

Stream/Aquifer Interactions in a Semi-Arid Artificial River: The Effects of Effluent

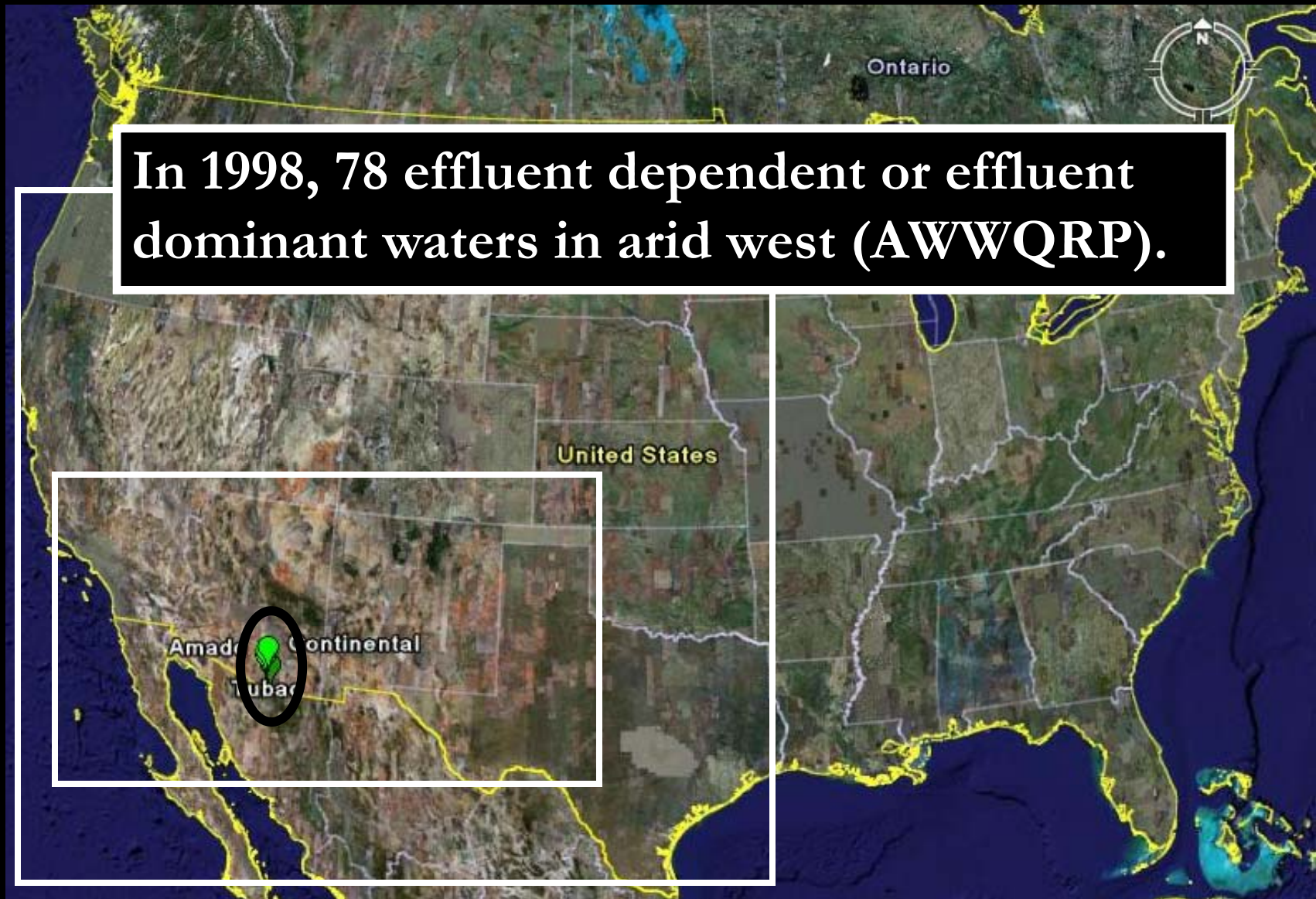


Thomas Meixner

March 27, 2009

Effluent: an Important Water Source

In 1998, 78 effluent dependent or effluent dominant waters in arid west (AWWQRP).



Spring 2005 Tree Deaths: Diverse Species, Random Locations



Santa Cruz River: Spring 2005

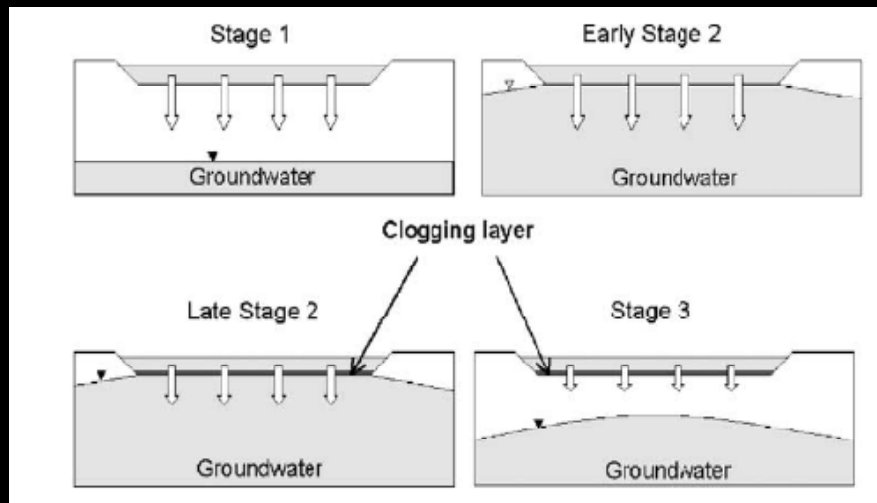
Speculations:

- Herbicides
- Drought
- Root Rot
- Insects



Santa Cruz River: Autumn 2007

Clogging and Artificial Recharge



Greskowiak 2005

Clogging Cycle:

Stage 1: Max infiltration

Stage 2: Clogging layer develops

Stage 3: Clogging layer slows infiltration- disconnection between basin and aquifer.

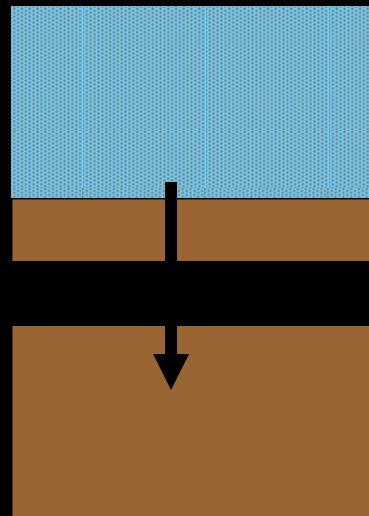
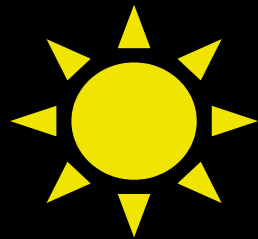
Types of Clogging:

Biological-algae, bacteria or biomass reduce the size of pores

Physical – present in rivers (Blaschke et al 2003)

Chemical-chemical reactions occur products impede infiltration process

How does a clogging layer form?

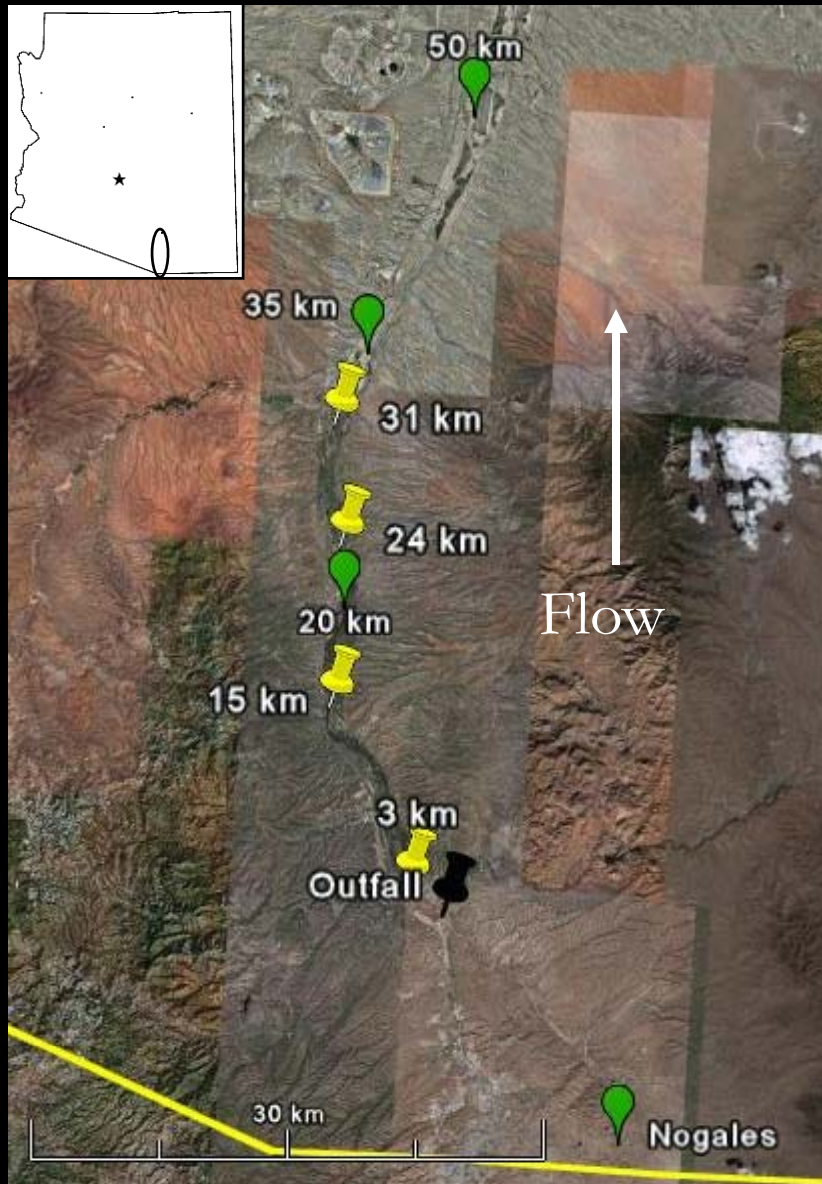


Research Questions

- What physical evidence is there to suggest the existence of clogging in an effluent dependent streambed?
- What impact does clogging have on the streambed?
- What impact does the clogging layer have on the aquifer and riparian area?
- What impact does a semi-arid hydrologic cycle have on clogging?

Site Description

7



4 Main Field Sites

3 km

15 km

24 km

31 km

NIWTP flow records

4 USGS stream gages

Nogales

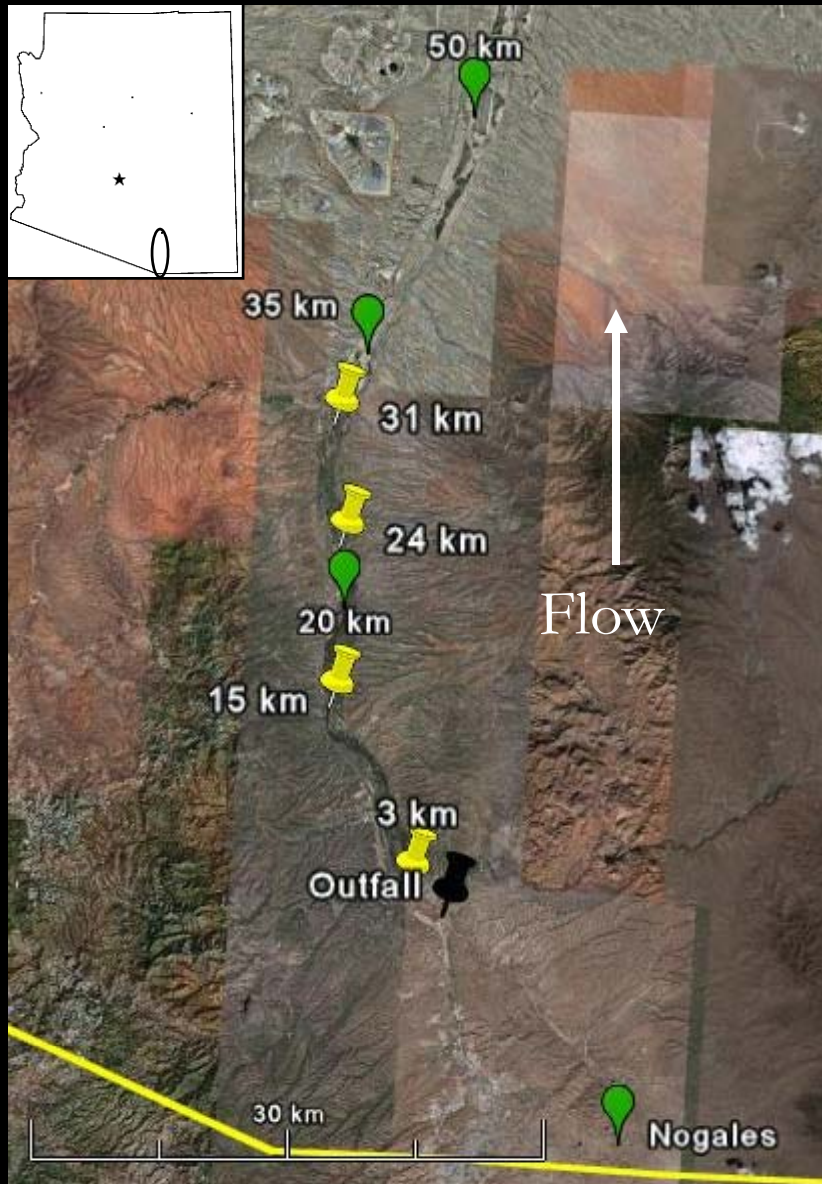
20 km (Tubac)

35 km (Amado)

50 km (Continental)

Site Description

8



16 Data Collection Points

Sampling includes:

Piezometers

Soil Cores

Stream Gauging

Water Samples

Evidence of clogging

Soil Cores

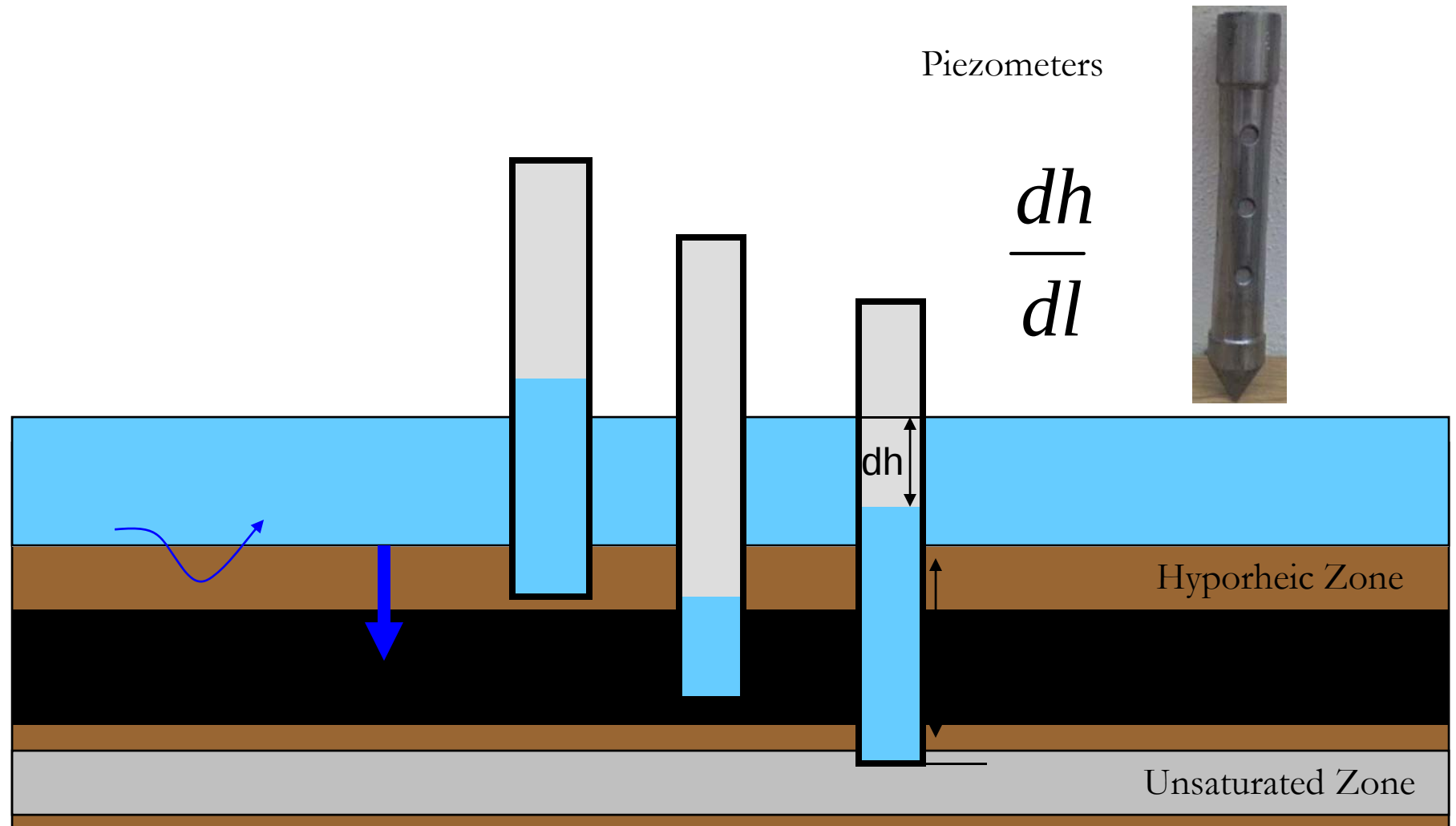
# of Cores	Type	Mean Ksat (cm/sec)	Median Ksat (cm/sec)	Standard deviation
64	Santa Cruz all	0.300	0.263	0.217
32	Santa Cruz PreMonsoon	0.311	0.263	0.261
32	Santa Cruz PostMonsoon	0.290	0.263	0.159
14	Santa Cruz Clogged	0.159	0.136	0.099



The streambed

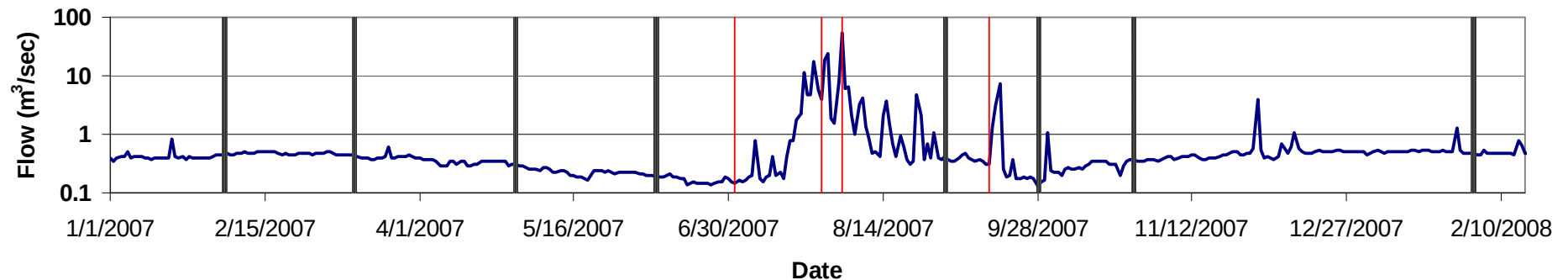
Field Measurements

Gradient and Losing Reaches

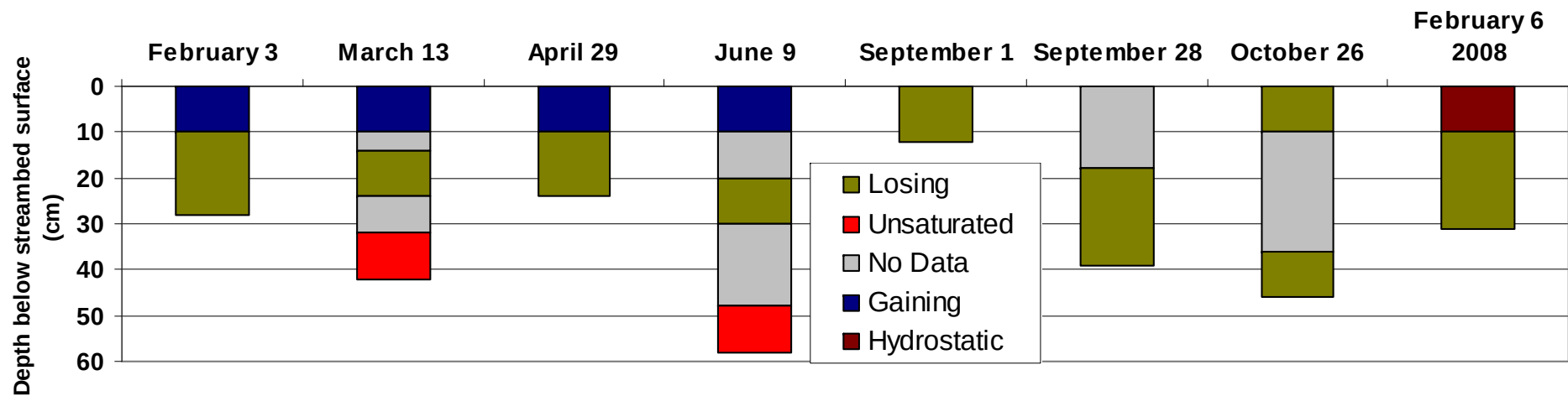


Streambed Processes

Streamflow at 20 km from NIWTP outfall (Tubac) 2007-2008

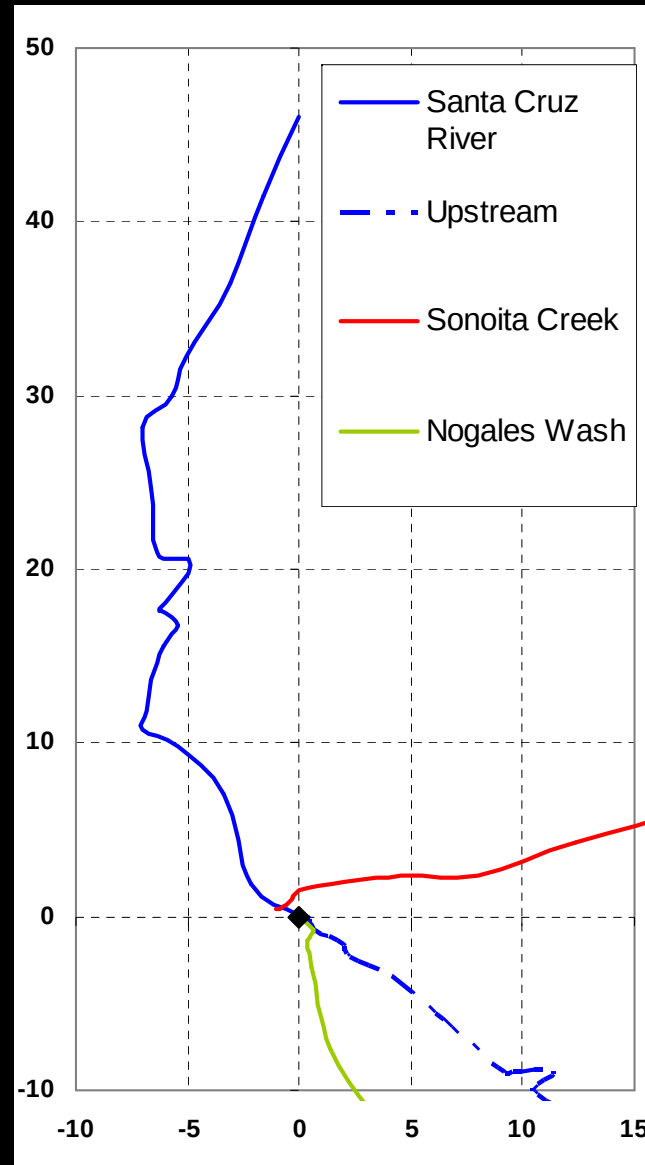


Streambed profile 3.15 Km from Outfall

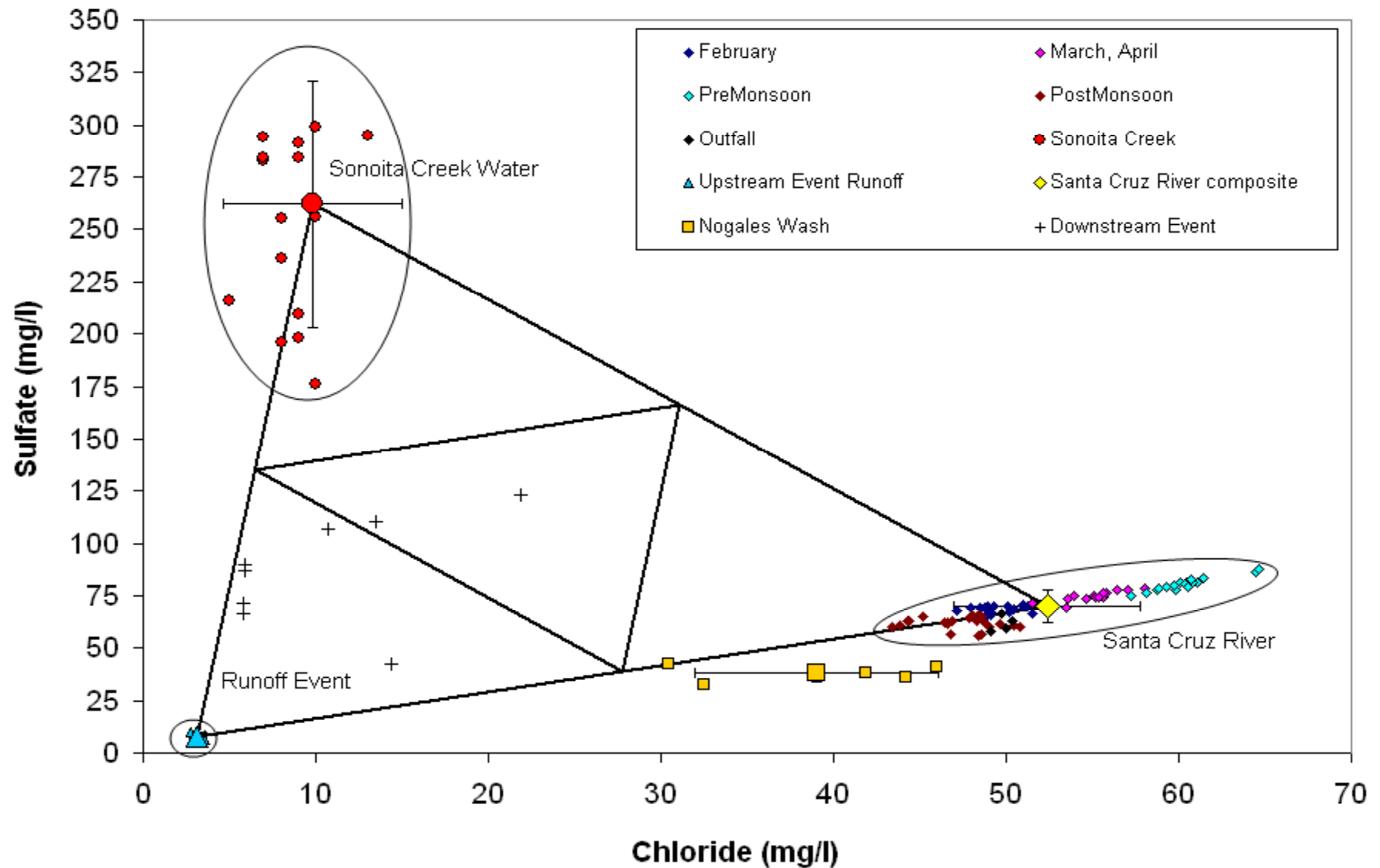


The aquifer

Surface Waters

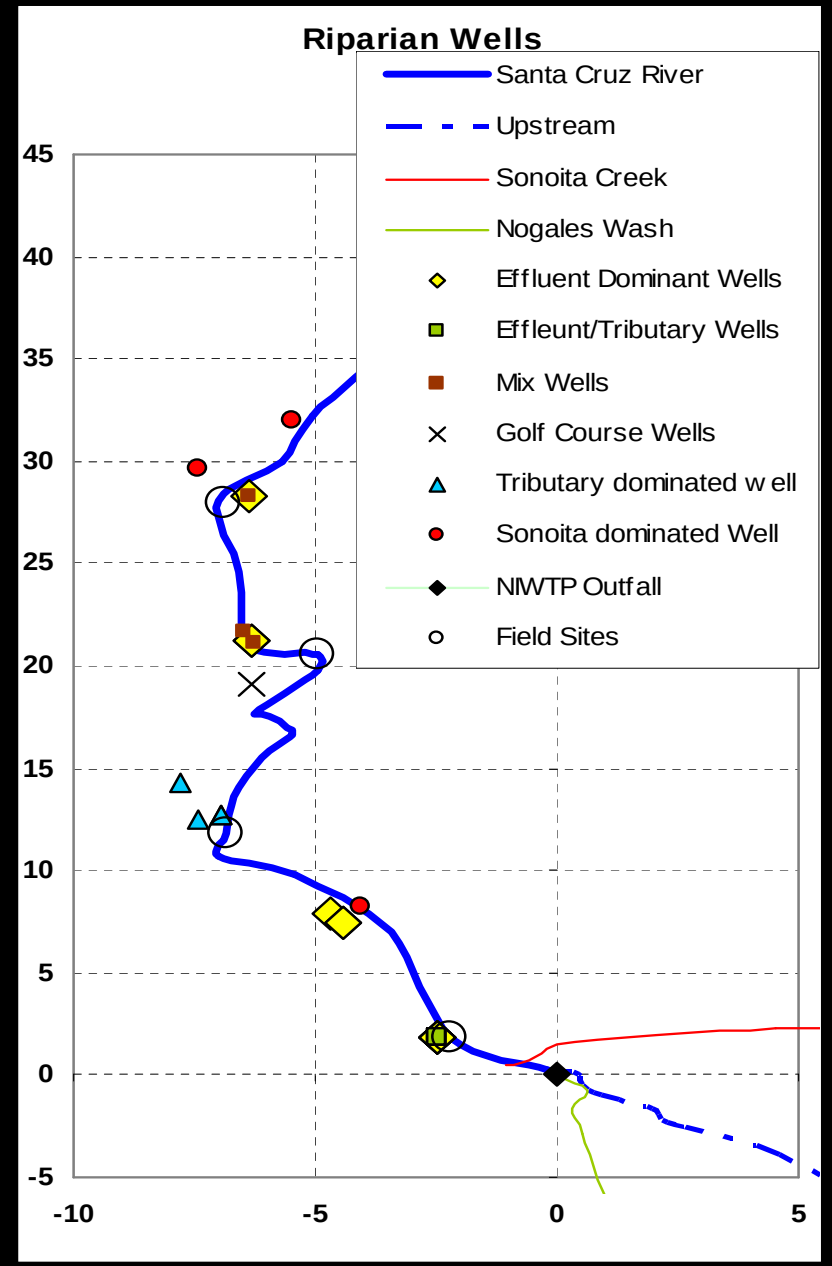
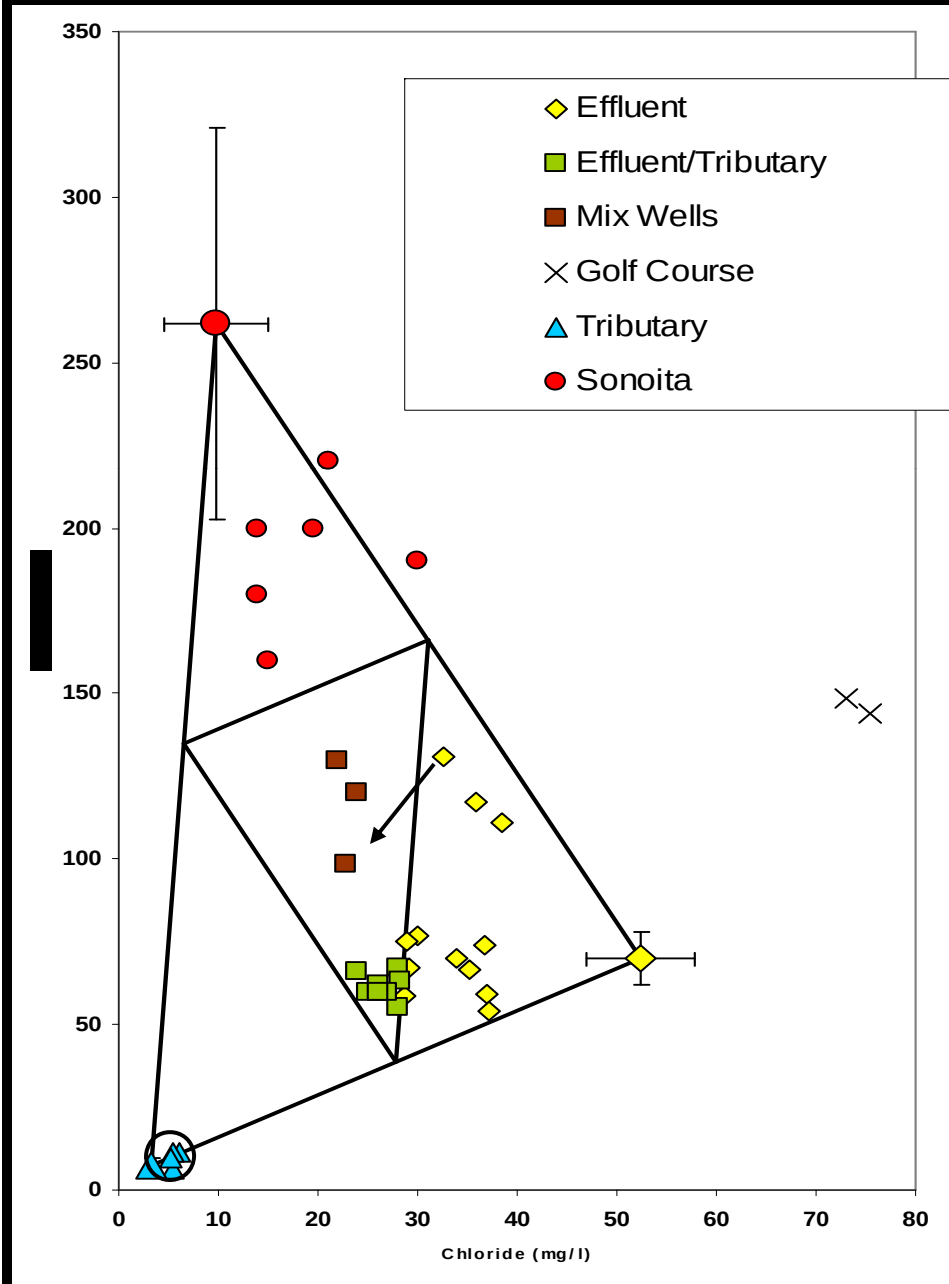


Surface Waters



Riparian Wells: Mixing Model Results

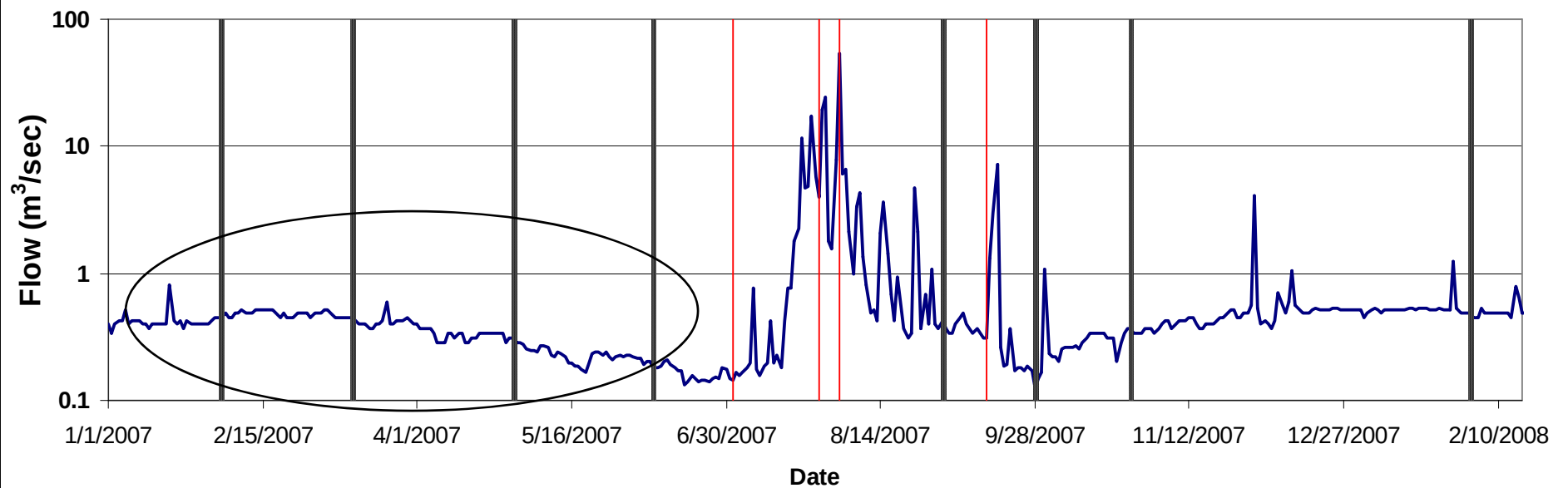
17



Semi-Arid Hydrologic Cycle

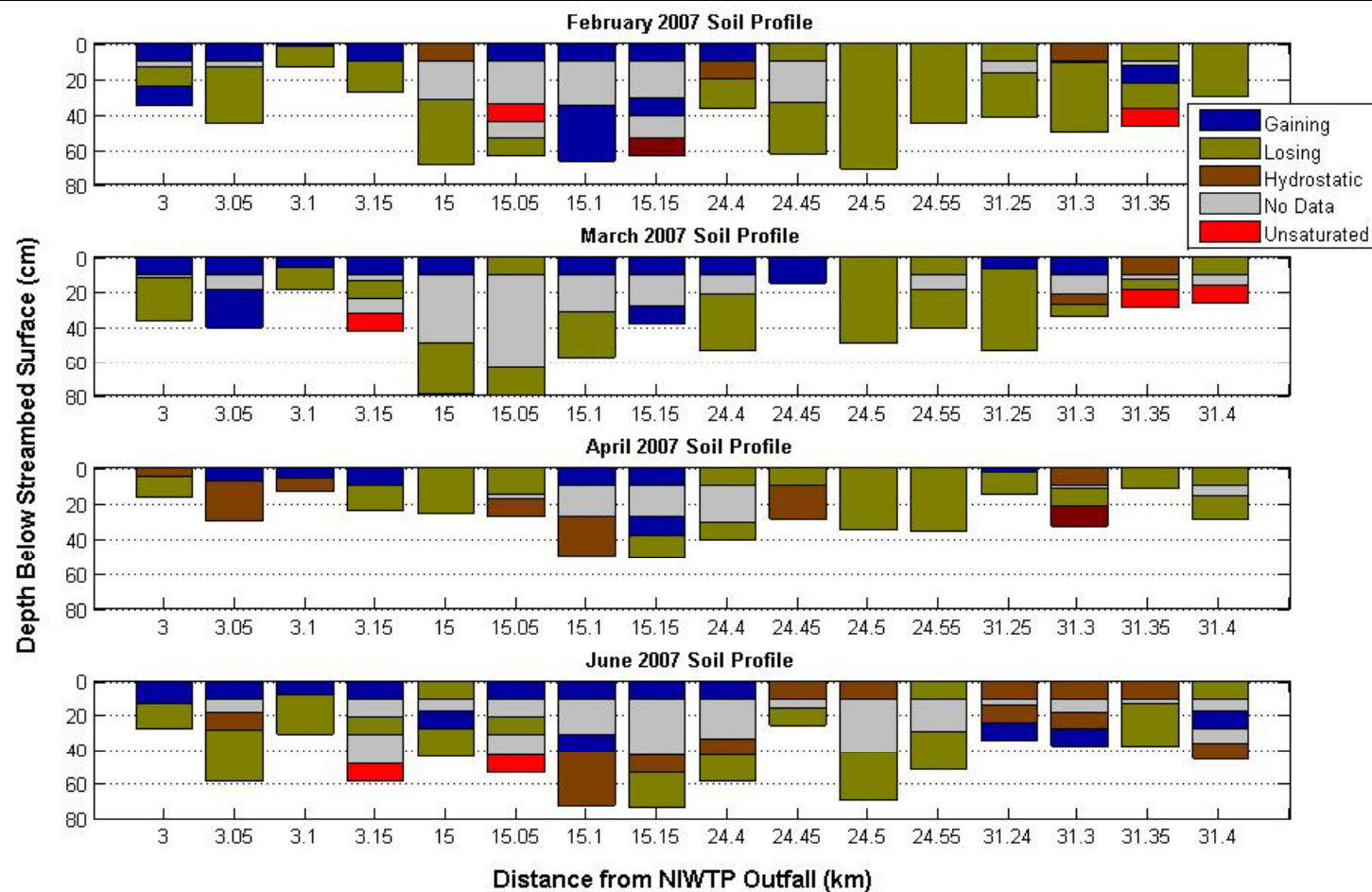
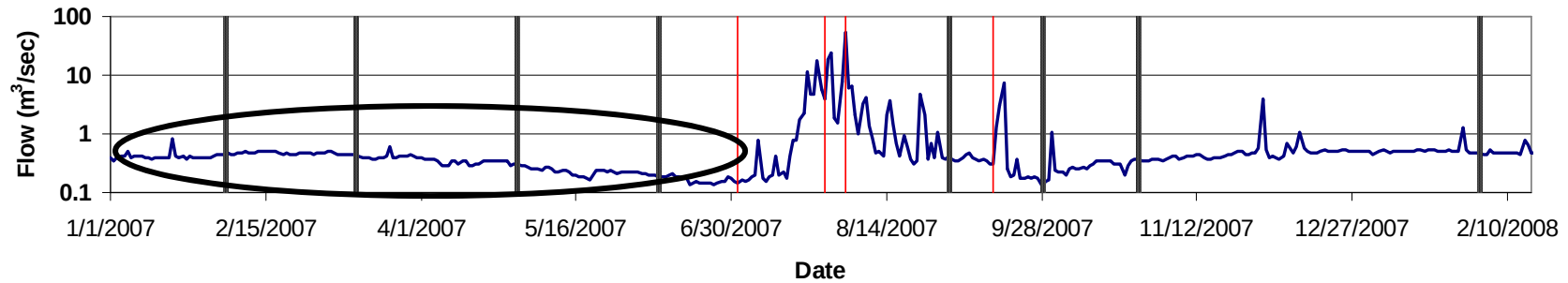
Dry

Streamflow at 20 km from NIWTP outfall (Tubac) 2007-2008

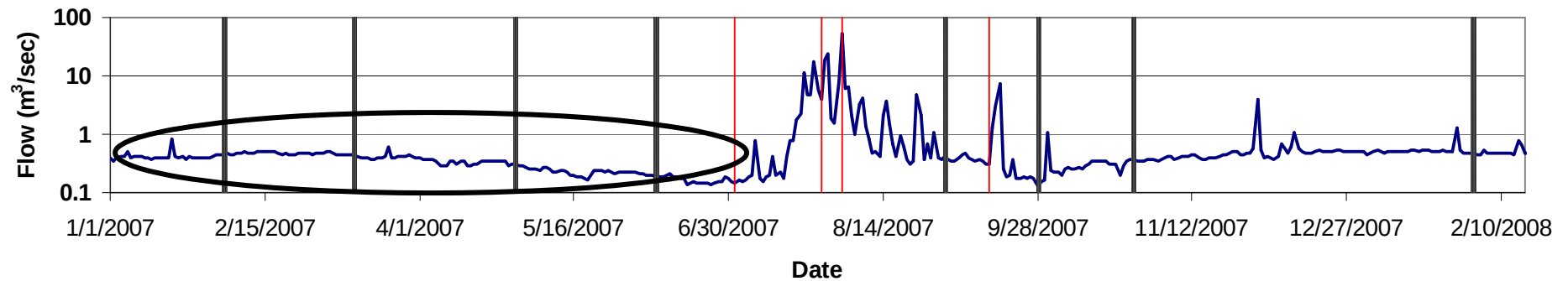


Streamflow at 20 km from NIWTP outfall (Tubac) 2007-2008

20



Streamflow at 20 km from NIWTP outfall (Tubac) 2007-2008

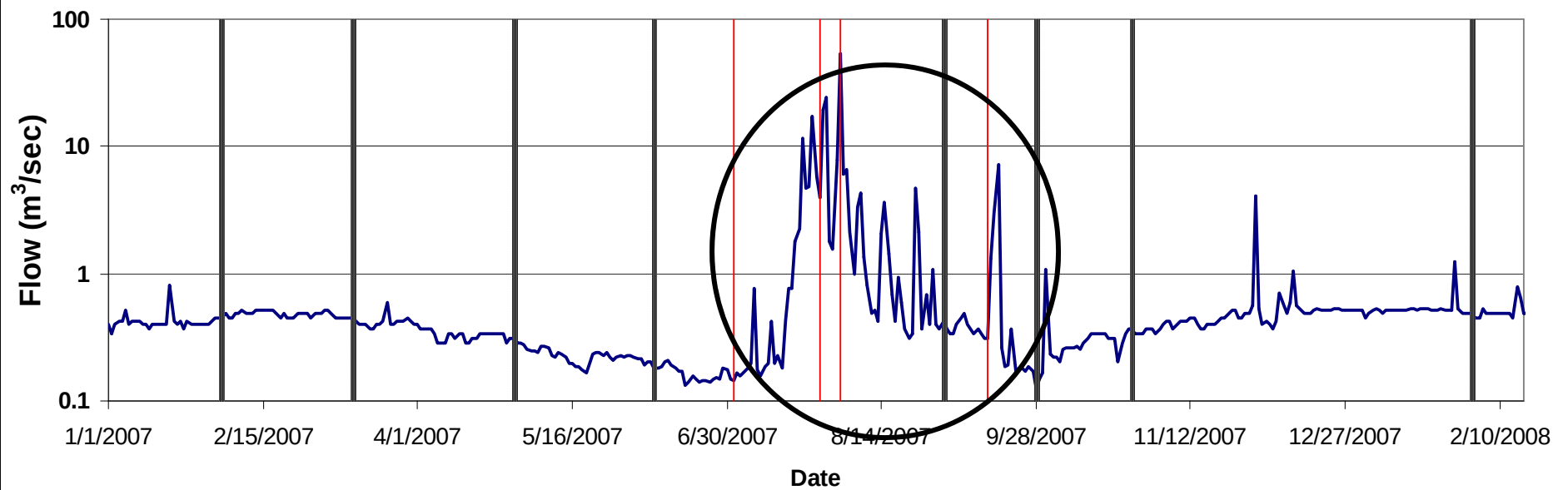


Clogged Cores Per Reach

	3 km	15 km	24 km	31 km
Pre Monsoon	4	3	6	1
Post Monsoon	0	0	0	0

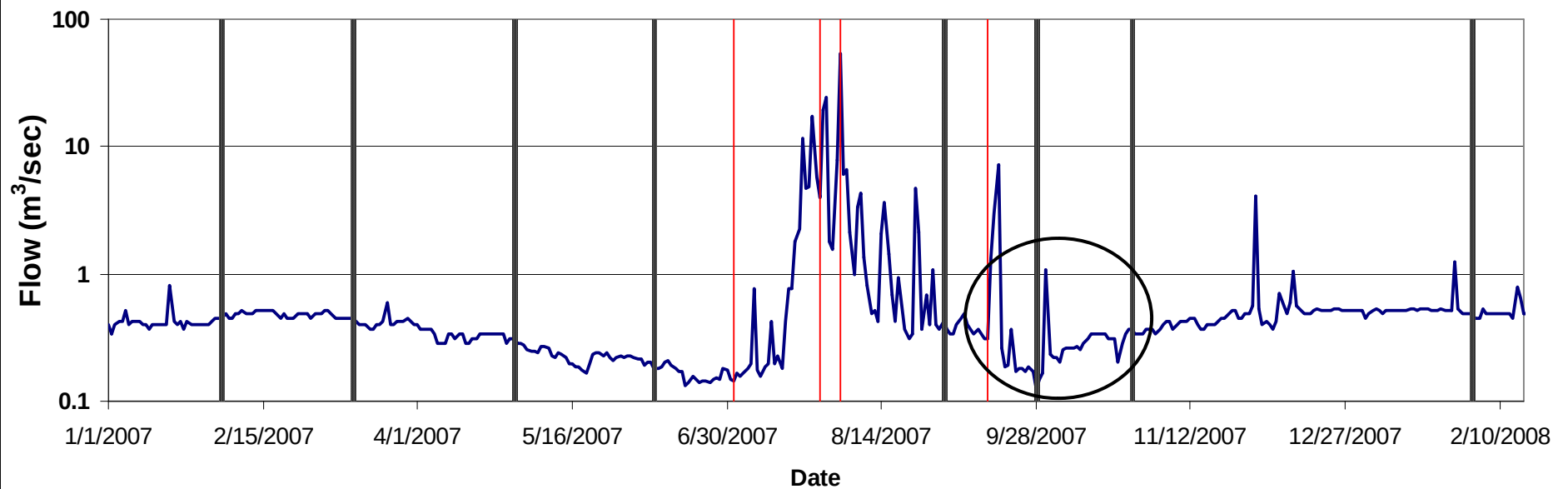
Monsoon

Streamflow at 20 km from NIWTP outfall (Tubac) 2007-2008

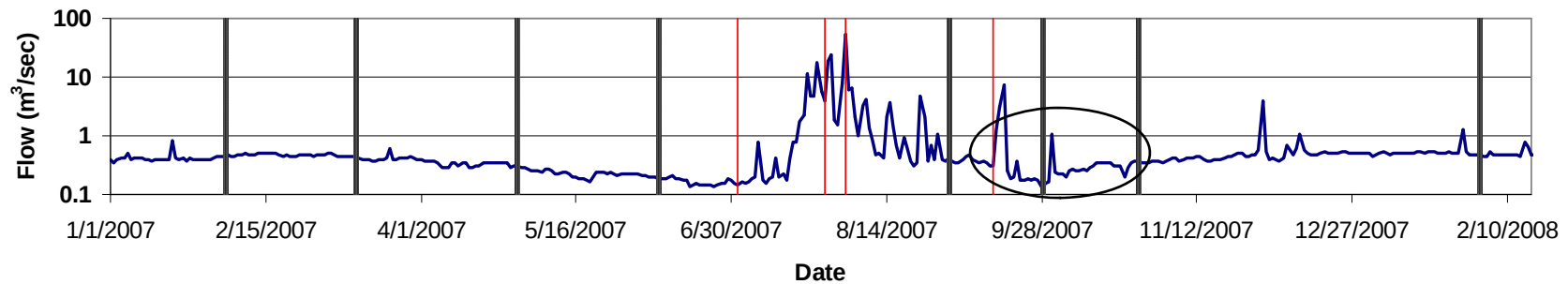


Post Monsoon

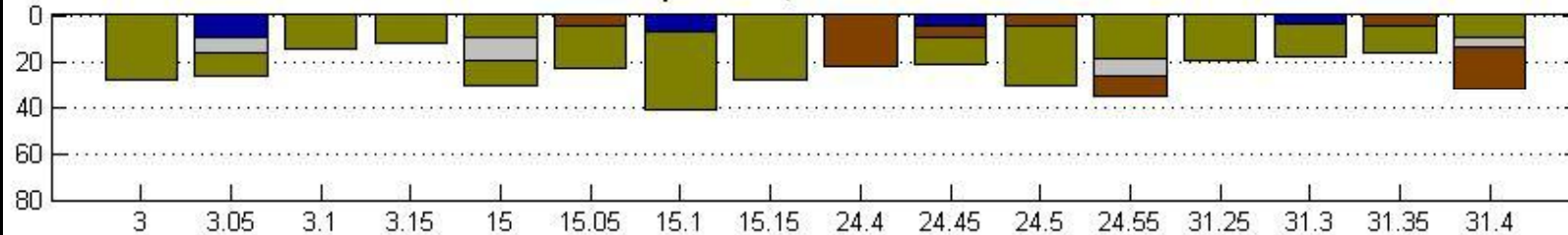
Streamflow at 20 km from NIWTP outfall (Tubac) 2007-2008



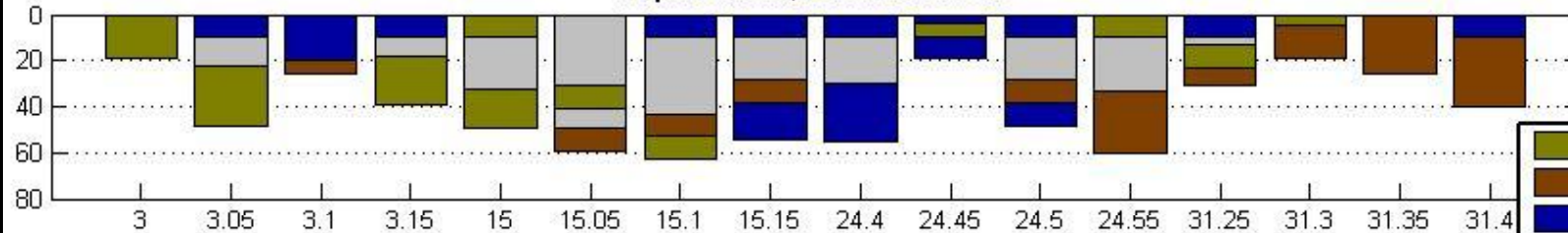
Streamflow at 20 km from NIWTP outfall (Tubac) 2007-2008



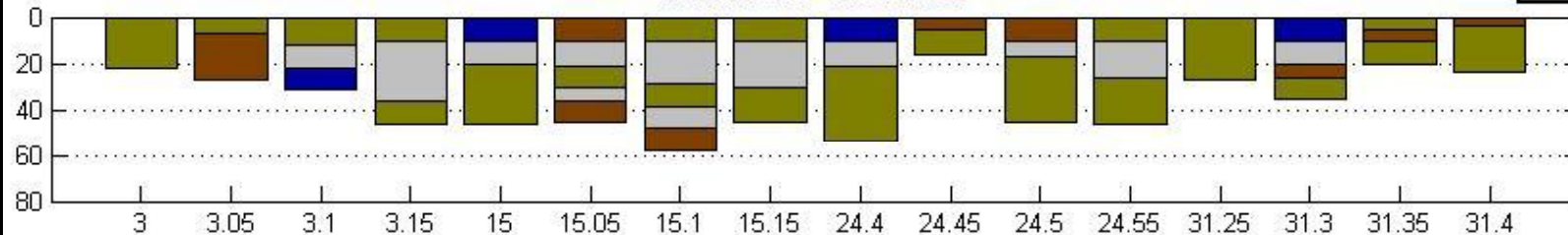
September 1, 2007 Soil Profile



September 29, 2007 Soil Profile

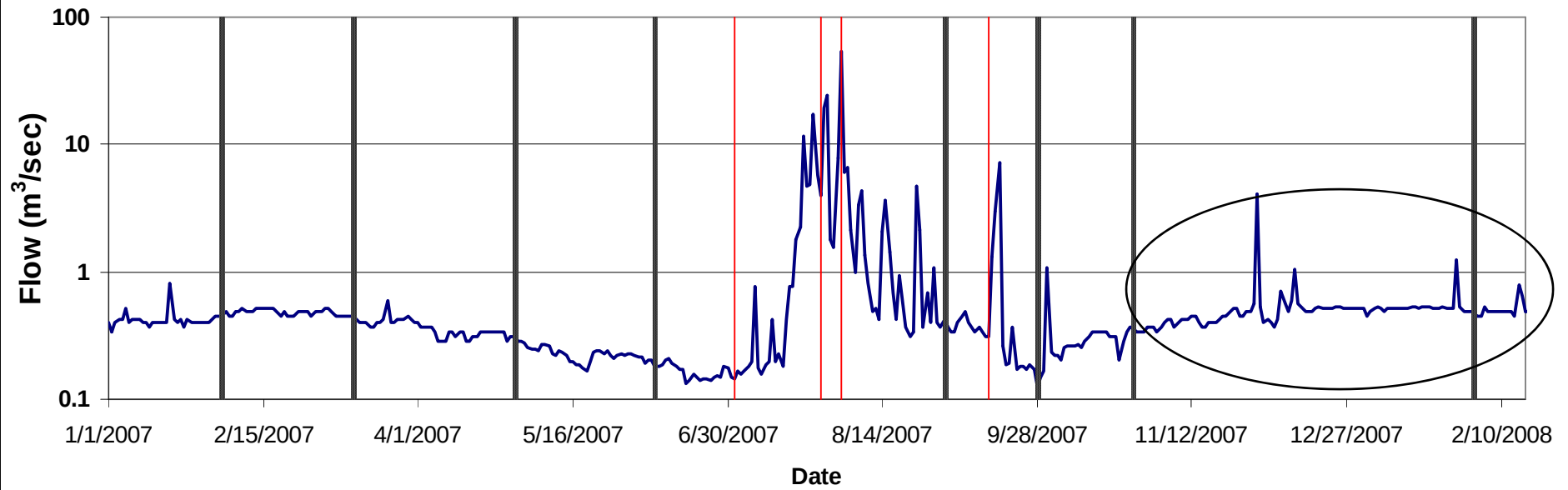


October 2007 Soil Profile

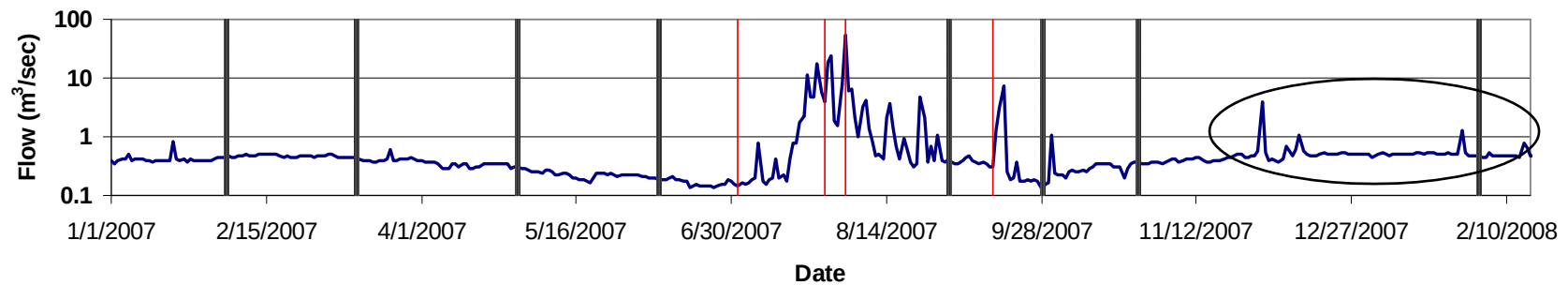


Winter Rains

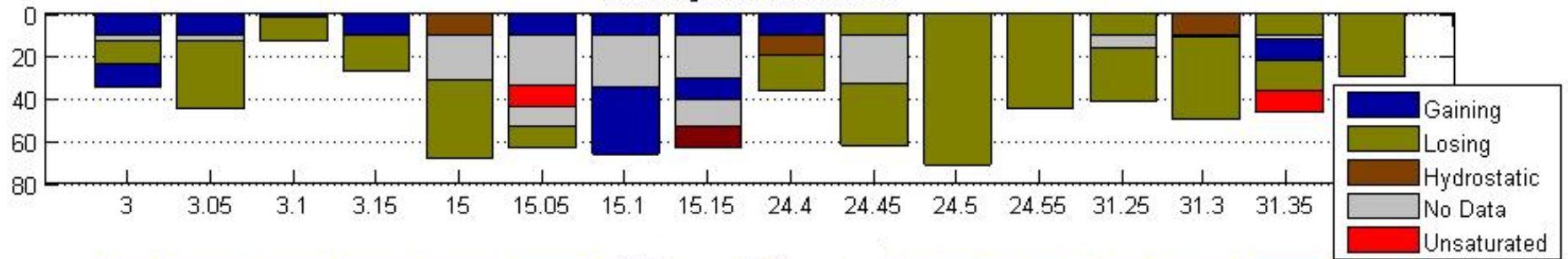
Streamflow at 20 km from NIWTP outfall (Tubac) 2007-2008



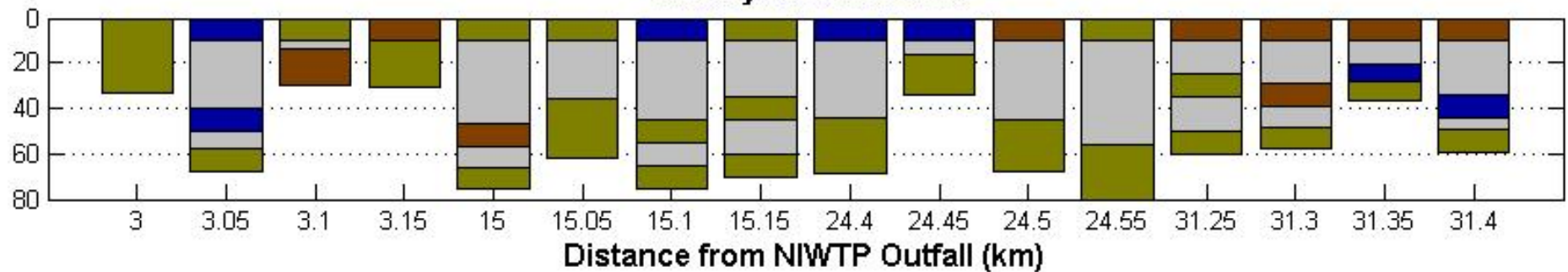
Streamflow at 20 km from NIWTP outfall (Tubac) 2007-2008



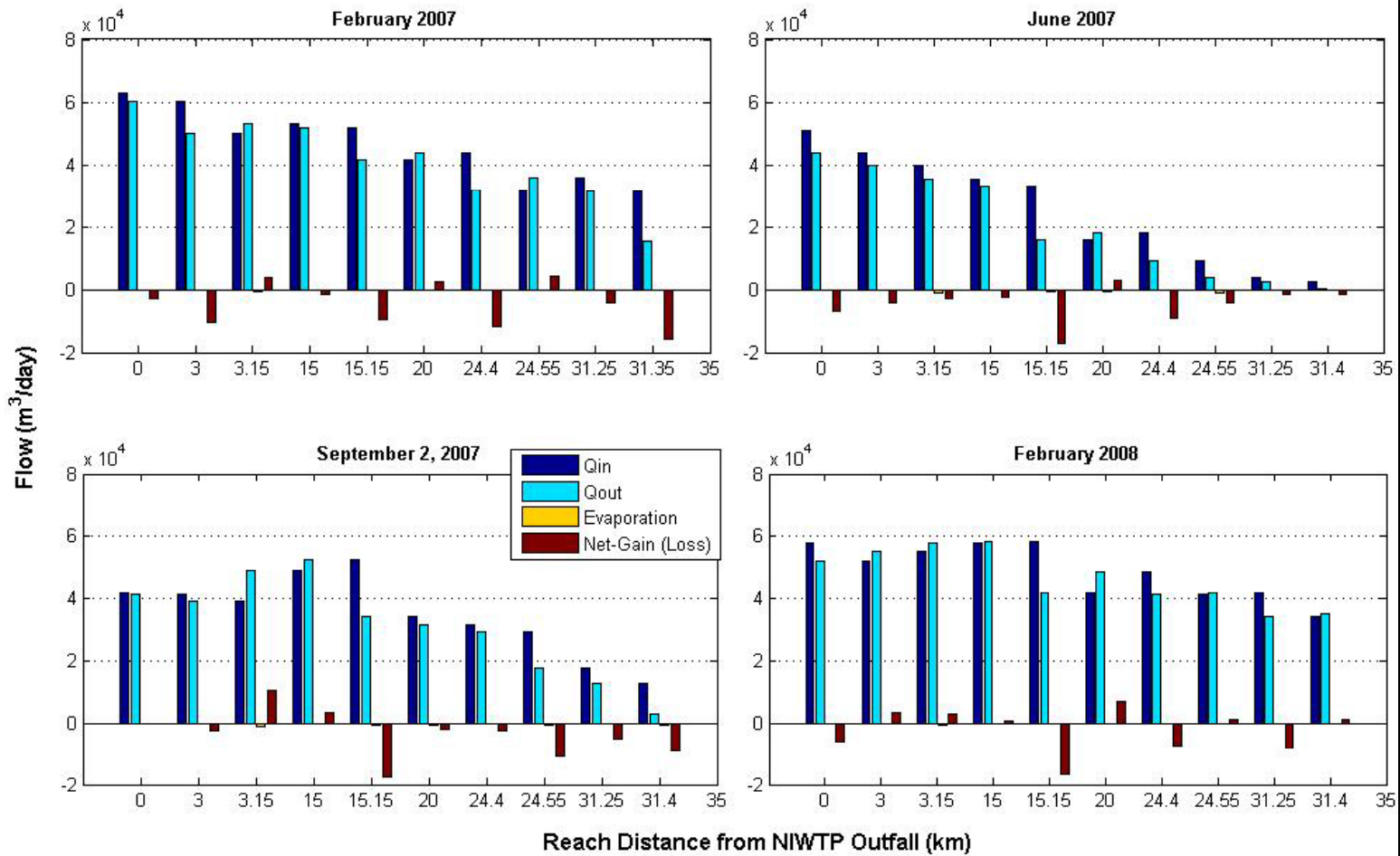
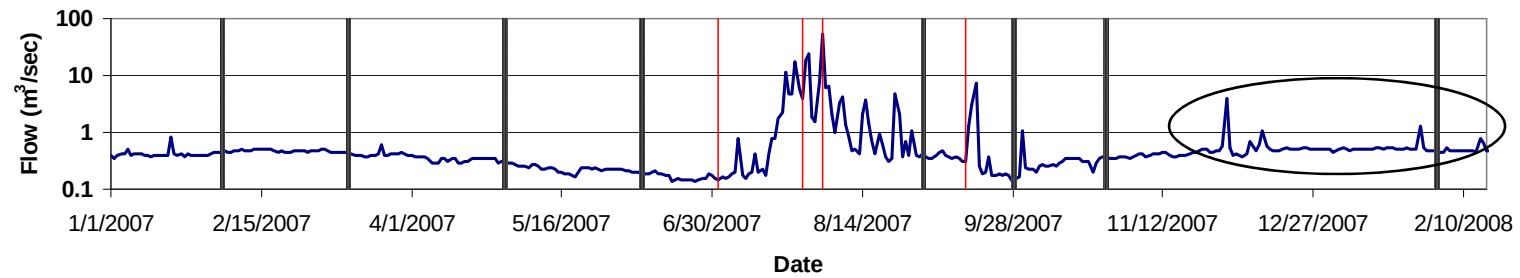
February 2007 Soil Profile



February 2008 Soil Profile



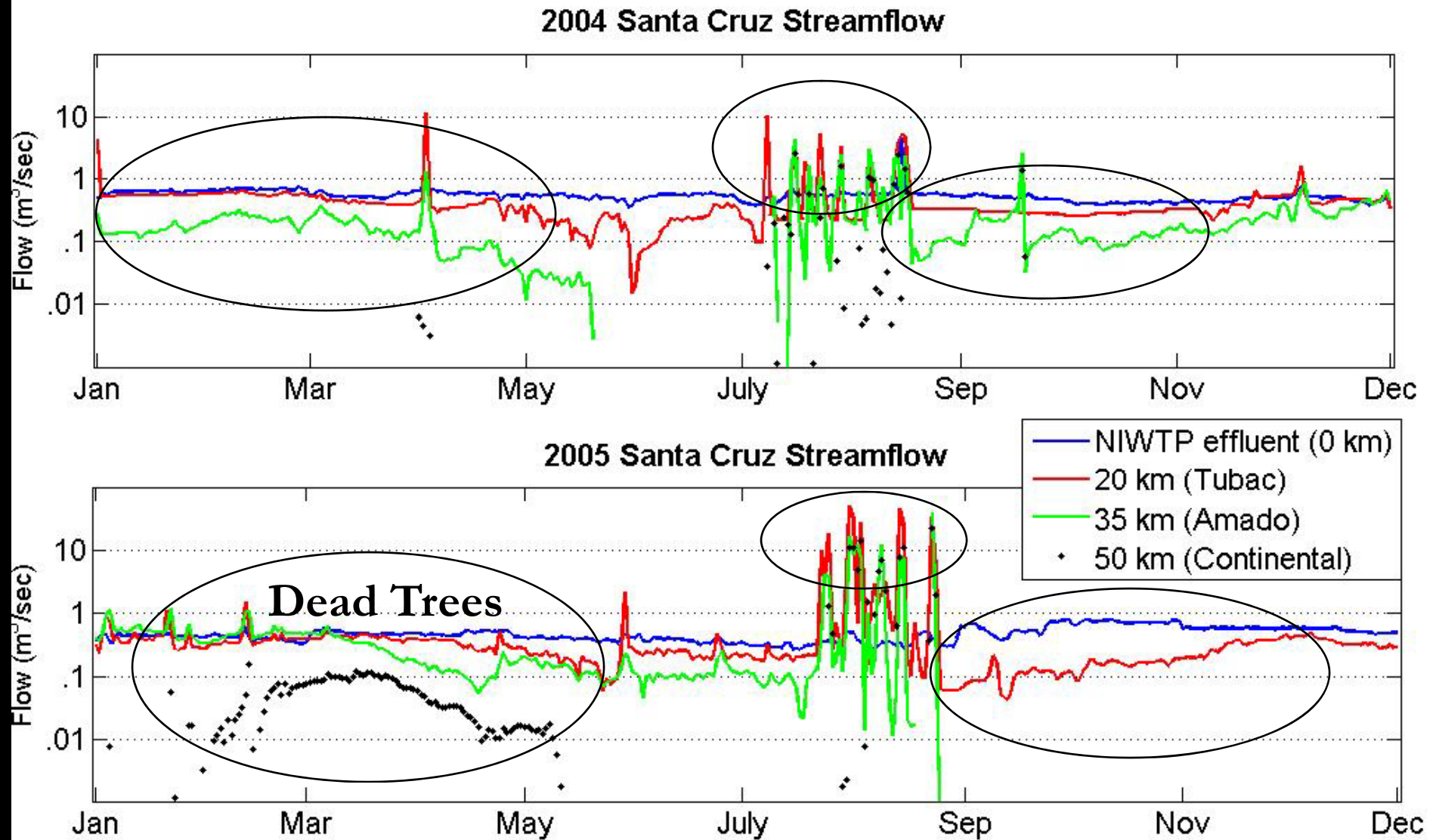
Streamflow at 20 km from NIWTP outfall (Tubac) 2007-2008





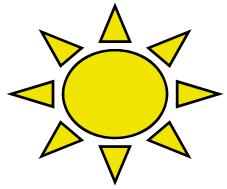
The Trees

29

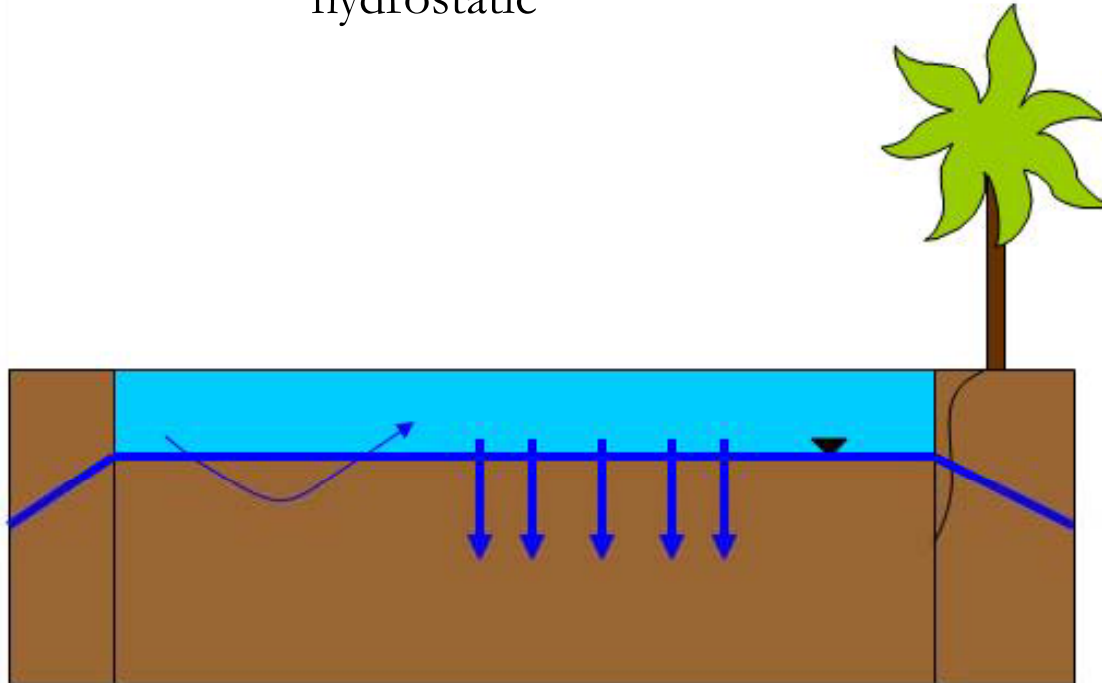


A Conceptual Model

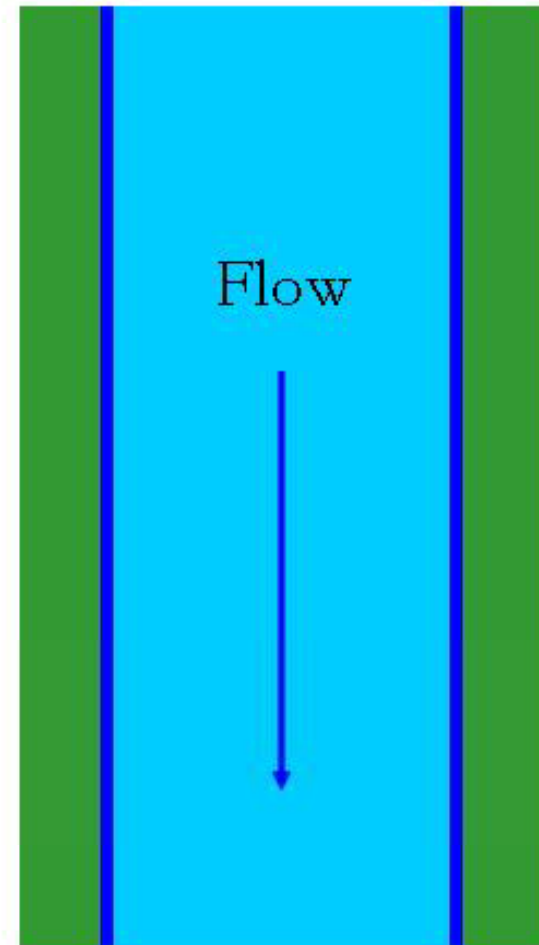
Stage 1



- Immediately Post Large Flow
- Stream can be gaining, losing or hydrostatic

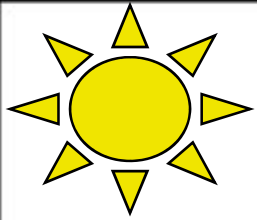


Vertical Profile

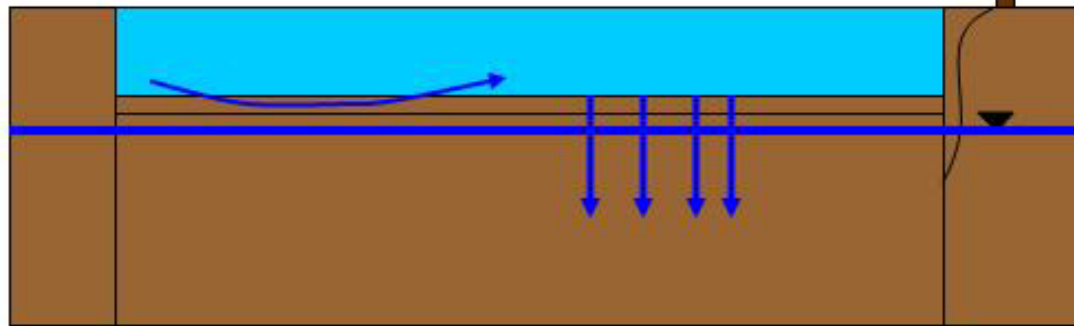


Plan View

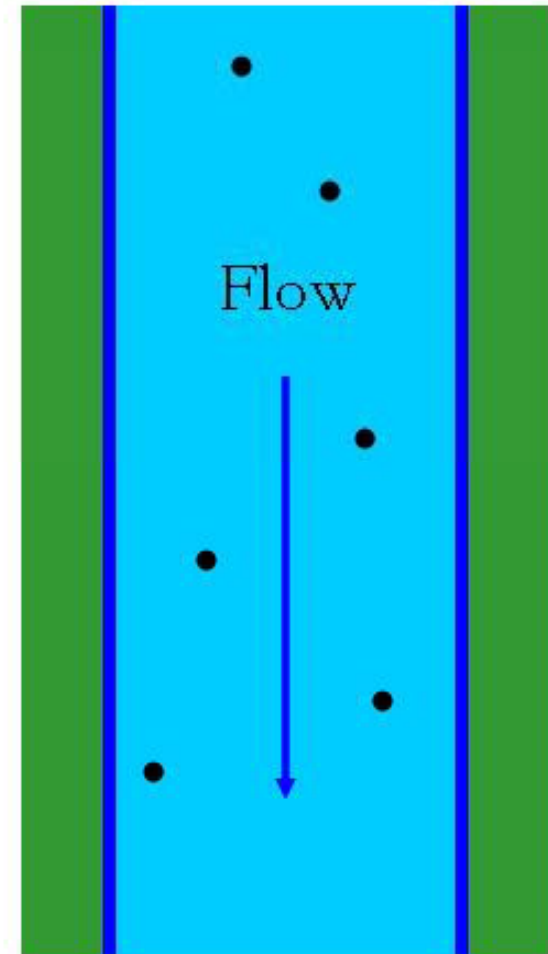
Stage 2



- Post Monsoon/ Early Winter
- Thin detritus layer filtered out of water
- Stream can be losing or hydrostatic
- Not so hot

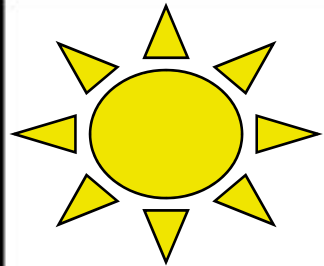


Vertical Profile

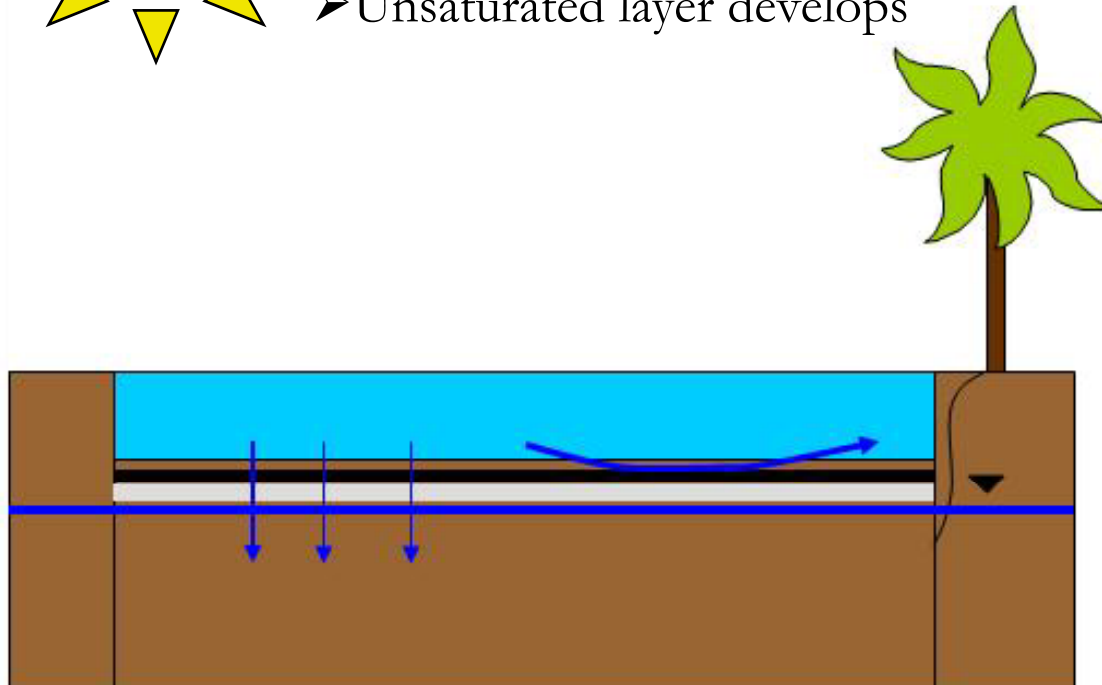


Plan View

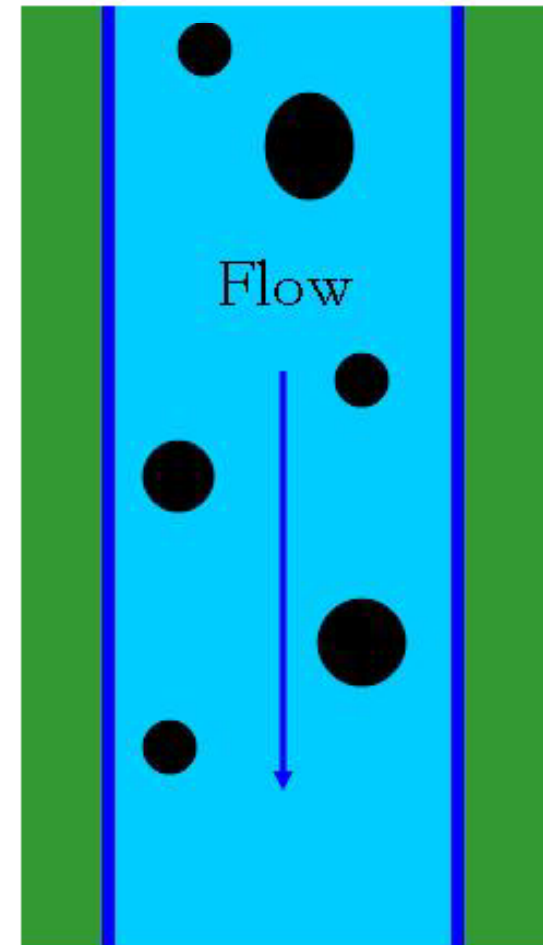
Early Stage 3



- Winter/ Early PreMonsoon (Dec-Apr)
- Losing stream
- Unsaturated layer develops

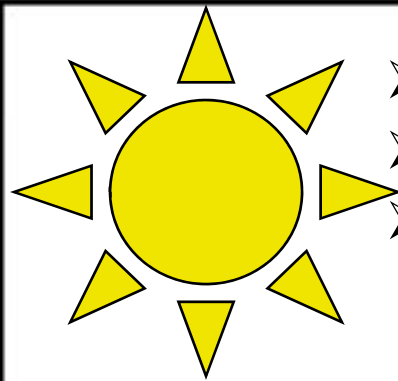


Vertical Profile

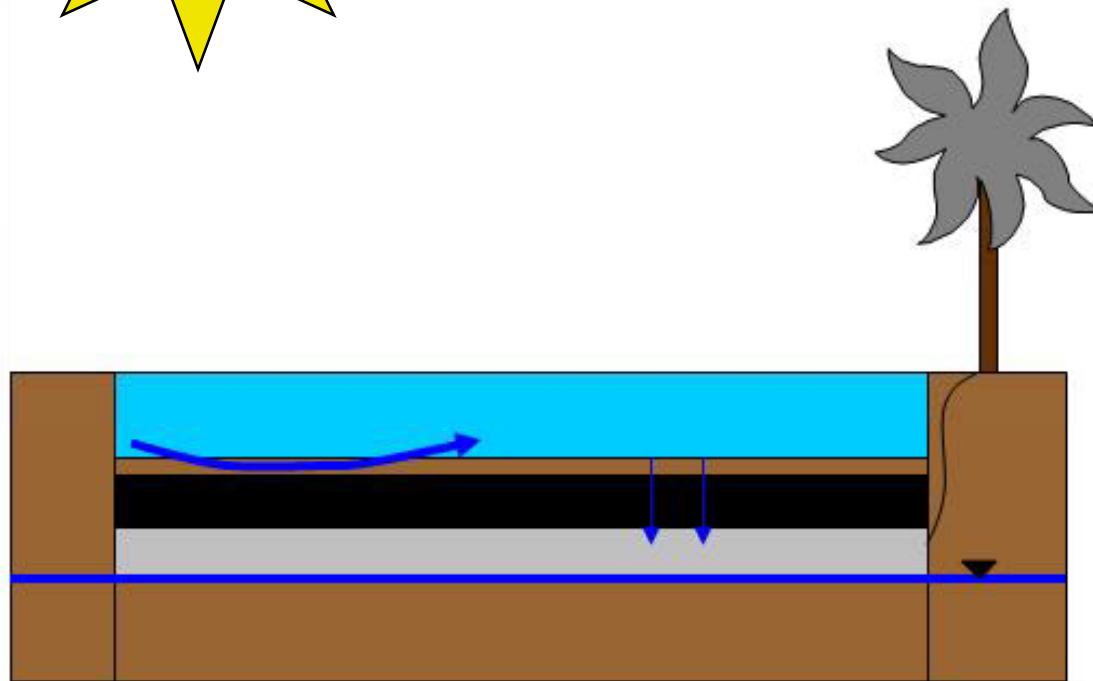


Plan View

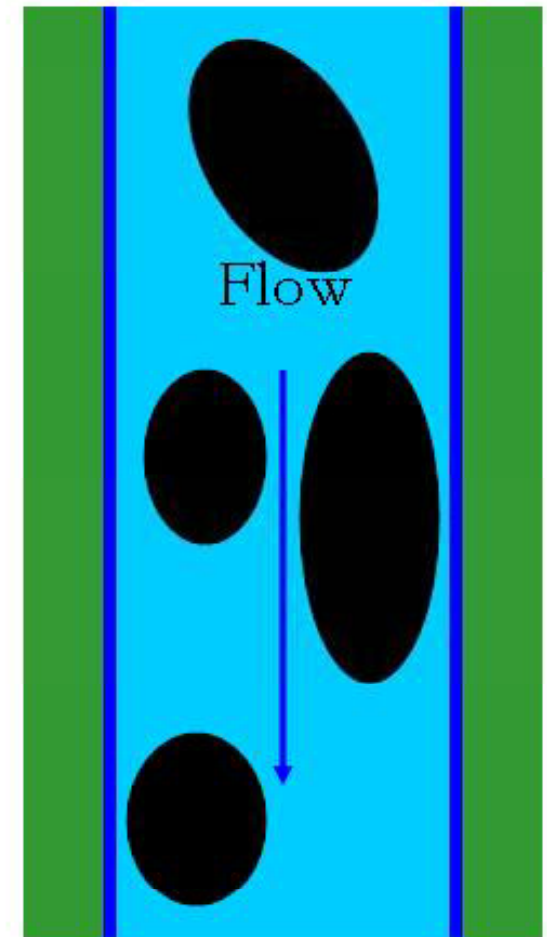
Late Stage 3



- Pre-Monsoon (Apr-July): **HOT**
- Thick clogging layer
- Vegetation starts to be affected

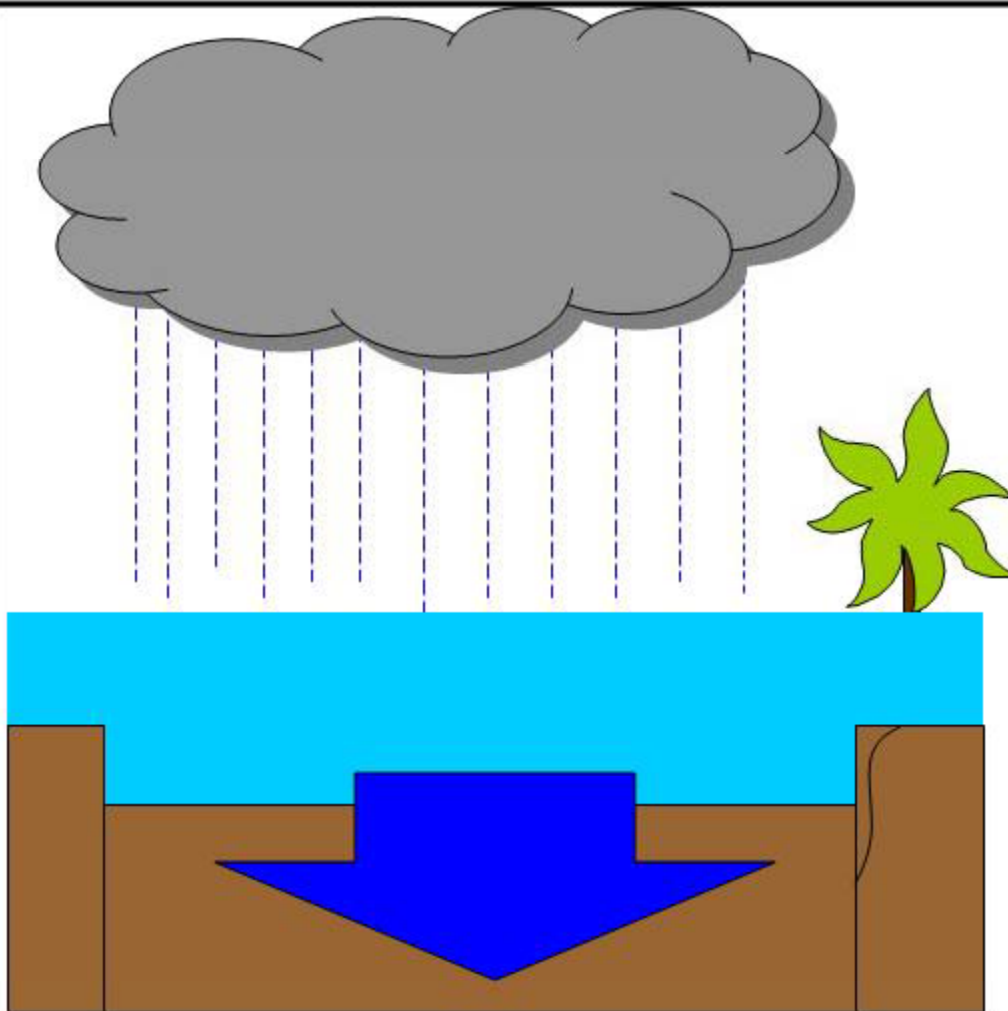


Vertical Profile

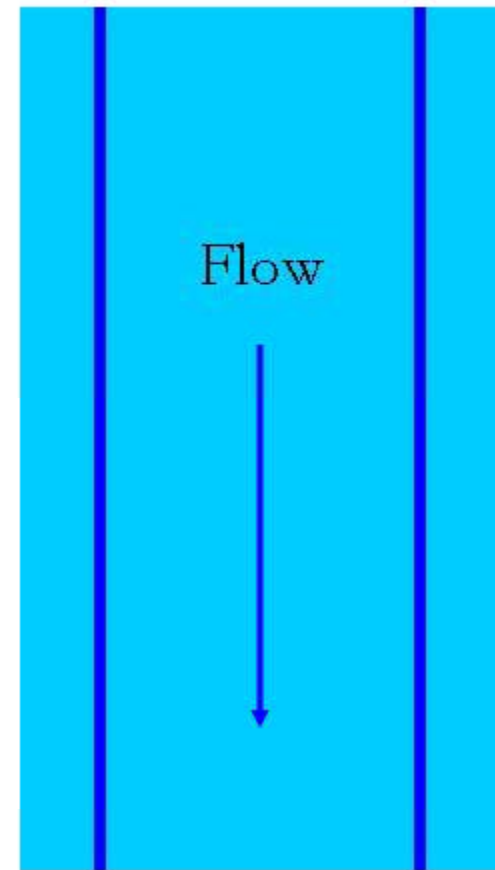


Plan View

Stage 4

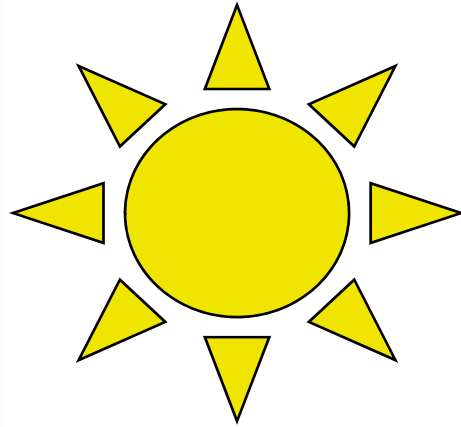


Vertical Profile

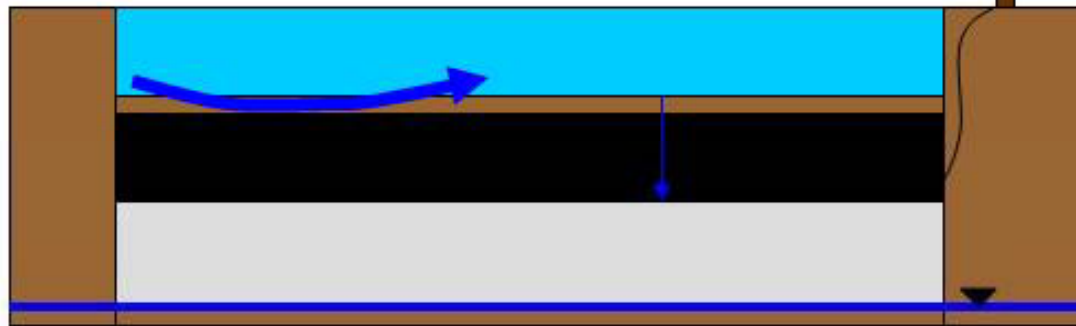
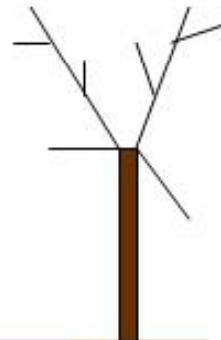


Plan View

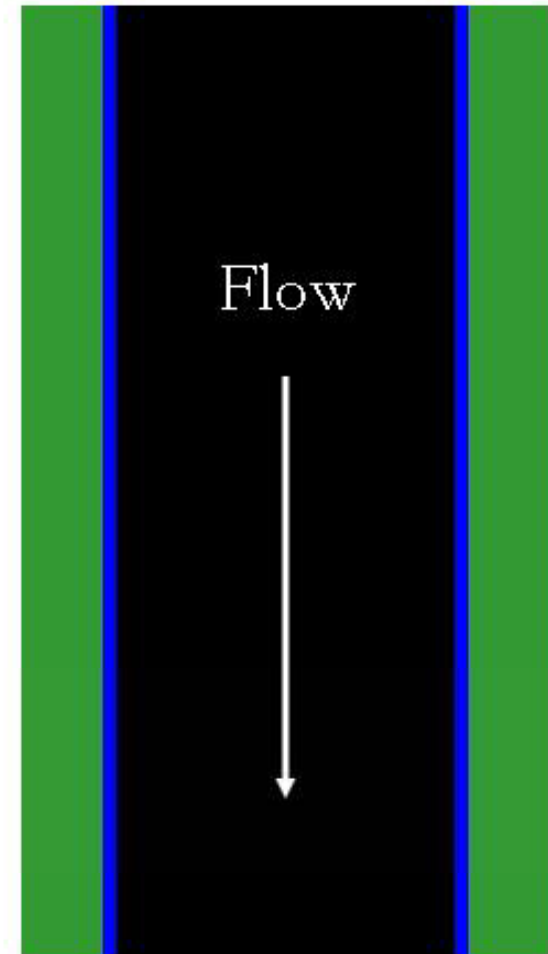
Extended Stage 3



- Weak/no storms prolong stage 3
- Thick clogging layer
- Deep unsaturated zone
- Dead vegetation



Vertical Profile



Plan View

Unsurprising Conclusions

1. What physical evidence is there to suggest the existence of clogging in an effluent dependent streambed ?
 - **The soil cores qualitatively confirm clogging.**
2. What impact does clogging have on the streambed?
 - **Clogging perches stream and shallow streambed leading to a desaturation of the deep streambed.**
3. What effect does clogging have on the aquifer and riparian area?
 - **Clogging not removed can negatively impact aquifer and riparian area, as both dependent on stream inputs.**
4. What effect does a semi-arid hydrologic cycle have on clogging?
 - **Low flow winter and premonsoon seasons promote clogging growth while monsoon storms remove clogging layers with big turbulent flows cresting 10 m³/sec.**

Acknowledgments

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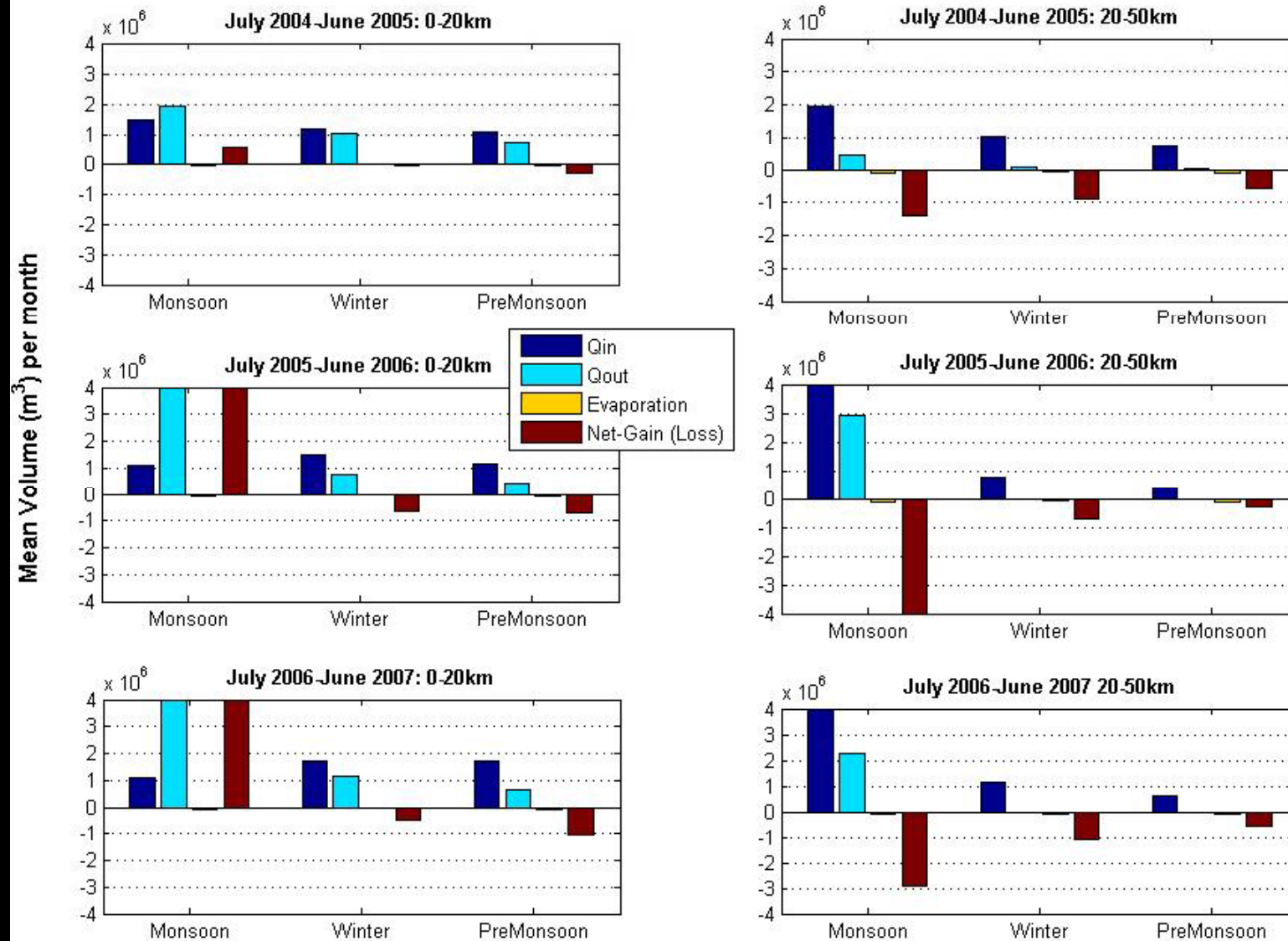


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- H. Ajami, N. Case, K. Chief, N. Deiwakh, L. Delacruz, J. Driscoll, J. Gawad, M. Lindsey, M. Maloney, S. Simpson, C. Soto, F. Yuan, and C. Zlatos generously donated hours and weekends to helping me in the field, lab, and conference room.



Water Balances



Soil Cores: Time and Space

