Ten-Year Performance Evaluation of the Evapotranspiration Cover at Barrick Goldstrike Mine's AA Leach Pad

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Thanks to Dale Hammermeister and Joe Vinson

Background

- Goldstrike Mine located in north-central Nevada
  - Average precipitation = 11.7 in/yr (29.7 cm/yr): 1990-2011
  - Primarily snow, December through May
- AA Leach Pad
  - HDPE lined gold heap leaching facility
  - Operated from 1987 to 1999
  - 224 acres and 55 million tons of ROM leached ore
- Estimates of natural groundwater recharge rates
  - Function of elevation and precipitation
  - Maxey-Eakin (1949) approximation – 3% to 5% of precipitation
- Evapotranspiration (ET) cover designed and placed in 2000-2001

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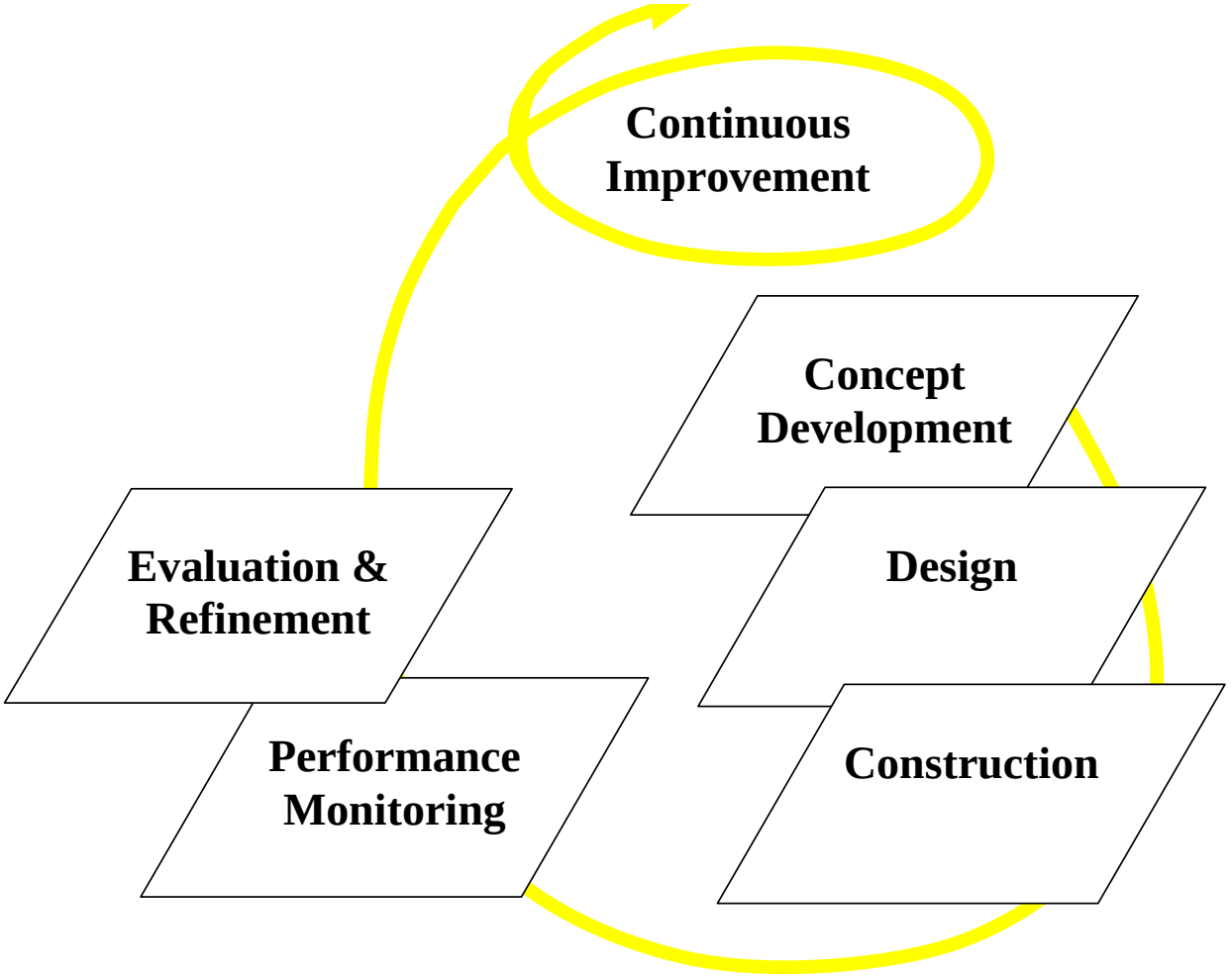
Barrick Gold Closure Objectives



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Designing an ET Cover

ET Cover – Seasonal storage and release of soil water

1. Fall

Soil is initially dry due to previous growing season

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Designing an ET Cover

ET Cover – Seasonal storage and release of soil water

2. Winter

Rain and snowmelt gradually infiltrates, increasing soil water

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Designing an ET Cover

ET Cover – Seasonal storage and release of soil water

3. Spring

Net percolation is most likely in this season (April-June) after a wet winter

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Desig Cover

ET Cover – Seasonal storage and release of soil water

4. Late Spring & Early Summer

Temperature warms, and evapo-transpiration increases

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Designing an ET Cover

ET Cover – Seasonal storage and release of soil water

5. Late Summer

Continued transpiration by vegetation removes stored soil water from root zone

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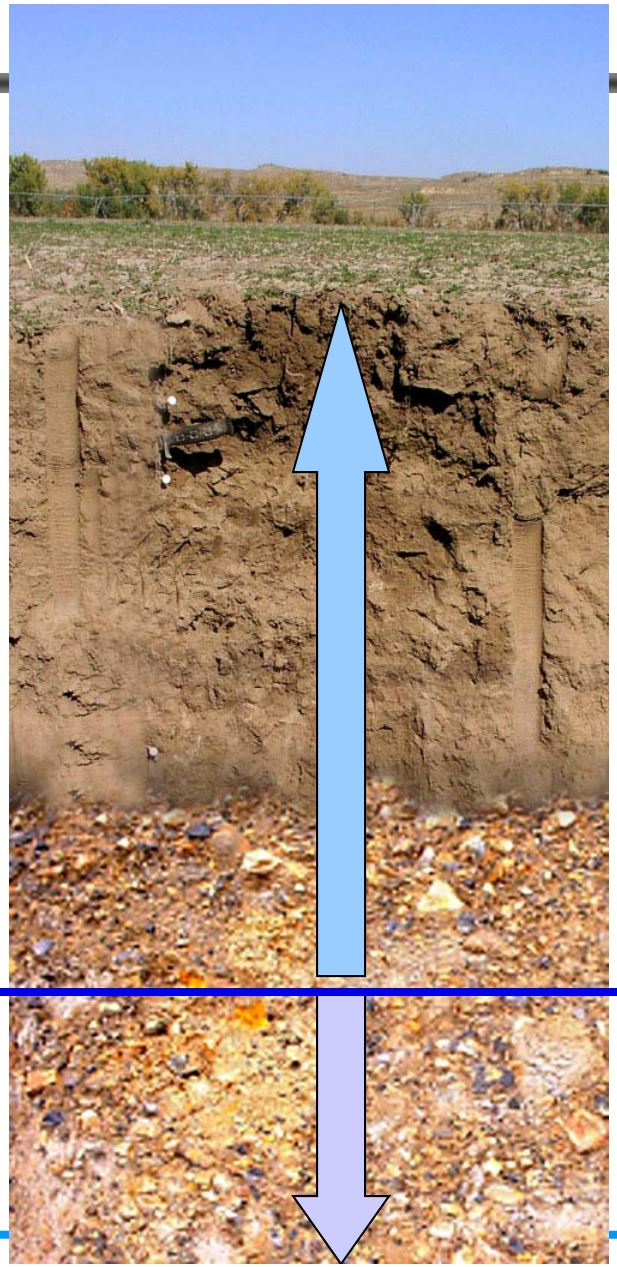
Designing an ET Cover

Design Factors

- Cover should contain ample water-holding capacity (loams ideal)
- An abrupt textural contrast from loams/silts to gravel/ sands may create capillary break



- Downward/upward flux rates are controlled by soil hydraulic properties and pressure potential gradients
- Zero flux plane defines depth at which downward flux is occurring

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AA Pad Closure

- ET Cover Design Parameters
  - **Minimize net percolation from meteoric water**
  - Promote vegetation growth
- Borrow material: fine grained topsoil or valley fill deposits (Carlin silt)
  - Unsaturated flow modeling predicted nominal changes in flux above a 4 foot ET cover
- Four foot ET cover (3 ft to 5.5 ft), placed in 2000-2001

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AA Pad Cover Performance Monitoring

- Soil cover monitoring stations (14)
  - Soil water dynamics (water content, soil water pressure potential)
  - In-situ and laboratory hydraulic property characterization
  - Various monitoring locations to access solar aspect, slope location, proximity to runoff channels, cover material type
    - East transect – Carlin Silt, east aspect
    - West transect – Topsoil, north aspect
    - South transects - Carlin Silt, south aspect
  - Station installation 2001 (East and West) and 2005 (South)
- Estimate net percolation:
  - Use 1D Darcy approximation using pressure potential data and hydraulic properties from bottom two sensor locations

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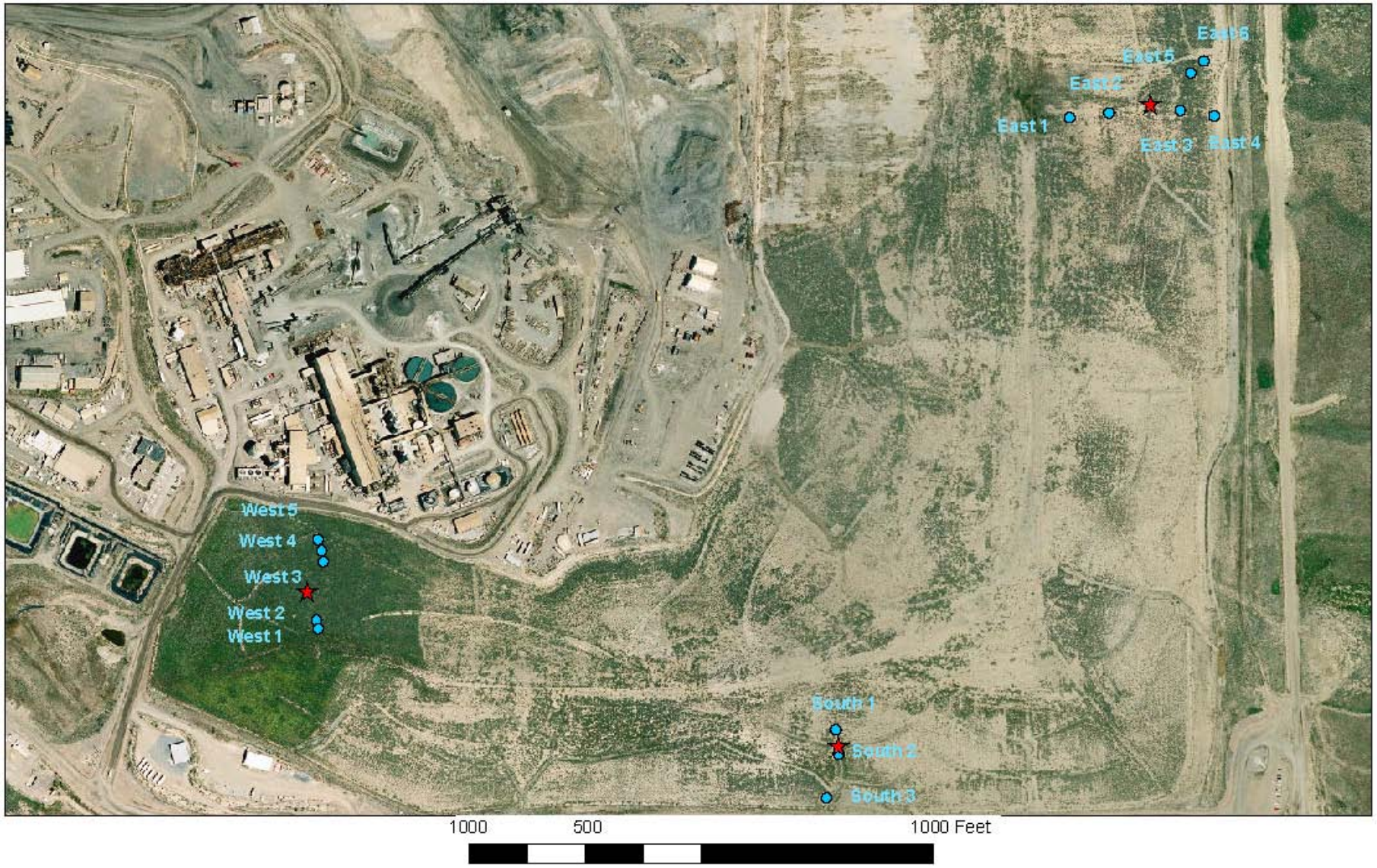

Legend

- AA Pad Dataloggers
- AA Pad Monitoring Stations

Figure 2. Monitoring sites at AA Pad

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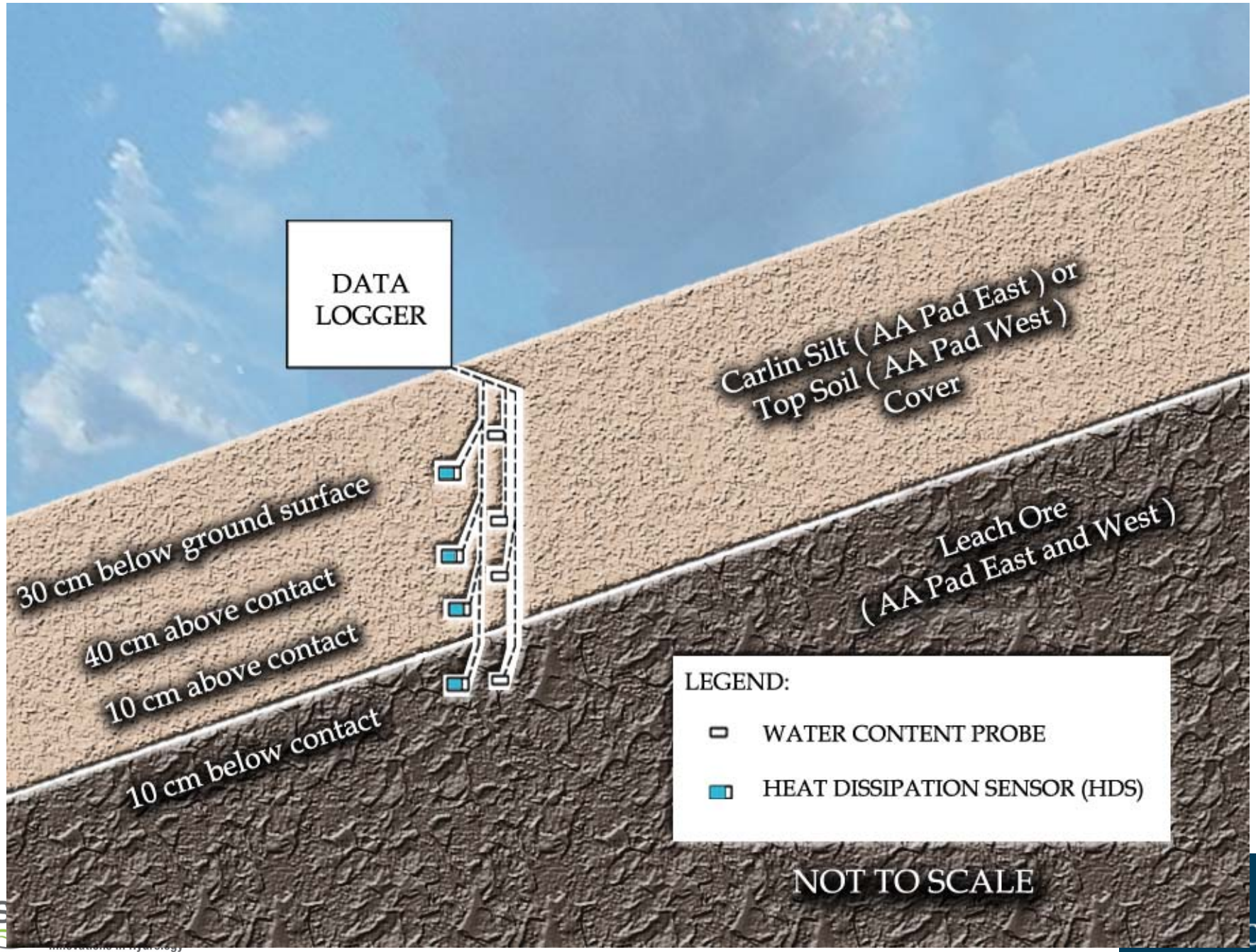
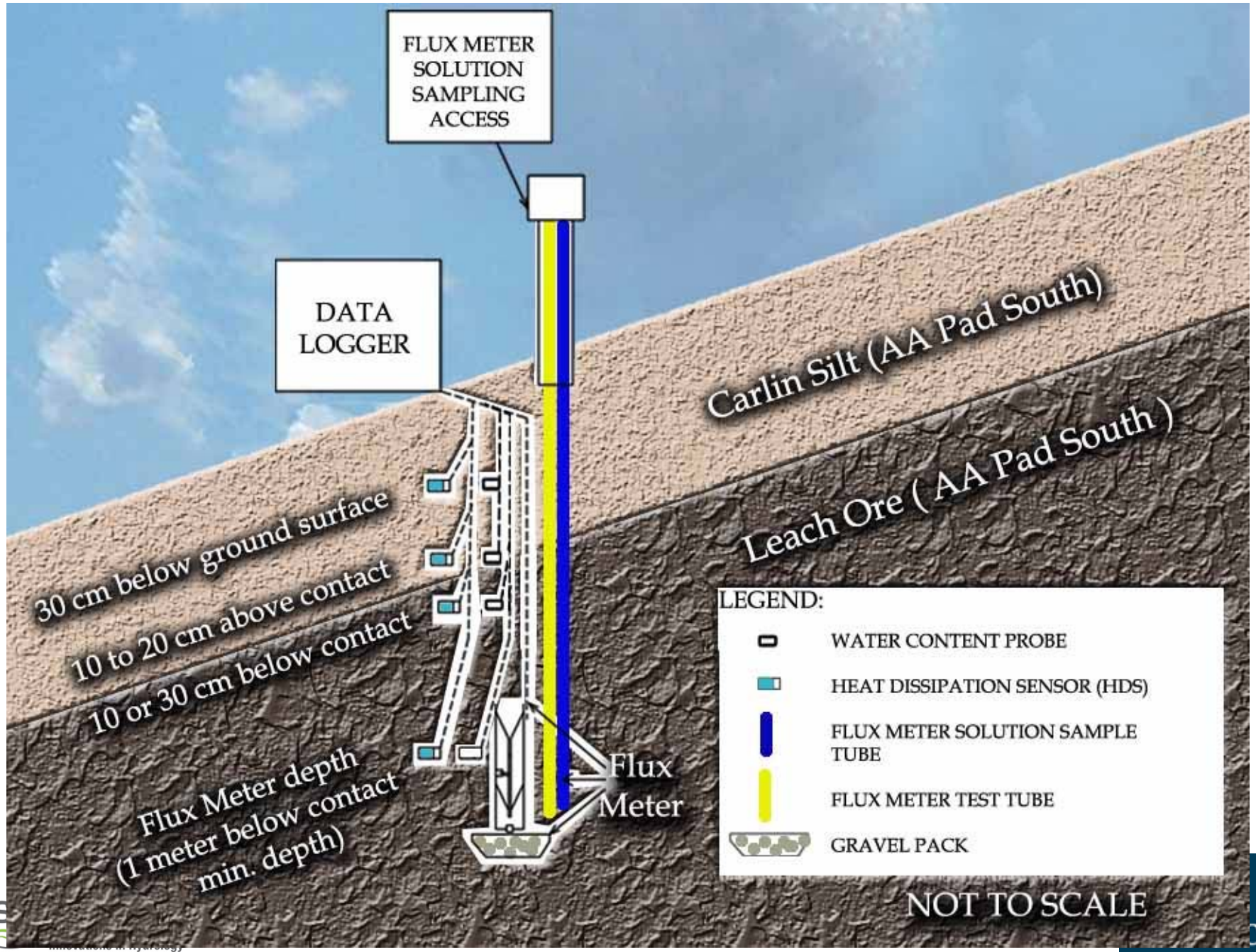

DATA LOGGER
Carlin Silt (AA Pad East) or Top Soil (AA Pad West) Cover
Leach Ore (AA Pad East and West)
30 cm below ground surface
40 cm above contact
10 cm above contact
10 cm below contact
LEGEND:
WATER CONTENT PROBE
HEAT DISSIPATION SENSOR (HDS)
NOT TO SCALE


FLUX METER SOLUTION SAMPLING ACCESS
DATA LOGGER
Carlin Silt (AA Pad South)
Leach Ore (AA Pad South)
30 cm below ground surface
10 to 20 cm above contact
10 or 30 cm below contact
Flux Meter depth (1 meter below contact min. depth)
Flux Meter
LEGEND:
WATER CONTENT PROBE
HEAT DISSIPATION SENSOR (HDS)
FLUX METER SOLUTION SAMPLE TUBE
FLUX METER TEST TUBE
GRAVEL PACK
NOT TO SCALE

Sensor Installation

Data Summary

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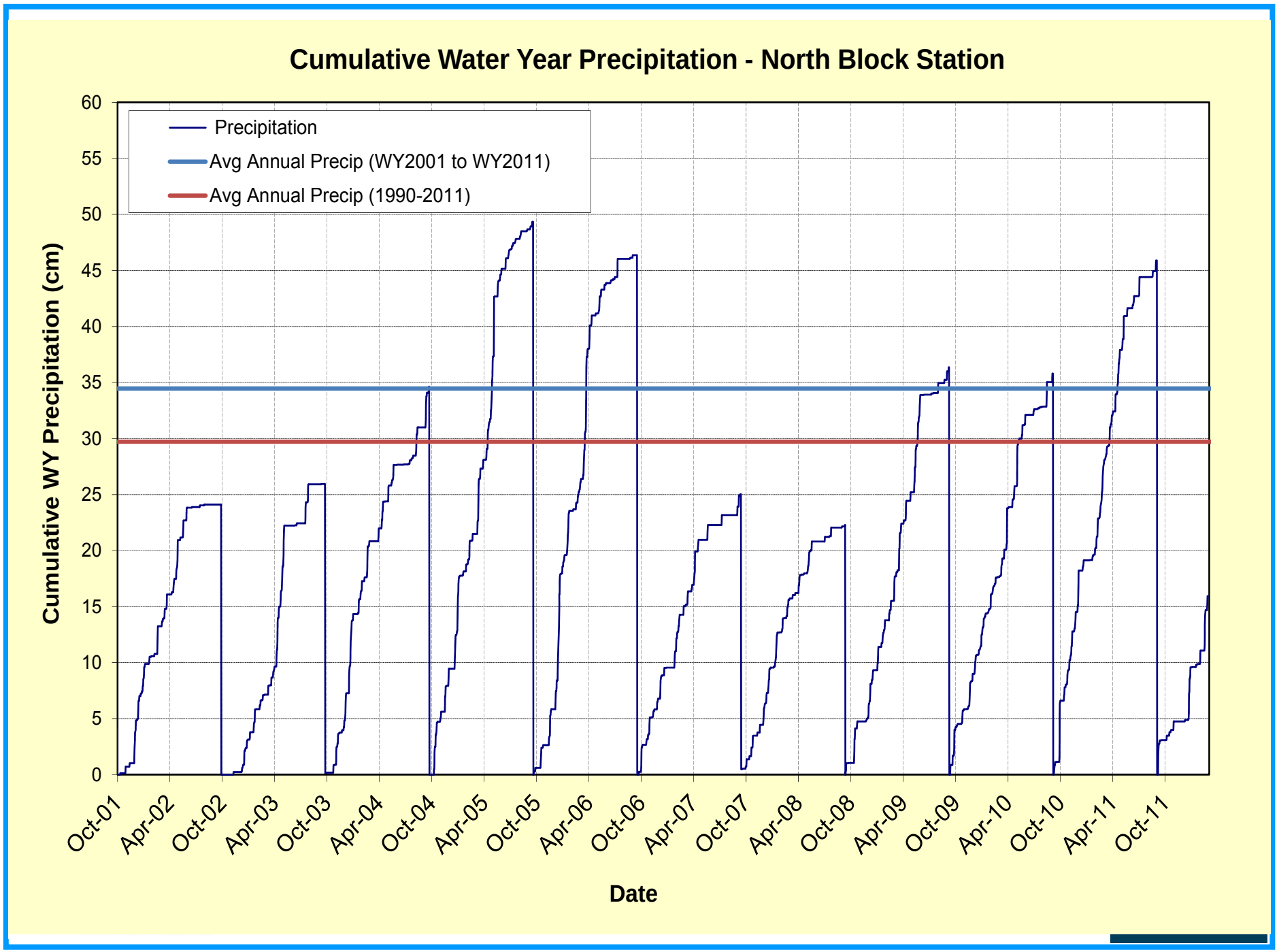
Cumulative Water Year Precipitation - North Block Station
Precipitation
Avg Annual Precip (WY2001 to WY2011)
Avg Annual Precip (1990-2011)
Cumulative WY Precipitation (cm)
0
5
10
15
20
25
30
35
40
45
50
55
60
Oct-01
Apr-02
Oct-02
Apr-03
Oct-03
Apr-04
Oct-04
Apr-05
Oct-05
Apr-06
Oct-06
Apr-07
Oct-07
Apr-08
Oct-08
Apr-09
Oct-09
Apr-10
Oct-10
Apr-11
Oct-11
Date

Vegetation Data

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Vegetation after 10 years

Ground Cover Type	Transect		
	East	South	West
Total Plant	26%	36%	89%
Perennial	24%	31%	88%
Shrub and Forb	17%	21%	87%

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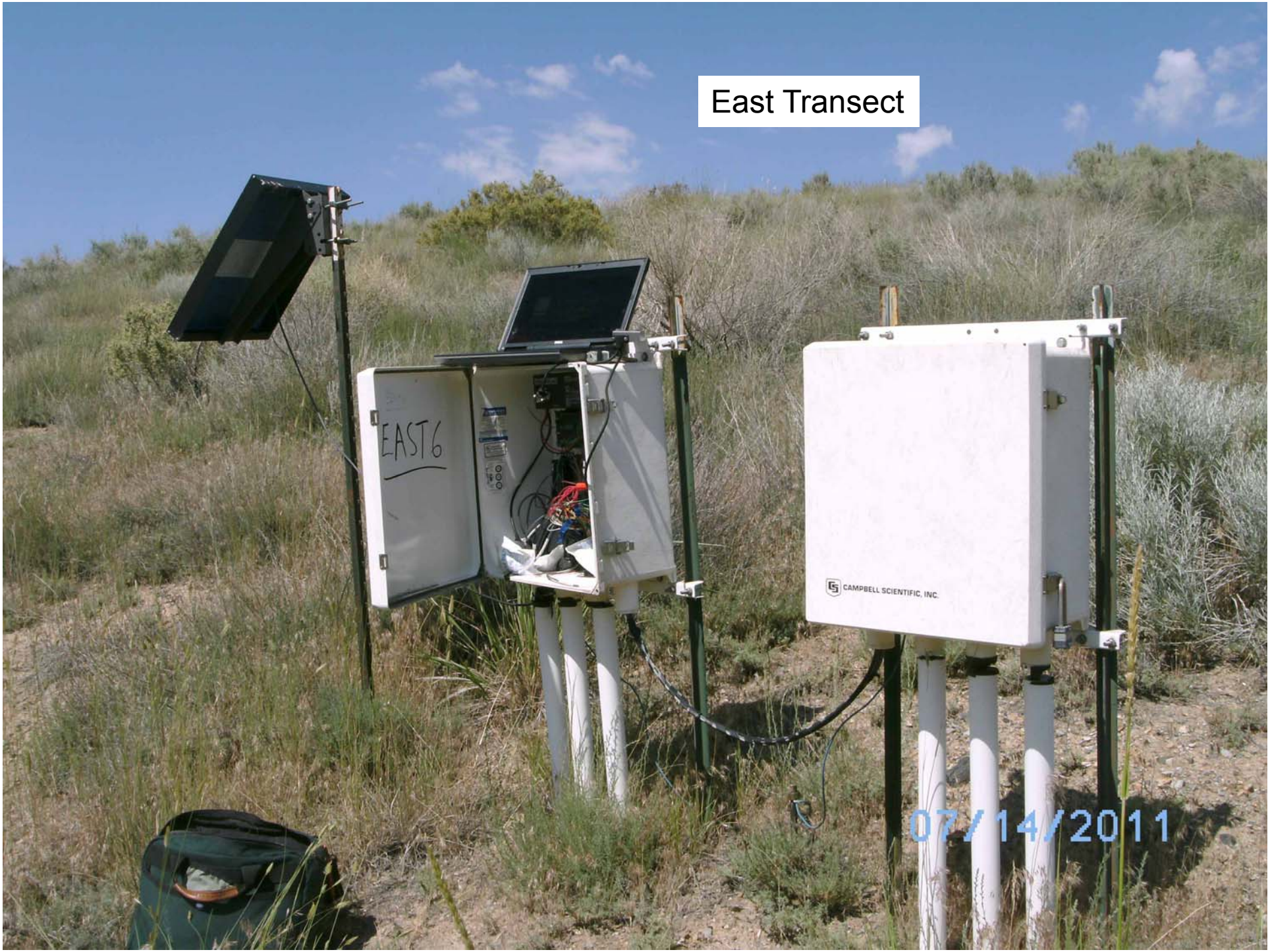
East Transect
EAST6
CAMPBELL SCIENTIFIC, INC.
07/14/2011

Water Content Data

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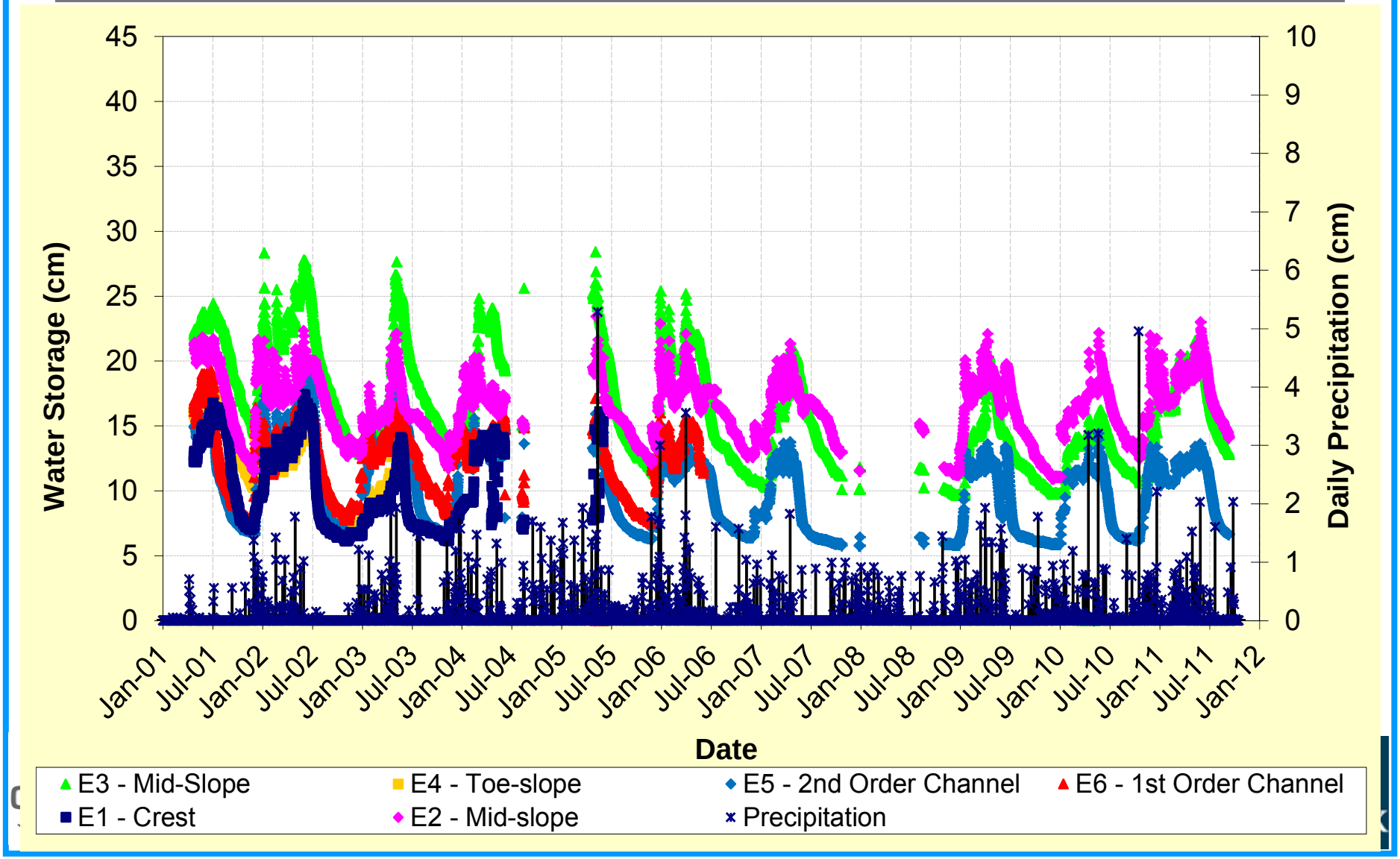
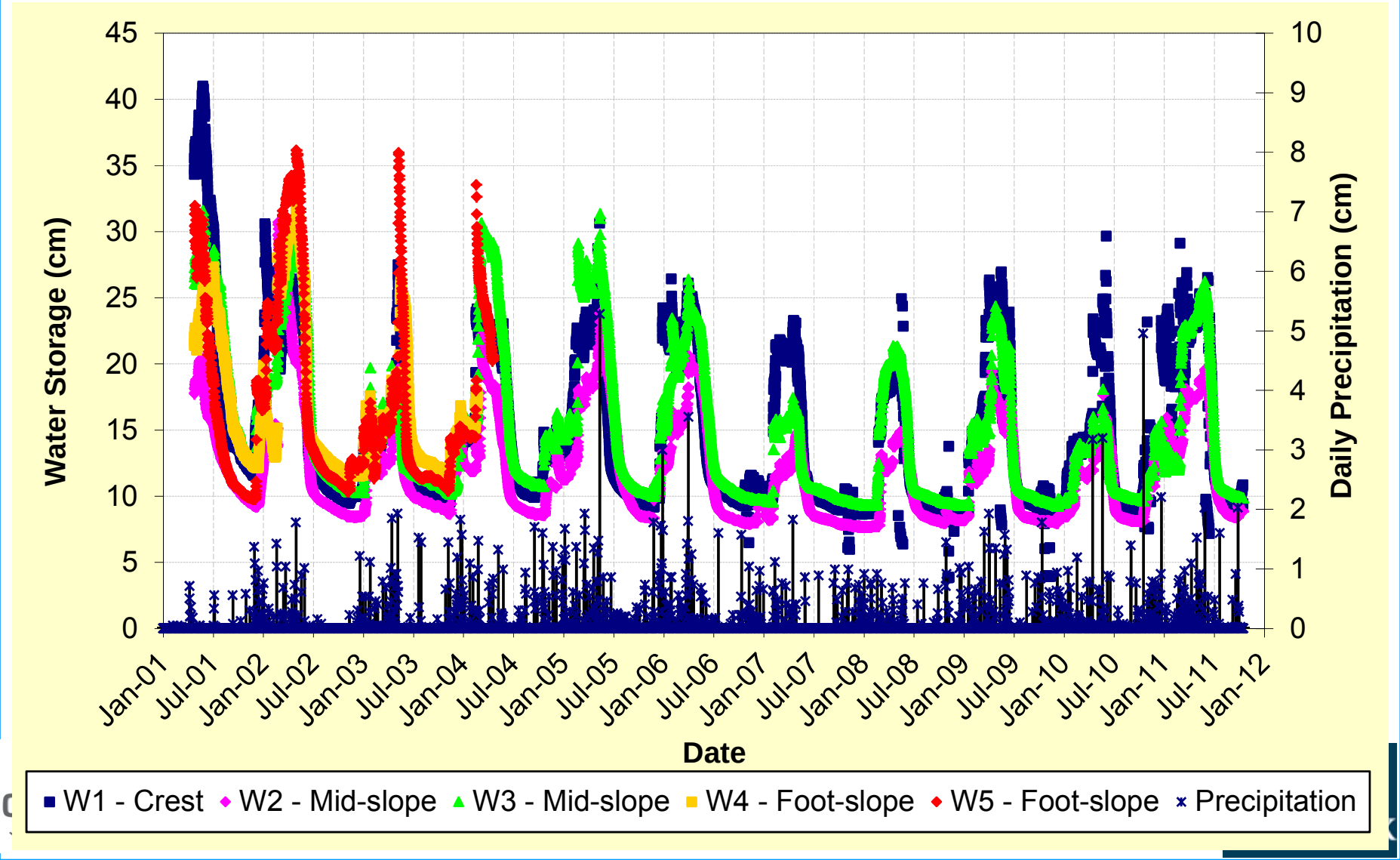
East Transect Water Storage



West Transect Water Storage



Field Water Holding Capacity

Location	Cover Thickness (cm)	Average Maximum Cover Water Content (cm)	Average Minimum Cover Water Content (cm)	Estimated Plant-Available Water (cm)
Carlin Silt Cover				
East Transect Average	104	17.2	8.7	8.5
East Transect Std Dev	13.0	3.5	2.5	1.3
South Transect Average	151	25.7	16.9	8.8
South Transect Std Dev	57.5	8.8	7.4	4.8
Carlin Average	120	20	11.4	8.6
Topsoil Cover				
Topsoil Average	145	26	10.2	15.8
Topsoil Std Dev	14.0	3.4	1.4	2.4

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Pressure Potential Data

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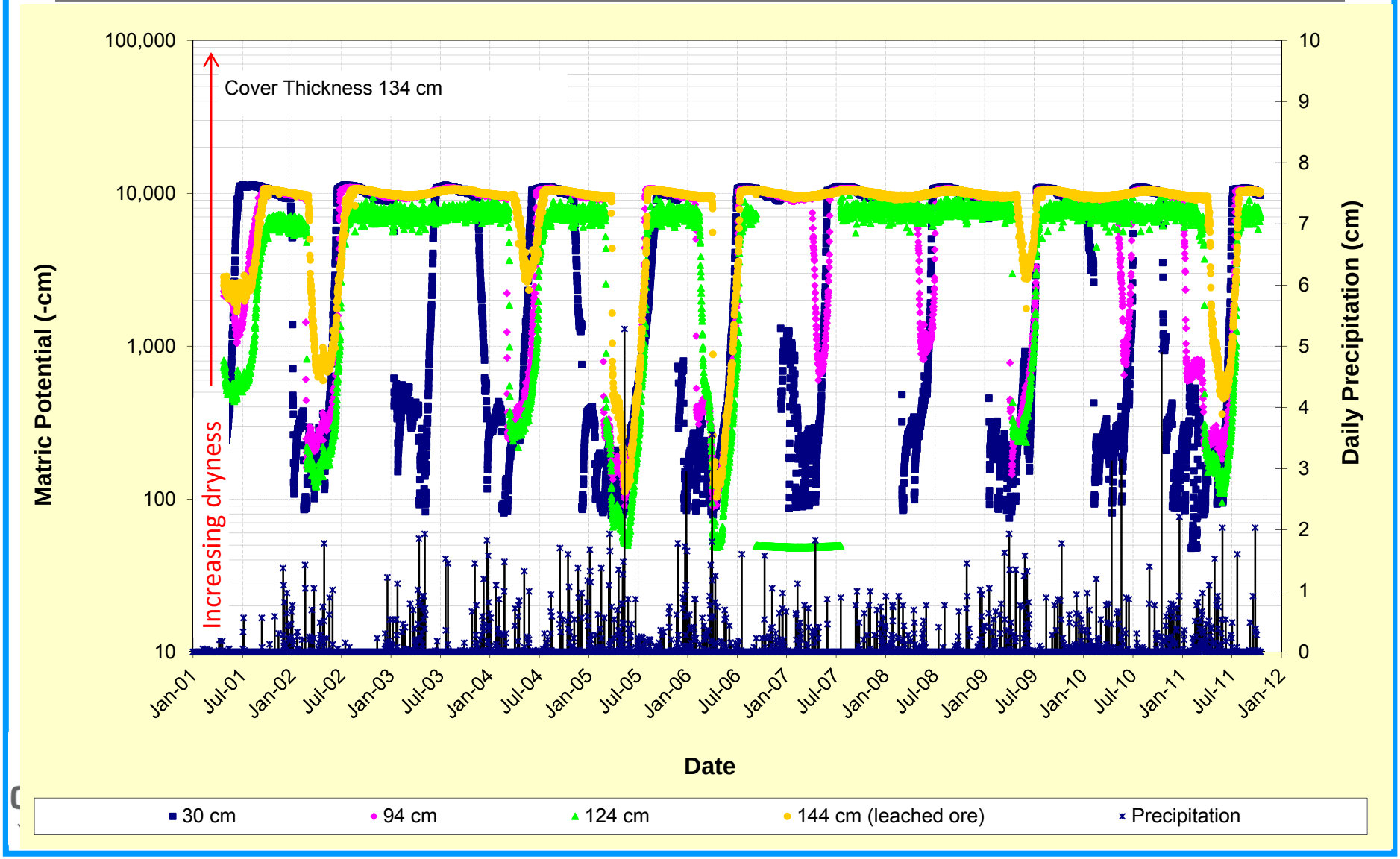
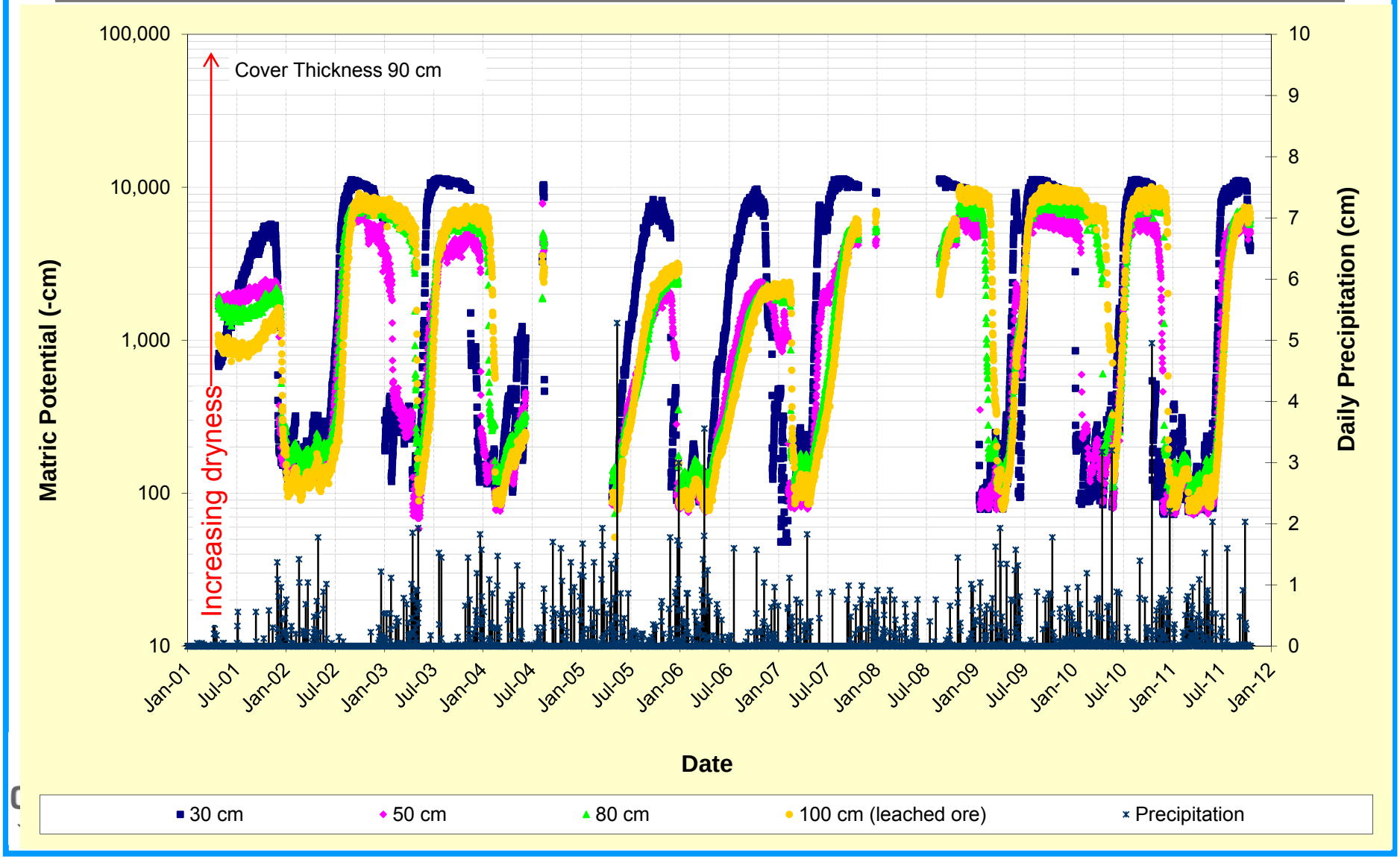
West 2 Matric Potential



East 4 Matric Potential



Estimated Net Percolation Fluxes

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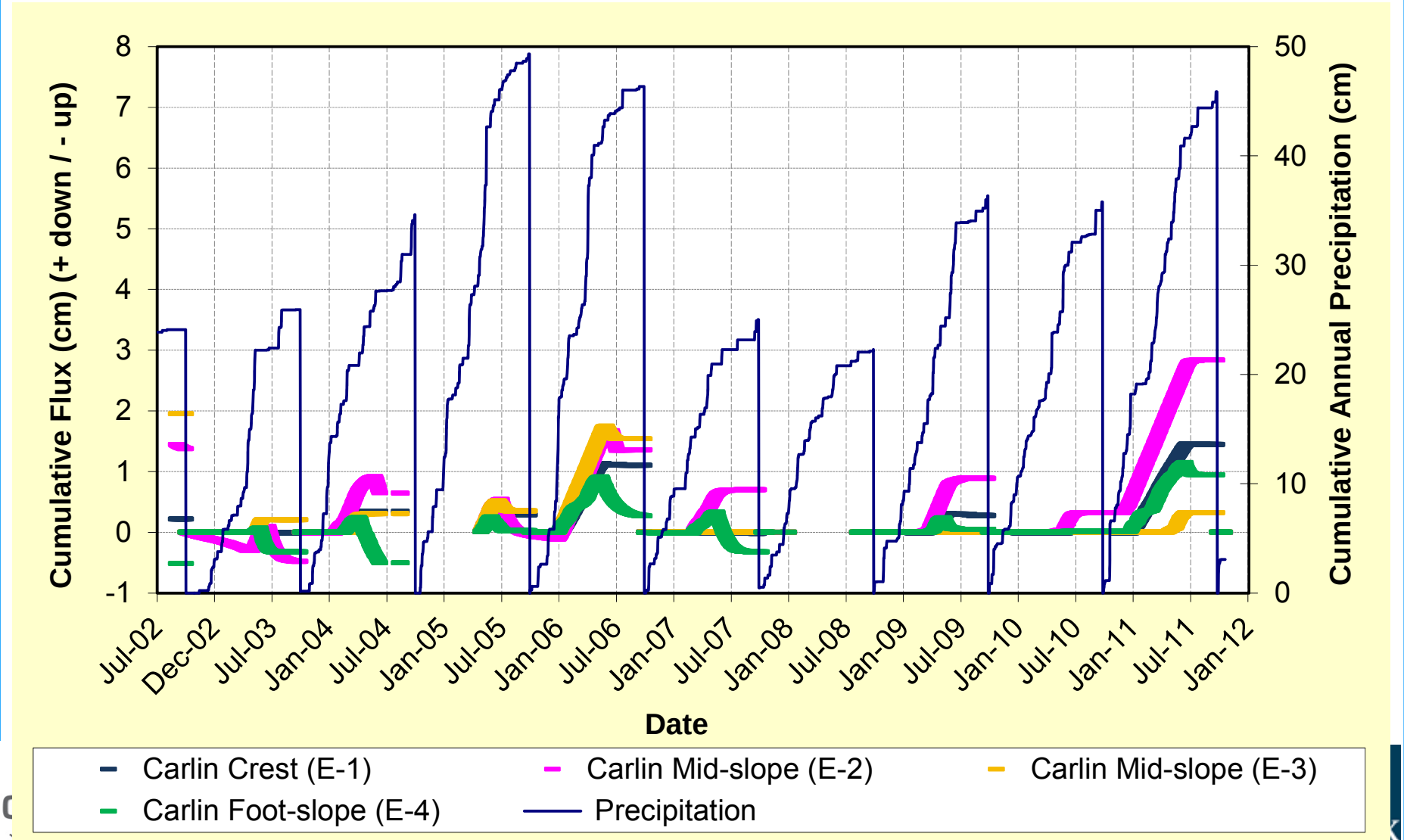
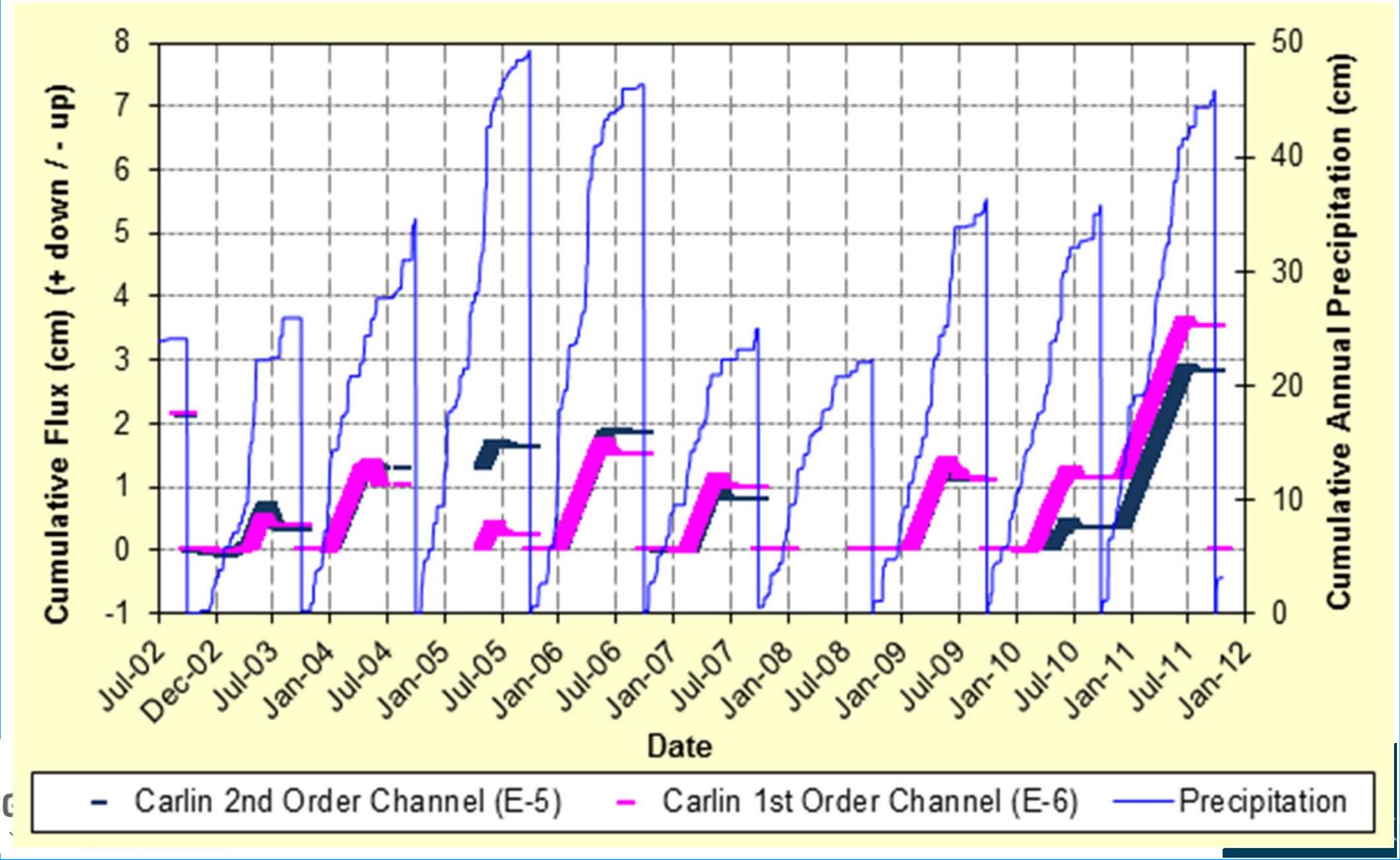
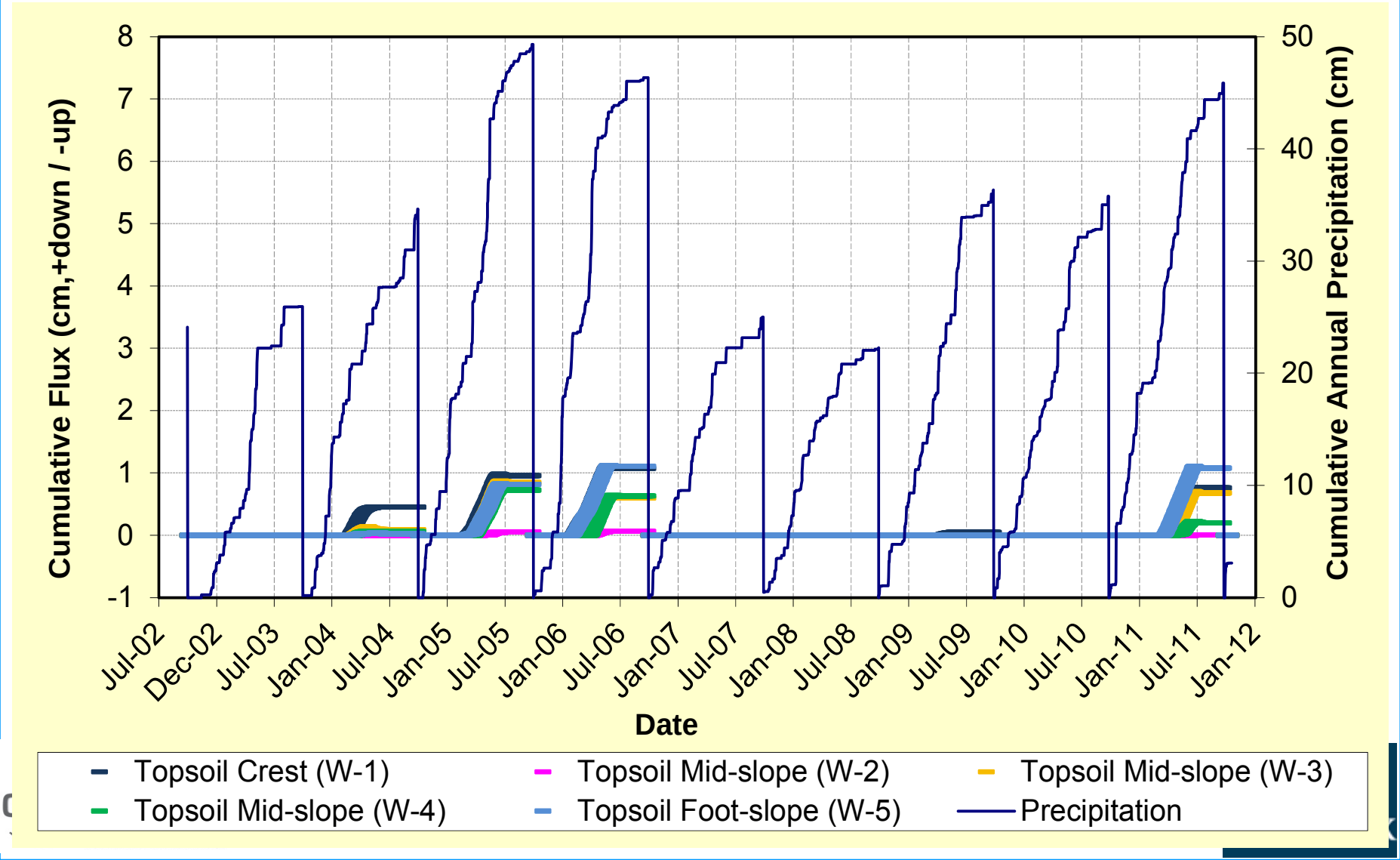
Estimated Cumulative Flux East Transect



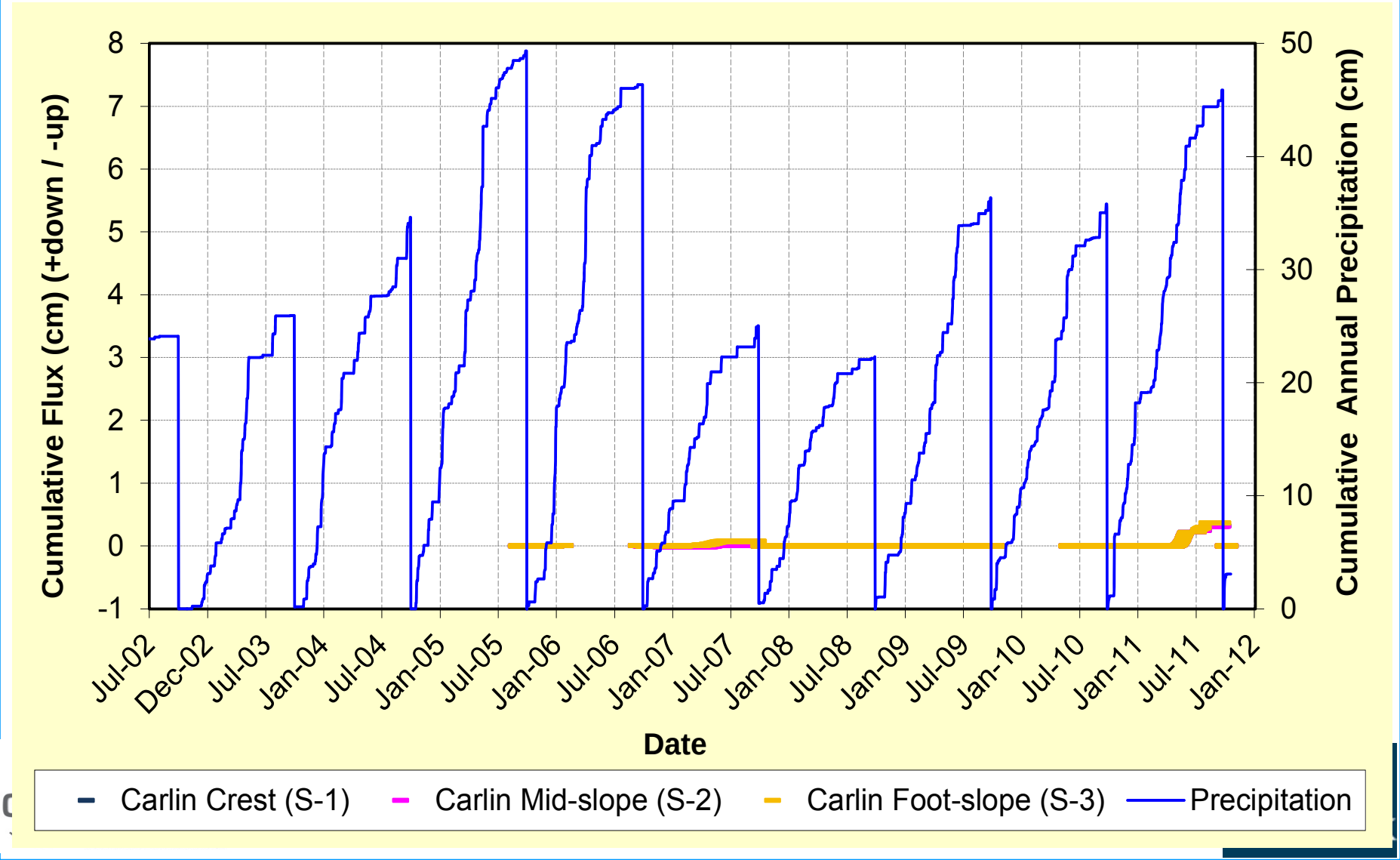
Estimated Cumulative Flux Channels



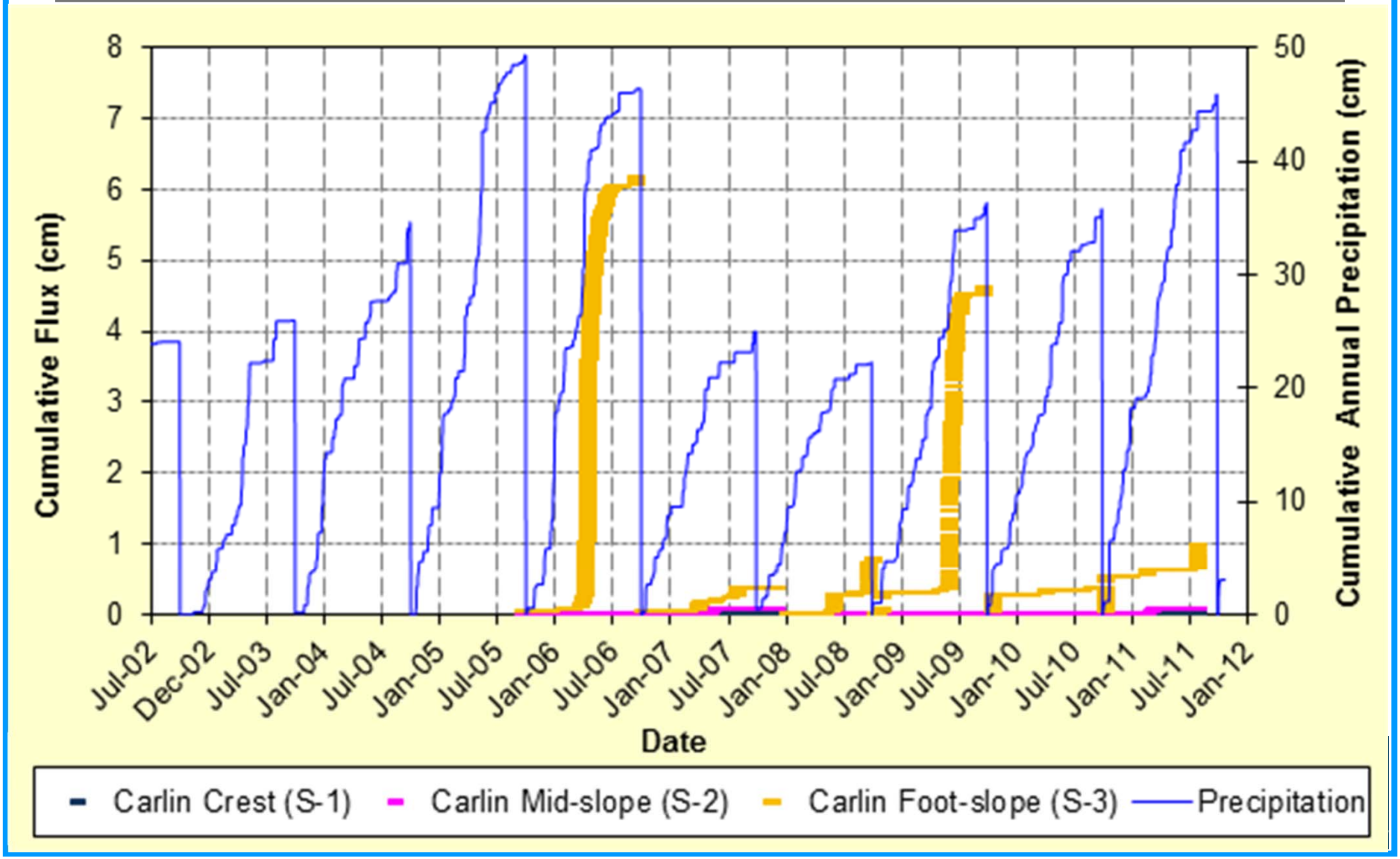
Estimated Cumulative Flux West Transect



Estimated Cumulative Flux South Transect



Estimated Cumulative Flux South WFMs



Summary of Monitoring Data

- Average precipitation during monitoring period (2001-2011) was 13.6 in/yr (34.5 cm/yr)
  - 2004-2005 wettest year in 35 years (Elko, NV)
- Estimated net percolation (from pressure potential monitoring data) as percent of annual precipitation:
  - 0.7% for topsoil and 1.5% for Carlin
  - 3.7% for Carlin channels
  - Area weighted average ≈ 0.85%
- Significantly higher estimated net percolation in channels, some evidence of downslope water accumulation
- Average and dry years - little to no deep percolation
- Observed ET and rooting from greater than 5 feet

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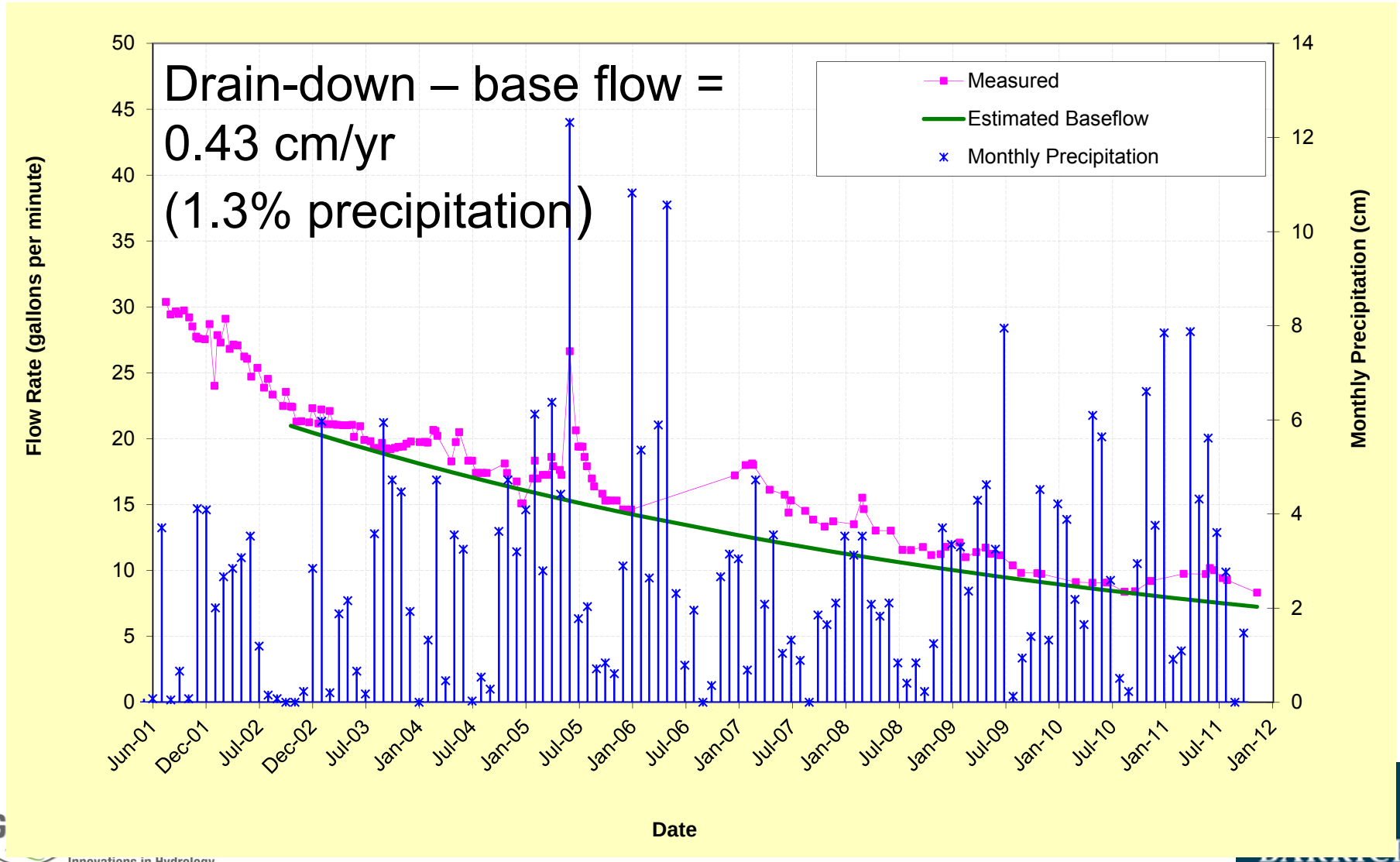
AA Pad drain-down



Conclusions

- ET cover has sufficient water storage, variable
- Majority of net percolation is episodic, channels are foci
- Estimated net percolation is well below regional estimates of recharge
  - Topsoil shows best performance, Carlin adequate
  - Variable soil and vegetation characteristics, rooting is not limited to cover material
- Generally good agreement between monitoring data and draindown data
- Multiple years of monitoring necessary

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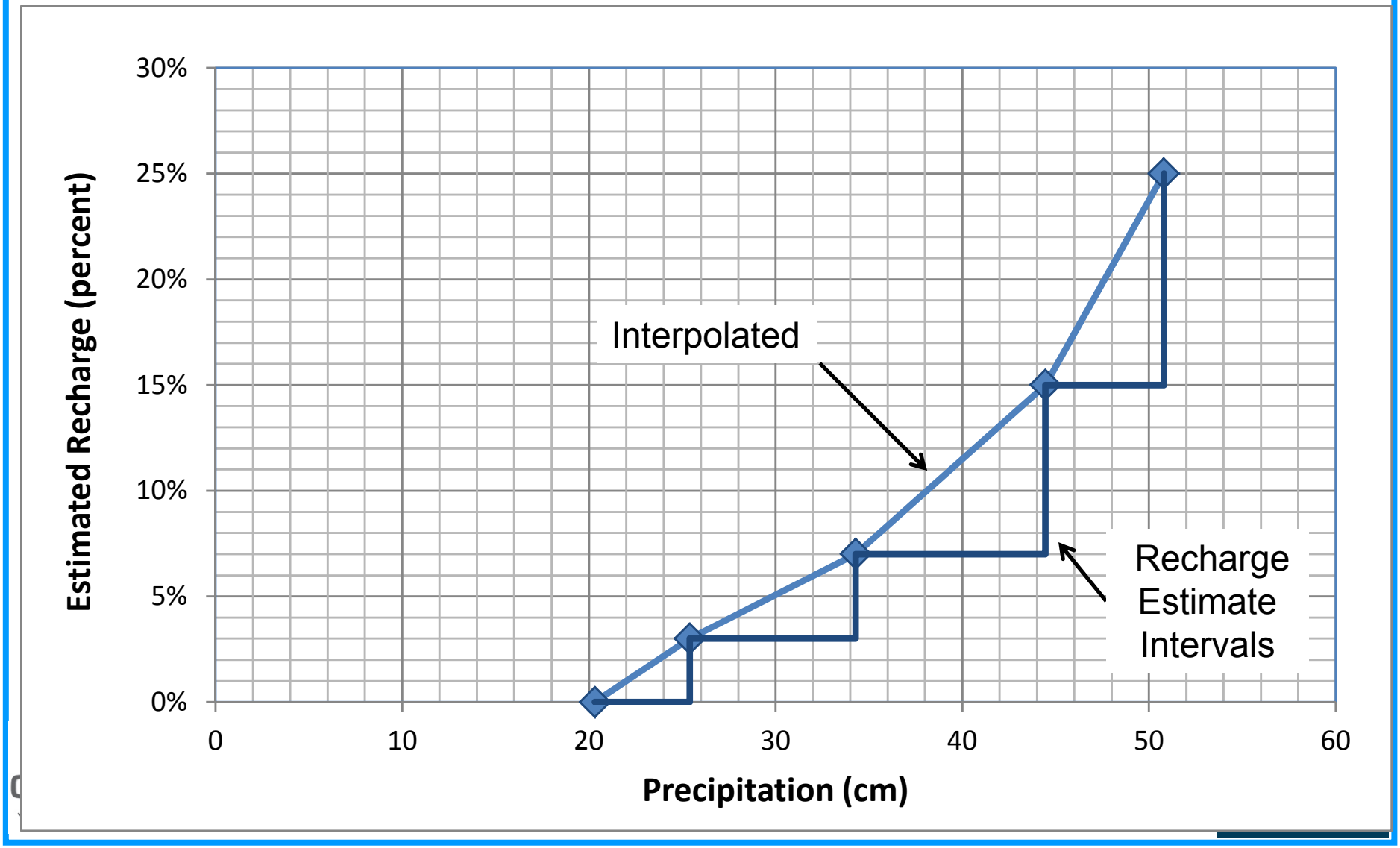
THANK YOU

More information at:
http://www.gsanalysis.com/minepub.html

Maxey-Eakin Estimated Recharge (White River Valley, NV, 1949)



Atriplex Canescens (4-wing saltbush)

Purshia Tridenta (Bitterbush)

Estimated Net Percolation (Pressure Potential data)

Station	Water Years 2003-2011	
	Average Annual Flux (cm)	Average Flux as % of Precip (%)
Carlin Silt Cover		
Carlin East Transect Average	0.76	2.1
Channel Carlin East Transect Average	1.3	3.7
Non-Channel Carlin East Transect Average	0.47	1.3
Carlin South Transect Average	0.08	0.26
Carlin Silt Stations Average	0.59	1.49
Topsoil Cover		
Topsoil Stations Average	0.24	0.67
All Stations Average		
All Stations Average	0.42	1.2
Area Weighted Station Average	0.30	0.85

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