The ELF Model

– An operational low flow forecasting system for British Columbia

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BC River Forecast Centre

August 23, 2023

The Extrapolating Logarithmic Flow (ELF) Model

Koksilah River, June 18, 2019

1. Why ELF Model – drought in BC
2. What is low flow and characteristics
3. Why not a hydrological model
4. Empirical model and fundamental assumption
5. Basic equations
6. Solving the exponential recession equation for overdetermined system
7. Data issues and twelve-step and twelve-scenario scheme
8. Products of ELF Model
9. Evaluation of ELF Model forecast accuracy
10. Forecasts of rise
11. Forecasts for regulated stations
12. Summary and conclusions

2015 DROUGHT LEVELS AT A GLANCE

Drought Levels: 1 Normal; 2 Dry; 3 Very Dry; 4 Extremely Dry

Basins	15-May	28-May	25-Jun	03-Jul	09-Jul	15-Jul	21-Jul	23-Jul	05-Aug	06-Aug	20-Aug	03-Sep	17-Sep	01-Oct
Northwest	2	1	1	1	1	1	1	1	1	1	1	1	1	1
Stikine	2	1	1	1	1	1	1	1	1	1	1	1	1	1
Northeast	1	1	1	1	2	2	2	2	2	2	1	1	1	1
Peace	1	1	1	1	2	2	2	2	2	2	2	1	1	1
East Peace	1	2	1	1	2	2	2	2	2	2	2	1	1	1
Skeena-Nass	1	1	1	1	1	1	1	2	2	2	2	1	1	1
Nechako	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Upper Fraser	1	1	1	1	1	1	1	2	2	2	2	2	1	1
Upper Columbia	1	1	1	1	1	1	1	2	2	2	2	2	1	1
Lower Columbia	1	1	2	2	2	2	2	2	2	3	3	3	2	2
West Kootenay	1	1	2	2	2	2	2	2	2	3	3	3	2	2
East Kootenay	2	1	2	2	2	2	2	2	2	3	3	3	1	1
Middle Fraser	2	1	1	1	1	1	1	2	2	3	3	3	2	1
North Thompson	1	1	1	1	2	2	2	2	3	3	4	4	2	1
South Thompson	1	1	2	2	3	3	3	4	4	4	4	4	3	2
Okanagan-Kettle	2	2	2	2	3	3	3	3	4	4	4	4	3	3
Kettle (separated July 23)								4	4	4	4	4	3	3
Nicola	2	2	2	2	3	3	4	4	4	4	4	4	3	2
Similkameen	2	2	2	2	3	3	3	4	4	4	4	4	3	2
Skagit	1	1	1	1	3	3	3	4	4	4	4	3	2	1
Lower Fraser	2	2	3	3	3	4	4	4	4	4	4	3	2	1
South Coast	2	2	3	3	3	4	4	4	4	4	4	3	2	1
Vancouver Island	2	3	3	4	4	4	4	4	4	4	4	3	2	1
Haida Gwaii	1	3	3	3	3	3	3	3	3	3	2	1	1	1
Central Coast	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Prepared By: Water Management Branch, Ministry of Forests, Lands and Natural Resource Operations

Last Update: October 2, 2015

2021 DROUGHT LEVELS AT A GLANCE

Drought Levels: 0 | 1 | 2 | 3 | 4 | 5

BASINS	26-May	09-Jun	23-Jun	07-Jul	14-Jul	21-Jul	28-Jul	04-Aug	11-Aug	18-Aug	20-Aug	25-Aug	01-Sep	08-Sep	15-Sep	17-Sep	22-Sep	29-Sep	06-Oct	20-Oct	28-Oct	01-Nov
Fort Nelson	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
East Peace	0	0	1	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
North Peace	0	0	0	0	2	2	2	2	2	2	2	0	0	0	0	0	1	1	0	0	0	0
South Peace	0	0	1	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
Northwest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stikine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Skeena-Nass	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0
Bulkley-Lakes	0	0	0	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
Finlay	0	0	0	0	0	2	2	2	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Parsnip	0	0	0	0	0	1	1	1	1	1	1	1	1	2	1	1	1	0	0	0	0	0
Upper Fraser West	0	0	0	2	2	2	1	1	1	1	1	1	1	2	2	2	1	1	1	0	0	0
Upper Fraser East	0	0	0	1	2	2	2	2	2	1	1	1	2	2	1	1	0	0	0	0	0	0
Upper Columbia	0	0	0	0	1	1	2	2	2	1	1	1	2	2	2	2	1	0	0	0	0	0
Lower Columbia	1	1	1	2	3	4	4	4	4	4	4	4	4	4	4	4	4	3	2	2	1	1
West Kootenay	1	1	1	2	3	4	4	4	4	4	4	4	4	4	4	4	4	3	2	2	1	1
East Kootenay	1	1	1	1	2	2	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2
Kettle	1	2	2	3	4	4	4	5	5	5	5	5	5	5	5	5	5	4	3	3	2	2
Middle Fraser	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	0	0	0	0
North Thompson	0	0	0	1	3	3	4	4	4	4	4	4	4	4	4	4	3	3	3	0	0	0
South Thompson	1	1	1	2	3	3	4	4	4	4	4	4	4	4	4	4	4	4	3	1	1	1
-Salmon River	1	2	2	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	3	3	3
Nicola	1	1	2	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	3	1	1	2
-Coldwater River	1	1	1	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	3	1	1	1
Okanagan	1	1	1	3	3	3	3	3	4	4	4	4	4	4	4	4	3	3	3	2	2	2
Similkameen	0	0	1	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1
Skagit	1	1	1	1	2	3	3	3	3	3	3	3	3	3	3	3	2	1	0	0	0	0
Lower Fraser	1	1	1	1	2	3	4	4	4	4	4	4	4	4	3	3	2	1	0	0	0	0
South Coast	1	1	1	1	3	3	4	4	4	4	4	4	4	4	3	3	2	1	0	0	0	0
Central Coast	0	0	0	0	0	0	0	0	0	1	1	1	2	2	2	2	0	0	0	0	0	0
West Vancouver Island	1	1	1	3	3	3	4	4	4	4	5	5	5	5	5	4	2	0	0	0	0	0
East Vancouver Island	2	2	2	4	4	4	4	4	4	4	5	5	5	5	5	4	2	1	0	0	0	0
Haida Gwaii	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Prepared By: Water Management Branch - Ministry of Forests, Lands, Natural Resource Operations and Rural Development

2023 DROUGHT LEVELS AT A GLANCE

Drought Levels:	0		1		2		3		4		5

BASINS	01-Jun	08-Jun	15-Jun	22-Jun	29-Jun	06-Jul	13-Jul	20-Jul	27-Jul	03-Aug	10-Aug	17-Aug	24-Aug	31-Aug	07-Sep	14-Sep	21-Sep	28-Sep	05-Oct	12-Oct	19-Oct	26-Oct	02-Nov
Fort Nelson	2	3	4	4	4	4	5	5	5	5	5	5											
East Peace	3	3	4	4	4	4	4	4	4	4	4	4											
North Peace	1	2	3	3	4	4	4	4	4	4	4	4											
South Peace	1	2	2	2	3	4	4	5	5	5	5	5											
Northwest	0	0	0	0	1	1	1	1	1	1	1	1											
Stikine	0	0	0	0	1	2	2	2	2	2	2	2											
Skeena-Nass	0	1	1	2	3	3	3	3	3	3	3	3											
Bulkley-Lakes	1	2	3	3	4	4	5	5	5	5	5	5											
Finlay	1	2	2	4	4	4	4	5	5	5	5	5											
Parsnip	1	2	2	3	4	4	4	5	5	5	5	5											
Upper Fraser West	1	2	2	3	4	4	4	5	5	5	5	5											
Upper Fraser East	1	2	2	2	4	4	4	4	4	4	4	4											
Upper Columbia	2	2	3	3	3	3	3	3	4	4	4	4											
Lower Columbia	1	2	3	3	3	3	4	4	4	4	4	4											
West Kootenay	1	2	3	3	3	3	4	4	4	4	4	4											
East Kootenay	2	2	3	3	3	3	4	4	4	4	4	4											
Kettle	0	2	3	3	3	3	3	3	3	4	4	4											
Middle Fraser	1	2	2	2	3	3	4	3	3	3	3	3											
Lower Thompson	0	2	2	2	2	3	3	3	3	4	4	5											
North Thompson	0	2	2	2	3	4	4	4	4	5	5	5											
South Thompson	0	2	2	2	3	4	4	4	4	5	5	5											
-Salmon River	0	3	3	3	3	4	4	4	5	5	5	5											
Nicola	1	2	2	2	2	3	3	3	3	4	4	5											
-Coldwater River	2	3	3	3	3	4	4	4	4	4	4	5											
Okanagan	0	2	2	2	2	3	3	3	3	4	4	5											
Similkameen	2	3	3	3	3	3	3	3	4	4	4	5											
Central Pacific Range	1	2	2	2	3	3	3	3	3	3	3	3											
Eastern Pacific Range	2	3	3	3	3	3	3	3	3	4	4	5											
Sunshine Coast	2	3	3	3	4	4	4	4	4	4	4	5											
Lower Mainland	2	3	3	3	4	4	4	4	4	4	4	5											
Central Coast	1	2	2	2	2	2	3	3	3	4	4	4											
West Vancouver Island	2	3	3	3	4	4	5	5	5	5	5	5											
East Vancouver Island	2	3	3	3	4	4	5	5	5	5	5	5											
Haida Gwaii	0	1	2	3	3	3	4	4	4	3	3	2											

Appendix 4: Provincial and Federal Agency Drought Responsibilities

British Columbia Drought and Water Scarcity Response Plan

Updated April 2023

Prepared by the Ministry of Water, Land and Resource Stewardship on behalf of the Inter-Agency Drought Working Group

Ministry of Forests, (FOR)	• Lead provincial agency for drought coordination and response • Administers the *Water Sustainability Act* • Operates the River Forecast Centre; collects and interprets snow, meteorological and stream flow data to provide warnings and forecasts of stream and lake runoff conditions • Monitors ambient water quality and groundwater levels • Protects and restores fish habitat and aquatic ecosystems

The RFC collects and interprets snow, meteorological and stream flow data to provide warnings and forecasts of stream and lake runoff conditions around the province.

Appendix 7: Additional Resources

All emergency situations that affect the health and safety of the public should be reported to EMBC at 1-800-663-3456.

Provincial Government Resources

- General Drought Information B.C. webpage: Links to low provincial government drought information including stream flow advisories, handbooks, fact sheets, and more.
- River Forecast Centre (RFC): The RFC collects and interprets snow, meteorological and stream flow data to provide warnings and forecasts of stream and lake runoff conditions around the province.

Flood/High flow forecasting

WANRS Model for Fraser/ Skeena (1976)

COFFEE Model

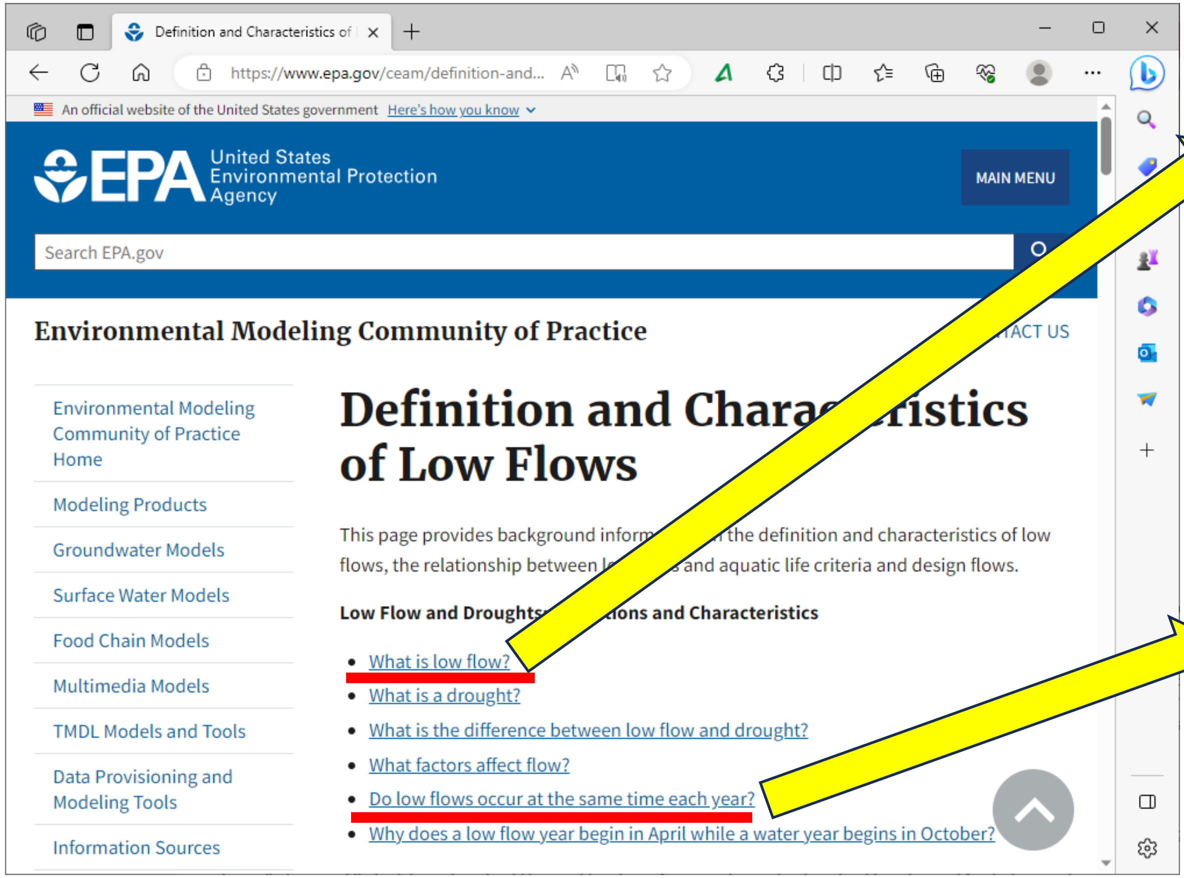
RAVEN Model for Okanagan Lake

CLEVER Model

FRôUT Model for Fraser

ELF

The RFC collects and interprets snow, meteorological and stream flow data to provide warnings and forecasts of stream and lake runoff conditions around the province.



https://www.epa.gov/ceam/definition-and-characteristics-low-flows

What is low flow?
Low flow is the "flow of water in a stream during prolonged dry weather," according to the World Meteorological Organization. Many states use design flow statistics such as the 7Q10 (the lowest 7-day average flow that occurs on average once every 10 years) to define low flow for setting permit discharge limits.

Do low flows occur at the same time each year?
Most streams will illustrate annual variation that can be explained by seasonal changes in snowmelt, rainfall and other factors. For many areas in the country, the lowest flows often occur near the end of the summer or beginning of fall. However, each stream is different and any particular year can be an anomaly in terms of if and when low flows occur. The magnitude and duration of low flows can vary significantly from year to year.

Low flows almost unpredictable!

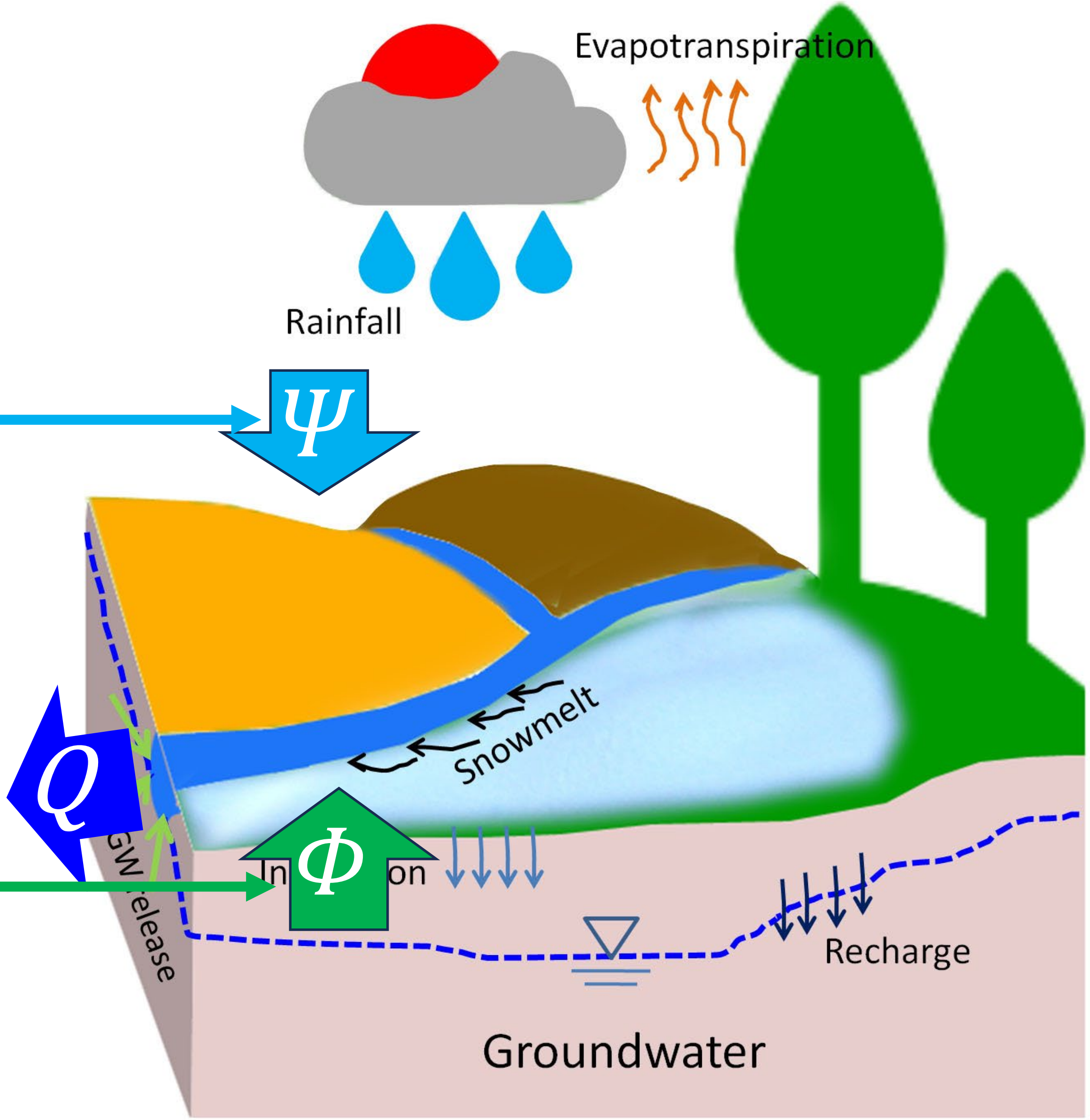
Q - outflow from the watershed:

$$Q = \left(-\frac{dS}{dt}\right) + (R + M - E)A$$

$$Q = \Phi + \Psi$$

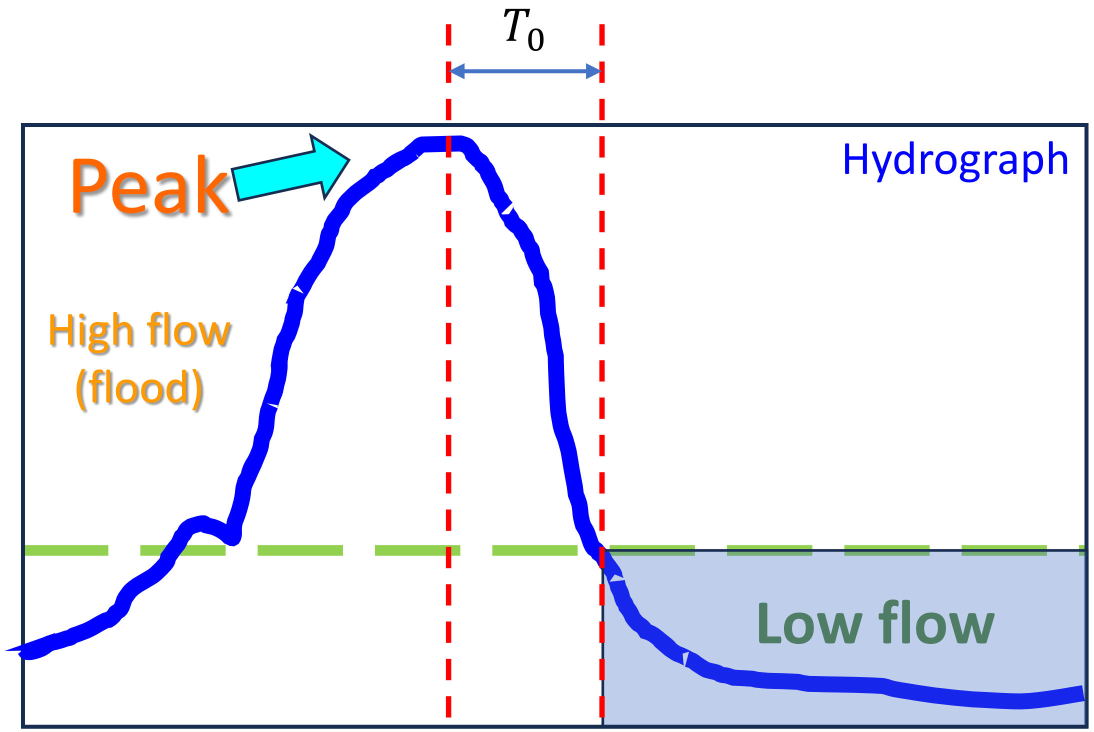
$\Phi = -ds/dt$, the water release rate from the watershed liquid water storage.

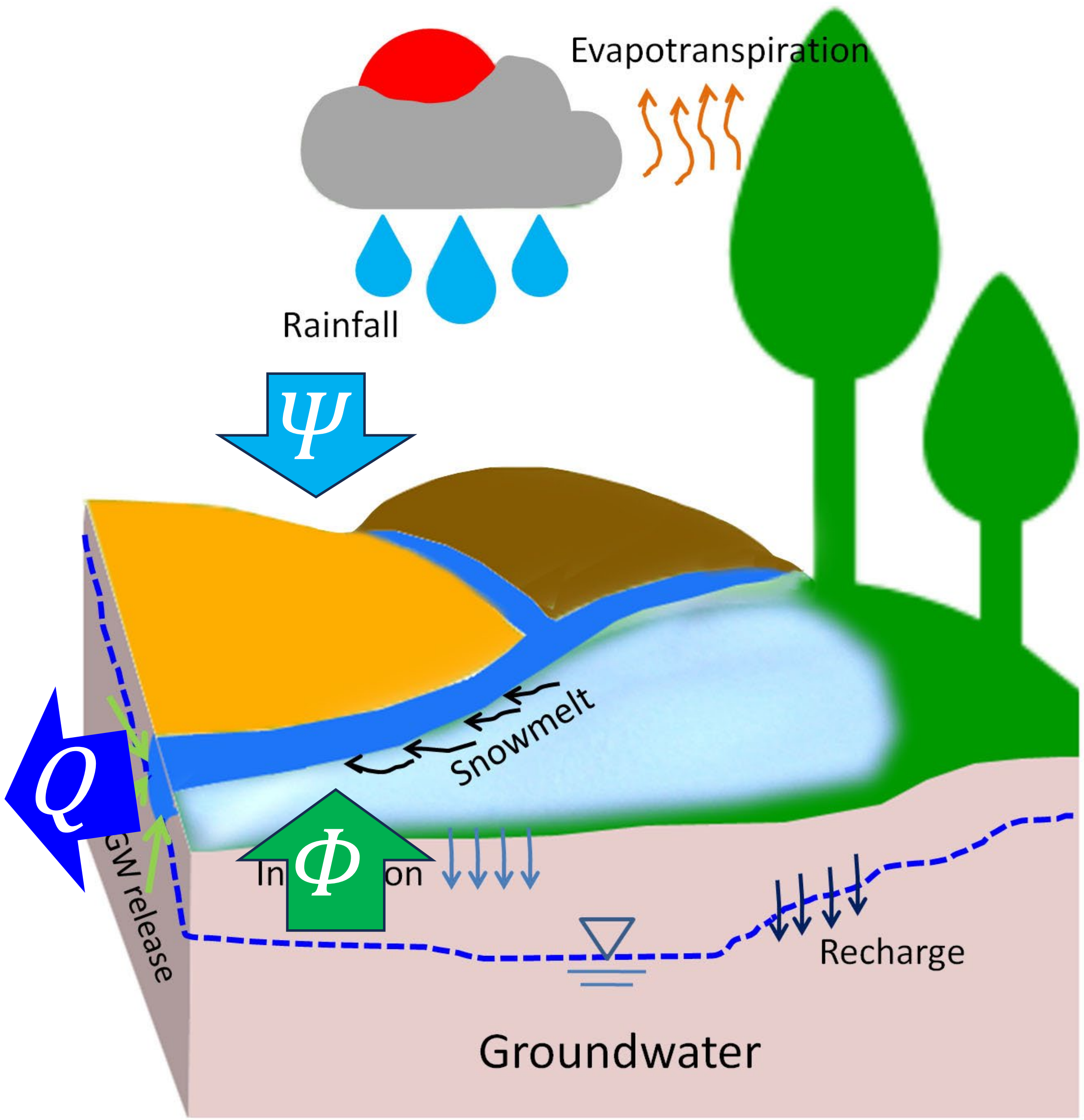
$\Psi = (R + M - E)A$, the net meteorological liquid water input rate to the watershed.



Definition: The low flow Q_L is the outflow from a watershed that has been continuously decreasing from the most recent high peak for a period (T_0):

$$\begin{cases} \Delta Q = \Delta(\Phi + \Psi) < 0 \\ Q_L = Q_t, \quad when\ t \geq T_0 \end{cases}$$





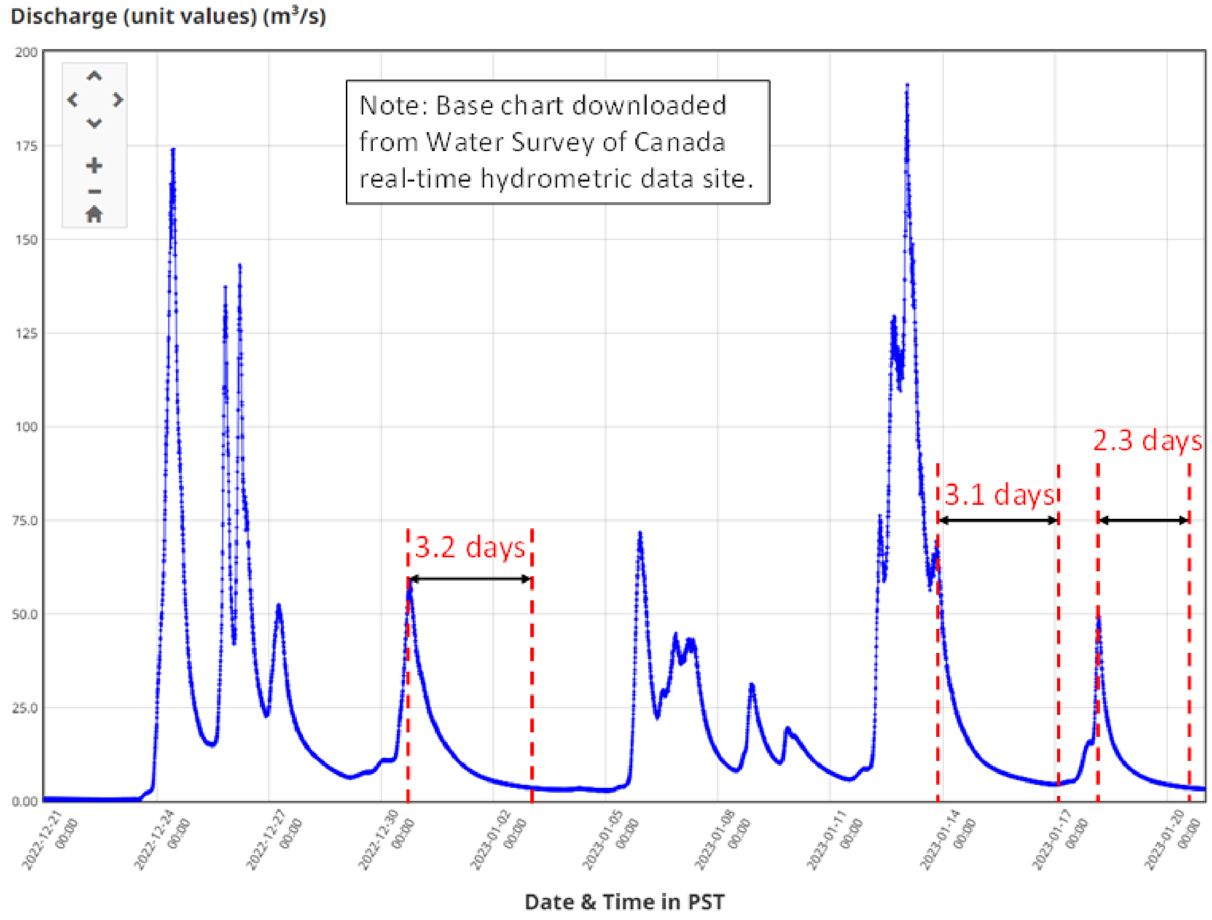
STATION ID	STATION NAME	A (km^2)	SQRT(A) (km)	MAD (m^3/s)	½ MAD (m^3/s)	T_0 (days)	WTS
08HB086	TOFINO CREEK NEAR THE MOUTH	38.6	6.2	6.8	3.4	3	COASTAL
08GB013	CLOWHOM RIVER NEAR CLOWHOM LAKE	147	12.1	15.4	7.7	5	COASTAL
08MH147	STAVE RIVER ABOVE STAVE LAKE	290	17.0	34.5	17.2	5	COASTAL
08GF007	WAKEMAN RIVER BELOW ATWAYKELLESSE RIVER	698	26.4	78.1	39.1	5	COASTAL
08GA071	ELAHO RIVER NEAR THE MOUTH	1200	34.6	105.0	52.5	6	COASTAL
08GE002	KLINAKLINI RIVER EAST CHANNEL (MAIN) NEAR THE MOUTH	5780	76.0	299.9	149.9	12	COASTAL
08CG001	ISKUT RIVER BELOW JOHNSON RIVER	9500	97.5	465.0	232.5	33	COASTAL
08DB001	NASS RIVER ABOVE SHUMAL CREEK	18400	135.6	806.1	403.1	18	COASTAL
08CE001	STIKINE RIVER AT TELEGRAPH CREEK	29000	170.3	421.3	210.6	39	COASTAL
08EF001	SKEENA RIVER AT USK	42300	205.7	911.6	455.8	34	COASTAL
08NJ026	DUHAMEL CREEK ABOVE DIVERSIONS	52.9	7.3	1.5	0.8	32	INTERIOR
08NG077	ST. MARY RIVER BELOW MORRIS CREEK	208	14.4	7.1	3.6	29	INTERIOR
08NF001	KOOTENAY RIVER AT KOOTENAY CROSSING	416	20.4	4.9	2.4	36	INTERIOR
08NG002	BULL RIVER NEAR WARDNER	1520	39.0	32.5	16.3	40	INTERIOR
08NN026	KETTLE RIVER NEAR WESTBRIDGE	2140	46.3	28.0	14	26	INTERIOR
08NL038	SIMILKAMEEN RIVER NEAR HEDLEY	5580	74.7	48.6	24.3	30	INTERIOR
08NG065	KOOTENAY RIVER AT FORT STEELE	11500	107.2	172.5	86.2	62	INTERIOR
08LF051	THOMPSON RIVER NEAR SPENCES BRIDGE	55400	235.4	778.1	389	79	INTERIOR
08MC018	FRASER RIVER NEAR MARGUERITE	114000	337.6	1456.9	728.5	78	INTERIOR
08MF005	FRASER RIVER AT HOPE	217000	465.8	2720.4	1360.2	100	INTERIOR

T_0 - receding period

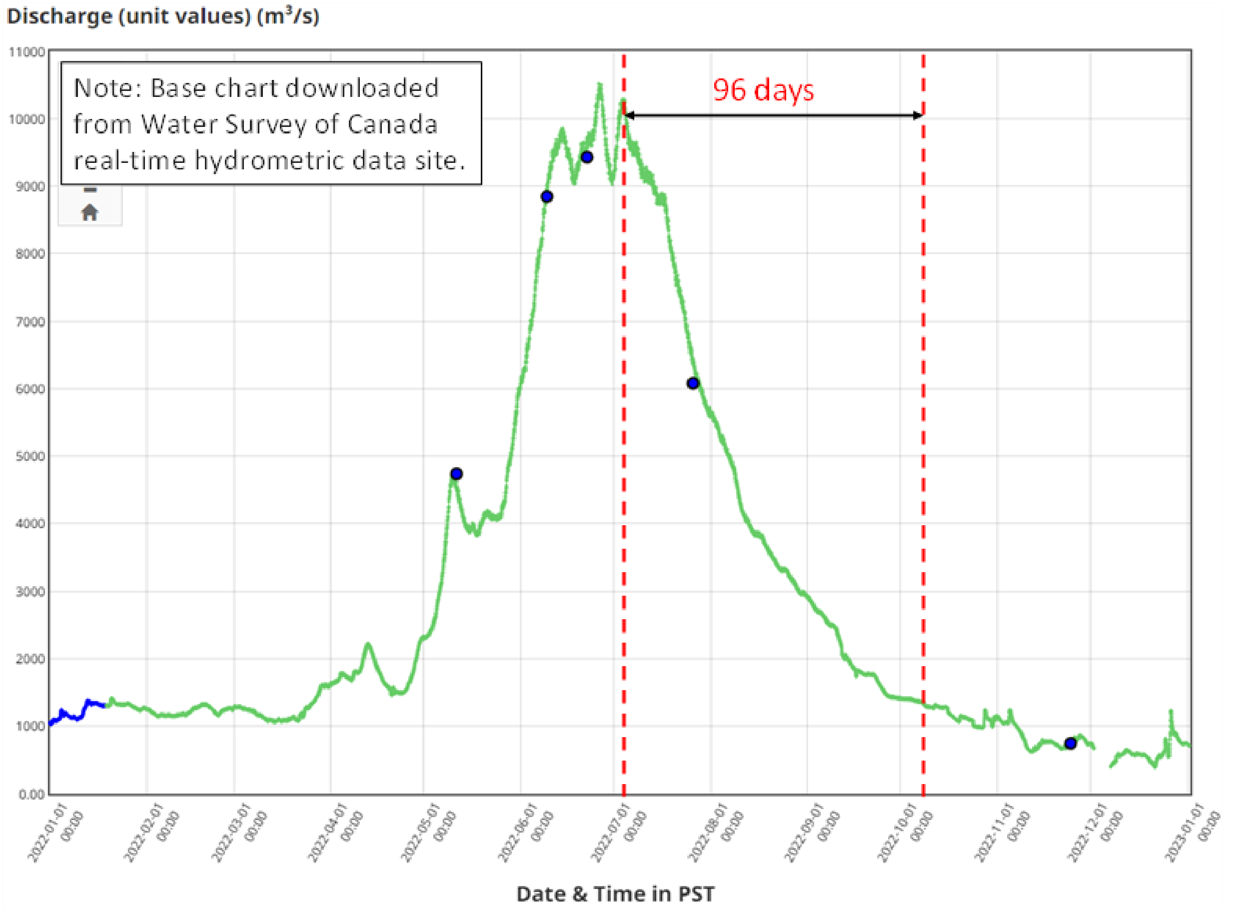
"Recent high peak"
>= 2 x MAD (mean annual discharge)

"For a period"
= time from the "recent high peak" until the streamflow reaches 1/2 MAD.

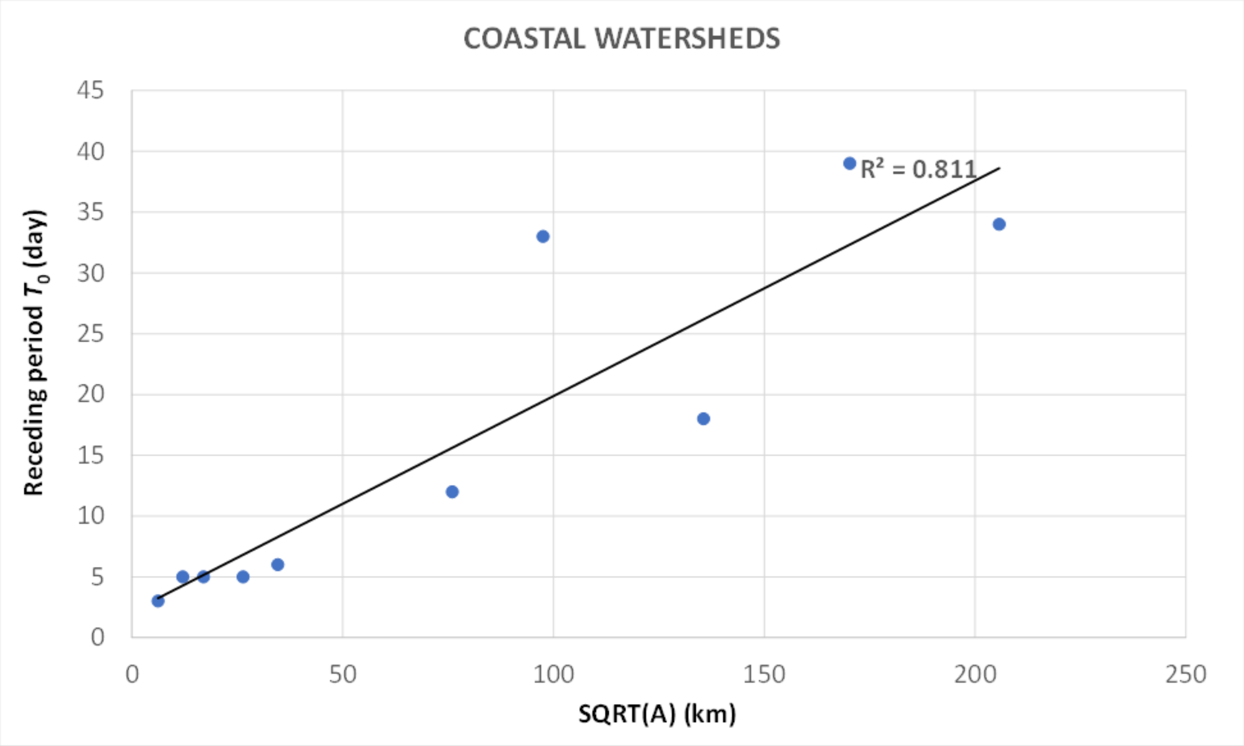
Recent 10 years of data

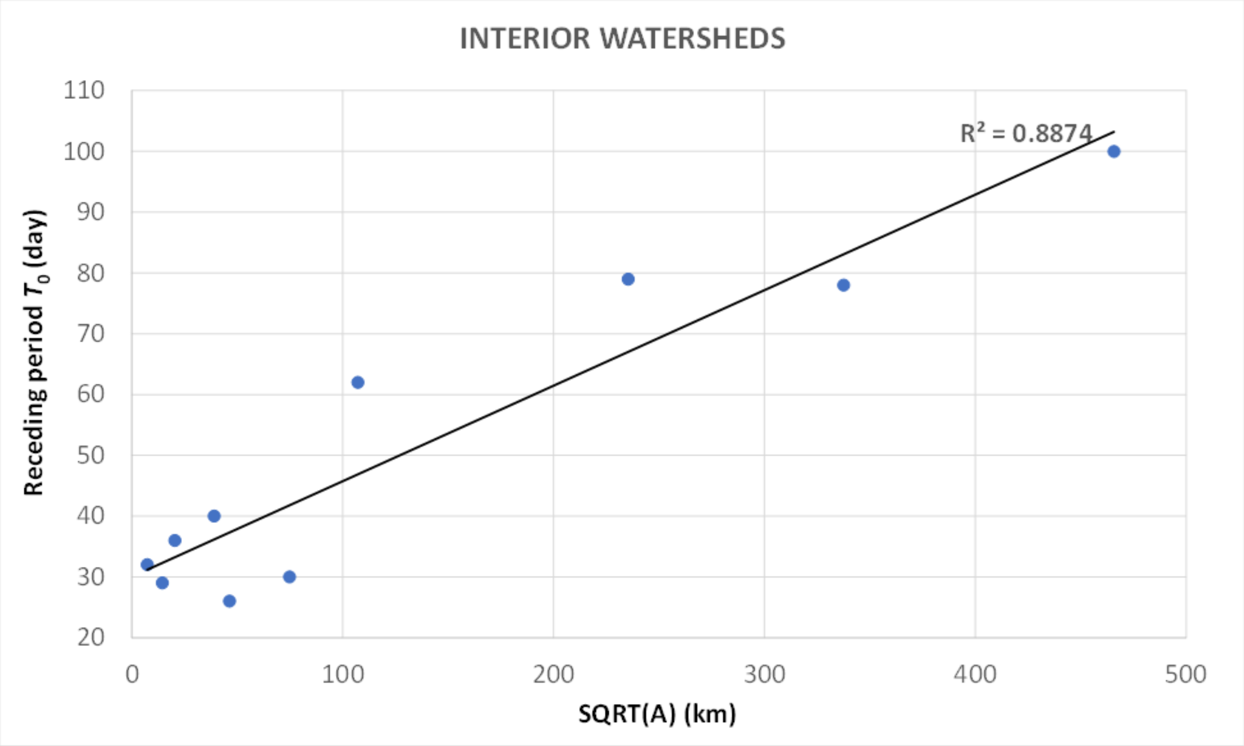


(a) TOFINO CREEK NEAR THE MOUTH (08HB086): $T_0 = 2.3$ to 3.2 days for Dec. 21, 2022 – Jan. 20, 2023



(b) FRASER RIVER AT HOPE (08MF005): $T_0 = 96$ days for 2022

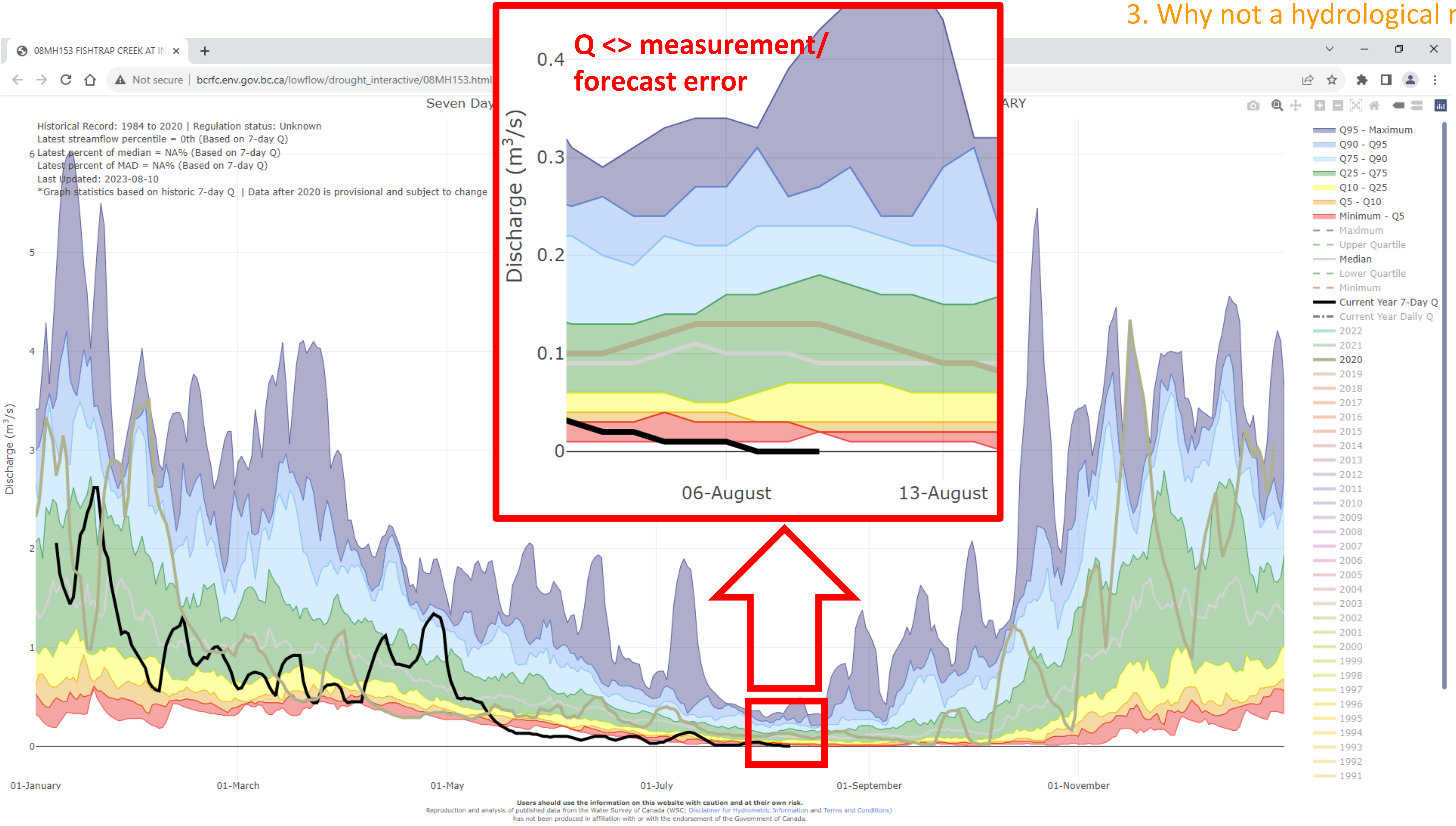

COASTAL WATERSHEDS
Receding period T_0 (day)
45
40
35
30
25
20
15
10
5
0
0
50
100
150
200
250
SQRT(A) (km)
R^2 = 0.811


INTERIOR WATERSHEDS
Receding period T_0 (day)
110
100
90
80
70
60
50
40
30
20
0
100
200
300
400
500
SQRT(A) (km)
R^2 = 0.8874

http://www.pacfish.ca/wcviweather/Content%20Pages/Sproat/CameraStream3.aspx

Characteristics of low flow:

a. The streamflow is **decreasing**.
b. The sum of the rate of release from the watershed liquid water storage plus the rate of net meteorological liquid water input is **decreasing**.
c. The net meteorological liquid water input is insufficient to replenish the liquid water storage in the watershed.
d. The watershed liquid water storage is **decreasing**.


08MH153 FISHTRAP CREEK AT IN
Not secure | bcrfc.env.gov.bc.ca/lowflow/drought_interactive/08MH153.html
Seven Day
ARY
Historical Record: 1984 to 2020 | Regulation status: Unknown
Latest streamflow percentile = 0th (Based on 7-day Q)
Latest percent of median = NA% (Based on 7-day Q)
Latest percent of MAD = NA% (Based on 7-day Q)
Last Updated: 2023-08-10
*Graph statistics based on historic 7-day Q | Data after 2020 is provisional and subject to change
Discharge (m³/s)
01-January
01-March
01-May
01-July
01-September
01-November
Q95 - Maximum
Q90 - Q95
Q75 - Q90
Q25 - Q75
Q10 - Q25
Q5 - Q10
Minimum - Q5
Maximum
Upper Quartile
Median
Lower Quartile
Minimum
Current Year 7-Day Q
Current Year Daily Q
2022
2021
2020
2019
2018
2017
2016
2015
2014
2013
2012
2011
2010
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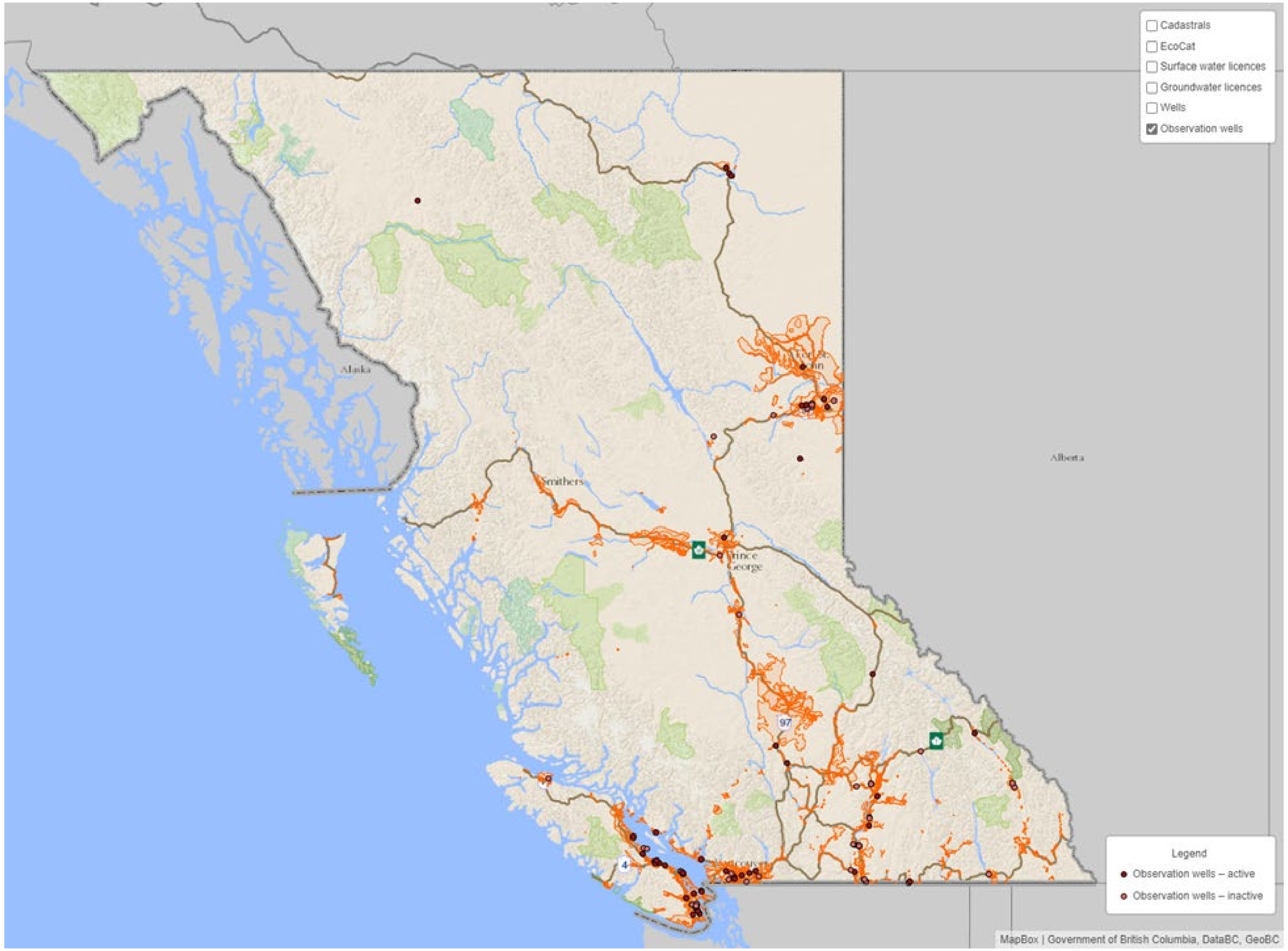
Users should use the information on this website with caution and at their own risk.
Reproduction and analysis of published data from the Water Survey of Canada (WSC; Disclaimer for Hydrometric Information and Terms and Conditions) has not been produced in affiliation with or with the endorsement of the Government of Canada.
Q <> measurement/
forecast error
Discharge (m³/s)
06-August
13-August

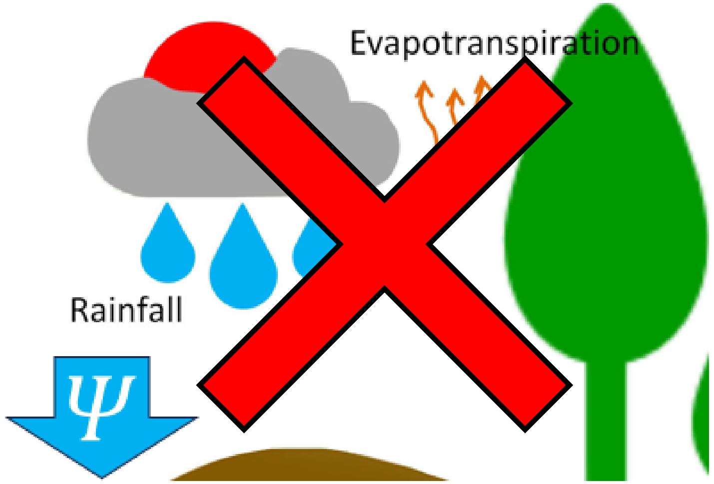
Sparsity of BC observation wells (dark brown dots, 340) and mapped aquifers (brown lines and filled patches) - BC Groundwater Wells and Aquifers website
https://apps.nrs.gov.bc.ca/gwells/aquifers?map_centre=53.810684,-124.817461

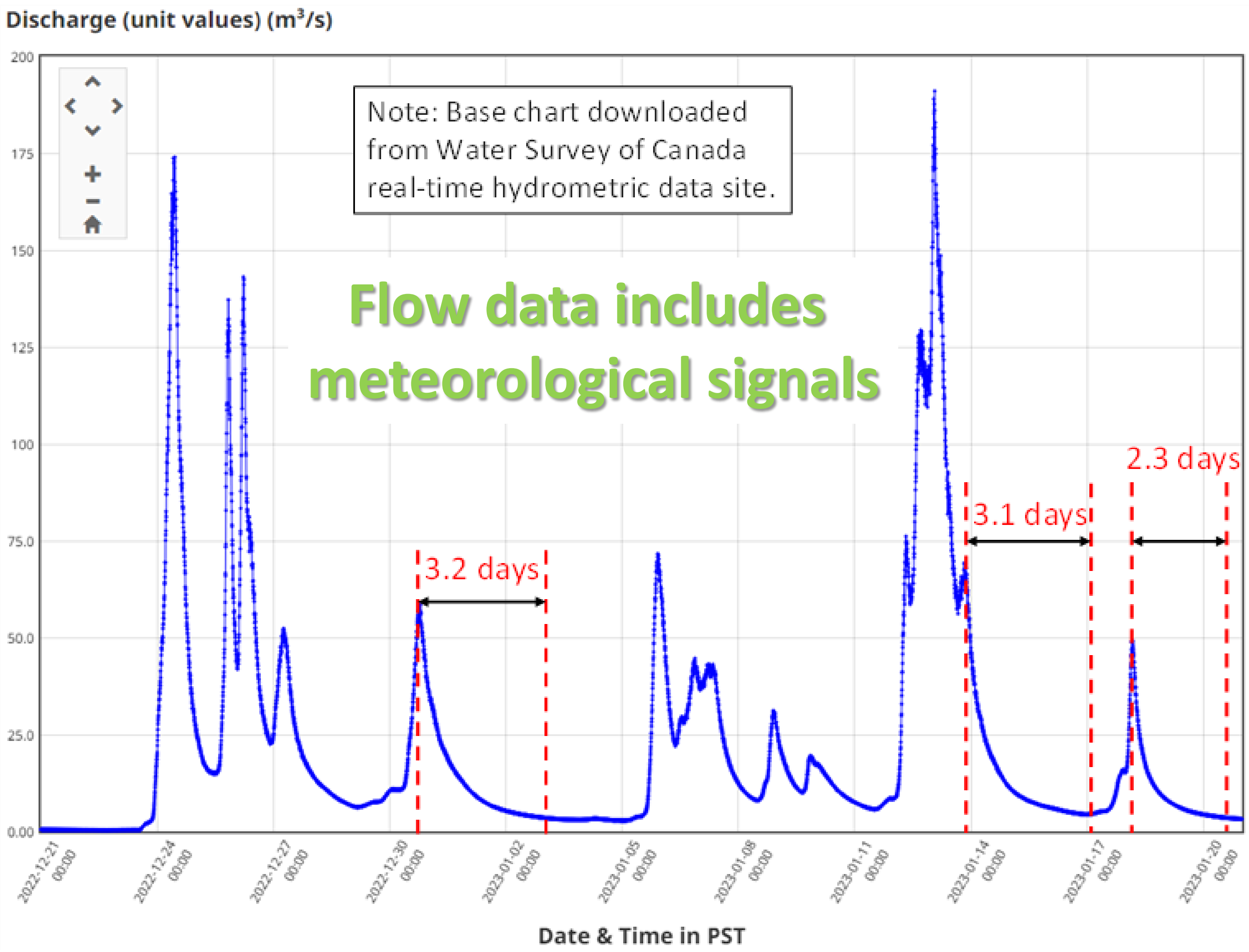


Low flow = baseflow

Conceptual/ Lumped-sum Models: Baseflow = constant

Physically based distributed Models: Baseflow = Groundwater release

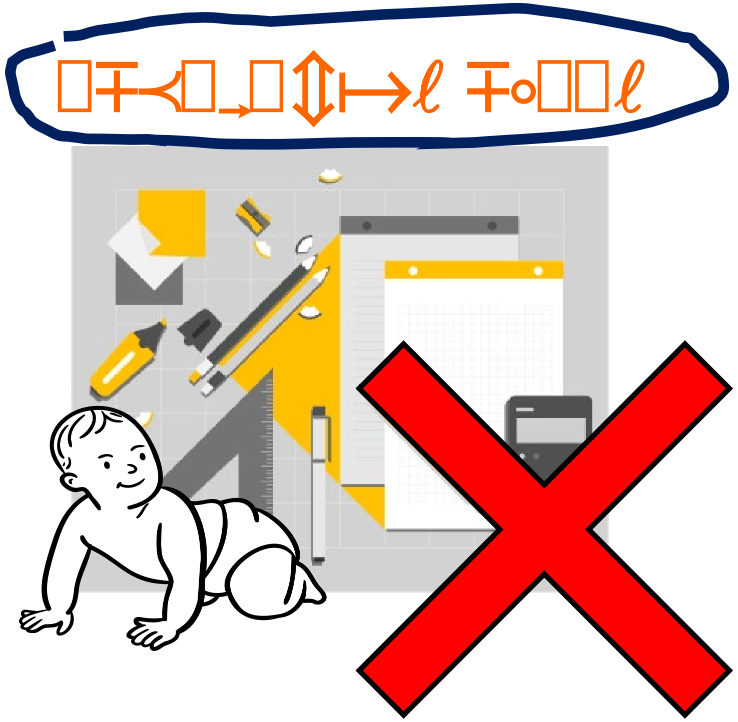

Evapotranspiration
Rainfall
Ψ

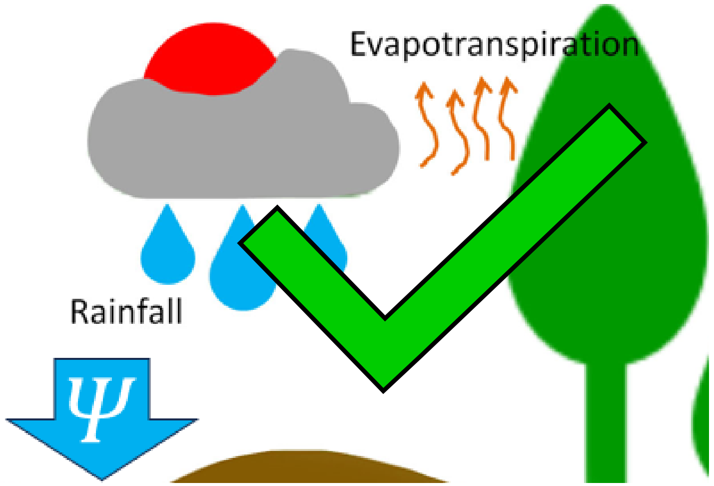

Discharge (unit values) (m³/s)
Note: Base chart downloaded from Water Survey of Canada real-time hydrometric data site.
Flow data includes meteorological signals
3.2 days
3.1 days
2.3 days
200
175
150
125
100
75.0
50.0
25.0
0.00
2022-12-21 00:00
2022-12-24 00:00
2022-12-27 00:00
2022-12-30 00:00
2023-01-02 00:00
2023-01-05 00:00
2023-01-08 00:00
2023-01-11 00:00
2023-01-14 00:00
2023-01-17 00:00
2023-01-20 00:00
Date & Time in PST

1) The sum of the water release rate from the watershed liquid water storage plus the net meteorological liquid water input rate to the streamflow is a function of time and parameters.

$$Q = \Phi + \Psi = f(p_i, t)$$

2) The function parameters p_i remain constant for a certain period.





$$Q(t) = Q_0 e^{-\alpha t}$$

$\boldsymbol{ln(Q) = -\alpha t + ln(Q_0)}$ The Extrapolating Logarithmic Flow (ELF)Model

$$\frac{d}{dt}[ln(Q)] = \frac{d}{dt}[-\alpha t + ln(Q_0)]$$

$$\frac{1}{Q}\frac{dQ}{dt} = -\alpha$$

$$\frac{dQ}{dt} = -\alpha Q$$

$$\frac{d^2Q}{dt^2} = \alpha^2 Q$$

The first characteristic of low flow is extended as,

a. The streamflow is **decreasing**, and the decreasing rate of the streamflow becomes **smaller and smaller with time (decreasing)**.

$y = ax + b$

$$\begin{cases} y = \ ln(Q) \\ x = t \\ a = -\alpha \\ b = \ ln(Q_0) \end{cases}$$

2 unknow: a, b

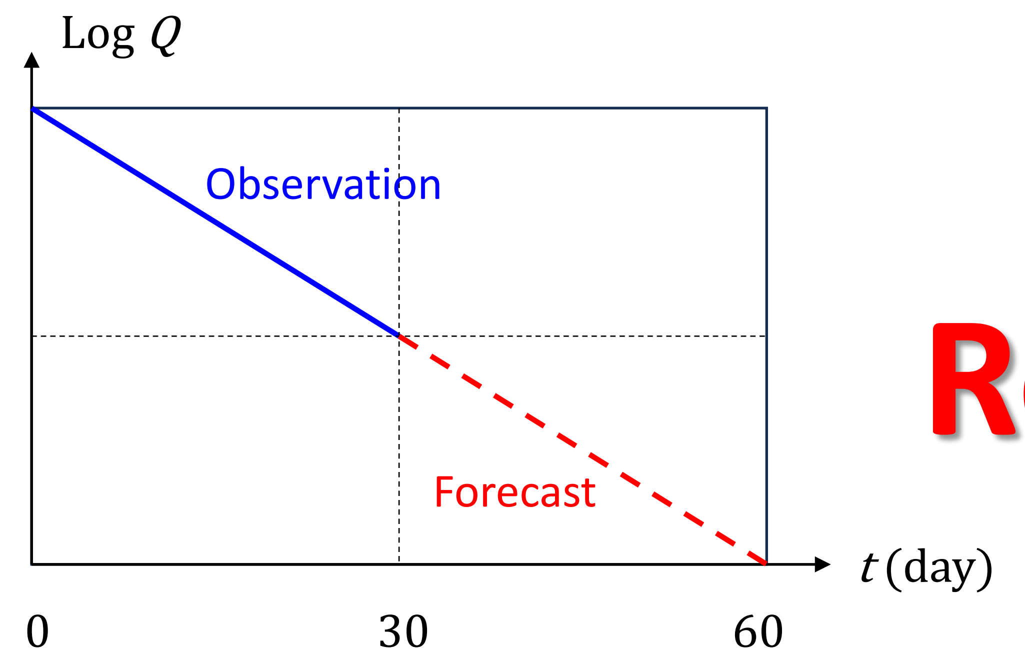
2 data/equations

Supper easy!!!

If 30 data, overdetermined: $f = y = ax + b$

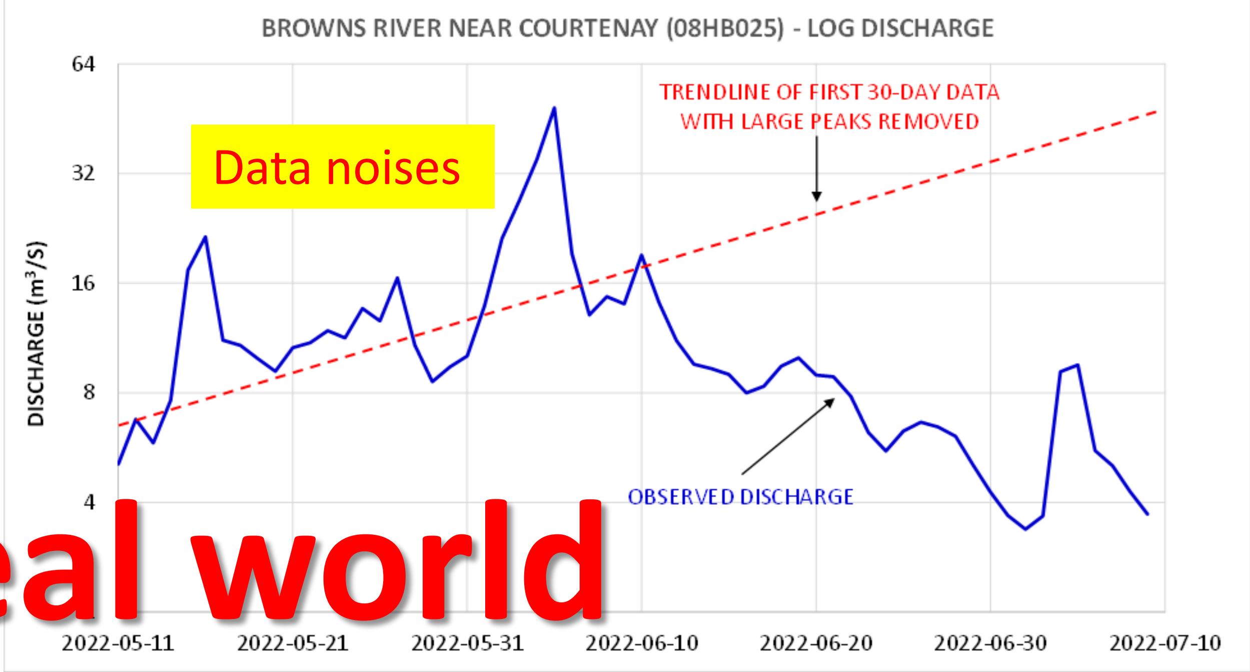
$$\begin{cases} R^2 = \sum_{i=1}^{n} \left[y_i - f(x_i, a_1, a_2, \dots, a_j, \dots, a_m) \right]^2 \\ \dfrac{\partial (R^2)}{\partial a_i} = 0, i = 1 \ to \ n \end{cases}$$

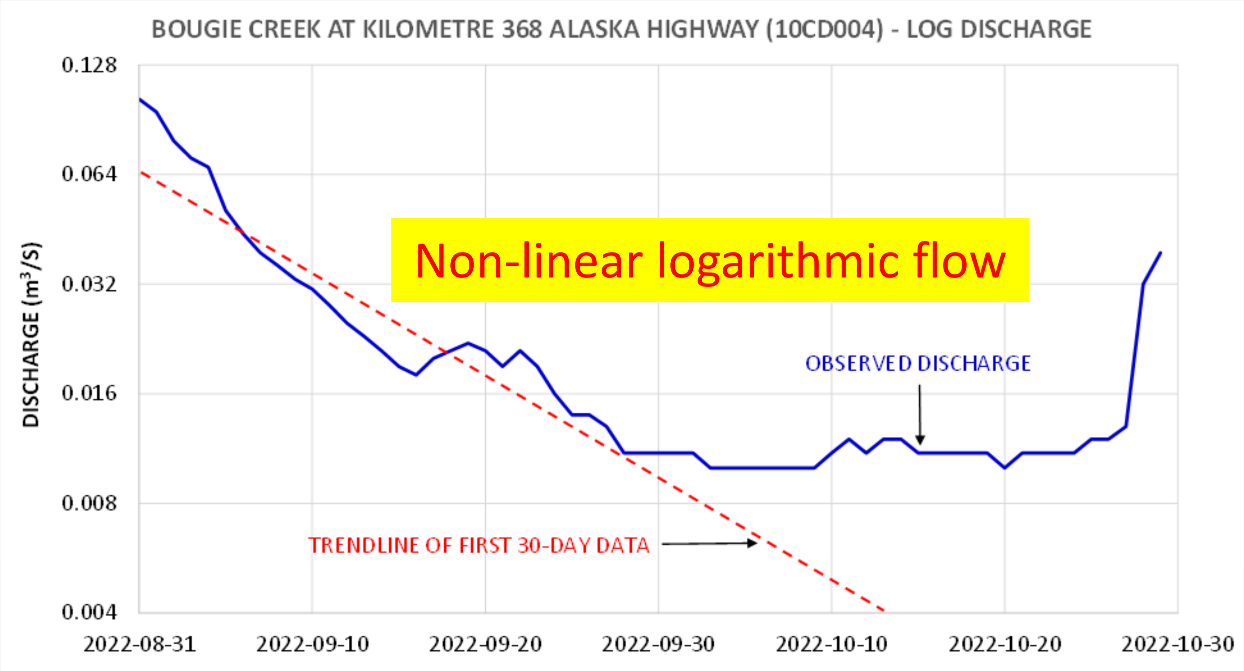
$$\begin{cases} a = \dfrac{\sum_i^n (x_i y_i) - n\bar{x}\bar{y}}{\sum_i^n x_i^2 - n\bar{x}^2} \\ b = \dfrac{\bar{y} \sum_i^n x_i^2 - \bar{x} \sum_i^n (x_i y_i)}{\sum_i^n x_i^2 - n\bar{x}^2} \end{cases} \qquad \begin{cases} \bar{x} = \dfrac{1}{n} \sum_{n=1}^{n} x_i \\ \bar{y} = \dfrac{1}{n} \sum_{n=1}^{n} y_i \end{cases}$$



Theory

Real world





ELF Model uses 30-day daily flows as input to produce 30-day forecasts

Step 1. prepare data:

$$\begin{cases} Q_i = Q_{obsi} > 0 \\ H_i = H_{obsi} - H_{min} > 0 \end{cases}$$

Step 2. Calculate the logarithms for observed discharges/water levels

Step 3. Calculate 5-day moving averages:

$$\left(\overline{\log Q}\right)_j = \frac{1}{5}\sum_{i=d}^{d+4} \log Q_i$$

Step 4. Calculate increment of $\left(\overline{\log Q}\right)_j$:

$$\left(\Delta\,\overline{\log Q}\right)_l = \left(\overline{\log Q}\right)_{j+1} - \left(\overline{\log Q}\right)_j$$

$\Delta\,\overline{\log Q} \approx d\left(\overline{\log Q}\right)\Delta t \approx dy = a$ Eq (31)

Or

$\boldsymbol{\Delta\,\overline{\log Q} \approx d\left(\overline{\log Q}\right)\Delta t \approx dy = ax + b}$ Eq (32)

Step 5. Calculating the increment of $\left(\Delta\,\overline{\log Q}\right)_l$:

$$\Delta\Delta\,\overline{\log Q} \approx d\left(d\left(\overline{\log Q}\right)\right)\Delta t \approx d(dy) = da = 0$$

Or

$$\Delta\Delta\,\overline{\log Q} \approx d\left(d\left(\overline{\log Q}\right)\right)\Delta t \approx d(dy) = d(ax+b) = a$$

Step 6. *Scenario 1* – Fit 25 points of $\Delta\,\overline{\log Q}$ in Eq (32): $\boldsymbol{\Delta\,\overline{\log Q} \approx d\left(\overline{\log Q}\right)\Delta t \approx dy = ax + b}$

Step 7. Calculating the mean of $\left(\Delta\Delta\overline{\log Q}\right)_n$ = 0 or non-0 constant

Step 8. *Scenario 2 to 8* – Eliminate data points of $\left(\Delta\overline{\log Q}\right)_l$ with the 2, 4, 6, 8, 10, 12, and 14 largest deviations of $\left(\Delta\Delta\overline{\log Q}\right)_n$ from the mean, and fit the rest of data points of $\Delta\overline{\log Q}$ in Eq (32):

$$\boldsymbol{\Delta\overline{\log Q} \approx d(\overline{\log Q})\Delta t \approx dy = ax + b}$$

Step 9. *Scenario 9* – Fit the 10 data points of $\left(\Delta\overline{\log Q}\right)_l$ from the last 15 days which have the minimum deviations of $\left(\Delta\Delta\overline{\log Q}\right)_n$ from the mean in Eq (31):

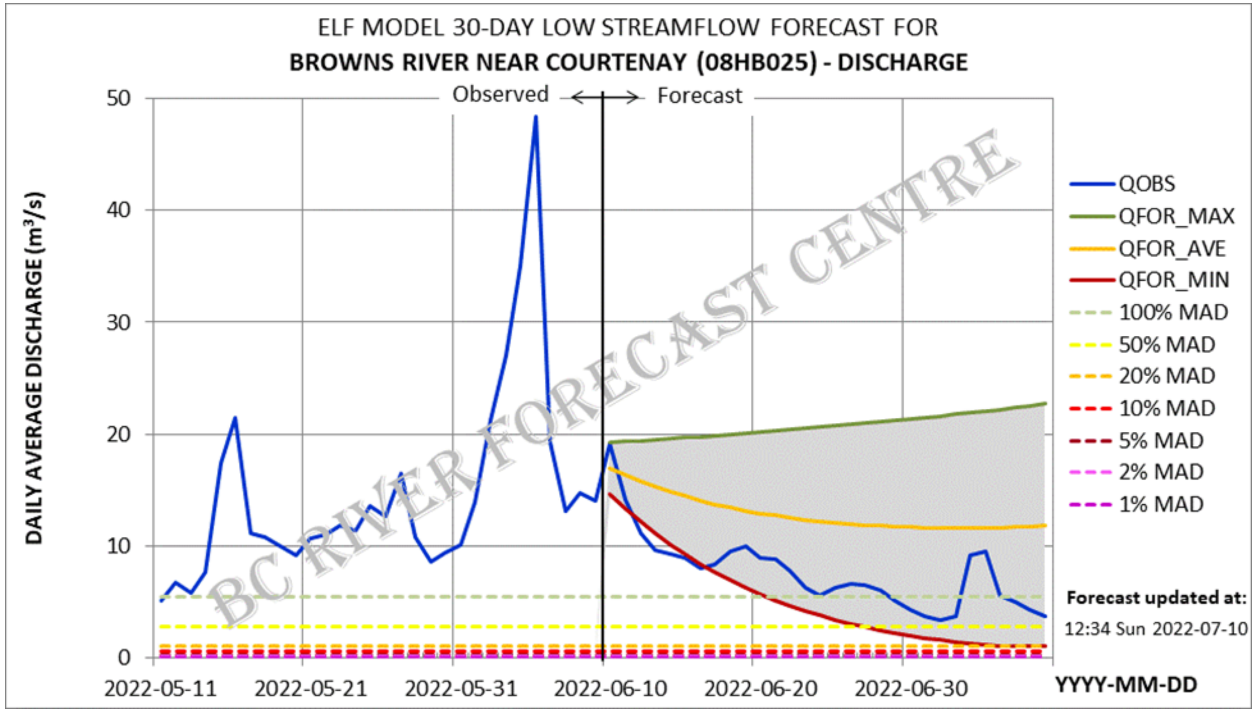
$$\boldsymbol{\Delta\overline{\log Q} \approx d(\overline{\log Q})\Delta t \approx dy = a}$$

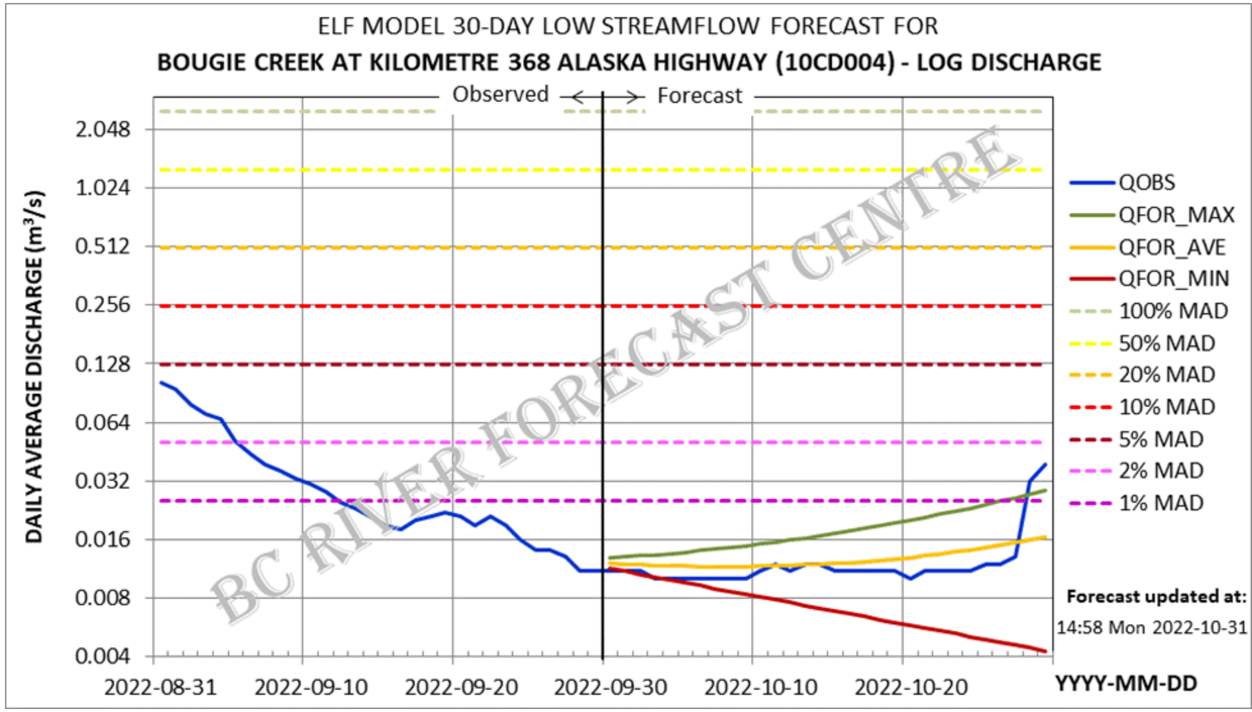
Or Eq (32) with: $\begin{cases} \boldsymbol{a = 0} \\ \boldsymbol{b = \bar{y}} \end{cases}$ Eq (40)

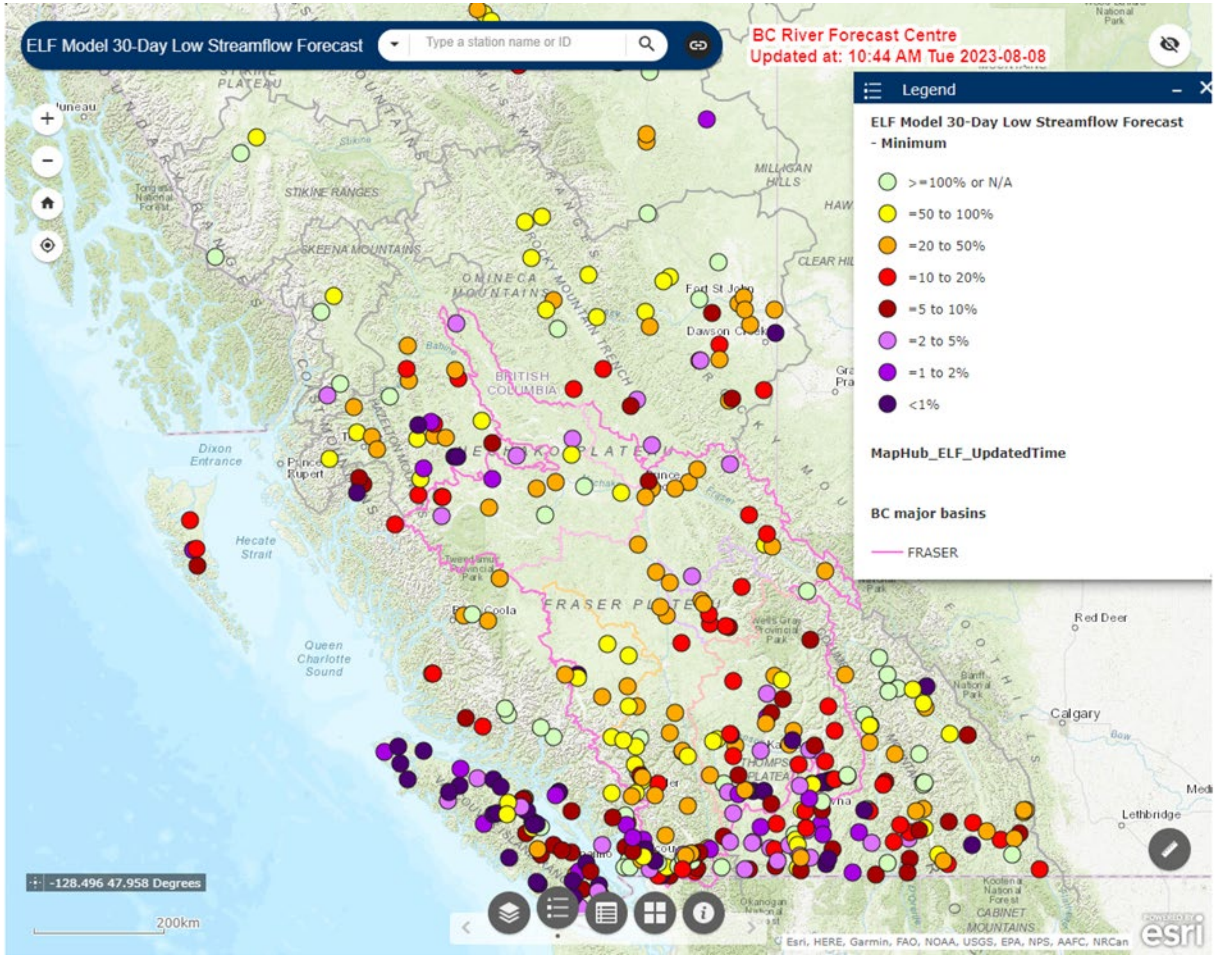
Step 10. *Scenario 10 to 12* – Fit the last 10, 5, and 2 data points of $\left(\Delta\overline{\log Q}\right)_l$ in Equation (31), or Equation (32) with Equation (40), to estimate a and b.

Step 11. Finding the forecast maximum and minimum from the 12 scenarios for each day of the 30-day forecasting period, and the forecast average is the average of the forecast maximum and minimum.

Step 12. Restrict the forecast maximum and minimum and recalculate the forecast average when there was a recent rainfall/melt event.

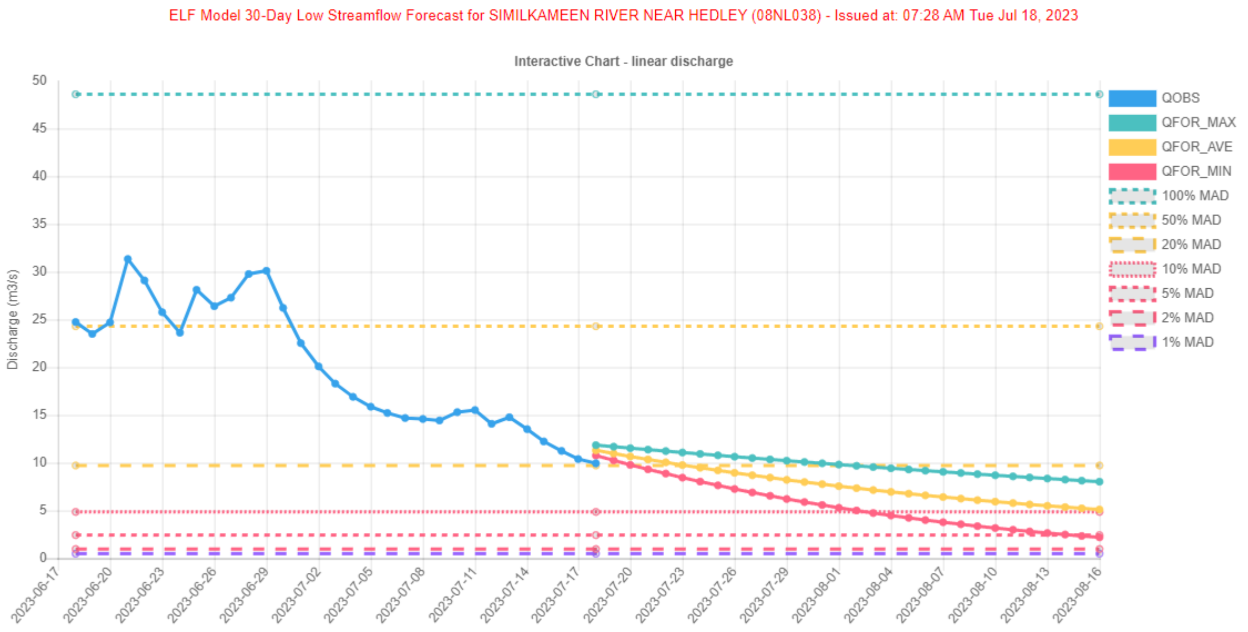

ELF MODEL 30-DAY LOW STREAMFLOW FORECAST FOR
BROWNS RIVER NEAR COURTENAY (08HB025) - DISCHARGE
Observed
Forecast
DAILY AVERAGE DISCHARGE (m³/s)
50
40
30
20
10
0
2022-05-11
2022-05-21
2022-05-31
2022-06-10
2022-06-20
2022-06-30
YYYY-MM-DD
QOBS
QFOR_MAX
QFOR_AVE
QFOR_MIN
100% MAD
50% MAD
20% MAD
10% MAD
5% MAD
2% MAD
1% MAD
Forecast updated at:
12:34 Sun 2022-07-10
BC RIVER FORECAST CENTRE

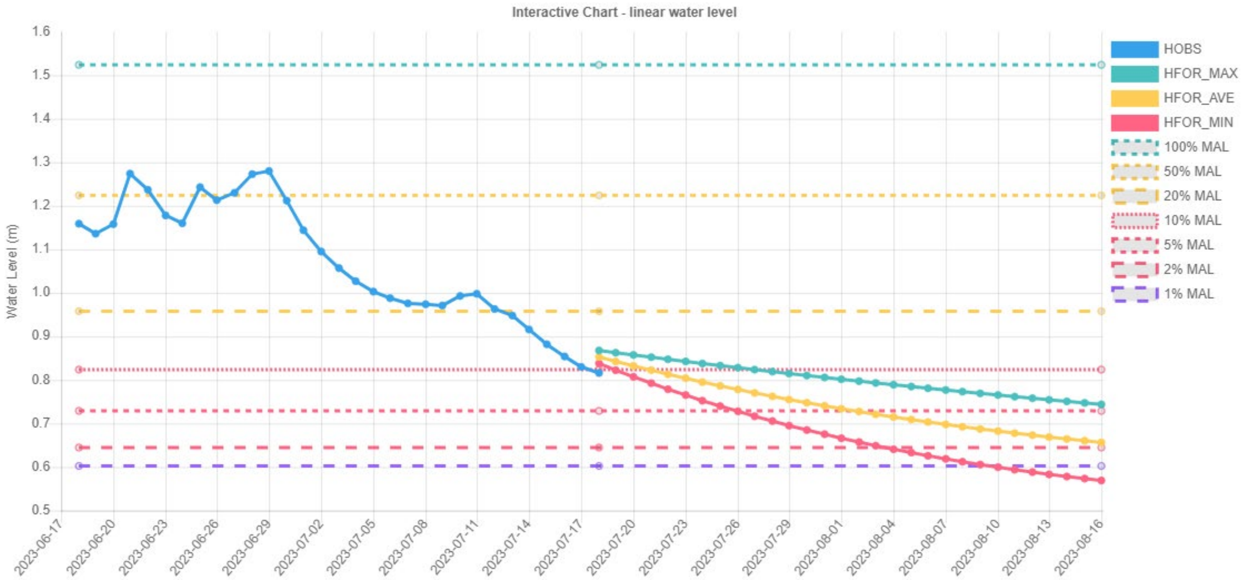

ELF MODEL 30-DAY LOW STREAMFLOW FORECAST FOR
BOUGIE CREEK AT KILOMETRE 368 ALASKA HIGHWAY (10CD004) - LOG DISCHARGE
Observed
Forecast
DAILY AVERAGE DISCHARGE (m³/s)
2.048
1.024
0.512
0.256
0.128
0.064
0.032
0.016
0.008
0.004
2022-08-31
2022-09-10
2022-09-20
2022-09-30
2022-10-10
2022-10-20
YYYY-MM-DD
QOBS
QFOR_MAX
QFOR_AVE
QFOR_MIN
100% MAD
50% MAD
20% MAD
10% MAD
5% MAD
2% MAD
1% MAD
Forecast updated at:
14:58 Mon 2022-10-31
BC RIVER FORECAST CENTRE

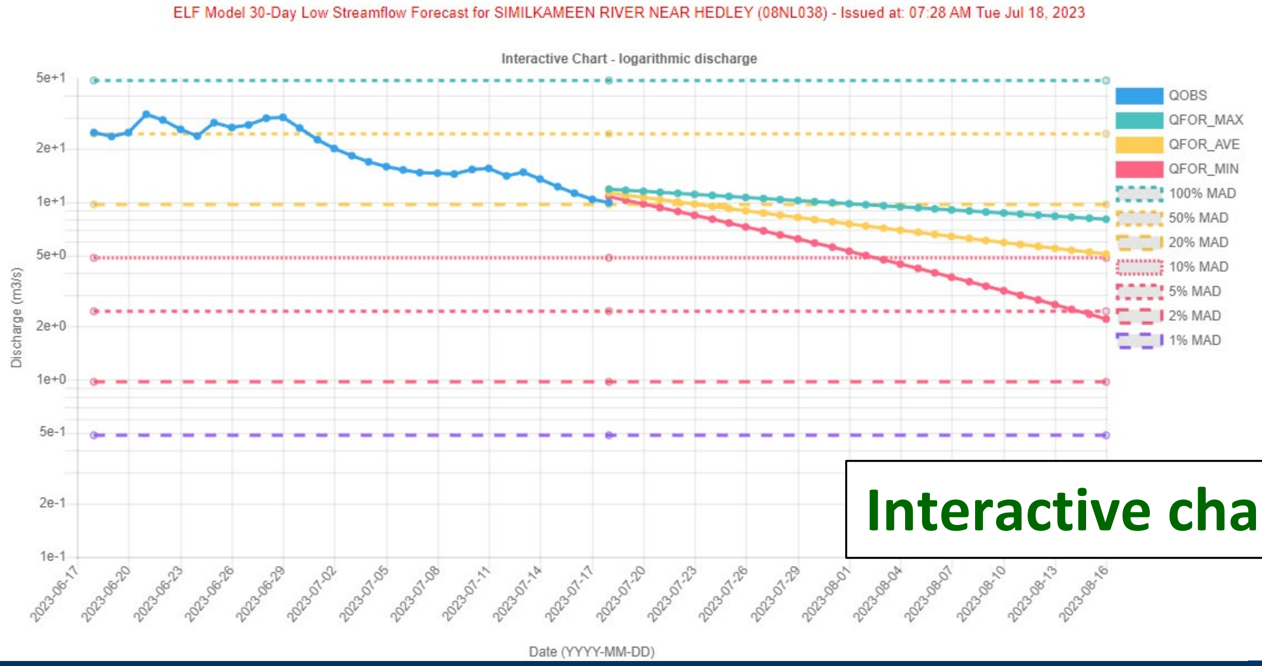


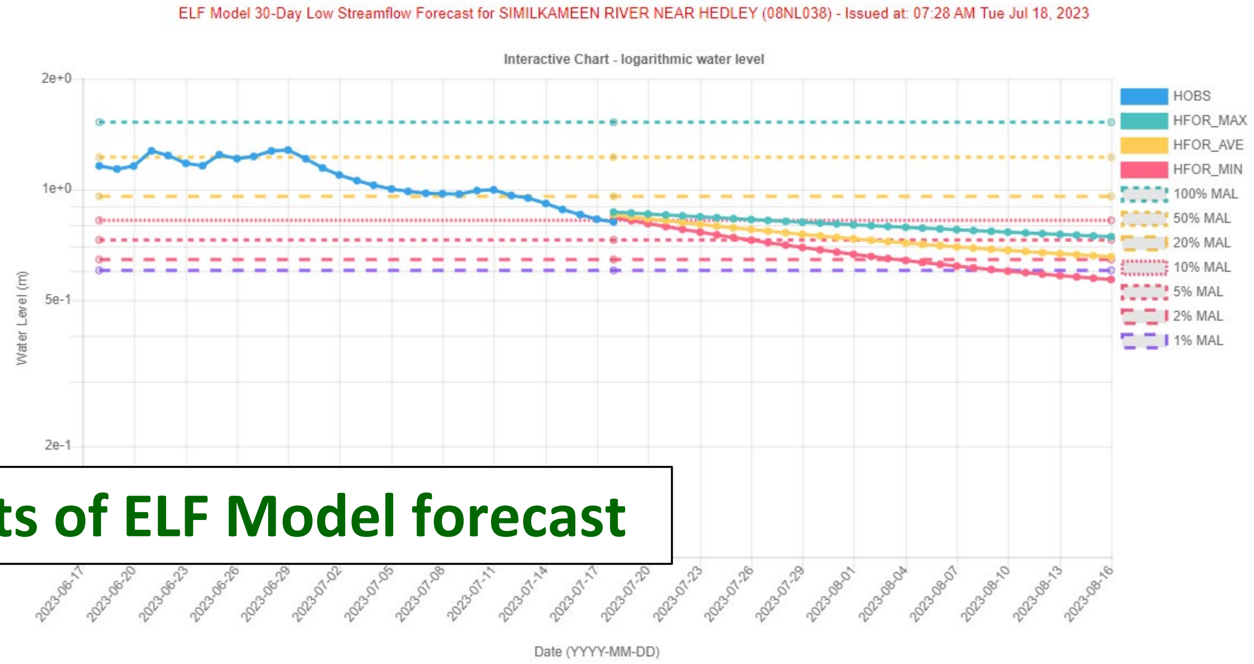
Maphub GIS map of ELF Model with color coded markers (http://bcrfc.env.gov.bc.ca/lowflow/map_elf.html)

8. Products of ELF Model



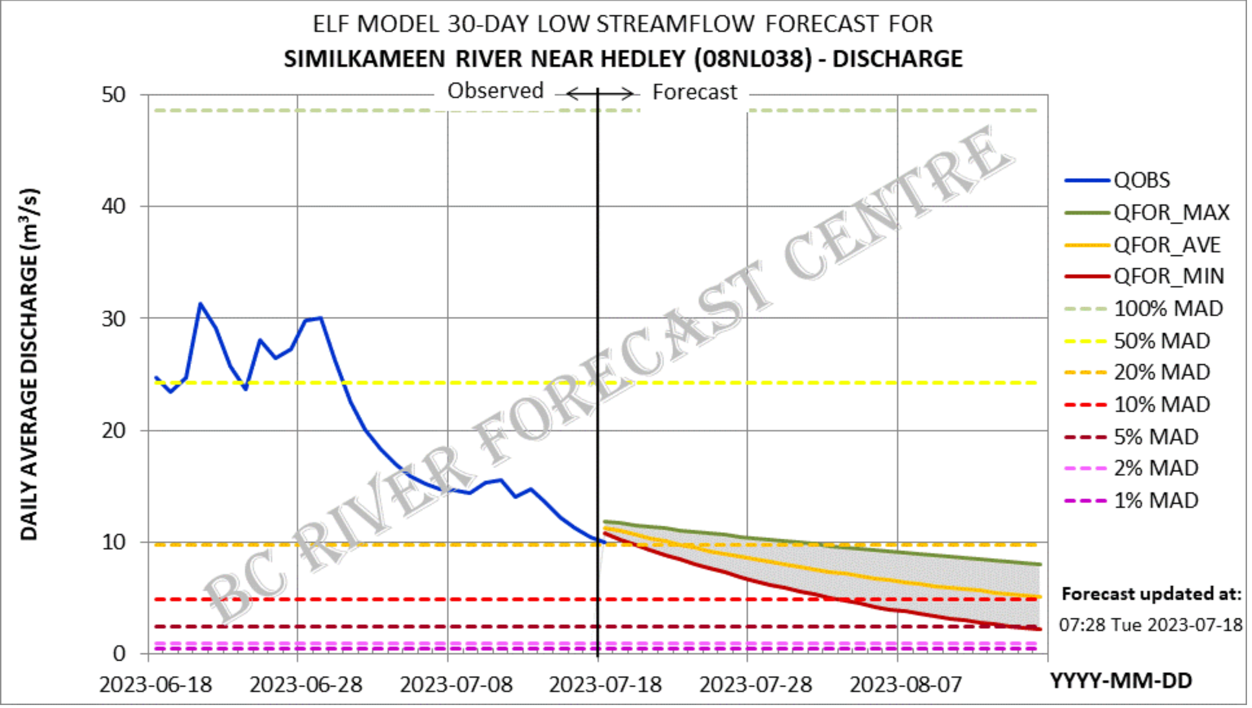


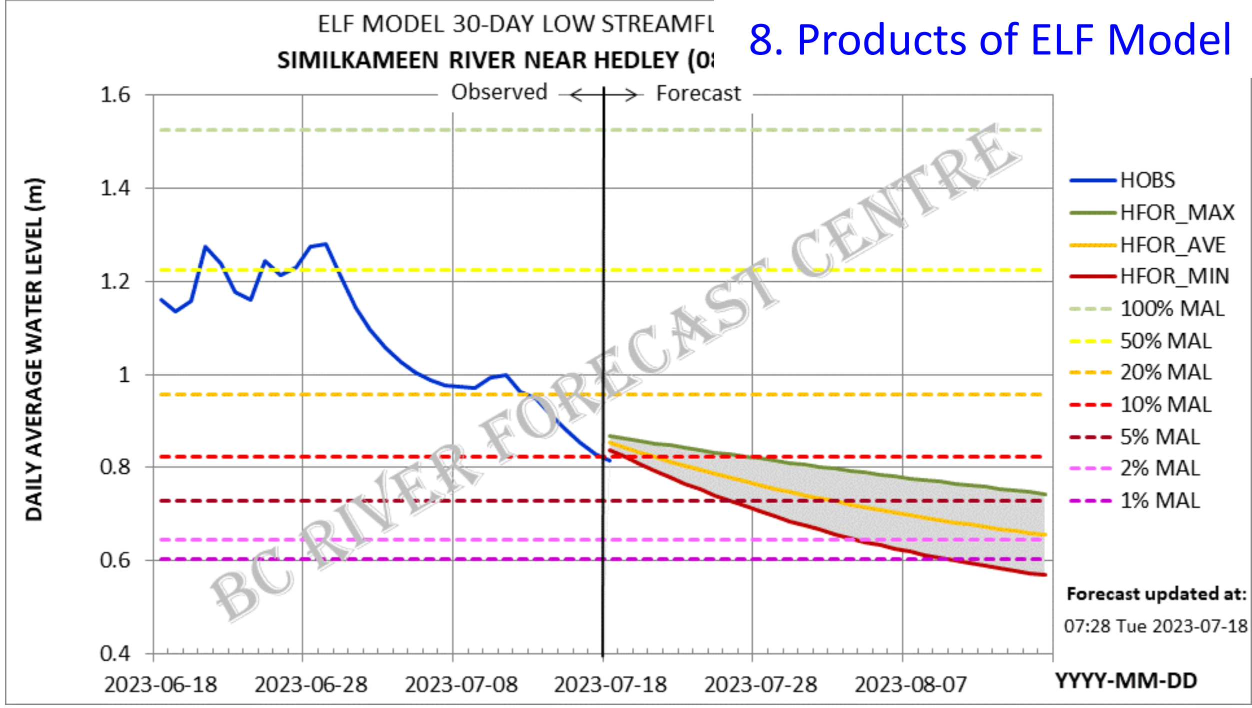


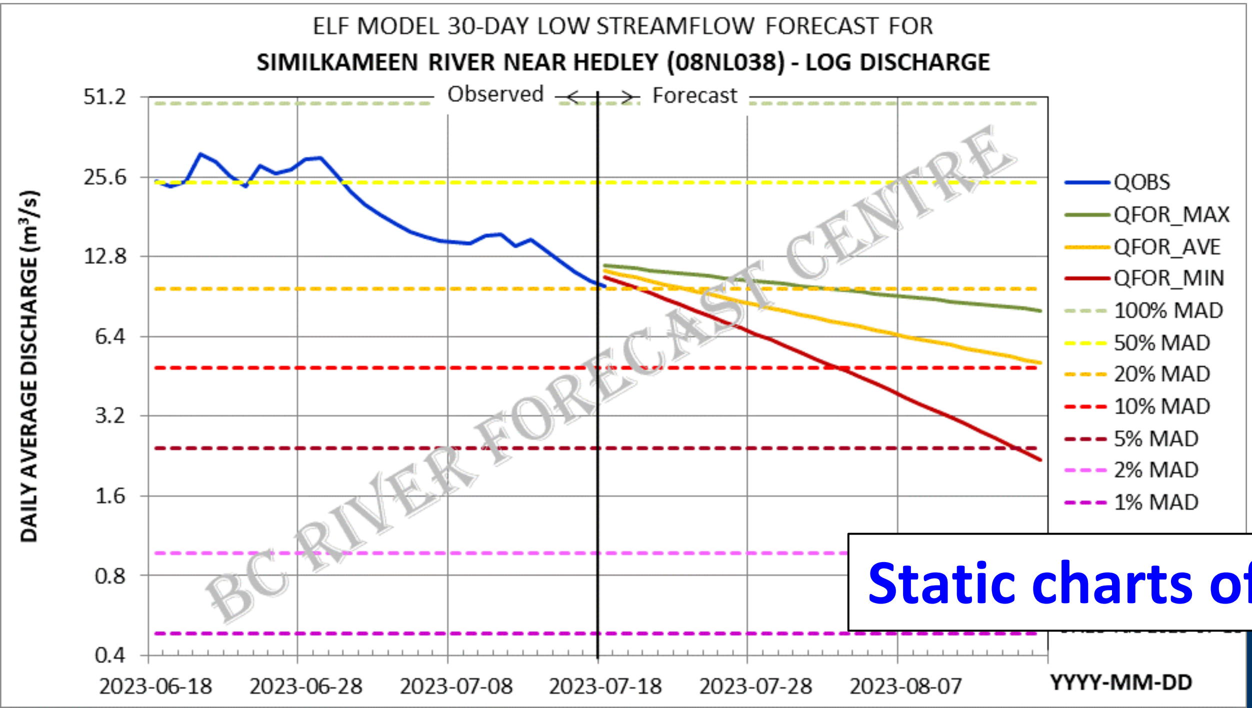


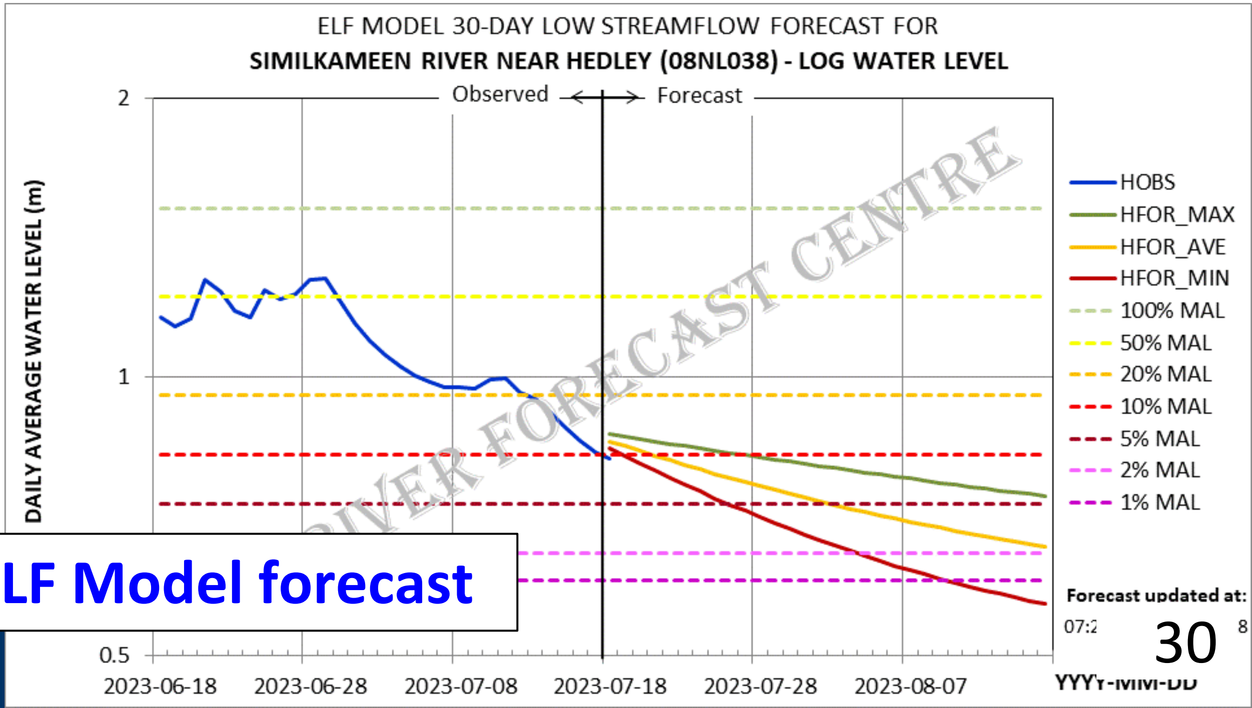
Interactive charts of ELF Model forecast

8. Products of ELF Model



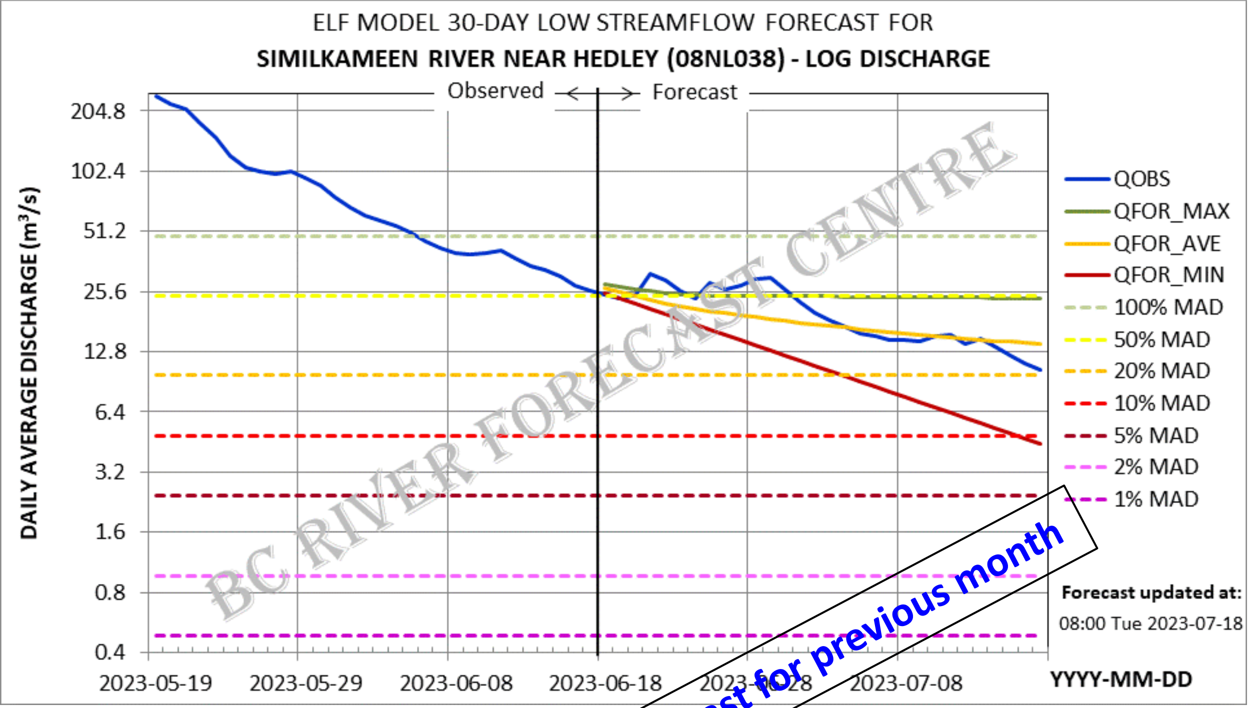


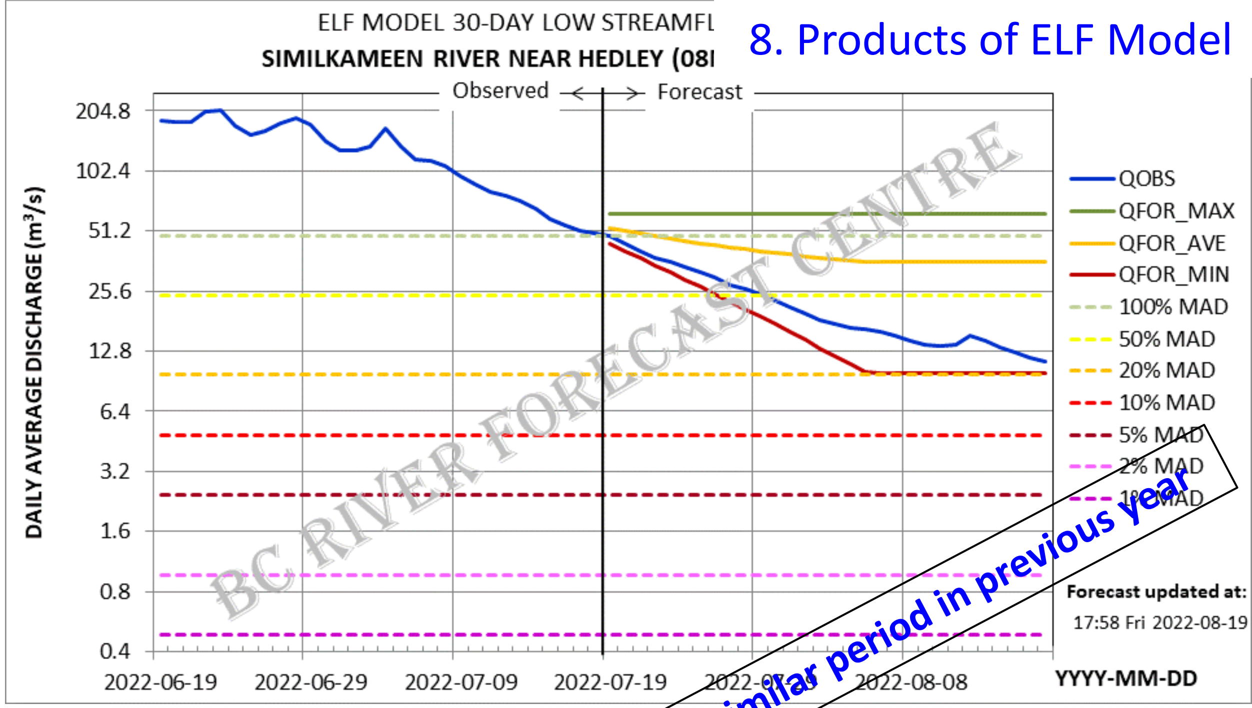


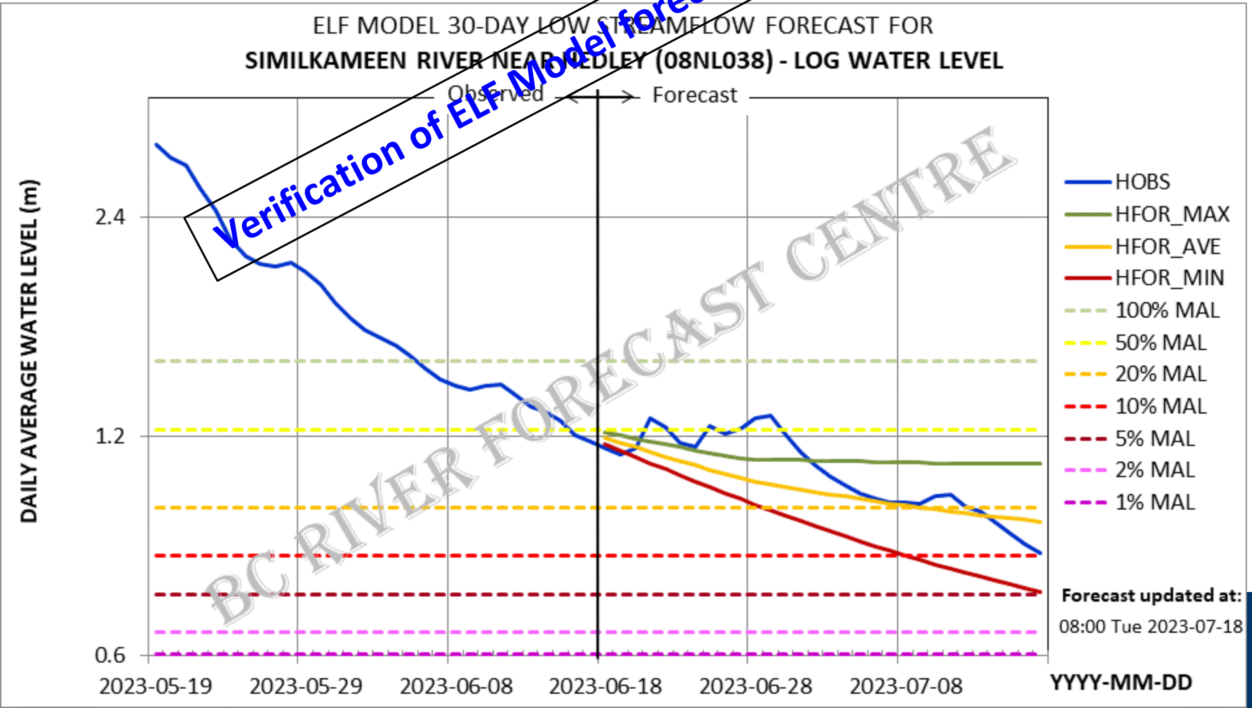


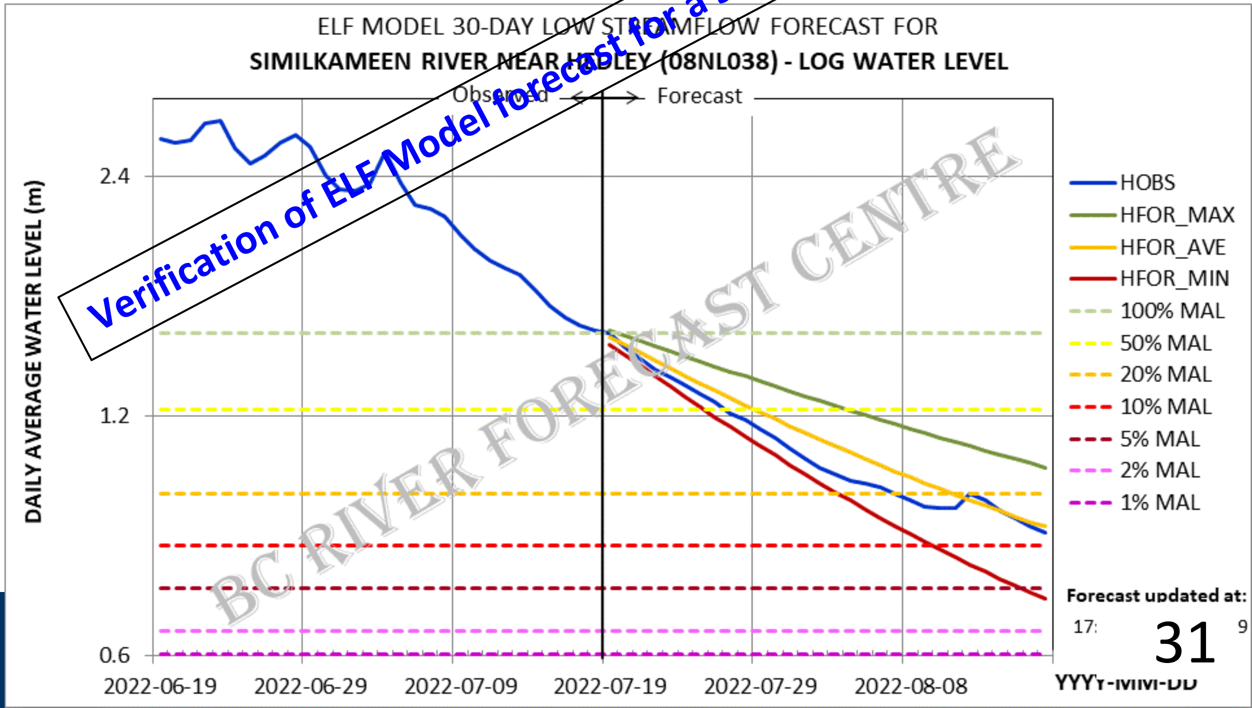
Static charts of ELF Model forecast

8. Products of ELF Model

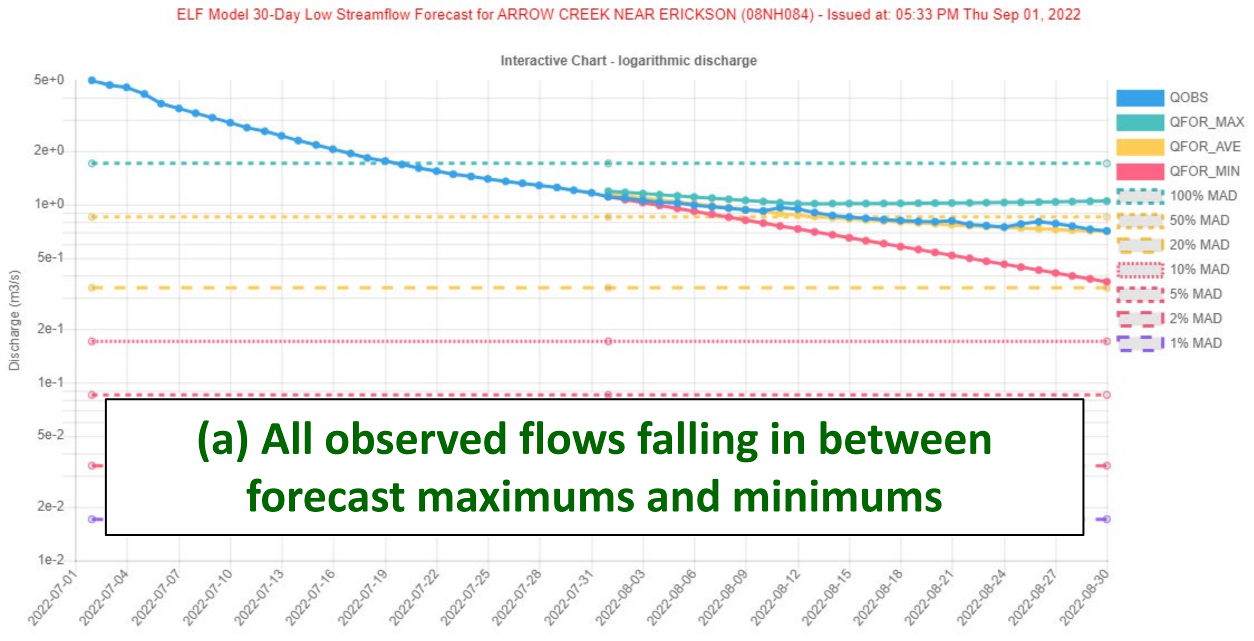


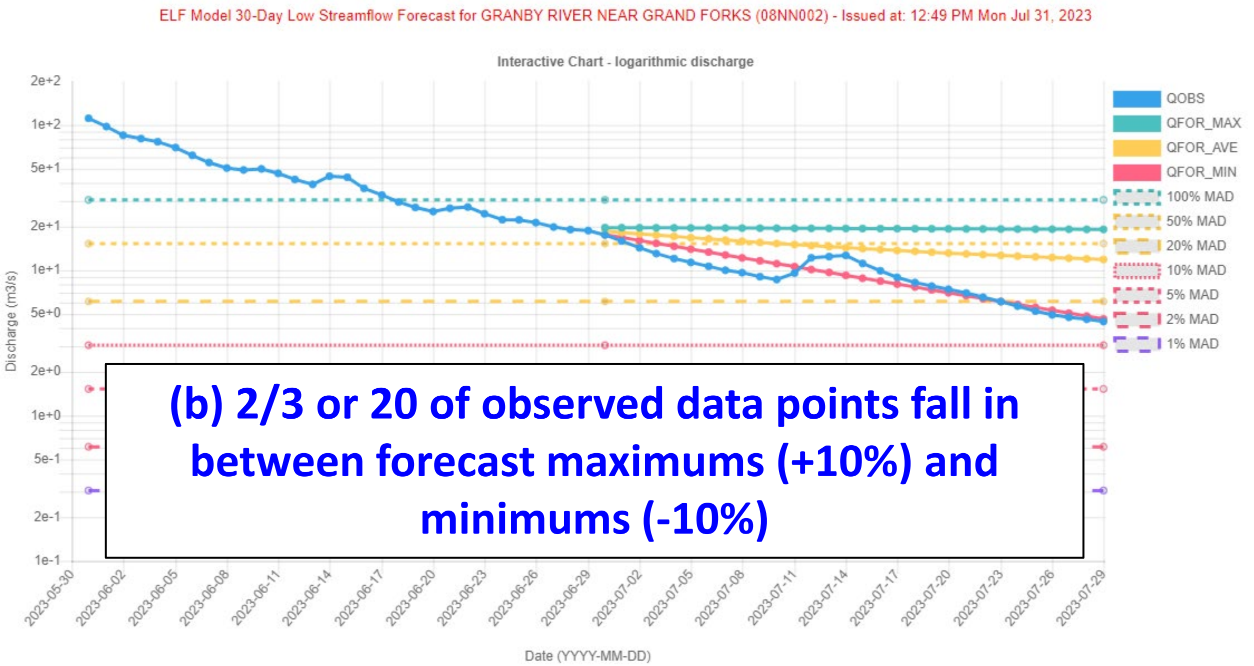


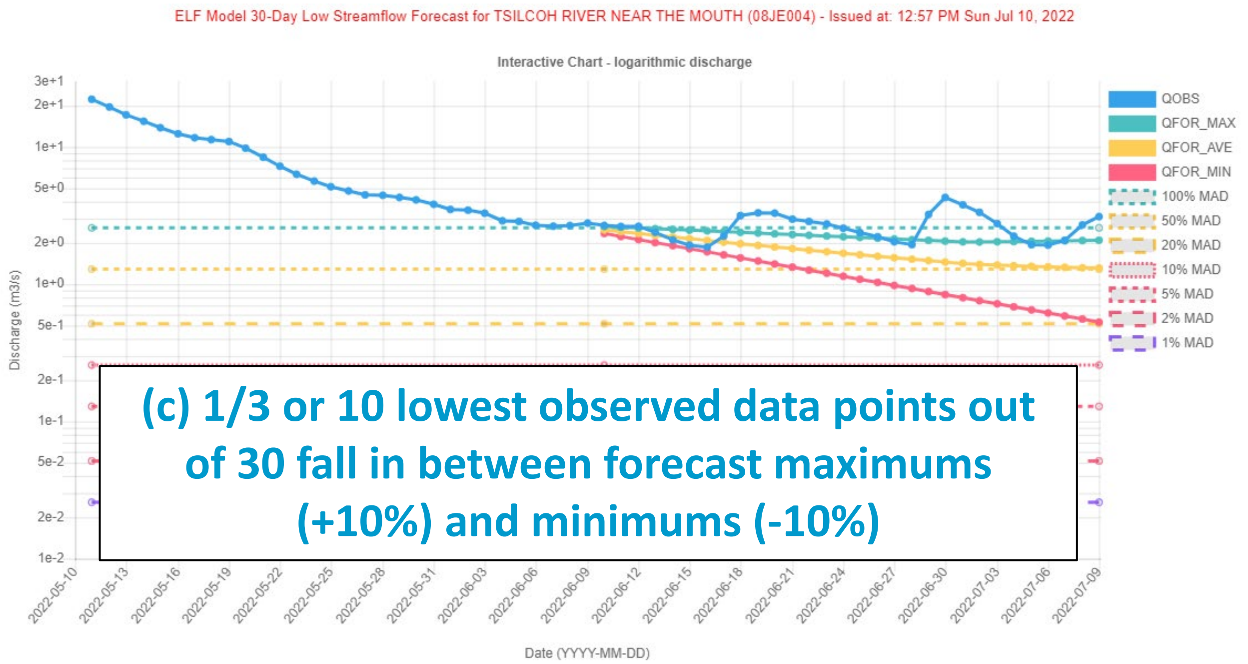


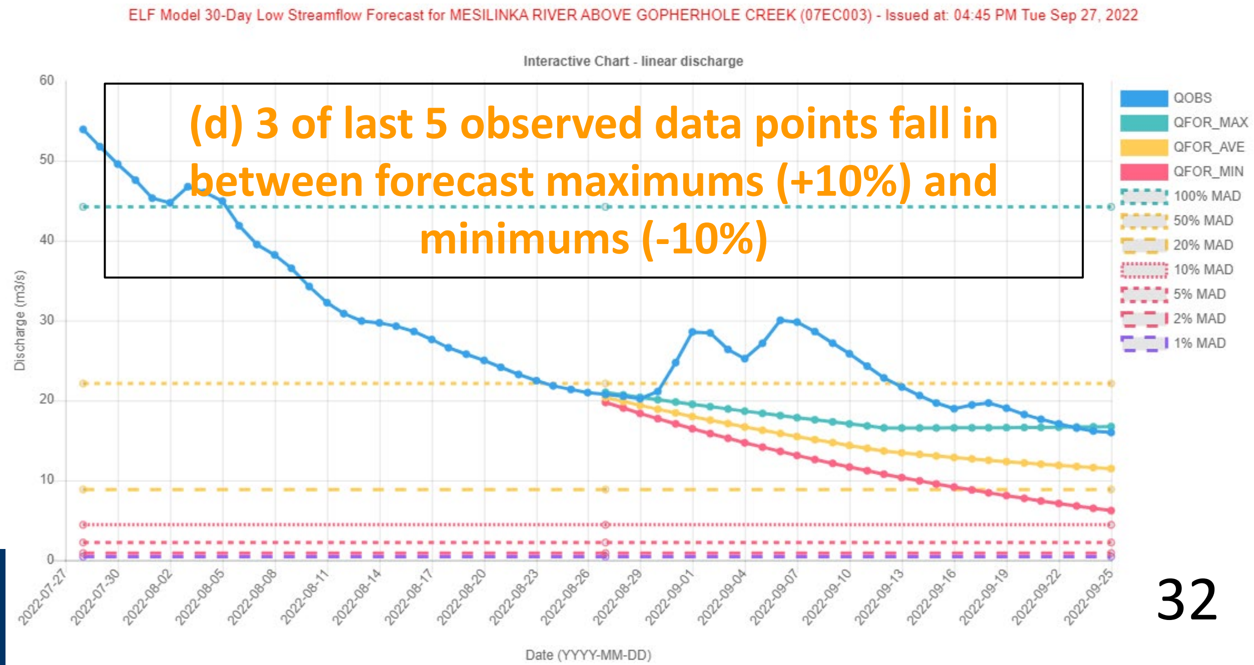


9. Evaluation of ELF Model forecast accuracy









Reconstructed forecasts from January 2015 to June 2018

+

ELF Model started operational forecasting as July 2018

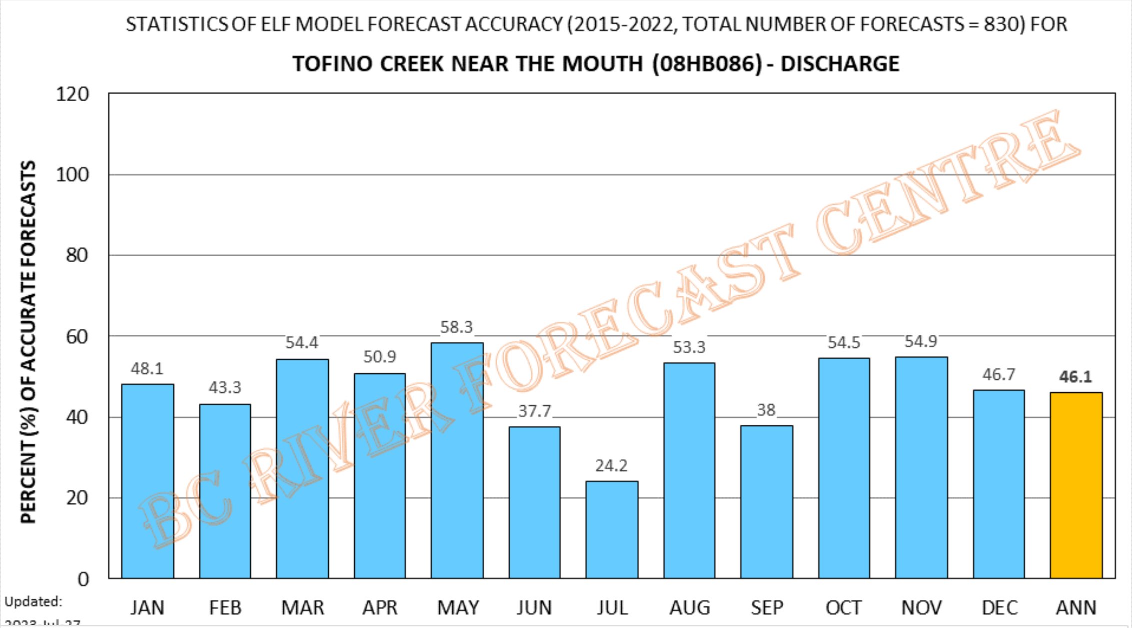
To the end of 2022

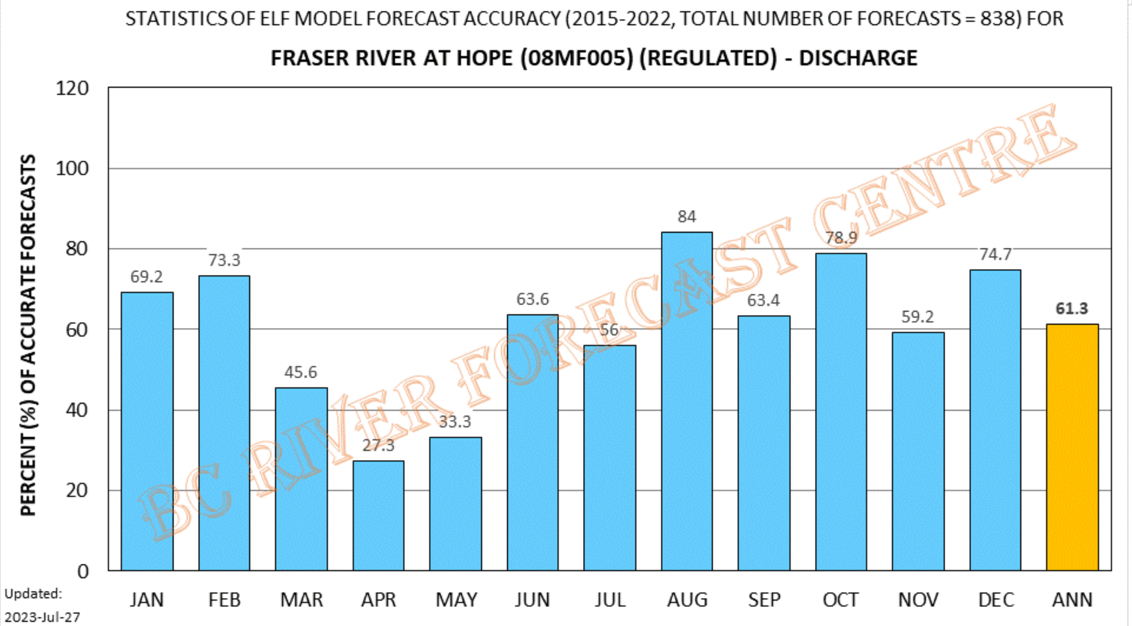
Eight (8) years of forecasts (800) for about 440 stations: 800x440 = 352,000 files of forecasts to open and read for a statistical analysis

Consuming 40 hours of computing time of this server after program optimized.

9. Evaluation of ELF Model forecast accuracy

STATION ID	STATION NAME	PERCENT (%) OF ELF MODEL ACCURATE FORECASTS FOR DISCHARGES													TTL NO OF FOR
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	
08HB086	TOFINO CREEK NEAR THE MOUTH	48.1	43.3	54.4	50.9	58.3	37.7	24.2	53.3	38.0	54.5	54.9	46.7	46.1	830
08GB013	CLOWHOM RIVER NEAR CLOWHOM LAKE	48.1	60.0	49.1	29.1	40.3	64.9	57.1	49.3	53.7	46.5	57.7	76.0	53.5	838
08MH147	STAVE RIVER ABOVE STAVE LAKE	55.8	55.0	54.4	25.5	38.9	57.1	59.3	53.3	57.3	59.2	63.4	76.0	55.4	838
08GF007	WAKEMAN RIVER BELOW ATWAYKELLESSE RIVER	53.8	63.3	49.1	36.4	38.9	68.8	69.2	62.7	58.5	35.2	56.3	69.3	56.1	838
08GA071	ELAHO RIVER NEAR THE MOUTH	65.4	56.7	28.1	14.5	30.6	54.5	61.5	41.3	57.3	64.8	76.1	78.7	53.6	838
08GE002	KLINAKLINI RIVER EAST CHANNEL (MAIN) NEAR THE MOUTH	63.5	73.3	49.1	10.9	27.8	33.8	71.4	61.3	52.4	73.2	69.0	61.3	54.7	838
08CG001	ISKUT RIVER BELOW JOHNSON RIVER	51.9	50.9	70.6	14.8	15.3	61.0	58.2	60.0	65.9	64.8	57.7	54.7	52.9	824
08DB001	NASS RIVER ABOVE SHUMAL CREEK	75.0	63.3	52.6	10.9	30.6	61.0	57.1	64.0	65.9	53.5	57.7	78.7	56.6	838
08CE001	STIKINE RIVER AT TELEGRAPH CREEK	59.6	66.7	86.0	12.2	15.3	54.5	65.9	37.3	52.4	50.7	63.4	36.0	50.2	832
08EF001	SKEENA RIVER AT USK	61.5	66.7	52.6	9.1	29.2	55.8	75.8	62.7	59.8	64.8	69.0	56.0	56.4	838
08NJ026	DUHAMEL CREEK ABOVE DIVERSIONS	71.2	61.7	22.8	9.1	25.0	36.4	70.3	82.7	63.4	53.5	52.1	74.7	53.3	838
08NG077	ST. MARY RIVER BELOW MORRIS CREEK	82.1	54.5	54.5	16.7	46.7	35.9	76.1	86.0	34.5	69.6	59.6	51.0	56.0	493
08NF001	KOOTENAY RIVER AT KOOTENAY CROSSING	73.1	60.0	60.0	14.5	33.3	51.9	68.1	76.0	62.2	78.9	67.6	58.7	59.4	836
08NG002	BULL RIVER NEAR WARDNER	67.3	70.0	24.6	12.7	51.4	46.8	76.9	93.3	70.7	67.6	67.6	82.7	62.9	838
08NN026	KETTLE RIVER NEAR WESTBRIDGE	75.0	60.0	20.0	9.4	33.3	51.9	65.9	80.0	46.3	46.5	53.5	66.7	52.0	834
08NL038	SIMILKAMEEN RIVER NEAR HEDLEY	42.3	53.3	38.6	14.5	43.1	50.6	80.2	86.7	50.0	38.0	42.3	54.7	51.4	838
08NG065	KOOTENAY RIVER AT FORT STEELE	71.2	63.3	59.6	12.7	29.2	53.2	75.8	89.3	69.5	74.6	67.6	64.0	62.1	838
08LF051	THOMPSON RIVER NEAR SPENCES BRIDGE	78.8	82.1	64.9	18.2	37.5	59.7	52.7	88.0	61.0	76.1	70.4	88.0	64.9	834
08MC018	FRASER RIVER NEAR MARGUERITE	71.2	51.7	59.3	28.3	47.2	59.7	68.1	80.0	62.2	59.2	62.0	78.7	61.6	833
08MF005	FRASER RIVER AT HOPE	69.2	73.3	45.6	27.3	33.3	63.6	56.0	84.0	63.4	78.9	59.2	74.7	61.3	838





Top ranked 50 stations ELF Model has largest annual percent of accurate forecasts

A. Forecasts for water levels better than for discharges.
B. Many lake stations included in the top ranked 50 stations.
C. More interior stations than coastal stations include in the top ranked 50 stations.

Forecast for discharges

RK	STATION ID	STATION NAME	PERCENT (%) OF ELF MODEL ACCURATE FORECASTS FOR DISCHARGES													
			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	JL+AG
1	08JE001	STUART RIVER NEAR FORT ST. JAM	92	98	91	13	3	62	81	99	100	94	93	97	77.8	90.0
2	08EC013	BABINE RIVER AT OUTLET OF NILK	92	93	83	16	39	68	88	88	93	78	85	91	77.0	88.0
3	08HD021	QUINSAM RIVER AT ARGONAUT B	71	83	95	55	71	82	88	93	83	41	61	51	73.2	90.6
4	08JB002	STELLAKO RIVER AT GLENANNAN	90	88	84	16	46	68	64	89	89	69	73	91	72.7	76.5
5	08ME029	BRIDGE RIVER BELOW LAJOIE DAN	79	86	91	70	48	64	80	70	31	60	89	100	70.8	74.9
6	08NK022	LINE CREEK AT THE MOUTH	79	69	73	32	35	53	82	88	95	83	66	75	70.6	85.0
7	10BE009	TEETER CREEK NEAR THE MOUTH	84	72	71	42	61	69	75	72	63	65	66	79	68.3	73.4
8	08NM002	OKANAGAN RIVER AT OKANAGAN	75	40	58	69	50	69	62	65	76	82	85	79	67.7	63.4
9	08LE108	EAST CANOE CREEK ABOVE DAM	64	69	27	13	67	85	77	96	60	76	68	69	67.5	86.7
10	09AA001	ATLIN LAKE AT ATLIN	91	93	100	100	18	0	34	77	60	79	98	88	67.5	55.6
11	08LF033	THOMPSON RIVER NEAR SAVONA	0	100	56	50	21	64	54	100	67	86	90	88	67.3	76.9
12	08NM085	OKANAGAN RIVER NEAR OLIVER	71	48	61	56	51	68	68	64	71	78	85	77	67.1	66.1
13	09AA013	TUTSHI RIVER AT OUTLET OF TUTS	75	92	81	64	15	52	68	75	66	63	83	79	67.0	71.4
14	08NM247	OKANAGAN RIVER BELOW MCINT	69	45	63	64	63	61	63	67	66	75	85	81	66.9	64.7
15	08LD001	ADAMS RIVER NEAR SQUILAX	96	90	70	18	21	62	56	93	73	78	63	83	66.8	74.7
16	08LB024	FISHTRAP CREEK NEAR MCLURE	61	67	42	31	79	74	76	84	64	72	55	67	66.7	80.1
17	08JB003	NAUTLEY RIVER NEAR FORT FRASE	65	83	51	9	50	68	70	91	95	63	63	67	66.3	80.5
18	08MH024	FRASER RIVER AT MISSION	75	73	79	35	38	57	58	91	78	75	69	63	65.9	74.5
19	08LE031	SOUTH THOMPSON RIVER AT CHA	83	78	68	29	17	57	59	93	84	79	59	79	65.8	76.3
20	08EE020	TELKWA RIVER BELOW TSAI CREEK	89	83	75	11	24	68	70	65	77	65	73	84	65.8	67.8
21	08ME002	CAYOOSH CREEK NEAR LILLOOET	75	68	75	47	29	51	58	73	81	78	72	79	65.4	65.8
22	08MH005	ALOUETTE RIVER NEAR HANEY	48	65	65	47	60	68	97	92	67	55	47	55	65.3	94.4
23	08NH016	DUCK CREEK NEAR WYNNDEL	87	67	55	25	30	42	79	81	82	54	80	90	65.3	80.0
24	08NK018	FORDING RIVER AT THE MOUTH	79	78	70	15	26	49	75	76	87	87	65	65	65.2	75.4
25	08LF051	THOMPSON RIVER NEAR SPENCES	79	82	65	18	38	60	53	88	61	76	70	88	64.9	70.4
26	08NH084	ARROW CREEK NEAR ERICKSON	67	68	42	22	29	57	88	89	76	68	66	83	64.8	88.6
27	10BE013	SMITH RIVER NEAR THE MOUTH	80	53	52	62	80	68	85	68	85	63	27	43	64.8	76.3
28	08KH006	QUESNEL RIVER NEAR QUESNEL	79	67	60	24	39	71	55	92	62	73	69	80	64.7	73.5
29	08JA017	NECHAKO RIVER BELOW CHESLAT	85	87	68	36	54	68	43	35	79	65	73	89	64.6	38.8
30	07ED001	NATION RIVER NEAR FORT ST. JAM	0	38	100	63	7	9	77	100	100	100	90	63	64.5	88.5
31	08ME025	YALAKOM RIVER ABOVE ORE CREE	55	71	93	23	27	48	70	83	81	83	64	65	64.4	76.1
32	08KA007	FRASER RIVER AT RED PASS	94	88	83	29	14	48	63	79	56	75	68	84	64.2	70.7
33	08ME003	SETON RIVER NEAR LILLOOET	94	78	84	46	56	47	52	60	31	85	90	69	64.2	55.8
34	08KH001	QUESNEL RIVER AT LIKELY	89	90	65	27	21	62	50	92	66	69	58	85	64.1	70.8
35	08LF099	ARROWSTONE CREEK NEAR THE M	71	93	50	23	63	43	67	57	86	59	76	75	64.1	61.8
36	08NK016	ELK RIVER NEAR NATAL	73	67	67	12	18	43	73	83	94	93	63	65	64.0	78.0
37	08NM037	SHATFORD CREEK NEAR PENTICTO	92	82	43	15	29	49	84	91	57	49	79	87	63.9	87.1
38	08NM050	OKANAGAN RIVER AT PENTICTON	64	42	67	75	42	64	67	69	65	55	82	73	63.7	68.2
39	08NB016	SPLIT CREEK AT THE MOUTH	93	89	91	45	19	49	44	78	66	78	57	82	63.7	61.2
40	08NL076	EWART CREEK NEAR CATHEDRAL P	87	83	69	4	27	49	72	88	59	60	74	84	63.6	80.1
41	08LC002	SHUSWAP RIVER NEAR ENDERBY	94	80	51	29	22	44	64	89	70	70	65	81	63.4	76.5
42	08MG001	CHEHALIS RIVER NEAR HARRISON	80	50	67	63	29	36	85	100	80	43	40	72	63.3	92.3
43	07FD01[illegible]	PEACE RIVER ABOVE ALCES RIVER	60	67	72	[illegible]	50	[illegible]	65	65	61	62	72	79	63.2	65.1
44	08LC00[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	73	66	78	73	91	63.1	67.4
45	08MF040	FRASER RIVER ABOVE TEXAS CREE	73	67	51	26	40	69	65	84	[illegible]	82	62	64	63.0	74.4
46	08NG002	BULL RIVER NEAR WARDNER	67	70	25	13	51	47	77	93	71	68	68	83	62.9	85.1
47	08HD005	QUINSAM RIVER NEAR CAMPBELL	52	58	72	75	76	70	84	85	45	39	49	45	62.9	84.4
48	08NJ160	LEMON CREEK ABOVE SOUTH LEM	81	65	68	9	25	43	85	84	59	70	73	81	62.9	84.3
49	08NH005	KASLO RIVER BELOW KEMP CREEK	87	65	51	11	26	47	70	85	60	80	75	87	62.8	77.8
50	08LC018	SHUSWAP RIVER AT OUTLET OF SU	96	63	63	29	21	46	53	75	65	78	79	91	62.8	63.7

Forecast for water levels

RK	STATION ID	STATION NAME	PERCENT (%) OF ELF MODEL ACCURATE FORECASTS FOR WATER LEVELS													
			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	JL+AG
1	08NM084	SKAHA LAKE AT OKANAGAN FALLS	100	98	98	87	94	83	98	99	94	100	100	100	95.9	98.3
2	08NM143	KALAMALKA LAKE AT VERNON PUM	100	100	98	78	68	92	93	100	96	97	100	100	93.7	96.7
3	08EC003	BABINE LAKE AT TOPLEY LANDING	100	82	91	38	40	70	90	99	93	100	99	100	84.1	94.4
4	08NM083	OKANAGAN LAKE AT KELOWNA	100	83	86	40	38	77	80	97	100	97	99	100	83.7	88.8
5	08NL076	EWART CREEK NEAR CATHEDRAL PA	98	87	92	33	50	66	81	99	84	88	95	97	81.2	89.9
6	08LF099	ARROWSTONE CREEK NEAR THE M	82	89	61	48	71	70	86	67	98	96	92	90	80.7	76.6
7	08HD021	QUINSAM RIVER AT ARGONAUT BR	85	83	97	56	78	91	95	97	90	51	69	60	79.8	95.9
8	08JB007	NADINA LAKE NEAR NORALEE	100	90	84	40	53	79	84	89	78	68	78	84	77.3	86.4
9	08LG046	NICOLA LAKE NEAR NICOLA	100	60	75	44	26	84	62	87	100	92	93	99	77.2	74.1
10	08EC001	BABINE RIVER AT BABINE	90	100	93	24	38	66	87	88	89	75	80	87	76.8	87.4
11	10BE009	TEETER CREEK NEAR THE MOUTH	88	78	86	56	71	79	78	77	83	80	68	76	76.8	77.7
12	08NB016	SPLIT CREEK AT THE MOUTH	86	89	100	55	35	83	55	84	90	80	89	82	76.5	69.4
13	08GE003	ICY CREEK NEAR THE MOUTH	83	80	74	49	71	69	97	73	79	76	69	77	75.5	85.0
14	08JB003	NAUTLEY RIVER NEAR FORT FRASE	75	90	58	24	67	74	80	97	96	70	70	75	74.6	88.8
15	08NM002	OKANAGAN RIVER AT OKANAGAN F	77	55	65	73	61	78	77	72	76	86	85	81	74.2	74.5
16	08NK022	LINE CREEK AT THE MOUTH	71	61	82	32	35	59	92	86	100	91	77	67	73.4	89.4
17	08JB002	STELLAKO RIVER AT GLENANNAN	83	87	63	18	54	75	76	89	85	61	70	83	71.5	82.6
18	08MH005	ALOUETTE RIVER NEAR HANEY	54	67	75	58	67	70	95	97	78	66	49	63	71.2	95.9
19	08NL050	HEDLEY CREEK NEAR THE MOUTH	89	85	69	35	74	71	79	85	63	56	75	68	71.0	82.2
20	08LG008	SPIUS CREEK NEAR CANFORD	80	69	82	51	44	65	79	93	75	65	63	78	70.6	85.8
21	08KG001	WEST ROAD RIVER NEAR CINEMA	81	89	62	34	61	71	66	90	69	79	63	78	70.3	78.1
22	08ME029	BRIDGE RIVER BELOW LAJOIE DAM	65	74	72	68	39	75	90	84	31	55	87	98	70.1	87.3
23	08NM065	VERNON CREEK AT OUTLET OF KAL	77	83	77	62	39	79	63	67	66	73	78	83	70.0	64.7
24	08NG002	BULL RIVER NEAR WARDNER	67	73	44	22	53	53	80	96	84	76	79	85	69.6	88.1
25	08NK030	ELK RIVER BELOW ELKO DAM	75	57	61	35	44	52	80	93	89	85	75	73	69.6	86.8
26	08NM050	OKANAGAN RIVER AT PENTICTON	73	50	72	75	50	73	68	75	68	69	80	77	69.2	71.4
27	08LF002	BONAPARTE RIVER BELOW CACHE (	77	65	53	46	71	46	70	89	84	89	69	63	69.1	79.8
28	07FA003	HALFWAY RIVER ABOVE GRAHAM I	83	74	77	67	39	73	76	80	87	83	30	63	69.1	77.9
29	08NM243	VASEUX LAKE NEAR THE OUTLET	81	77	81	55	60	64	74	48	63	63	83	85	69.1	60.8
30	08LE108	EAST CANOE CREEK ABOVE DAM	68	75	39	13	67	79	77	90	69	65	57	88	68.6	83.8
31	08JA023	NECHAKO RESERVOIR AT SKINS LAK	100	88	79	53	1	35	42	96	89	78	89	85	68.3	68.9
32	08HB084	PUNTLEDGE RIVER BELOW DIVERS	38	69	69	61	83	86	75	70	41	70	64	78	67.9	72.3
33	08LF027	DEADMAN RIVER ABOVE CRISS CRE	70	69	67	29	56	72	53	86	93	72	74	64	67.8	69.2
34	08NM171	VASEUX CREEK ABOVE SOLCO CREE	87	67	51	35	51	62	77	75	73	65	78	83	67.7	75.8
35	07FB009	FLATBED CREEK AT KILOMETRE 110	75	63	74	38	63	58	78	80	73	69	72	60	67.5	79.0
36	08NM200	INKANEEP CREEK NEAR THE MOUTH	73	73	44	46	74	57	74	84	51	61	83	84	67.5	78.8
37	08MH168	OR CREEK NEAR COQUITLAM	50	68	65	75	62	73	85	85	52	65	62	60	67.4	85.0
38	08NM085	OKANAGAN RIVER NEAR OLIVER	73	58	63	60	50	69	68	63	66	78	83	76	67.4	65.4
39	08HD022	CAMPBELL RIVER AT CAMPBELL RIV	0	88	89	63	93	64	85	70	56	14	60	25	67.3	77.3
40	08HA016	BINGS CREEK NEAR THE MOUTH	52	63	74	86	96	77	91	81	52	39	52	39	67.2	86.3
41	08HF004	TSITIKA RIVER BELOW CATHERINE	63	67	60	58	73	71	79	89	57	53	64	64	67.1	83.7
42	08NM174	WHITEMAN CREEK ABOVE BOULEA	73	70	53	38	58	62	60	87	74	73	72	76	67.1	73.6
43	08KA007	FRASER RIVER AT RED PASS	96	90	88	35	19	51	67	[illegible]	59	69	[illegible]	88	67.1	72.9
44	08EC013	[illegible]	[illegible]	[illegible]	60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	80	66.9	80.9
45	08JE001	STUART RIVER NEAR FORT ST. JAM	87	88	79	11	1	46	55	96	93	80	80	84	66.8	75.5
46	08ME003	SETON RIVER NEAR LILLOOET	96	78	86	51	60	57	54	64	31	83	90	72	66.8	58.9
47	08NM037	SHATFORD CREEK NEAR PENTICTON	90	80	49	25	46	52	80	89	56	62	81	83	66.7	84.8
48	08NK016	ELK RIVER NEAR NATAL	65	69	56	12	38	59	79	87	96	93	54	65	66.6	82.9
49	08HD027	QUINSAM RIVER BELOW LOWER Q	46	67	72	76	89	70	80	72	52	58	59	51	66.3	76.1
50	08ME002	CAYOOSH CREEK NEAR LILLOOET	81	72	74	47	31	60	59	71	72	78	76	79	66.2	65.0

Top ranked 50 stations ELF Model has largest Jul + Aug percent of accurate forecasts

A. Forecasts for water levels better than for discharges.
B. Many lake stations included in the top ranked 50 stations.
C. More interior stations than coastal stations include in the top ranked 50 stations.

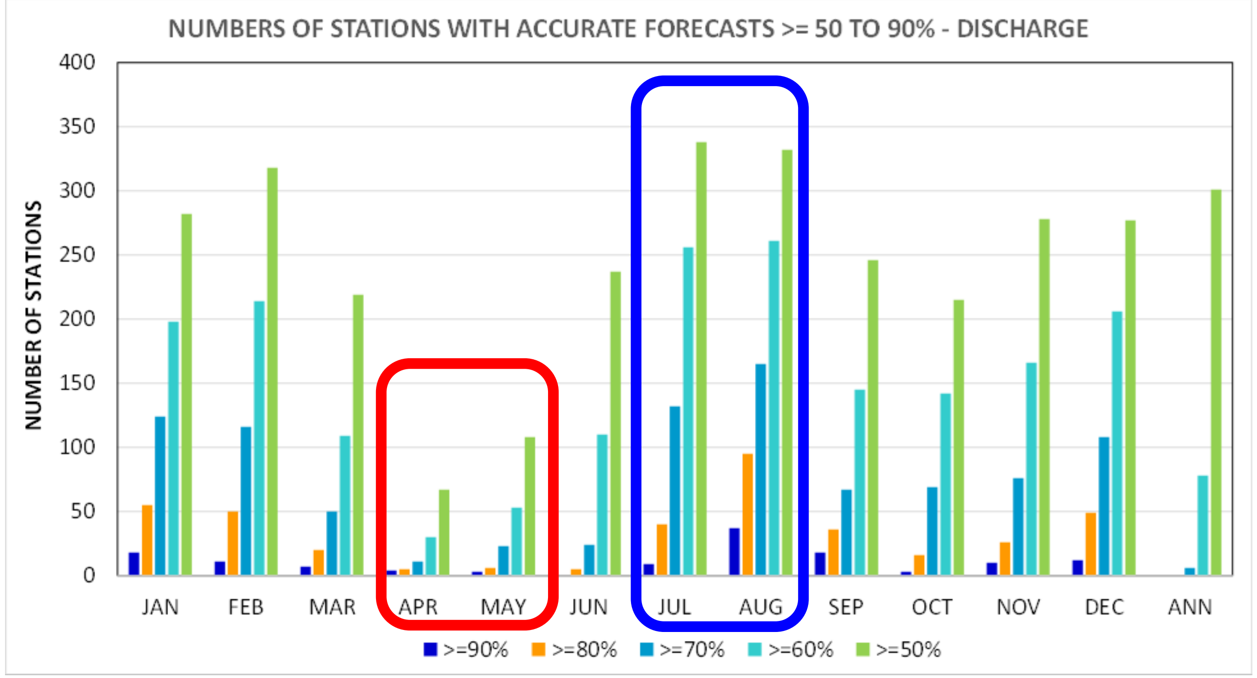
Forecast for discharges

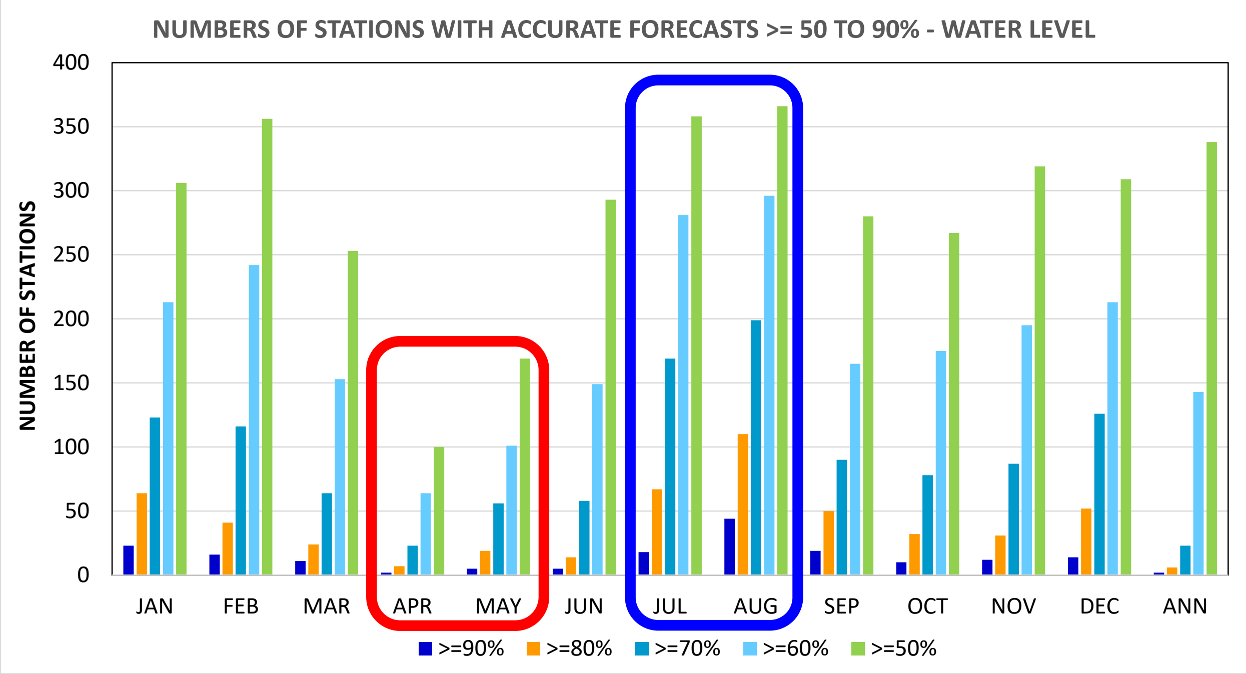
RK	STATION ID	STATION NAME	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	JL+AG
			PERCENT (%) OF ELF MODEL ACCURATE FORECASTS FOR DISCHARGES													
1	08MH005	ALOUETTE RIVER NEAR HANEY	48	65	65	47	60	68	97	92	67	55	47	55	65.3	94.4
2	08NE039	BIG SHEEP CREEK NEAR ROSSLAND	65	38	20	9	33	62	86	100	71	58	68	70	59.9	93.1
3	08MG001	CHEHALIS RIVER NEAR HARRISON	80	50	67	63	29	36	85	100	80	43	40	72	63.3	92.3
4	08NE130	WHATSHAN RIVER BELOW BARNE	0	75	44	13	0	0	85	100	22	86	60	75	48.6	92.3
5	08HD021	QUINSAM RIVER AT ARGONAUT B	71	83	95	55	71	82	88	93	83	41	61	51	73.2	90.6
6	08JE001	STUART RIVER NEAR FORT ST. JAM	92	98	91	13	3	62	81	99	100	94	93	97	77.8	90.0
7	08NH084	ARROW CREEK NEAR ERICKSON	67	68	42	22	29	57	88	89	76	68	66	83	64.8	88.6
8	07ED001	NATION RIVER NEAR FORT ST. JAM	0	38	100	63	7	9	77	100	100	100	90	63	64.5	88.5
9	08HA002	COWICHAN RIVER AT LAKE COWI	40	57	63	49	51	46	79	97	57	23	56	39	55.7	88.2
10	08EC013	BABINE RIVER AT OUTLET OF NILK	92	93	83	16	39	68	88	88	93	78	85	91	77.0	88.0
11	08NM037	SHATFORD CREEK NEAR PENTICTO	92	82	43	15	29	49	84	91	57	49	79	87	63.9	87.1
12	08NL070	SIMILKAMEEN RIVER ABOVE GOO	75	75	60	9	23	49	85	89	51	44	63	73	59.2	86.9
13	08LE108	EAST CANOE CREEK ABOVE DAM	64	69	27	13	67	85	77	96	60	76	68	69	67.5	86.7
14	08MF062	COQUIHALLA RIVER BELOW NEED	58	73	58	12	32	45	85	87	49	22	63	65	55.3	86.1
15	08NG002	BULL RIVER NEAR WARDNER	67	70	25	13	51	47	77	93	71	68	68	83	62.9	85.1
16	08NK022	LINE CREEK AT THE MOUTH	79	69	73	32	35	53	82	88	95	83	66	75	70.6	85.0
17	10AB001	FRANCES RIVER NEAR WATSON LA	38	100	67	25	0	18	100	70	67	57	10	35	46.8	85.0
18	08NE087	DEER CREEK AT DEER PARK	75	57	11	8	41	49	70	100	61	46	56	78	56.9	84.8
19	08GB014	HORSESHOE RIVER ABOVE LOIS LA	40	70	58	58	74	70	81	88	48	32	45	53	60.7	84.7
20	08HD005	QUINSAM RIVER NEAR CAMPBELL	52	58	72	75	76	70	84	85	45	39	49	45	62.9	84.4
21	08NJ160	LEMON CREEK ABOVE SOUTH LEM	81	65	68	9	25	43	85	84	59	70	73	81	62.9	84.3
22	08NE074	SALMO RIVER NEAR SALMO	79	60	25	11	36	48	87	81	51	54	62	65	56.4	84.1
23	08NH139	MOYIE RIVER ABOVE NOKE CREEK	89	73	48	12	27	39	91	76	61	36	64	63	58.7	83.8
24	08NE114	HIDDEN CREEK NEAR THE MOUTH	68	54	40	7	37	49	79	89	51	51	73	73	58.0	83.7
25	08LG016	PENNASK CREEK NEAR QUILCHENA	79	67	46	3	20	59	80	88	41	28	55	74	54.7	83.6
26	08NL038	SIMILKAMEEN RIVER NEAR HEDLE	42	53	39	15	43	51	80	87	50	38	42	55	51.4	83.5
27	08NM172	PEARSON CREEK NEAR THE MOUT	0	88	33	13	7	9	77	90	67	43	50	63	47.7	83.5
28	08NJ013	SLOCAN RIVER NEAR CRESCENT VA	83	68	46	13	32	53	68	97	62	68	58	80	61.6	82.7
29	08NK002	ELK RIVER AT FERNIE	42	57	33	18	32	46	81	84	84	82	68	59	59.5	82.7
30	08NG065	KOOTENAY RIVER AT FORT STEELE	71	63	60	13	29	53	76	89	70	75	68	64	62.1	82.6
31	08NG076	MATHER CREEK BELOW HOULE CR	78	54	39	21	50	45	84	81	66	61	58	70	60.7	82.3
32	08HB023	ASH RIVER BELOW MORAN CREEK	42	65	58	58	54	74	87	77	52	31	55	39	58.7	82.1
33	08NN023	BURRELL CREEK ABOVE GLOUCEST	70	70	28	8	39	27	73	91	37	31	43	49	48.0	82.1
34	08NG077	ST. MARY RIVER BELOW MORRIS	82	55	55	17	47	36	76	86	35	70	60	51	56.0	81.1
35	08JB003	NAUTLEY RIVER NEAR FORT FRASE	65	83	51	9	50	68	70	91	95	63	63	67	66.3	80.5
36	08HB034	NANAIMO RIVER NEAR CASSIDY	42	55	56	56	63	65	74	87	35	47	37	32	54.5	80.2
37	08LB024	FISHTRAP CREEK NEAR MCLURE	61	67	42	31	79	74	76	84	64	72	55	67	66.7	80.1
38	08NL076	EWART CREEK NEAR CATHEDRAL P	87	83	69	4	27	49	72	88	59	60	74	84	63.6	80.1
39	08MF068	COQUIHALLA RIVER ABOVE ALEXA	52	72	47	36	53	55	80	80	49	37	62	68	58.6	80.1
40	08NH016	DUCK CREEK NEAR WYNNDEL	87	67	55	25	30	42	79	81	82	54	80	90	65.3	80.0
41	08LB020	BARRIERE RIVER AT THE MOUTH	64	62	28	9	31	39	75	85	48	61	54	64	52.9	80.0
42	08NL007	SIMILKAMEEN RIVER AT PRINCETO	48	65	56	9	46	38	81	79	55	44	47	47	52.5	80.0
43	08GA04[illegible]	ROBERTS CREEK AT ROBERTS CREE	44	50	47	[illegible]	64	[illegible]	79	81	34	39	41	36	52.5	80.0
44	08LG01[illegible]	COLDWATER RIVER NEAR MERRIT	[illegible]	[illegible]	47	[illegible]	[illegible]	[illegible]	[illegible]	83	[illegible]	[illegible]	45	36	46.9	79.8
45	08HB022	NILE CREEK NEAR BOWSER	53	54	73	57	72	65	84	75	41	54	53	30	59.6	79.5
46	08LG048	COLDWATER RIVER NEAR BROOKI	56	71	48	16	39	39	77	81	29	35	47	56	50.3	79.1
47	08FB006	ATNARKO RIVER NEAR THE MOUT	89	78	67	7	24	58	66	92	62	62	66	67	61.8	79.0
48	08NL004	ASHNOLA RIVER NEAR KEREMEOS	46	54	39	4	29	54	75	83	66	63	55	68	55.4	79.0
49	08NN003	WEST KETTLE RIVER AT WESTBRID	44	50	13	15	51	36	68	89	46	48	59	45	49.1	78.7
50	08NH007	LARDEAU RIVER AT MARBLEHEAD	93	67	42	7	25	57	62	95	54	81	71	83	62.2	78.6

Forecast for water levels

RK	STATION ID	STATION NAME	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	JL+AG
			PERCENT (%) OF ELF MODEL ACCURATE FORECASTS FOR WATER LEVELS													
1	08MH156	PEPIN CREEK AT INTERNATIONAL B	0	0	0	0	79	73	100	100	100	57	50	63	69.3	100.0
2	08MH029	SUMAS RIVER NEAR HUNTINGDON	38	50	56	100	93	46	100	100	11	100	50	41	65.3	100.0
3	08NM084	SKAHA LAKE AT OKANAGAN FALLS	100	98	98	87	94	83	98	99	94	100	100	100	95.9	98.3
4	08NM143	KALAMALKA LAKE AT VERNON PUM	100	100	98	78	68	92	93	100	96	97	100	100	93.7	96.7
5	07ED001	NATION RIVER NEAR FORT ST. JAM	0	25	22	0	0	9	92	100	89	29	20	38	39.3	96.2
6	08HD021	QUINSAM RIVER AT ARGONAUT BR	85	83	97	56	78	91	95	97	90	51	69	60	79.8	95.9
7	08MH005	ALOUETTE RIVER NEAR HANEY	54	67	75	58	67	70	95	97	78	66	49	63	71.2	95.9
8	08EC003	BABINE LAKE AT TOPLEY LANDING	100	82	91	38	40	70	90	99	93	100	99	100	84.1	94.4
9	08NP003	HOWELL CREEK ABOVE CABIN CREE	68	53	49	13	35	60	100	89	95	52	57	82	65.5	94.3
10	08HA009	COWICHAN LAKE NEAR LAKE COWI	37	52	67	66	88	95	87	95	55	42	55	40	66.1	90.8
11	08NK002	ELK RIVER AT FERNIE	44	52	30	36	49	49	85	96	88	83	68	51	63.2	90.3
12	08NL076	EWART CREEK NEAR CATHEDRAL PA	98	87	92	33	50	66	81	99	84	88	95	97	81.2	89.9
13	08NE039	BIG SHEEP CREEK NEAR ROSSLAND	68	44	29	26	47	69	82	97	54	51	64	59	59.7	89.6
14	08NK022	LINE CREEK AT THE MOUTH	71	61	82	32	35	59	92	86	100	91	77	67	73.4	89.4
15	08NL069	PASAYTEN RIVER ABOVE CALCITE C	68	75	58	21	58	42	81	97	73	64	54	22	60.5	88.9
16	08NM083	OKANAGAN LAKE AT KELOWNA	100	83	86	40	38	77	80	97	100	97	99	100	83.7	88.8
17	08JB003	NAUTLEY RIVER NEAR FORT FRASE	75	90	58	24	67	74	80	97	96	70	70	75	74.6	88.8
18	08NE130	WHATSHAN RIVER BELOW BARNES	0	50	0	13	14	18	77	100	33	57	40	50	41.1	88.5
19	08NG002	BULL RIVER NEAR WARDNER	67	73	44	22	53	53	80	96	84	76	79	85	69.6	88.1
20	08NE114	HIDDEN CREEK NEAR THE MOUTH	70	58	36	29	52	55	79	97	60	59	66	79	63.7	87.7
21	08EC001	BABINE RIVER AT BABINE	90	100	93	24	38	66	87	88	89	75	80	87	76.8	87.4
22	08ME029	BRIDGE RIVER BELOW LAJOIE DAM	65	74	72	68	39	75	90	84	31	55	87	98	70.1	87.3
23	08MG001	CHEHALIS RIVER NEAR HARRISON	53	50	56	50	36	36	85	90	75	43	50	76	60.1	87.3
24	08NK030	ELK RIVER BELOW ELKO DAM	75	57	61	35	44	52	80	93	89	85	75	73	69.6	86.8
25	08MF068	COQUIHALLA RIVER ABOVE ALEXAN	62	67	56	44	49	57	82	91	54	44	55	77	62.3	86.6
26	08MF062	COQUIHALLA RIVER BELOW NEEDL	65	65	73	23	47	46	81	92	41	25	58	71	58.1	86.6
27	08JB007	NADINA LAKE NEAR NORALEE	100	90	84	40	53	79	84	89	78	68	78	84	77.3	86.4
28	08HA001	CHEMAINUS RIVER NEAR WESTHO	44	63	67	71	76	78	84	89	39	39	61	45	63.6	86.4
29	08HA016	BINGS CREEK NEAR THE MOUTH	52	63	74	86	96	77	91	81	52	39	52	39	67.2	86.3
30	08LG008	SPIUS CREEK NEAR CANFORD	80	69	82	51	44	65	79	93	75	65	63	78	70.6	85.8
31	08HA002	COWICHAN RIVER AT LAKE COWICH	35	55	72	56	51	47	77	95	50	27	61	43	56.3	85.8
32	08HB022	NILE CREEK NEAR BOWSER	62	55	63	64	76	70	91	80	45	59	58	39	64.0	85.4
33	08HD025	WOKAS LAKE NEAR CAMPBELL RIVE	44	59	70	40	43	66	75	96	84	48	47	72	63.5	85.4
34	08LG016	PENNASK CREEK NEAR QUILCHENA	85	76	54	19	37	63	80	91	53	38	55	75	61.4	85.4
35	08MH155	NICOMEKL RIVER AT 203 STREET L	50	70	63	69	75	75	89	81	56	41	44	44	63.8	85.2
36	08GE003	ICY CREEK NEAR THE MOUTH	83	80	74	49	71	69	97	73	79	76	69	77	75.5	85.0
37	08MH168	OR CREEK NEAR COQUITLAM	50	68	65	75	62	73	85	85	52	65	62	60	67.4	85.0
38	08HD018	ELK RIVER ABOVE CAMPBELL LAKE	58	68	60	60	65	70	85	85	52	51	58	72	66.1	85.0
39	08NL007	SIMILKAMEEN RIVER AT PRINCETO	56	70	58	18	58	48	85	85	61	58	42	47	58.5	85.0
40	10AA006	LIARD RIVER BELOW SCURVY CREE	0	0	88	25	14	36	100	70	22	43	20	93	48.7	85.0
41	08NM037	SHATFORD CREEK NEAR PENTICTON	90	80	49	25	46	52	80	89	56	62	81	83	66.7	84.8
42	08NJ160	LEMON CREEK ABOVE SOUTH LEMC	64	63	53	16	35	49	80	89	60	58	61	73	59.8	84.8
43	08HB023	ASH RIVER BELOW MORAN CREEK	52	67	75	64	64	77	88	81	56	39	[illegible]	49	64.9	84.6
44	08NL038	SIMILKAMEEN RIVER NEAR HEDLEY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	78	[illegible]	[illegible]	[illegible]	[illegible]	59	53.3	84.4
45	08NJ026	DUHAMEL CREEK ABOVE DIVERSIO	85	65	30	27	53	46	82	85	63	59	55	84	62.4	83.9
46	08LE108	EAST CANOE CREEK ABOVE DAM	68	75	39	13	67	79	77	90	69	65	57	88	68.6	83.8
47	08HF004	TSITIKA RIVER BELOW CATHERINE	63	67	60	58	73	71	79	89	57	53	64	64	67.1	83.7
48	08NH139	MOYIE RIVER ABOVE NOKE CREEK	89	63	52	8	50	54	96	71	56	36	72	67	62.1	83.6
49	08GC007	THEODOSIA RIVER BELOW OLSEN L	69	63	54	39	54	63	86	81	45	62	61	68	63.2	83.5
50	08NK016	ELK RIVER NEAR NATAL	65	69	56	12	38	59	79	87	96	93	54	65	66.6	82.9

	NUMBERS OF STATIONS WITH ACCURATE FORECASTS >= 50 TO 90%									
	FORECASTS OF DISCHARGE					FORECASTS OF WATER LEVEL				
Month	>=90%	>=80%	>=70%	>=60%	>=50%	>=90%	>=80%	>=70%	>=60%	>=50%
JAN	18	55	124	198	282	23	64	123	213	306
FEB	11	50	116	214	318	16	41	116	242	356
MAR	7	20	50	109	219	11	24	64	153	253
APR	4	5	11	30	67	2	7	23	64	100
MAY	3	6	23	53	108	5	19	56	101	169
JUN	0	5	24	110	237	5	14	58	149	293
JUL	9	40	132	256	338	18	67	169	281	358
AUG	37	95	165	261	332	44	110	199	296	366
SEP	18	36	67	145	246	19	50	90	165	280
OCT	3	16	69	142	215	10	32	78	175	267
NOV	10	26	76	166	278	12	31	87	195	319
DEC	12	49	108	206	277	14	52	126	213	309
ANN	0	0	6	78	301	2	6	23	143	338

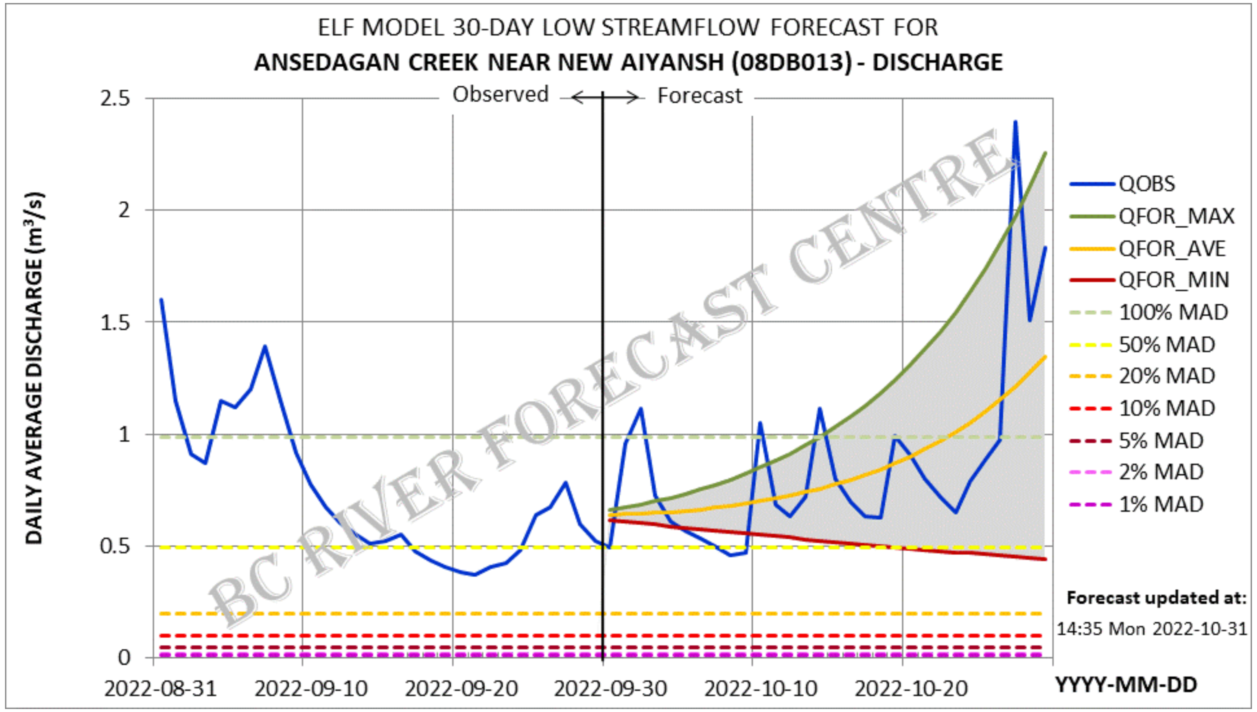


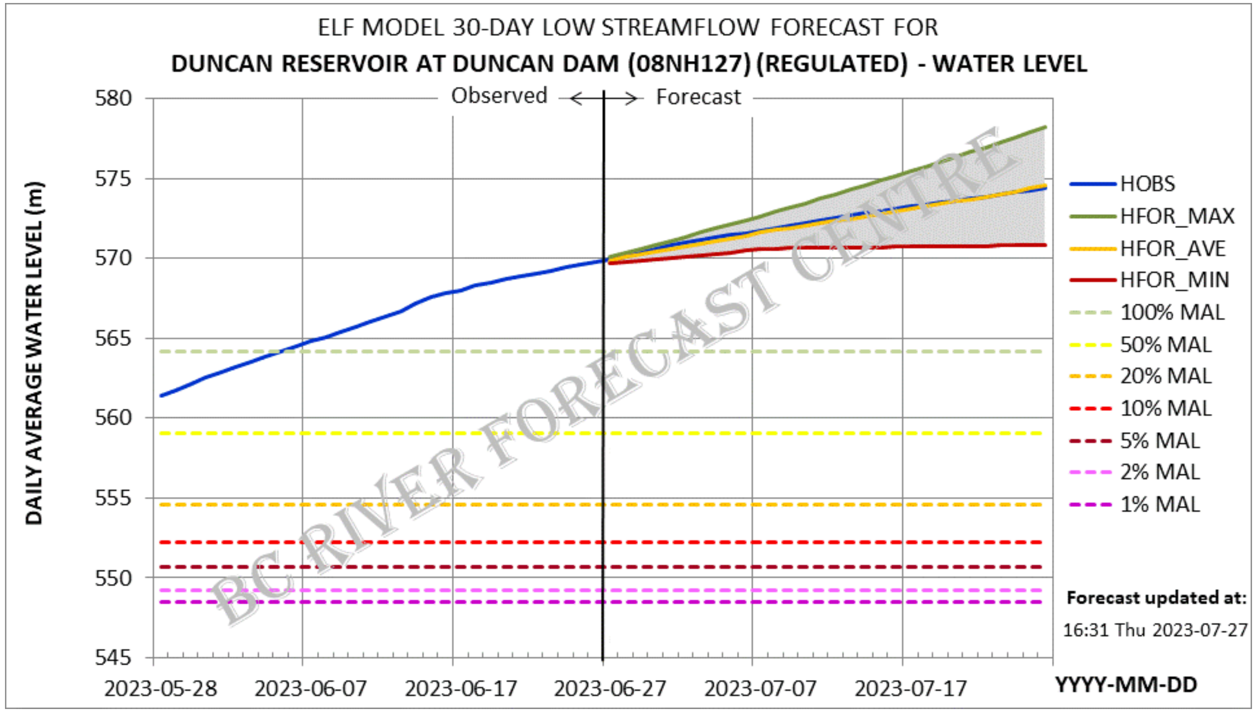


A. July and August are the two months that there are the largest numbers of stations that the ELF Model has large percents (>=50 to 90%) of accurate forecasts.

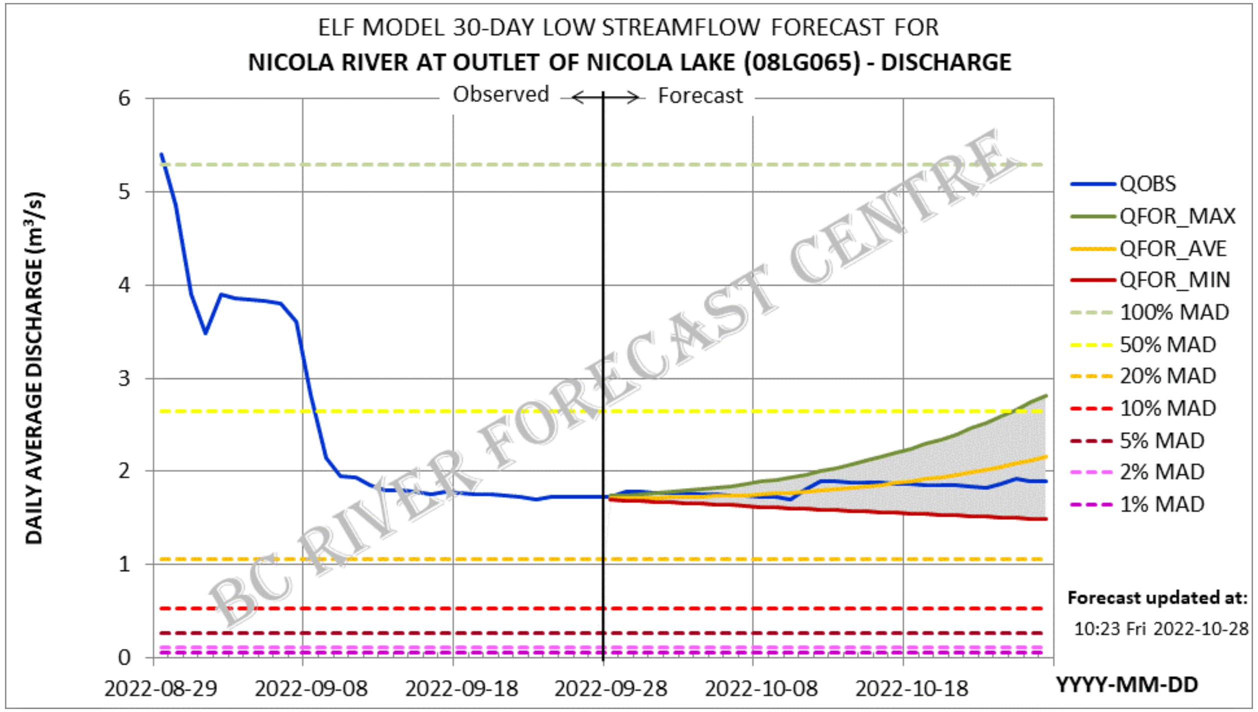
B. April and May are the two months that there are the least numbers of stations that the ELF Model has large percents (>=50 to 90%) of accurate forecasts.

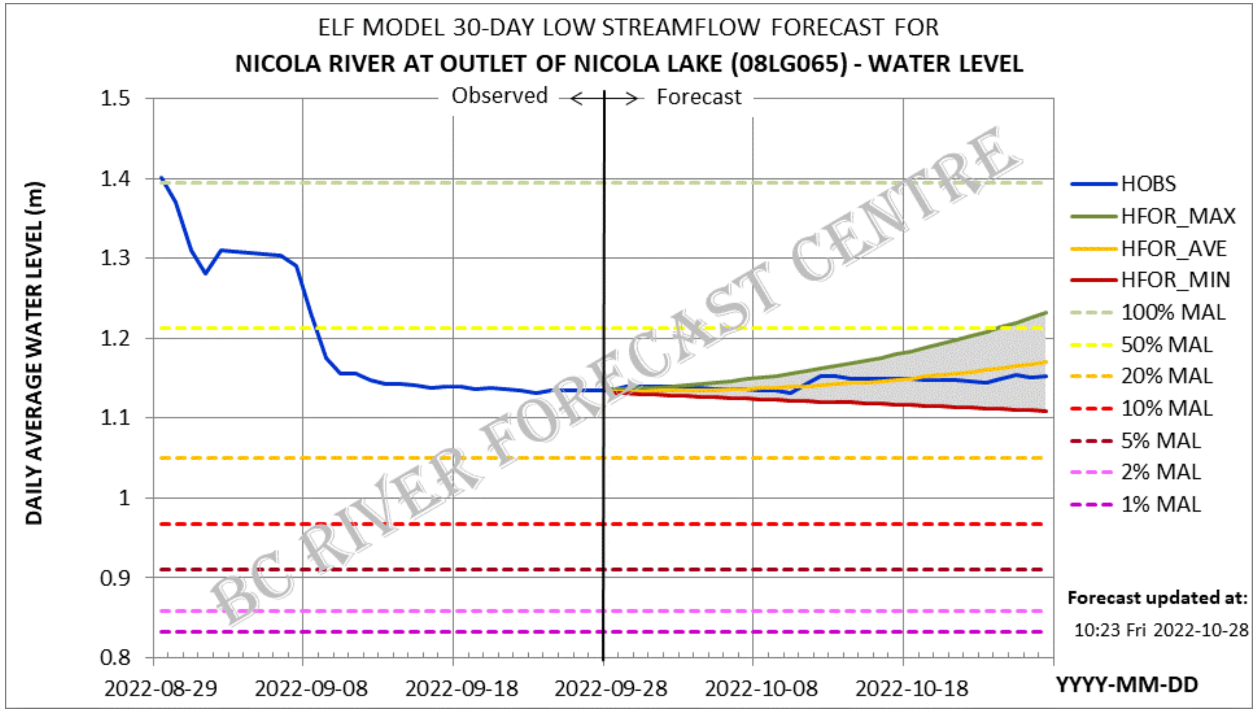
C. Other months are in between.





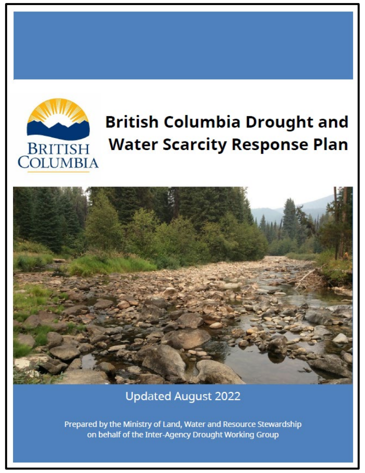
The ELF Model is run all year round using 30 day observed flow data (discharges and/or water levels) to produce forecasts for the next 30 days regardless the flow is rising or dropping. These forecasts of rise are **for information only** and are not recommended for management purposes because the ELF Model is not developed for forecasting rises and because the model **has no meteorological data input**.





The regulated flow stations are not removed from the list of modeled stations. As such, the ELF Modal also produce forecasts for the regulated stations and sometimes the forecasts are also accurate as long as the operation of the regulating facilities is consistent during the period of the model's input data and the period of forecasting. These forecasts are also **for information only** and are not recommended for management purpose either because **the forecast accuracy is uncertain**.

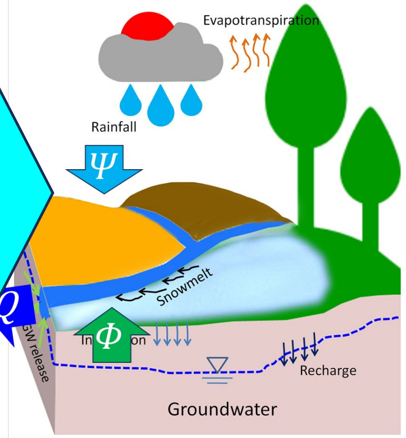
Background


British Columbia Drought and Water Scarcity Response Plan

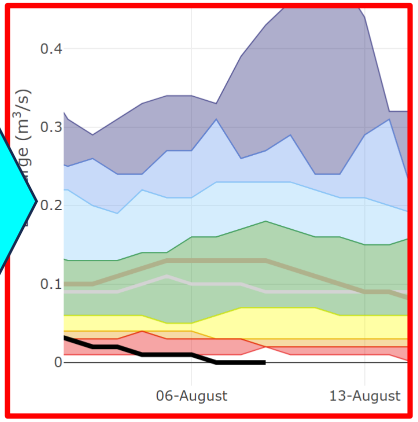
Updated August 2022

Prepared by the Ministry of Land, Water and Resource Stewardship on behalf of the Inter-Agency Drought Working Group

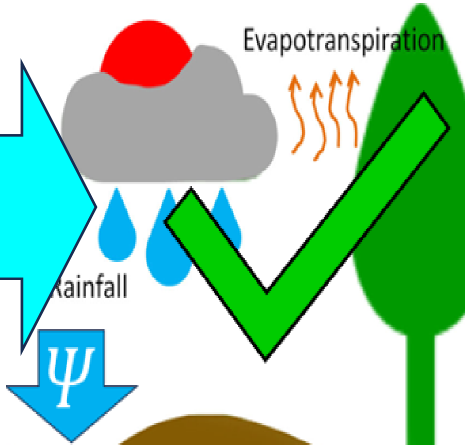
Definition of Low Flow



Why not hydrol md



Fundamental sump



Basic equations

$Q(t) = Q_0 e^{-at}$

$$ln(Q) = -at + ln(Q_0)$$

If 30 data, overdetermined: $f = y = ax + b$

$$R^2 = \sum_{i=1}^{n} [y_i - f(x_i, a_1, a_2, \ldots, a_j, \ldots, a_m)]^2$$

$$\frac{\partial(R^2)}{\partial a_i} = 0, i = 1 \; to \; n$$

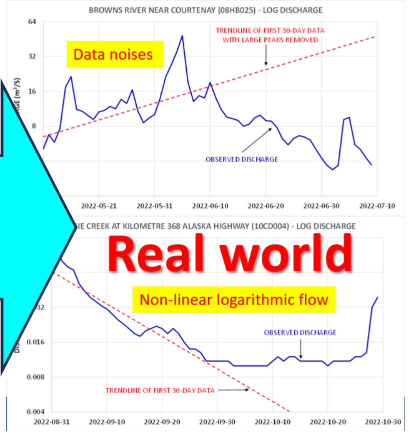
$$a = \frac{\sum_i^n (x_i y_i) - n\bar{x}\bar{y}}{\sum_i^n x_i^2 - n\bar{x}^2}$$

$$b = \frac{\bar{y}\sum_i^n x_i^2 - \bar{x}\sum_i^n (x_i y_i)}{\sum_i^n x_i^2 - n\bar{x}^2}$$

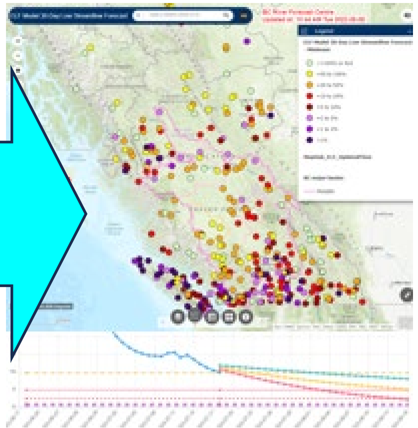
$$\bar{x} = \frac{1}{n}\sum_{n=1}^{n} x_i$$

$$\bar{y} = \frac{1}{n}\sum_{n=1}^{n} y_i$$

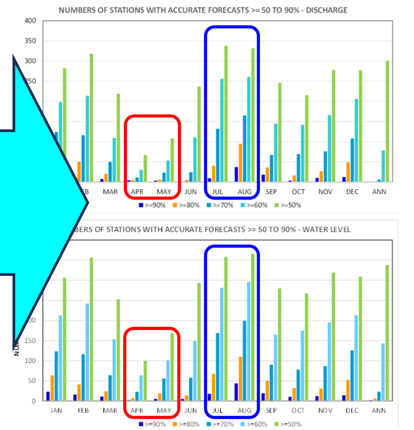
Solve overdetermined system exp ress equ.



Data issues & 12-step /12 scenario scheme



Products of ELF Model



Evaluation of ELF M forecast accuracy

Conclusion:
The ELF Model can produce accurate low flow forecast when streamflow conditions fulfill the fundamental assumption and the basic equation.

THANK YOU!

QUESTIONS?

Charles.Luo@gov.bc.ca