Performance of an Engineered Cover System After Six Years at the Areva Resources Cluff Lake Mine Waste Rock Pile in Northern Saskatchewan

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D. Hiller – AREVA Resources Canada (Saskatoon)

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AREVA

O'Kane Consultants

Integrated Geotechnical Engineering Services
Specialists in Unsaturated Zone Hydrology

Discussion Points

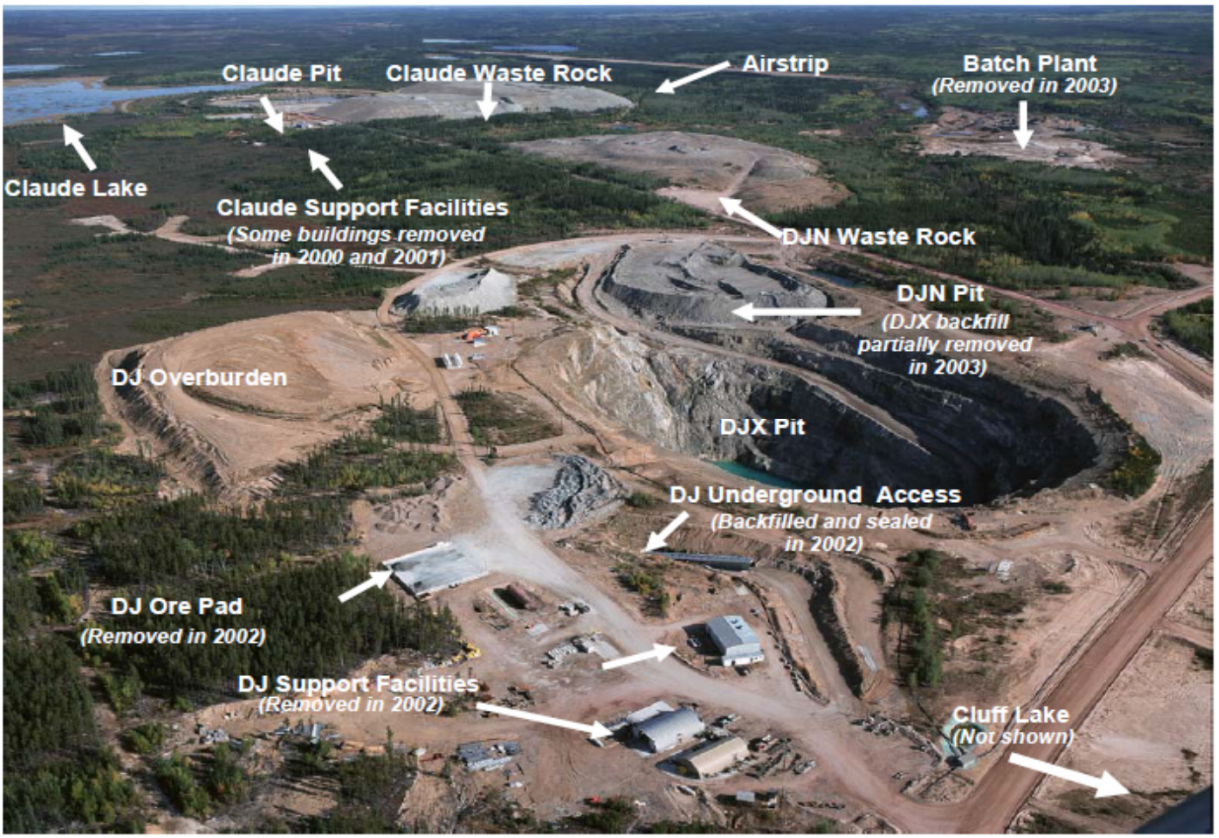
- *Background*
- *Cover System Design*
- *Cover System Construction*
- *Monitoring Program Results*
- *Concluding Remarks*
- *New Cover System Guidance Document*

Background

- *Cluff Lake uranium mine, AREVA Resources Canada*
- *Athabasca basin, 75 km S of Lake Athabasca, 15 km E of AB border*

- *Operation 1980-2002, decommissioned 2004-2006*
- *Semi-arid climate*
  - *Mean annual precip. of 450 mm (30% as snow)*
  - *Potential evaporation of 600 mm*

Mine History



- *Operated 1980 – 2002*
- *Produced 6.25M lbs. of yellowcake (U_3O_8)*

- *Production planned to cease December 2000 due to depletion of economically viable reserves, and max tailings volume reached.*
- *Higher grade of production allowed operation to December 2002.*

http://www.ceaa-acee.gc.ca/41B79974-docs/report_e.pdf

Decommissioning

- *Commenced in in 2004 and now completed*
- *Claude pit backfilled, mill and other outbuildings dismantled*
- *Tailings area covered*
- *Waste rock piles re-sloped and covered*

http://www.ceaa-acee.gc.ca/41B79974-docs/report_e.pdf

Decommissioning cont'd

- *Site specific water quality objectives developed for iron, uranium, molybdenum and cobalt, as SK did not have guidelines for these CoCs.*
- *No adverse impact on surface water.*

http://www.ceaa-acee.gc.ca/41B79974-docs/report_e.pdf

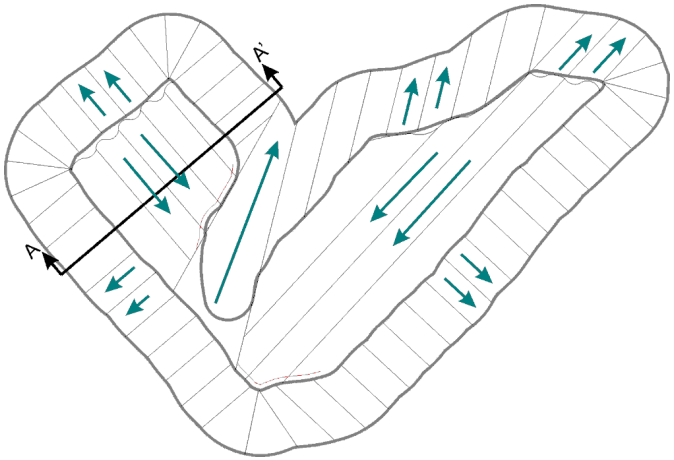
Decommissioning cont'd

- *A mixture of six native woody species were planted, selected from local seed availability.*
- *800,000 trees and shrubs planted since 2004*

http://www.ceaa-acee.gc.ca/41B79974-docs/report_e.pdf

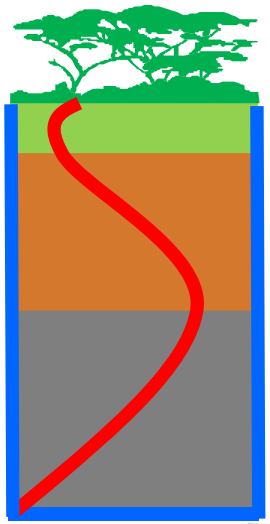
Claude Waste Rock Pile

- *Claude waste rock pile constructed 1982-1989 using end dumping*
- *Claude pile - 7.23 million tonnes of waste from the Claude pit*
- *High levels of uranium (200 mg/L and nickel (43 mg/L) in piezometers at pile toe*



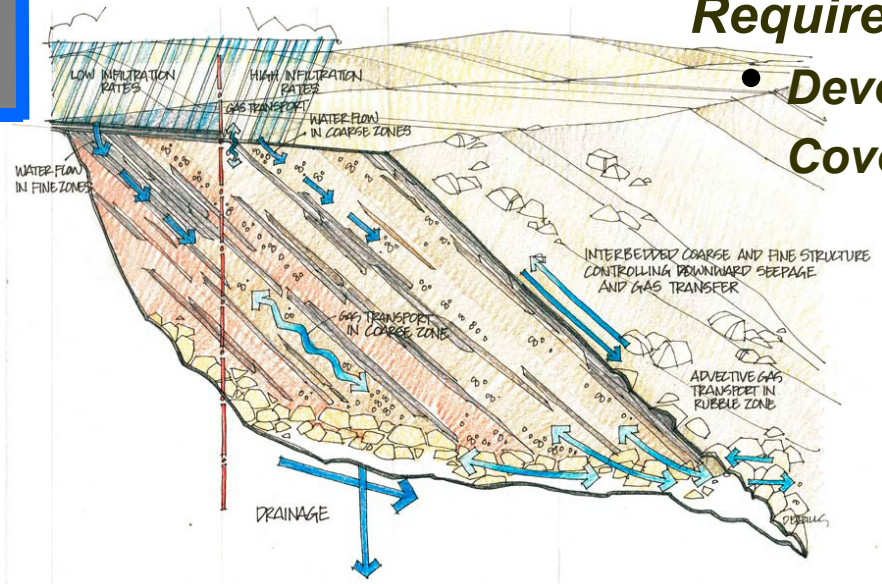
Cover System Design Approach

Soil-Plant-Atmosphere



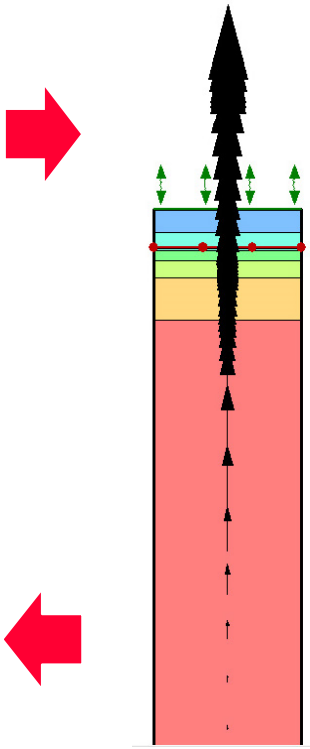
Cover System Design Modelling

- *Arise after Setting Closure Objectives through Consultation*
- *Link Impacts to the Receiving Environment to Determine Required Performance*
- *Develop a Rationale Basis for Cover System Design Criteria*



Cover System Design Approach

Cover System Field Trials

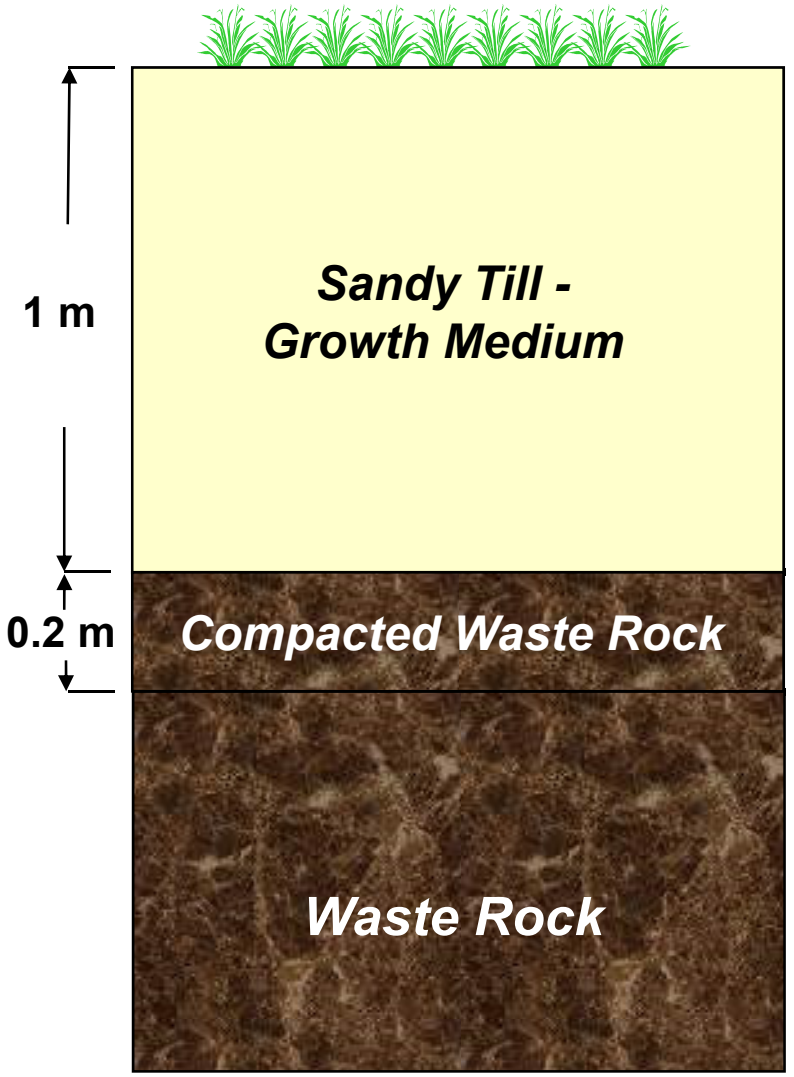


Soil-Plant-Atmosphere Cover Design Modelling

Full-Scale Cover Design

Cover System Design

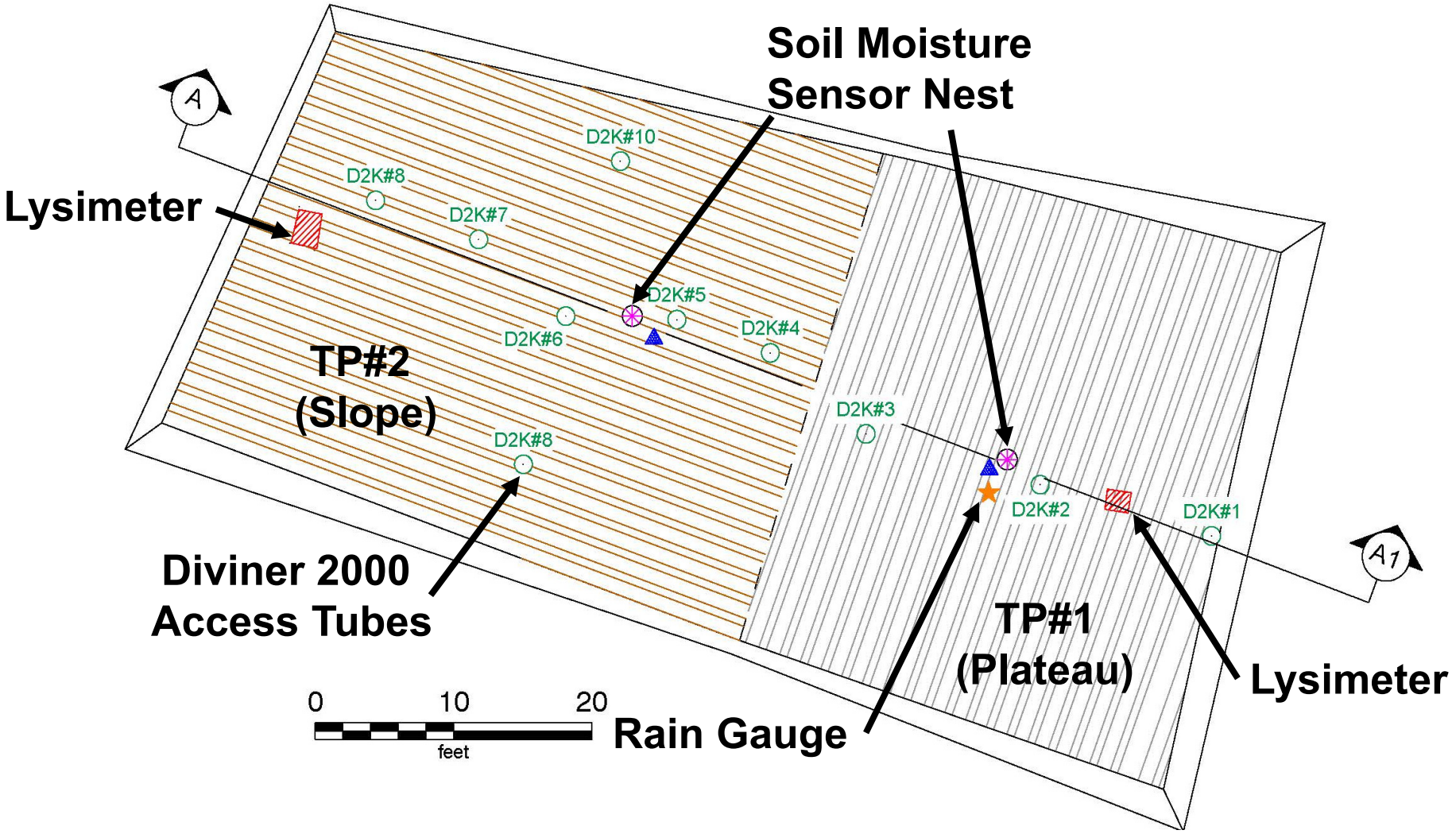
- *Cover System Design Objectives:*
  - *Reduce net percolation to meet aquatic receptor criteria*
  - *Stable landform*
  - *Attenuate radiation*
  - *Growth medium*



Cover System Field Trials

- Constructed and instrumented in 2001, plateau and slope areas
- 20 cm compacted waste rock overlain by 100 cm sandy till

Cover System Field Trials



Cover System Construction

- Slopes re-contoured to 4H:1V
- Waste rock top 20 cm compacted to minimum 95% dry density
- Waste rock $k_{sat} = 10^{-5}$ to 10^{-6} cm/s

Cover System Construction

- Surface drainage channels for 24 hour, 100-year design storm event

- Applied seed and fertilizer mixture using a drill seeder

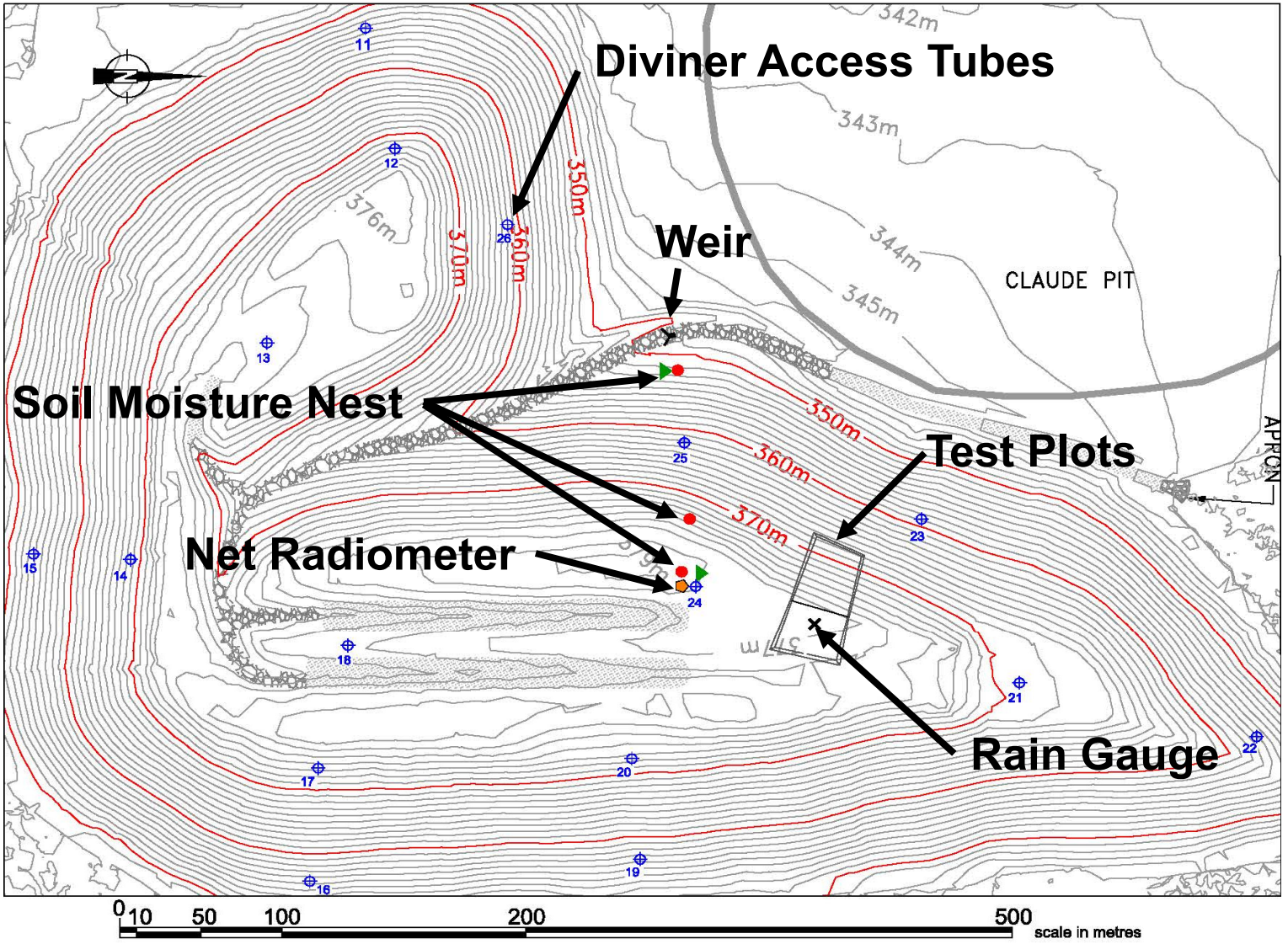
Cover System Instrumentation

- **Meteorological monitoring:**
  - **Precipitation**
  - **Net radiation**
  - **Wind speed and direction**
  - **Air temperature and RH**
  - **Runoff**

Cover System Instrumentation

- *In situ cover* monitoring:
  - Temperature
  - Matric suction
  - Volumetric water content

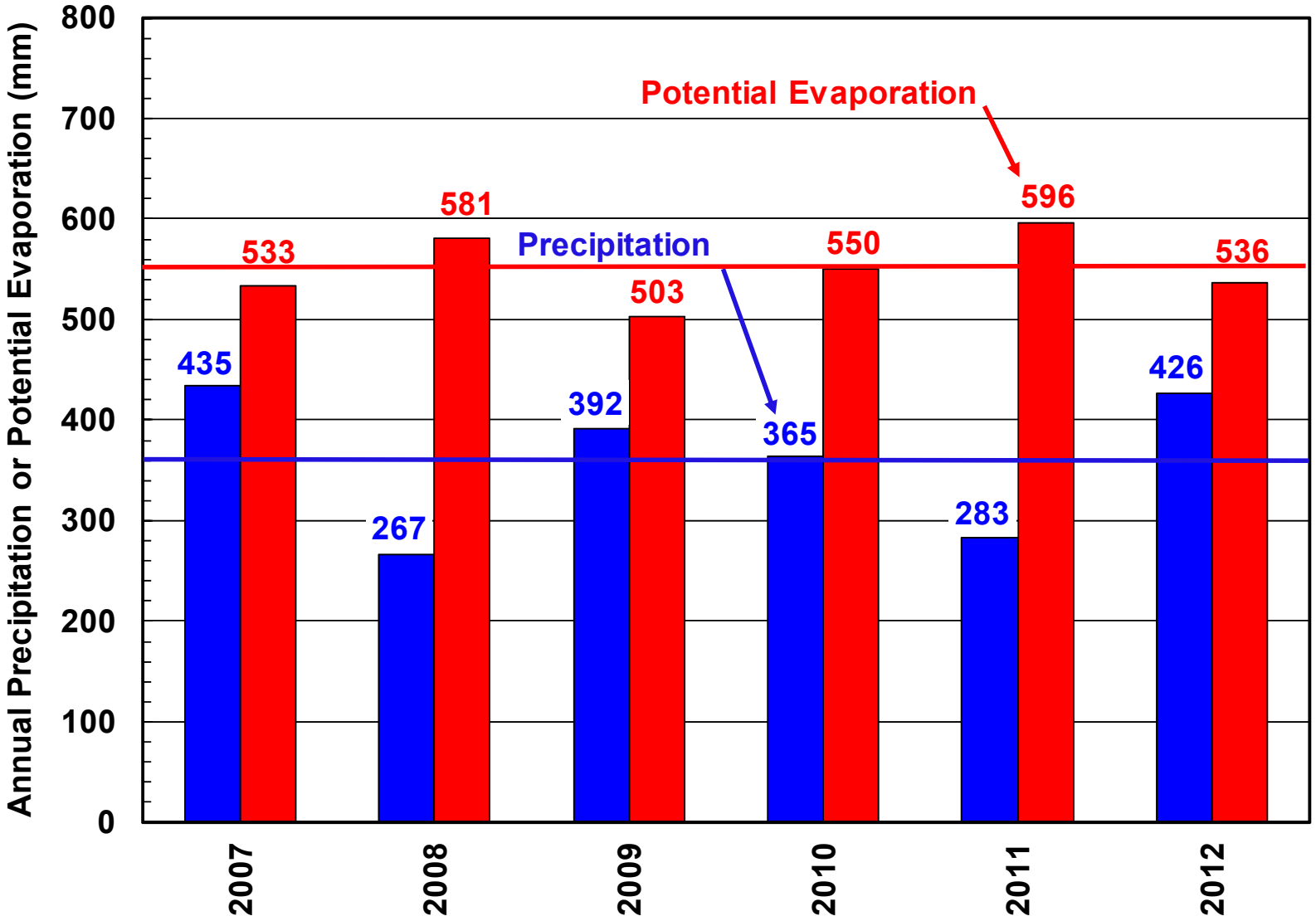
Cover System Instrumentation



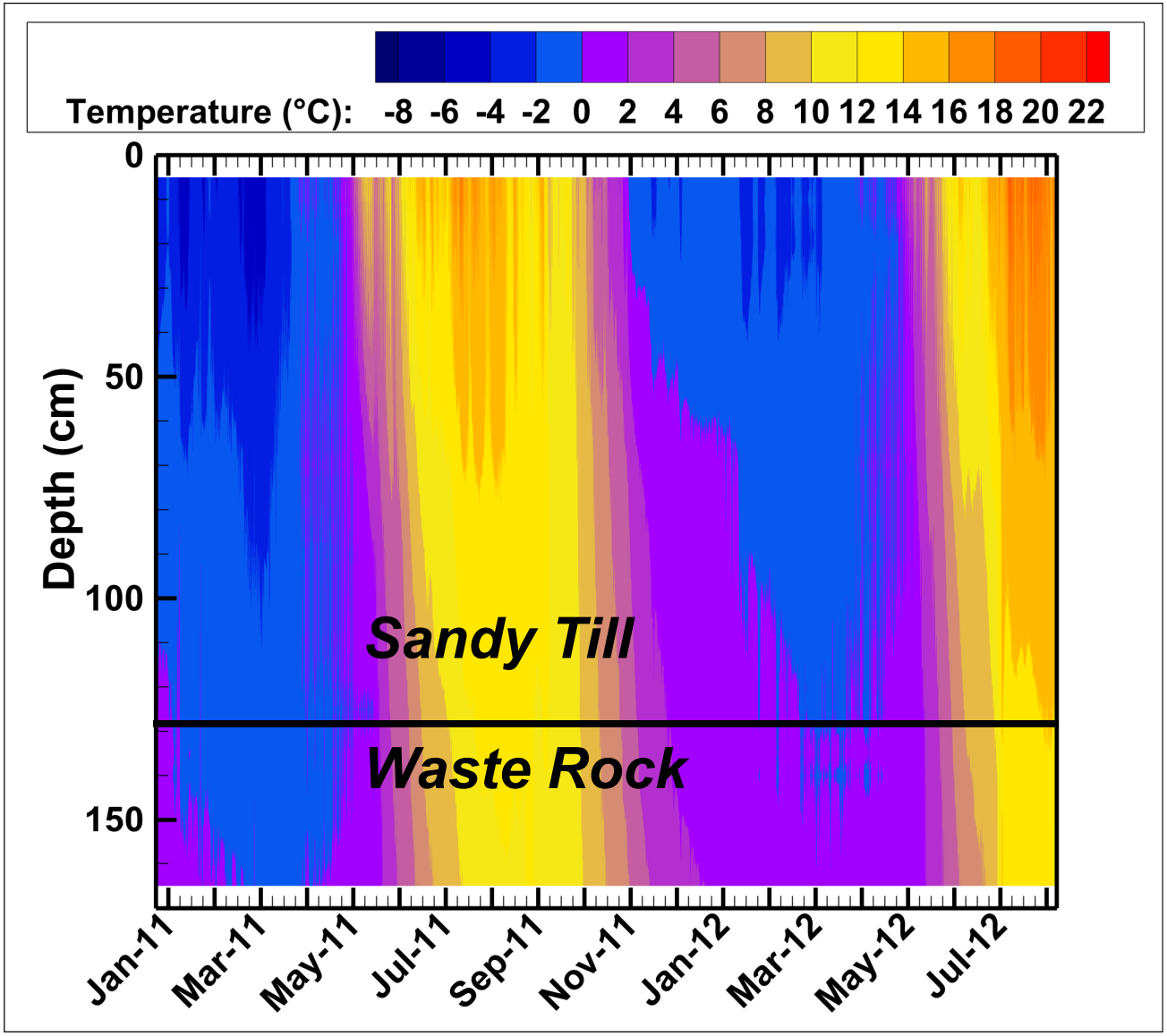
Slide 18

LT22 This is okay. Look for a higher resolution version, and put your own arrows and symbols showing what is what.
Lindsay Tallon, 8/29/2013

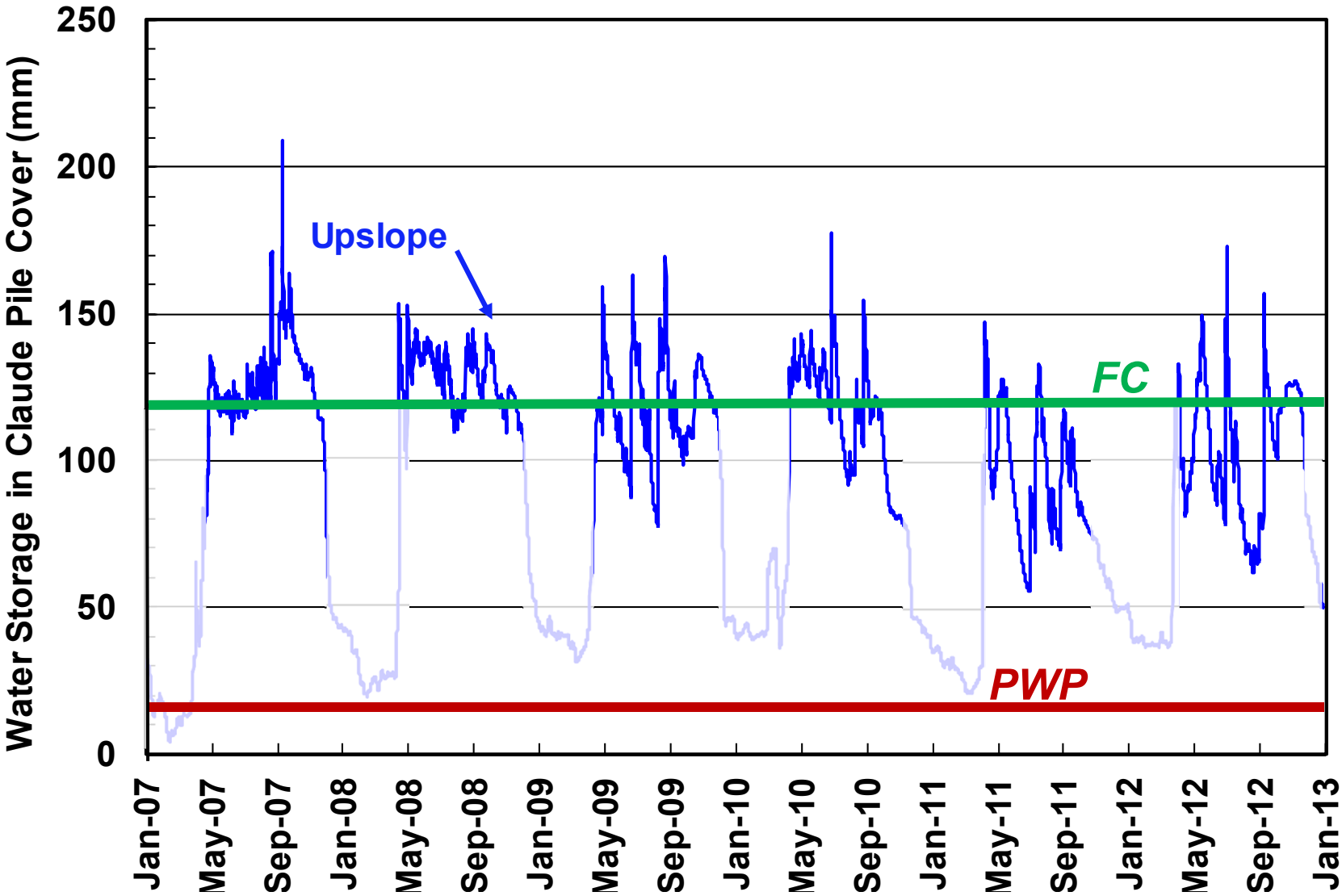
Meteorological Data



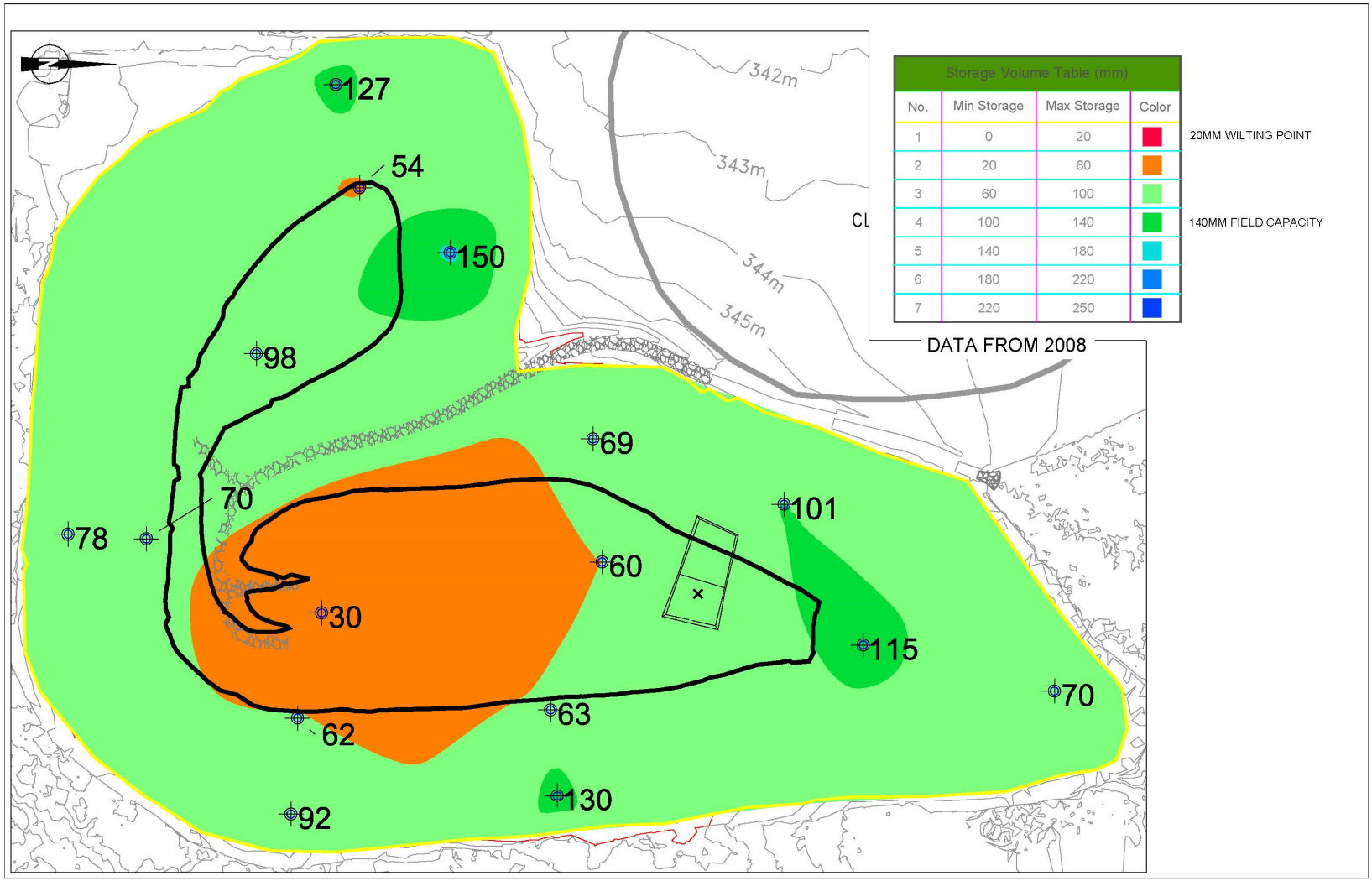
Thermal Cycling in Cover



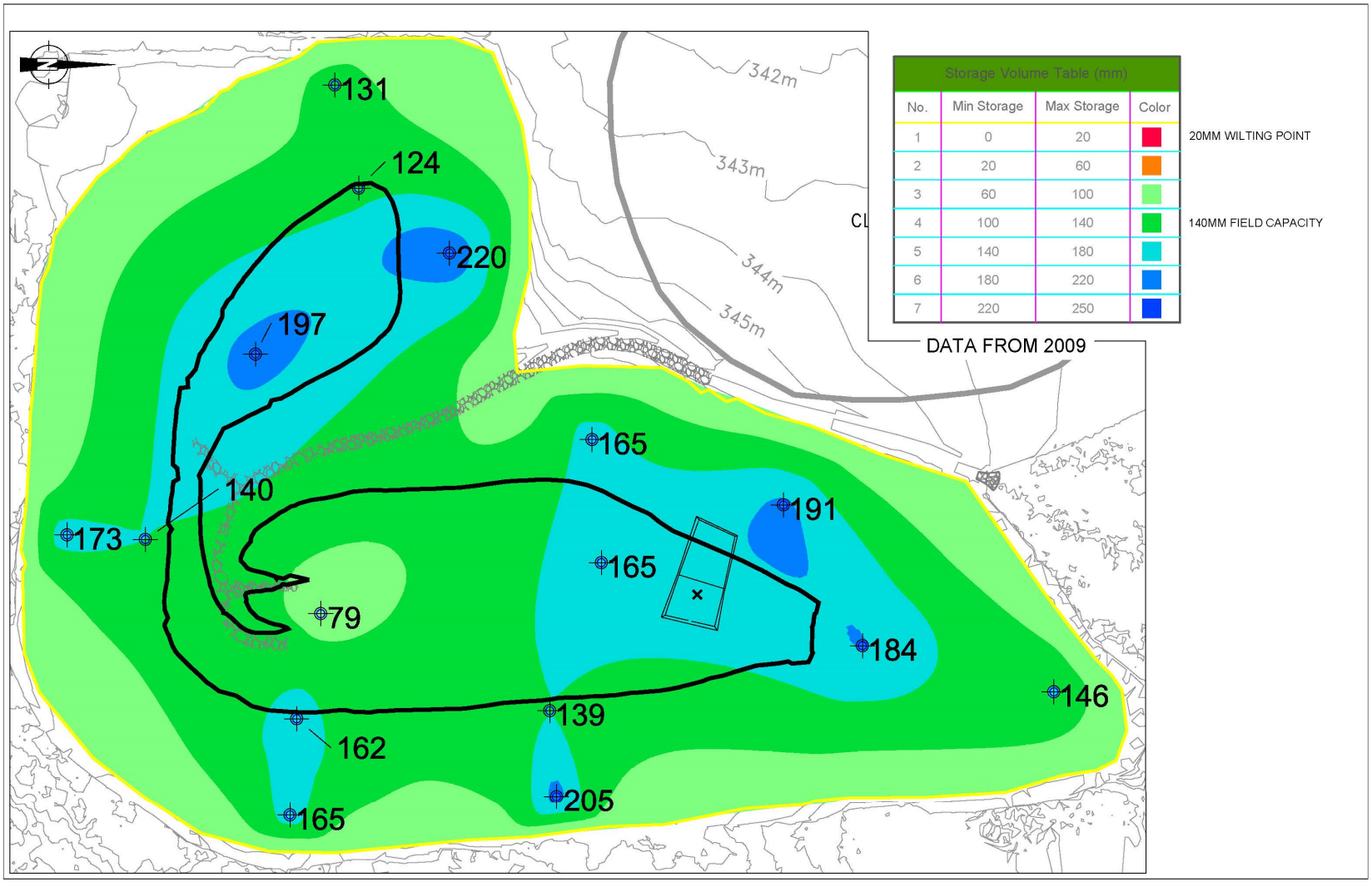
Moisture Cycling in Cover



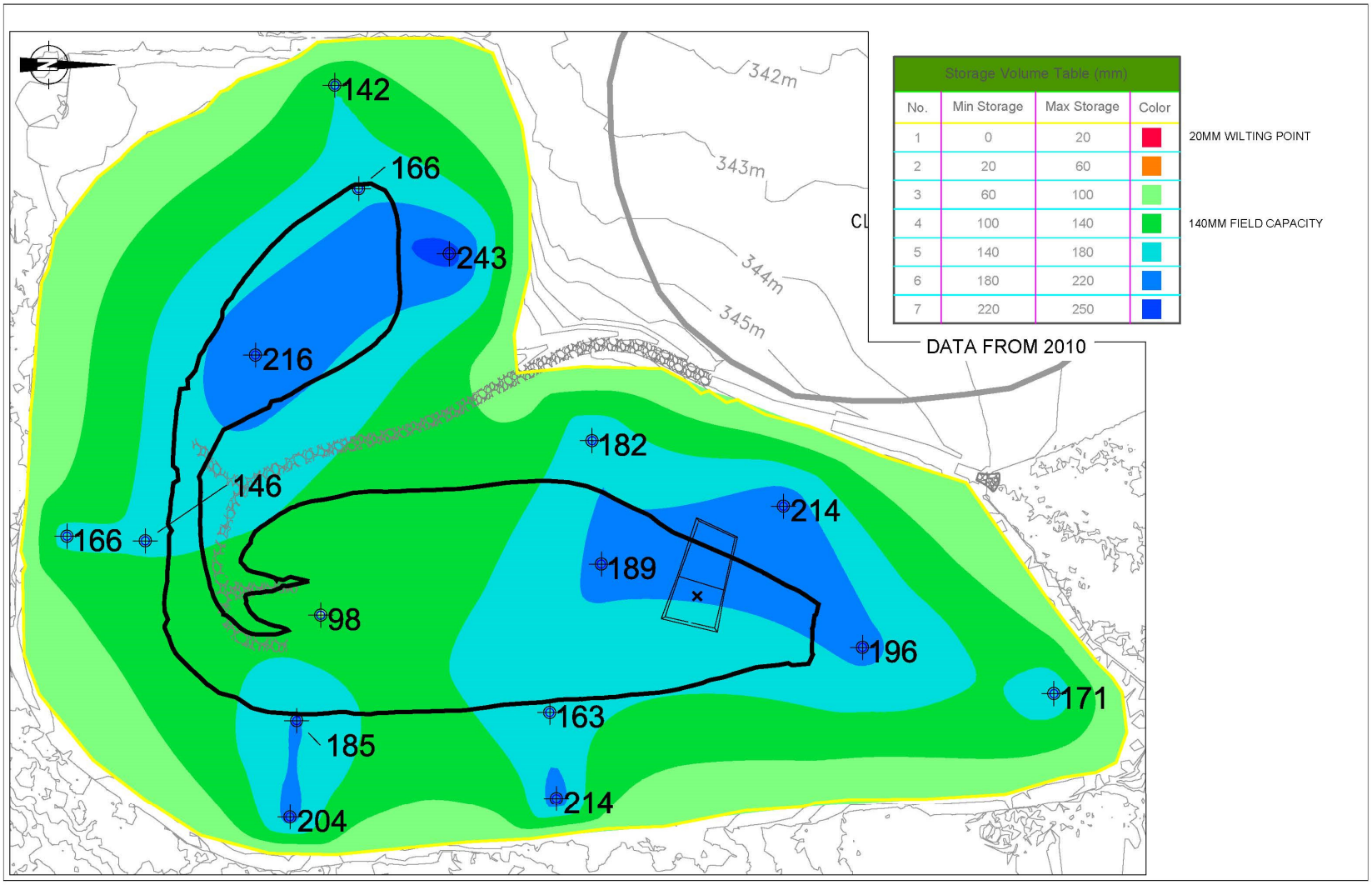
Moisture Availability (2008)



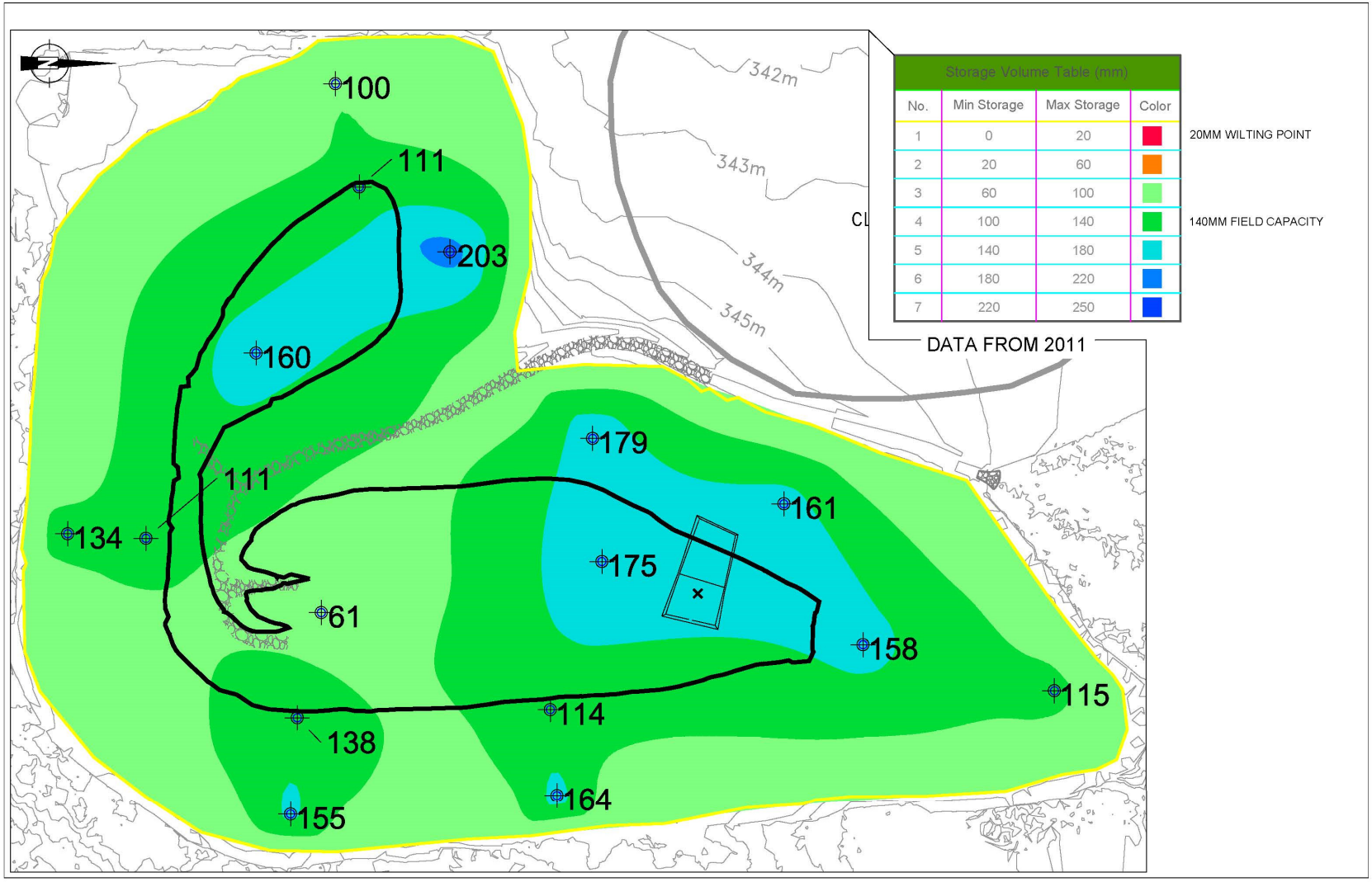
Moisture Availability (2009)



Moisture Availability (2010)



Moisture Availability (2011)



Cover System Evolution

Waste Rock Pile Water Balance

Plateau	PPT (mm)	Water Balance Fluxes (mm and % of precipitation)			
		AET	Δ S	R	NP
2007	450	231 (51%)	34 (8%)	6 (1%)	179 (40%)
2008	272	297 (109%)	-96 (-35%)	6 (2%)	66 (24%)
2009	387	290 (75%)	31 (8%)	5 (1%)	61 (16%)
2010	358	303 (85%)	12 (3%)	2 (1%)	40 (11%)
2011	271	182 (67%)	9 (3%)	2 (1%)	58 (21%)
2012	430	317 (74%)	33 (8%)	5 (1%)	105 (24%)

Slope	PPT (mm)	Water Balance Fluxes (mm and % of precipitation)				
		AET	Δ S	R	LD	NP
2007	419	239 (57%)	17 (4%)	58 (14%)	0 (0%)	104 (25%)
2008	261	308 (118%)	-85 (-33%)	50 (19%)	-57 (-22%)	45 (17%)
2009	396	314 (79%)	15 (4%)	41 (10%)	0 (0%)	26 (7%)
2010	371	320 (86%)	4 (1%)	22 (6%)	-21 (-6%)	46 (12%)
2011	295	231 (78%)	3 (1%)	19 (6%)	25 (9%)	44 (15%)
2012	422*	310 (73%)*	51 (12%)*	24 (6%)*	0 (0%)	92 (22%)*

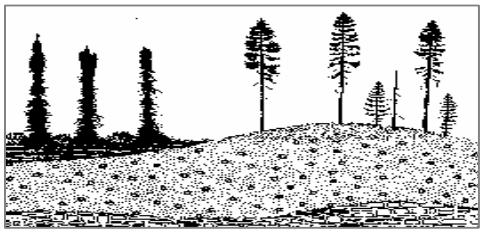
Waste Rock Pile Water Balance

Landform as a Whole

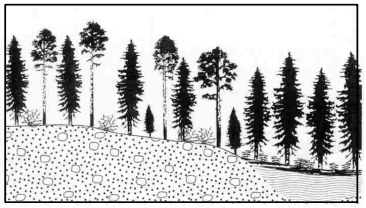
Year	PPT(mm)	NP
2007	433	138 (32%)
2008	266	55 (20%)
2009	392	42 (11%)
2010	365	43 (12%)
2011	284	50 (18%)
2012	426	98 (23%)

Cover System: Building Blocks

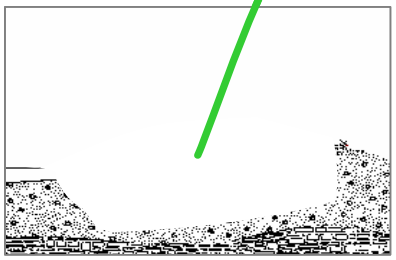
Pre-disturbance Capability



Post-disturbance Capability



Disturbance

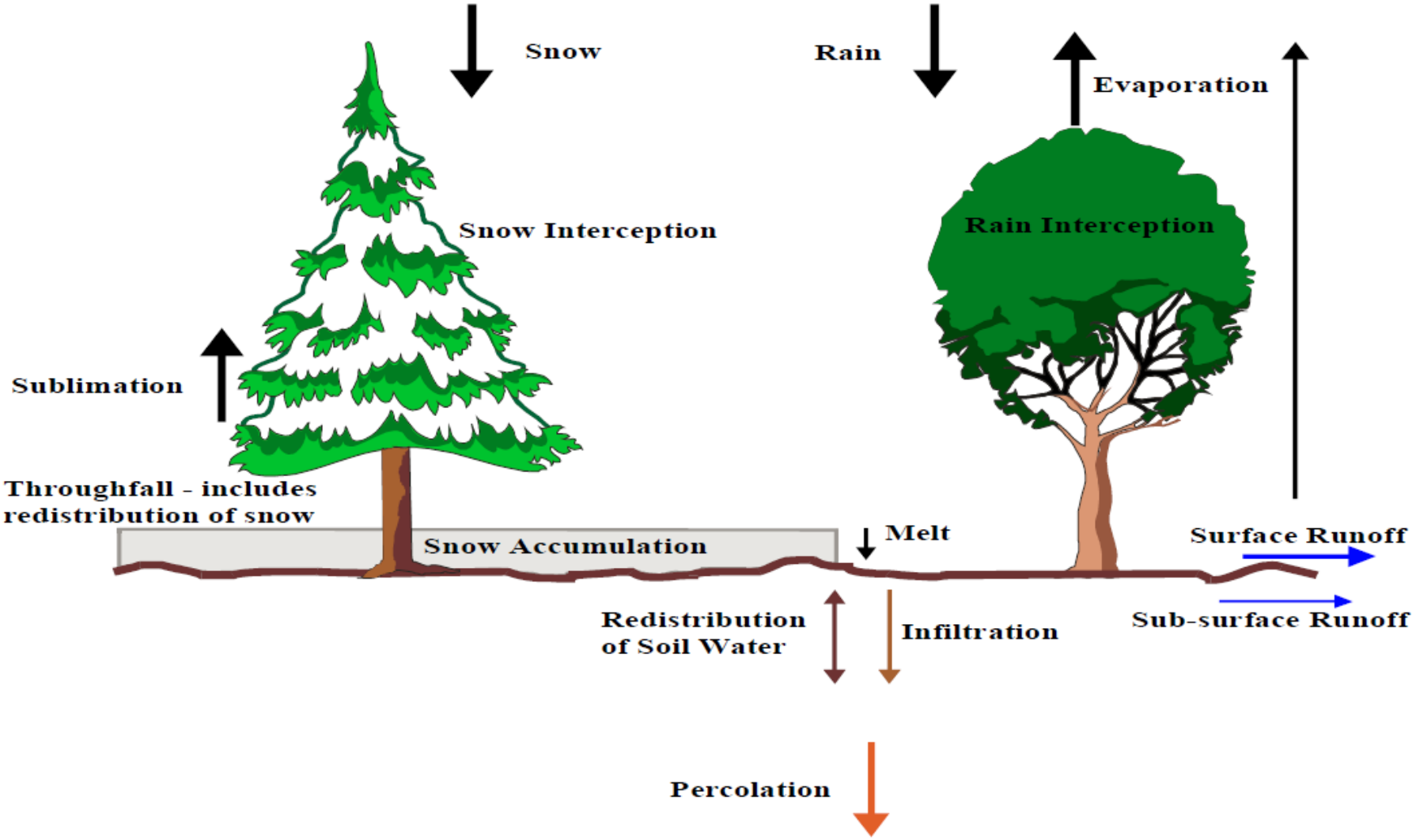


Capability = 0

- ***Establish the Building Blocks for the new Landscape***
  - ***Trajectory of Evolution is Correct (rate and end point)***
- ***Not Restoring a Landscape***
  - ***Providing Conditions such that the Landscape can Redevelop Towards and Equivalent Capability***

Time

Waste Rock Pile Water Balance



Summary

- *Net percolation has generally decreased*
  - *Increase vegetation cover*
  - *Increase evapotranspiration*
- *Timing of precipitation important:*
  - *Storm events in fall 2012 – greater net percolation due to decreased evapotranspiration capacity*
  - *Cover did not freeze in 2012*
    - *Net percolation continued during winter*

Slide 31

LT32 I don't like reading when I'm watching a presentation. Is there some sort of picture you can put up.
Lindsay Tallon, 8/29/2013

Key Points

- *Claude cover system is a stable landform and design objectives are being met*
- *Importance of long-term perspective when evaluating cover system performance*
  - *Natural climatic variability*
  - *Trajectory of vegetation cover*

Cover System Guidance Document

INAP

- *Build off of Cold Regions Cover System Design Guidance Document*
- *Expand to 'Other' Climate Regions*
- *Advance Approach / Methodology for Cover System Design*

- *International Network for Acid Prevention*
  - *Consortium of ten companies*

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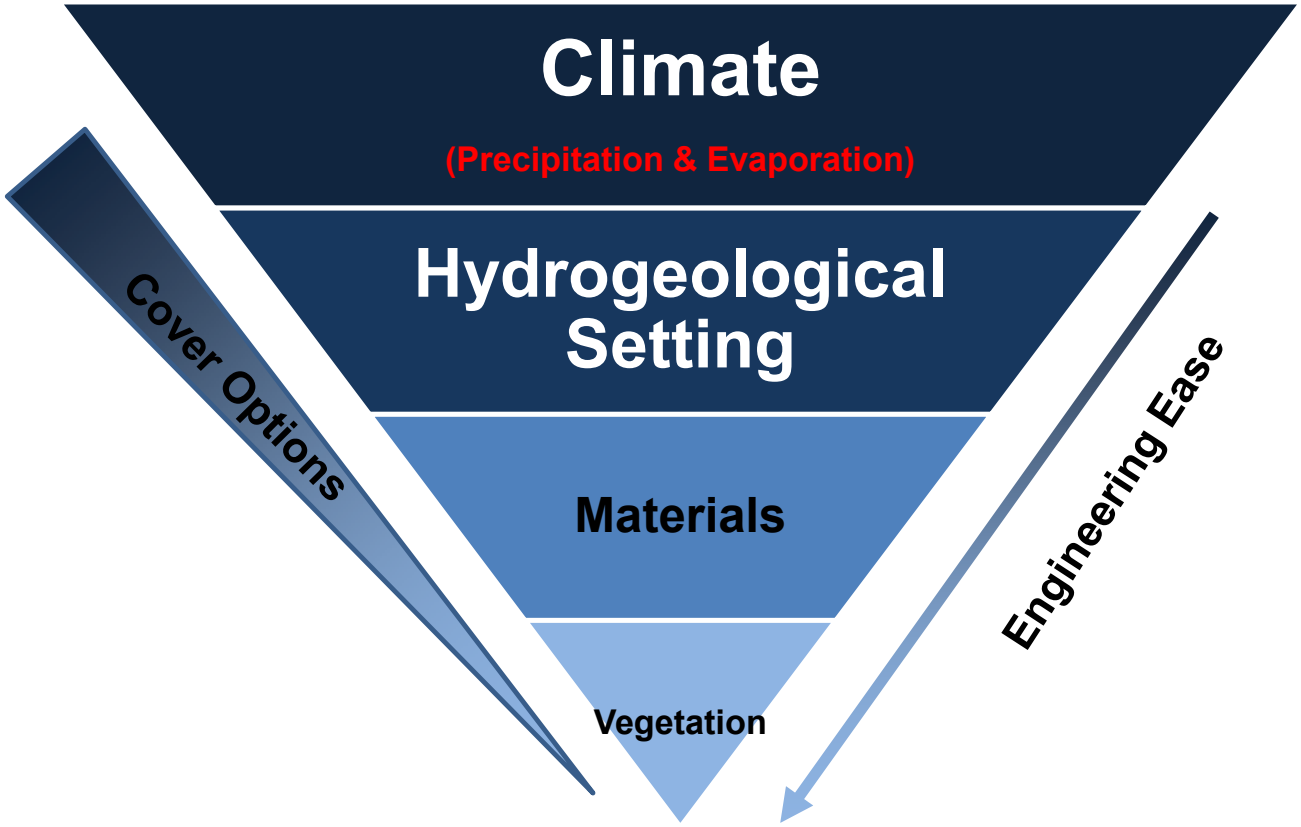
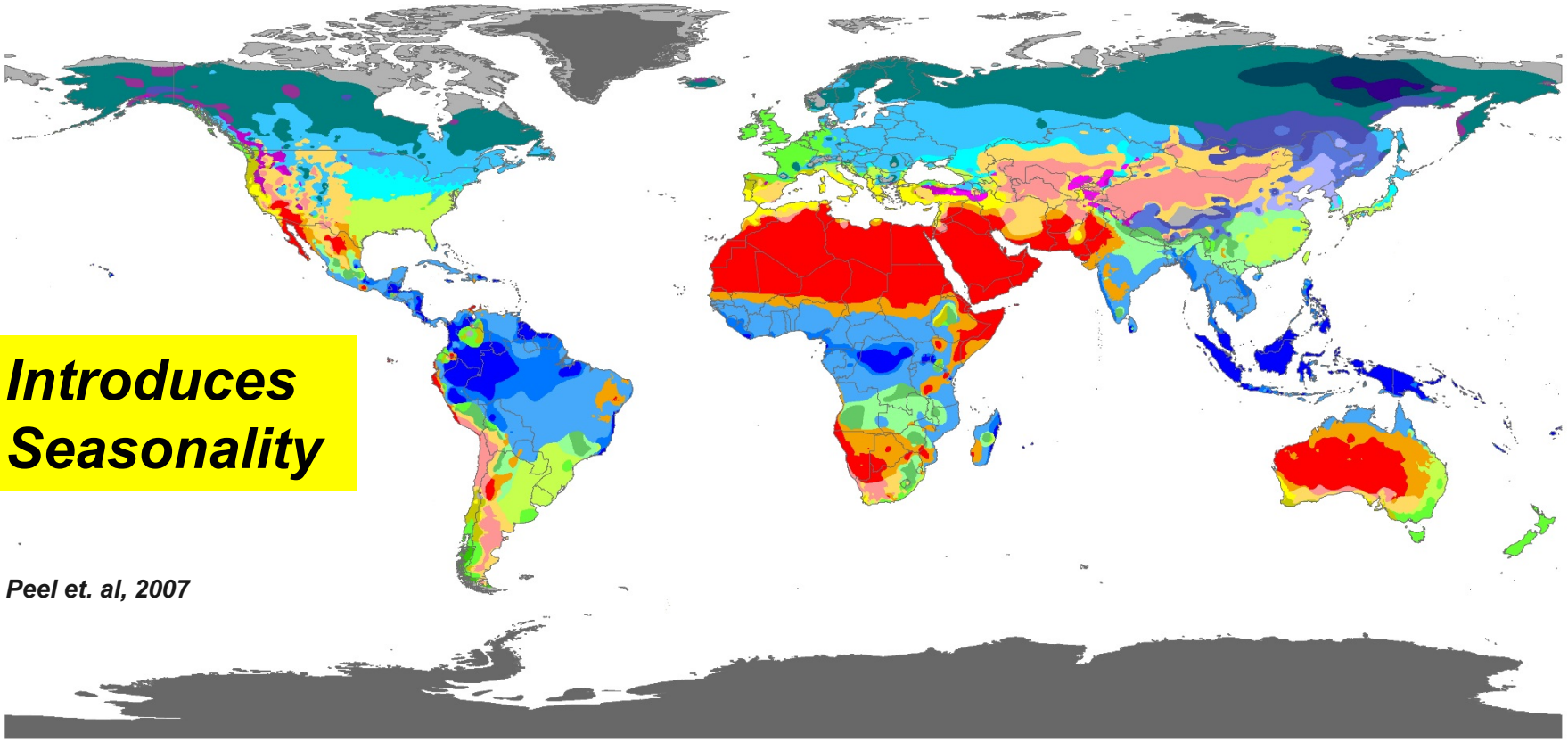
Cover System Guidance Document

- *What **attributes** of the region can be **exploited, enhanced, or combined** to achieve performance criteria*



Cover System Guidance Document

World map of Köppen-Geiger climate classification



Introduces Seasonality

Peel et. al, 2007

THE UNIVERSITY OF MELBOURNE

Af	BWh	Csa	Cwa	Cfa	Dsa	Dwa	Dfa	ET
Am	BWk	Csb	Cwb	Cfb	Dsb	Dwb	Dfb	EF
Aw	BSh		Cwc	Cfc	Dsc	Dwc	Dfc	
	BSk				Dsd	Dwd	Dfd	

Contact : Murray C. Peel (mpeel@unimelb.edu.au) for further information

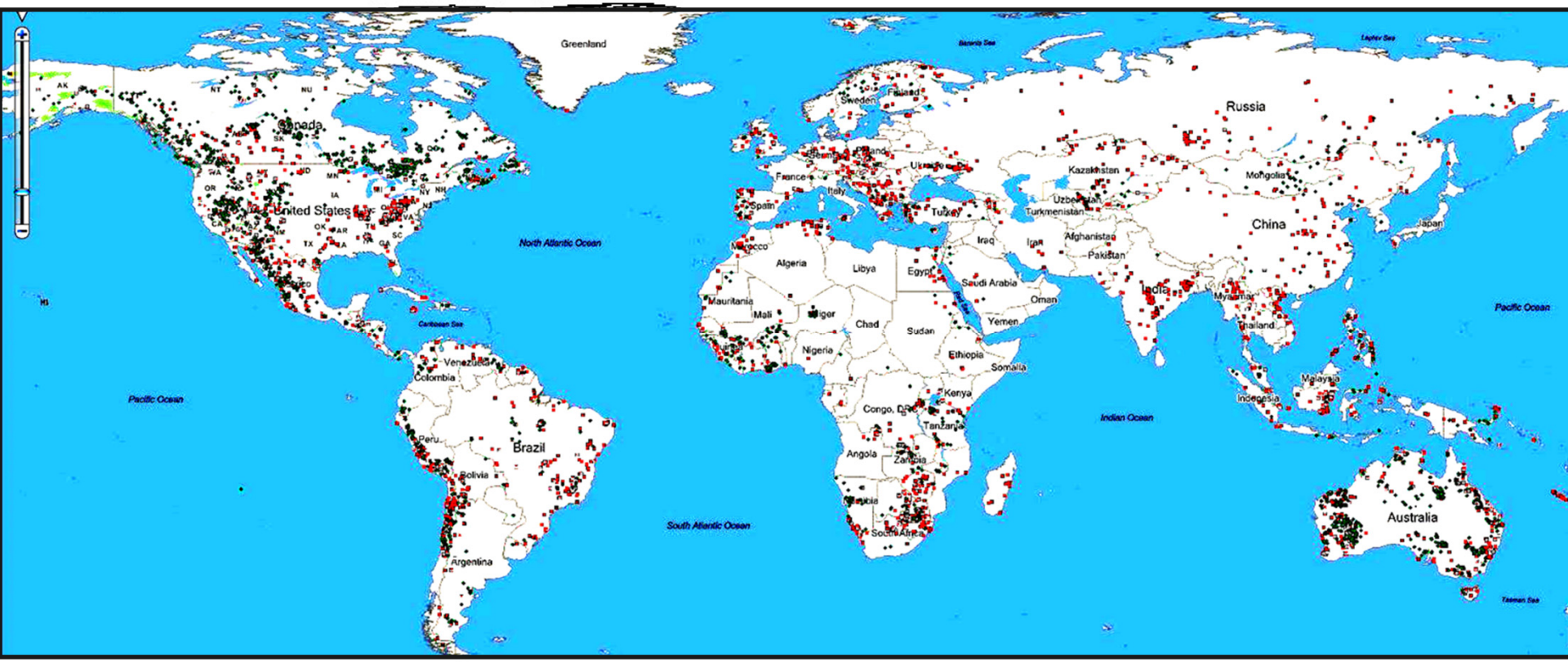
DATA SOURCE : GHCN v2.0 station data
Temperature (N = 4,844) and
Precipitation (N = 12,396)

PERIOD OF RECORD : All available

MIN LENGTH : ≥30 for each month.

RESOLUTION : 0.1 degree lat/long

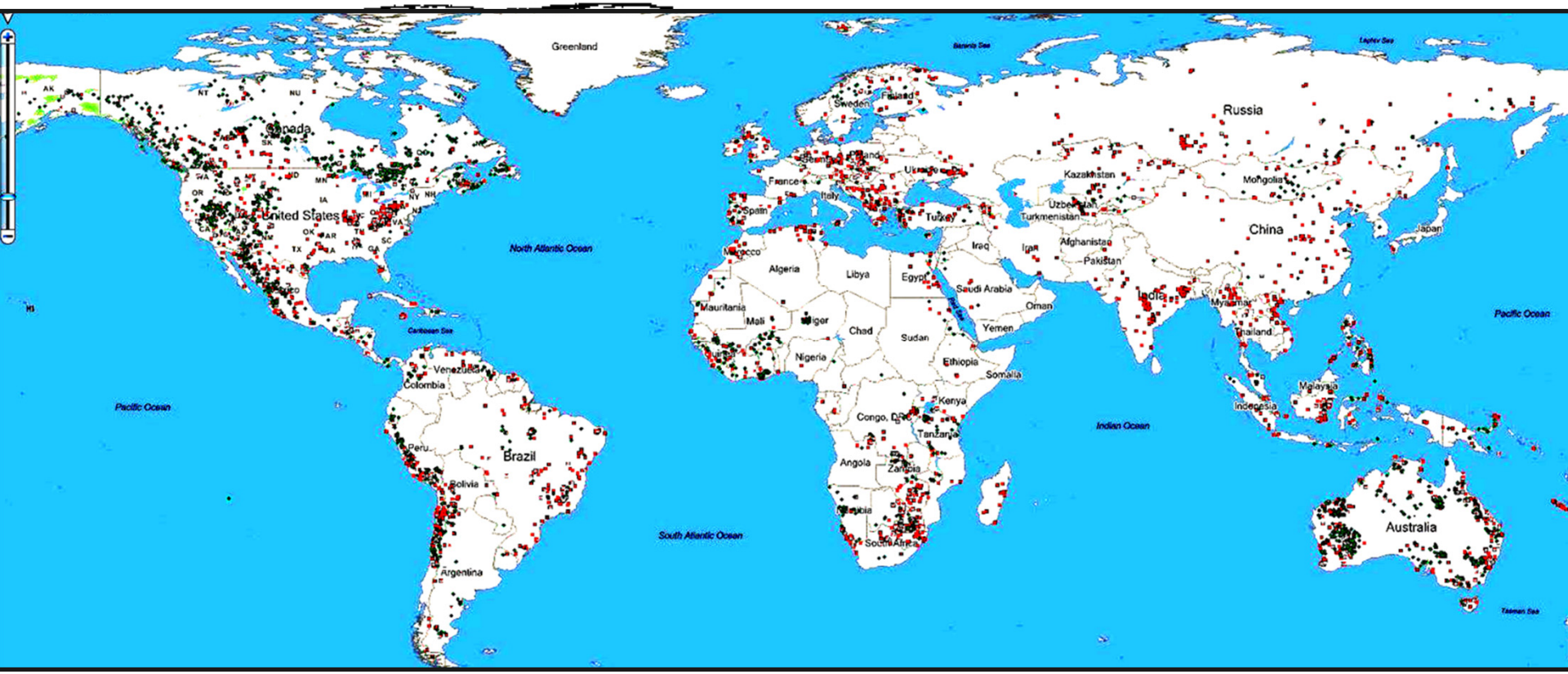
Significant Temperate Regions



Temperate

Csa	Cwc
Csb	Cfa
Cwa	Cfb
Cwb	Cfc

Significant Temperate Regions



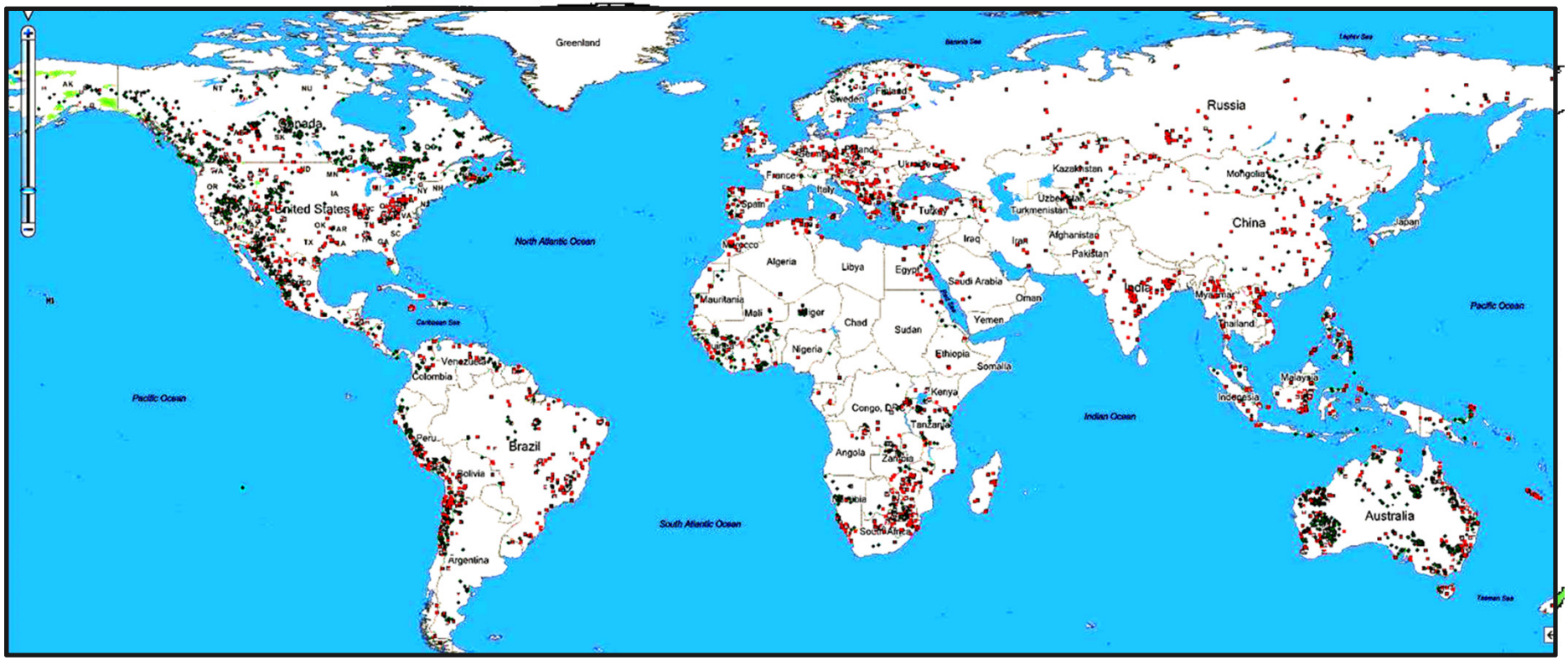
Temperate

- Csa
- Csb
- Cwa
- Cwb
- Cwc
- Cfa
- Cfb
- Cfc

Arid

- BWh
- BWk
- BSh
- BSk

Climate Regions for Guidance Document



Temperate

- Csa
- Csb
- Cwa
- Cwb
- Cwc
- Cfa
- Cfb
- Cfc

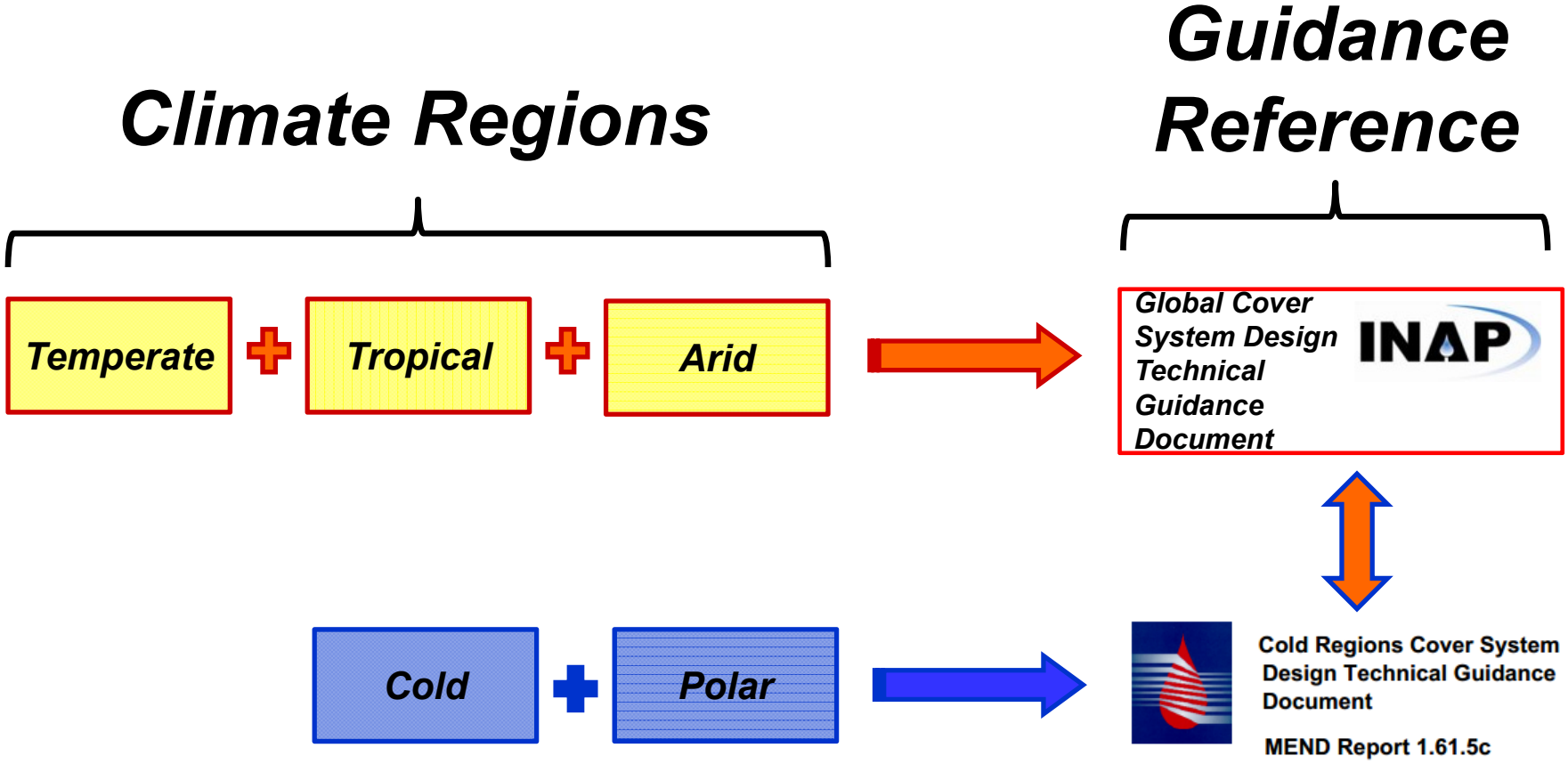
Arid

- BWh
- BWk
- BSh
- BSk

Tropical

- Af
- Am
- Aw

Context of Focus for Guidance

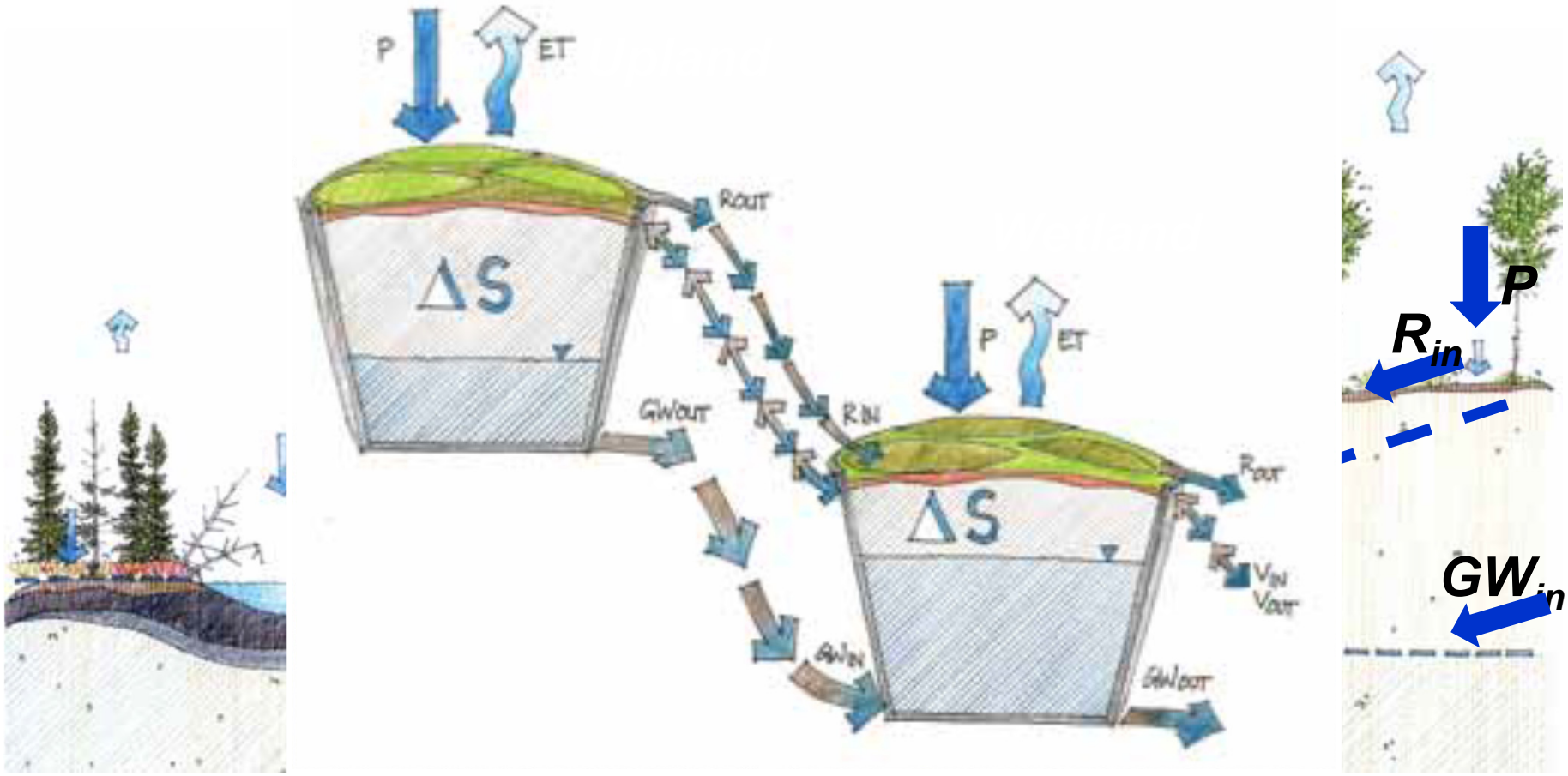


Approach within Document

Oil Sands Example

Deficit /Seasonal Ice.

$$\Delta S = P - ET + (R_{in} - R_{out}) + (GW_{in} - GW_{out})$$



Devito, K., Mendoza, C., Qualizza, C. (2012).

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