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Credit Valley Conservation – inspired by nature

→ **Lisa Bowering**
Water Resources Engineer

Navigating Watershed Futures:
Muskoka River Ecological Flow Assessment in a Changing Climate

Source to Stream Conference 2025

Welcome

Background – Muskoka River Watershed

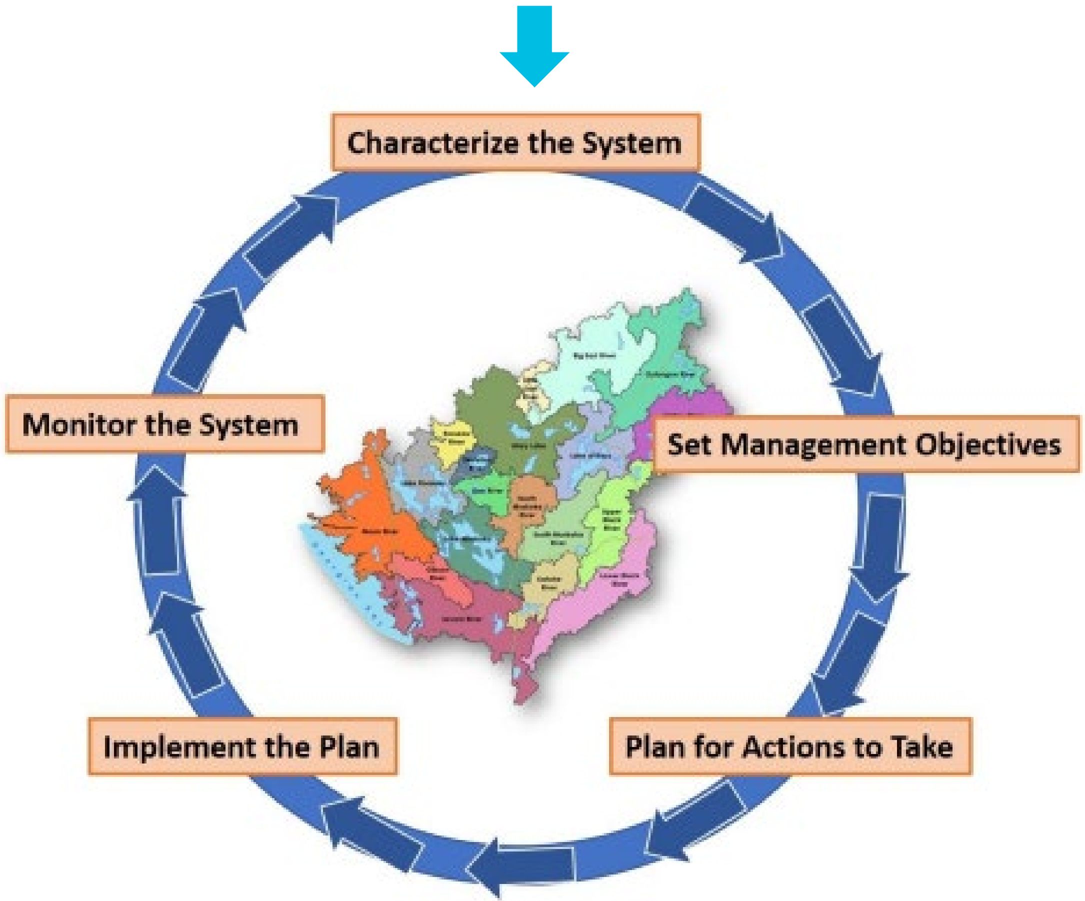
Context

- Historic Flooding
- Provincial Funding
- Muskoka River Watershed Hydrologic Model Development

Objectives

- Understand Watershed Processes & Potential Impacts to Flow Regime
- Improve Watershed Health

We are here



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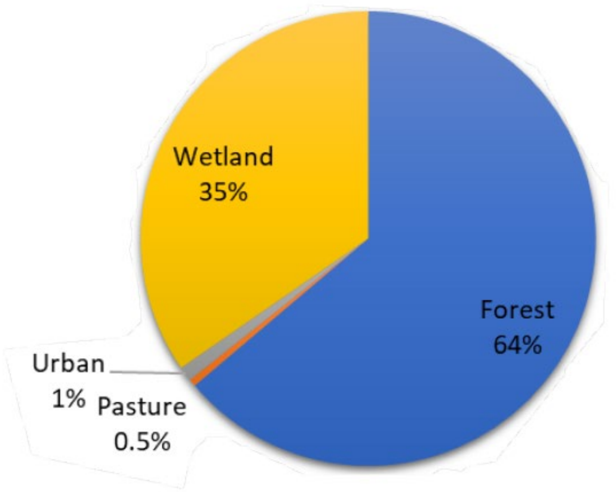
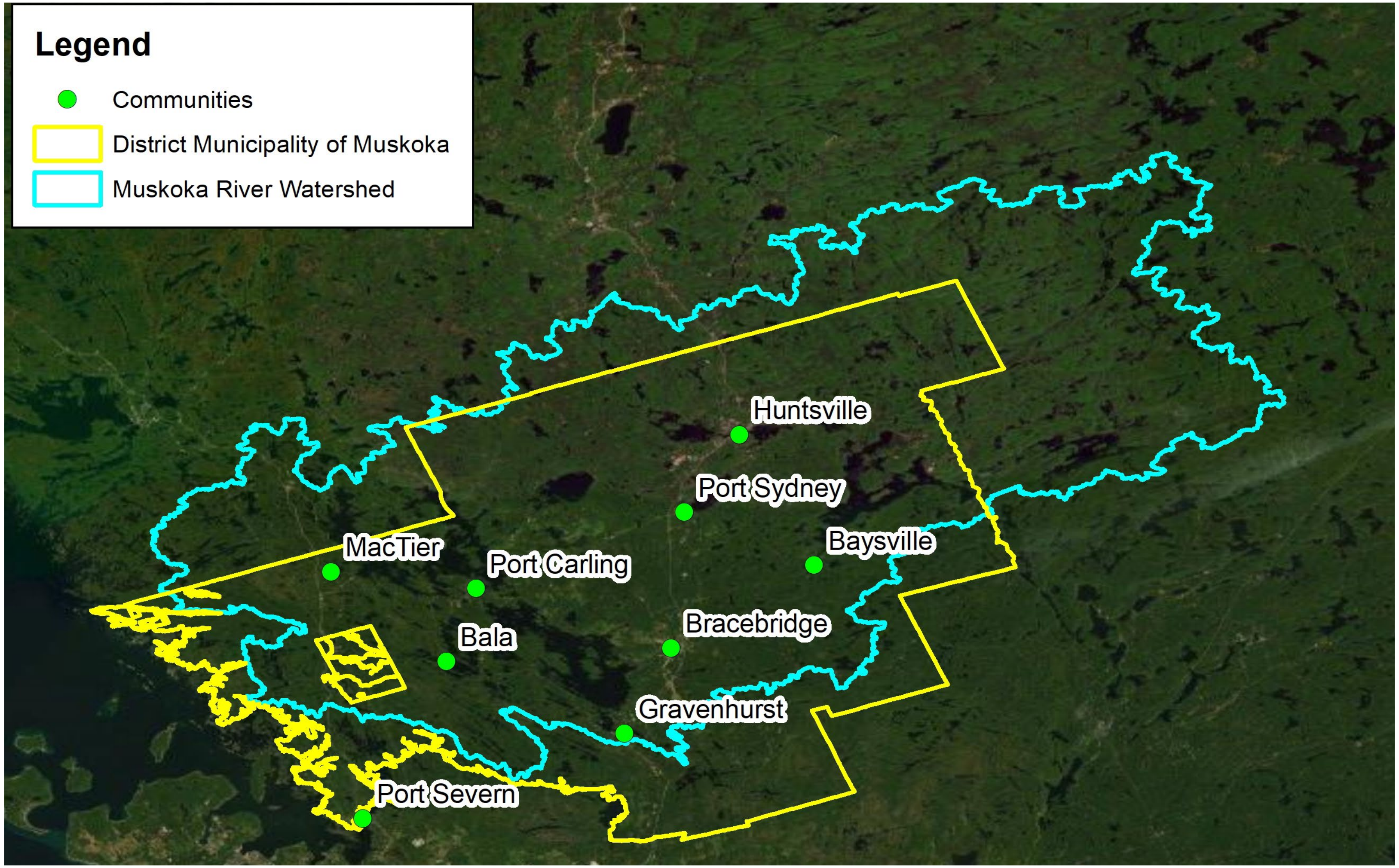
This study was done in partnership with District Municipality of Muskoka with funding from the Provincial Government of Ontario

Background – Muskoka River Watershed

- ~5,100 km^2
- Mainly forested
- Several urban centres
- 42 water control structures
- 38 significant wetlands
- Peak flows during freshet



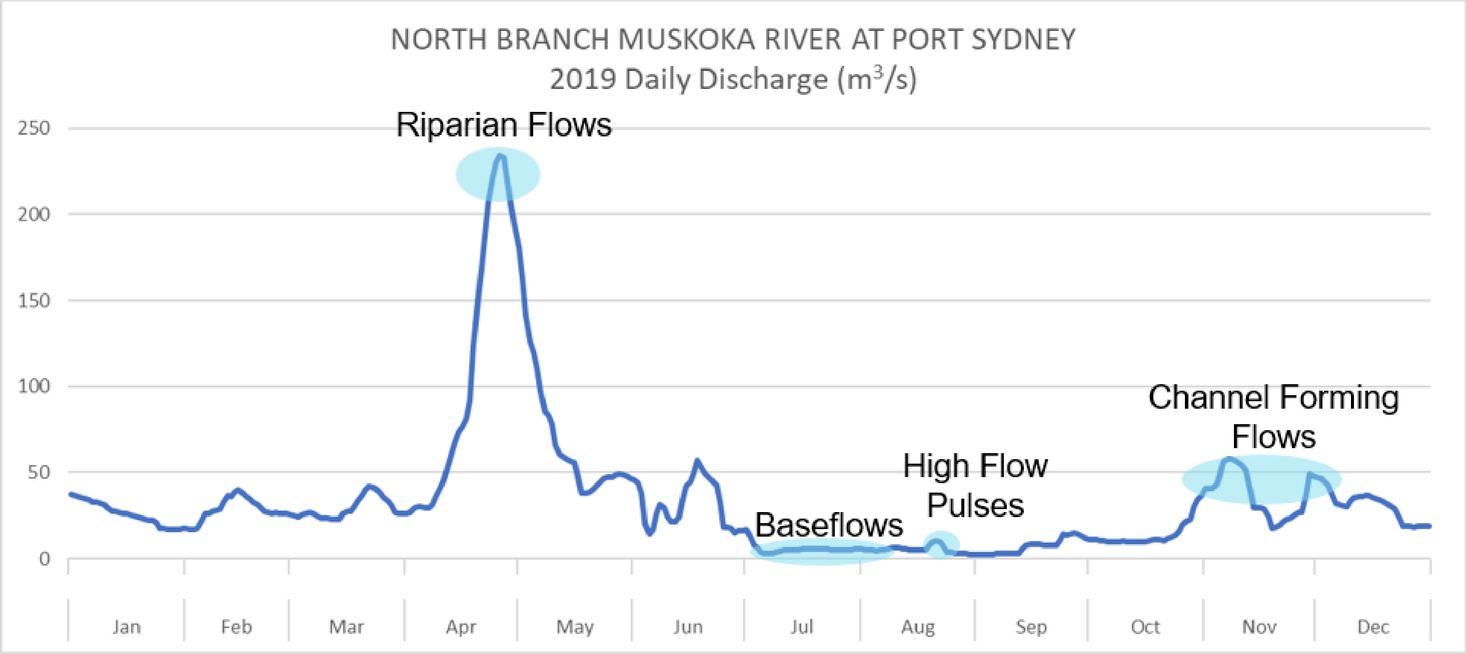


Approach – Ecological Flow Assessment

Ministry of Natural Resources and Forestry's (MNRF) Aquatic Ecosystem Assessment for Rivers

– A science-based framework for assessing baseline riverine ecosystems and identifying potential changes from alteration of physical and biological processes.

1. Select indicators
2. Compare future scenarios against Baseline (30-years daily data)
3. Calculate degree of alteration (Low, Medium, High)



Ecologically Important Components of the Flow Regime. Adapted from Metcalfe et. al, 2013

Approach – Ecological Flow Assessment

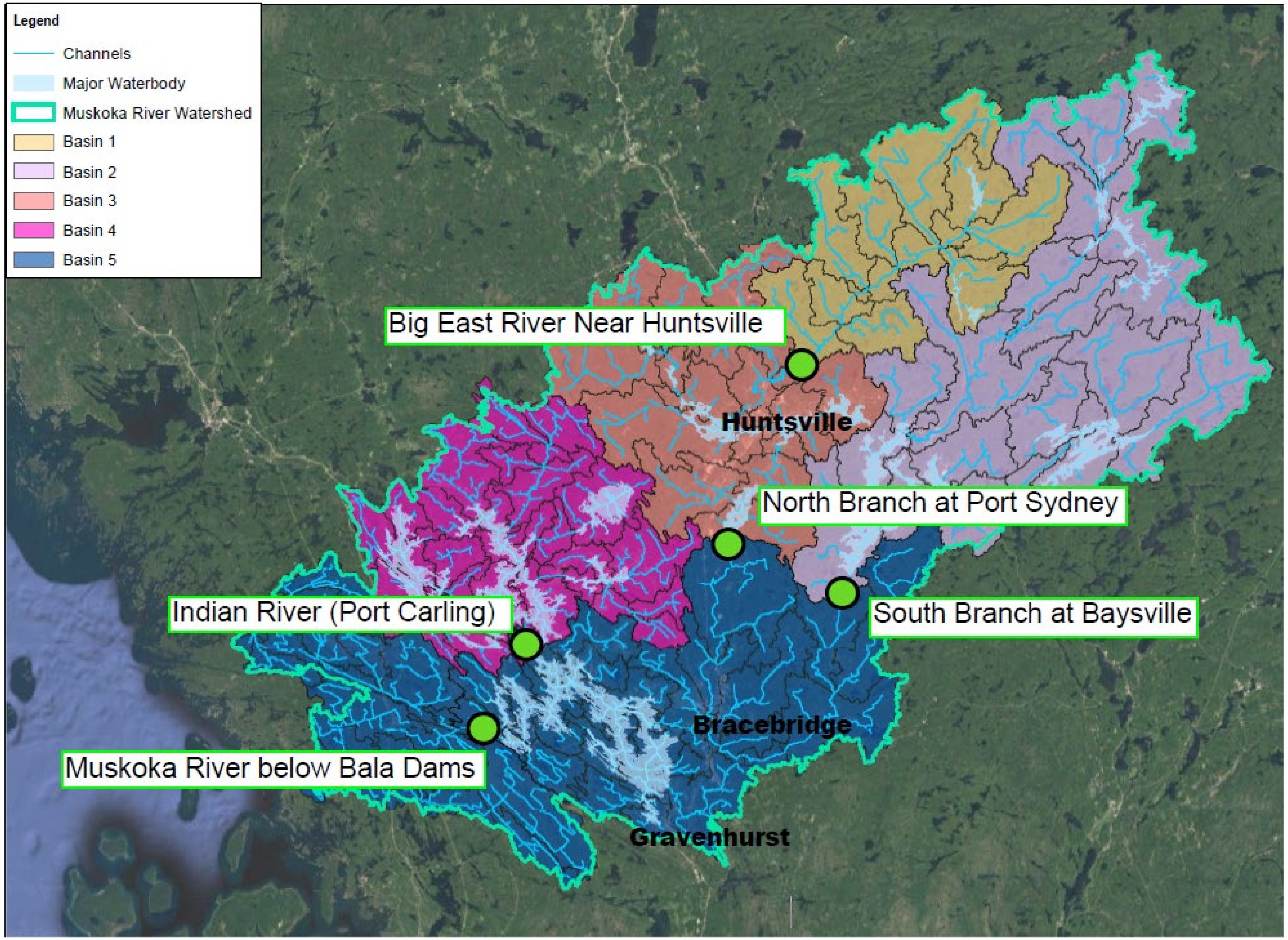
Indicators

Subsistence Flows (Q95)

- Infrequent, naturally occurring, very low flows
- Flows are exceeded 95% of the time
- Can be used to evaluate worst-case impacts to fish and fish habitat

Channel Forming Flows (Magnitude, Duration, & Timing)

- Flow with recurrence interval of 1.5 years
- Bankfull flow stage
- Exceed threshold for sediment erosion
- Produce and maintain natural channel structures

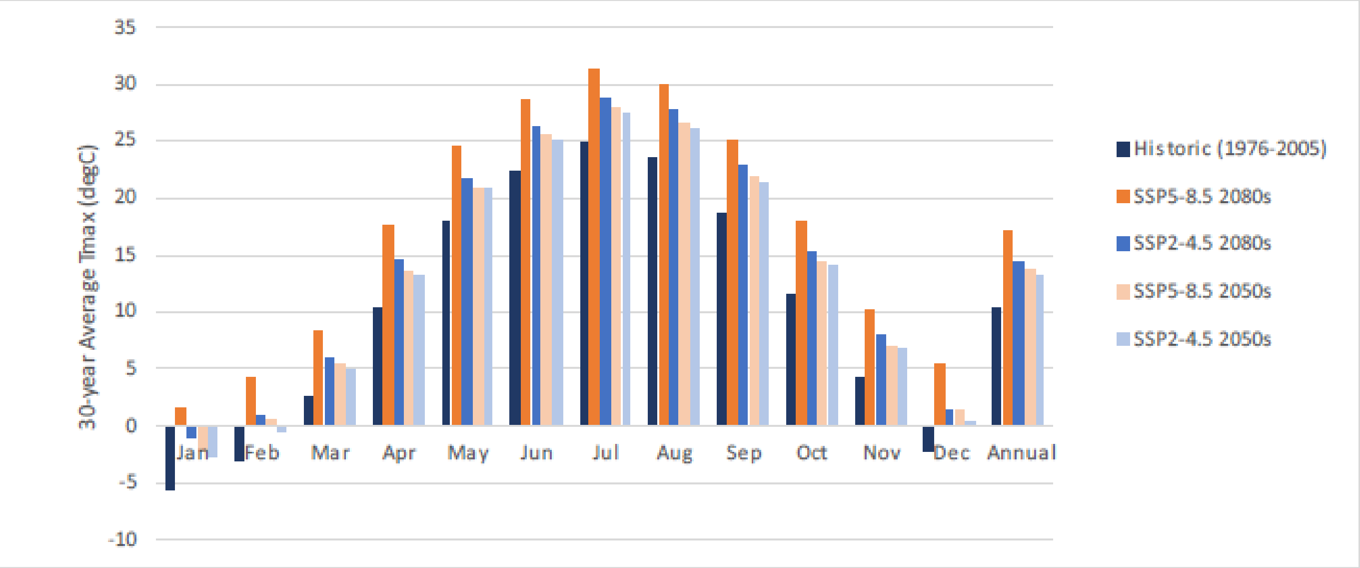


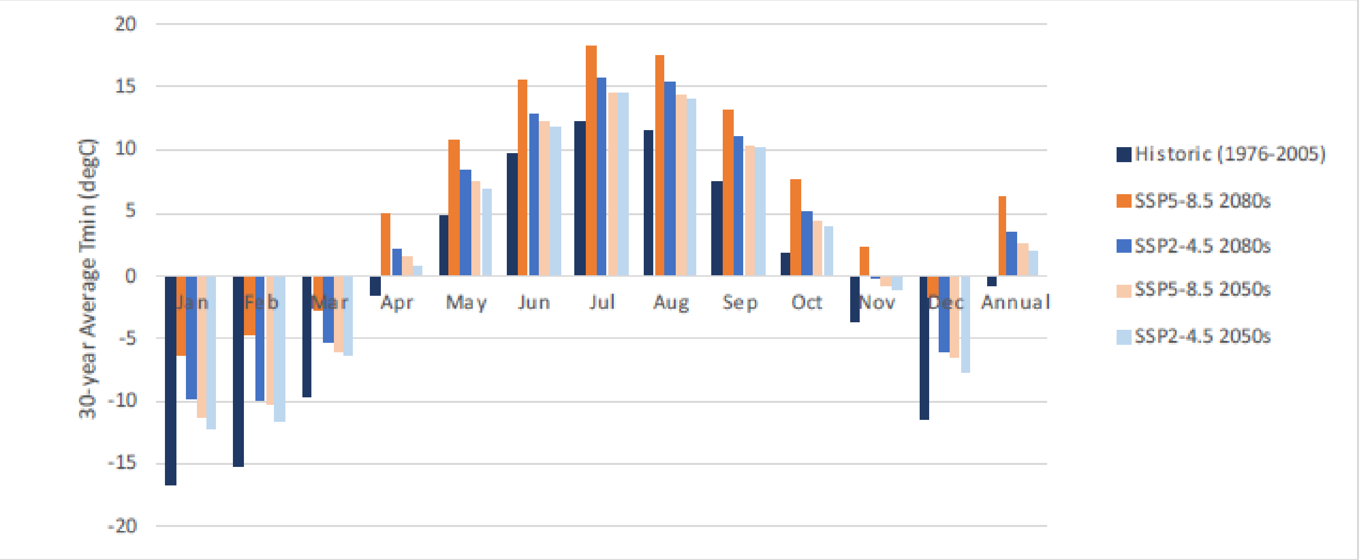
Approach – Scenario Analysis

- What-if??
- Compare existing conditions to potential "future" conditions
- Explore possible impacts to ecological flows
- Identify topics and areas for further study

Scenario Categories

- Climate Change (11)
- Development (5)
- Wetland Enhancement (6)
- Deforestation (6)
- Forest Fire (1)
- Dam & Storage Alteration (4)

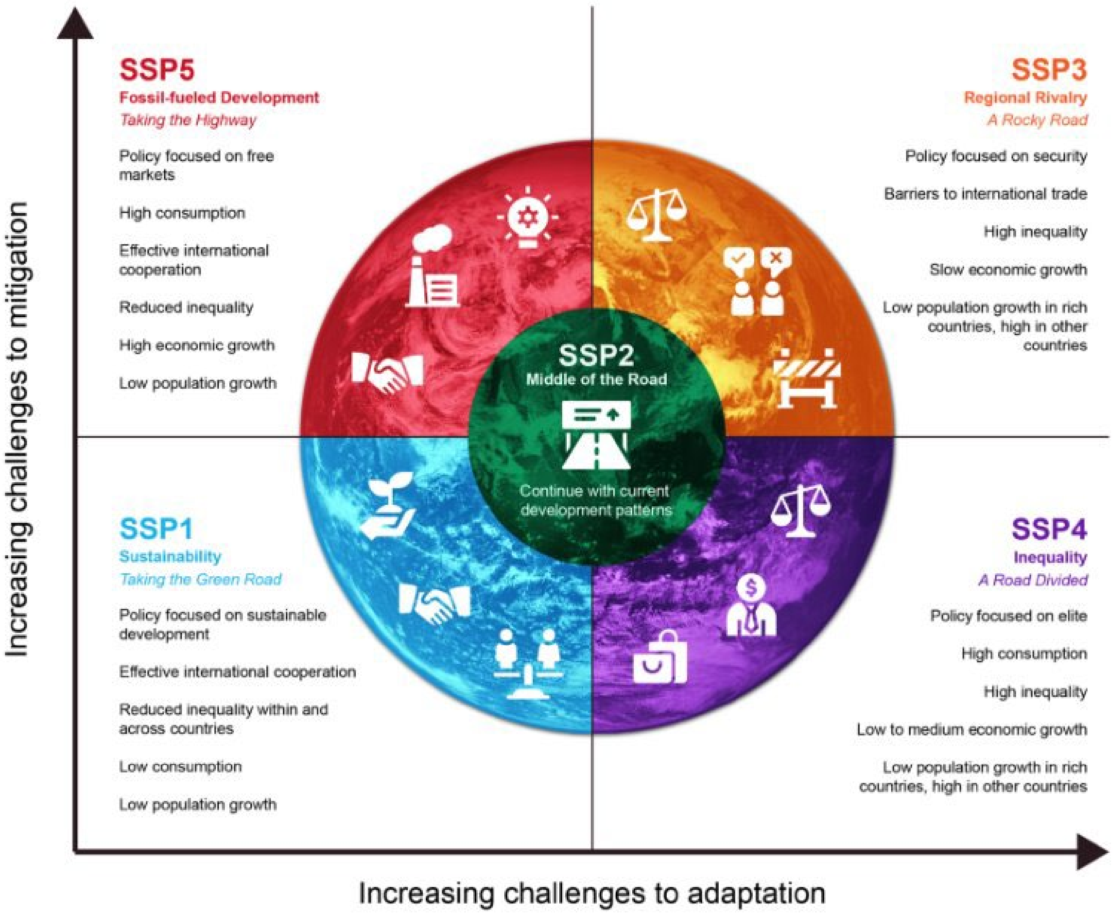




Approach – Scenario Analysis

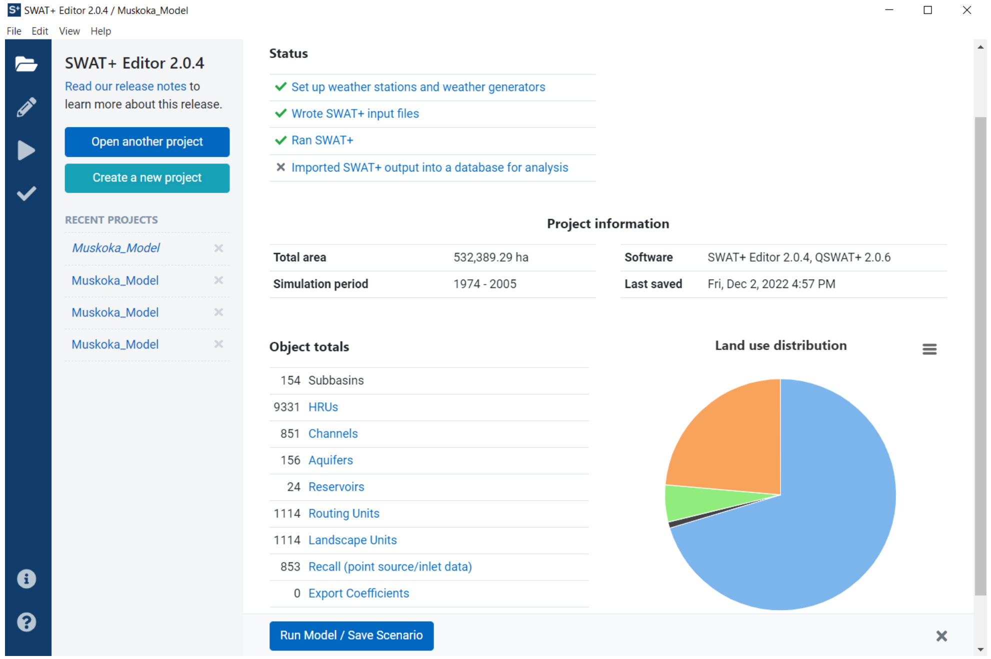
Climate Change

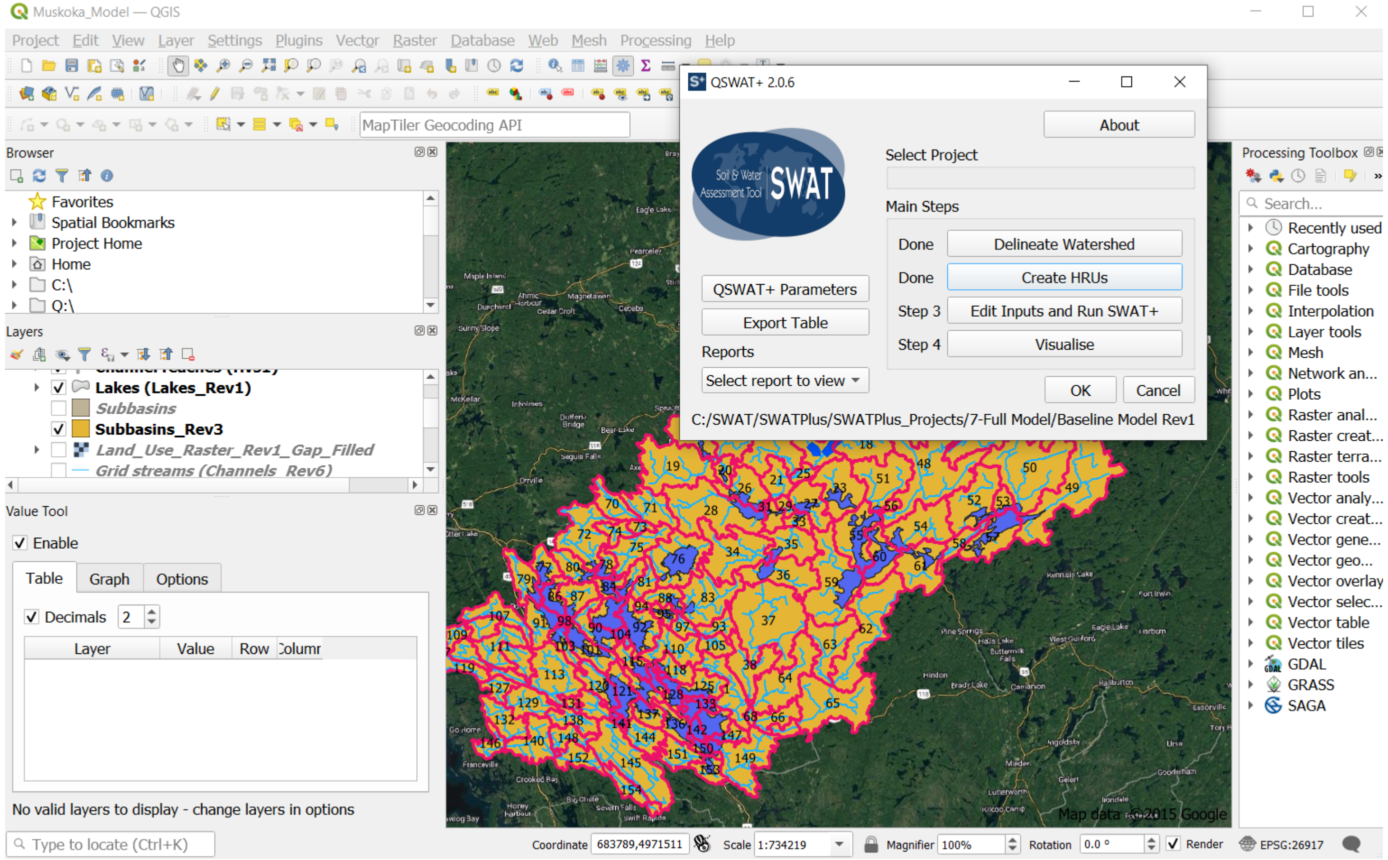
- 11 Scenarios
- 2100 & 2050 projections for Dry, Median, and Wet precipitation with 2100 & 2050 median projection for temperature change
- 2100 and 2050 Wet scenarios with historic temperature (Cold & Wet scenarios)
- Coincident spring melt
- RCP5-8.5 and RCP4-8.5



Approach – Modelling

- SWAT+ is a public domain hydrological modelling software used to simulate the quantity and quality of streamflow at a watershed scale





– Command-line executable file that runs text file inputs and uses two interfaces: SWAT+ Editor and QSWAT+

Approach – Modelling

SWAT+

- Predicts impacts of changes to watershed
- Model includes the following hydrologic processes:
    - Snowmelt/accumulation
    - Evapotranspiration
    - Infiltration
    - Reservoir operation
    - Groundwater flow
    - Surface runoff
    - **Streamflow**
- Model does not calculate:
    - Water levels/extents
    - Water quality

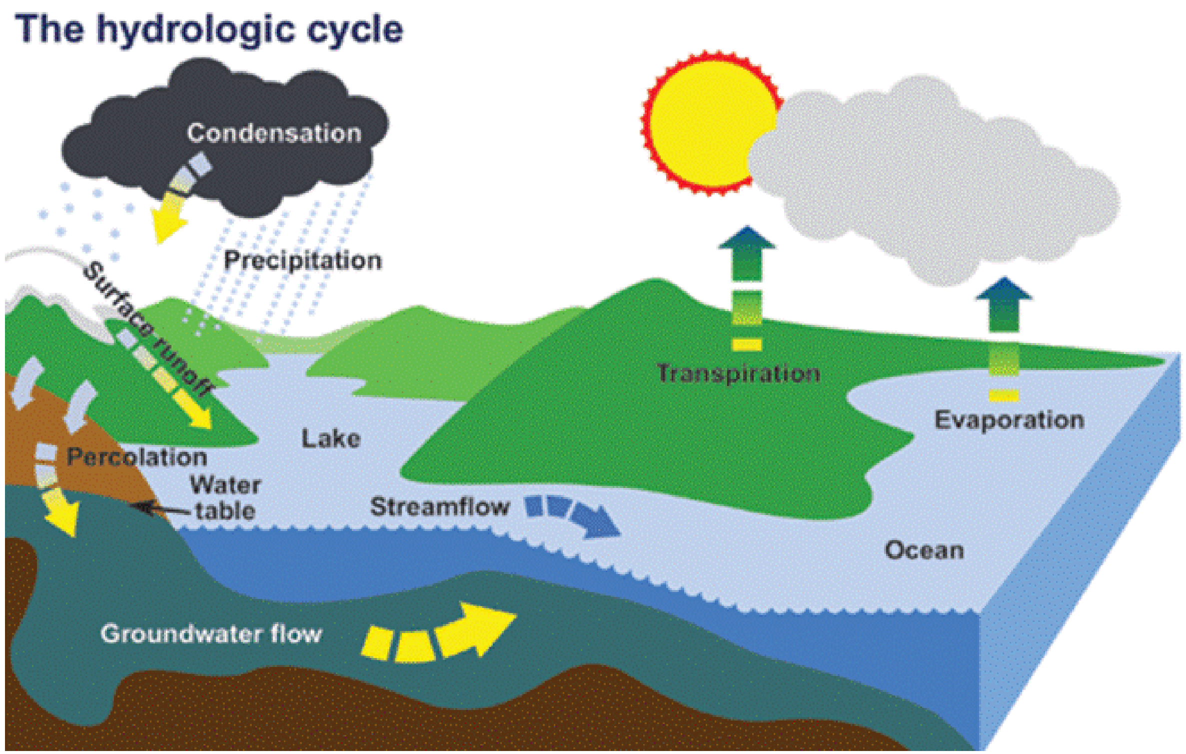
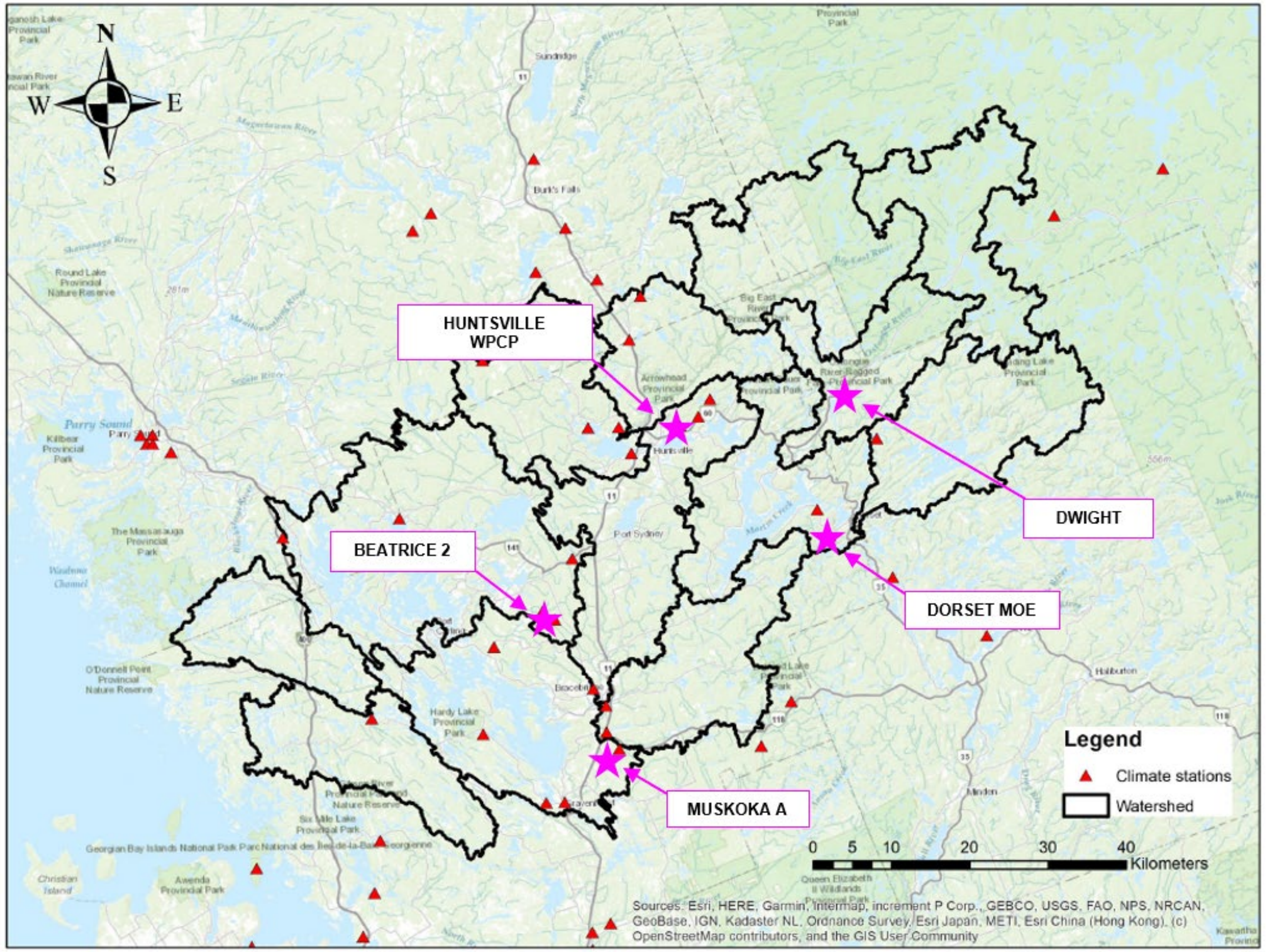


Figure 1.1 Hydrological cycle (statcan.gc.ca)

Approach – Modelling

	DATA INPUTS
Watershed, Channel Delineation (Subbasins, Watersheds)	Elevation Data
Hydrologic Response Unit Generation	Land Use, Soil, Slope Data (vary by scenario)
Reservoir Characterization	Lake Bathymetry, Reservoir Operations Data (MNRF)
Hydrological Process Selection, Parameterization, Simulation Settings	Climate Data (vary by scenario)
Calibration and Validation	Observed Streamflow Data (WSC)
Streamflow Analysis	**Ecological Flow Assessment**

Approach – Modelling



- Climate inputs: 32-year daily timeseries of precipitation, minimum and maximum temperature

Main Computational Codes

Hydrological Process	Code
Evapotranspiration	Hargreaves
Infiltration	Curve Number
Overland Routing	Triangular UH
Channel Routing	Variable Storage Method

Types of Calibration Parameters

- Snowmelt (snowfall temp, snowpack temp, snowmelt factors)
- Evapotranspiration (factors controlling ET from soil, aquifers)
- Groundwater flow (factors controlling occurrence and rate of baseflow)

Approach – Modelling

- Model was calibrated and validated for both low and high flow conditions
- 30-year, daily continuous model
- Daily streamflow evaluated at select locations along Muskoka River

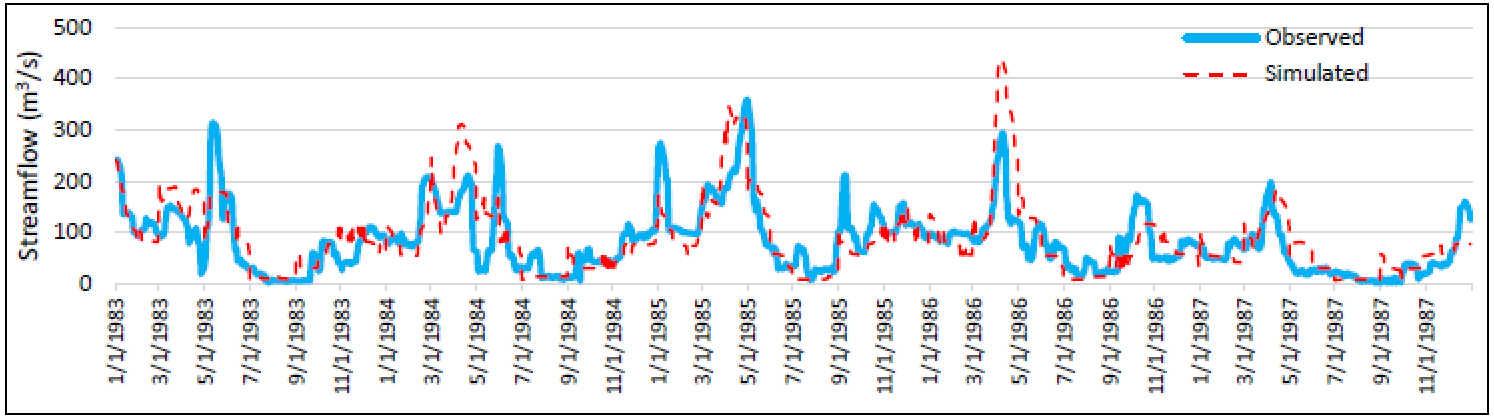


Figure 20 Basin 5 Observed and Modelled Streamflow During Calibration Period

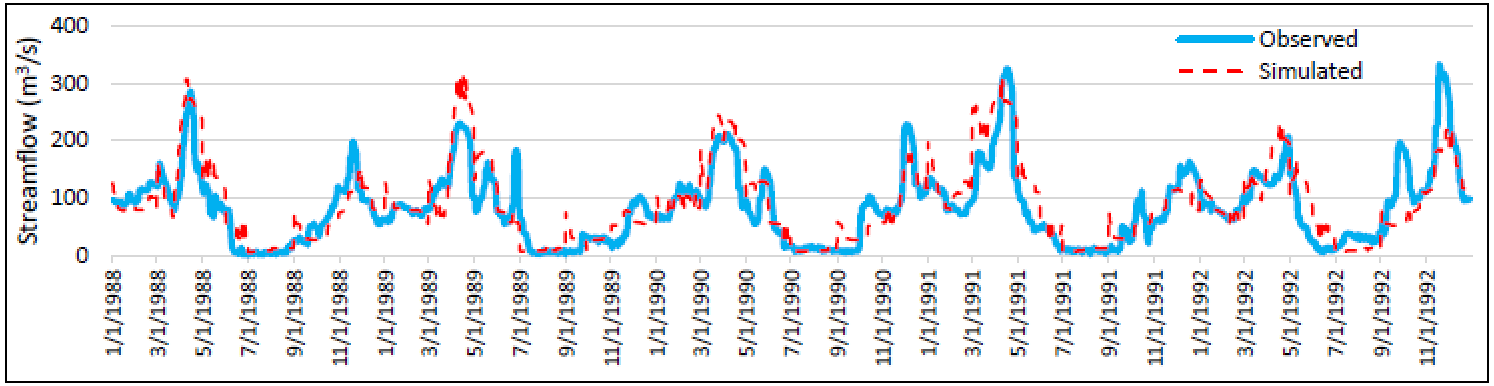


Figure 21 Basin 5 Observed and Modelled Streamflow During Validation Period

Results – Subsistence Flows

Indicator: Q95 (total streamflow)

Degree of Alteration (change compared to baseline)

Low: > 95% exceedance flow

– flow is higher compared to baseline

Medium: > 99% exceedance flow

– flow is slightly lower compared to baseline

High: < 99% exceedance flow

– flow is much lower compared to baseline

Scenario ID	Description	Subsistence Flows – Degree of Alteration				
		Basin 1	Basin 2	Basin 3	Basin 4	Basin 5
SL02	Climate Change	LOW	LOW	LOW	LOW	LOW
SL02B	Climate Change	LOW	LOW	LOW	LOW	LOW
SL03	Climate Change	MEDIUM	LOW	LOW	HIGH	MEDIUM
SL04	Climate Change	LOW	LOW	LOW	MEDIUM	LOW
SL05	Climate Change	LOW	LOW	LOW	LOW	LOW
SL26	Climate Change	LOW	LOW	LOW	LOW	LOW
SL27	Climate Change	LOW	LOW	LOW	LOW	LOW
SL28	Climate Change	LOW	LOW	LOW	LOW	LOW
SL29	Climate Change	LOW	LOW	LOW	LOW	LOW
SL30	Climate Change	MEDIUM	LOW	LOW	MEDIUM	MEDIUM
SL31	Climate Change	LOW	LOW	LOW	HIGH	MEDIUM
SL06	Population Growth	LOW	LOW	LOW	LOW	LOW
SL07	Population Growth	LOW	LOW	LOW	LOW	LOW
SL08	Population Growth	LOW	LOW	LOW	LOW	LOW
SL09	Population Growth	LOW	LOW	LOW	LOW	LOW
SL10	Population Growth	MEDIUM	LOW	LOW	HIGH	MEDIUM
SL12	Extreme Event	LOW	LOW	LOW	LOW	LOW
SL13	Land Use	LOW	LOW	LOW	LOW	LOW
SL14	Land Use	LOW	LOW	LOW	LOW	LOW
SL15	Land Use	LOW	LOW	LOW	LOW	LOW
SL16	Land Use	LOW	LOW	LOW	LOW	LOW
SL17	Land Use	LOW	LOW	LOW	LOW	LOW
SL18	Land Use	LOW	LOW	LOW	LOW	LOW
SL19	Land Use	LOW	LOW	LOW	LOW	LOW
SL20	Land Use	LOW	LOW	LOW	LOW	LOW
SL21	Land Use	LOW	LOW	LOW	LOW	LOW
SL22	Land Use	LOW	LOW	LOW	LOW	LOW
SL23	Land Use	LOW	LOW	LOW	LOW	LOW
SL24	Land Use	LOW	LOW	LOW	LOW	LOW
SL37	Physical Change	LOW	LOW	LOW	LOW	LOW
SL38	Physical Change	LOW	LOW	LOW	LOW	LOW
SL39	Physical Change	LOW	LOW	LOW	LOW	LOW
SL40	Physical Change	LOW	LOW	LOW	LOW	LOW

Results – Subsistence Flows

Climate Change (all scenarios SSP5-8.5 unless otherwise noted). All other scenarios = LOW

Scenario	Basin 1	Basin 2	Basin 3	Basin 4	Basin 5
2100 Wet	LOW	LOW	LOW	LOW	LOW
2100 Wet & Cold	LOW	LOW	LOW	LOW	LOW
2100 Dry	MEDIUM	LOW	LOW	HIGH	LOW
2100 Median	LOW	LOW	LOW	MEDIUM	LOW
Coincident Spring Melt	LOW	LOW	LOW	LOW	LOW
2050 Wet	LOW	LOW	LOW	LOW	LOW
2050 Wet & Cold	LOW	LOW	LOW	LOW	LOW
2100 Wet (SSP2-4.5)	LOW	LOW	LOW	LOW	LOW
2100 Wet & Cold (SSP2-4.5)	LOW	LOW	LOW	LOW	LOW
2050 Dry	MEDIUM	LOW	LOW	MEDIUM	MEDIUM
2050 Dry (SSP2-4.5)	LOW	LOW	LOW	HIGH	MEDIUM
2100 Dry + Increased Development	MEDIUM	LOW	LOW	HIGH	MEDIUM

Results – Channel Forming Flows

Indicators

Magnitude: Flow with recurrence interval of 1.5 years

Duration: Median Duration (days) of all CFF events in record

Timing: Modal Month of all CFF events in record

Degree of Alteration (change compared to baseline)

	Low	Medium	High
Magnitude	≥ baseline	≥ 80% of baseline	< 80% of baseline
Duration	Within 38th – 62nd percentiles	13th – 38th or 62nd – 87th percentiles	<13th percentile >87th percentile
Timing	Same month	±1 month	>1 month

Results – Channel Forming Flows

Scenario ID	Category	Magnitude (cms)					Duration (days)					Timing (month)				
		Basin 1	Basin 2	Basin 3	Basin 4	Basin 5	Basin 1	Basin 2	Basin 3	Basin 4	Basin 5	Basin 1	Basin 2	Basin 3	Basin 4	Basin 5
SL01	Baseline											Mar	Apr	Apr	Apr	Apr
SL02	Climate Change	MEDIUM	LOW	LOW	LOW	LOW	LOW	HIGH	MEDIUM	HIGH	HIGH	MEDIUM	HIGH	HIGH	HIGH	HIGH
SL02B	Climate Change	LOW	LOW	LOW	LOW	LOW	HIGH	HIGH	HIGH	HIGH	HIGH	MEDIUM	LOW	LOW	LOW	LOW
SL03	Climate Change	HIGH	HIGH	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH	MEDIUM	MEDIUM
SL04	Climate Change	HIGH	LOW	MEDIUM	LOW	LOW	MEDIUM	LOW	LOW	MEDIUM	LOW	MEDIUM	HIGH	HIGH	MEDIUM	MEDIUM
SL05	Climate Change	LOW	MEDIUM	MEDIUM	LOW	MEDIUM	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
SL26	Climate Change	LOW	LOW	LOW	LOW	LOW	MEDIUM	HIGH	MEDIUM	HIGH	HIGH	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM
SL27	Climate Change	LOW	LOW	LOW	LOW	LOW	MEDIUM	HIGH	MEDIUM	HIGH	HIGH	LOW	LOW	MEDIUM	LOW	LOW
SL28	Climate Change	LOW	LOW	LOW	LOW	LOW	MEDIUM	HIGH	MEDIUM	HIGH	HIGH	LOW	HIGH	MEDIUM	MEDIUM	MEDIUM
SL29	Climate Change	LOW	LOW	LOW	LOW	LOW	MEDIUM	HIGH	MEDIUM	HIGH	HIGH	LOW	HIGH	MEDIUM	MEDIUM	MEDIUM
SL30	Climate Change	MEDIUM	LOW	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	LOW	LOW	MEDIUM	MEDIUM	LOW	MEDIUM
SL31	Climate Change	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH	MEDIUM	MEDIUM	MEDIUM
SL06	Population Growth	LOW	LOW	MEDIUM	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
SL07	Population Growth	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
SL08	Population Growth	MEDIUM	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
SL09	Population Growth	MEDIUM	LOW	LOW	LOW	LOW	LOW	HIGH	MEDIUM	HIGH	HIGH	MEDIUM	HIGH	MEDIUM	HIGH	HIGH
SL10	Population Growth	HIGH	HIGH	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH	MEDIUM	MEDIUM
SL12	Extreme Event	LOW	LOW	LOW	LOW	LOW	MEDIUM	LOW	MEDIUM	LOW	LOW	LOW	LOW	LOW	LOW	LOW
SL13	Land Use	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
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SL15	Land Use	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
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SL17	Land Use	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
SL18	Land Use	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
SL19	Land Use	LOW	LOW	LOW	LOW	LOW	LOW	MEDIUM	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
SL20	Land Use	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
SL21	Land Use	LOW	LOW	LOW	LOW	LOW	LOW	MEDIUM	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
SL22	Land Use	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
SL23	Land Use	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
SL24	Land Use	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
SL37	Physical Change	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
SL38	Physical Change	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
SL39	Physical Change	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
SL40	Physical Change	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW

Results – Channel Forming Flows

Climate Change

- Strong Impact
- Timing shifts earlier in nearly all scenarios – sensitive to warming
- Flow sensitive to dry scenarios
- Duration very sensitive (increases with wet, decreases with dry)

Development

- Minimal impact on watershed level
- Development combined with climate change shows similar impact to CC

Land Use

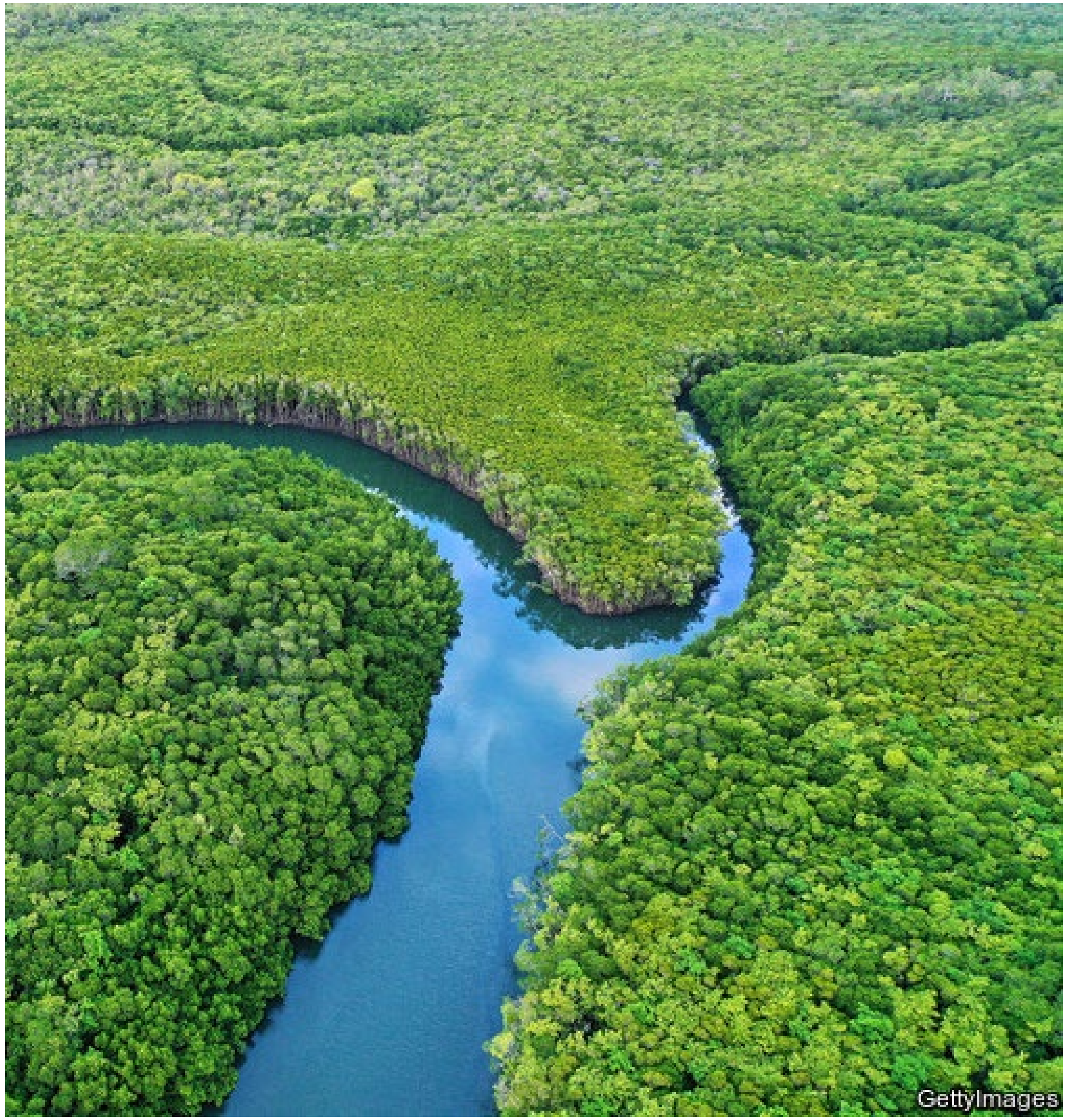
- Deforestation and Wetland changes show minimal impact on watershed level
- Basin 2 (upper watershed) duration slightly impacted by deforestation (higher)

Physical Change

- Local changes had no impact on watershed level

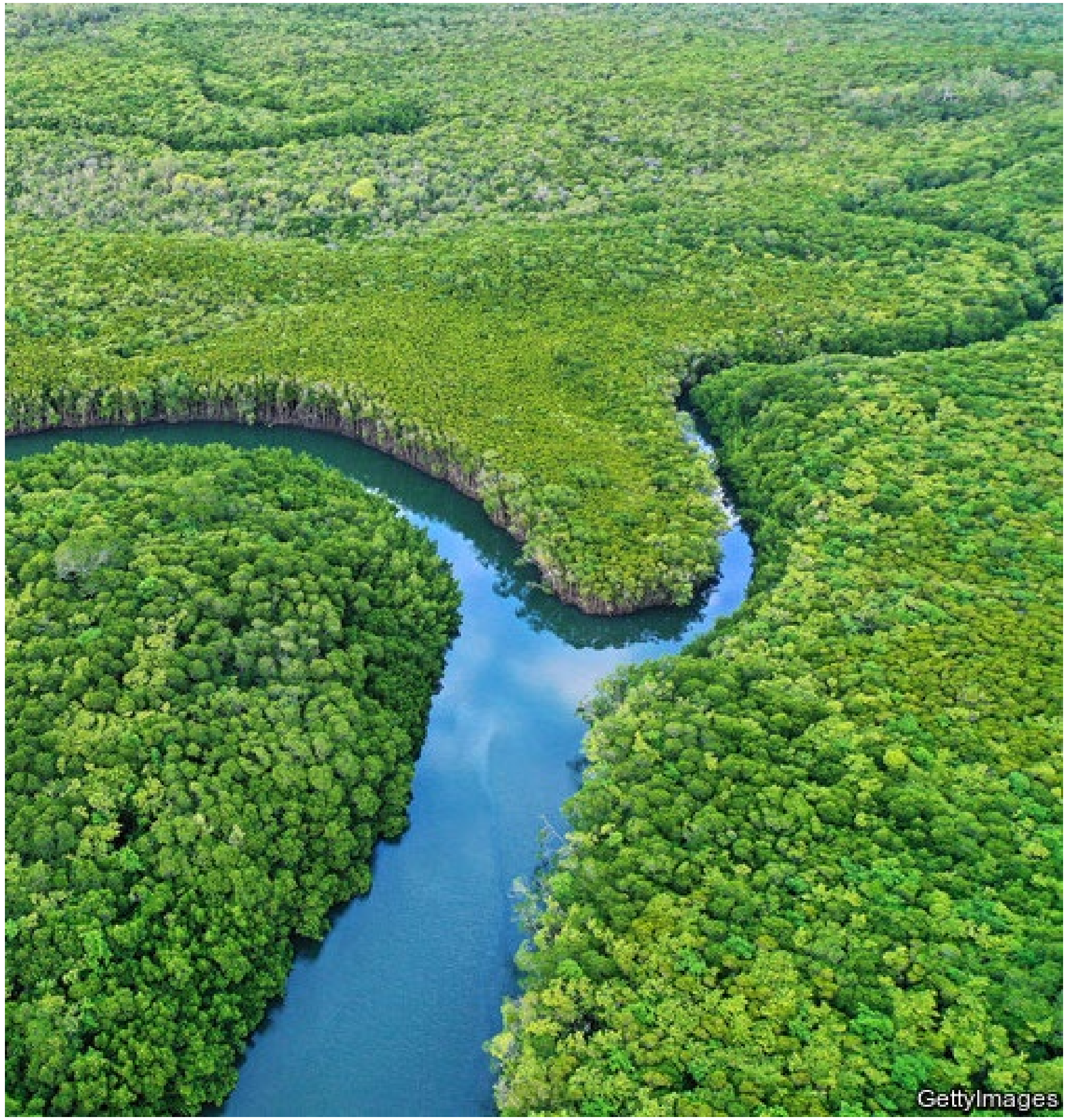
Key Takeaways

- **Subsistence** flows are **sensitive to dry** climate change scenarios
- **Channel forming** flows (CFF) are **sensitive to most** climate change scenarios
  - Magnitude is mainly impacted by “Dry” scenarios
  - Timing is impacted in most (by temperature) **shifting earlier**
  - Duration is impacted by most, increasing with “Wet” scenarios, decreasing with “Dry” scenarios
- An increase in channel forming flows with climate change may lead to **increased erosion** in the channel
- Changes to CFF may impact natural channel structures which impacts fish spawning and migration habits. Timing shifts can **impact fish life histories**.
- Of all factors modelled, **climate change is predicted to have the strongest impact** on ecological flows in the watershed.



Next Steps

- Additional studies that integrate baseline fish and fish habitat data
- Identification of key indicator fish species most sensitive life history processes (spawning, rearing, migration) to interpret impact of timing shifts
- Detailed modelling at key locations
- Re-visit assessment as new climate change modelling becomes available



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