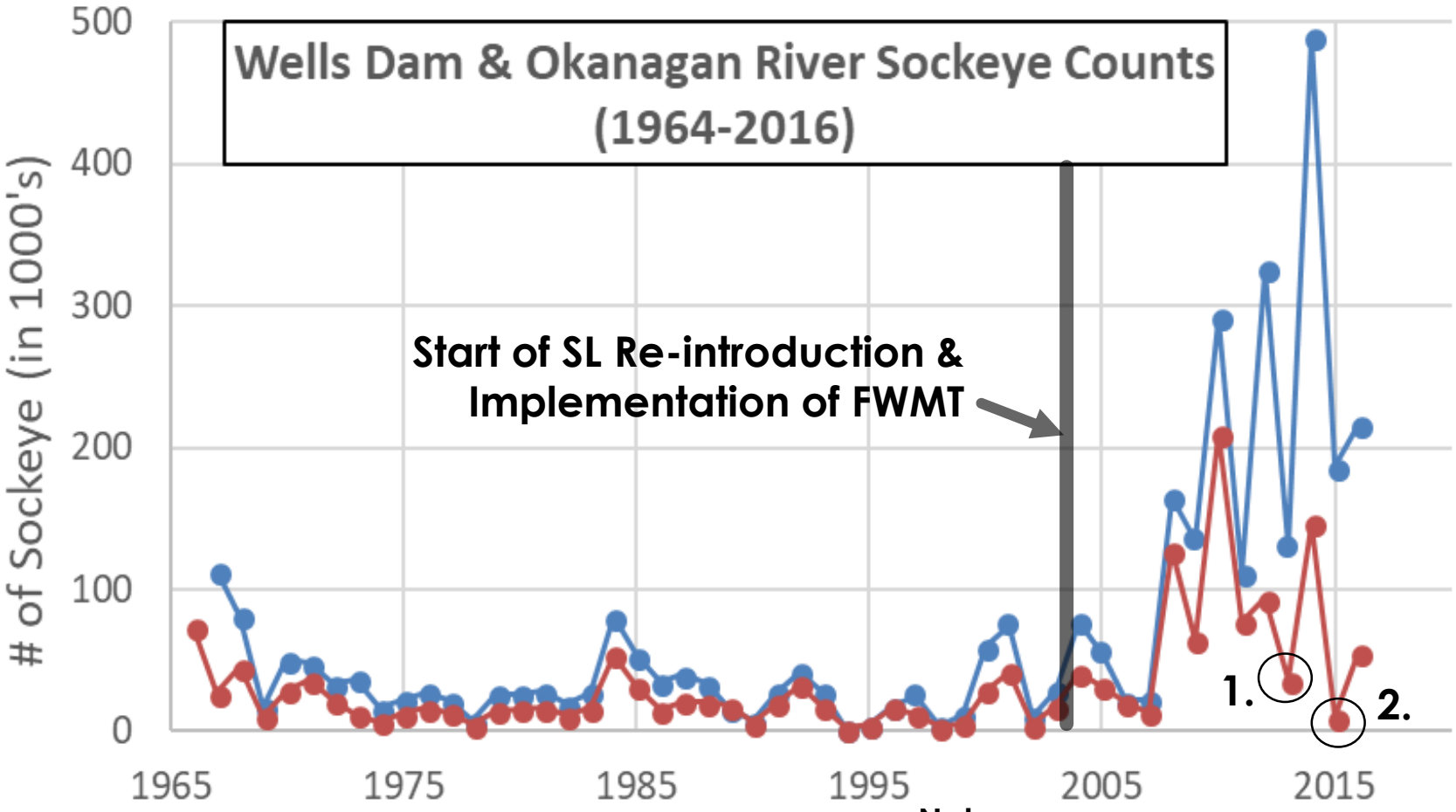
# Reconstructing channelized sections of Okanagan River to restore "Natural Habitat"




Source: H. Wright, ONA

**McIntyre Irrigation Dam:**
**Replacement of Roller Gates with Fish Friendly Overshot Gates (2010)**

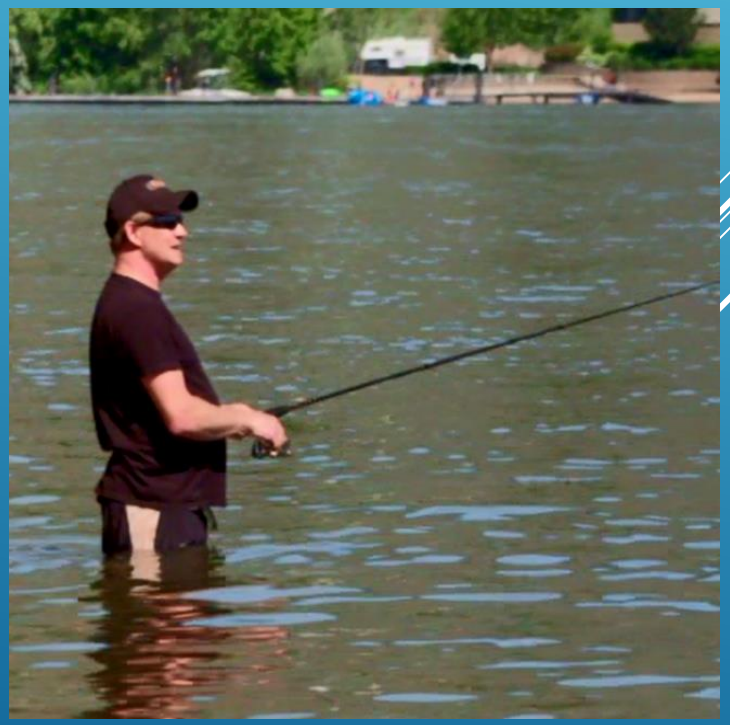
# Impact of FWMT & Re-introduction AM Projects?




**Notes:**

1. 2013 Testalinden debris flow (2010)
2. 2015 Extreme high water temps

# Higher sockeye returns have enabled new Food, Commercial and Recreational Fisheries in the Okanagan

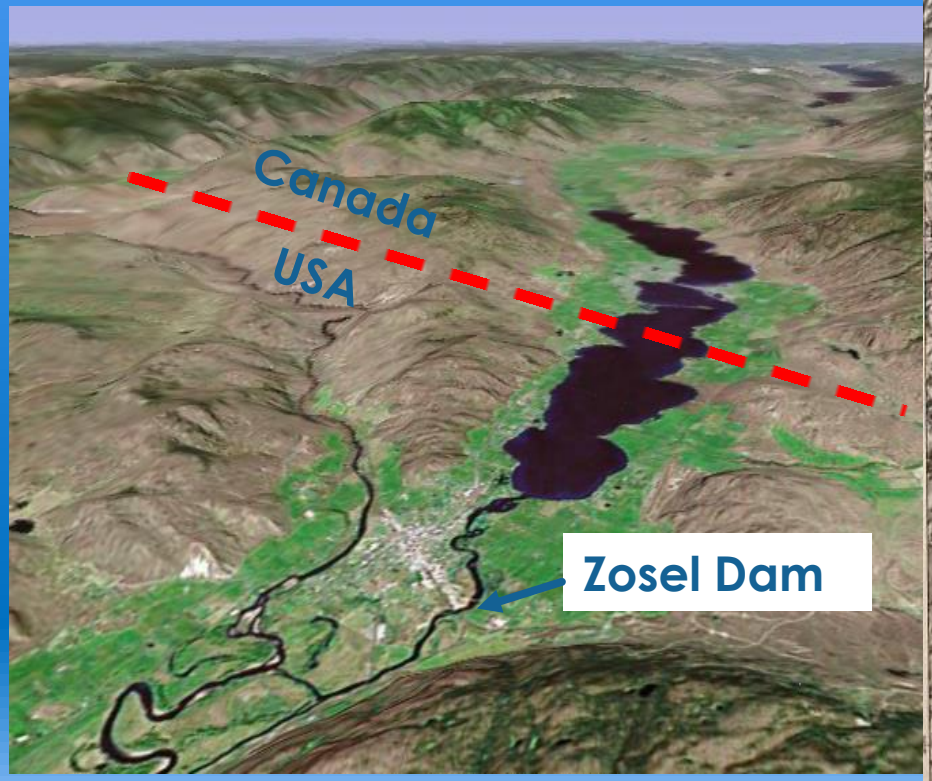


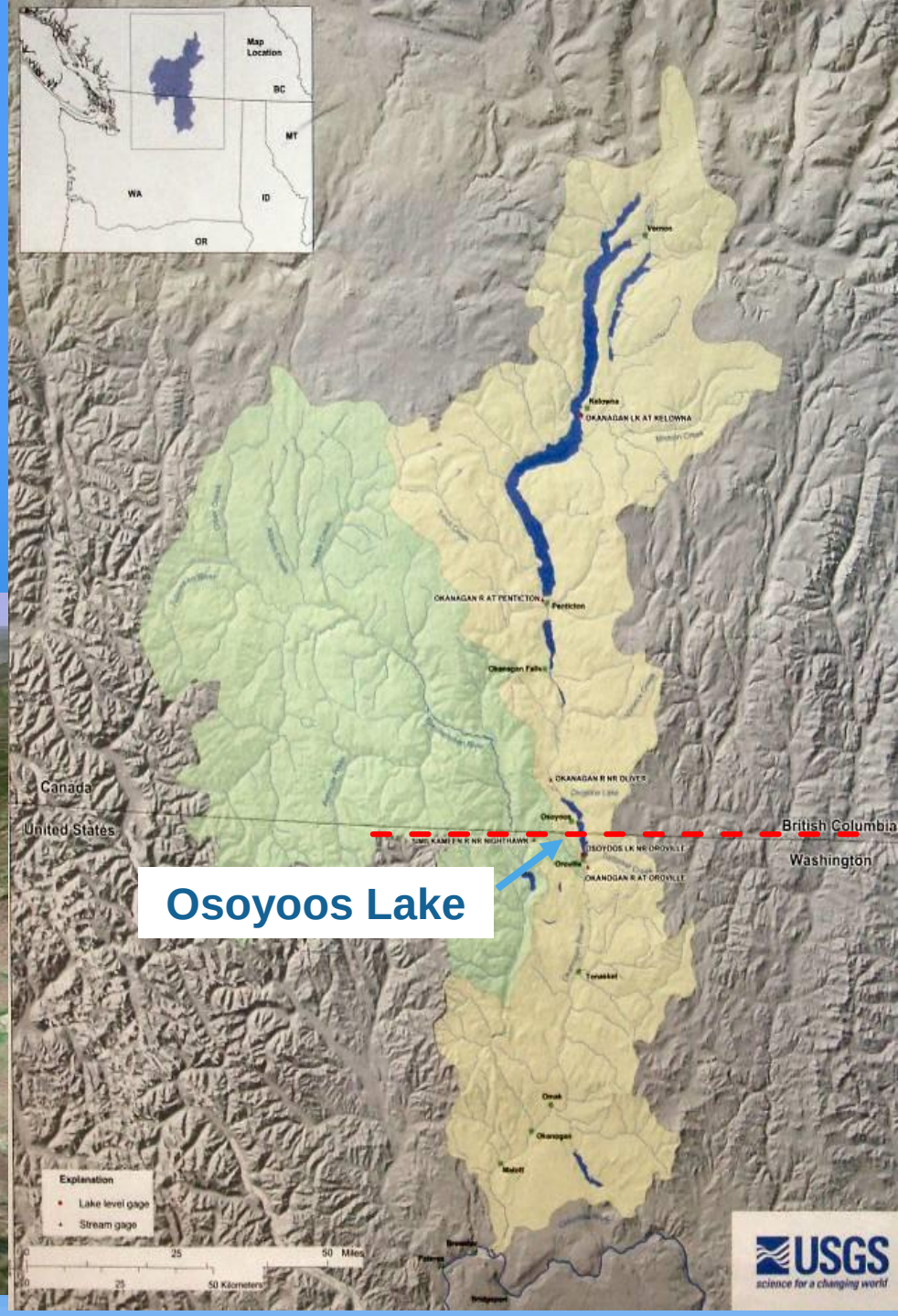
# ADAPTIVE MANAGEMENT EXAMPLE 3:

## RENEWAL OF INTERNATIONAL JOINT COMMISSION ORDERS FOR OSOYOOS LAKE & ZOSEL DAM

# OSOYOOS LAKE & ZOSEL DAM

**Osoyoos Lake straddles the international boundary in south central British Columbia and north central Washington**

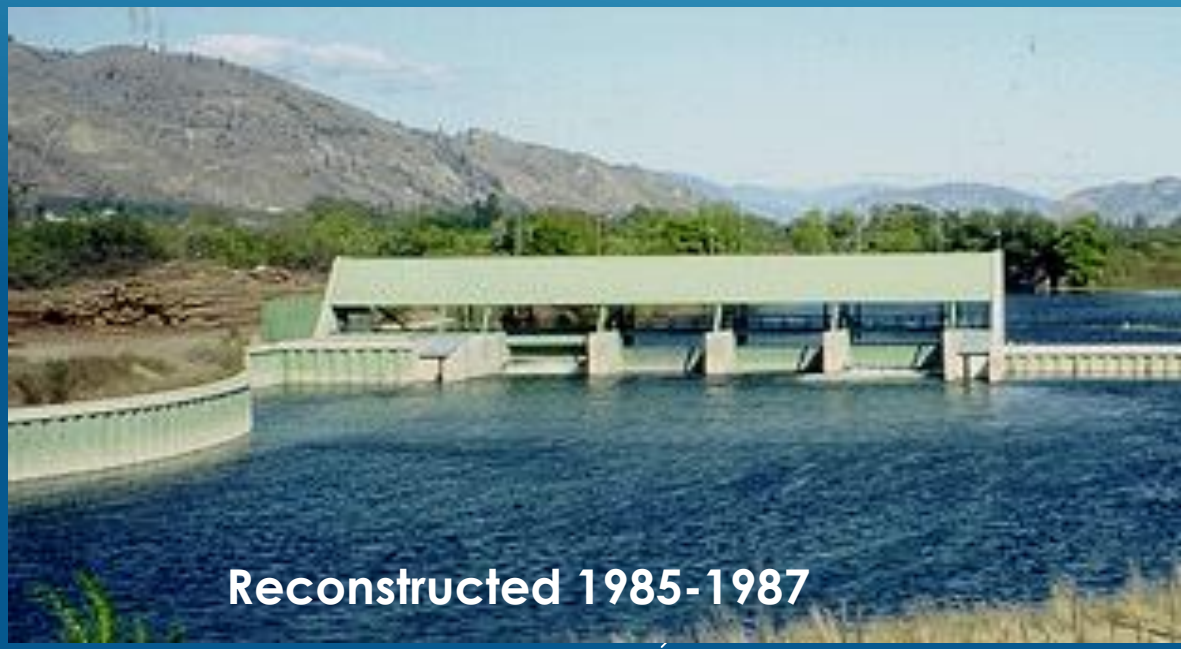


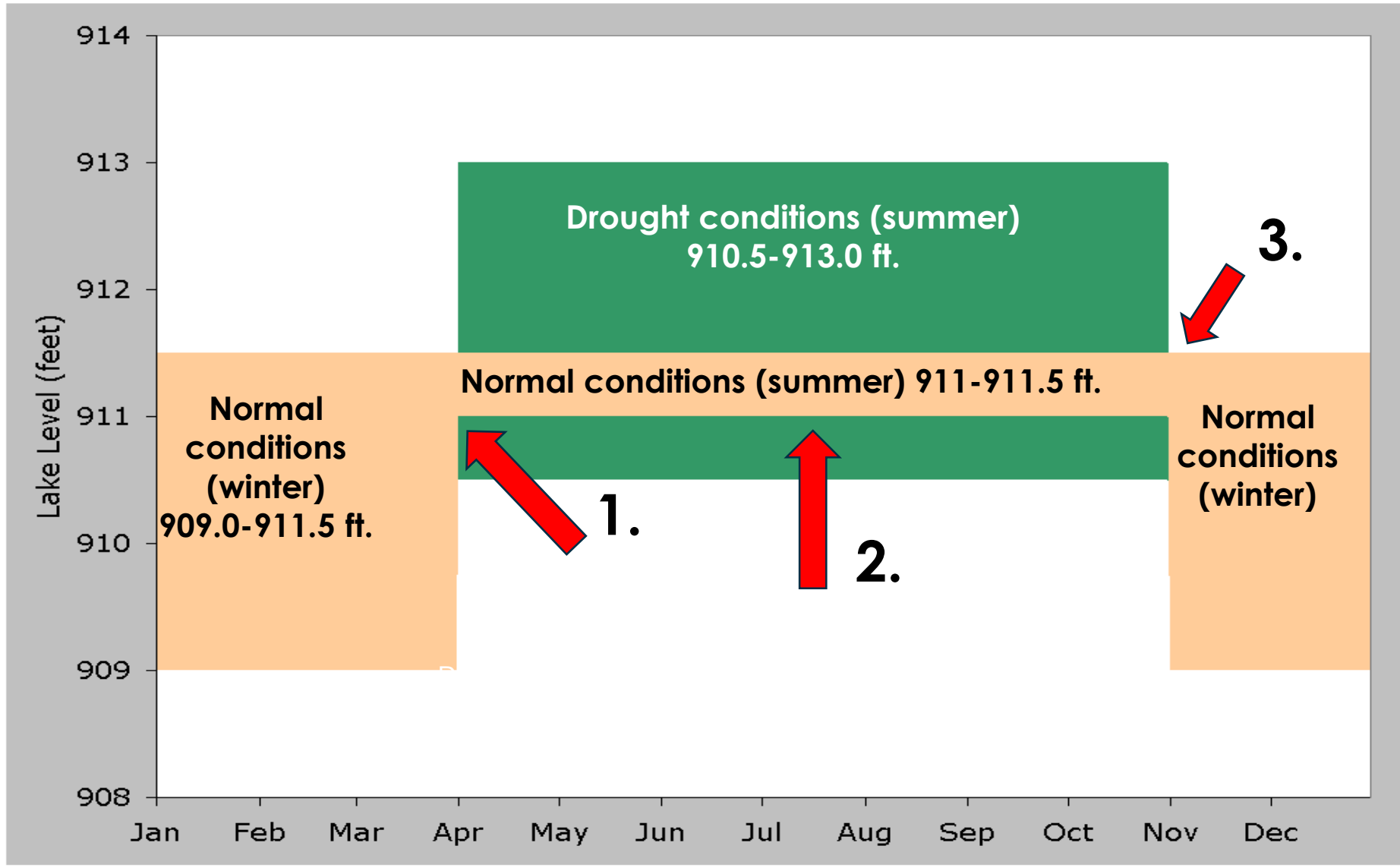
# IJC AND OSOYOOS LAKE

- Osoyoos Lake levels controlled by Zosel Dam
- IJC became involved in the regulations of previous dam in 1940's due to its impacts on the lake's level on both sides of border
- IJC appoints the Members of the International Osoyoos Lake Board of Control to monitor Orders


Constructed circa.1928


Reconstructed 1985-1987

# 1985 IJC RULE CURVE (EXPIRED 2013)



# ORDER RENEWAL PROCESS

- 1985 IJC Order was to expire in February 2013.
- IJC process to renew the Osoyoos Lake Order
  - Plan of Study (2006) & 8 individual technical studies
  - 2011 Osoyoos Lake Water Science Forum
  - Board prepared recommendations for IJC
  - Public hearings & public comment period, and
  - Renewed application for Zosel Dam by State of Washington
- IJC committed to providing long term funding, organizational and technical support to renewal process

# SUPPORTING TECHNICAL STUDIES:

## Overall Plan of Study (2006)


- Drought Criteria
- Review of Key Operating Dates
- Assessment of Suitable Levels
- Factors Governing High Water
- Methods to Determine Channel Capacity
- Impacts of Regulation on Water Quality
- Evaluation of Ecosystem Requirements
- Operational Implications of Future Climate Change

# ADAPTIVE MANAGEMENT CONSIDERATIONS IN ORDER RENEWAL:

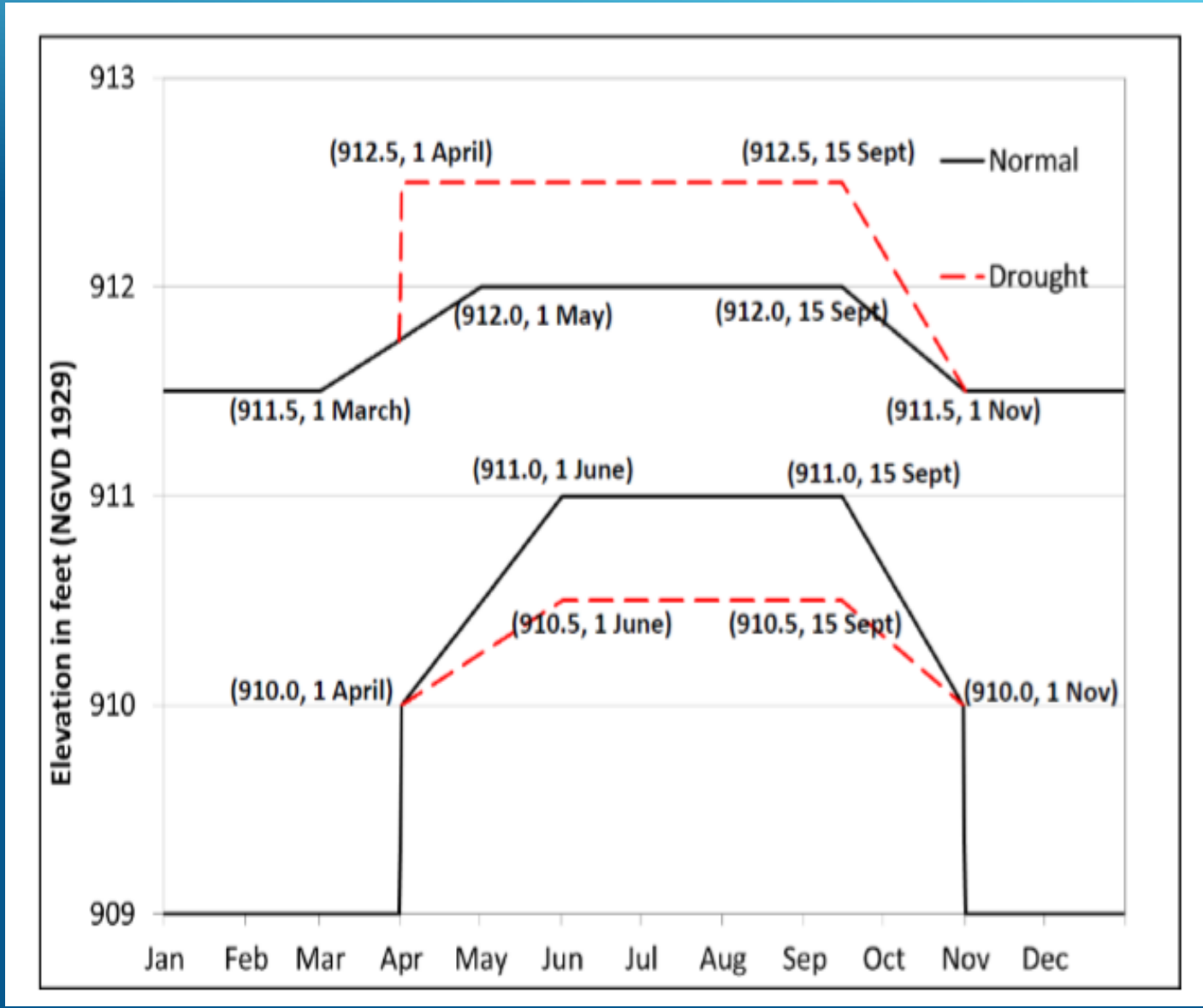
- IJC strategic direction
- Results of the 8 supporting studies
- Concerns of stakeholders and public gather through engagement at public meetings, water science forum and other feedback
- Dam manger's and Board's experiences with 1985 Order
- Desire to provide dam managers with greater operational flexibility & discretion to respond to real-time conditions

# OUTCOMES OF ORDER RENEWAL:

- A new "Rule Curve"
- Expansion of Board membership from previous federal and state/provincial agencies to include more local members
- A commitment by Board to greater ongoing information sharing and engagement with public through website & media releases
- Production and distribution of the documentary "A River Film".

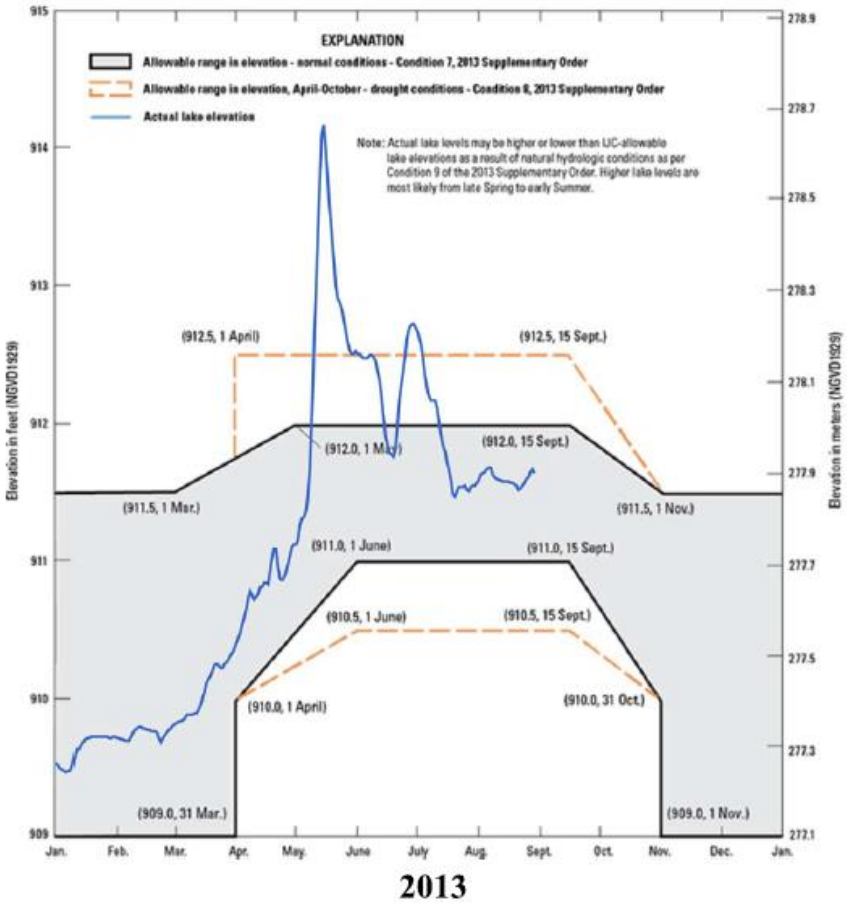
# 2013 IJC RULE CURVE:

Provides manager with greater operation flexibility and discretion to adapt operations in response to real-time conditions, including uncertainties associated with climate change



# IMPROVED PUBLIC INFORMATION ON LAKE LEVEL CHANGE

**Actual and Allowable Lake Elevations per IJC Orders of Approval, Osoyoos Lake near Oroville, Washington, USGS Station 12439000**




International Osoyoos Lake Board of Control

## Lake Level Forecasts

For current and past water level information for Osoyoos Lake, please click on the following link:

http://waterdata.usgs.gov/wa/nwis/uv/?site_no=12439000

For real-time Osoyoos Lake water levels plotted against the IJC rule curve, please click on the following link:

http://wa.water.usgs.gov/data/12439000.html

**Update: July 22 2013; Osoyoos Lake Water Level Trends – International Osoyoos Lake Board of Control**

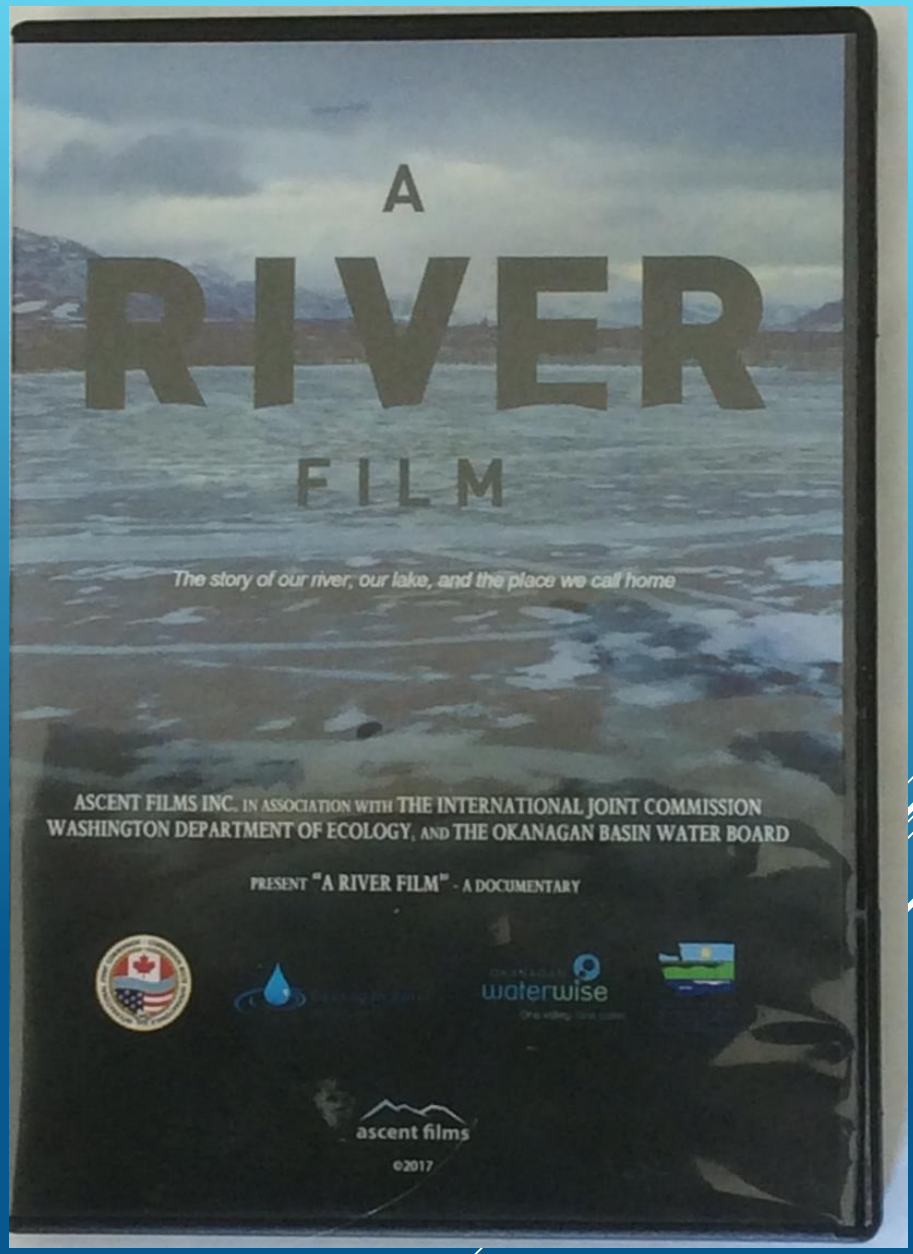
Decreasing inflow to the lake from the upstream Okanagan river and tributaries has resulted in a lowering of the water level of Osoyoos lake to within the Summer period operating range of 911.0 to 912.0 ft. (re. IJC Osoyoos Lake Supplementary Order of Approval, January 2013). Lake levels are expected to remain within this range for the remainder of the summer with Zosel Dam operations aiming to maintain a mid-range lake level elevation during this summer period.

**Update: July 2 2013; Osoyoos Lake Water Level Trends – International Osoyoos Lake Board of Control**

The level of Osoyoos Lake had been rising over the past week, reaching a peak lake level elevation of 912.73 ft. on June 28th and the lake level is now beginning to fall (lake level elevation was 912.67 ft. on July 1st). The rise in lake level was primarily due to increased flows in the Okanagan River due to heavy rainfall over the past two weeks which led to increased discharge from Okanagan Lake and tributary streams. Flows in the Similkameen River had also been increasing early last week, with a peak of 9660 cfs (cubic feet per second) on June 25th, but have been receding to lower flow rates since (e.g. 7170 cfs on July 1st). At these flow rates, a backwater effect on Okanogan River discharge (downstream of Zosel Dam) from the Similkameen River is considered a minor possible influence on Osoyoos Lake levels compared to the high inflows to Osoyoos Lake from the Okanagan River. The trend of receding tributary inflows is expected to continue over the next two weeks with the result that Osoyoos Lake levels are expected to fall into the normal summer operating range of 911.0-912.0 ft. by mid-July.

# “A RIVER FILM”

Production and distribution of documentary to increase public engagement and awareness of transboundary water regulation and collaboration in the Okanagan



# SUMMARY OF KEY OKANAGAN RIVER ADAPTIVE MANAGEMENT SUCCESSES:

- More effective, and collaborative use timely use of the available real-time data and the expanding scientific knowledge base
- A culture of experimentation and continuous learning
- New and strengthened organizational and funding partnerships
- Greater trust, transparency and collaboration in decision making
- Improved "balance" of ecosystem and human system objectives
- **Significant contributions towards recovery of Okanagan sockeye returns & available instream habitat**


Questions?
For more information:
Hyatt et al. 2003. Canadian Water Resources Journal 28 (4): 689-713.
FWMT: www.essa.com/tools/
IOLBC website: ijc.org/en_/iolbc/Home