# 2023 Cowichan River Fish Kill and Where We Go from Here


## Cowichan Watershed Board Fall Speaker Series

*Mon. Oct 21* | *VIU Cowichan Campus - Lecture Hall 140* | *Free*

Ken Ashley, B.Sc., M.Sc., M.A.Sc., Ph.D., R.P. Bio.

# Outline

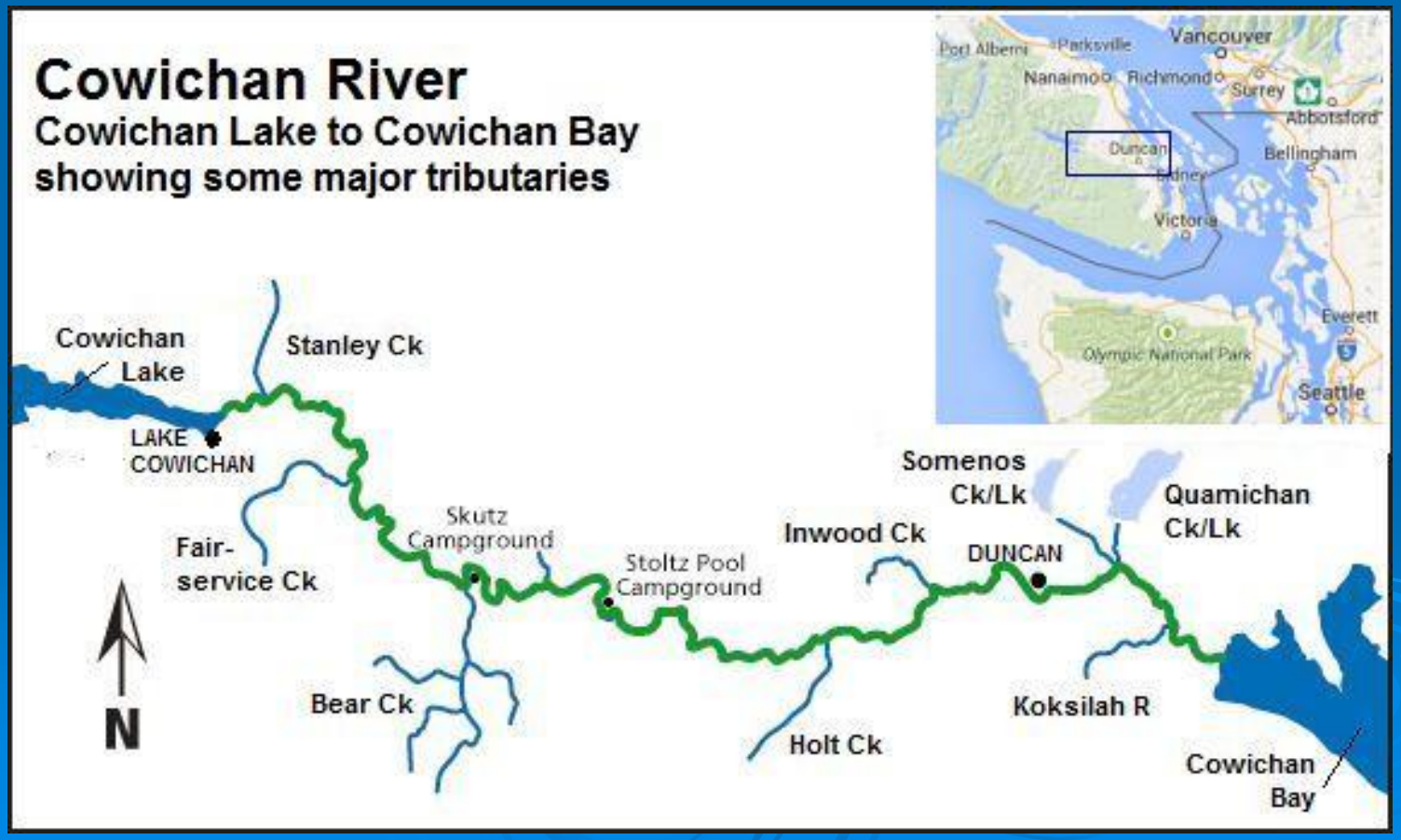
1. Welcome and Introduction
2. Cowichan River
3. Fish kill – July 2023
4. What happened?
5. Short tem solutions: 2024 action and strategies
6. Long term solutions and vision for Cowichan watershed
7. Closing comments

# Welcome and Introduction



# Cowichan River

- Cowichan River flows for ~ 47 kms from Cowichan Lake to Cowichan Bay.
- Designated BC Heritage River and Canadian Heritage River



It is a very important river because:

- cultural and spiritual value for the Cowichan Tribes people
- spawning river for salmon, trout and steelhead
- popular local and tourist destination for swimming, fishing, river tubing, kayaking, camping

- provides water for the Catalyst Paper pulp and paper mill in Crofton
- provides drinking water for Crofton.
- receives ToLC treated sewage effluent.
- **Cowichan River is the cultural, spiritual, economic and environmental cornerstone of the Cowichan Valley**


LANGLEY ADVANCE TIMES

News More Contests Shop Flyers E-Editions Classifieds Auto Jobs

**Cowichan River No. 2 fishing destination in Canada in 2024**

FishBooker says river the "go-to" destination on Vancouver Island for trout fishing

Robert Barron
Jan 23, 2024 4:25 PM
Updated Jan 23, 2024 4:26 PM




# Fish kill – July 2023

## River system

*Authorities trying to solve mystery of why fish in Cowichan River system died.*

**Carla Wilson** • Victoria Times Colonist

Published Jul 15, 2023 • Last updated Jul 17, 2023 • 4 minute read

Join the conversation

Joe Saysell in the Cowichan River with dead fry. Via Daegan Sheffar jpeg

Hundreds of tiny silver salmon and trout fry have been discovered dead at the bottom of a canyon at the base of Skutz Falls on the Cowichan River system and the cause of the mass die-off is a mystery.

BRITISH COLUMBIA

**MEMORANDUM**

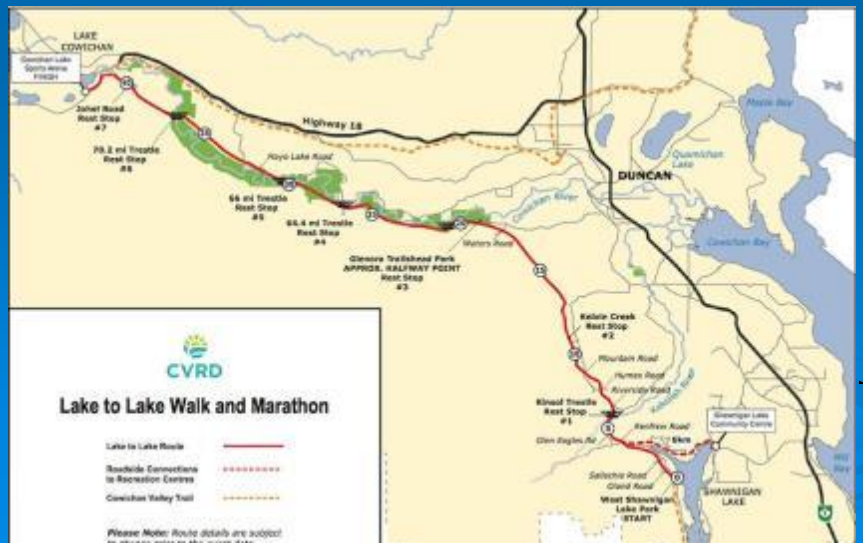
File Name: PE247

Date: February 12, 2024

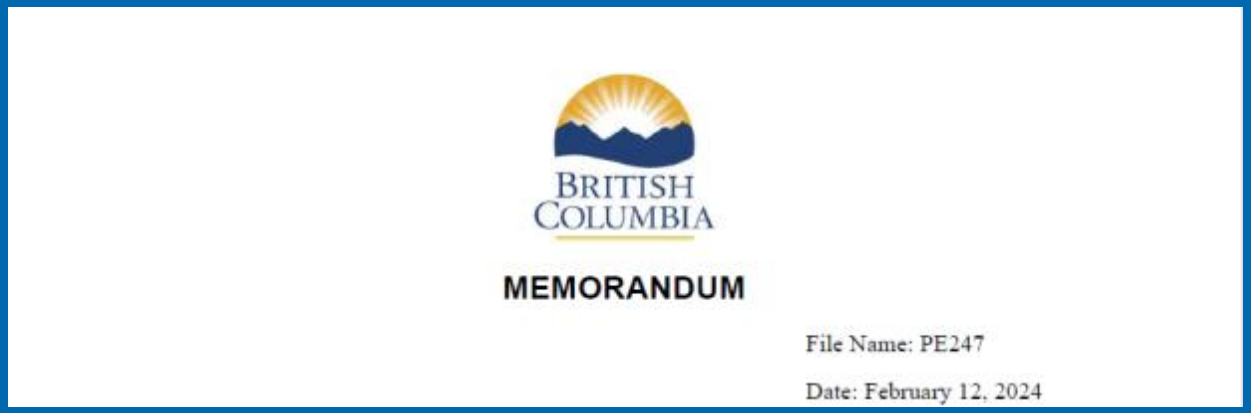
“In early July 2023 a severe fish kill occurred on the Cowichan River.

A fisheries survey conducted in late July as part of the annual trout index revealed that no steelhead trout (*Oncorhynchus mykiss)* fry were observed in an approximately 6 km stretch of the Cowichan River between the 70.2 Mile Trestle and Skutz Falls where they are normally present (BC WLRS 2023).

The impact of this mortality event on fish stocks is thought to be substantial, with estimates of **up to 84,000 steelhead fry killed** (BC WLRS 2023). ”



# What happened?



BRITISH COLUMBIA

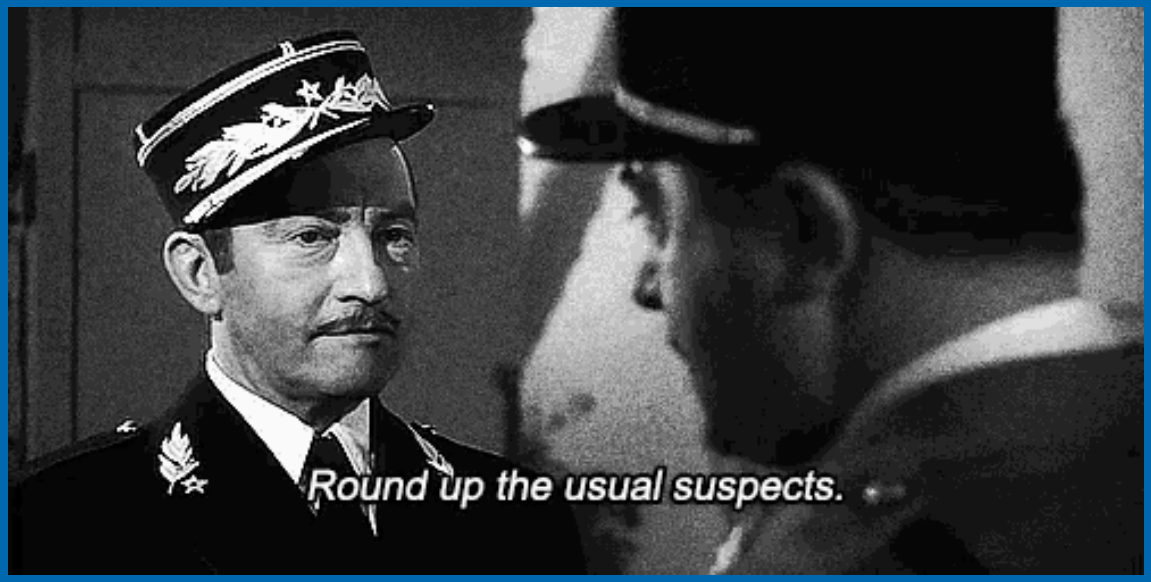
**MEMORANDUM**

File Name: PE247

Date: February 12, 2024

"River discharge in the Cowichan River was **low (approximately 4.5 m3/second)** at the time of the fish kill, leading to concern that **low effluent dilution**, **combined with high temperatures and potentially irregular effluent quality**, may have led to the mortality event."

- **Key point**: the fish kill was suspected to be due to a **combination** of environmental stressors, not a **single** stressor




1. low flow (approximately 4.5 m3/second)

2. high temperatures

3. low effluent dilution

4. irregular effluent quality

# Usual Suspect 1: low flow (approximately 4.5 m3/second)

- Vancouver Island was at Stage 5 drought condition in 2023

SUMMERLAND REVIEW

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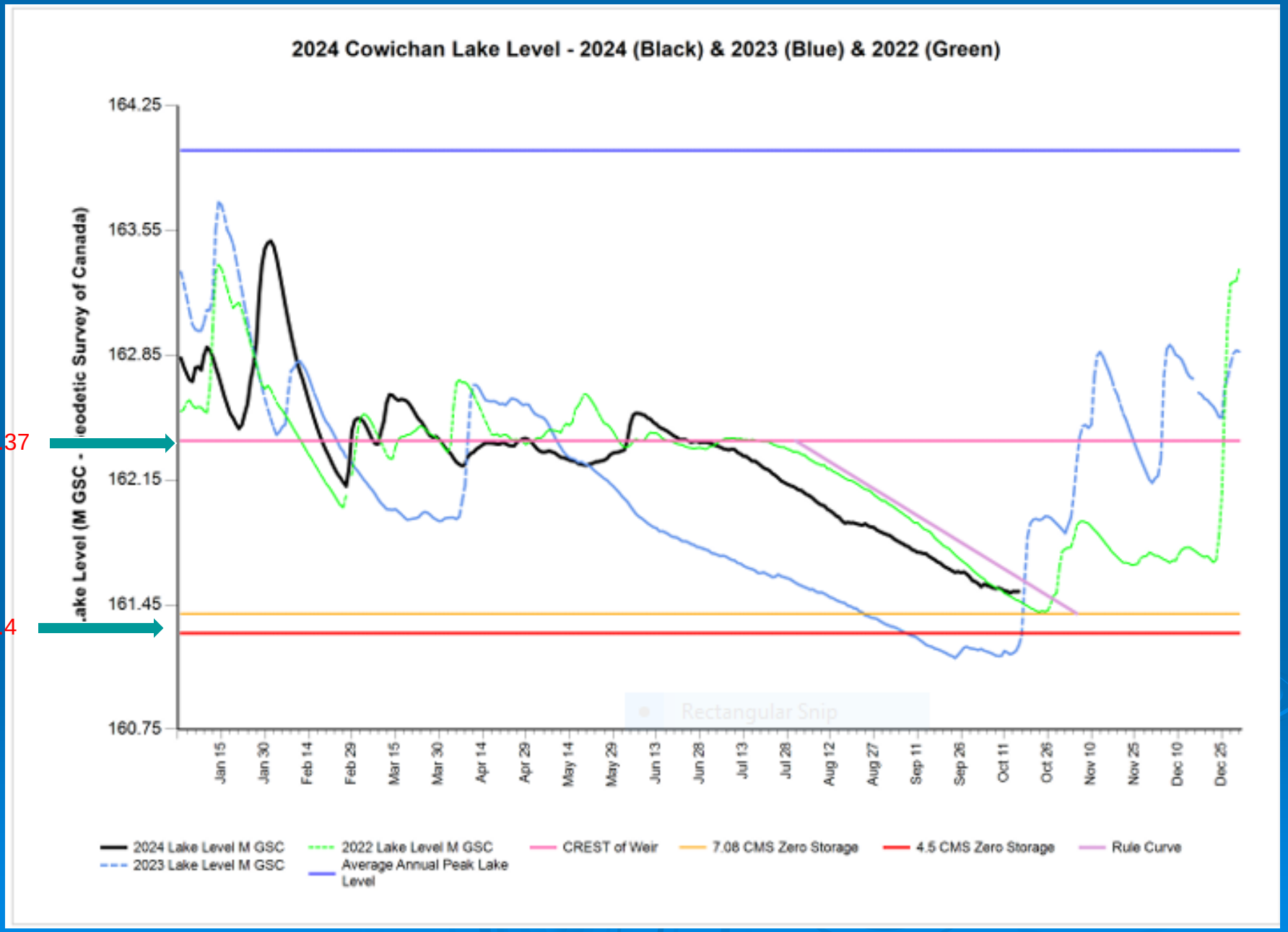
## Drought conditions intensify in British Columbia

Much of B.C. at most severe drought conditions

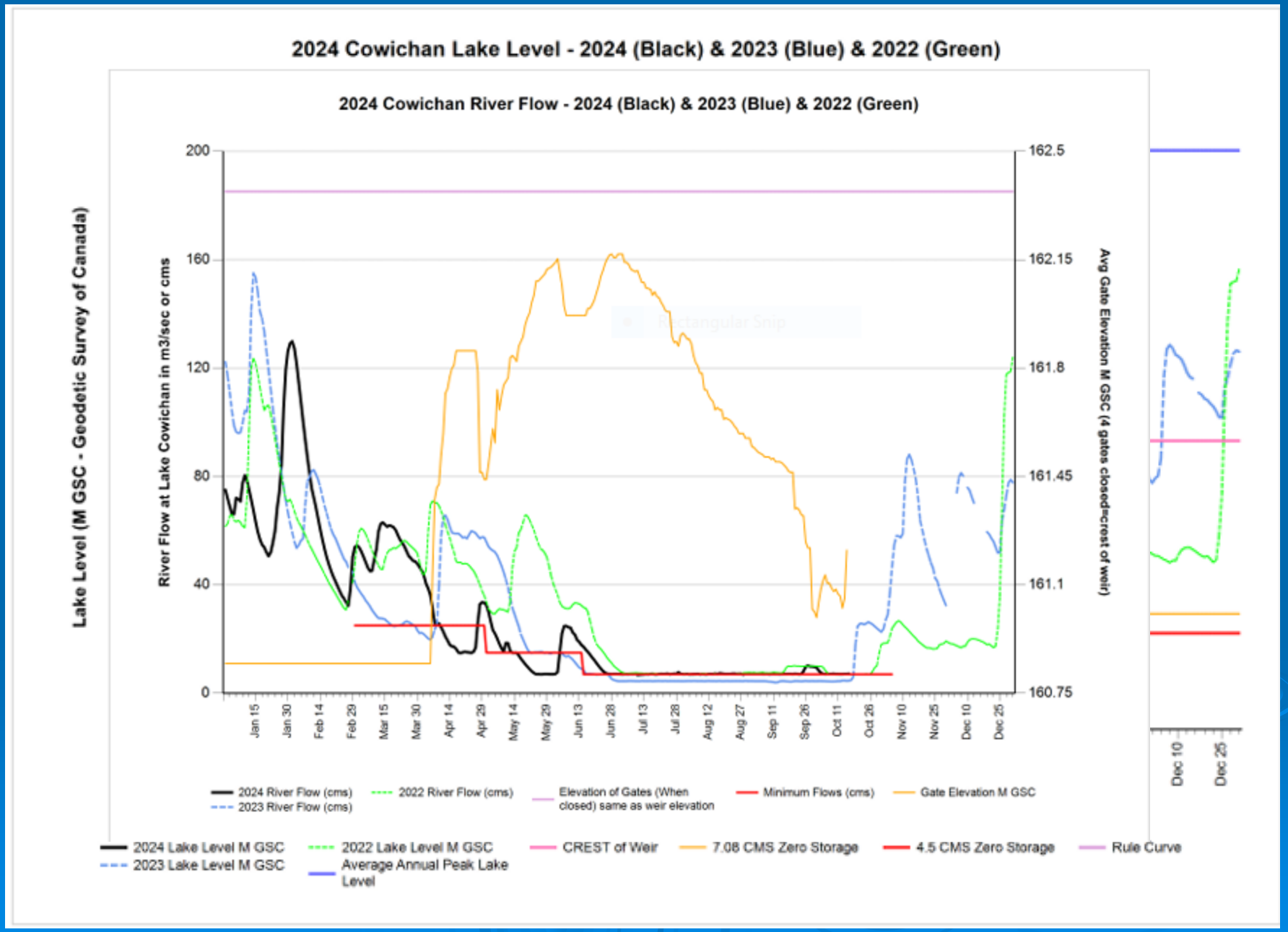
John Arendt
Aug 4, 2023 10:41 AM
Updated Aug 4, 2023 2:03 PM

*The red areas on the map from Aug. 3 show Drought Level 4 conditions, while the dark red areas show Drought Level 5. (Government of BC)*

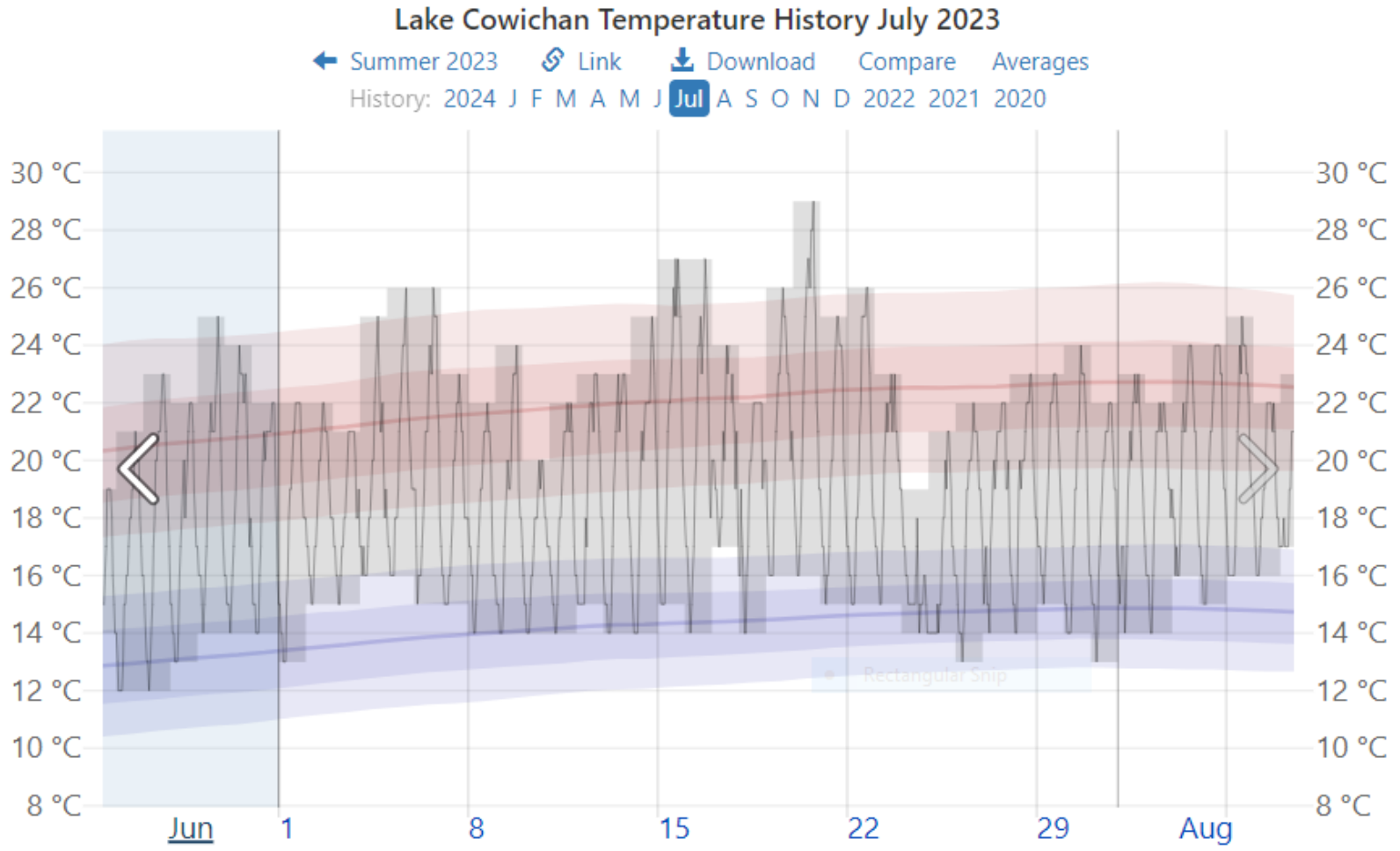

2024 Cowichan Lake Level - 2024 (Black) & 2023 (Blue) & 2022 (Green)
164.25
163.55
162.85
162.37
162.15
161.45
161.4
160.75
Jan 15
Jan 30
Feb 14
Feb 29
Mar 15
Mar 30
Apr 14
Apr 29
May 14
May 29
Jun 13
Jun 28
Jul 13
Jul 28
Aug 12
Aug 27
Sep 11
Sep 26
Oct 11
Oct 26
Nov 10
Nov 25
Dec 10
Dec 25
2024 Lake Level M GSC
2023 Lake Level M GSC
2022 Lake Level M GSC
Average Annual Peak Lake Level
CREST of Weir
7.08 CMS Zero Storage
4.5 CMS Zero Storage
Rule Curve

“Towards the end of the (2023) summer, water levels became so low that 20 pumps were turned on to pull water from the lake into the river.

They ran for 36 days and brought lake levels to historic lows, impacting the shoreline and the threatened Cowichan Lake lamprey species, Rutherford says.”

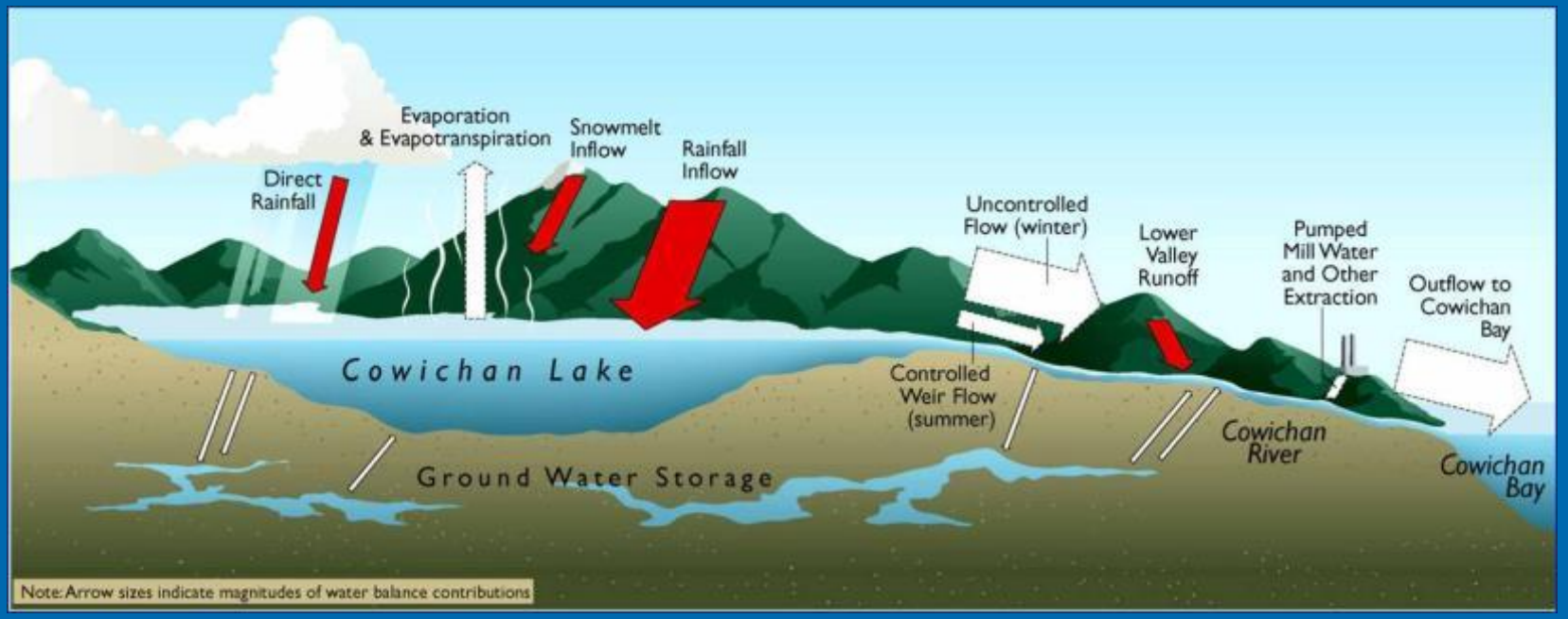

2024 Cowichan Lake Level - 2024 (Black) & 2023 (Blue) & 2022 (Green)
2024 Cowichan River Flow - 2024 (Black) & 2023 (Blue) & 2022 (Green)
Lake Level (M GSC - Geodetic Survey of Canada)
River Flow at Lake Cowichan in m3/sec or cms
Avg Gate Elevation M GSC (4 gates closed=crest of weir)
200
160
120
80
40
0
162.5
162.15
161.8
161.45
161.1
160.75
Jan 15
Jan 30
Feb 14
Feb 29
Mar 15
Mar 30
Apr 14
Apr 29
May 14
May 29
Jun 13
Jun 28
Jul 13
Jul 28
Aug 12
Aug 27
Sep 11
Sep 26
Oct 11
Oct 26
Nov 10
Nov 25
Dec 10
Dec 25
2024 River Flow (cms)
2023 River Flow (cms)
2022 River Flow (cms)
Elevation of Gates (When closed) same as weir elevation
Minimum Flows (cms)
Gate Elevation M GSC
2024 Lake Level M GSC
2023 Lake Level M GSC
2022 Lake Level M GSC
Average Annual Peak Lake Level
CREST of Weir
7.08 CMS Zero Storage
4.5 CMS Zero Storage
Rule Curve

# Usual Suspect 2: high temperature

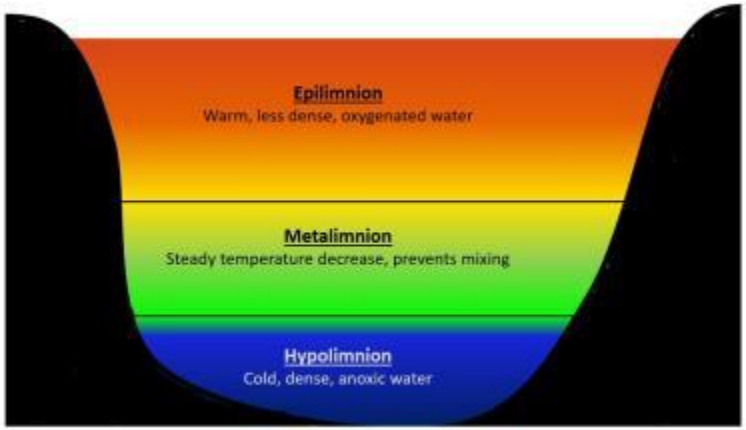



*The daily range of reported temperatures (gray bars) and 24-hour highs (red ticks) and lows (blue ticks), placed over the daily average high (faint red line) and low (faint blue line) temperature, with 25th to 75th and 10th to 90th percentile bands.*

- Lake headed rivers receive outflow water from the lake surface layers




- Since lakes stratify in summer, lake headed rivers can get very warm




Fisheries officials recorded the Cowichan River’s water temperature at 24 degrees Tuesday. A heat warning is currently in effect for B.C.’s South Coast, including parts of Vancouver Island.

- All salmonids (trout, salmon and char) are cold water fish



TABLE 4.8.—Lower lethal, upper lethal, and preferred temperatures (°C) for selected species of salmon, trout, and char based on techniques to determine incipient lethal temperatures (ILT) and critical thermal maxima (CTM).

| Species | Lethal temperature (°C) | | Preferred temperature (°C) | Source | Technique |
|---|---|---|---|---|---|
| | Lower lethal[a] | Upper lethal[b] | | | |
| Chinook salmon | 0.8 | 26.2 | 12–14 | Brett (1952) | ILT |
| Coho salmon | 1.7 | 26.0 | 12–14 | Brett (1952) | ILT |
| | | 28.8[c] | | Becker and Genoway (1979) | CTM |
| Sockeye salmon | 3.1 | 25.8 | 12–14 | Brett (1952) | ILT |
| Chum salmon | 0.5 | 25.4 | 12–14 | Brett (1952) | ILT |
| Steelhead | 0.0 | 23.9 | 10–13 | Bell (1986) | |
| Rainbow trout | | 29.4 | | Lee and Rinne (1980) | CTM |
| | | 25.0 | | Charlon et al. (1970) | ILT |
| Brown trout | | 29.9 | | Lee and Rinne (1980) | CTM |
| | | 26.7 | | Brett (1952) | ILT |
| Gila trout | | 29.6 | | Lee and Rinne (1980) | CTM |
| Apache trout | | 29.4 | | Lee and Rinne (1980) | CTM |
| Brook trout | | 29.8 | | Lee and Rinne (1980) | CTM |
| | | 25.8 | | Brett (1952) | ILT |
| | | | 14–16 | Graham (1949) | |
| Cutthroat trout | 0.6 | 22.8 | | Bell (1986) | |
| Atlantic salmon | | 27.1 | | Brett (1952) | ILT |
| | | 27.8 | | Garside (1973) | ILT |
| Lake trout | | 25.0 | | Brett (1952) | ILT |

[a] Acclimation temperature was 10°C; no mortality occurred in 5,500 min.
[b] Acclimation temperature was 20°C unless noted otherwise; 50% mortality occurred in 1,000 min.
[c] Acclimation temperature was 15°C.

## Field-Based Estimates of Thermal Tolerance Limits for Trout: Incorporating Exposure Time and Temperature Fluctuation

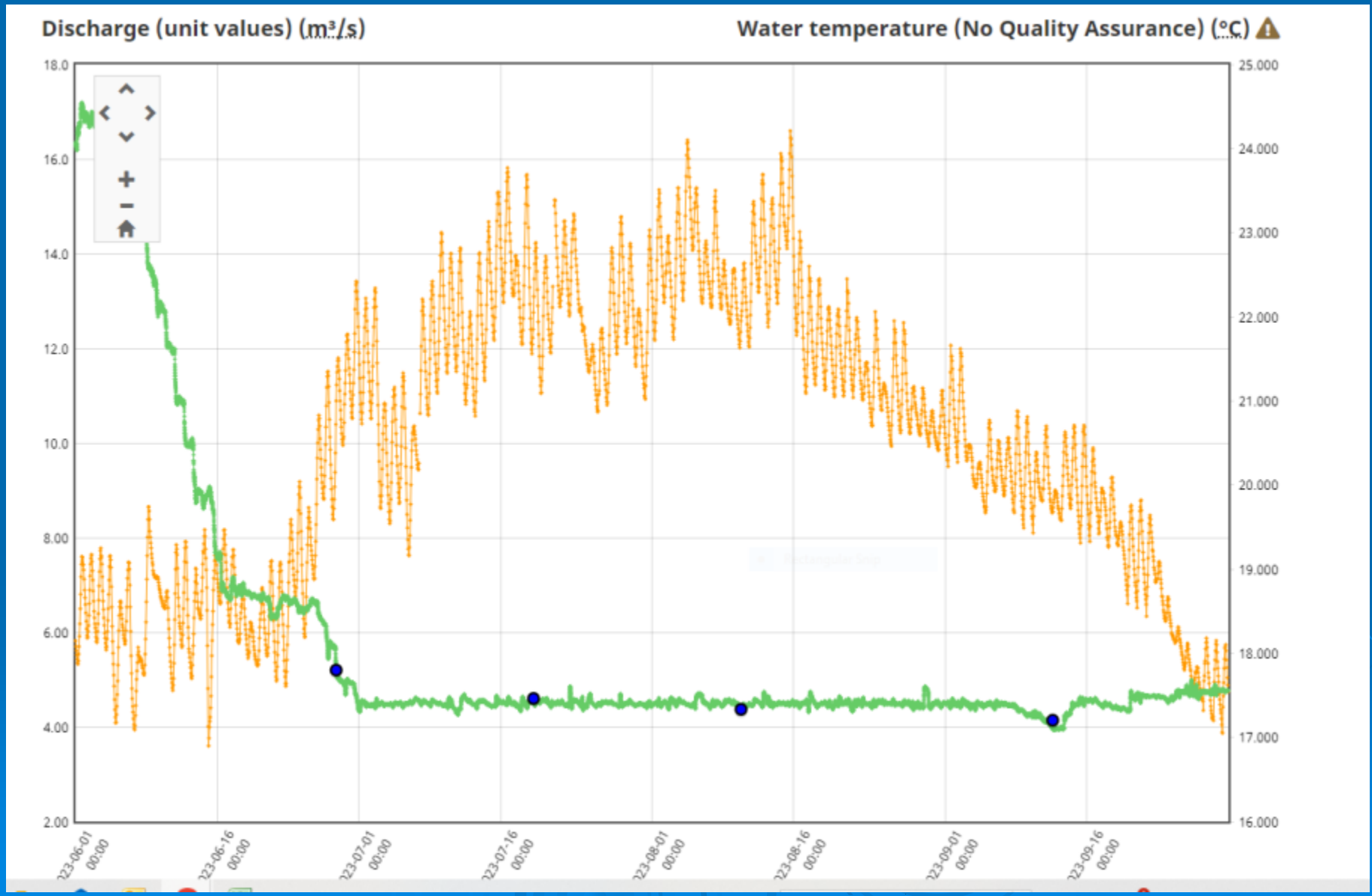
Article | Full-text available | Mar 2007

Kevin E. Wehrly · Lizhu Wang · Matthew Mitro

| Species | CTM (°C) | UILT (°C) | Acclimation temperature (°C) | Field observation (°C) | Reference |
|---|---|---|---|---|---|
| Brook trout | 28.7–29.8 | | 10–20 | | Lee and Rinne (1980) |
| | 28.3–30.8 | | 8–20 | | Selong et al. (2001) |
| | 29 | | 10 | | De Staso and Rahel (1994) |
| | | 25.3 (3 d) | 24 | | Fry et al. (1946) |
| | | 24.5 (7 d) | | | McCormick et al. (1972) |
| | | | | 24 (Maximum summer temperature) | Picard et al. (2003) |
| | | | | 25.6 (Maximum summer temperature) | Barton et al. (1985) |
| | | | | 26.5 (Maximum summer temperature) | Bowlby and Roff (1986) |
| | | | | 24.2–26.3 (Maximum summer temperature) | Binns and Eiserman (1979) |
| | | | | 24 (Maximum weekly temperature) | Meisner (1990) |
| | | | | 22.3 (Maximum weekly mean temperature) | Eaton et al. (1995) |
| Brown trout | 29.0–29.9 | | 10–20 | | Lee and Rinne (1980) |
| | 29.9 | | 20 | | Elliott and Elliott (1995) |
| | | 24.7 (7 d) | 22 | | Elliott (1981) |
| | | 25.3 (7 d) | 23 | | Frost and Brown (1967) |
| | | | | 25 (Maximum summer temperature) | Bowlby and Roff (1986) |
| | | | | 24.2–26.3 (Maximum summer temperature) | Binns and Eiserman (1979) |
| | | | | 24.1 (Maximum weekly mean temperature) | Eaton et al. (1995) |
| Rainbow trout | 28–29.8 | | 10–20 | | Currie et al. (1998) |
| | 28.5–29.4 | | 10–20 | | Lee and Rinne (1980) |
| | 29.4 | | | | Rodnick et al. (2004) |
| | | 26.6 (1 d) | 24 | | Charlon et al. (1970) |
| | | 25.6 (7 d) | 16 | | Hokanson et al. (1977) |
| | | 26.2 (7 d) | 24.5 | | Kaya (1978) |
| | | | | 25 (Maximum summer temperature) | Bowlby and Roff (1986) |
| | | | | 25.6 (Maximum summer temperature) | Barton et al. (1985) |
| | | | | 24.2–26.3 (Maximum summer temperature) | Binns and Eiserman (1979) |

-Critical thermal maxima (CTM), upper incipient lethal temperature (UILT), and field observations of upper temperature tolerances for brook, brown, and rainbow trout.

# Suspects 1 and 2: **confirmed**



# Usual Suspect 3: low effluent dilution

BRITISH COLUMBIA

**MEMORANDUM**

File Name: PE247

Date: February 12, 2024

- Town of Lake Cowichan has a permit to discharge treated lagoon effluent to the Cowichan River (daily flow 4,500 $m^3/d$, mean daily flow 2,200 $m^3/d$).

- lagoon effluent discharge point is located in the Cowichan River, approximately 3.5 km downstream of the Lake Cowichan outlet

**Figure 1**. Overview map showing the location of 2023 sample sites, including Little Beach (Little Beach/Road Pool), Saysell's (Sayselle's – km 45), the upstream (300 m above PE-247) and downstream (400 m below PE-247) lagoon effluent monitoring sites, 70.2 Mile Trestle (70.2 Trestle – km 40), Skutz Falls (Skutz Falls – km 34) and Horseshoe Bend (Horseshoe Bend – km 33).


| | | | |
|---|---|---|---|
| Ministry of Environment and Climate Change | Monitoring, Assessment and Stewardship | Mailing Address: 625 4th Street | Telephone: 250 342-4260 Website: www.gov.bc.ca/env |

**Goal 3** - Calculate dilution rations and summarize effluent discharge rates in the Cowichan River from 2021 to 2023.

- Daily lagoon effluent discharge data were obtained from the Town of Lake Cowichan effluent discharge reporting requirements and summarized for 2023. Cowichan River 2023 stream discharge data (Station 08HA002) was downloaded from Environment and Climate Change Canada's hydrometric database (EC 2023). The daily mean dilution ratio was calculated using the following equation (SLR 2022):

$$Mean\ Dilution\ Ratio = \frac{Mean\ River\ Discharge\ Rate\ (m^3/sec)}{Mean\ Effluent\ Discharge\ Rate\ (m^3/sec)}$$


BRITISH COLUMBIA

MEMORANDUM

File Name: PE247

Date: February 12, 2024

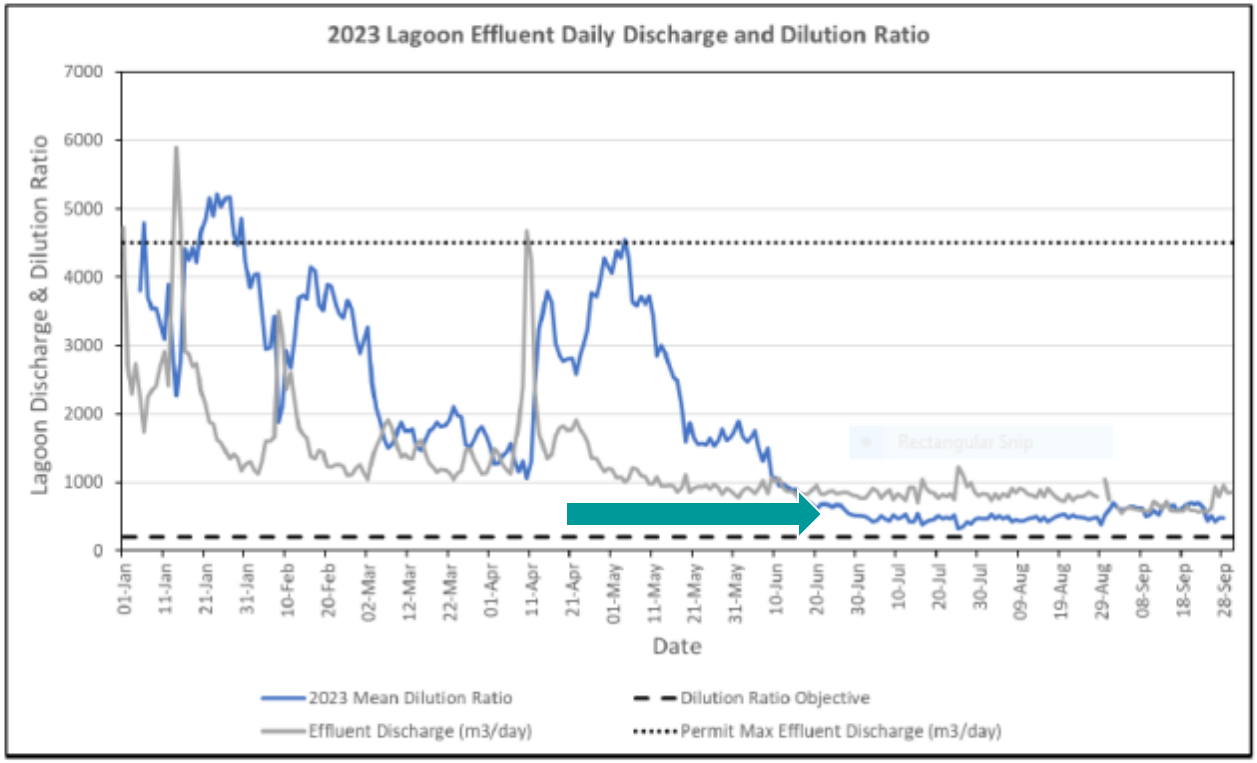
“The daily lagoon effluent flow permit limit (4,500 $m^3$/day) was exceeded on four days in 2023, including January 1st, January 14th, January 15th, and April 10th.

The mean dilution ratio calculated from January to September 2023 did not fall below the Cowichan River Water Quality Objective of 200:1.

**The original 200:1 dilution ratio objective was, however, intended to limit BOD and TSS loading to the Cowichan River (McKean 1989) and was not intended for interpreting dilution of nutrients such as Nitrogen and Phosphorus (SLR 2022).* ”

# Suspect 3: **not confirmed** *

**Figure 11.** January to September 2023 mean effluent dilution ratio (blue line) and Cowichan River dilution ratio of 200:1 (black dashed line), as well as the total daily effluent flow and permitted value (4,500 $m^3$/day; black dotted line).





| | | | |
|---|---|---|---|
| Ministry of Environment and Climate Change Strategy | Monitoring, Assessment and Stewardship Environmental Protection Division | Mailing Address: 625 4th Street Invermere BC V0A 1K0 | Telephone: 250 342-4260 Website: www.gov.bc.ca/env |

# Usual Suspect 4: irregular effluent quality

BRITISH COLUMBIA

MEMORANDUM

File Name: PE247

Date: February 12, 2024

"BC Fisheries staff described the Town of Lake Cowichan effluent discharge as "green and goopy" in July 2023 surveys, contrary to previous years of fisheries surveys where the effluent was described as "watery coffee" in appearance.

"Though green algae are not uncommon to observe downstream of the effluent discharge, in July 2023 patches of dense filamentous green algal growth were observed downstream of the lagoon effluent discharge pipe for about one kilometer;

…green algae were replaced by thick brown algae with a "scummy" appearance just upstream of the 70.2 Mile Trestle and below some right bank tributaries (BC WLRS 2023)."


Lake Cowichan July 19


70.2 Trestle July 14


Upper River July 19


Vimy July 19

BRITISH COLUMBIA

**MEMORANDUM**

File Name: PE247

Date: February 12, 2024

1) determine if there were any anomalies in lagoon effluent quality in 2023 compared with 2021 and 2022,

2) summarize and compare water quality data collected at monitoring locations located 300 m upstream and 400 m downstream (EMS 0120808 and EMS E206107, respectively) of the effluent discharge pipe, as required in PE-00247 from August and September 2021-2023,

# ToLC Effluent parameters

BRITISH COLUMBIA

MEMORANDUM

File Name: PE247

Date: February 12, 2024

"Overall, some **effluent parameters** were elevated in 2023 when compared with 2021-2022.

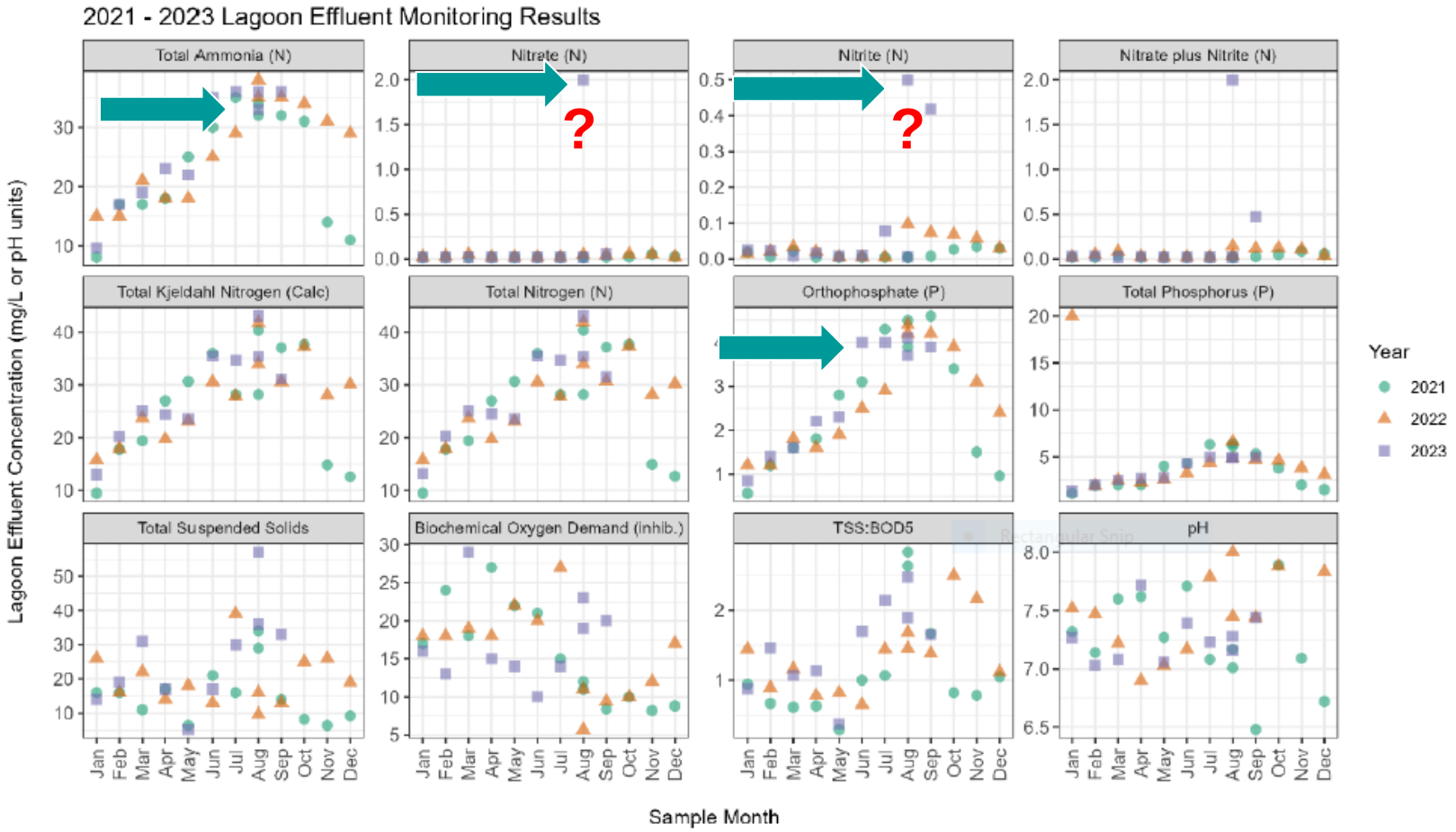
Specifically, in June, July and September 2023, **Total Ammonia (N)** was elevated in comparison with previous years.

**Nitrate (N), Nitrite (N) and Nitrate plus Nitrate (N)** were elevated in June, July and August of 2023.**(complications from lab interference)

**Orthophosphate** in lagoon effluent discharge was elevated in 2023 above previous years during the months of February, April, and **June** ."

# ToLC Effluent parameters

**Figure 2**. Town of Lake Cowichan lagoon effluent discharge data for parameters measured from January 2021 to September 2023. Note: outliers in August 2023 for Nitrate (N), Nitrite (N) and Nitrate plus Nitrite (N) are a result of analytical laboratory detection limitations.





| | | | |
|---|---|---|---|
| **Ministry of Environment and Climate Change Strategy** | Monitoring, Assessment and Stewardship Environmental Protection Division | Mailing Address: 625 4th Street Invermere BC V0A 1K0 | Telephone: 250 342-4260 Website: www.gov.bc.ca/env |

# Cowichan River parameters


BRITISH COLUMBIA

MEMORANDUM

File Name: PE247

Date: February 12, 2024

“The concentration of several parameters, including

Total Ammonia (N), Nitrate (N), Nitrate plus Nitrite (N),

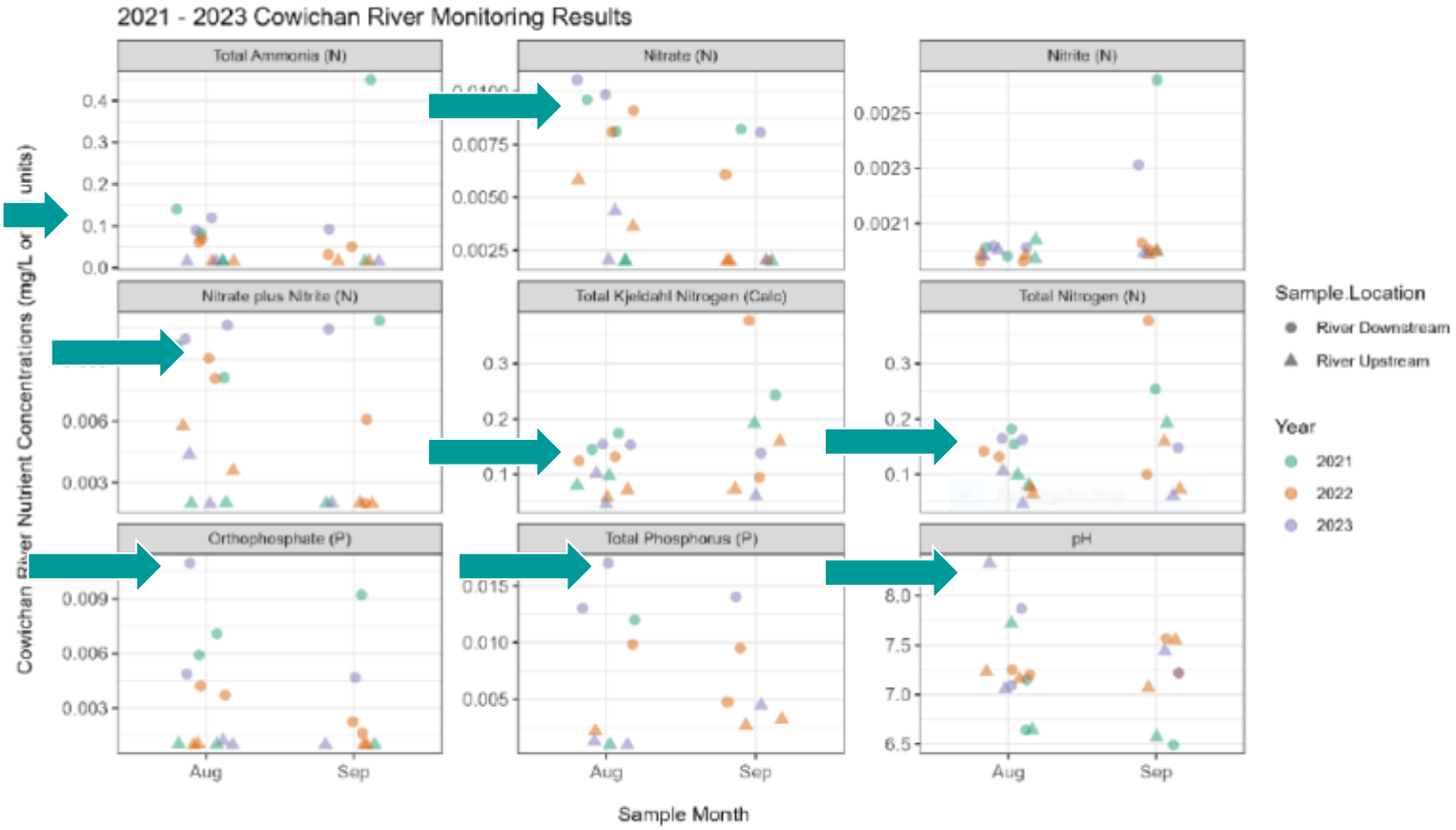
Total Kjeldahl Nitrogen (N), Total Nitrogen (N),

Total Phosphorus (P) and Orthophosphate (P)

were elevated in the **downstream site** in comparison with the **upstream river site**.”

# Cowichan River parameters

**Figure 6.** Cowichan River data showing chemical and nutrient parameters measured in the receiving environment at both 300 m upstream (triangles) and 400 m downstream (circles) monitoring sites in August (Aug) and September (Sep) from 2021-2023.




| | | | |
|---|---|---|---|
| Ministry of Environment and Climate Change Strategy | Monitoring, Assessment and Stewardship Environmental Protection Division | Mailing Address: 625 4th Street Invermere BC V0A 1K0 | Telephone: 250 342-4260 Website: www.gov.bc.ca/env |

**Note: river sampling started in August, 2023 - there are no June and July samples.**

**Figure 9.** Total Ammonia (N) concentration measured in the Cowichan River from 300 m upstream and 400 m downstream monitoring sites in August and September from 2021-2023. Boxplots show the yearly median (solid lines), 25th and 75th percentiles (boxes) and minimum and maximum values (whiskers). The black dashed line shows the Cowichan River mean Water Quality Objective value for May to September.

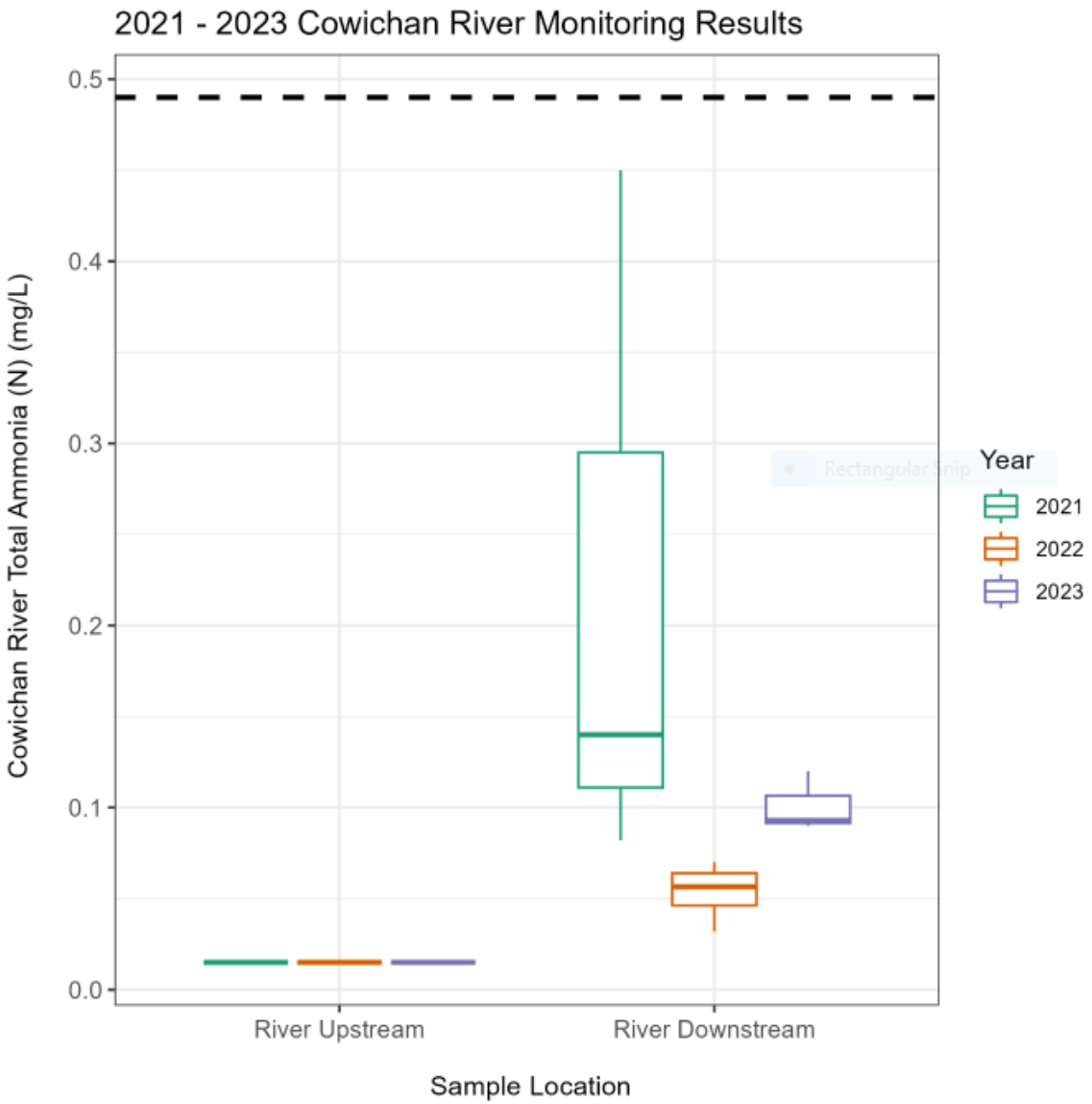
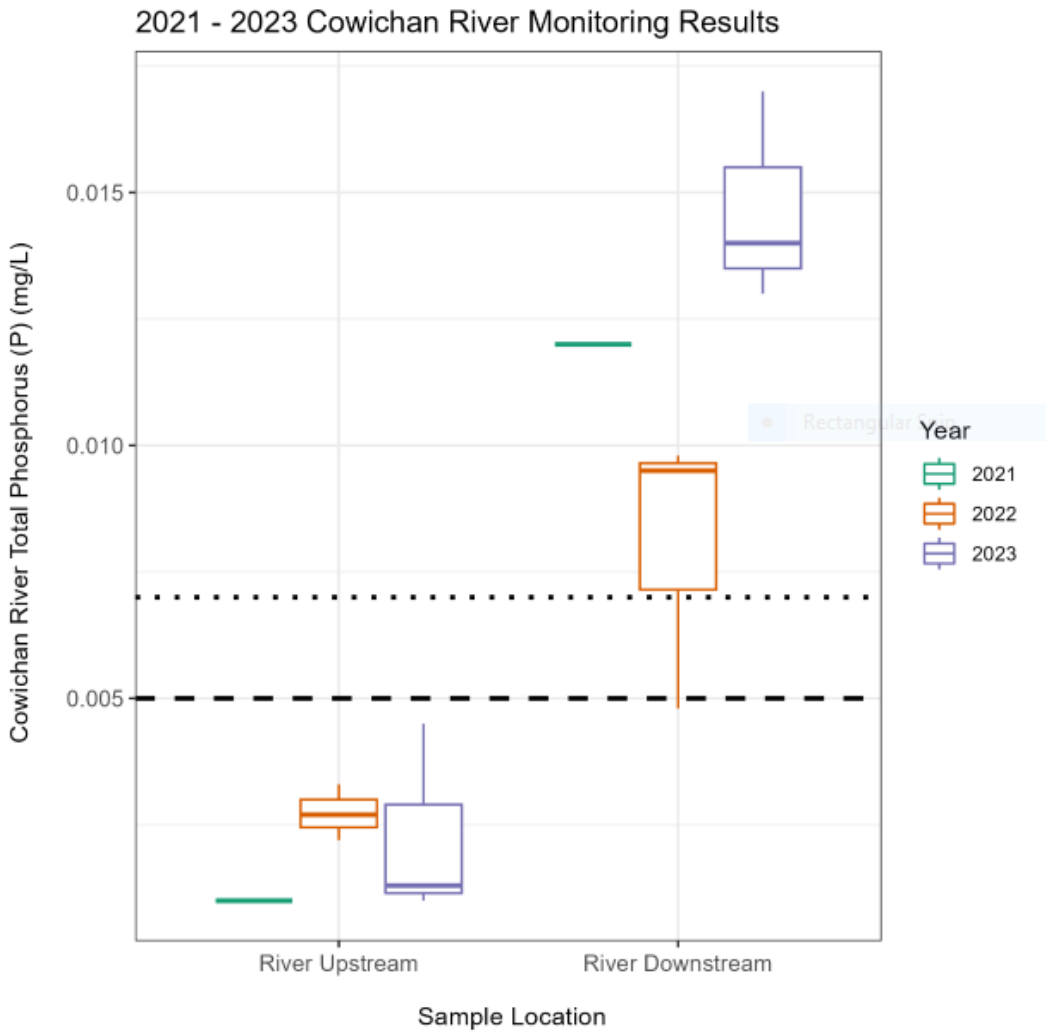


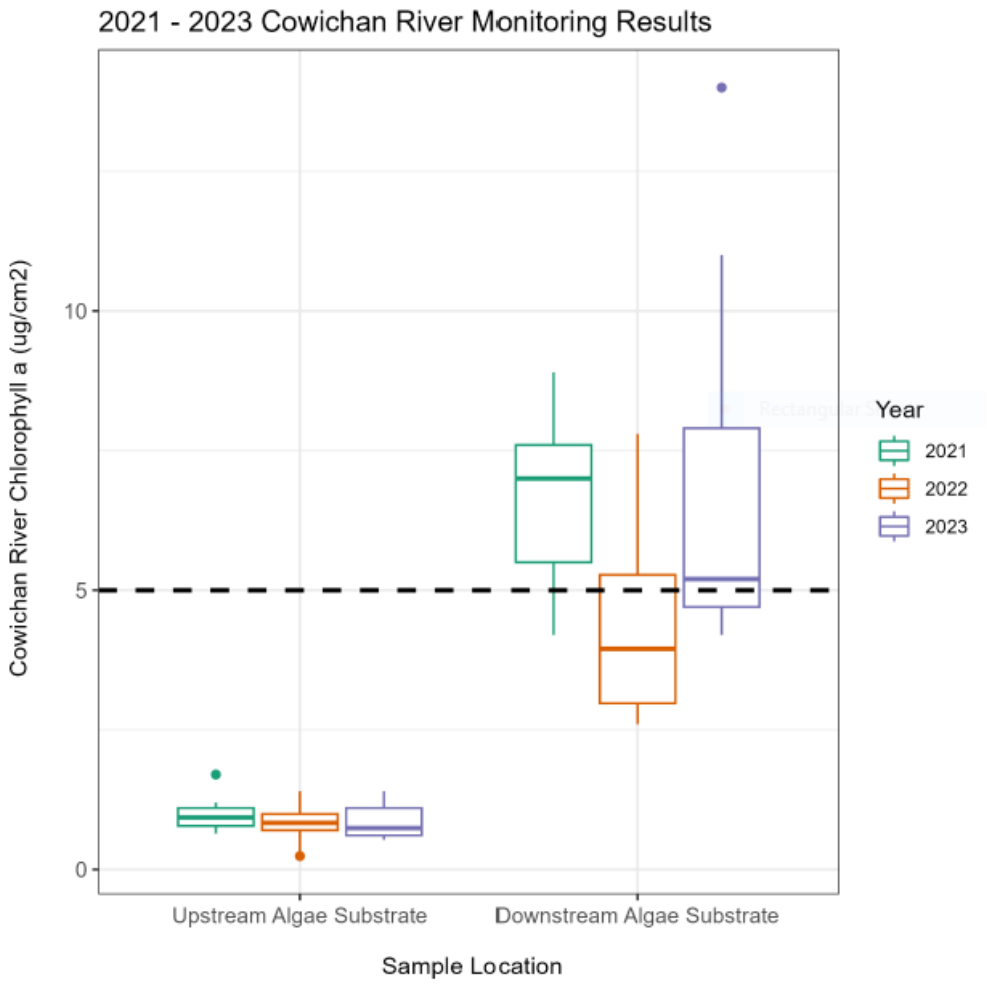
**Figure 10.** Total Phosphorus (P) concentration measured in the Cowichan River from both 300 m upstream and 400 m downstream in August and September from 2021-2023. Boxplots show the yearly median (solid lines), 25th and 75th percentiles (boxes) and minimum and maximum values (whiskers). Black dashed line (lower) shows the Cowichan River mean Water Quality Objective value, whereas the black dotted line (upper) shows the max value.



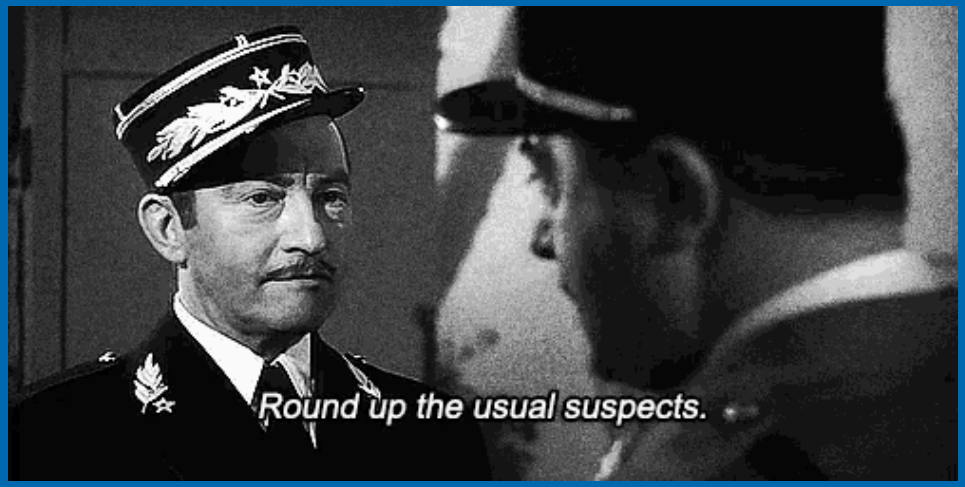
“Though green algae are not uncommon to observe downstream of the effluent discharge, in July 2023 patches of dense filamentous green algal growth were observed downstream of the lagoon effluent discharge pipe for about one kilometer; green algae were replaced by thick brown algae with a “scummy” appearance just upstream of the 70.2 Mile Trestle and below some right bank tributaries (BC WLRS 2023).”

# Suspect 4: **confirmed**

**Figure 8.** Chlorophyll a density measured in the Cowichan River from 300 m upstream and 400 m downstream monitoring sites in August and September from 2021-2023. Boxplots show the yearly median (solid lines), 25$^{th}$ and 75$^{th}$ percentiles (boxes), minimum and maximum values (whiskers) and outliers (points). The black dashed line shows the Cowichan River Water Quality Objective value for Chlorophyll a density (5 µg/cm$^2$).



# To recap:




**1. low flow (approximately 4.5 m3/second) - confirmed**

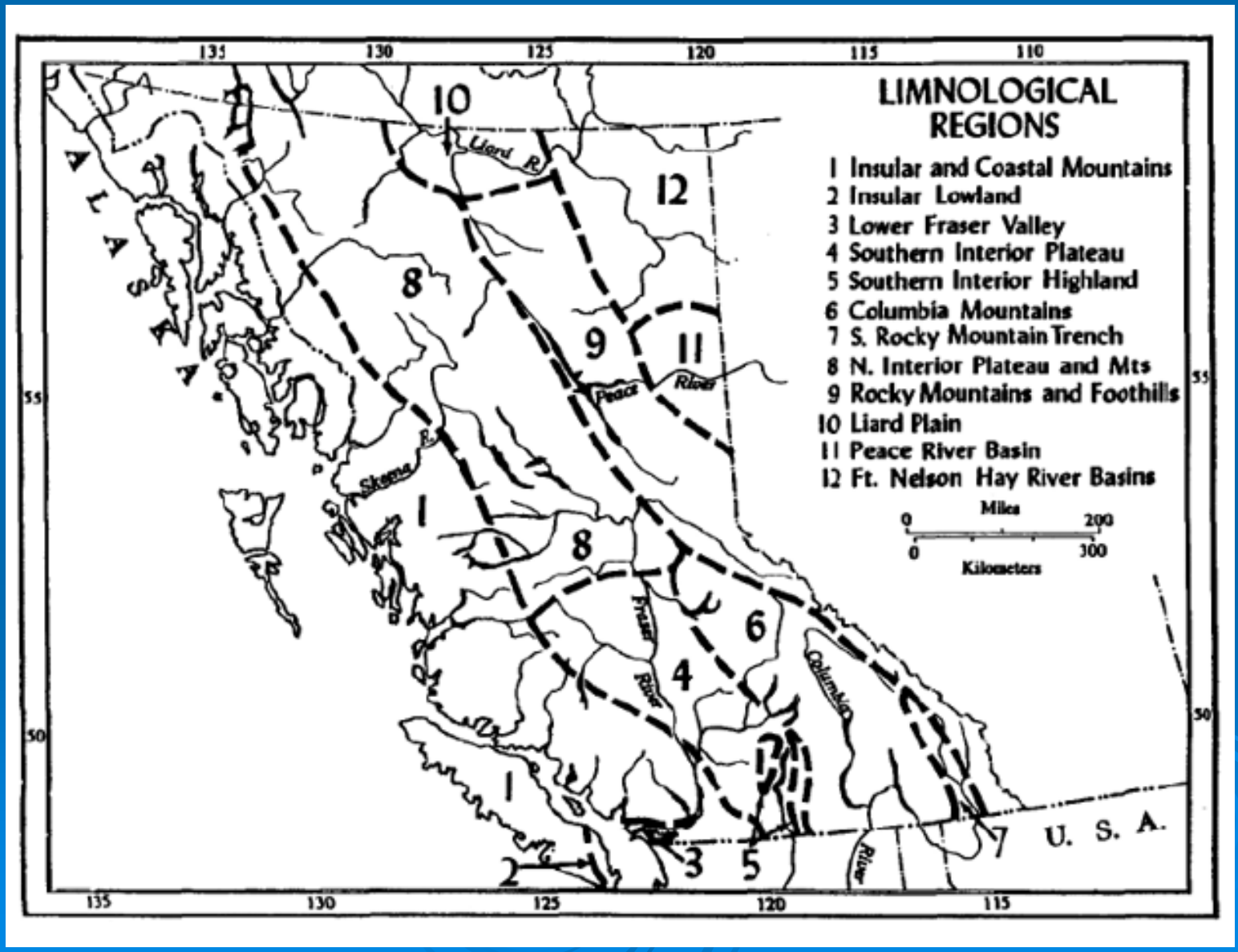
**2. high temperatures - confirmed**

**3. low effluent dilution – not confirmed ***

**4. irregular effluent quality - confirmed**

- Daily lagoon effluent flow and dilution ratio (**Figure 11**) were plotted for 2023 for the period where data were available (January to September) and compared with PE-00247 permit values. The daily lagoon effluent flow permit limit (4,500 $m^3$/day) was exceeded on four days in 2023, including January 1st, January 14th, January 15th, and April 10th (**Figure 11**). The mean dilution ratio calculated from January to September 2023 did not fall below the Cowichan River Water Quality Objective of 200:1 (McKean 1989). The original 200:1 dilution ratio objective was, however, intended to limit BOD and TSS loading to the Cowichan River (McKean 1989) and was not intended for interpreting dilution of nutrients such as Nitrogen and Phosphorus (SLR 2022).

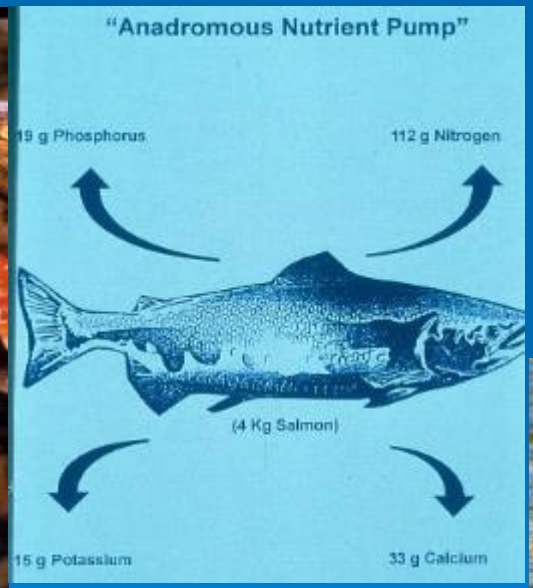
- Most coastal BC rivers are classified as nutrient poor or ‘oligotrophic’



- Algae, insects and fish in coastal rivers, esp. lake headed coastal rivers, are found at lower densities/biomass than interior rivers

- **unless** sustained by large runs of anadromous salmon which return marine derived nutrients to the watershed

- or external sources of nutrients (e.g. agriculture, wastewater)




# So what happens when you add P and N to a river?

**Fertilizers boost declining B.C. fish populations**

**Fry grow up to 95-per-cent bigger in streams treated with nutrients, fisheries biologists say**

By RANDY SHORE, Vancouver SunFebruary 14, 2011

**Young steelhead and salmon grew dramatically in streams seeded with sacks of slow-release fertilizer, a method that shows real promise to help rebuild collapsed spawning populations, according to B.C. biologists.**

**Photograph by: Ric Ernst, PNG files**

VANCOUVER - Young steelhead and salmon grew dramatically in streams seeded with sacks of slow-release fertilizer, a method that shows real promise to help rebuild collapsed spawning populations, according to B.C. biologists.

**International Conference:**
**Restoring Nutrients to Salmonid Ecosystems**

**April 24-26, 2001 Eugene, Oregon**

**www.gpafs.org/confnutr**

Salmon gather marine nutrients and "pump" them far into headwater ecosystems – fueling a nutrient dynamic that is integral to holistic salmonid restoration. This conference will define the cutting-edge research on, and management of, nutrients in salmon ecosystems. The program is robust with on-the-ground knowledge and experience assembled by many of the most insightful scientists on the subject, and sponsored by regional agencies and chapters of the American Fisheries Society.

Proposals for contributed presentations and posters are welcomed until December 1, 2000. Student travel awards are available. The registration form, student award applications, agenda, contributed paper criteria, and further information are available on the conference web page, or via Richard Grost at 541-496-4580 and rgrost@compuserve.com.

**Speakers and Session Chairs include:**

Bill Bakke – Oregon
Robert Bilby – Washington
C. Jeff Cederholm – Washington
Robert Lucke – Oregon
Jim Lichatowich – Washington
Goran Milbrink – Sweden
Wayne Minshall – Idaho
Takeshi Muroya – Japan
Tom Reimchen – British Columbia
John Stockner – British Columbia
Mark Wipfli – Alaska

**Registration Under $100 US**

- nutrients stimulate the growth of river algae (periphyton),at the base of the riverine food web

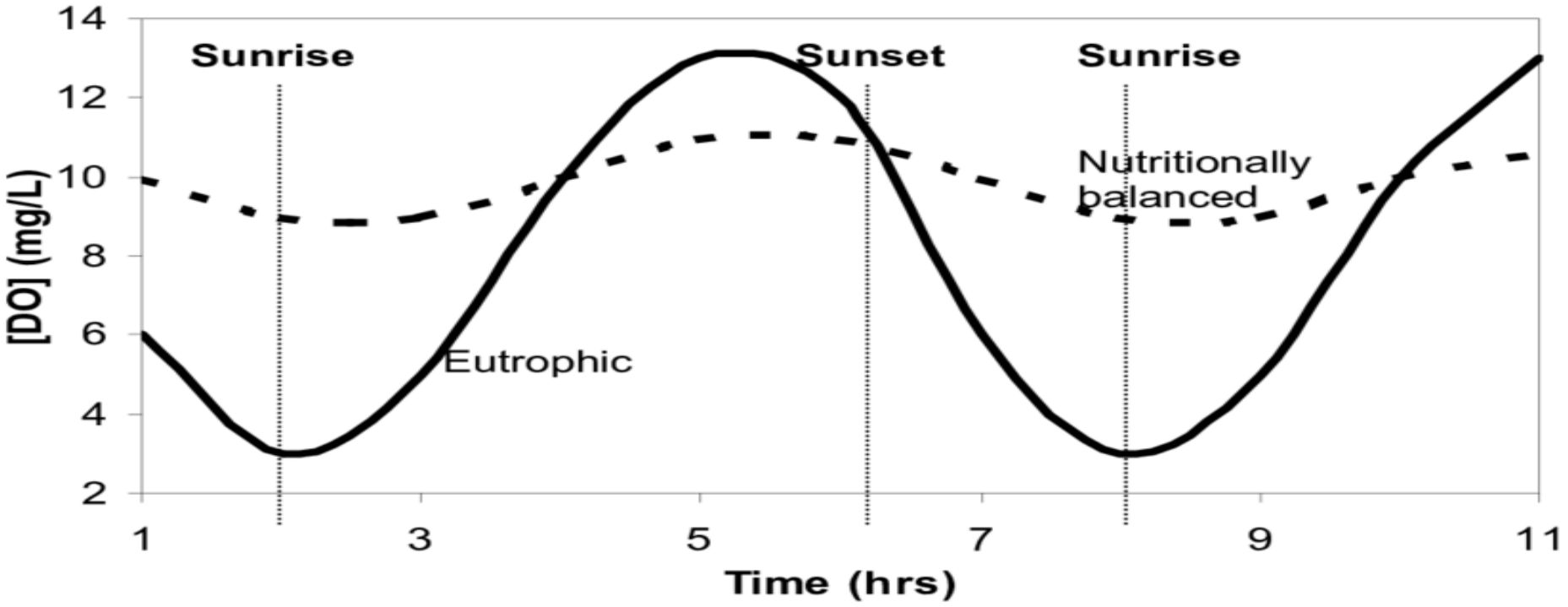
- periphyton produce oxygen via photosynthesis:

$$6\ CO_2 + 12\ H_2O \xrightarrow{\text{sun}} C_6H_{12}O_6 + 6\ H_2O + 6\ O_2$$

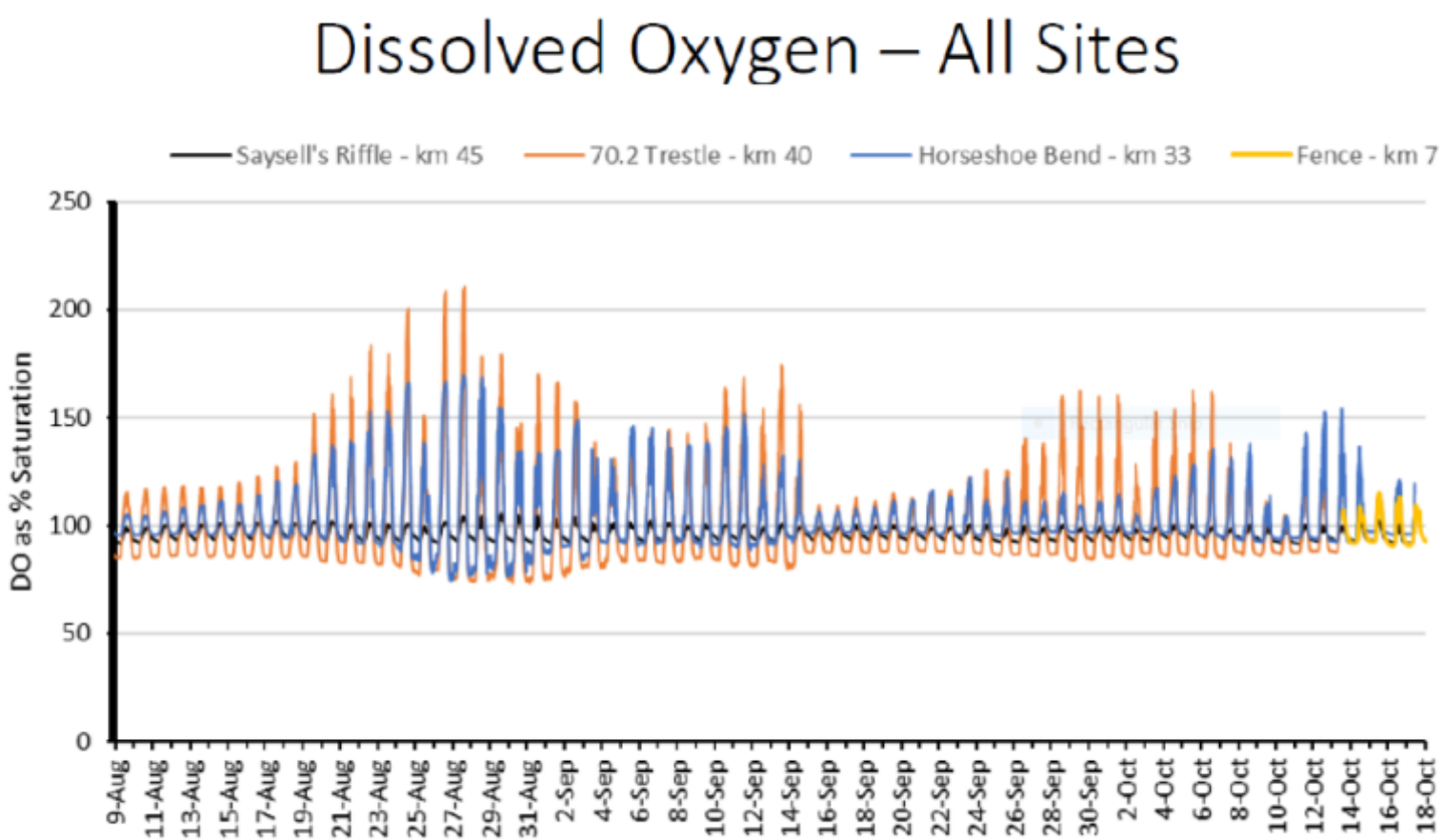
Consumption of oxygen at night by respiration is the same formula **in reverse**:

$$6\ CO_2 + 12\ H_2O \leftarrow\!\!\text{---------} C_6H_{12}O_6 + 6\ H_2O + 6\ O_2$$

- in rivers, this can result in large diurnal changes in oxygen concentration



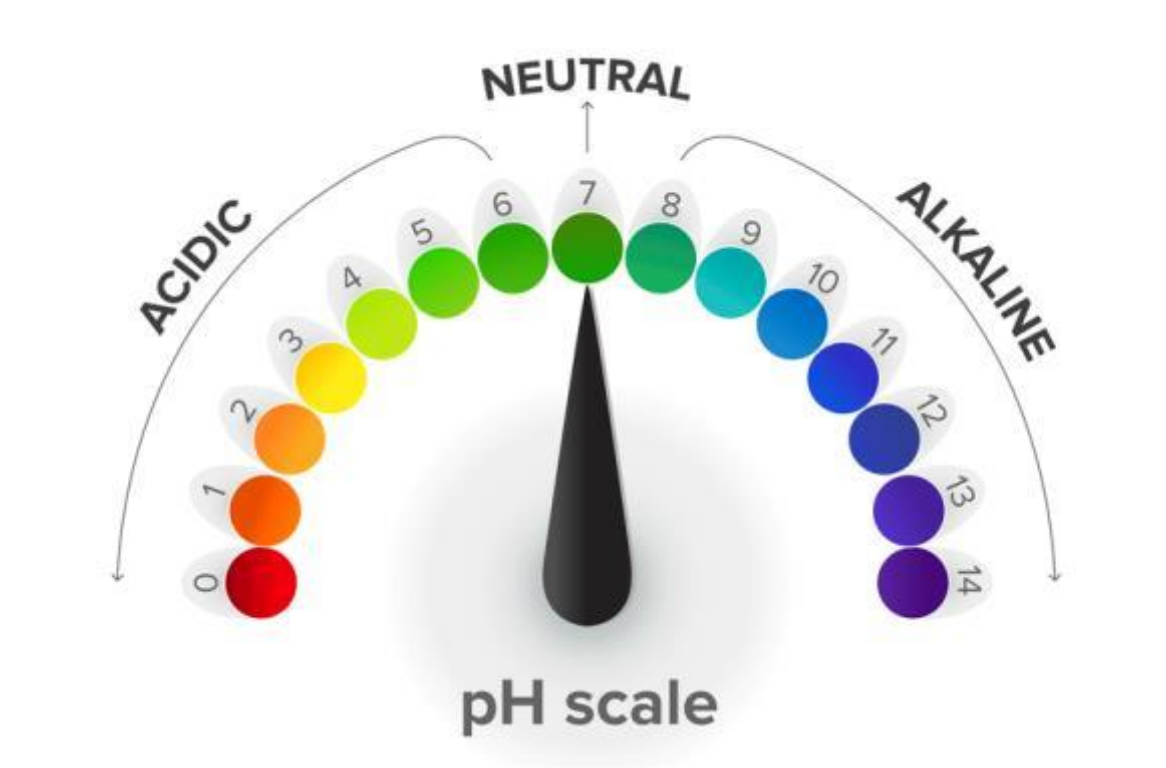
# Cowichan River dissolved oxygen – Aug-Sept 2023



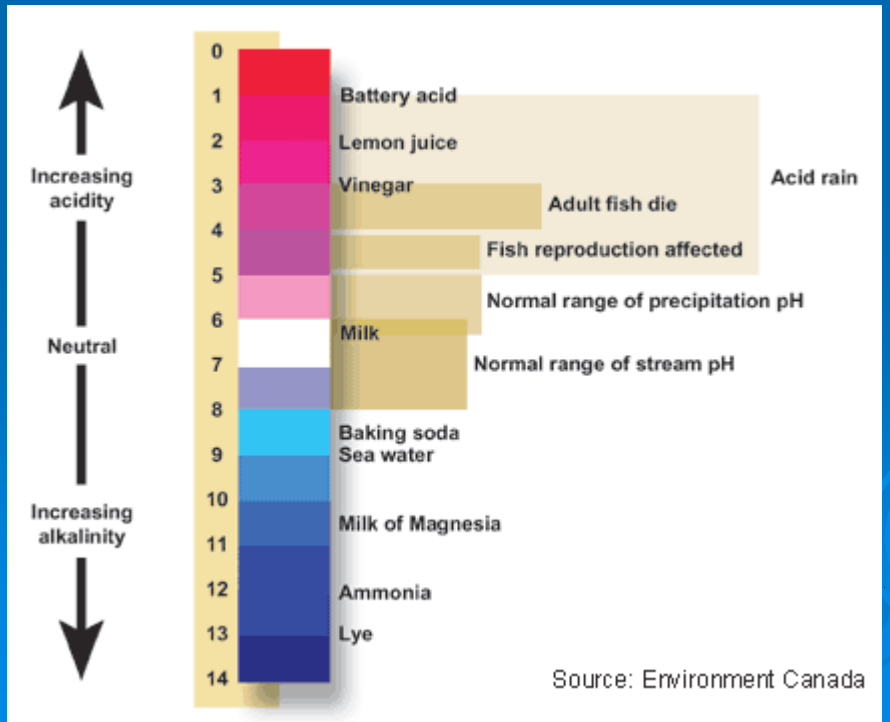
## Effect on pH

$$6\ CO_2 + 12\ H_2O \leftarrow\!\!-\!\!-\!\!-\!\!-\!\!-\!\!-\!\!-\!\!-\!\!- C_6H_{12}O_6 + 6\ H_2O + 6\ O_2$$

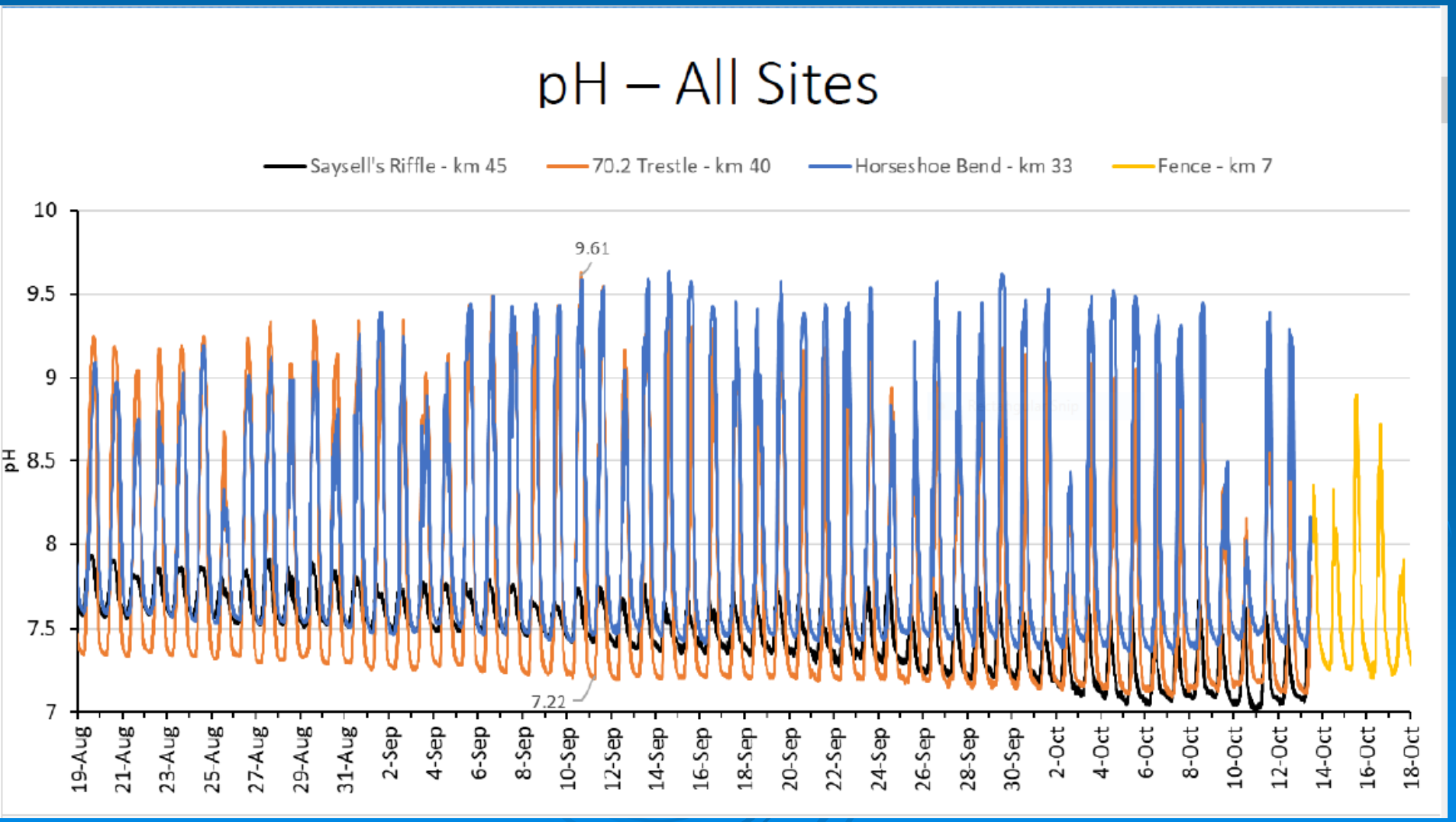
In ‘soft’ water, the uptake of $CO_2$ in the daytime, and production of $CO_2$ at night, also causes the pH of the river water to vary



- pH is a measure of the relative amount of free hydrogen and hydroxyl ions in the water.
- is "**the negative log of the hydrogen ion concentration" e.g. pH 10**
- water that has more free hydrogen ions is acidic
- water that has more free hydroxyl ions is basic.



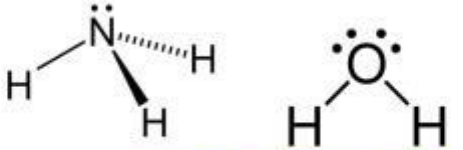
# Cowichan River pH – Aug-Sept 2023



# Ammonia nitrogen equilibria in water

## Ammonia + Water

$NH_3\ (aq) + H_2O\ (l)$

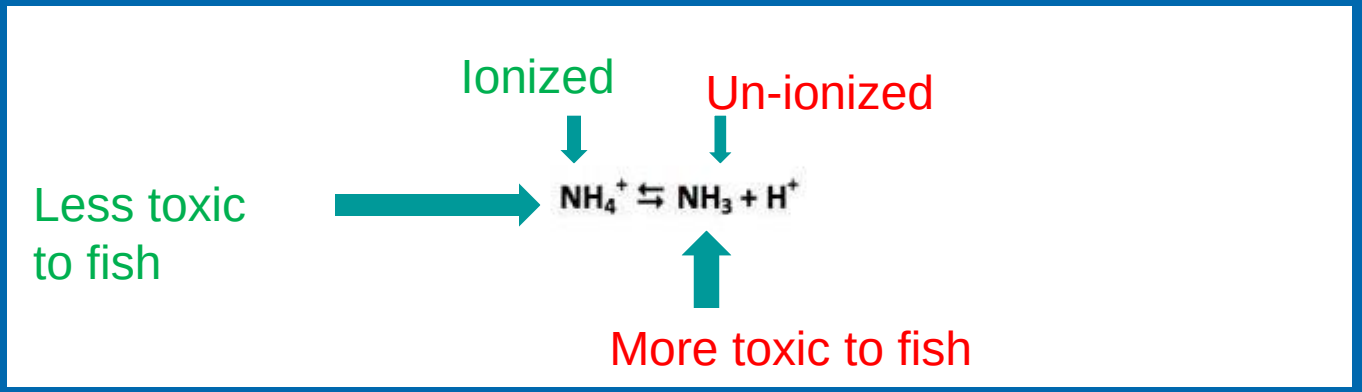


Ionized form

Un-ionized form

$NH_4^+ \leftrightarrows NH_3 + H^+$

# Ammonia nitrogen equilibria in water

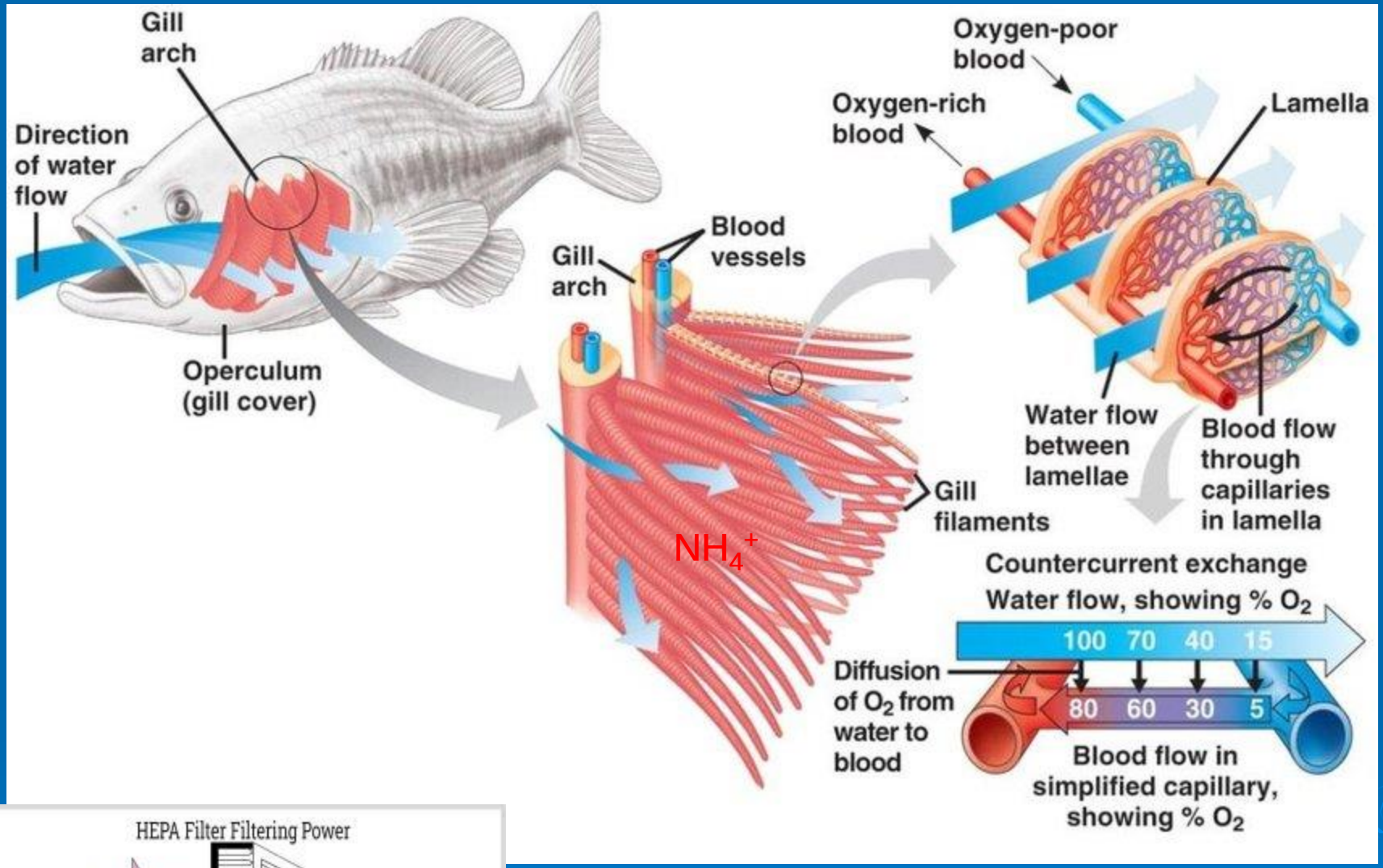


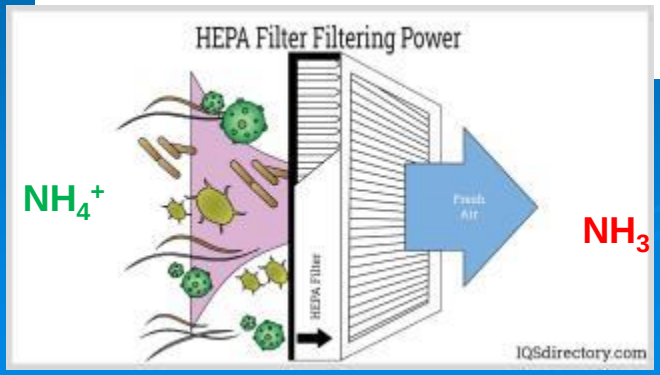

- As temperature and pH increase, the more toxic $NH_3$ fraction increases

**Table 3. Percent un-ionized aqueous ammonia solutions for 0-30°C and pH 6-10 (Emerson et al. 1975)**

| Temp (°C) | pH | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | 9.0 | 9.5 | 10 |
| 0 | 0.008 | 0.026 | 0.082 | 0.261 | 0.820 | 2.55 | 7.64 | 20.7 | 45.3 |
| 5 | 0.012 | 0.039 | 0.125 | 0.394 | 1.23 | 3.80 | 11.1 | 28.3 | 55.6 |
| 10 | 0.018 | 0.058 | 0.186 | 0.586 | 1.83 | 5.56 | 15.7 | 37.1 | 65.1 |
| 15 | 0.027 | 0.086 | 0.273 | 0.859 | 2.67 | 7.97 | 21.5 | 46.4 | 73.3 |
| 20 | 0.039 | 0.125 | 0.396 | 1.24 | 3.82 | 11.2 | 28.4 | 55.7 | 79.9 |
| 25 | 0.056 | 0.180 | 0.566 | 1.77 | 5.38 | 15.3 | 36.3 | 64.3 | 85.1 |
| 30 | 0.080 | 0.254 | 0.799 | 2.48 | 7.46 | 20.3 | 44.6 | 71.8 | 89.0 |

**July, 2023**


Gill arch
Direction of water flow
Operculum (gill cover)
Gill arch
Blood vessels
Gill filaments
$NH_4^+$
Oxygen-poor blood
Oxygen-rich blood
Lamella
Water flow between lamellae
Blood flow through capillaries in lamella
Countercurrent exchange
Water flow, showing % $O_2$
100 70 40 15
Diffusion of $O_2$ from water to blood
80 60 30 5
Blood flow in simplified capillary, showing % $O_2$


HEPA Filter Filtering Power
$NH_4^+$
HEPA Filter
Fresh Air
$NH_3$
IQSdirectory.com

# Ammonia toxicity in water

**Table 2. Water quality guidelines for total ammonia for the protection of aquatic life ($mg \cdot L^{-1}$ $NH_3$).**

| Temp (°C) | pH | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **6.0** | **6.5** | **7.0** | **7.5** | **8.0** | **8.5** | **9.0** | **10** |
| **0** | 231 | 73.0 | 23.1 | 7.32 | 2.33 | 0.749 | 0.250 | 0.042 |
| **5** | 153 | 48.3 | 15.3 | 4.84 | 1.54 | 0.502 | 0.172 | 0.034 |
| **10** | 102 | 32.4 | 10.3 | 3.26 | 1.04 | 0.343 | 0.121 | 0.029 |
| **15** | 69.7 | 22.0 | 6.98 | 2.22 | 0.715 | 0.239 | 0.089 | 0.026 |
| **20** | 48.0 | 15.2 | 4.82 | 1.54 | 0.499 | 0.171 | 0.067 | 0.024 |
| **25** | 33.5 | 10.6 | 3.37 | 1.08 | 0.354 | 0.125 | 0.053 | 0.022 |
| **30** | 23.7 | 7.50 | 2.39 | 0.767 | 0.256 | 0.094 | 0.043 | 0.021 |

July, 2023

*The guideline values and all reported total ammonia concentrations in this factsheet are reported in mg/L $NH_3$; measurements of total ammonia in the aquatic environment are often also expressed as mg/L total ammonia-N. The present guideline values (mg/L $NH_3$) can be converted to mg/L total ammonia-N by multiplying the corresponding guideline value by 0.8224.

** Values falling outside of shaded area should be used with caution.

*** No recommended guideline for marine waters.

**Table 2. Water quality guidelines for total ammonia for the protection of aquatic life ($mg \cdot L^{-1}$ $NH_3$).**

| Temp (°C) | pH | | | | | | | |
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| | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | 9.0 | 10 |
| 0 | 231 | 73.0 | 23.1 | 7.32 | 2.33 | 0.749 | 0.250 | 0.042 |
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** Values falling outside of shaded area should be used with caution.

*** No recommended guideline for marine waters.

**Calculated results**, no measured data in July, 2023

- **total ammonia exceeded water quality guidelines in July, 2023**

| | | | | | | | | | Measured Concentrat. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Cowichan | | WWTP | | Result | | Calculated Concent. | Upstream | Downstream |
| | Parameter | Flow | Conc | Flow | Conc. | mg/L | Date | ug/L | | |
| | TP | 4,500 | 0.003 | 10.0 | 5 | 0.014 | July | 14.1 | | |
| | SRP | 4,500 | 0.001 | 10.0 | 4 | 0.010 | July | 9.9 | | |
| | T NH3 | 4,500 | 0.005 | 10.0 | 36 | 0.085 | July | | | |
| | NO3-N | 4,500 | 0.005 | 10.0 | 0.02 | 0.005 | July | 25 - 43 | | |
| | pH | | 1 | | | 7.23 | July | | Measured | ug/L |
| | | | | | | | | ug/L | | |

# Forensic analysis


The Cowichan River fish kill in July 2023 was caused by the combined interaction of (1) low river flow, (2) **high water temperature**, (3) low ToLC effluent dilution for nutrients, (4) irregular ToLC effluent quality that (5) stimulated excessive algae growth that (6) **increased pH** and (7) shifted **$NH_3$ to the toxic un-ionized form** with (8) **overnight depressions in dissolved oxygen**.


Then Why Didn't You Just Say That
In The First Place?
Meme creator.org

# OK... so what now?

# Short term solutions: 2024 action and strategies

- Cowichan Watershed Board held two community workshops on March 12 and April 17/24 to develop strategies/actions to prevent future fish kills
- explored which “management levers” were feasible and created an action/response matrix with threshold ‘triggers’

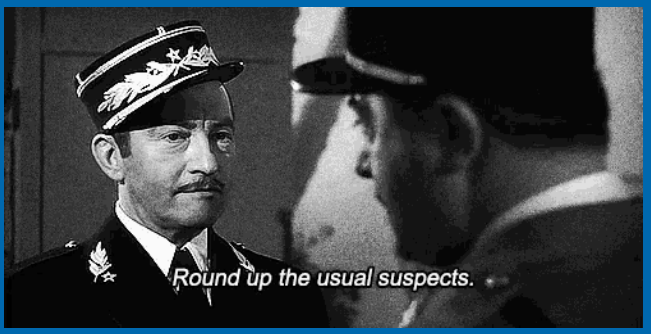
- considered 3 time horizons: immediate, short term and long term actions
- set flow in the Cowichan to 7 $m^3/s$ for summer 2024
- formed a “Incident Management Team”, that met Monday mornings throughout summer, 2024 (June-September) to discuss current conditions and take necessary actions

# Cowichan 2024 action matrix

- identified 5 general categories that require immediate, short term and long term intervention:

- 1. Cowichan River flow and temperature management
- 2. River use management - angling regulations/closures
- 3. ToLC sewage treatment effluent management
- 4. Habitat protection
- 5. Monitoring

# Long term solutions and vision for Cowichan watershed



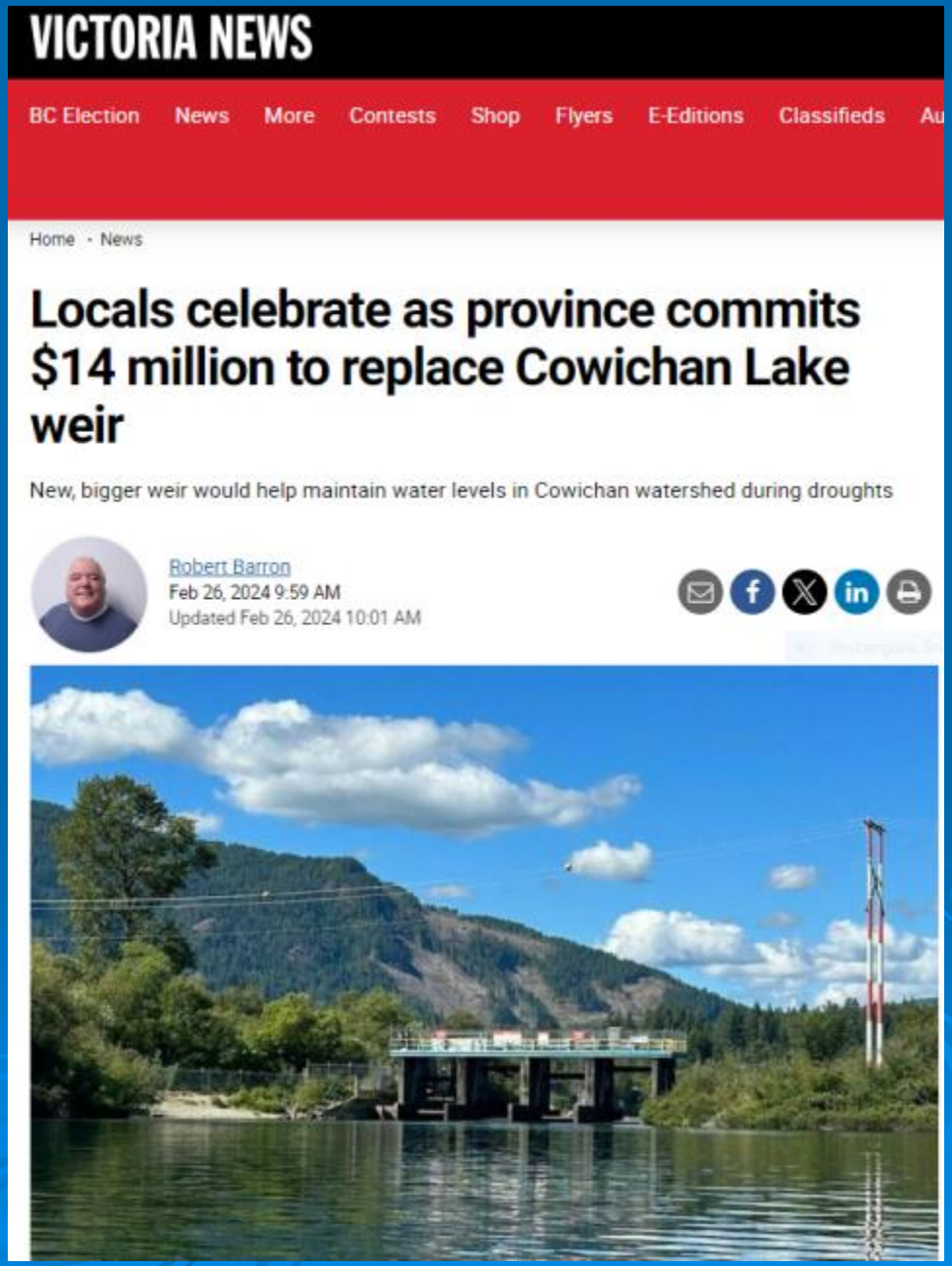

1. low flow
2. high temperatures
3. low effluent dilution
4. irregular effluent quality

# A new raised Cowichan Lake weir will resolve the first 3 issues:

1. low flow

2. high temperatures

3. low effluent dilution



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## Locals celebrate as province commits $14 million to replace Cowichan Lake weir

New, bigger weir would help maintain water levels in Cowichan watershed during droughts

Robert Barron
Feb 26, 2024 9:59 AM
Updated Feb 26, 2024 10:01 AM

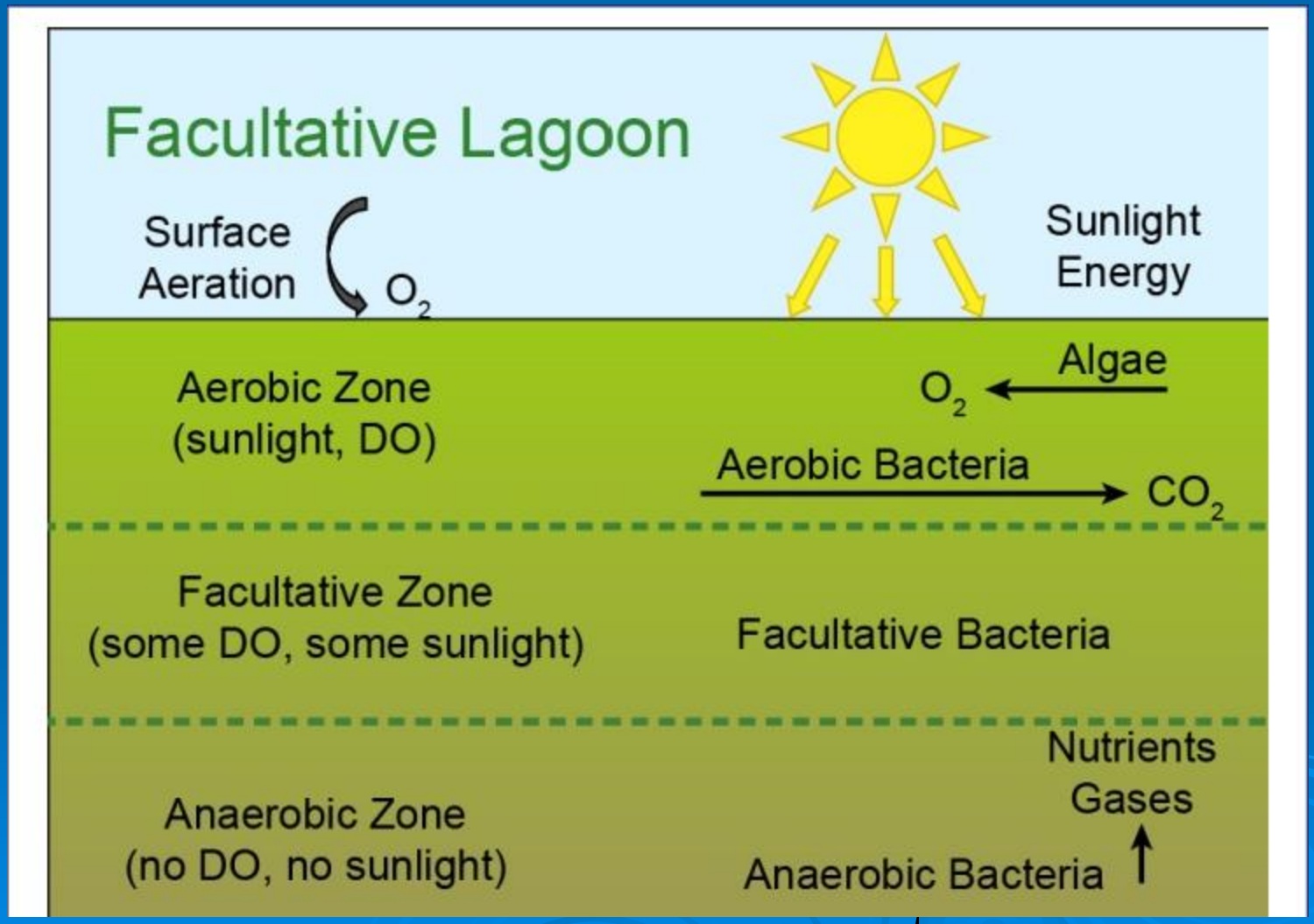
# But – the new weir must include a cold water release system

- more warm water will not be sufficient

## 4. irregular effluent quality

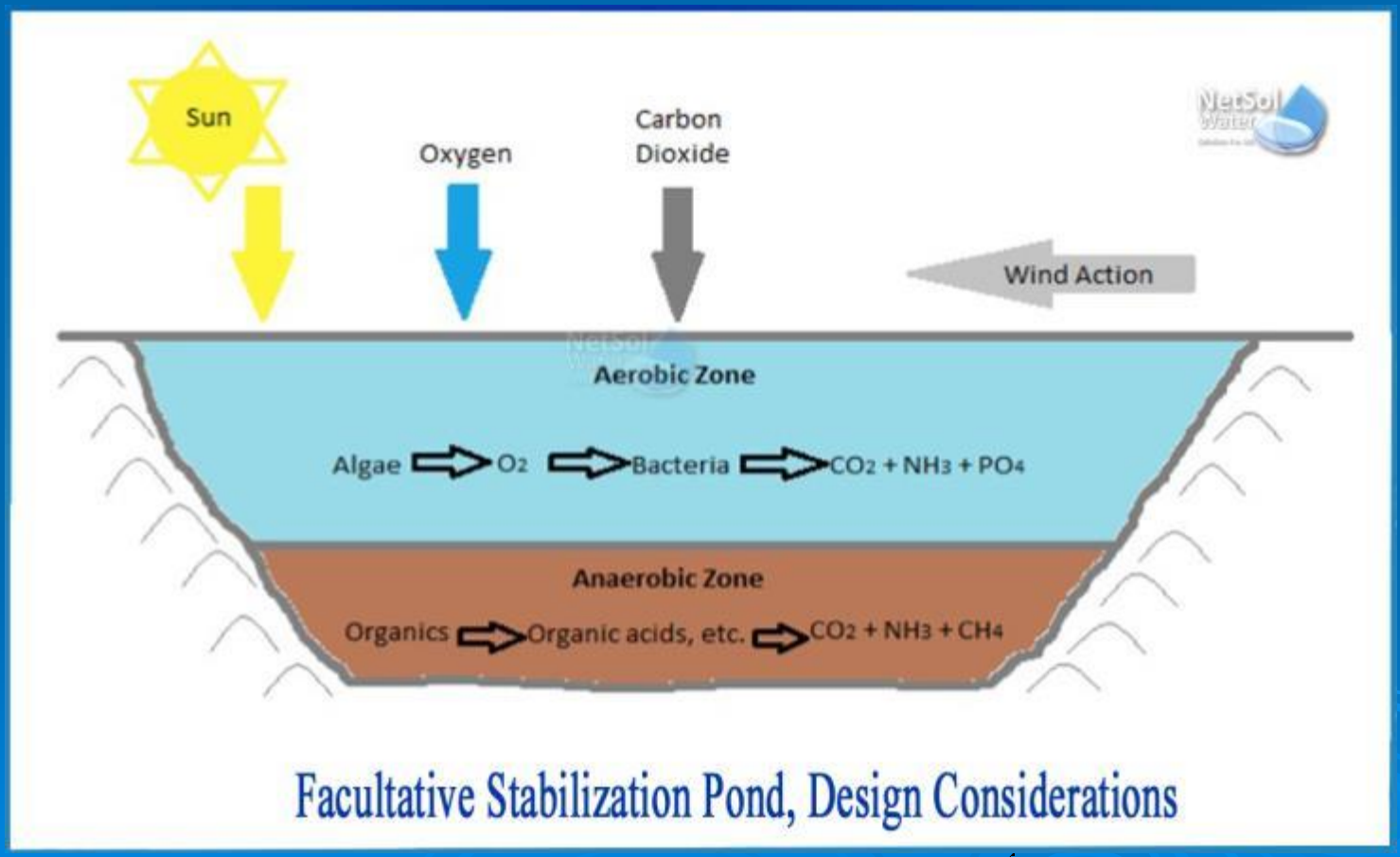
ToLC uses a “facultative lagoon” process to treats its wastewater

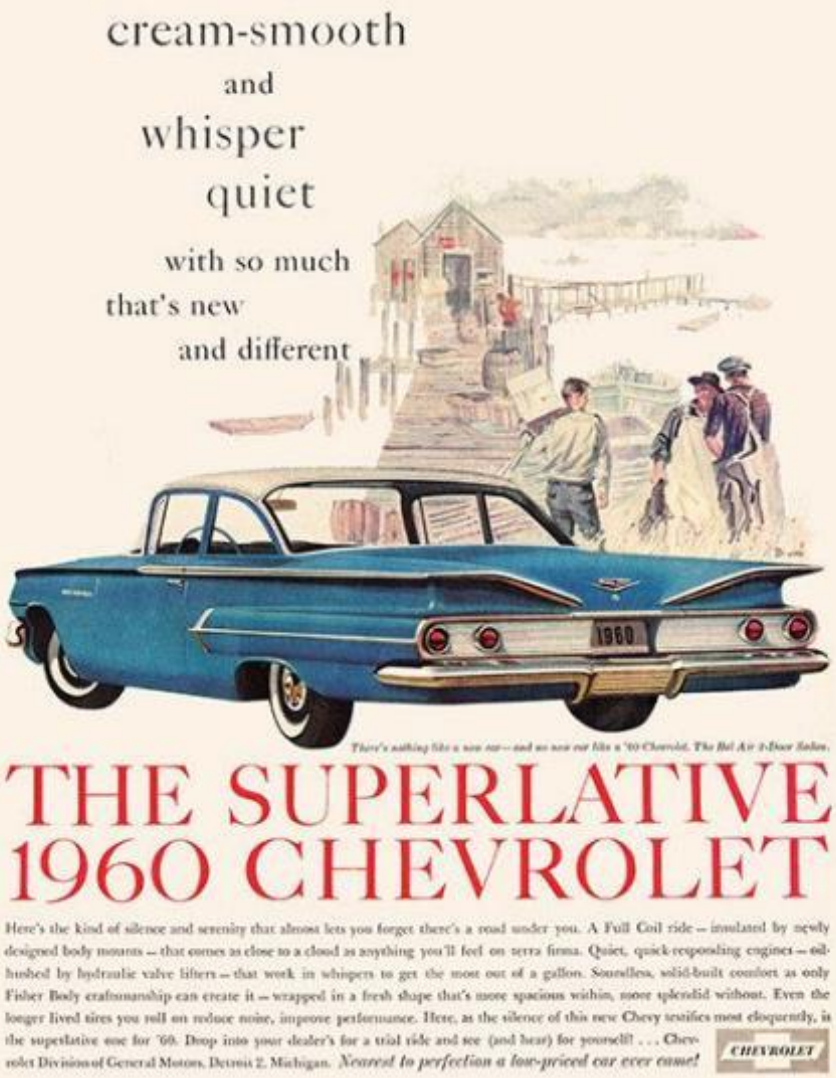
# How a facultative lagoon functions



- **Facultative lagoons have minimal effect on phosphorus, some effect on ammonia, minimal effect on emerging contaminants of concern**

- **become less effective as they age due to infilling with sludge**

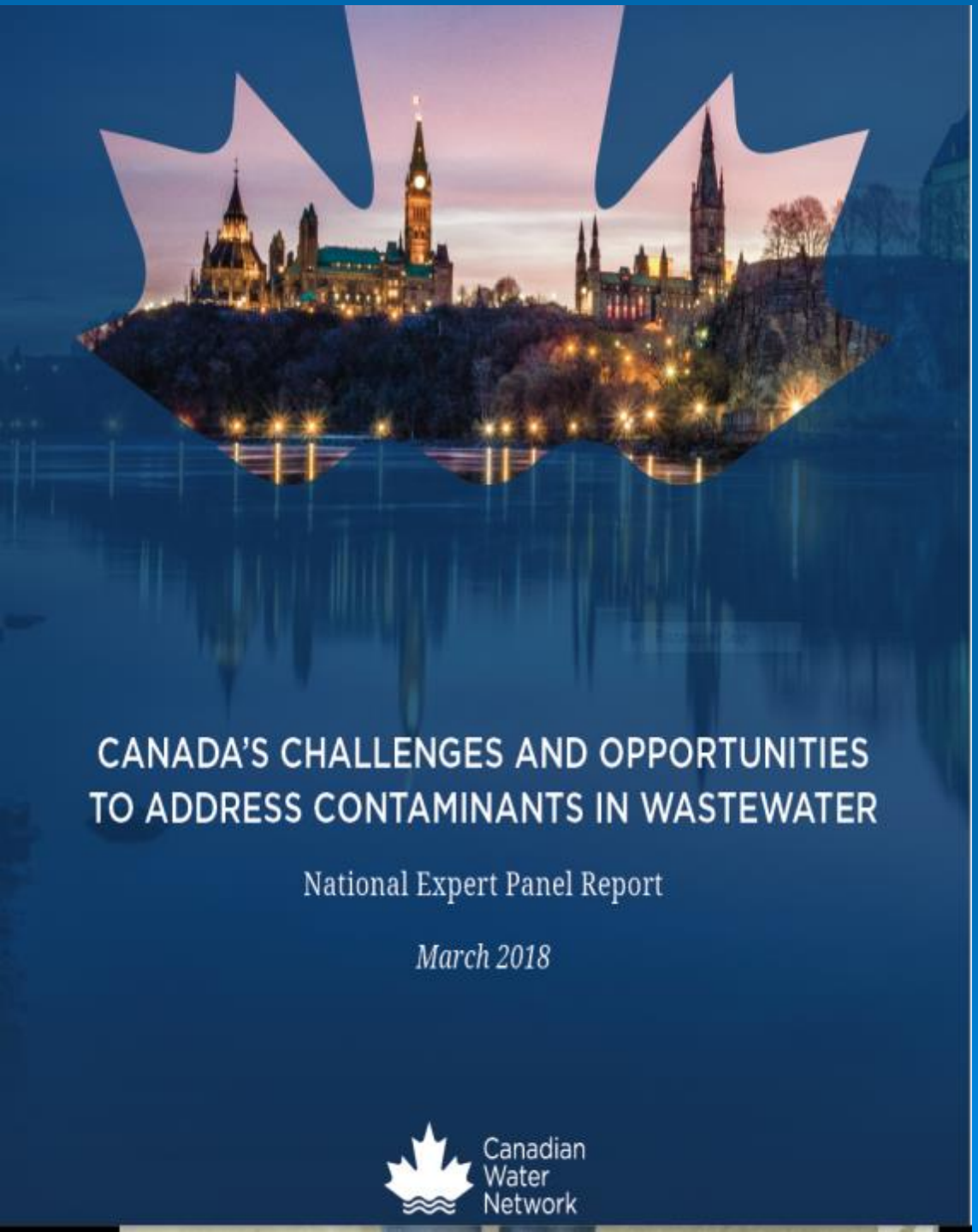




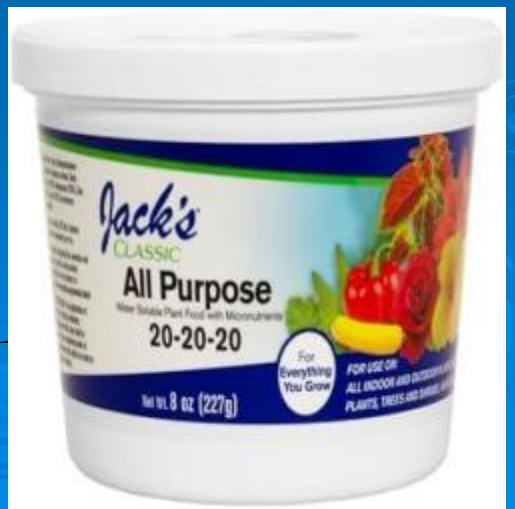

- Facultative lagoons were OK in the 1960s

=

- suited for remote small prairie towns with high evaporation rates

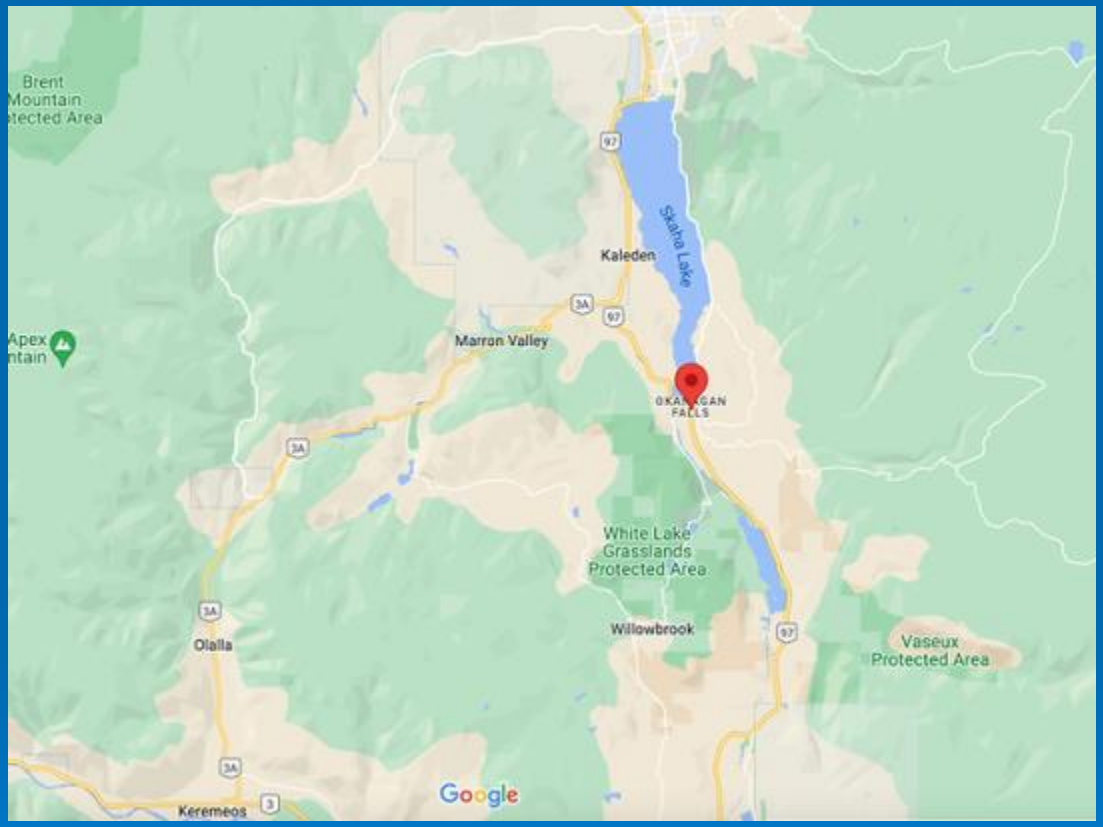



Conclusion: modern wastewater has many emerging contaminants of concern that must be treated and contains valuable resources that can be recovered: heat, P, N and C



# BC example of small town leadership

**OK Falls, population 2,500**



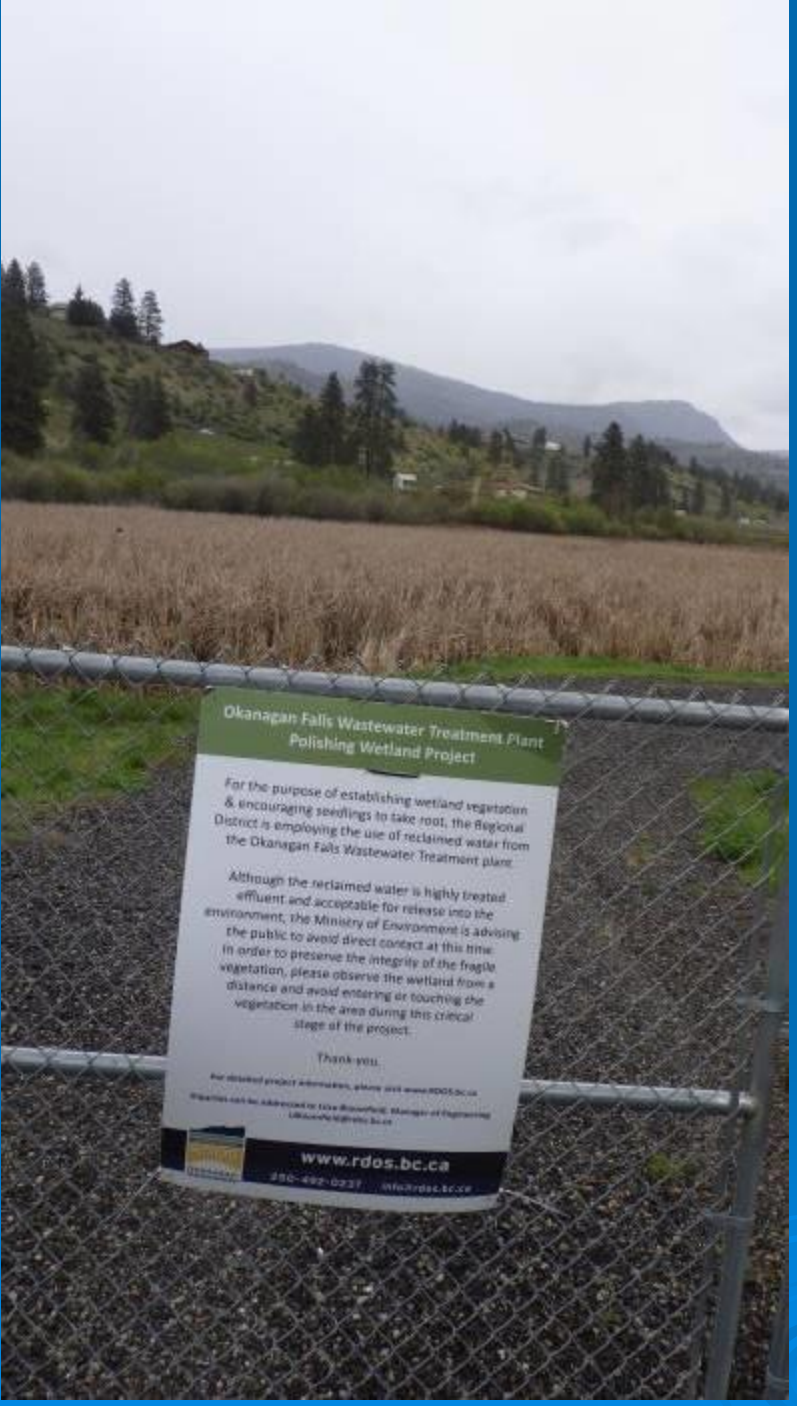

State of the art biological nutrient removal plant, discharging to the warm, and fish sensitive Okanagan River

## Okanagan seeing massive record-breaking sockeye salmon run

OCTOBER 6, 2024

Red streaks can be seen in the waterways near Oliver, but it's not anything to be concerned about, it's thousands of sockeye salmon that have returned to spawn. Sydney Morton takes us to the shores to learn about this year's record-breaking return.

# Discharges to a constructed wetland in summer




- OK plant uses UV to sterilize effluent discharge, and has P effluent concentration of 0.05 mg/L (100 times lower than ToLC lagoons)

- Plant has 3 full time employees, and can be remotely run from a cell phone

- The OK Falls plant, built in 2013, currently does not recover P, N, C and heat, but it can easily be retrofitted due to its modern design.

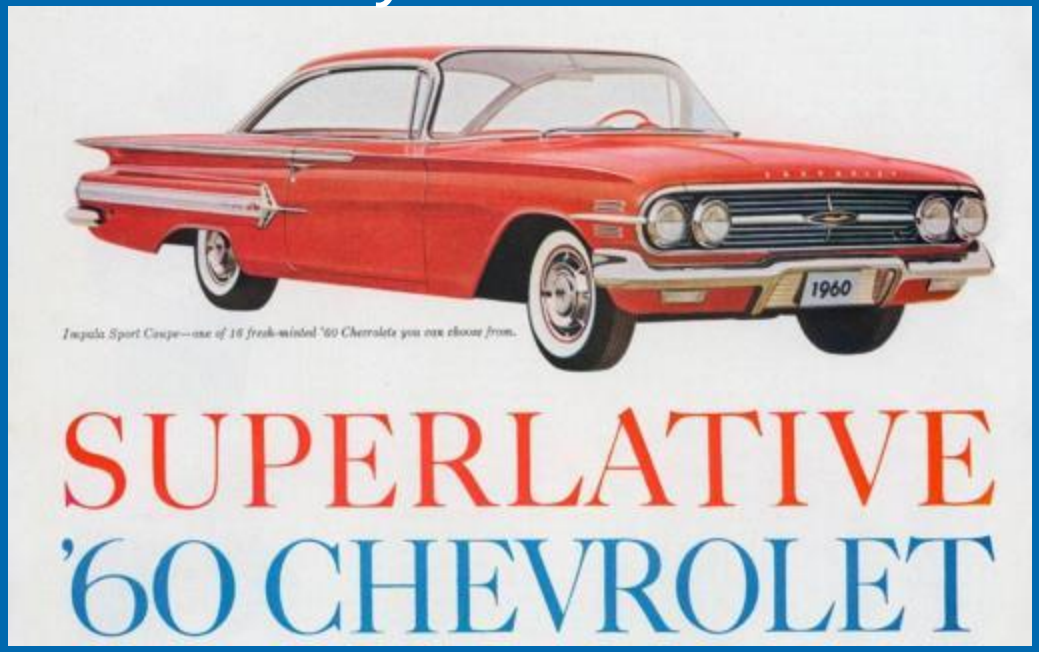
- ToLC could do similar, and include a greenhouse for year round local food security using recovered resources from wastewater


'FASCINATING'

# Closing Comments

- Cowichan River is the cultural, spiritual, economic and environmental cornerstone of the Cowichan Valley
- Climate change and population growth in the Cowichan watershed requires bold and innovative leadership to protect the river and its fish
- Solutions are not cheap, but are technically feasible and will have a positive impact on the river and community that will last generations
- Your future is up to you

# It is your decision:




or

# Thank-you for listening

# Cowichan 2024 action matrix

| Categories | Right now | In season | Long Term | Caution/Triggers |
|---|---|---|---|---|
| **ToLC Sewage Treatment** | Repair/replace all surface aerators, install alum injection system | Reduce/curtail P and NH3 discharges in June, July + Aug | Modern Okanagan BNR WWTP | Caution - reduce NH3 and P @ 8 m3/s in June, Trigger - curtail NH3 and P @ 6 m3/s in July+Aug |
| **Cowichan flows and temperature management** | Monitor Cowichan Lake level and river flows | Manage storage/discharges in May + June to allow > 6 m3/s in July and Aug | Refine weir siphon pipe size with modelling, build weir, and include hypolimnetic siphon for temperature management | Maintain July flow > 6 m3/s<br><br>Maintain Aug flows > 6 m3/s |
| **River use management** | Prepare Directors order for Angling closure | Close angling in July-Aug if flows < 4/5 m3/s and water temp > 22 C | | Caution - flows < 6.0 m3/s<br>Trigger flows < 4.5 m3/s<br>Caution - temp > 20 C<br>Trigger – temp > 22 C |
| **Habitat Protection** | Identify cold water refugia and critical riparian areas facing developmental pressures | Water use restrictions in June-Sept. | Enact WMAs on cold water refugia and critical riparian zones, enhanced riparian protection, convert houses on riparian septic systems to sewer collection | |
| **Monitoring** | Ongoing | Twice monthly in July and Aug, WWTP outfall weekly in July and August | TBA | As per Cowichan River monitoring plan |