Seven Years of Cover Performance at Mine Waste Rock Piles: Insights from the Sydney Coalfield

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BC MEND MLARD Workshop

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Western

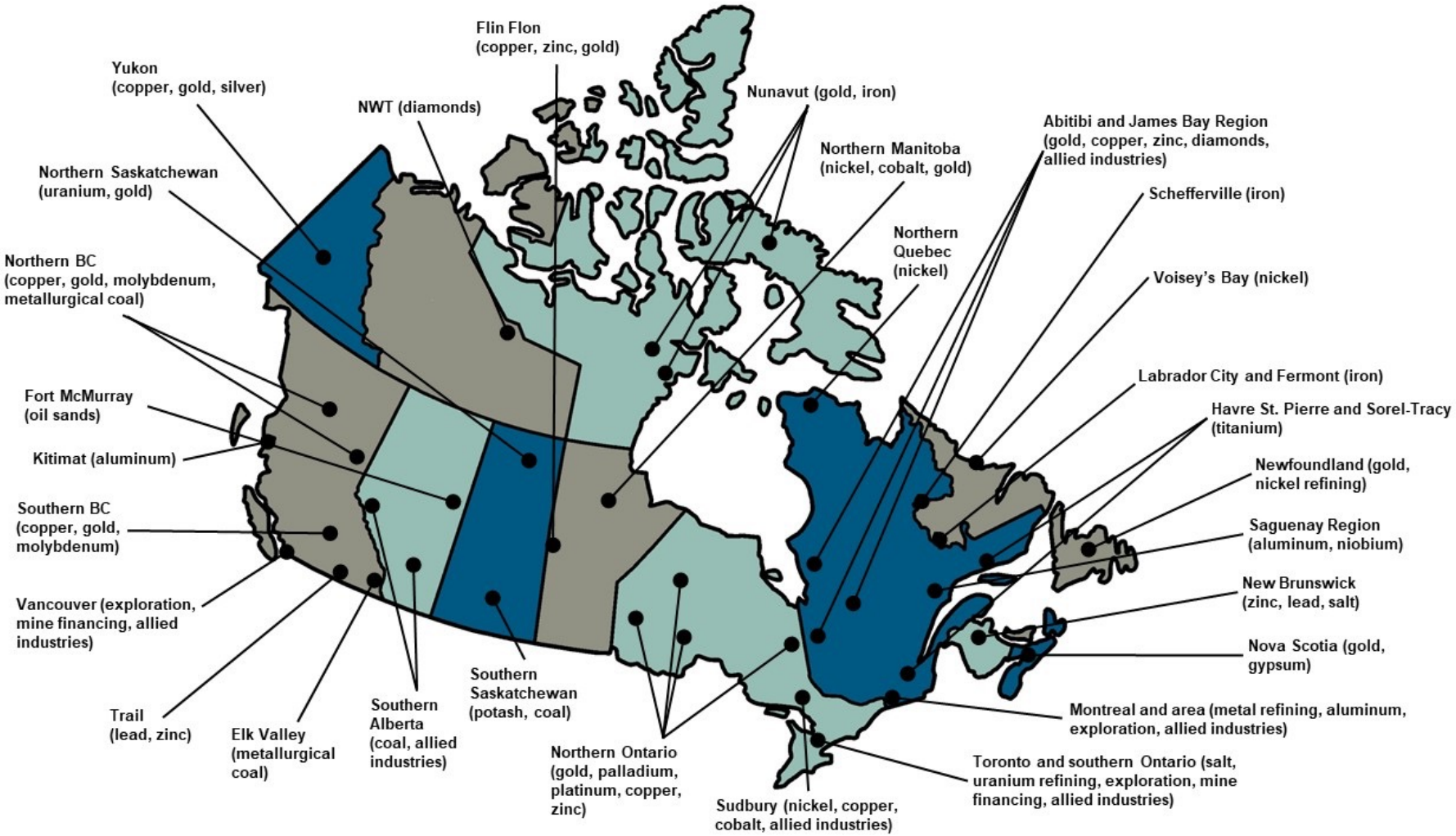
RESTORE

Outline

- Background
- Site Description
- Field Monitoring Program
- Cover Performance – Water Influx
- Cover Performance – Oxygen Influx
- Cover Performance – Environmental Quality
- Conclusions

Background

- Mining in Canada



Source: The Mining Association of Canada (2019)

Background

- Mining in Canada

Kitimat (alu
Southern BC (copper, gold, molybdenum
Vancouver (ex mine financin industries)
Trail (lead, zinc)
Elk Valley (metallurgical coal)
Southern Alberta (coal, allied industries)
Saskatchewan (potash, coal)
Northern O (gold, palla copper, zinc
Labrador City and Fermont (iron)
Pierre and Sorel- tanium)
wfoundland (gold, kel refining)
uenay Region minum, niobium)
Brunswick , lead, potash)
a Scotia c, gypsum)
efining, d industries)

Source: The Mining Association of Canada (2019)

Background

- **LEGACY**: mine waste storage facilities (MWSF)
  - Ponds of finer wetter tailings
  - Stockpiles of coarser, drier tailings
  - Stockpiles of waste rock

Background

- **LEGACY**: mine waste storage facilities (MWSF)
- **PROBLEM**: acid mine drainage and metal leaching

Background

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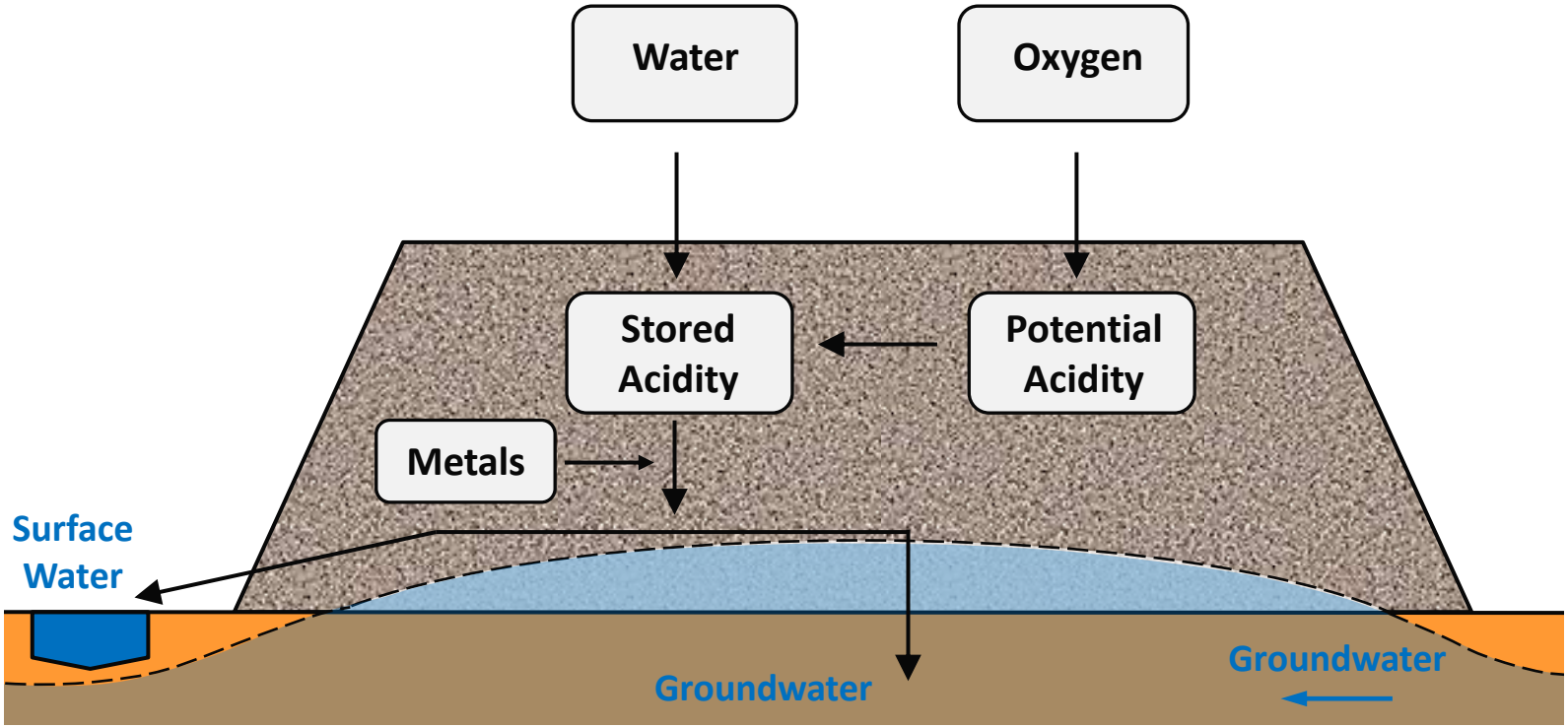
- **PROBLEM**: acid mine drainage and metal leaching

$$FeS_2 + {}^{7}\!/_{2}\, H_2O + {}^{15}\!/_{4}\, O_2 \rightarrow Fe(OH)_3 + H_2SO_4$$



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Background

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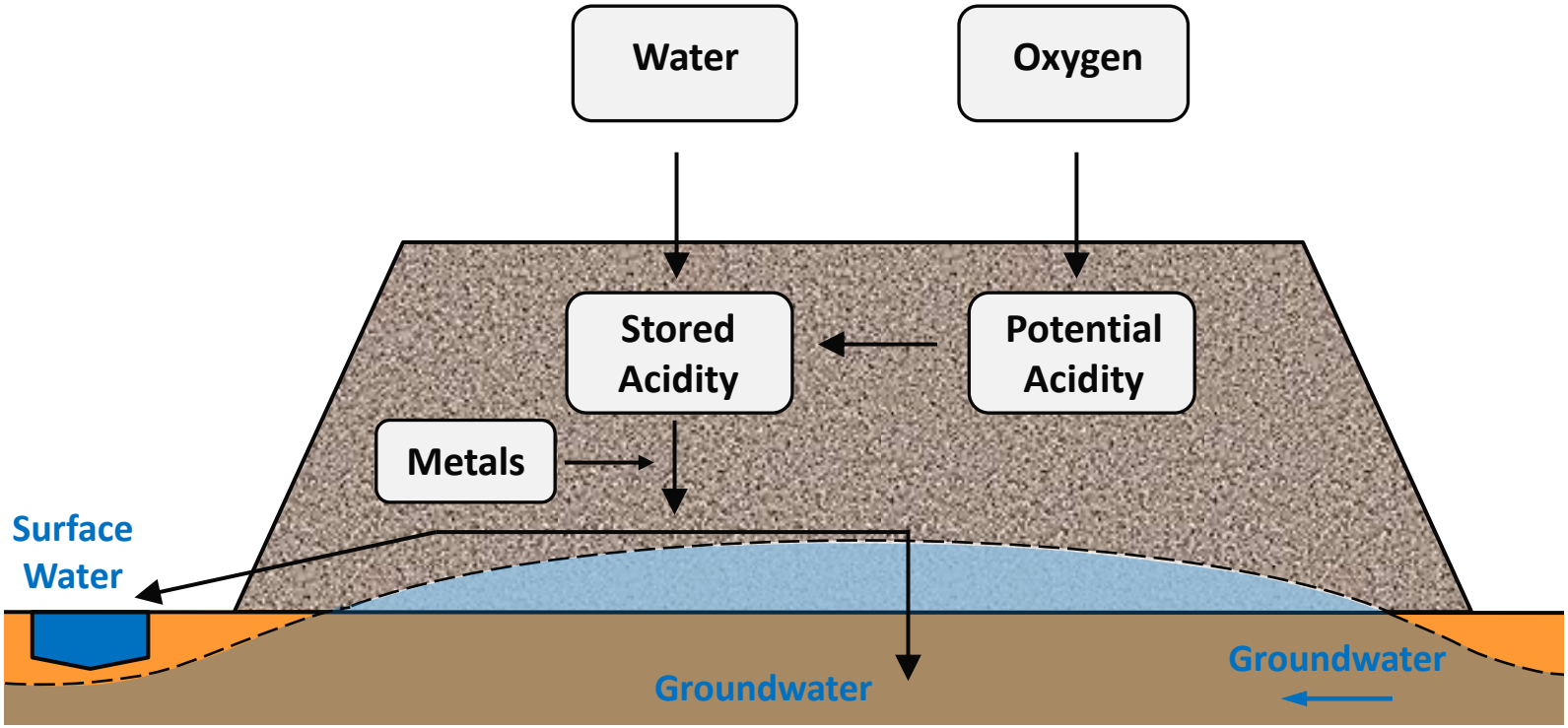
- **SOLUTION**: cover systems to isolate the waste



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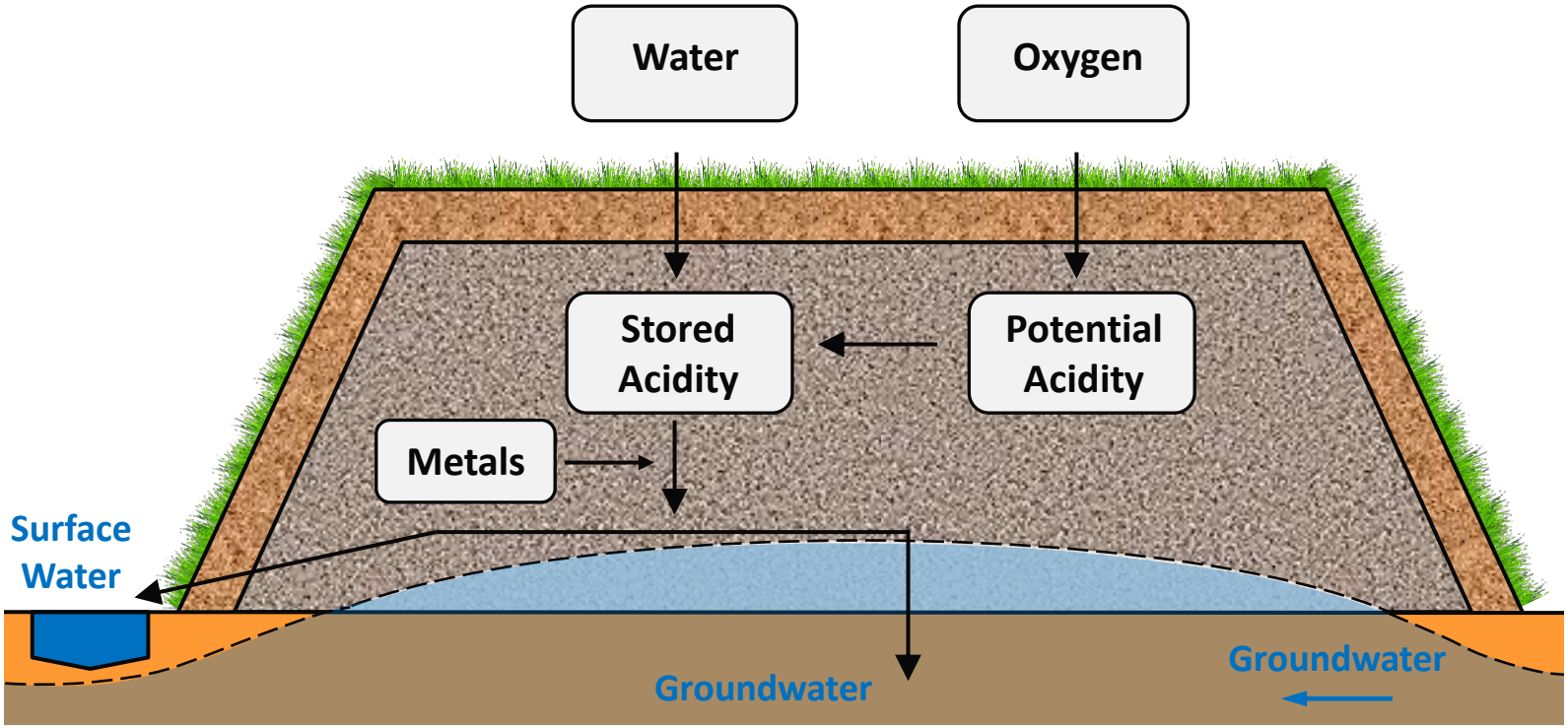


Background

- **Objectives**
  - Support end land use
  - Minimize degradation of receiving environment post-closure
- **Design Functions**
  - Waste isolation (‘keep clean water clean’)
  - Re-establish vegetation and ecosystems
  - Control wind and water erosion of waste material
  - Limit influx of oxygen to reactive waste material
  - Limit net percolation of meteoric water through the waste

Background

- Design Alternatives

Moisture Store & Release

Growth Medium

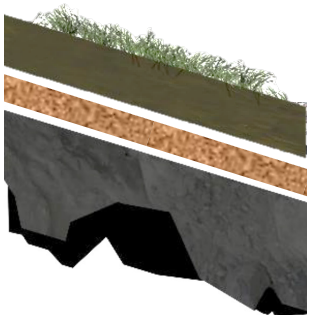
Waste Rock

Enhanced Moisture Store & Release

Growth Medium

Alternative Layer

Waste Rock

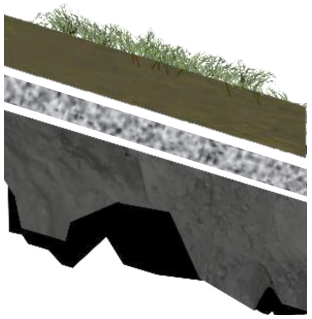


Barrier Type

Growth Medium

Barrier Layer

Waste Rock



Covers with Geosynthetics

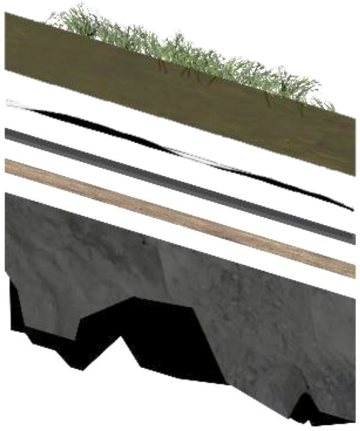
Growth Medium

Geotextile

HDPE

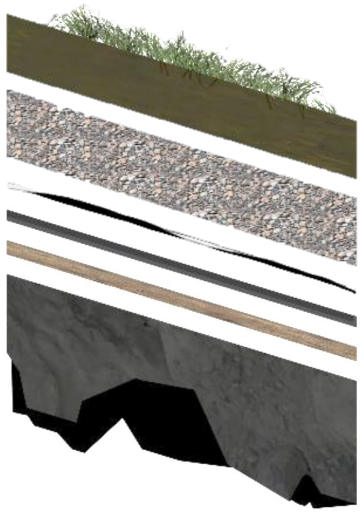
Bedding Sand

Waste Rock



Background

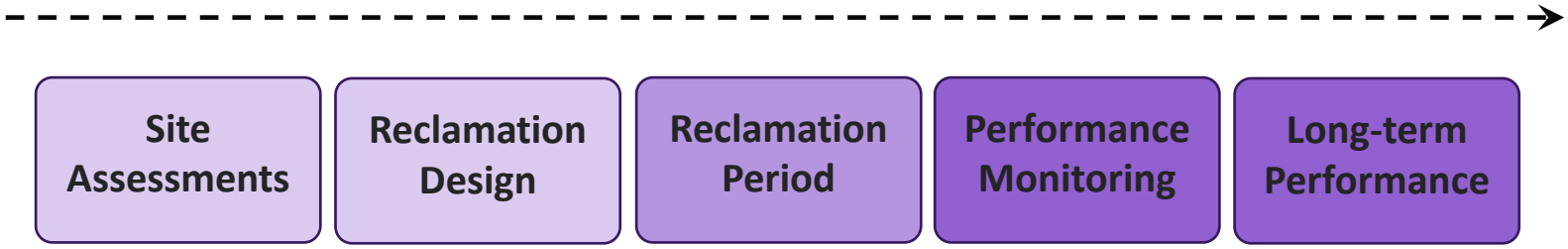
- **Selection will be influenced by numerous factors**
  - Landform attributes
    - Geochemistry: reactivity, solubility, etc.
    - Geotechnical: grain size, strength, etc.
    - Geometry: footprint, height, slopes
  - External factors
    - Climatic conditions
    - Hydrogeological setting
  - Material availability
  - Cost

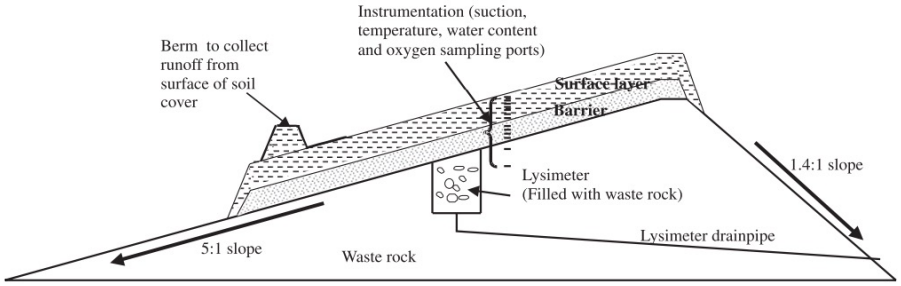


Background

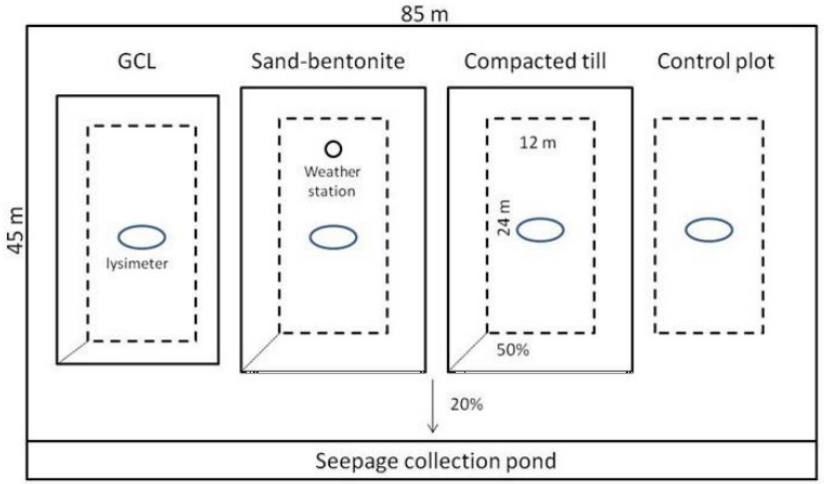
- **How will the selected cover perform?**

Timeline of Cover System





Test plots at Whistle Mine, Sudbury, ON



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Site Description

The Sydney Coalfield, NS, Canada

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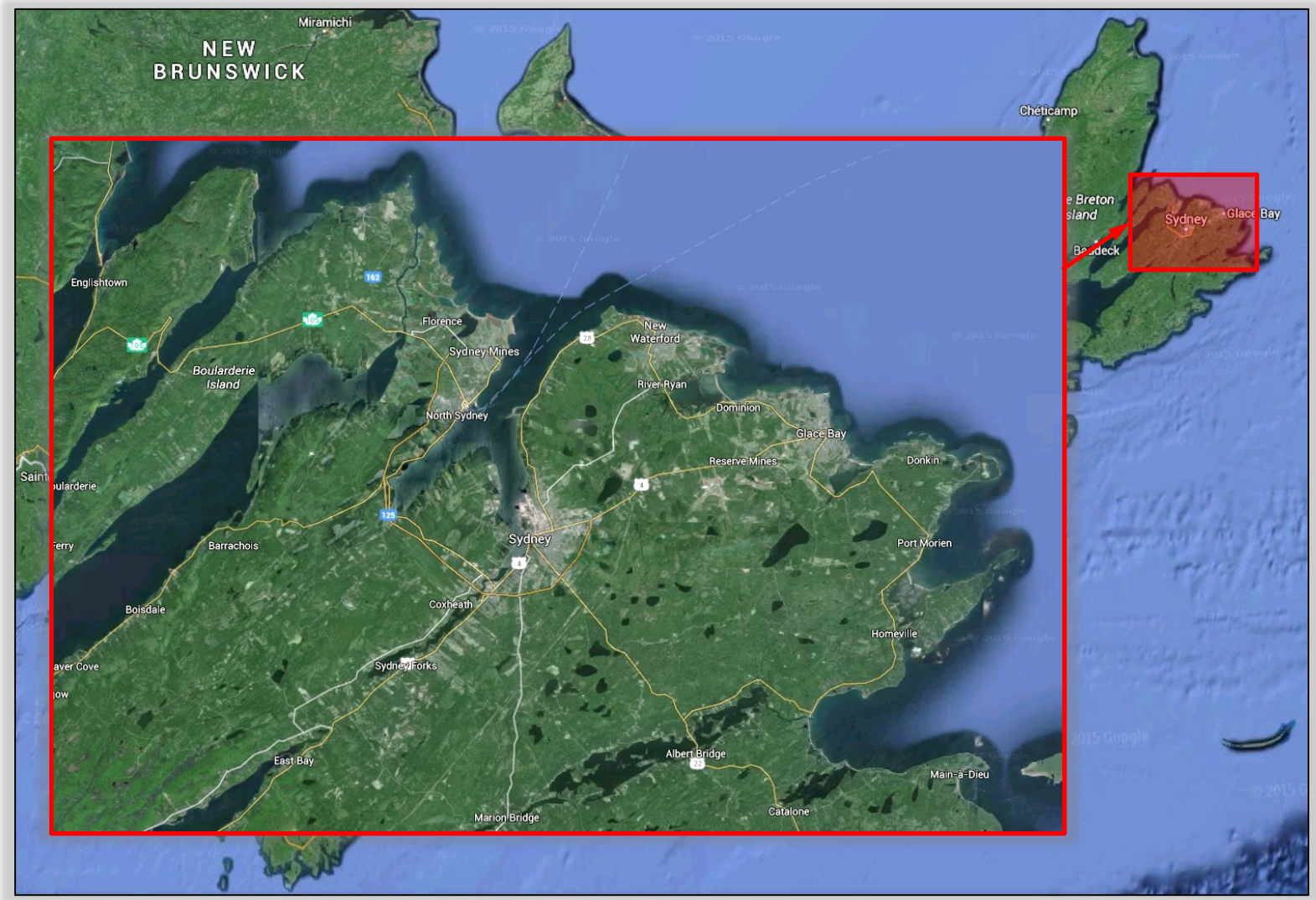

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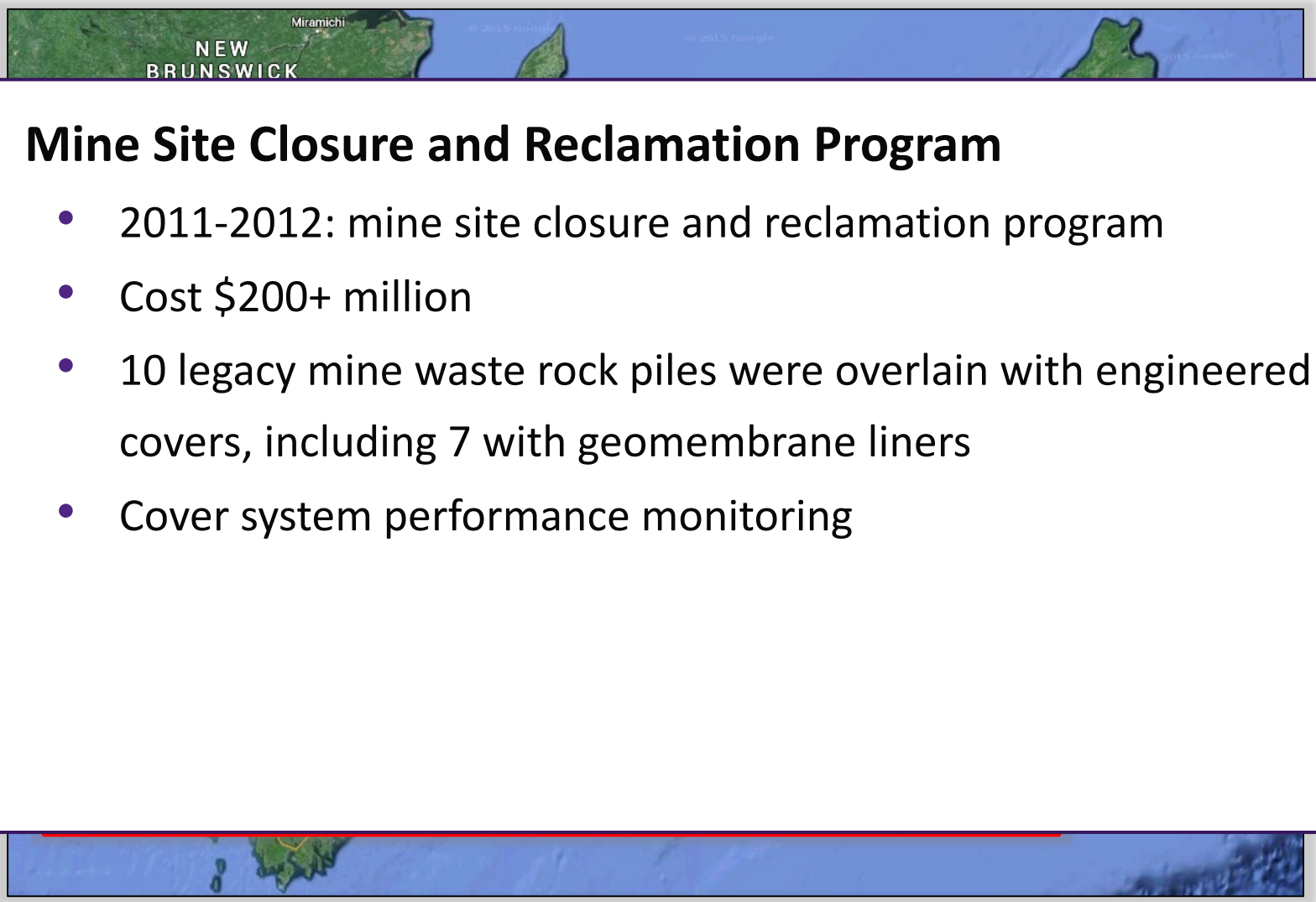


Mine Site Closure and Reclamation Program

- 2011-2012: mine site closure and reclamation program
- Cost $200+ million
- 10 legacy mine waste rock piles were overlain with engineered covers, including 7 with geomembrane liners
- Cover system performance monitoring

Site Description

The Sydney Co

- 2011-2012:

Princess Colliery

October 2010

October 2010

Scotchtown Summit

March 2012

Site Description

Lingan

Site Description

Lingan

- 646,000 tonnes of fill/waste rock
- Footprint of 82,028 m^2
- Thickness at center = 15 m
- Cover installed in 2011

Site Description

Scotchtown Summit

Site Description

Scotchtown Summit

- 2.5 million tonnes of fill/waste rock
- Footprint of 370,000 m^2
- Thickness range from 1.4 m to 10 m
- Cover installed in 2011

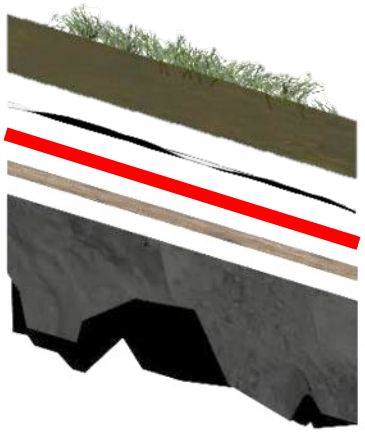
Growth Medium

Geotextile

HDPE

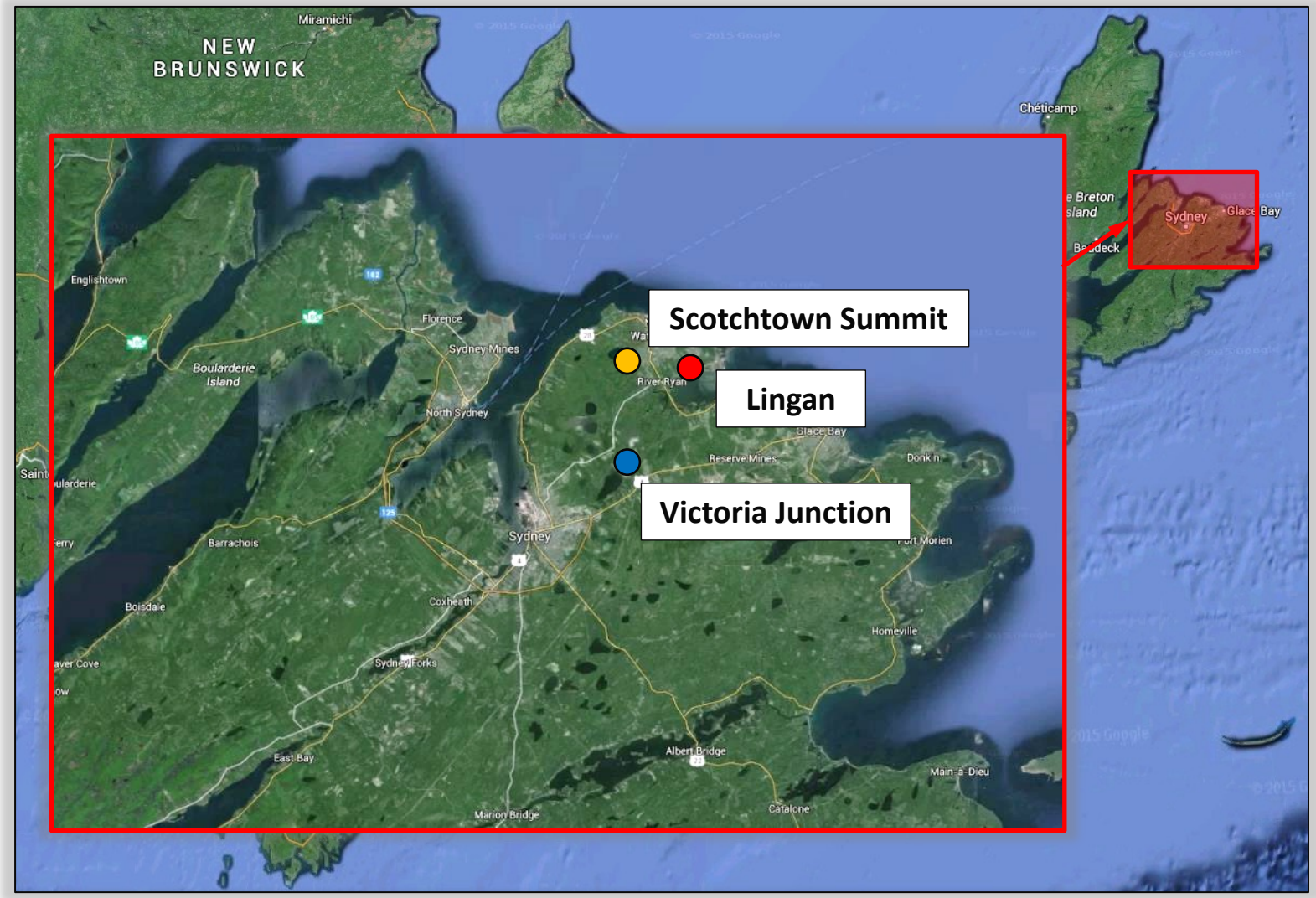
Bedding Sand

Waste Rock



Site Description

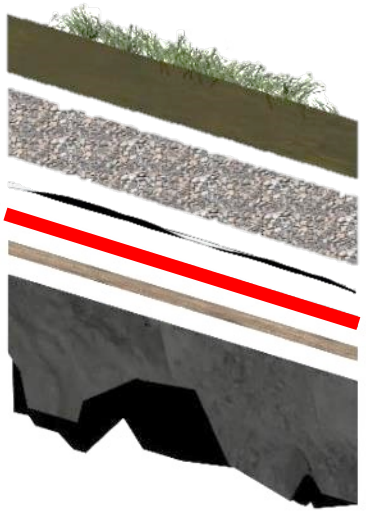
Victoria Junction

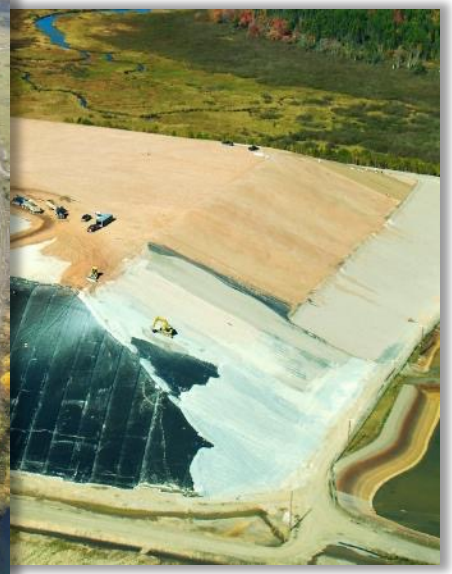


Site Description

Victoria Junction

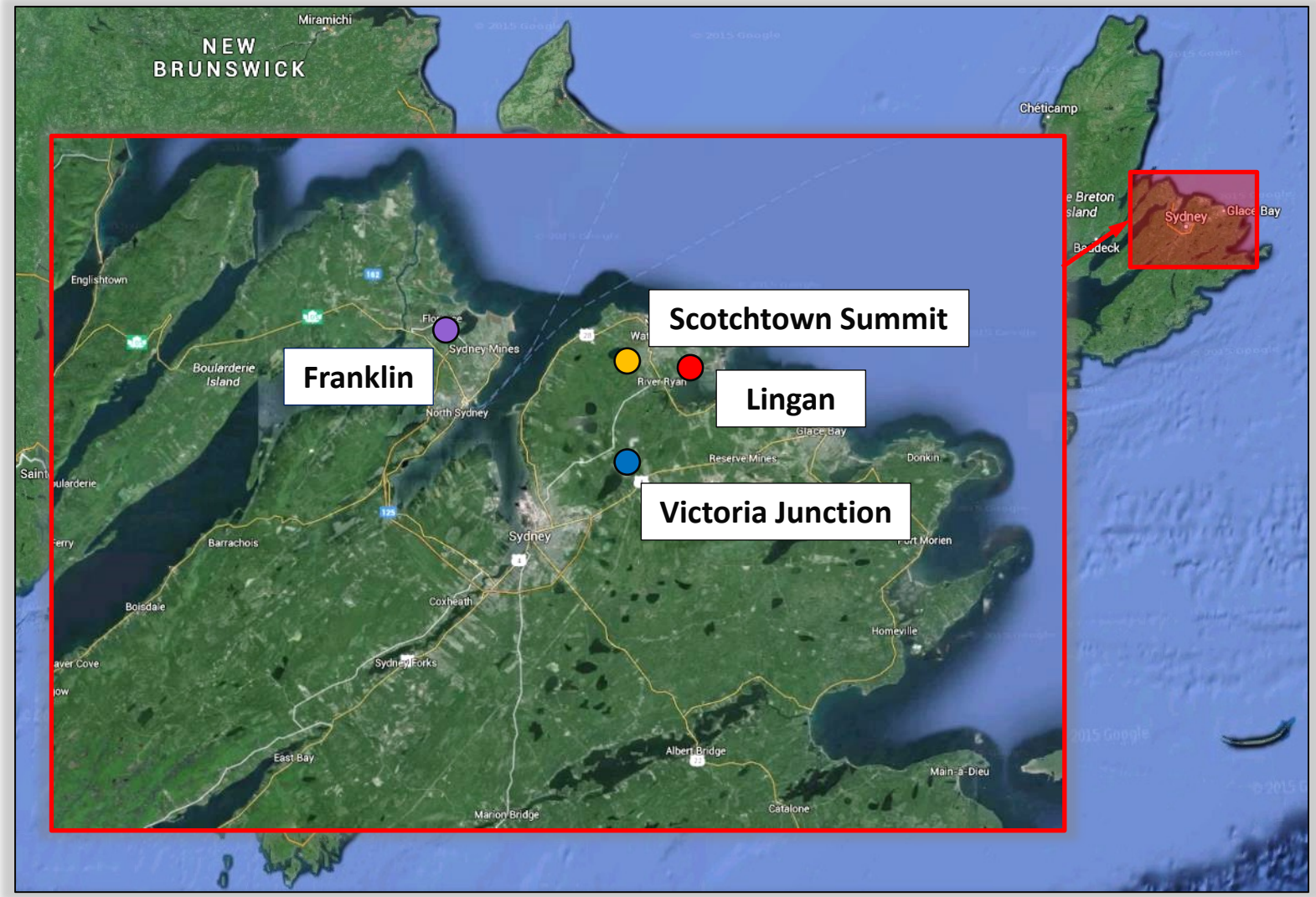
- 10 million tonnes of fill/waste rock
- Footprint of 260,000 m^2
- Waste rock height = 40 m
- Cover installed in 2007





Site Description

Franklin

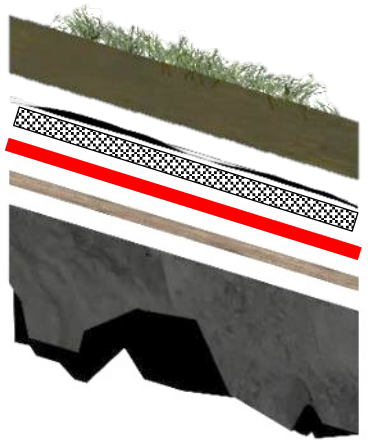


Site Description

Franklin

- 319,005 tonnes of fill/waste rock
- Footprint of 31,000 m^2
- Thickness at center = 11 m
- Cover installed in 2010

Growth Medium
Drainage Layer
Geotextile
HDPE
Bedding Sand
Waste Rock



Site Description

Site Description

Moisture Store & Release

Growth Medium

Waste Rock

Geosynthetic Cover 1

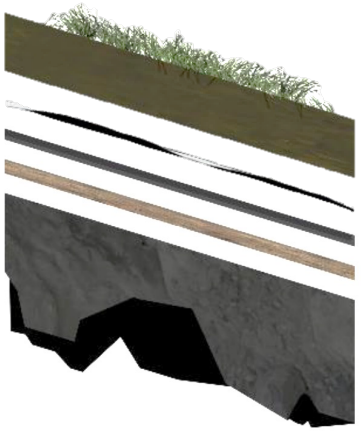
Growth Medium

Geotextile

HDPE

Bedding Sand

Waste Rock



Geosynthetic Cover 2

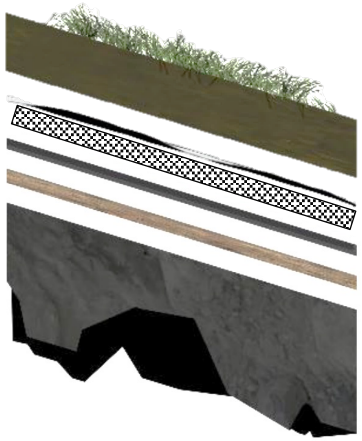
Growth Medium

PermaNet

HDPE

Bedding Sand

Waste Rock



Geosynthetic Cover 3

Growth Medium

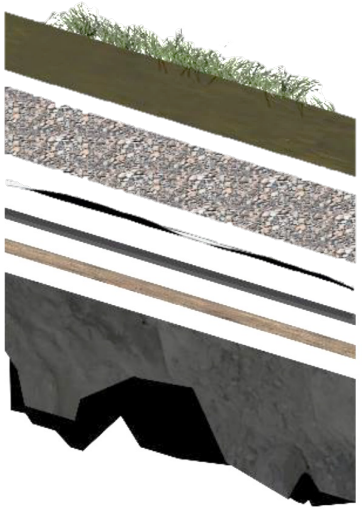
Drainage Layer

Geotextile

HDPE

Bedding Sand

Waste Rock



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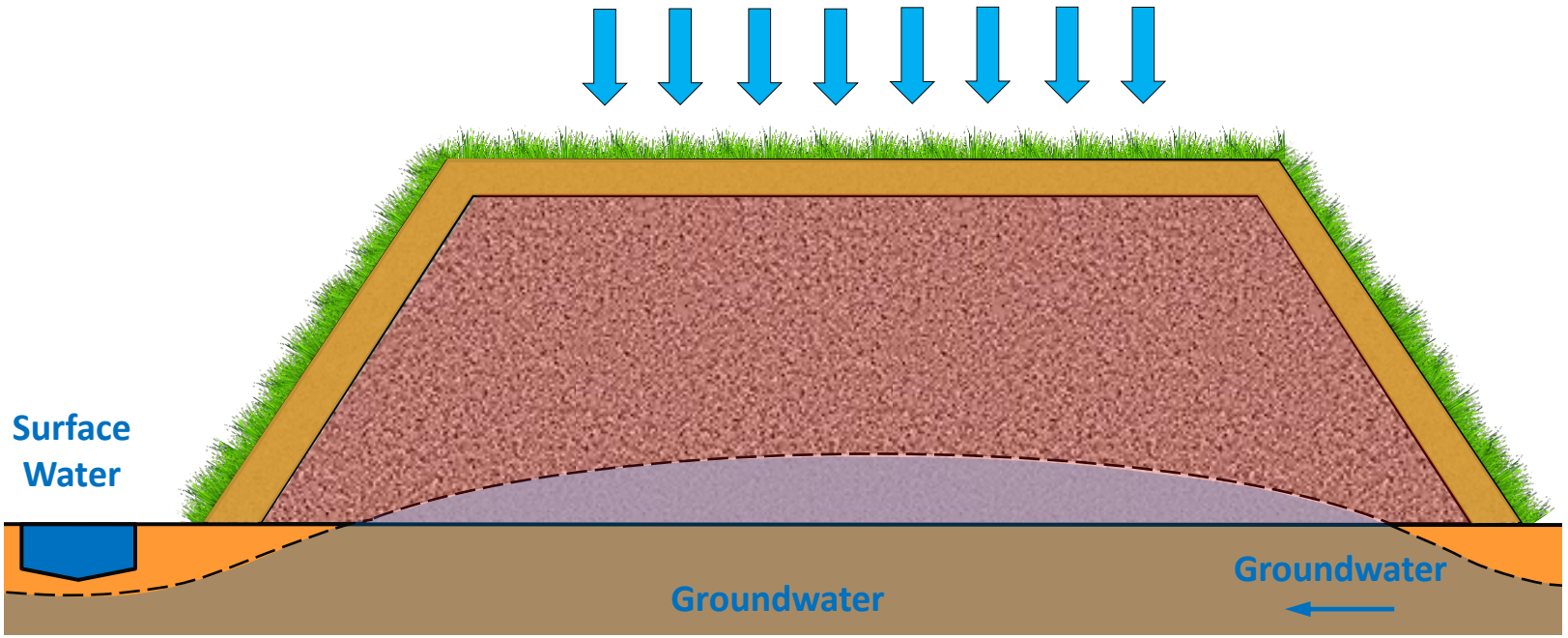
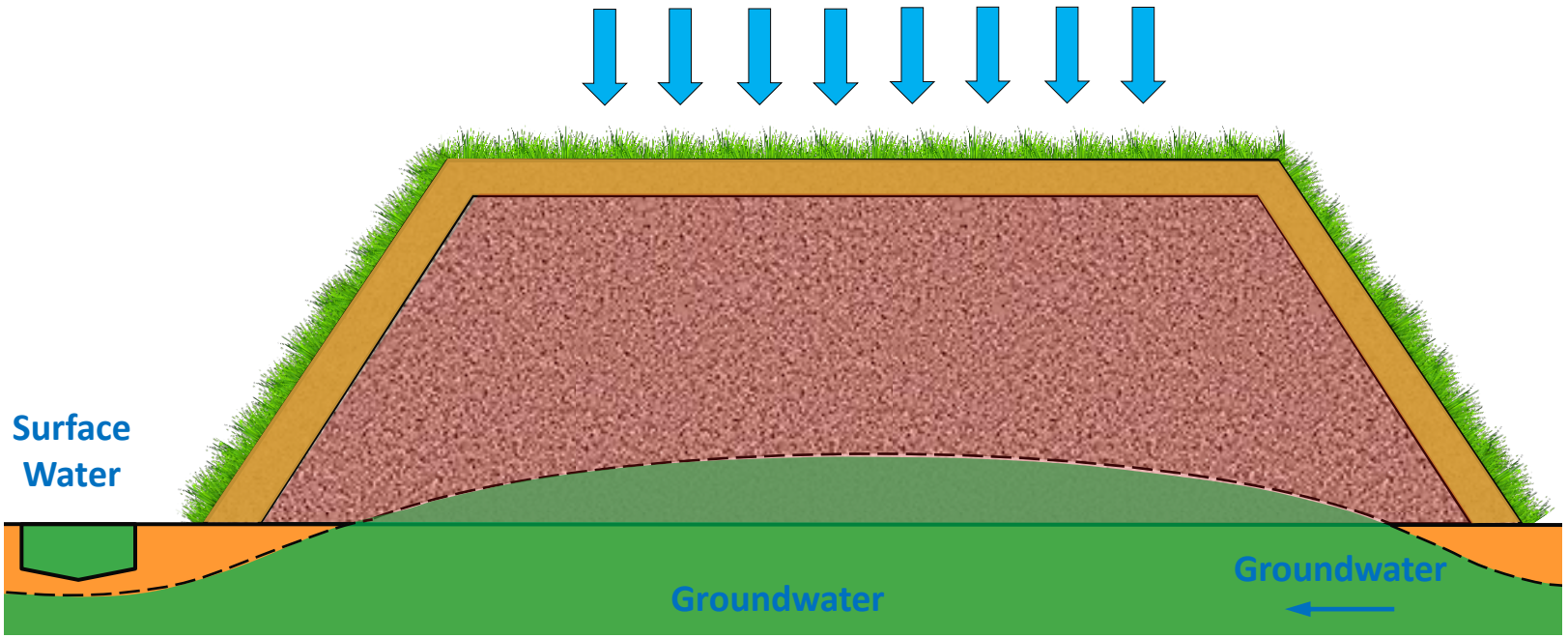
Field Performance Monitoring

- January 2012 to December 2018
  - **Atmosphere**
  - **Cover System**
  - **Waste Rock Pile**



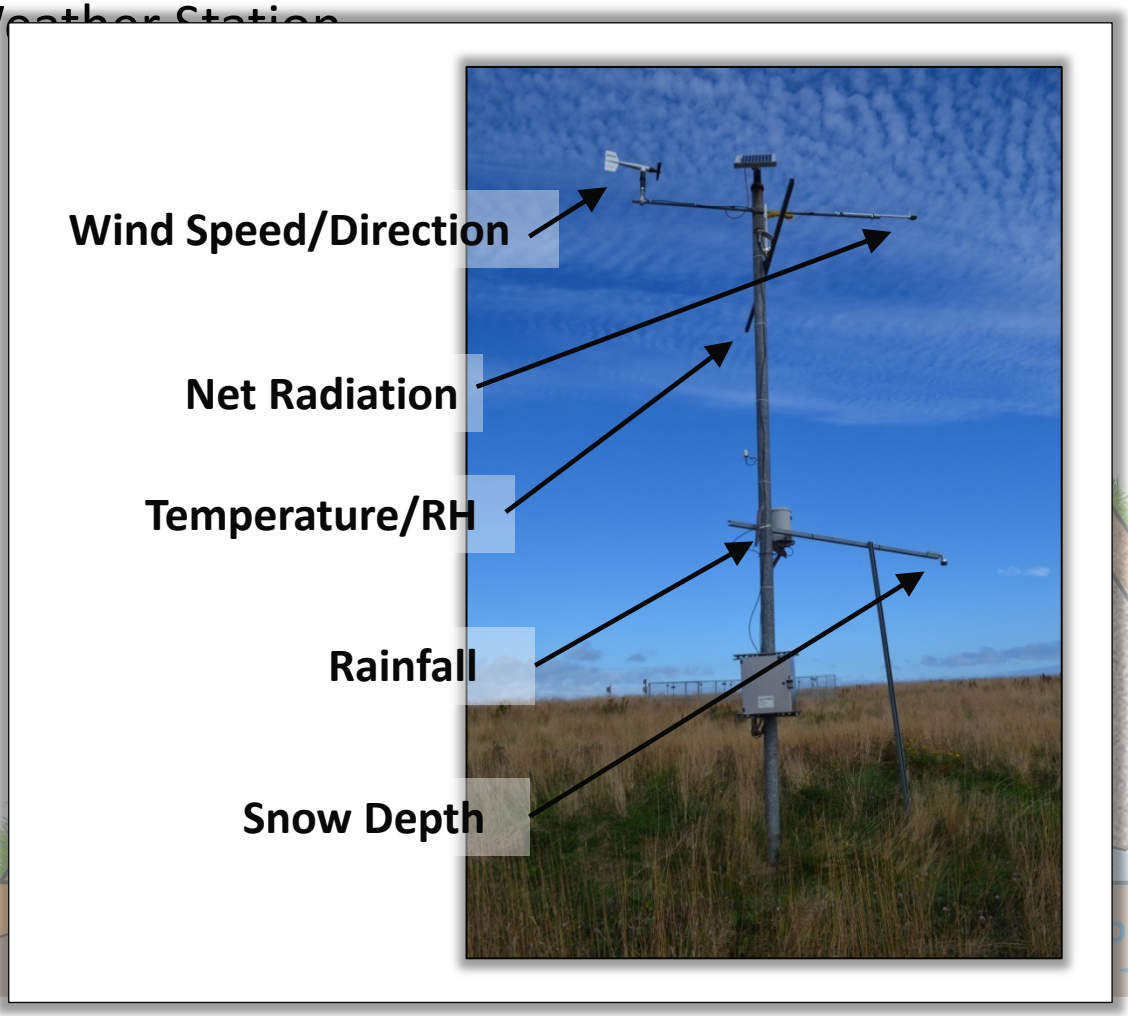
Field Performance Monitoring

- January 2012 to December 2018
  - **Atmosphere**
  - **Cover System**
  - **Waste Rock Pile**
  - **Environmental Receptors**



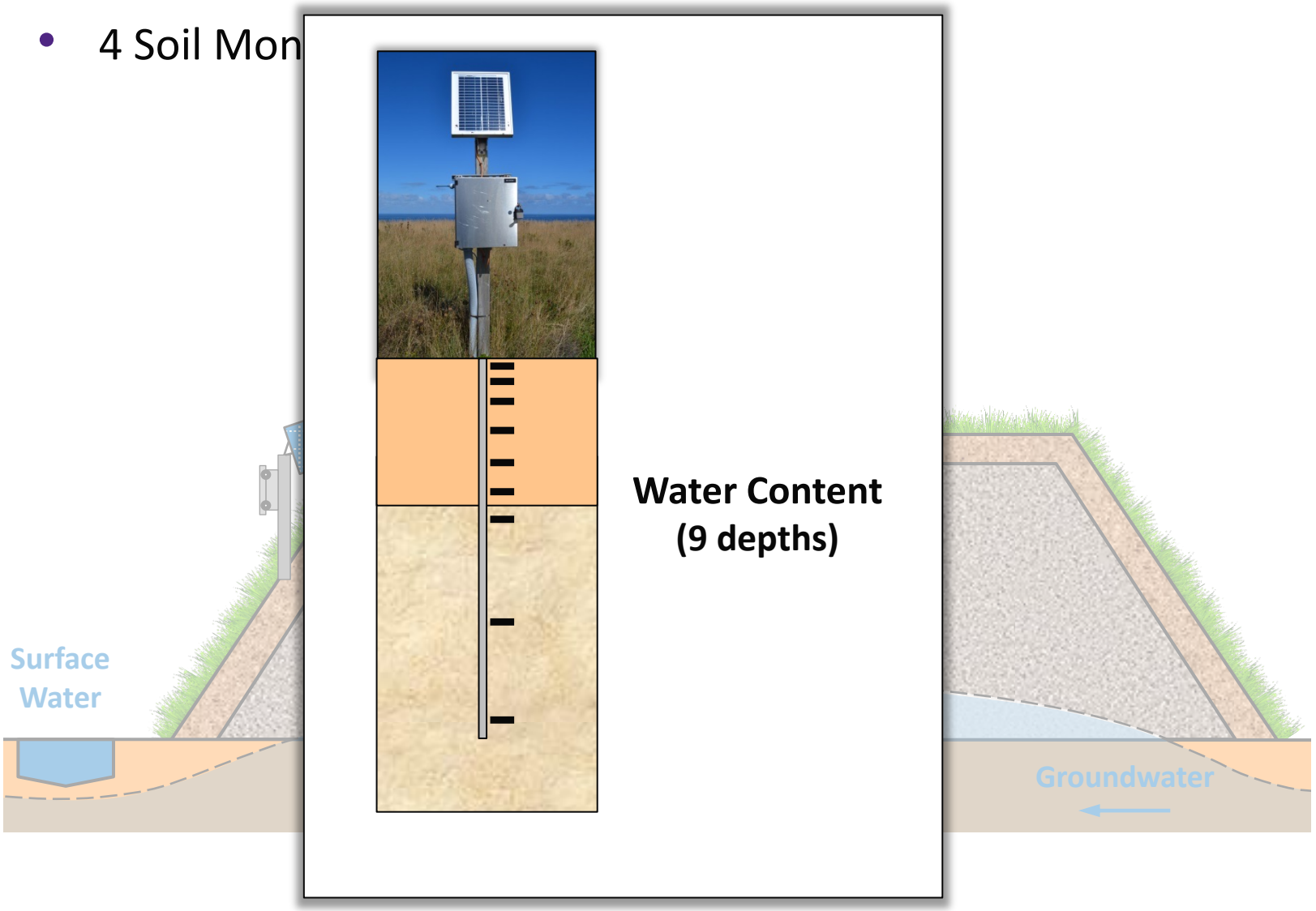
Field Performance Monitoring

- Key field instrumentation
  - 1 W[illegible]



Field Performance Monitoring

- Key field instrumentation
  - 4 Soil Mon



Field Performance Monitoring

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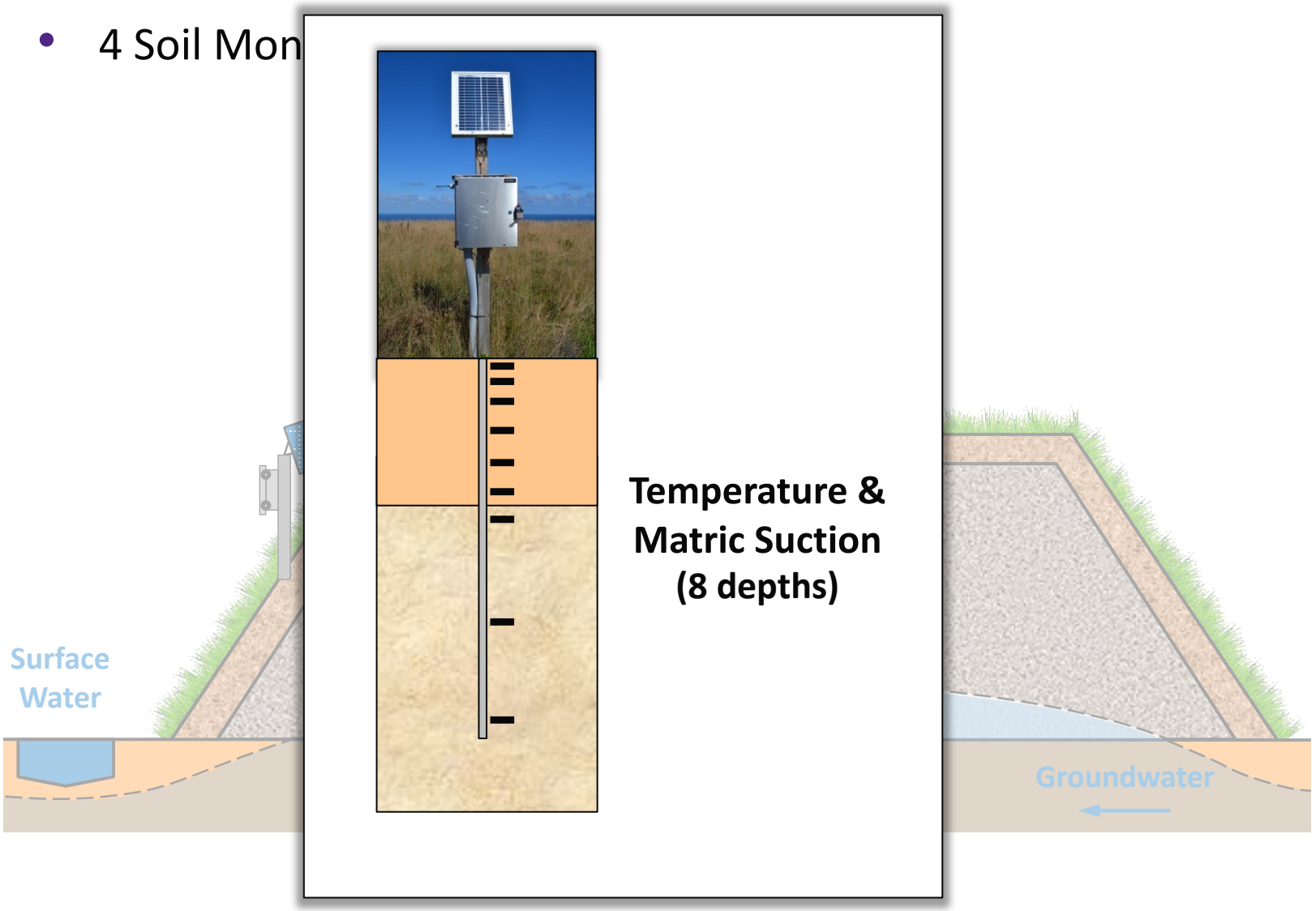

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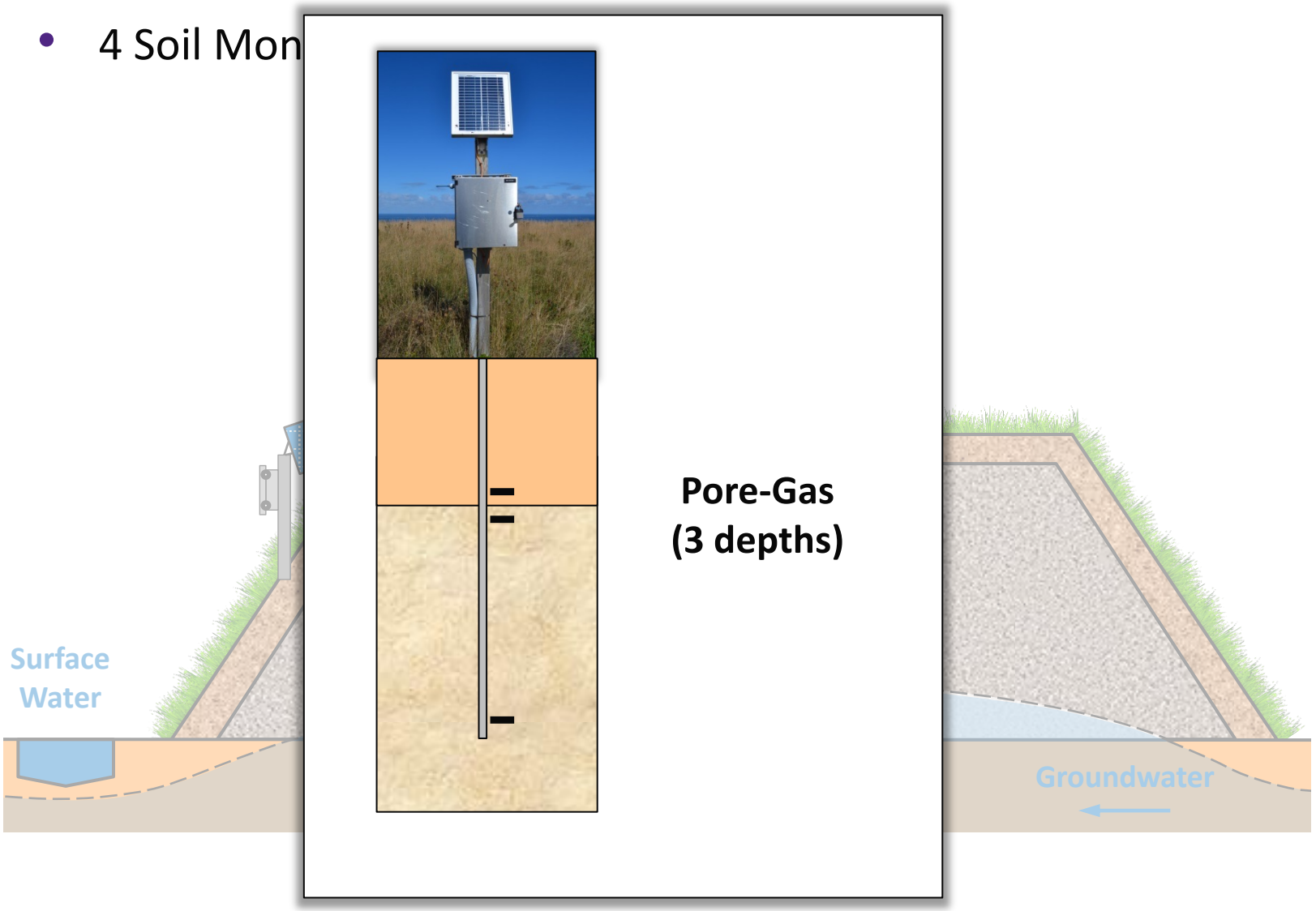
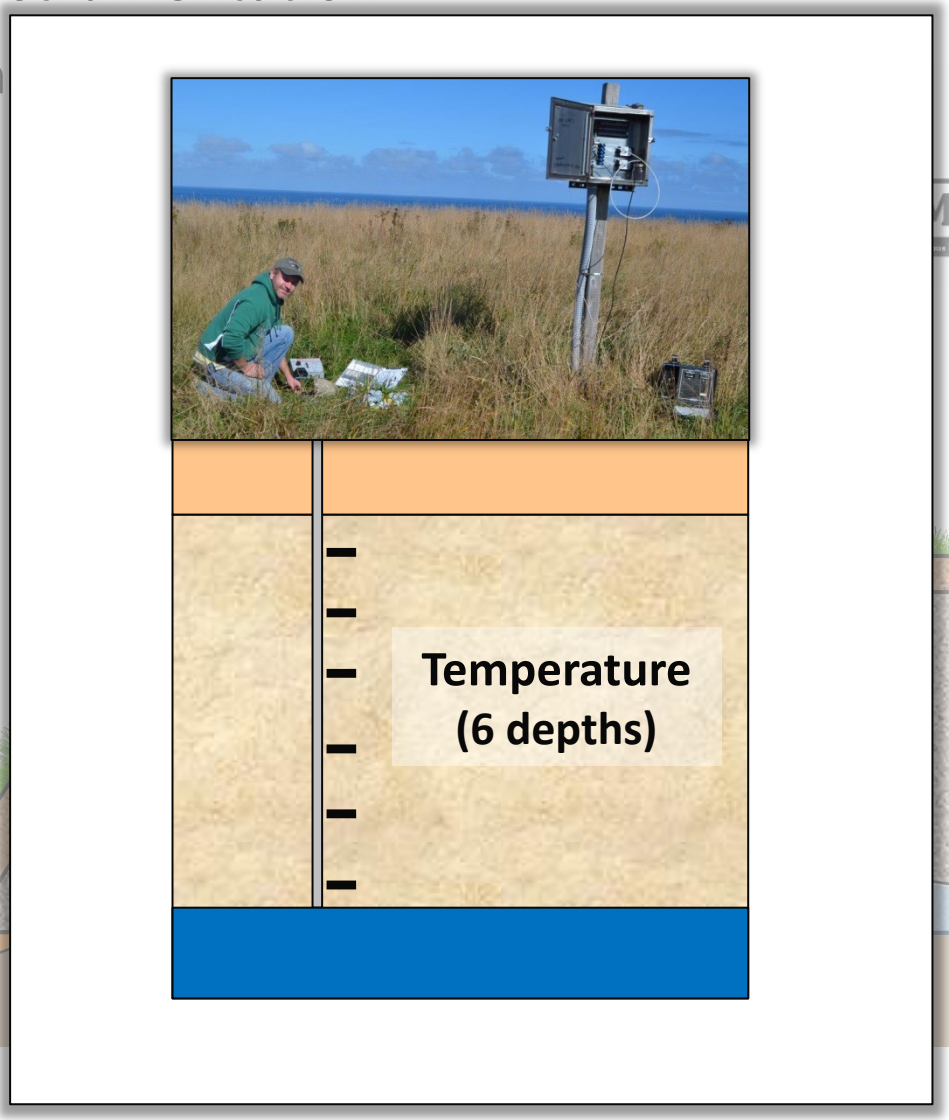


Field Performance Monitoring

- Key field instrumentation
  - 4 Intern



Source: Solinst Canada Ltd

Field Performance Monitoring

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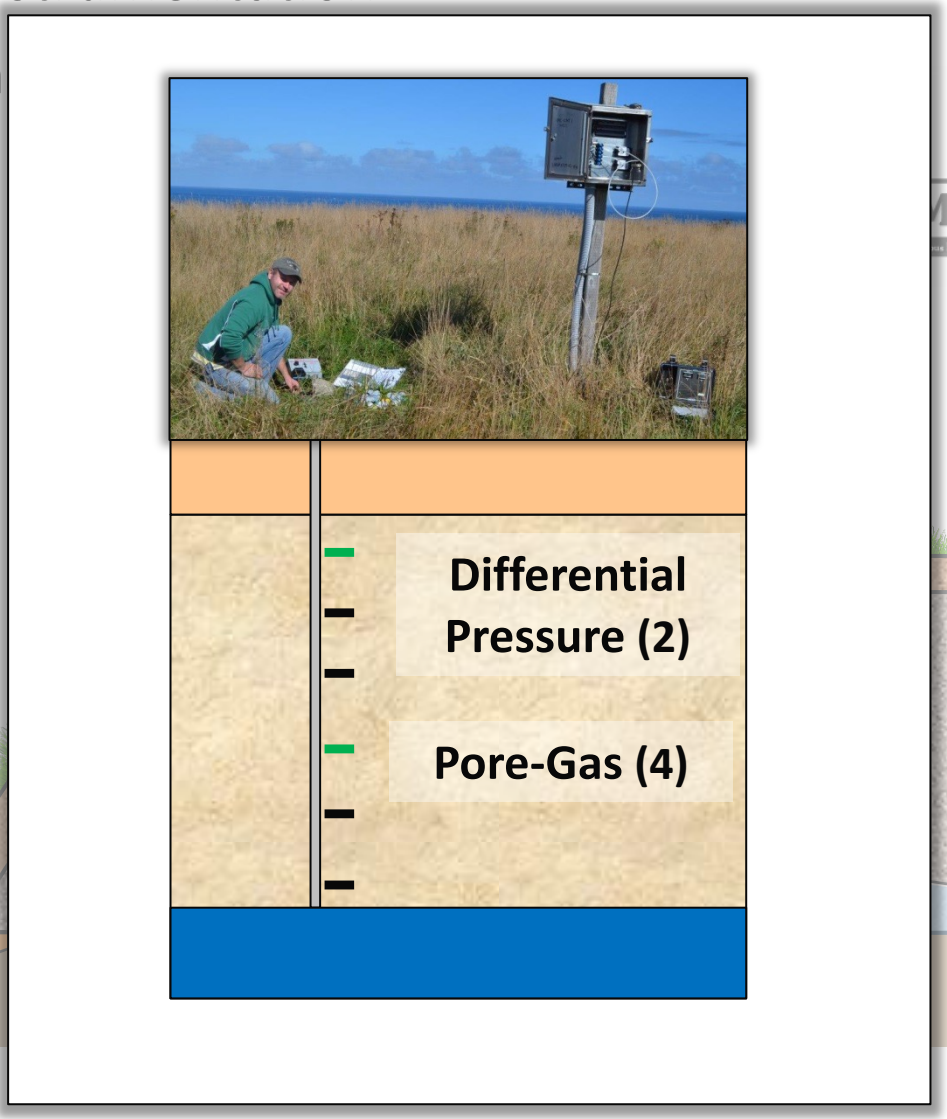

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Field Performance Monitoring

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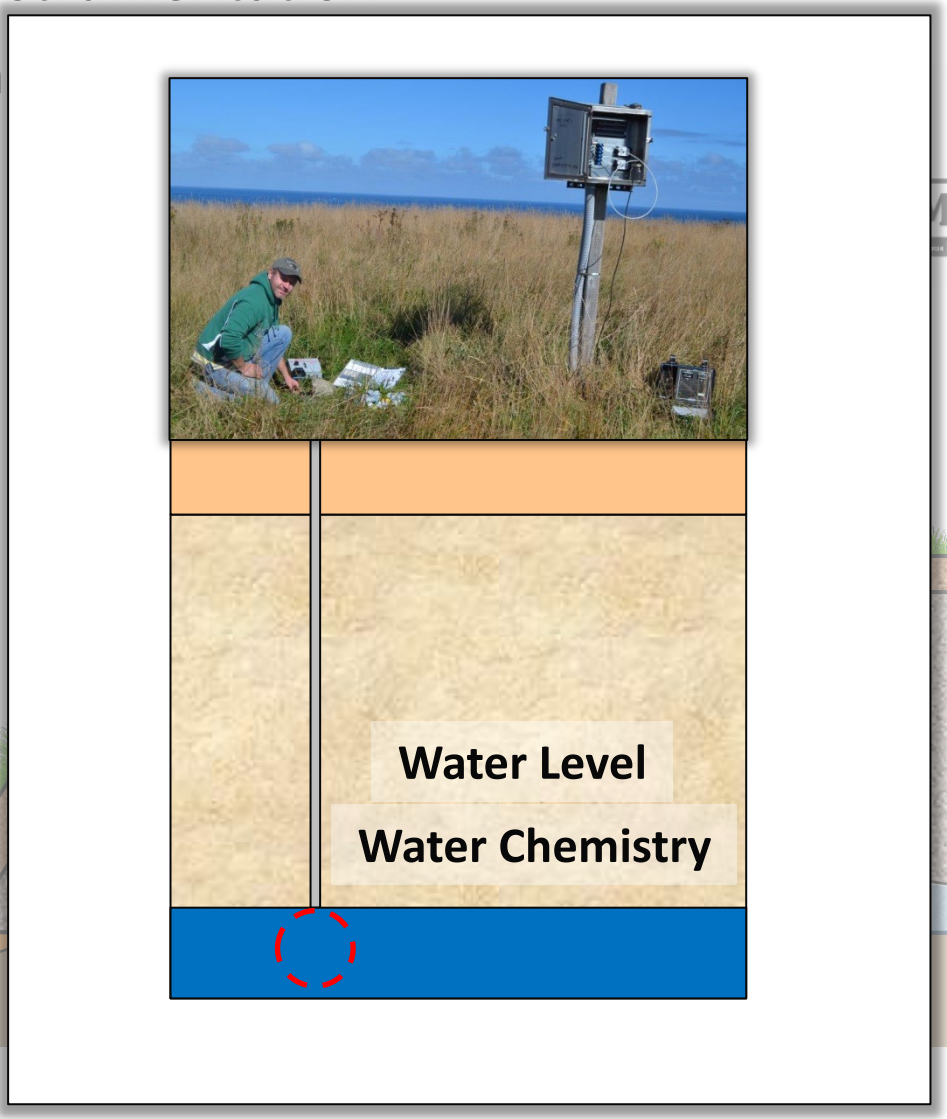


Source: Solinst Canada Ltd

Field Performance Monitoring

- Key field instrumentation
  - 1 Runoff Station (Weir)
  - 1 Interflow Collection System

Weir

Interflow Collection

Groundwater

Field Performance Monitoring

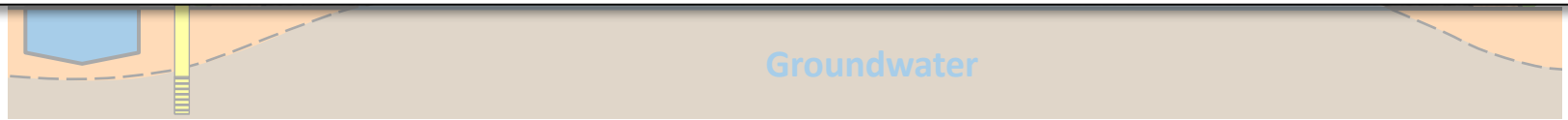
- Key field instrumentation
  - Acid base accounting – waste rock characterization

Field Performance Monitoring

- Key field instrumentation
  - Groundwater monitoring wells

Groundwater Wells

Surface Sampling Points



Field Performance Monitoring

Field Monitoring Summary

Monitoring Element	Number	Parameters	Material
Soil Monitoring Station	4	In situ temperature, matric suction, volumetric moisture content, O_2/CO_2 pore-gas concentrations, pore-water pressure	Cover and waste rock
CMT Wells	4	O_2/CO_2 pore-gas concentrations, differential pressure, temperature, groundwater level, water chemistry [a]	Waste rock and groundwater
Meteorological Station	1	Rainfall, air temperature, relative humidity, wind speed and direction, barometric pressure, snowpack depth, net radiation	Atmosphere and cover
Weir	1	Surface run-off from WRP	Cover
Interflow Collection System	1	Lateral flows through cover	Cover
Groundwater Monitoring Wells	42	Groundwater level, water chemistry [a]	Groundwater
Surface Water Sampling Points	10	Surface water flow rate, water chemistry [a]	Surface Water

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- Cover Performance – Acidity
- Cover Performance – Environmental Quality
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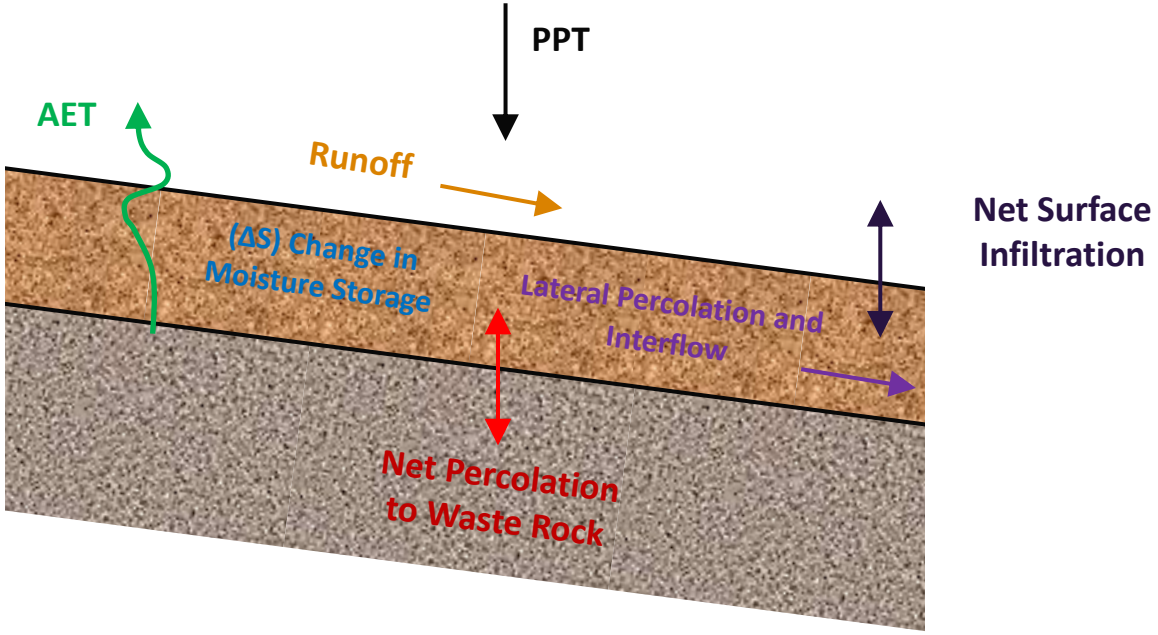
Cover Performance – Atmospheric Influx

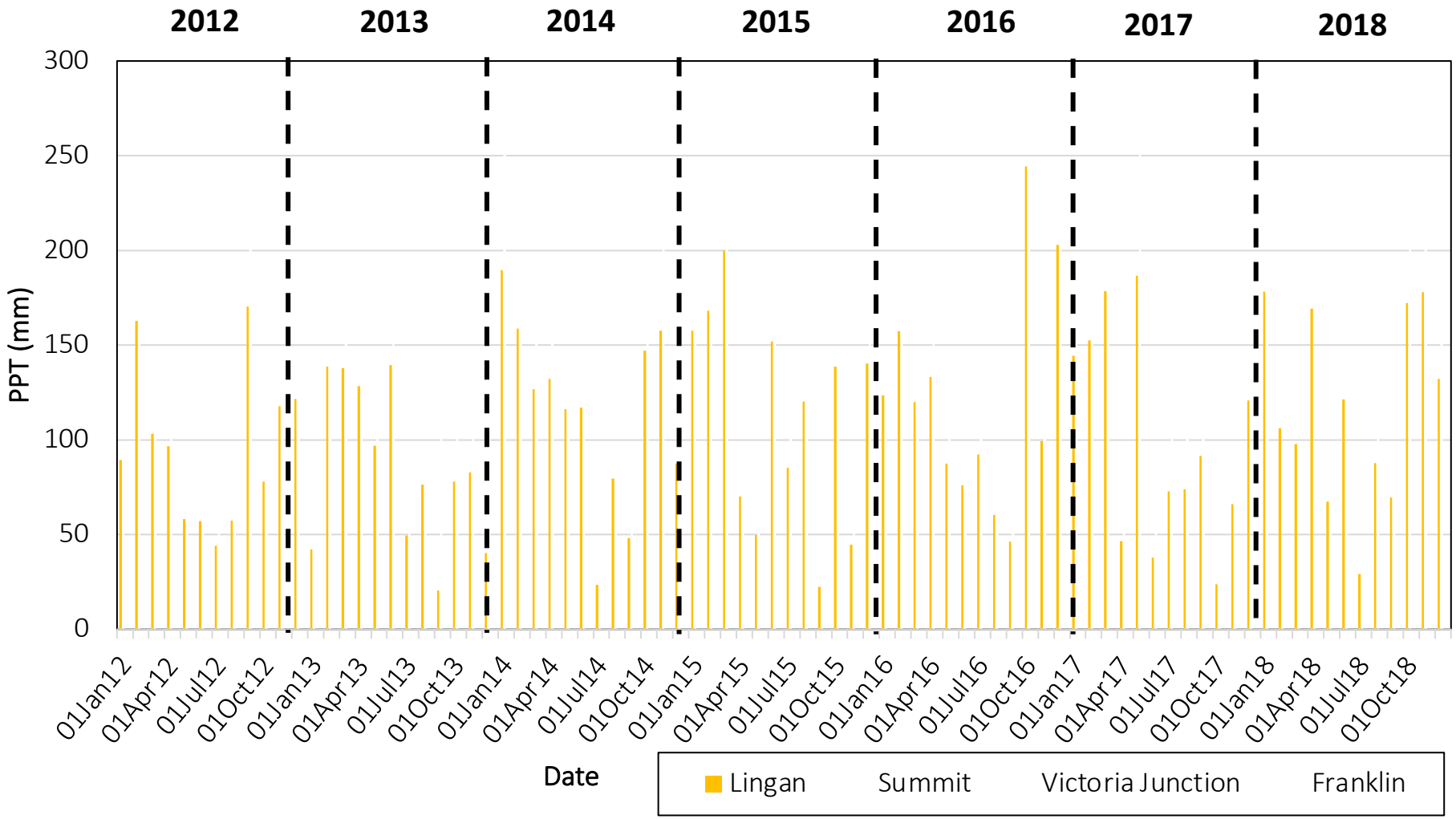
- Water influx
  - Comprehensive water balance



$$PPT = R + AET + \Delta S + LP + NP$$

Cover Performance – Atmospheric Influx

- Water influx - **Precipitation**



Cover Performance – Atmospheric Influx

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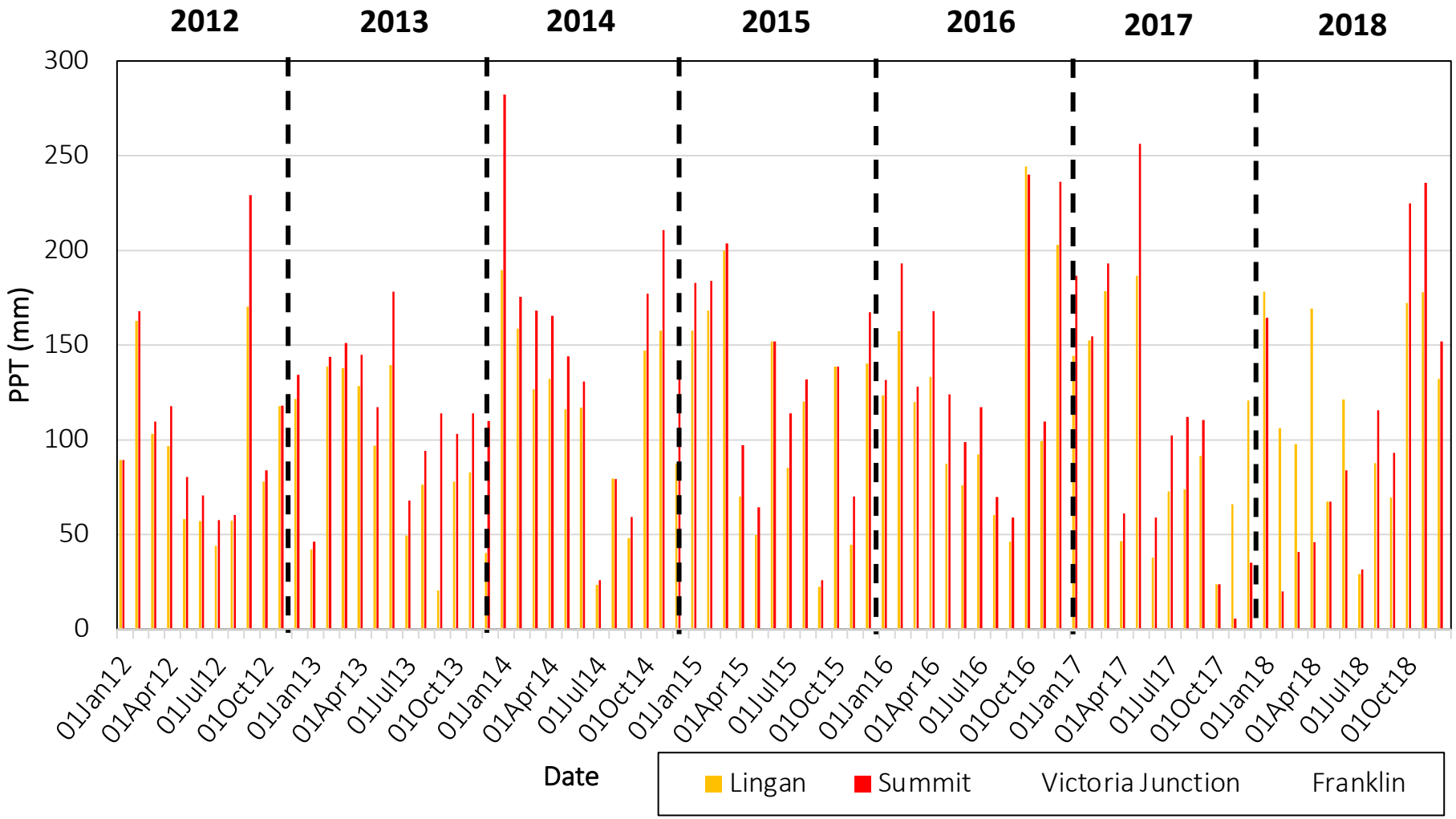

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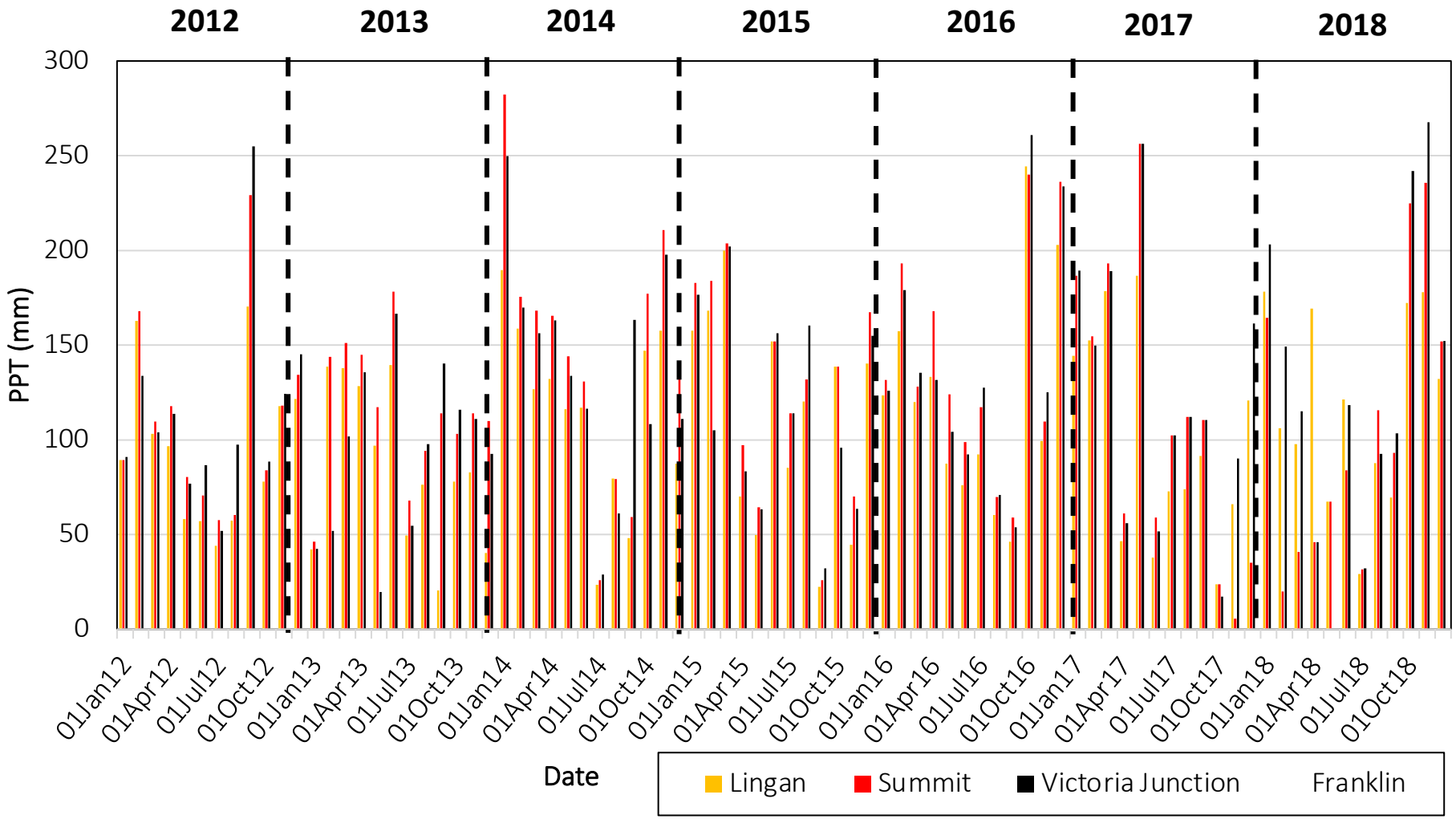

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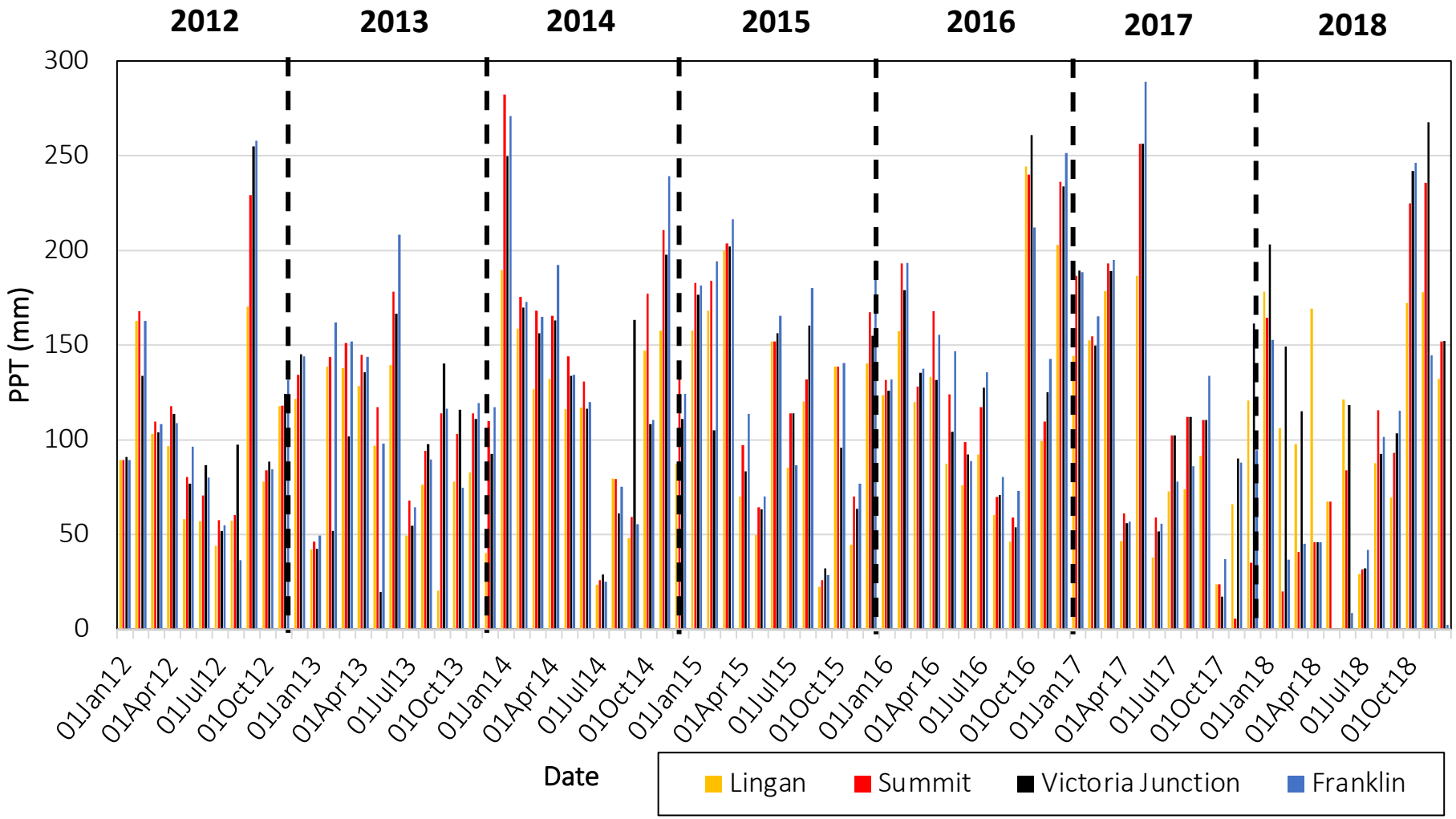

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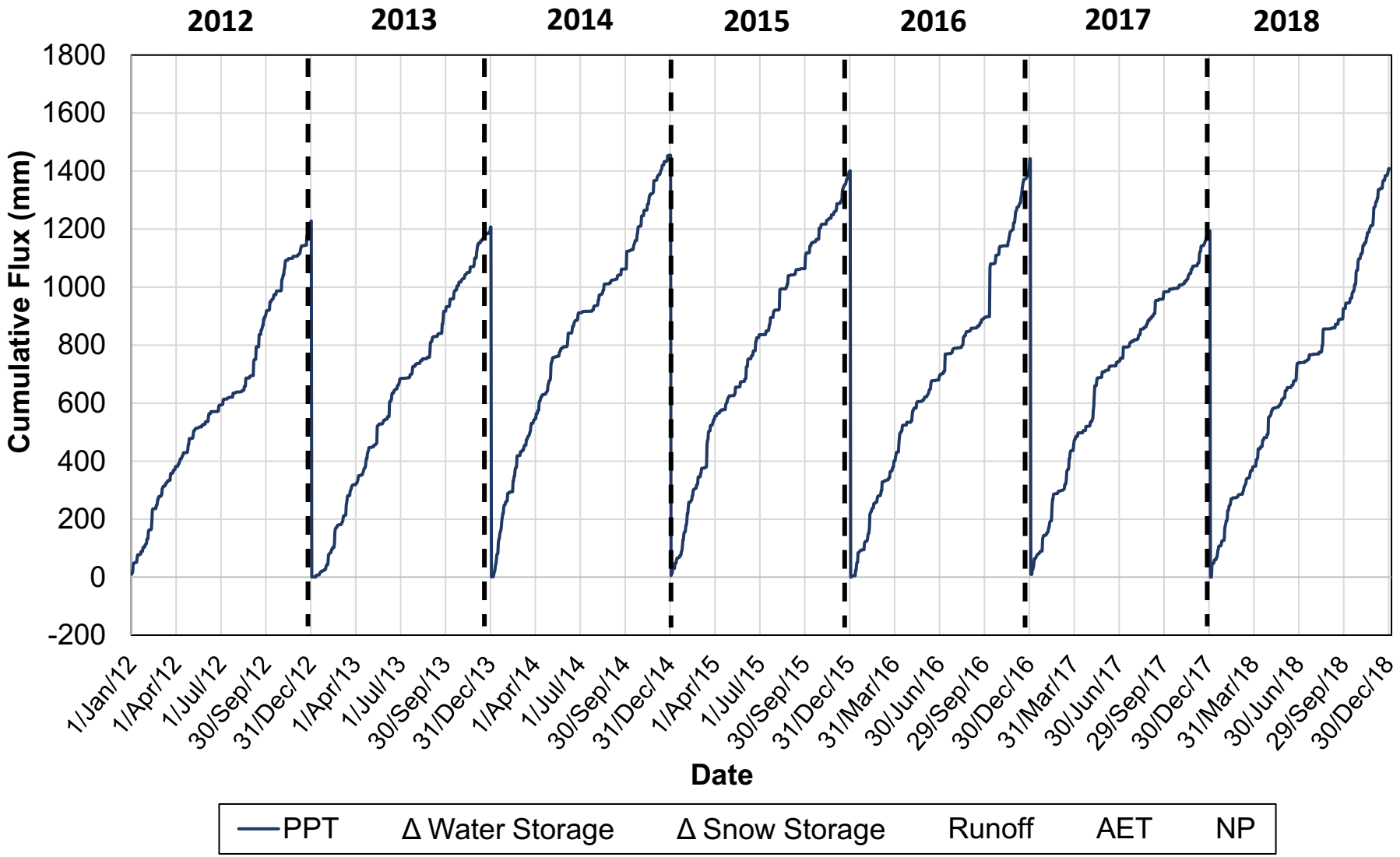
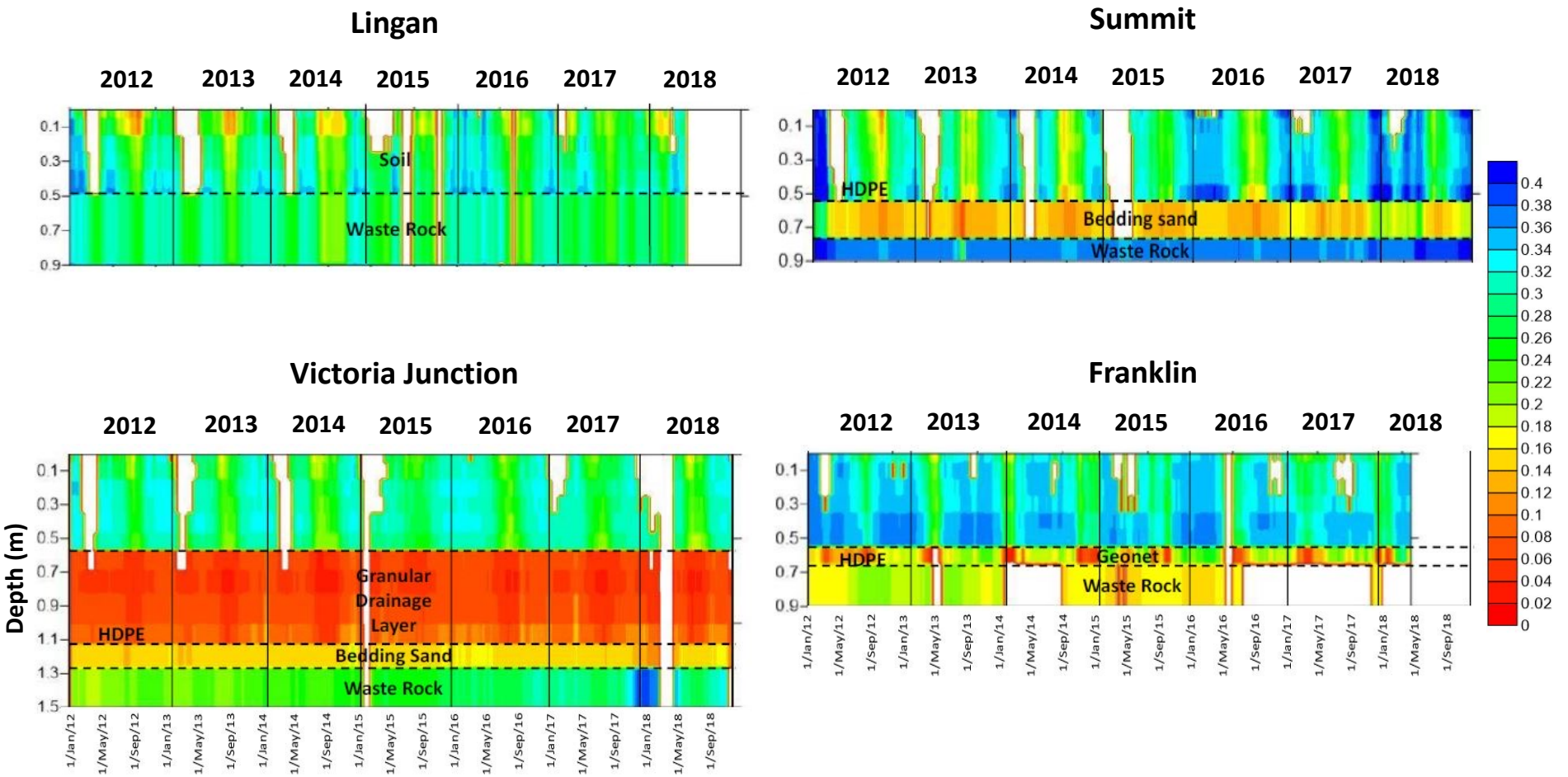
- Water influx - **Precipitation**



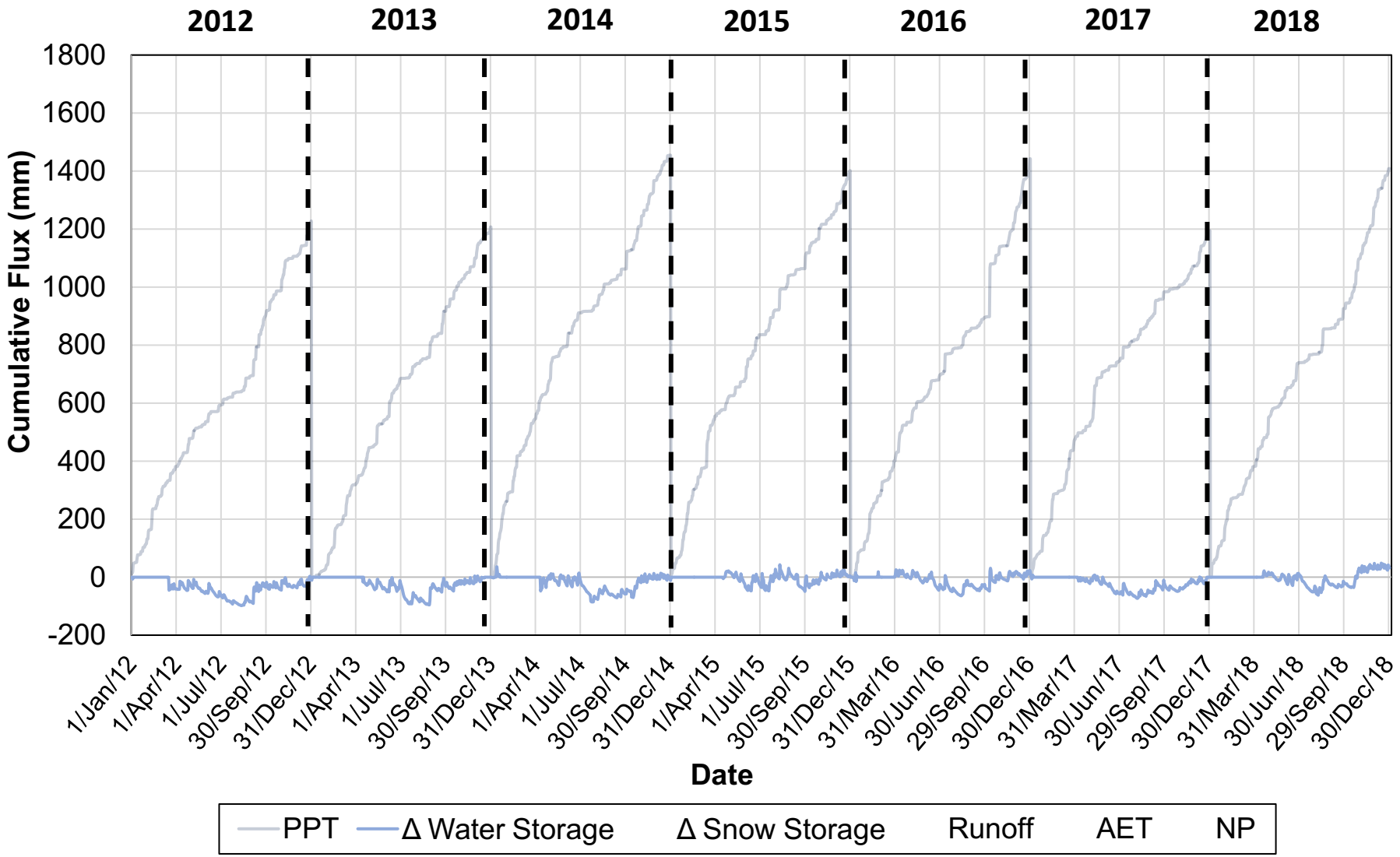
Cover Performance – Atmospheric Influx

- Water influx – **Water Storage**



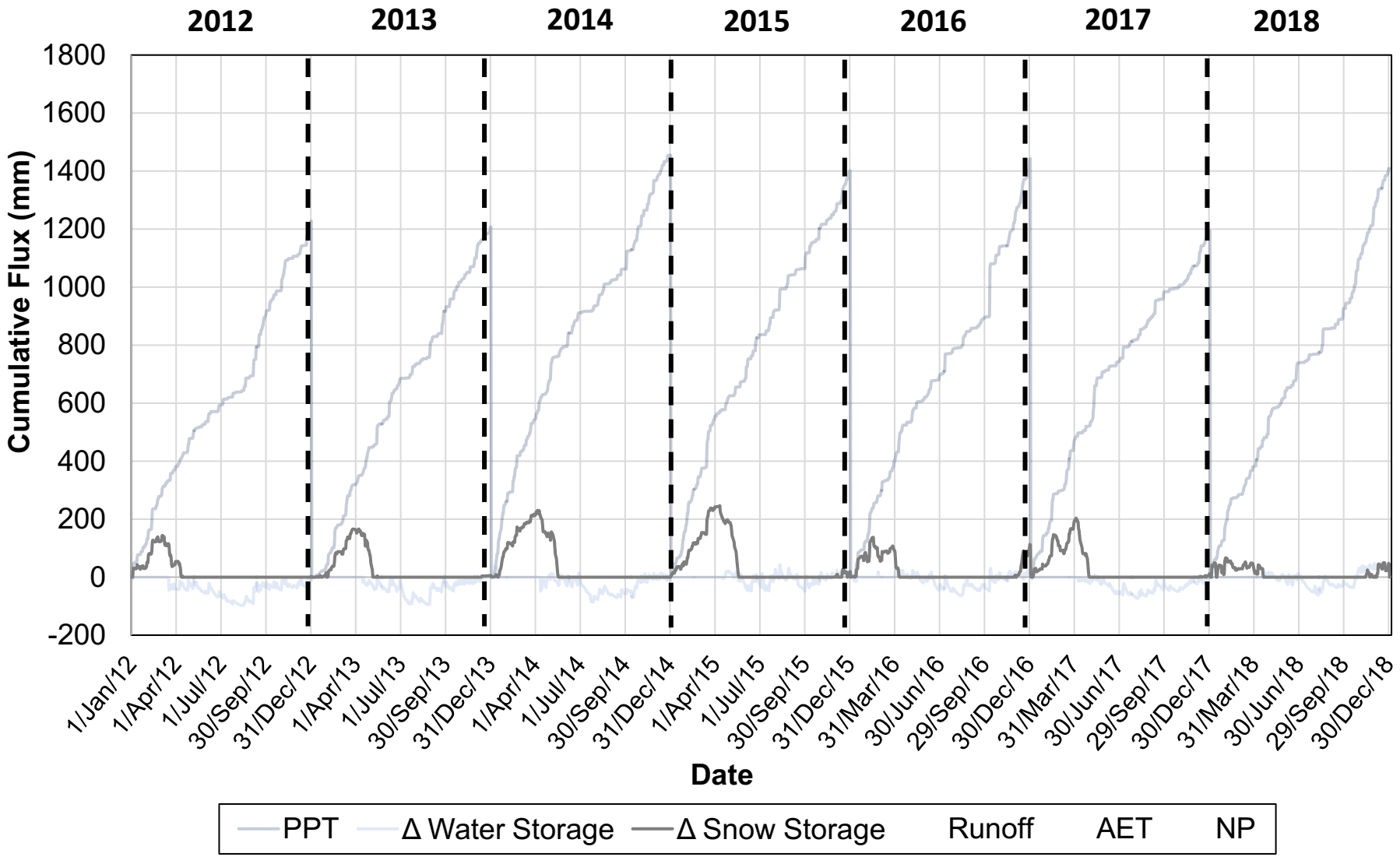
Cover Performance – Atmospheric Influx

- Water influx – **Water Storage**



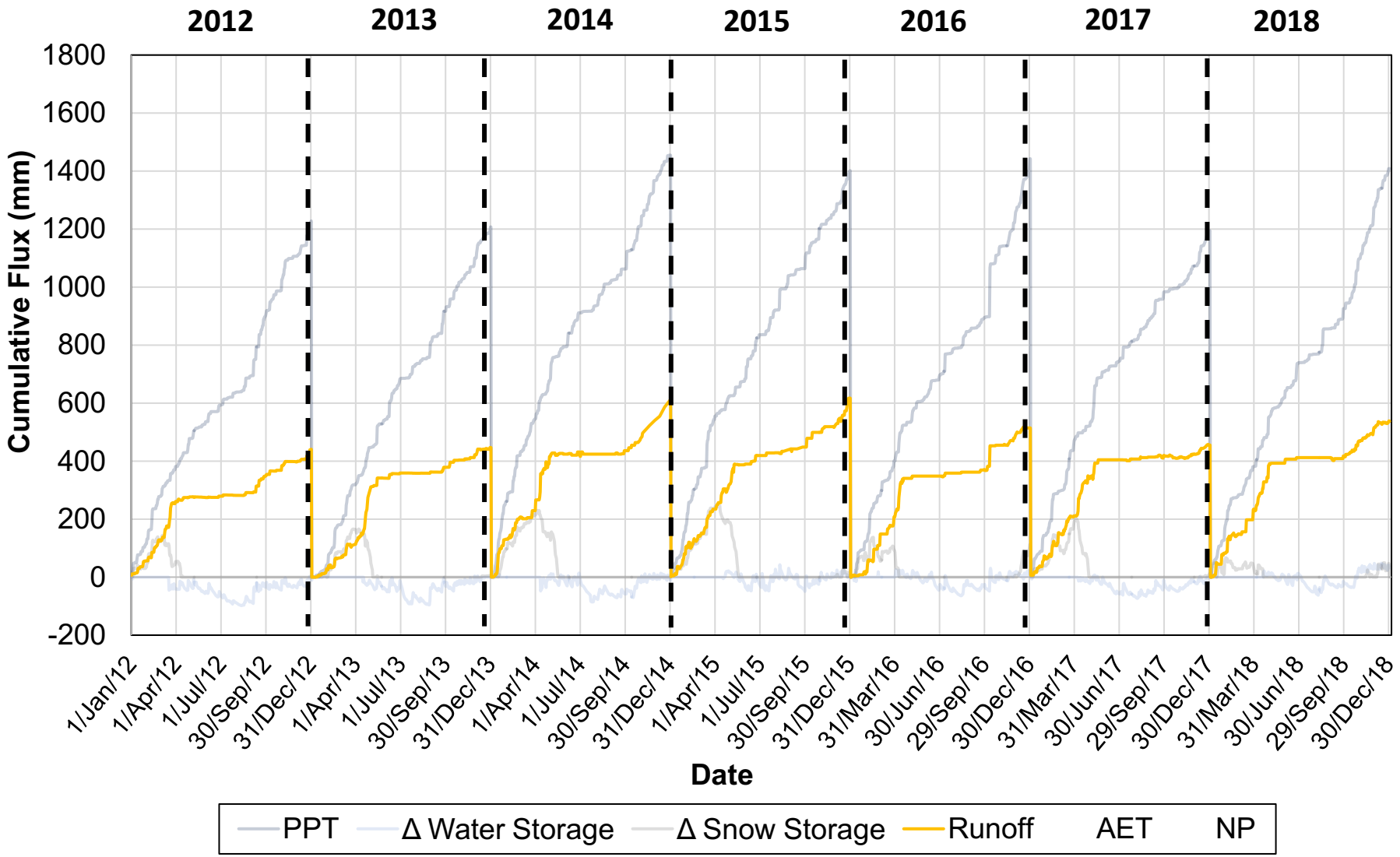
Cover Performance – Atmospheric Influx

- Water influx – **Snow Storage**



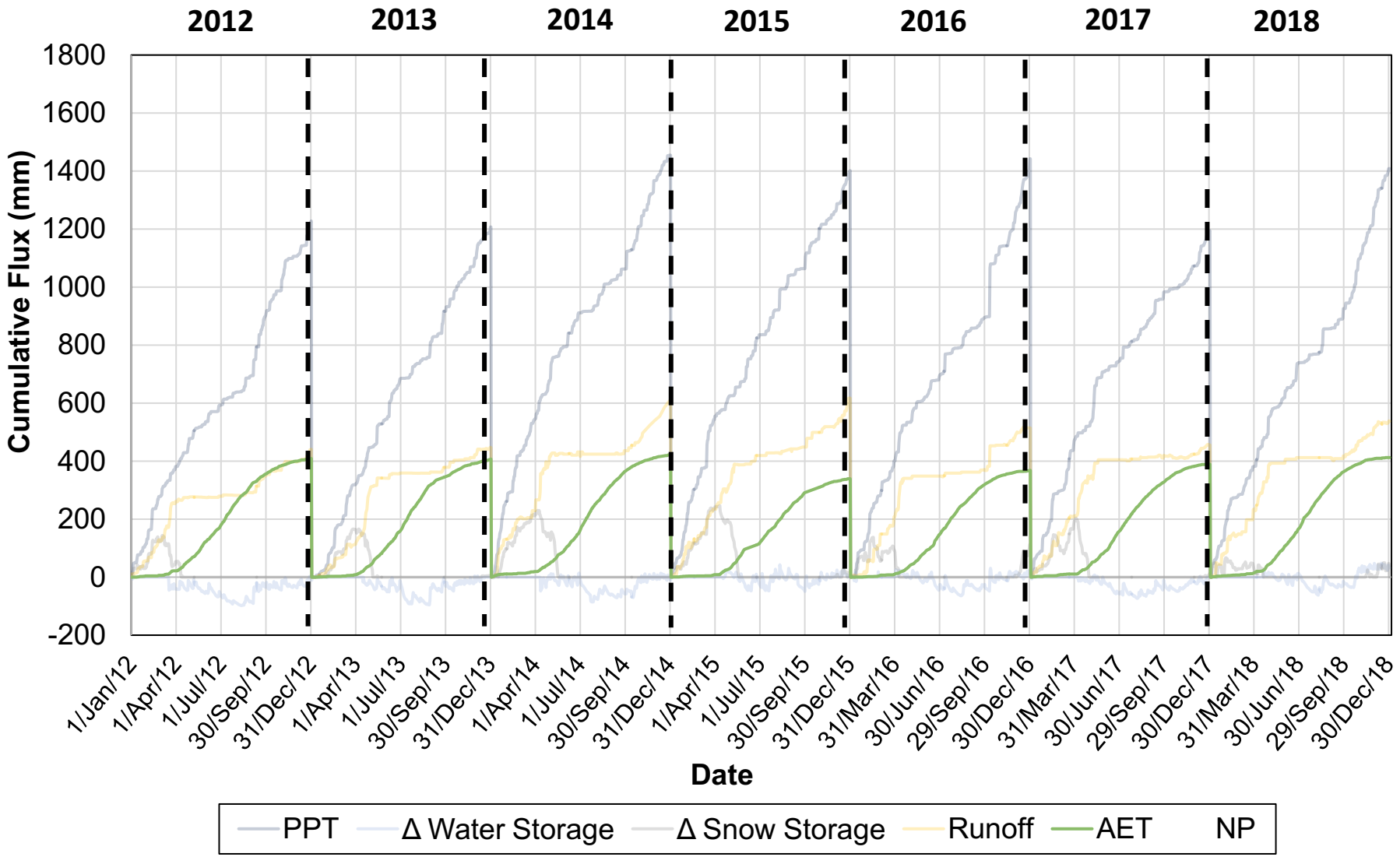
Cover Performance – Atmospheric Influx

- Water influx - **Runoff**



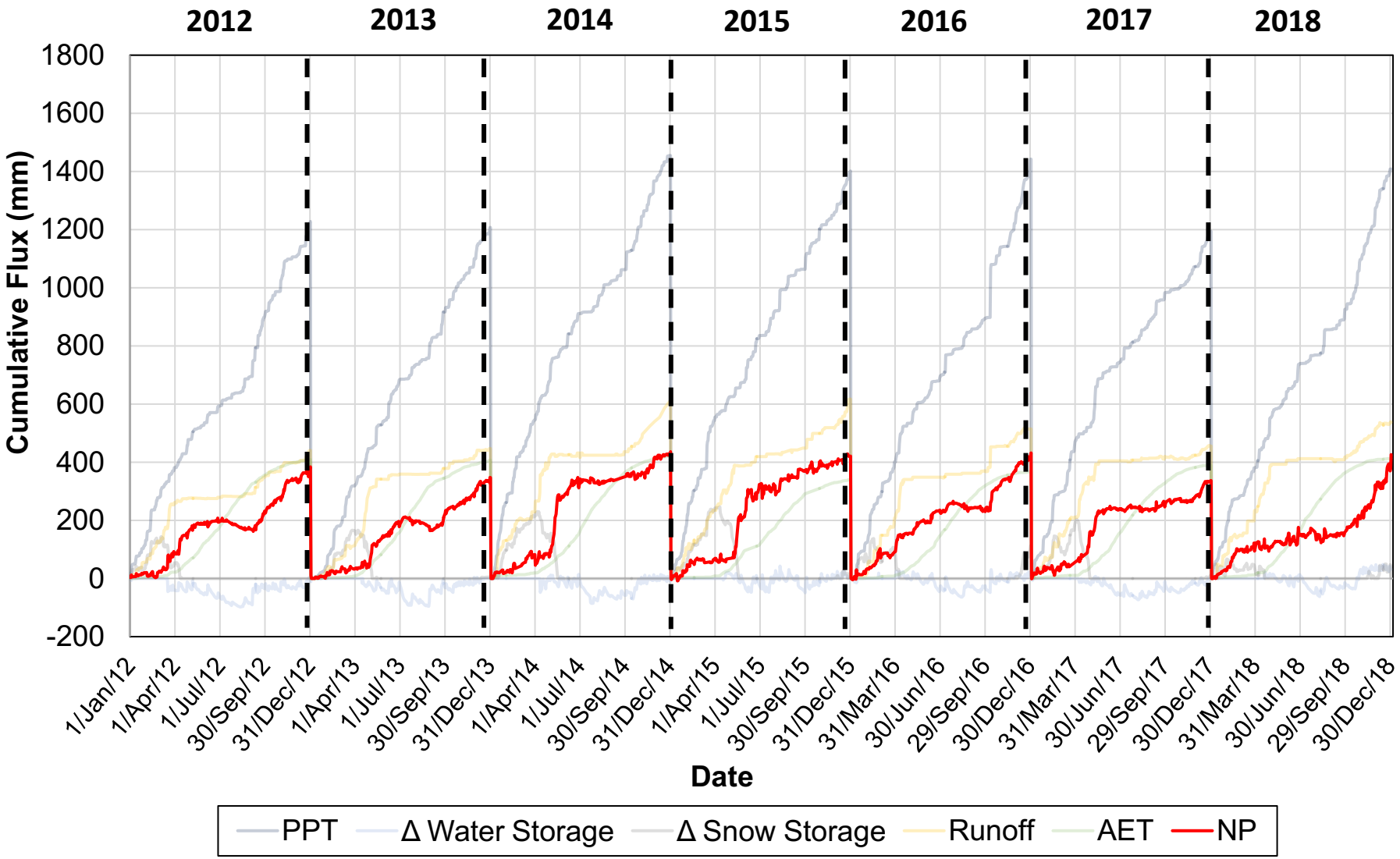
Cover Performance – Atmospheric Influx

- Water influx - **AET**



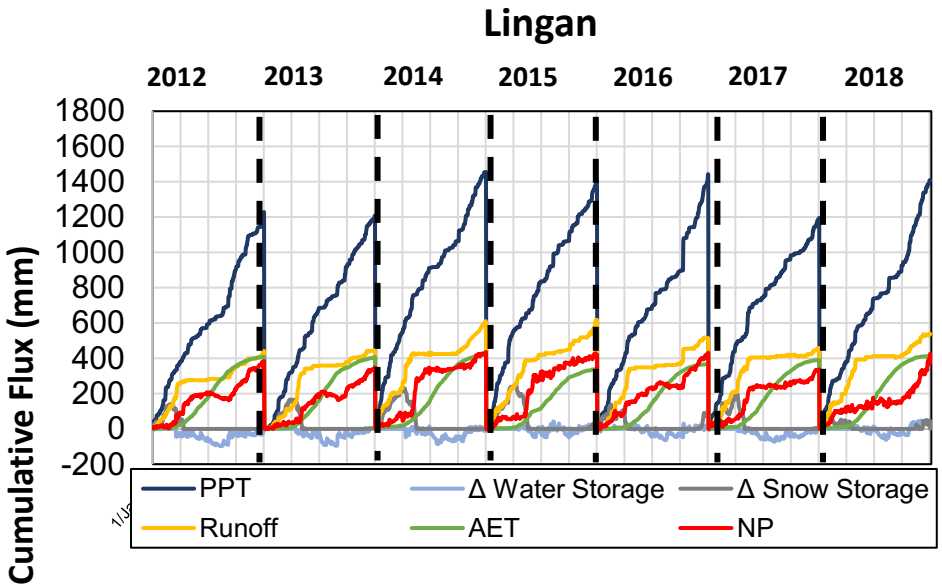
Cover Performance – Atmospheric Influx

- Water influx – **Net Percolation**



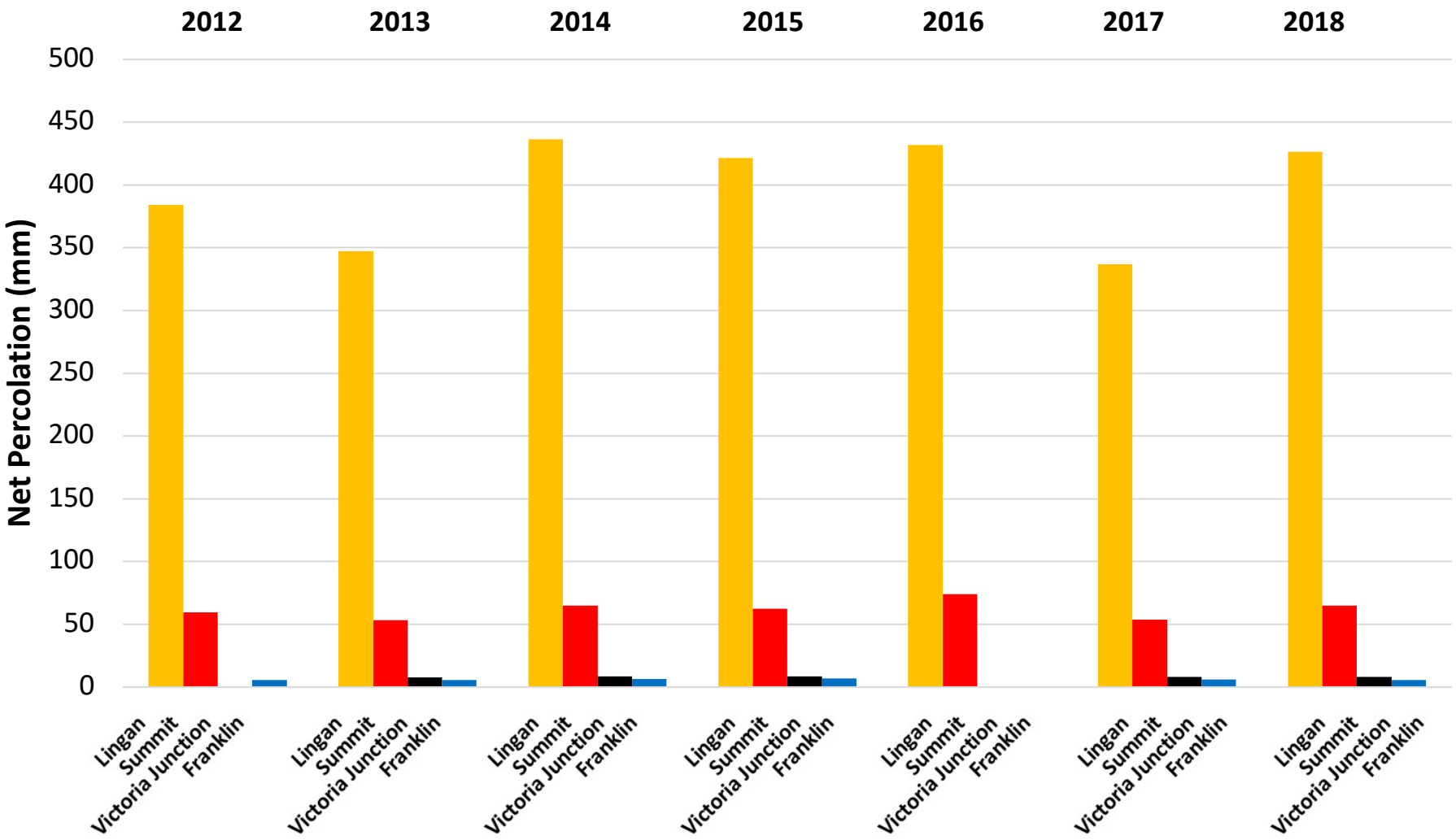
Cover Performance – Atmospheric Influx

- Water influx - **Precipitation**



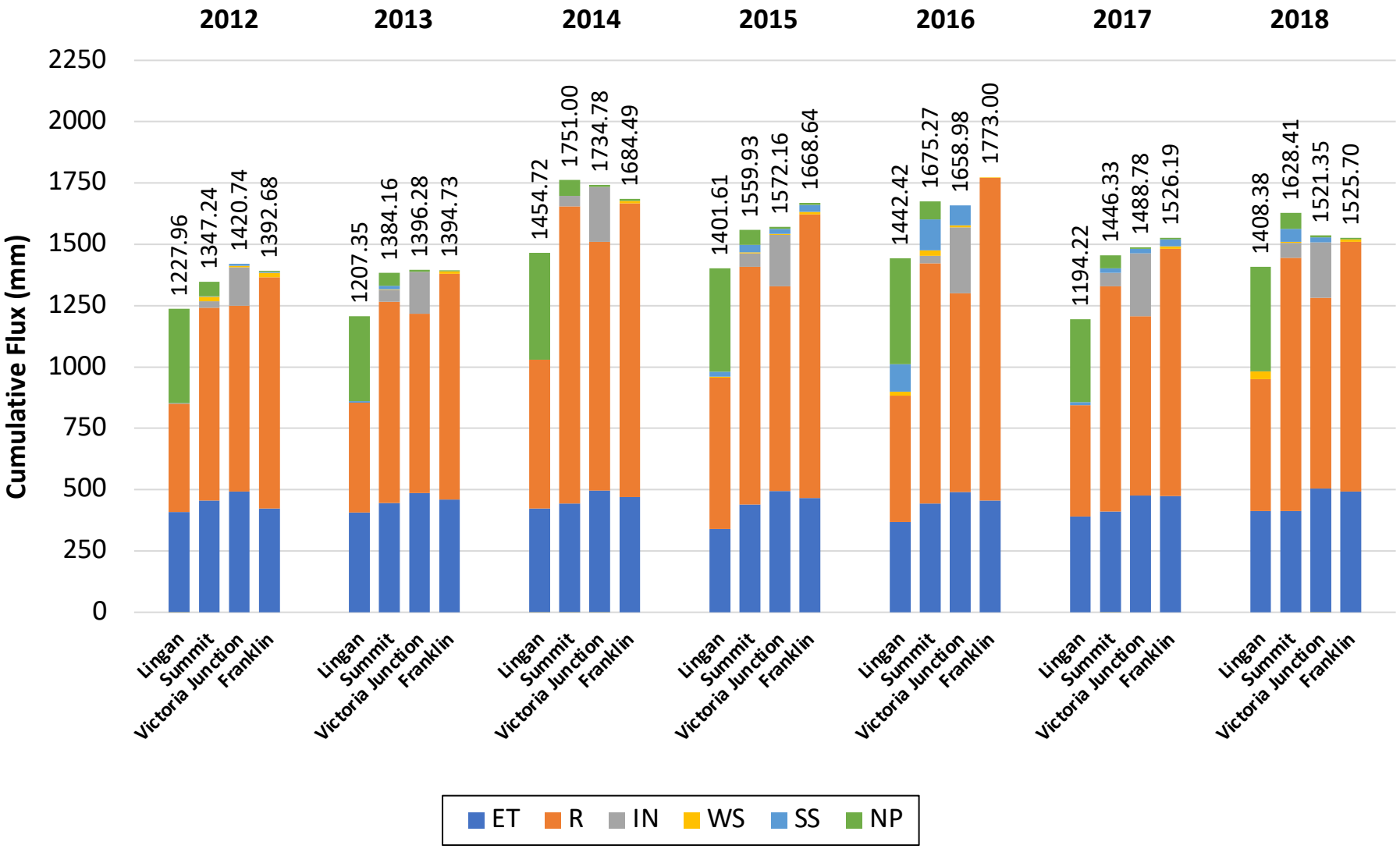
Cover Performance – Atmospheric Influx

- Water influx - **Precipitation**



Cover Performance – Atmospheric Influx

- Water influx – **Net Percolation**



Cover Performance – Atmospheric Influx

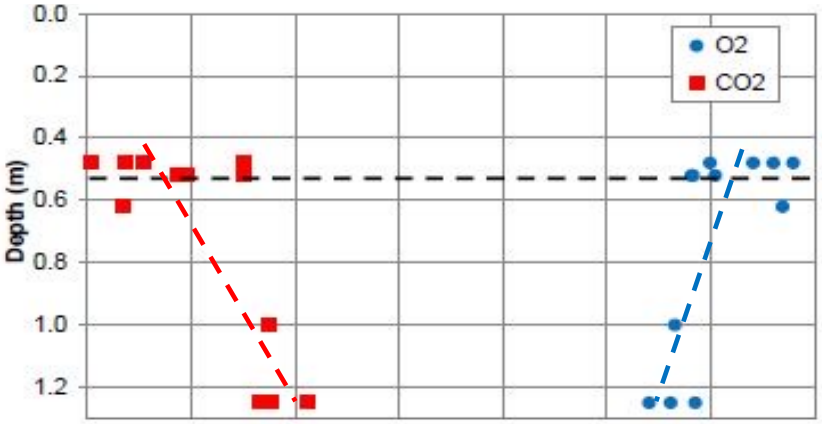
- Water influx – **Net Percolation**

Year	NP (mm)				NP (%PPT)			
	Lingan	Summit	VJ	Franklin	Lingan	Summit	VJ	Franklin
2012	384.18	24.45	3.78	0.48	31.29	1.85	0.28	0.035
2013	347.14	22.79	4.71	0.49	28.75	1.65	0.42	0.035
2014	436.21	27.93	4.72	0.59	29.99	1.60	0.28	0.035
2015	421.26	24.61	5.18	0.57	30.06	1.61	0.40	0.034
2016	431.93	36.30	5.99	0.61	29.94	2.17	0.37	0.034
2017	336.87	32.50	4.39	0.51	28.21	2.55	0.38	0.035
2018	426.32	32.36	5.00	0.33	30.27	2.68	0.33	0.024

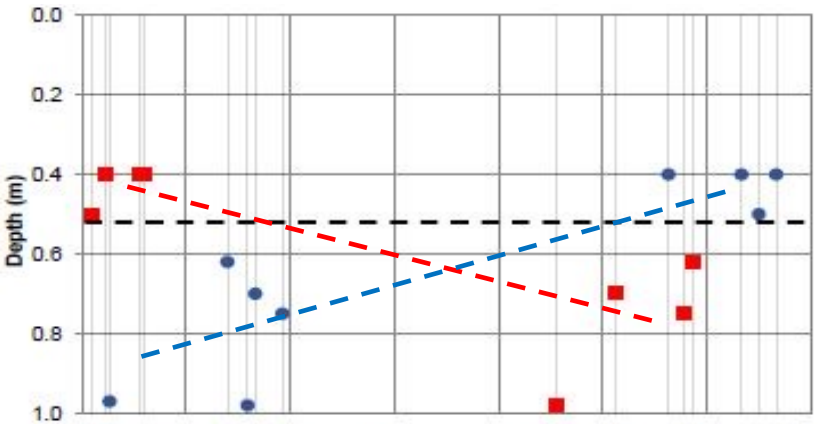
Cover Performance – Atmospheric Influx

- Oxygen influx

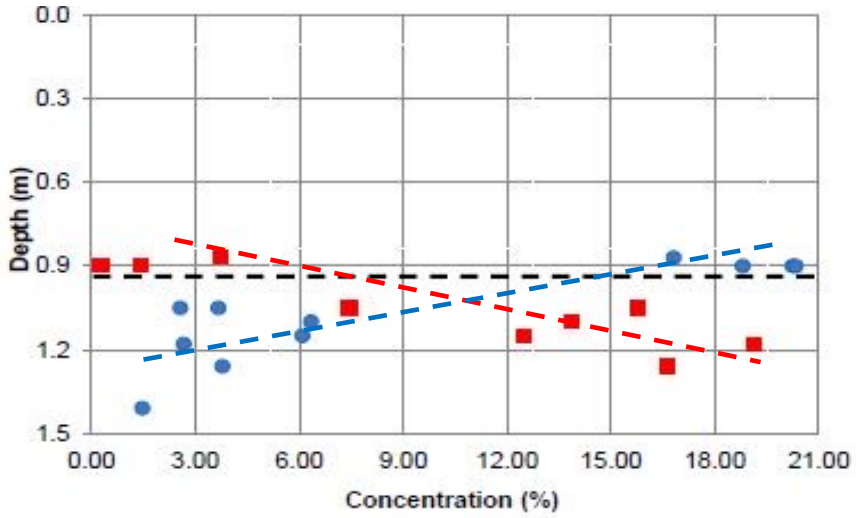
Lingan



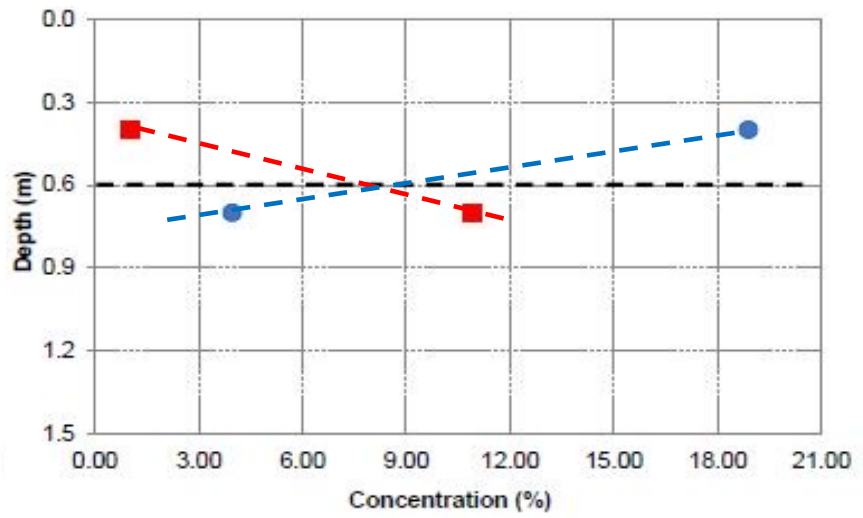
Summit



Victoria Junction



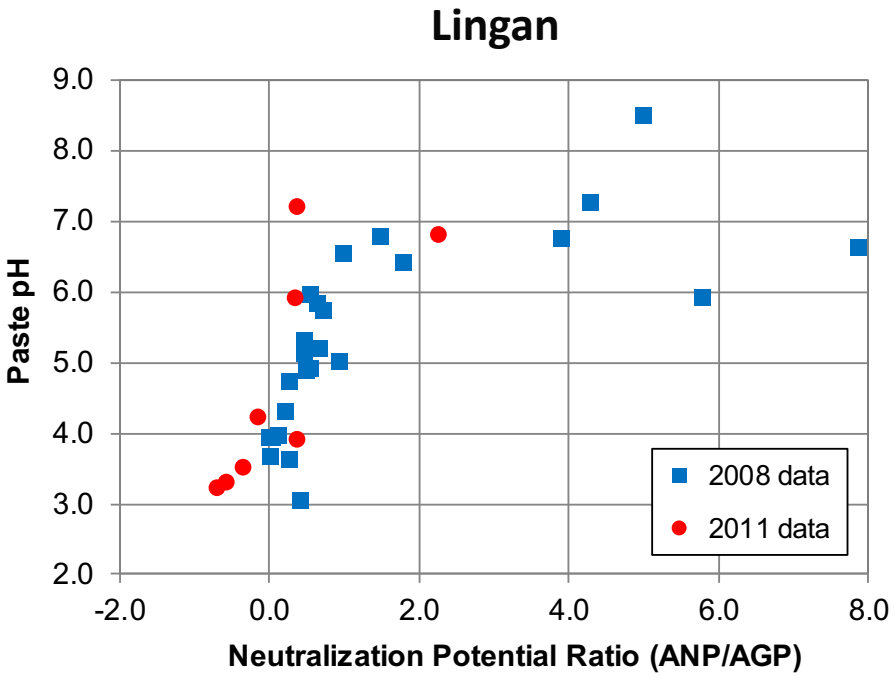
Franklin

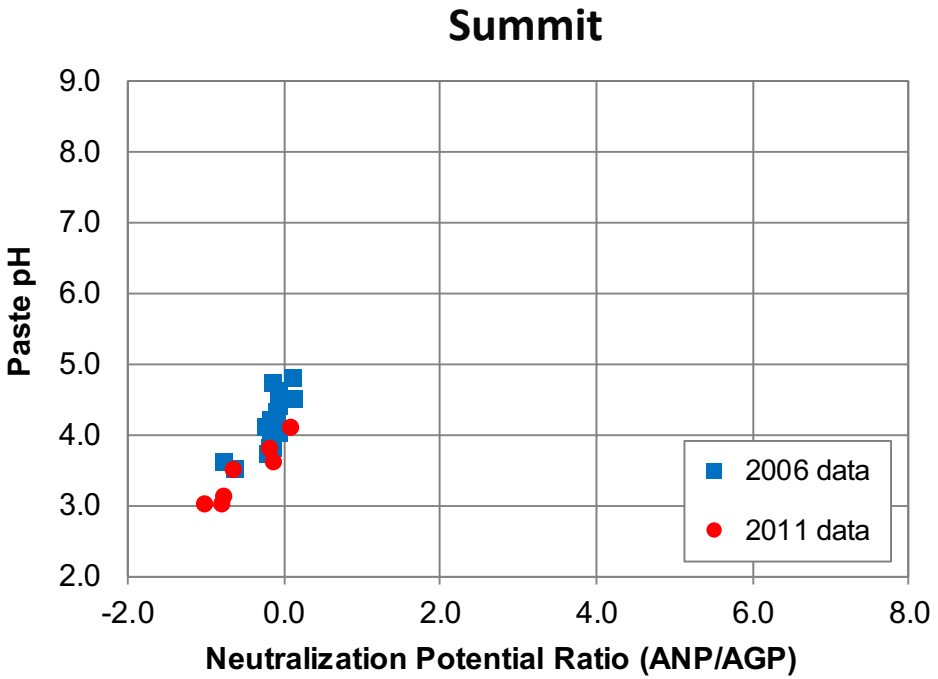


Outline

- Background
- Site Description
- Field Monitoring Program
- Cover Performance – Atmospheric Influx
- Cover Performance – Acidity
- Cover Performance – Environmental Quality
- Conclusions

Cover Performance – Acidity

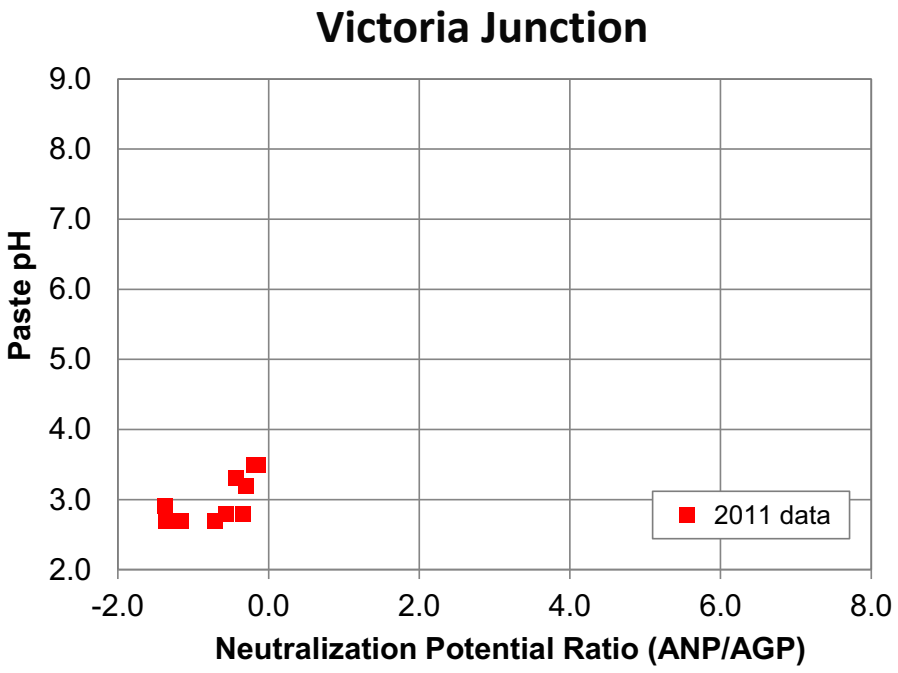


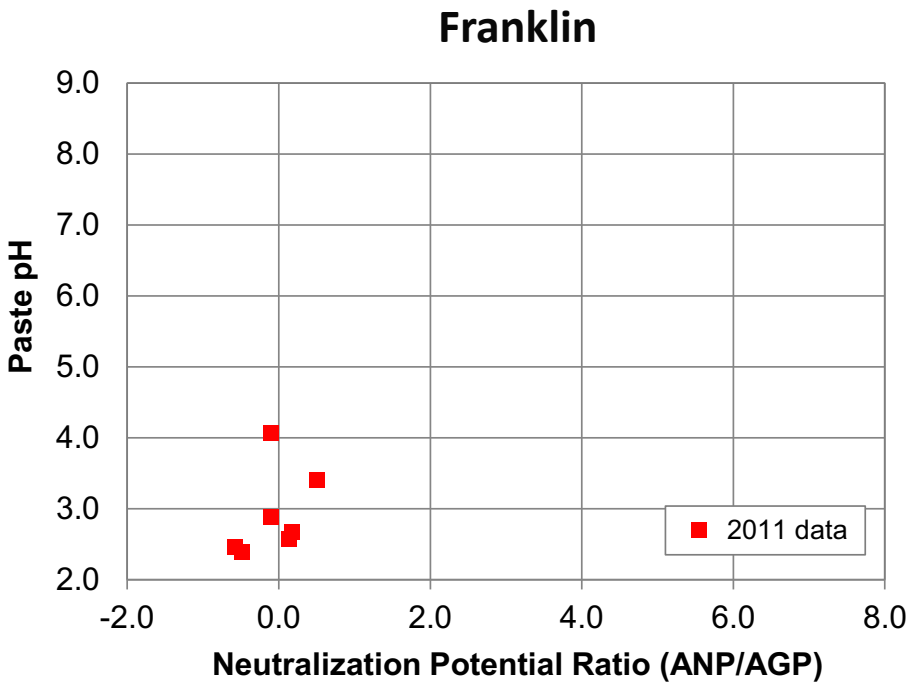


Parameter	Value	Unit
Paste pH	3.2 - 7.2	-
Acid Gen Potential	3.1 - 18.6	kg CaCO3/t
Potential Acidity	7,432	tonnes
Stored Acidity	6,922	tonnes

Parameter	Value	Unit
Paste pH	3.0 - 4.1	-
Acid Gen Potential	0.1 - 37.7	kg CaCO3/t
Potential Acidity	27,925	tonnes
Stored Acidity	43,088	tonnes

Cover Performance – Acidity





Parameter	Value	Unit
Paste pH	2.7 - 3.5	-
Acid Gen Potential	12.2 - 44.1	kg CaCO3/t
Potential Acidity	229,006	tonnes
Stored Acidity	355,653	tonnes

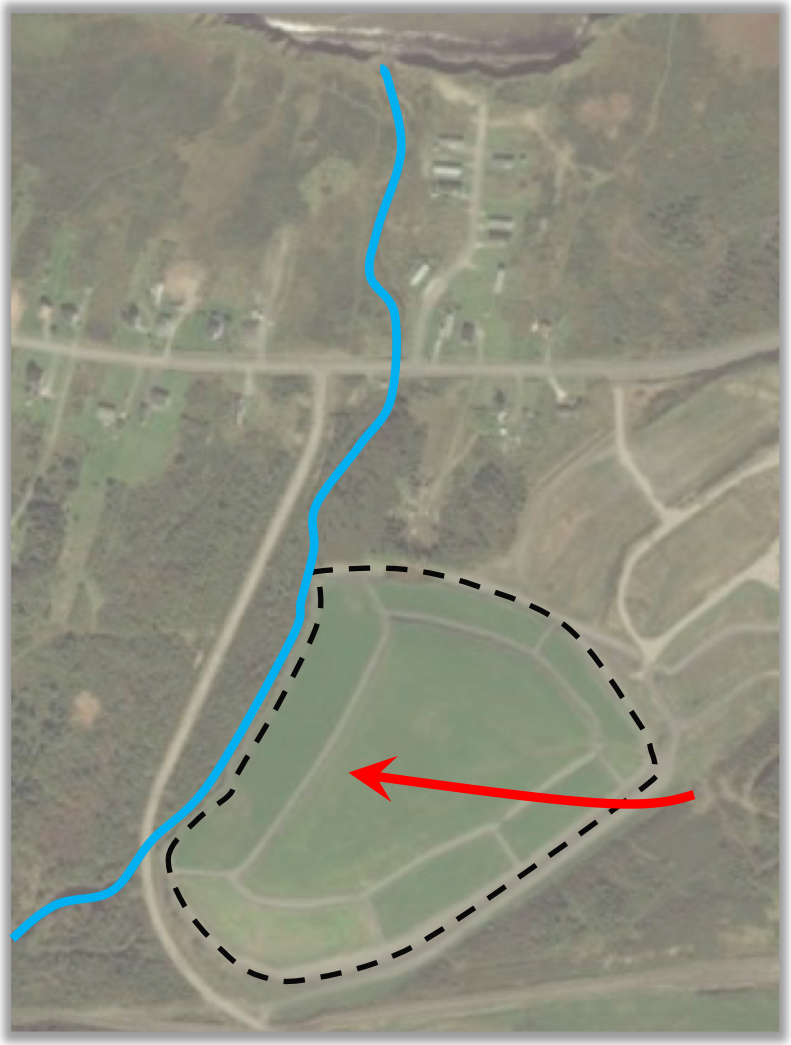
Parameter	Value	Unit
Paste pH	2.4 - 3.4	-
Acid Gen Potential	8.1 – 21.5	kg CaCO3/t
Potential Acidity	5,579	tonnes
Stored Acidity	5,981	tonnes

Outline

- Background
- Site Description
- Field Monitoring Program
- Cover Performance – Atmospheric Influx
- Cover Performance – Acidity
- Cover Performance – Environmental Quality
- Conclusions

Cover Performance – Environmental Quality

- Lingan



- Acid mine water leaves through base of WRP to **groundwater** flowing in N-W direction to ocean
- Acid water through toe of WRP to **surface water** (Graces Brook) flowing west of WRP to ocean

Cover Performance – Environmental Quality

- Lingan

- Site Closure Objectives:

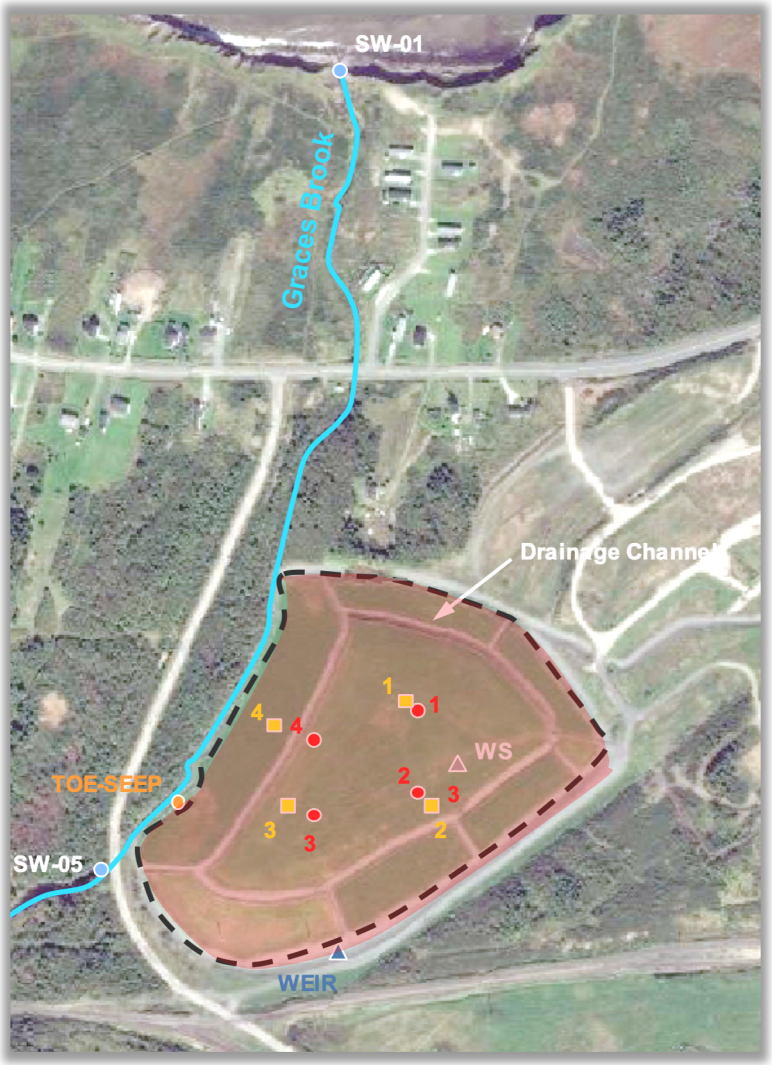
1 Improvement in Graces Brook

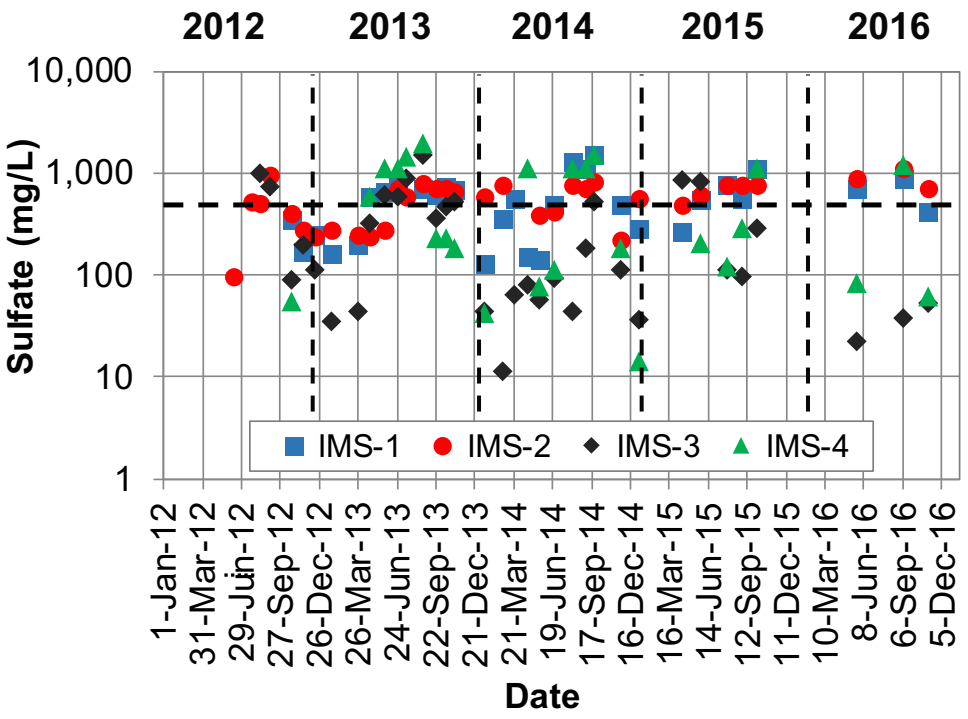
Growth Medium

Waste Rock

Cover Performance – Environmental Quality

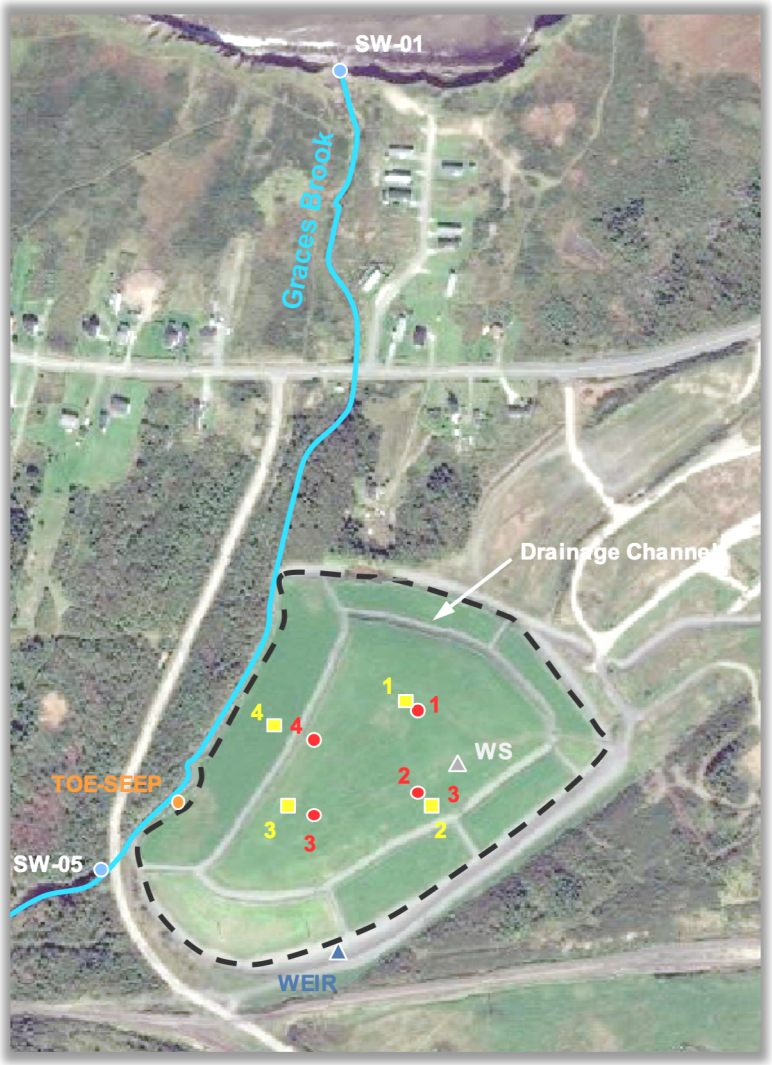
- Lingan



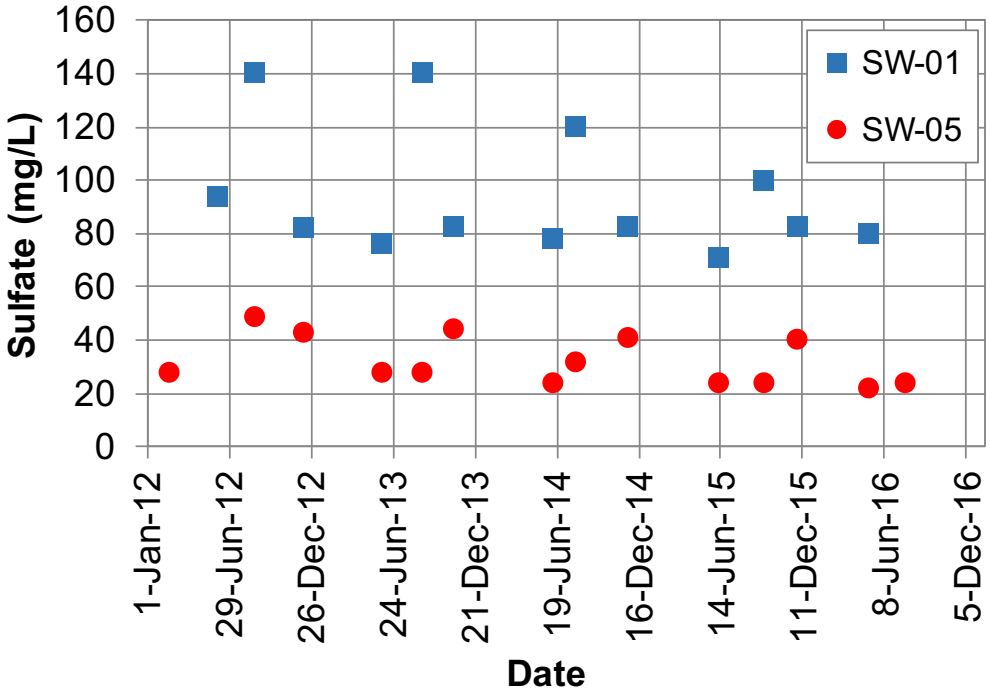


Cover Performance – Environmental Quality

- Lingan



Objective: Improvement of Graces Brook



Cover Performance – Environmental Quality

- Scotchtown Summit

- AMD leachate leaves through base of WRP to **groundwater** flowing to N-to-NW and S-to-SE

Cover Performance – Environmental Quality

- Scotchtown Summit

- AMD leachate leaves through base of WRP to **groundwater** flowing to N-to-NW and S-to-SE
- **Surface water** runoff water to perimeter ditches and key watercourses at the site

Cover Performance – Environmental Quality

- Scotchtown Summit

- Site Closure Objectives:

1. Improvement in Irish Brook
2. Protection of Waterford Lake
3. Protection of KLB

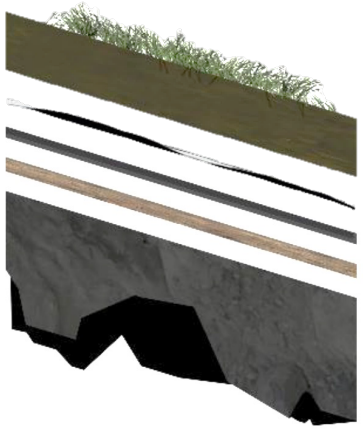
Soil

Geotextile

HDPE

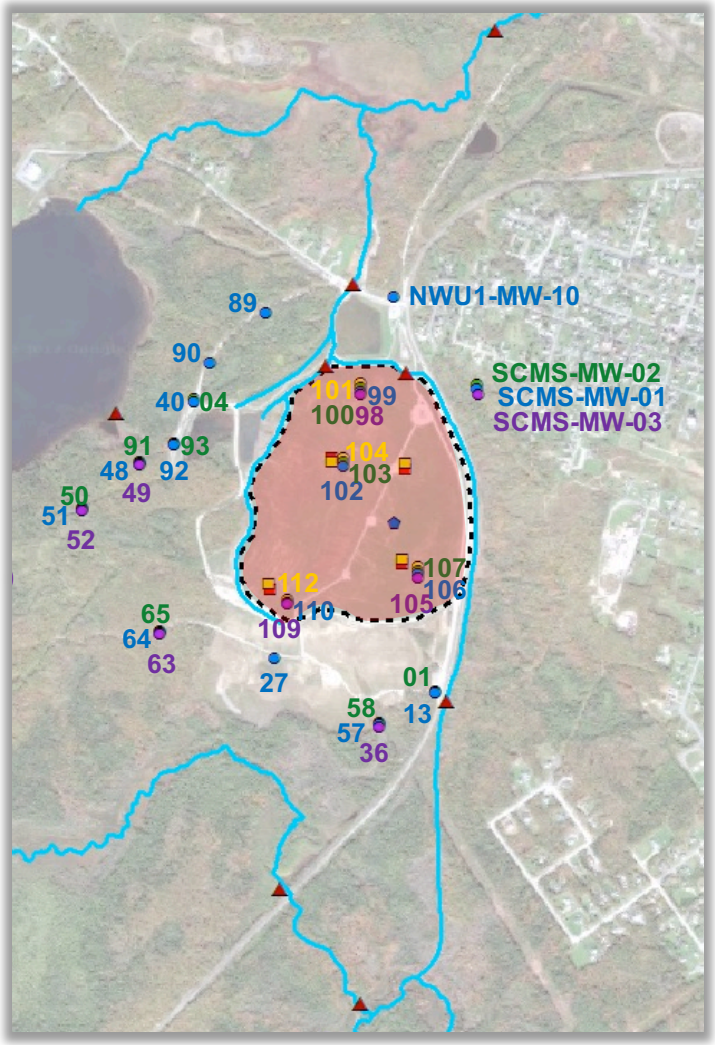
Bedding Sand

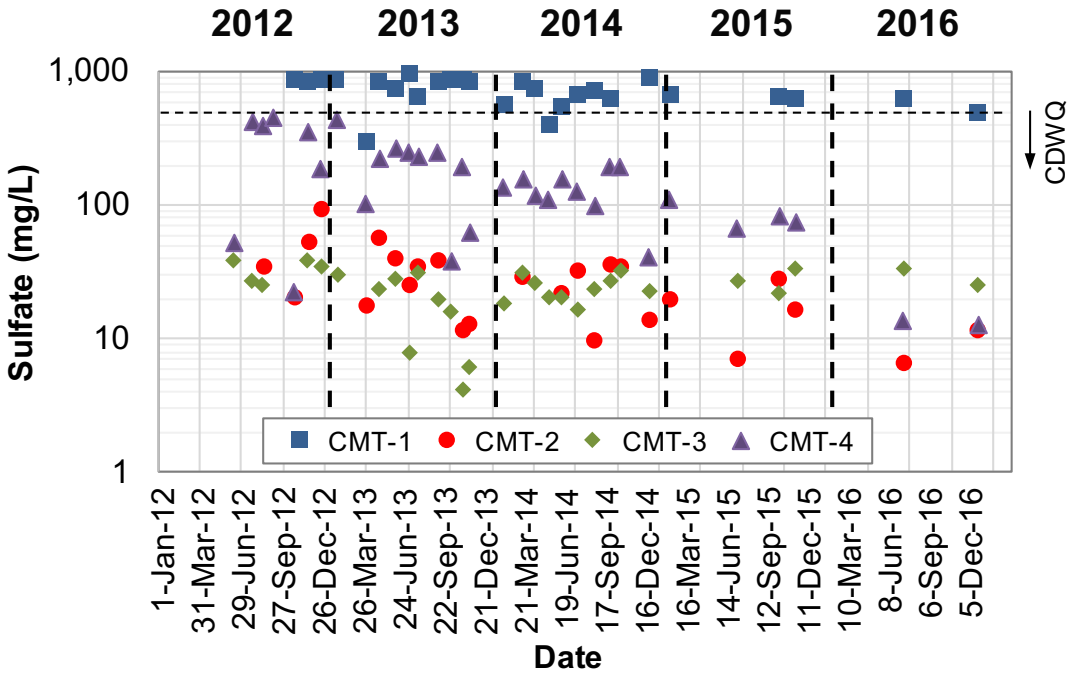
Waste Rock



Cover Performance – Environmental Quality

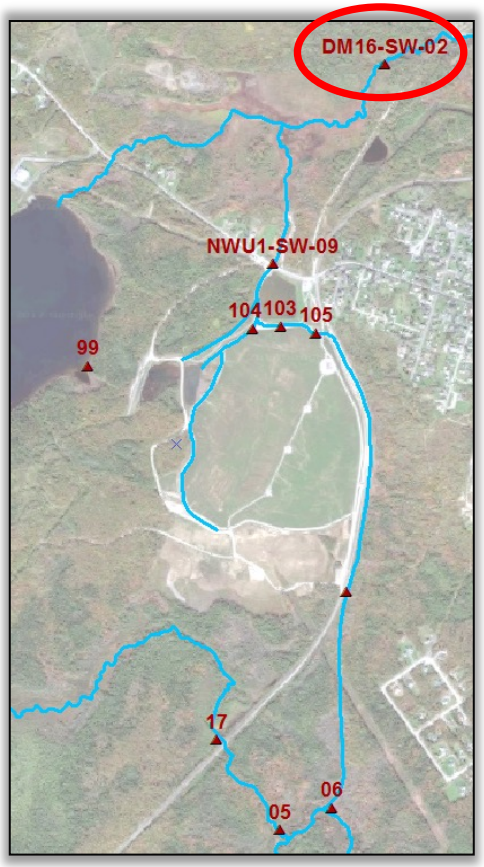
- Scotchtown Summit

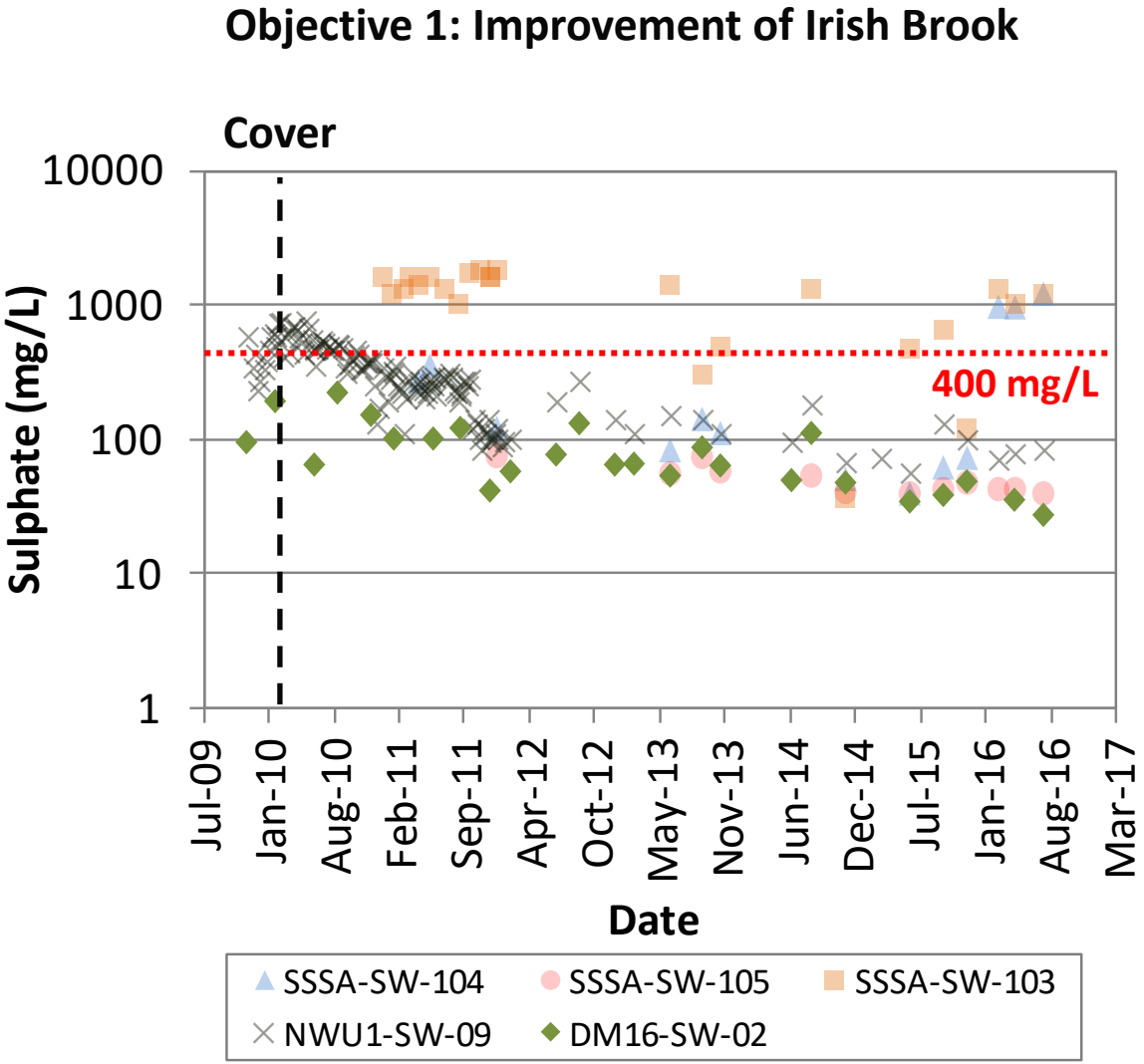




Cover Performance – Environmental Quality

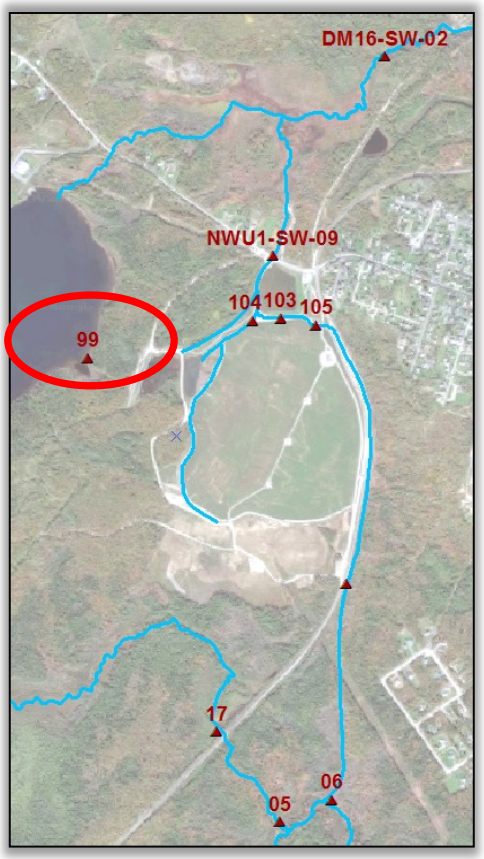
- Scotchtown Summit

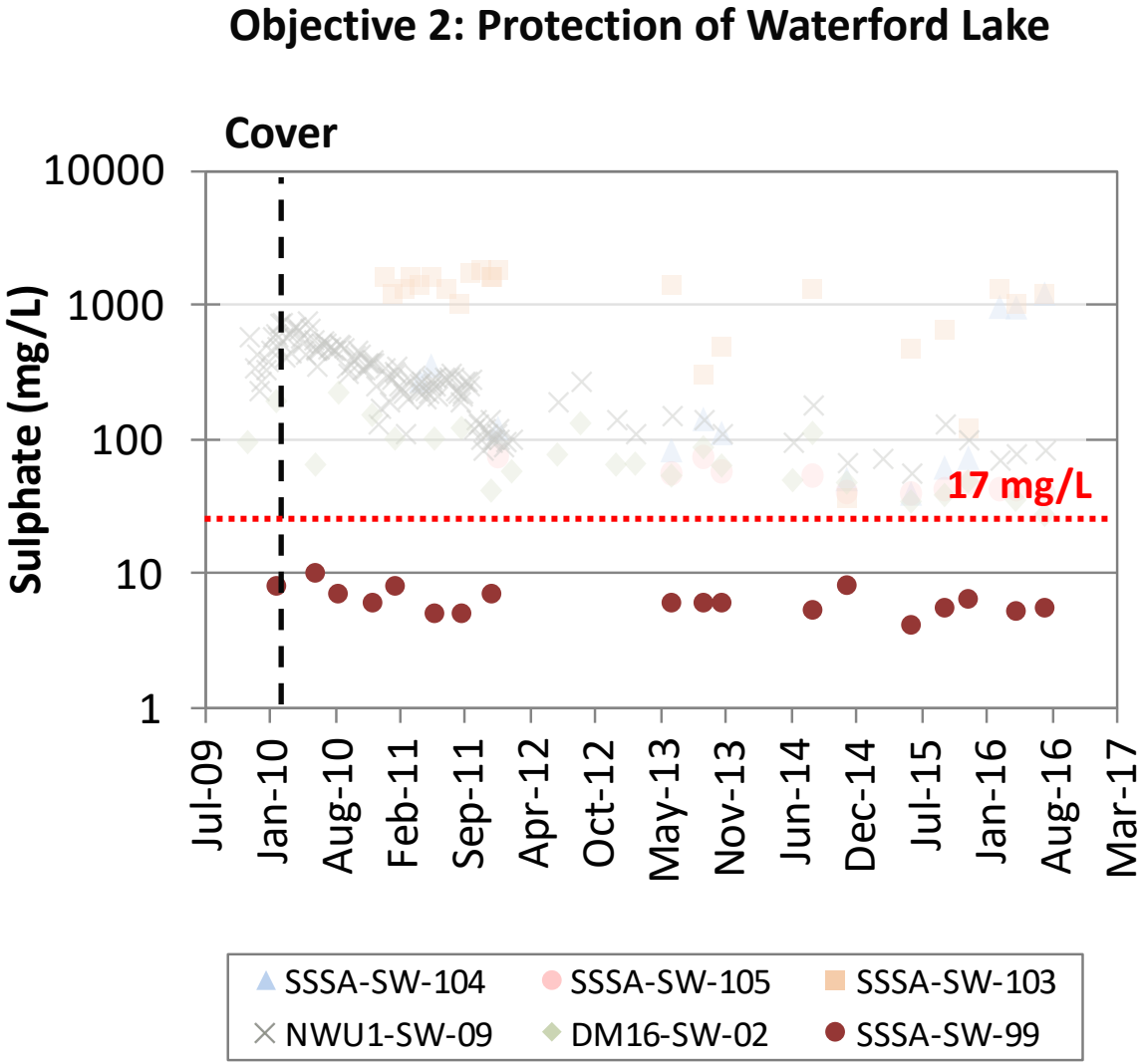




Cover Performance – Environmental Quality

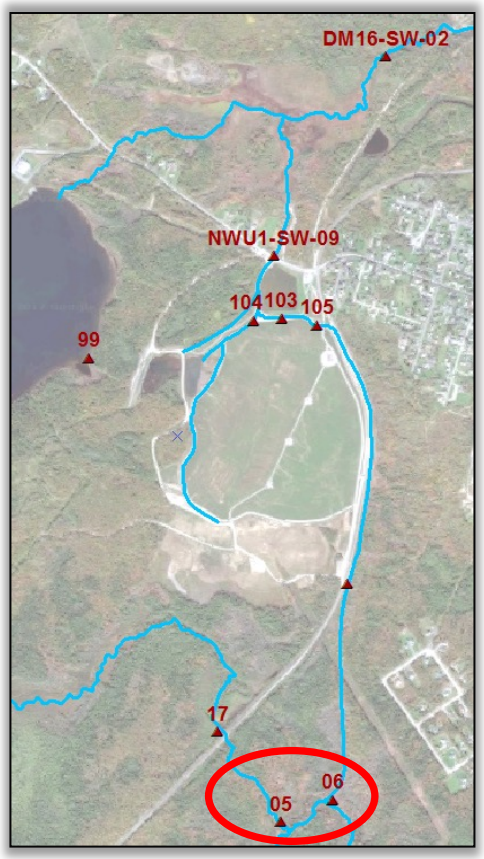
- Scotchtown Summit

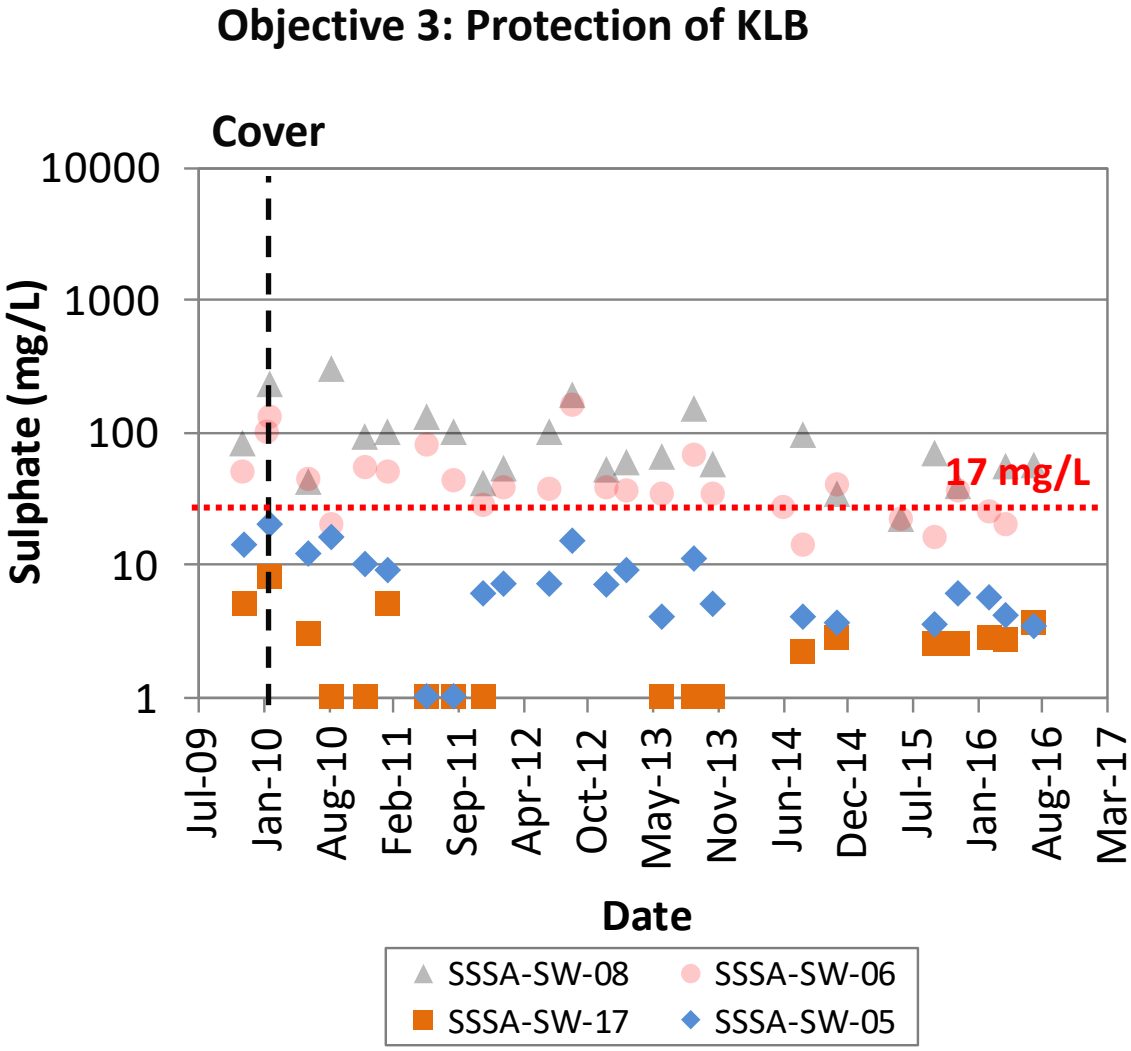




Cover Performance – Environmental Quality

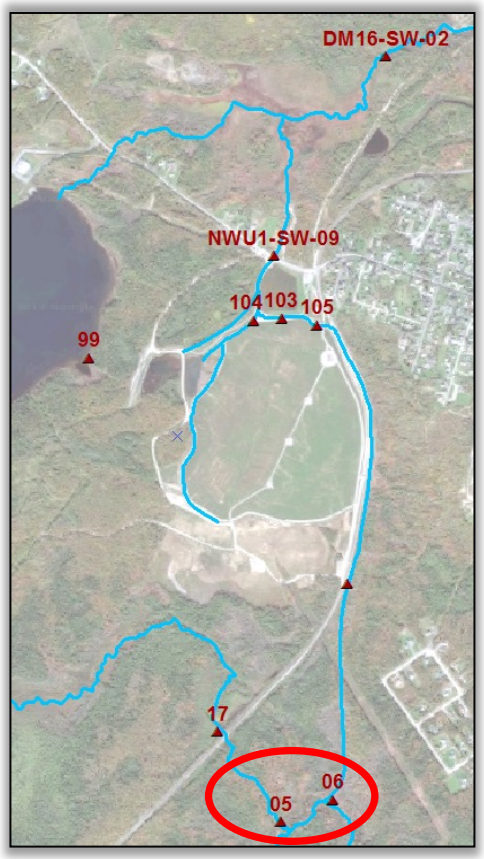
- Scotchtown Summit

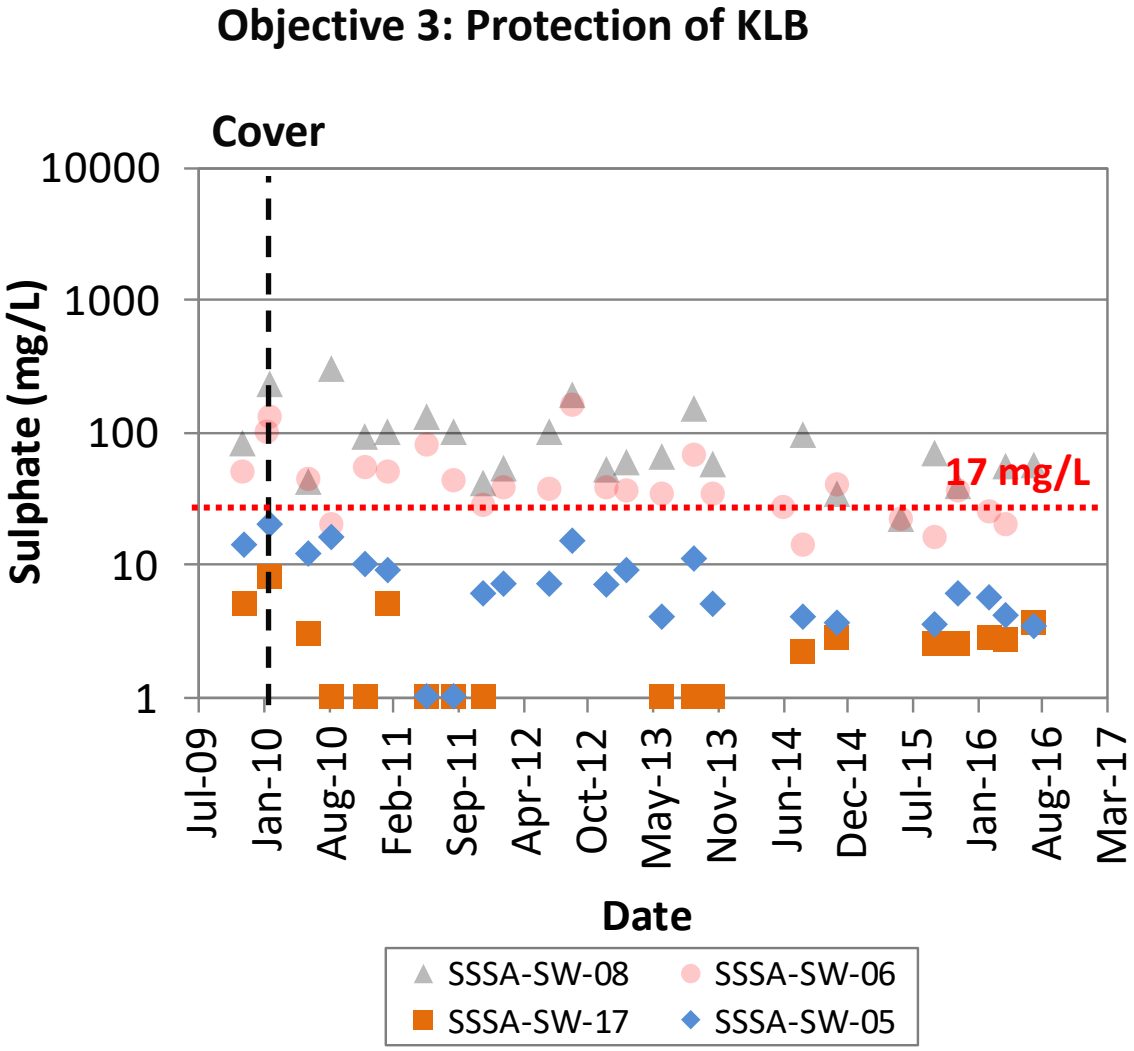




Cover Performance – Environmental Quality

- Victoria Junction





Cover Performance - Summary

Lingan

Moisture Store & Release

Growth Medium

Waste Rock

- Cost: $12 per m²
- Does not work well in humid climate
- Poor barrier to water and oxygen
- Good vegetative canopy. Stable landform.
- Eliminated contaminated surface runoff
- Improved quality in adjacent brook
- Satisfied closure objective

Scotchtown Summit

Geosynthetic Cover 1

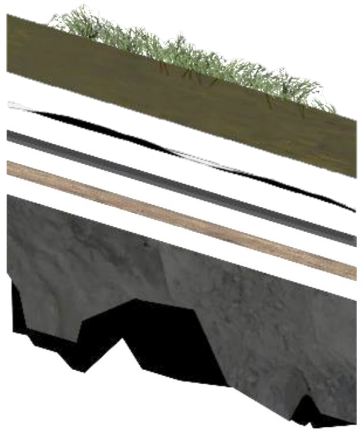
Growth Medium

Geotextile

HDPE

Bedding Sand

Waste Rock



- Cost: $38 per m²
- Works in humid climate
- Effective barrier to water and oxygen
- Poor vegetative growth
- Eliminated contaminated surface runoff
- Improved quality in all receptors
- Satisfied all closure objectives

Acknowledgements

- Beth Mason – Verschuren Centre, Cape Breton University
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- Fred Baechler – exp Consulting
- Greg Meiers – Wood
- Allan Gillis – Public Services and Procurement Canada

Public Services and Procurement Canada

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Stantec

Thank you for listening!

Any questions?

Christopher Power

cpower24@uwo.ca

Western

RESTORE

Research for Subsurface Transport and Remediation