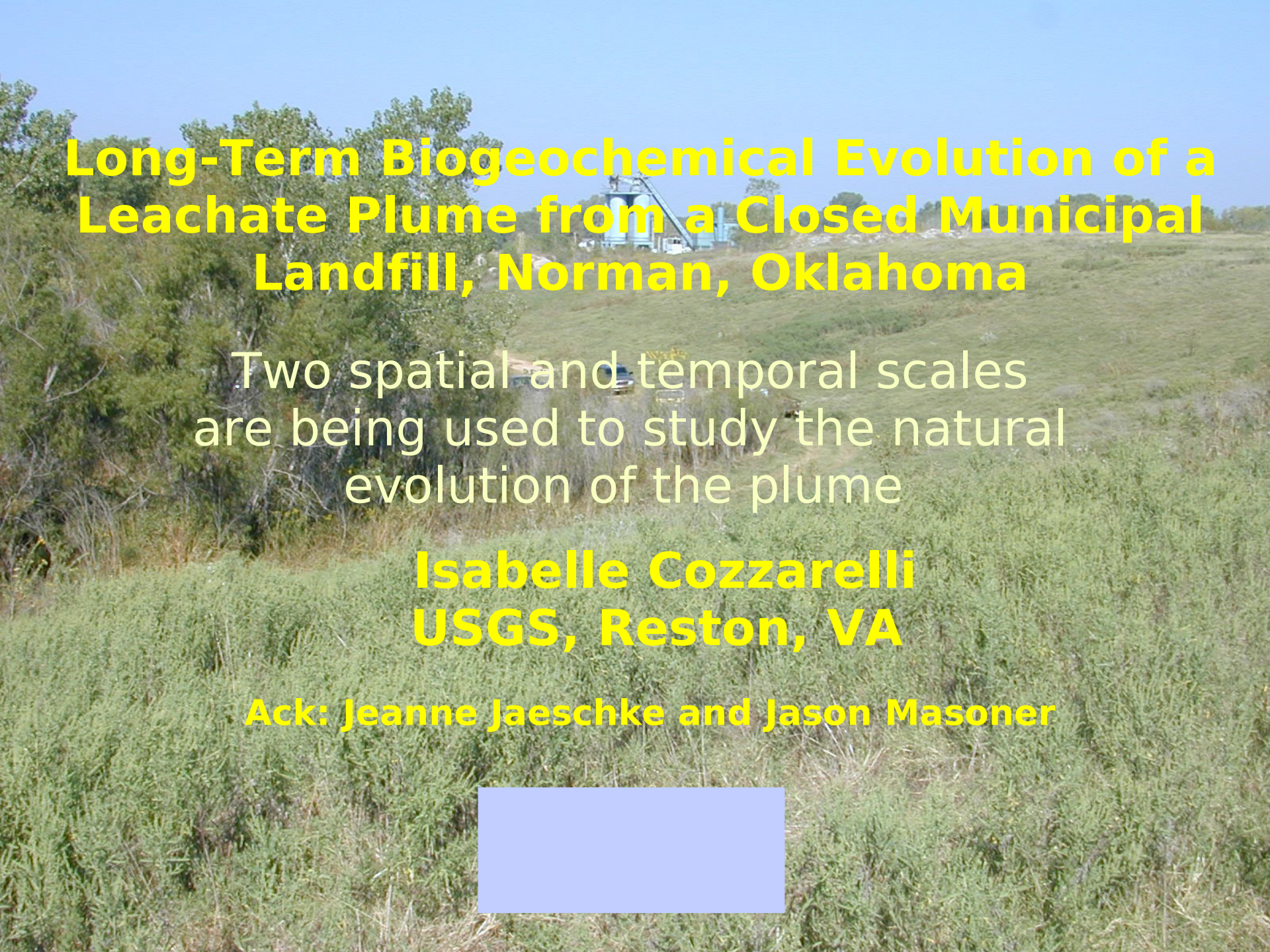


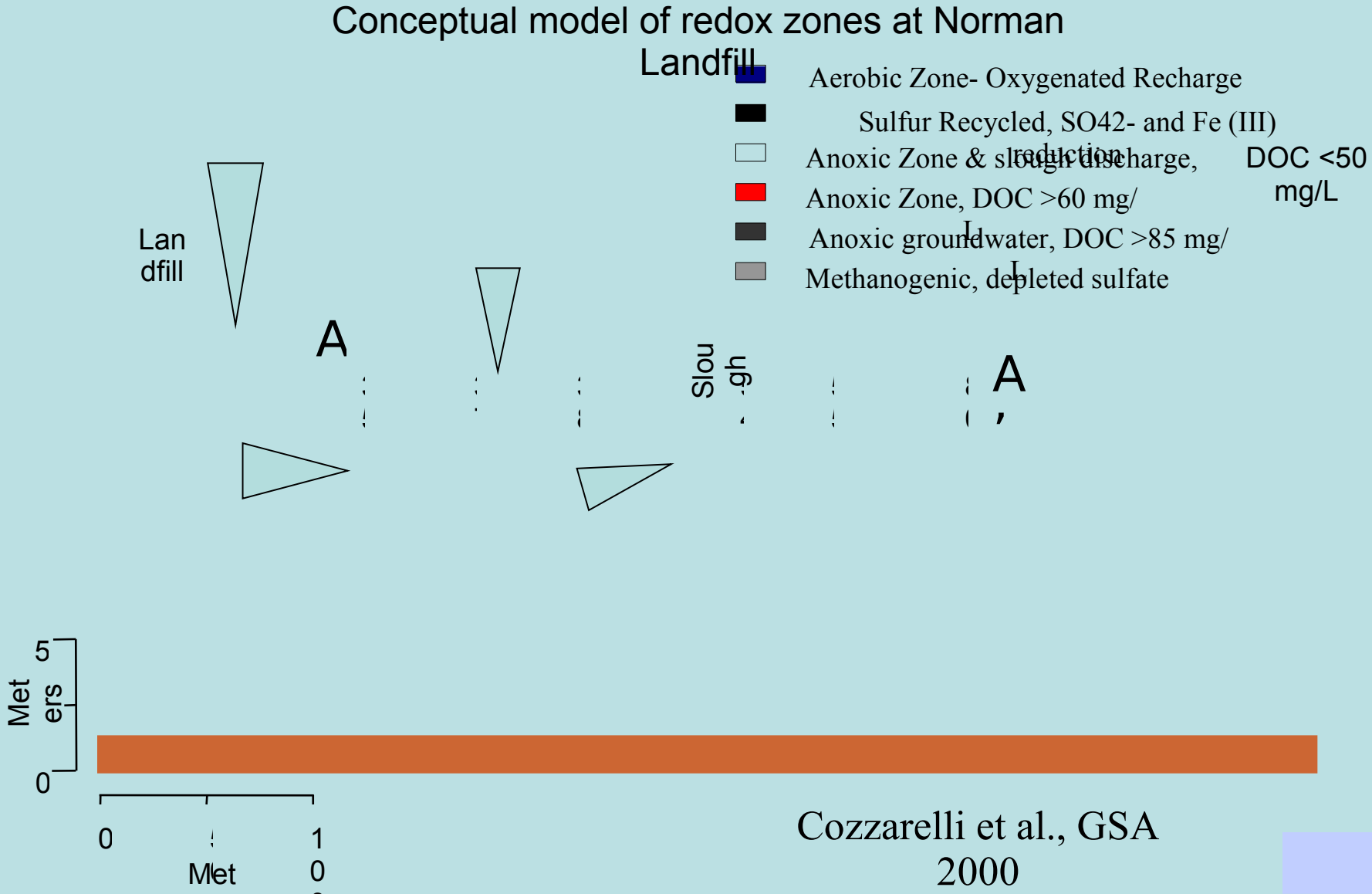
Long-Term Biogeochemical Evolution of a Leachate Plume from a Closed Municipal Landfill, Norman, Oklahoma

Two spatial and temporal scales are being used to study the natural evolution of the plume

Isabelle Cozzarelli
USGS, Reston, VA

Ack: Jeanne Jaeschke and Jason Masoner

Microbial Incubations and Geochemical Analyses were used to Map the Biogeochemical Zones



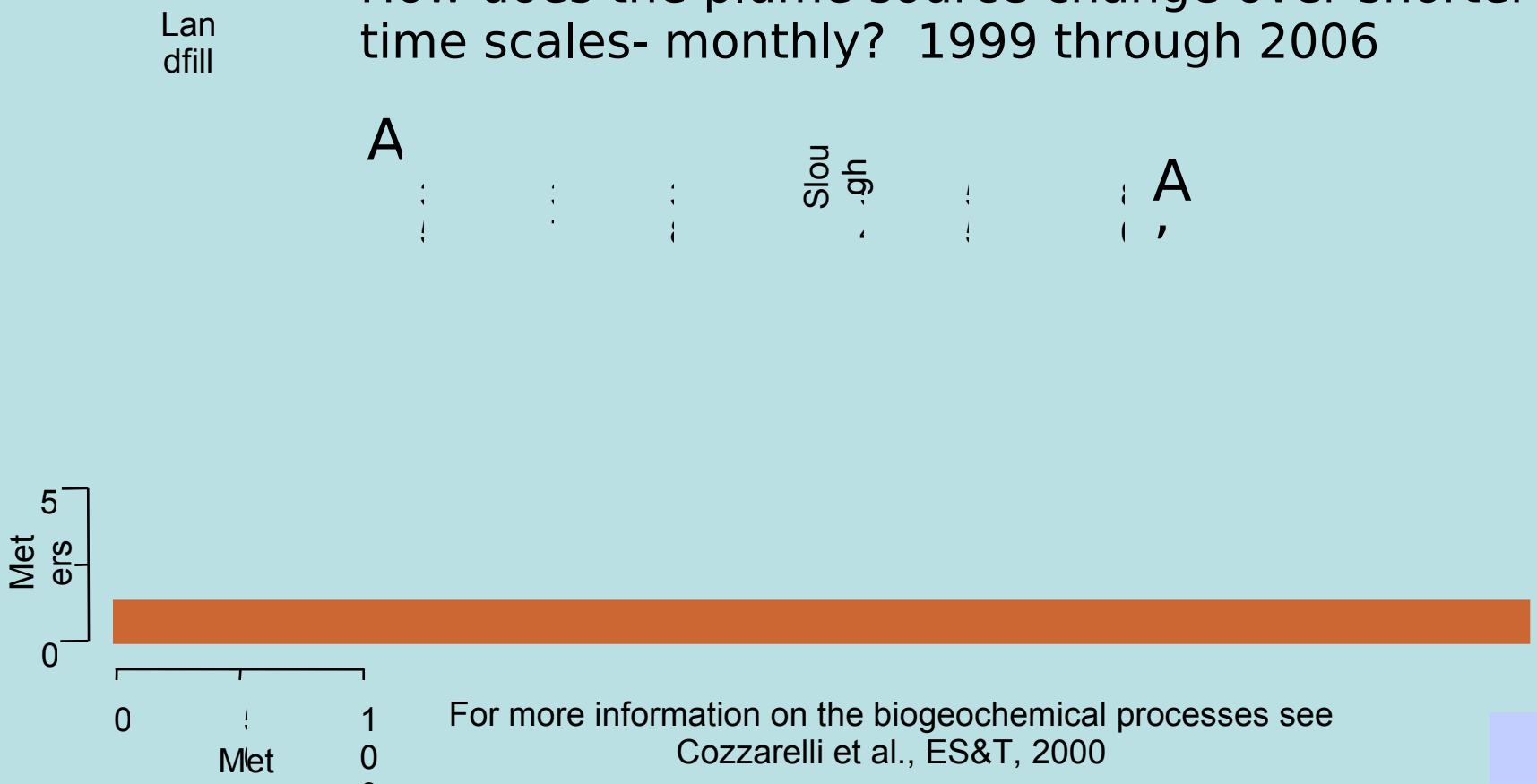
Cozzarelli et al., GSA 2000

The fate of reactive contaminants depends on understanding the biogeochemical processes that dominate in the system and also how stable they are over time.

Question: How does the distribution of redox zones change at the plume-scale over the period 1997-2006?

Approach: Plume scale studies were conducted annually or semi-annually between 1997 and 2006

How does the plume source change over shorter time scales- monthly? 1999 through 2006



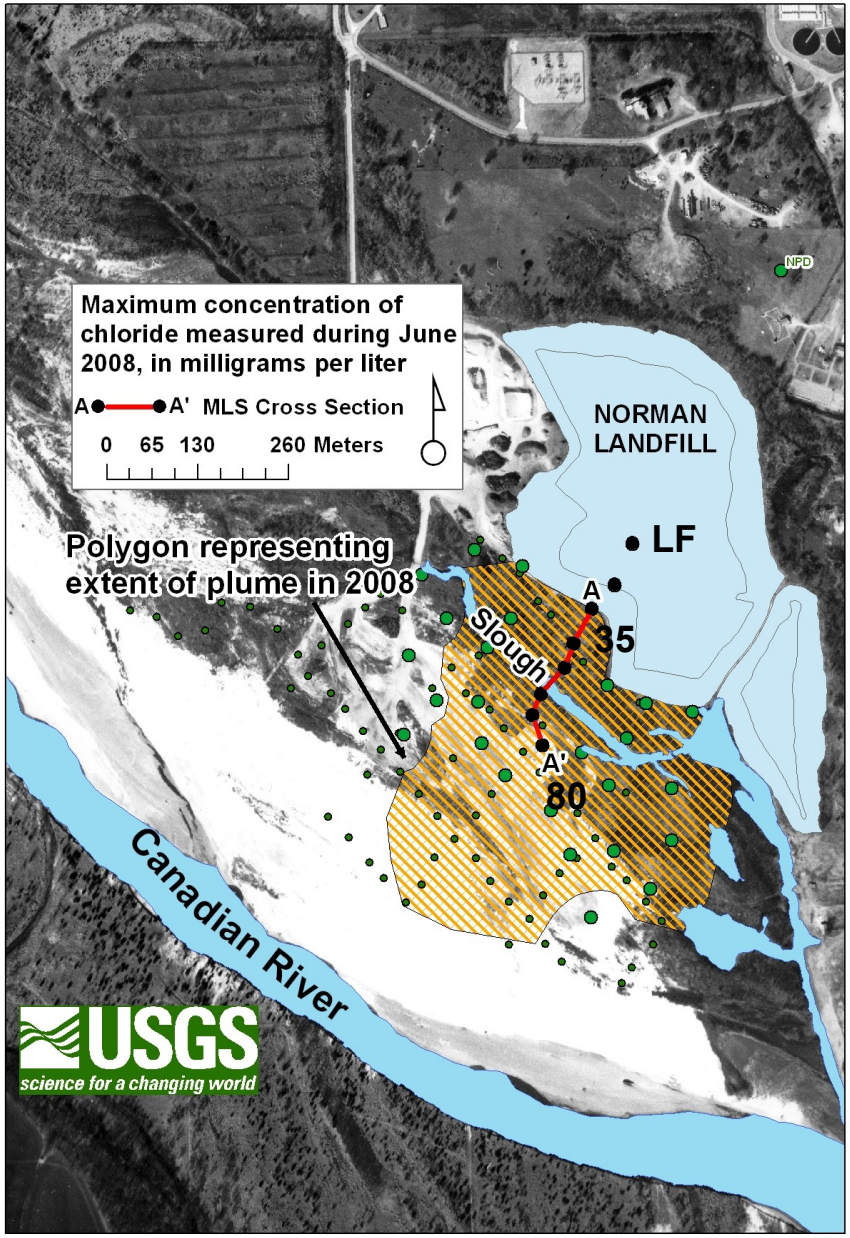
For more information on the biogeochemical processes see Cozzarelli et al., ES&T, 2000

Objective:

To assess how biogeochemical zones in the aquifer, downgradient from the landfill, are changing over time and impact the natural attenuation of leachate components in the plume.

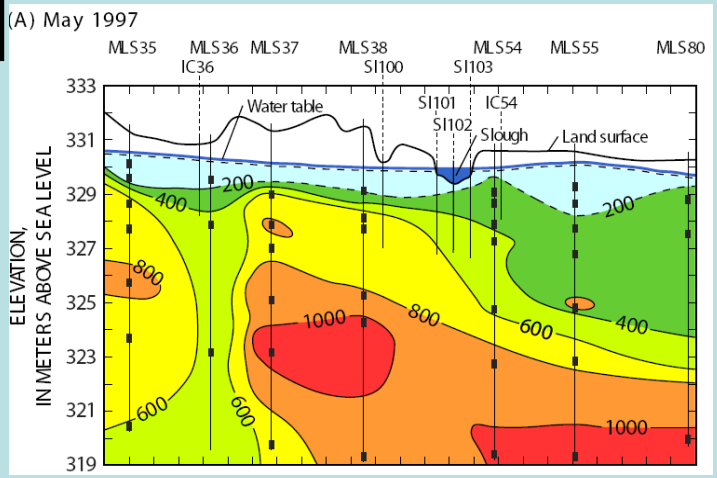
In order to evaluate changes in the plume we need to asses the temporal variability in the source itself.

The next several slides will show the variability in plume constituents or reactive species along this transect A-A'. In the last couple slides I'll show the monthly variability in a couple chemical constituents at the source and the water

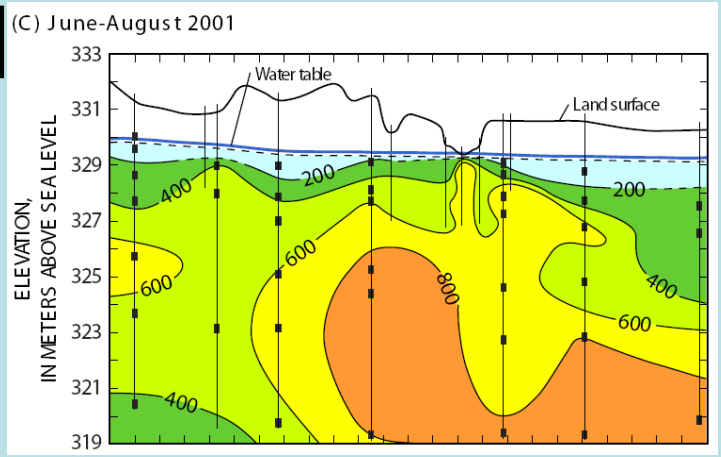


For more information see

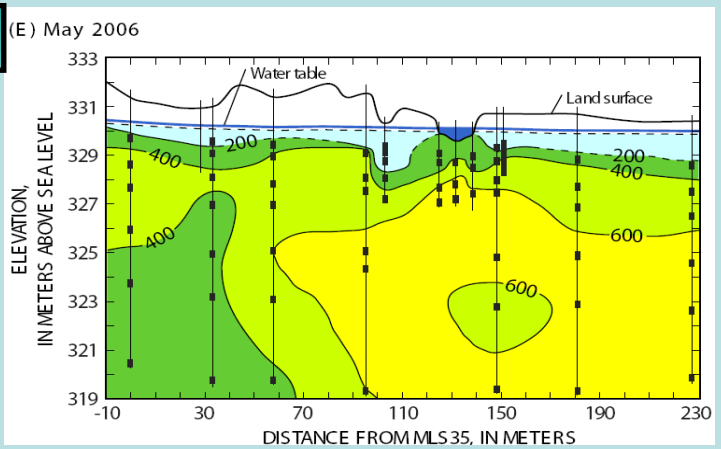
1997



2001



2006



Elevation (m)

Distance (m)

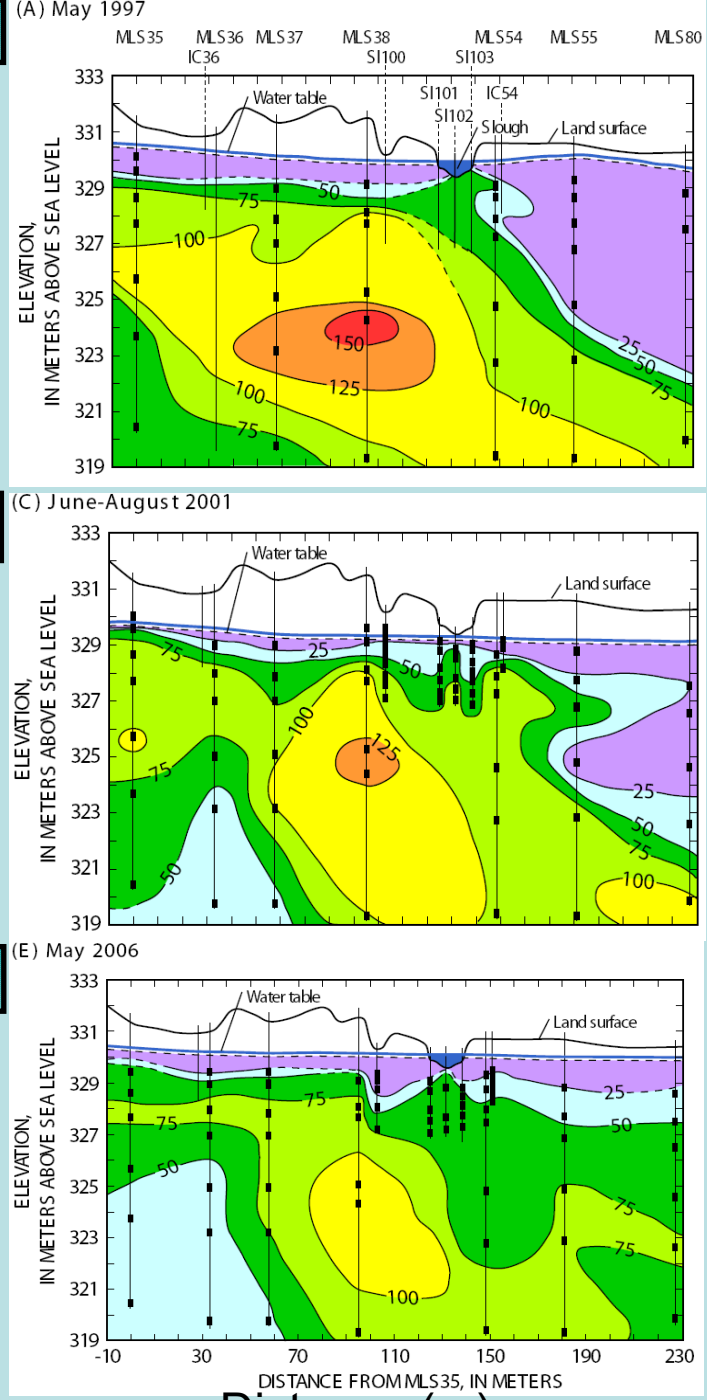
Cross Sectional View Along the A-A' Transect Cl- (mg/L) 1997 through 2006

Chloride is a good conservative tracer of the plume.

The plume sinks as it moves away from the landfill and appears to become more dilute over time

Cozzarelli et al. unpublished data

Cross Sectional View Along the A-A' Transect NVDOC (mg/L) 1997 through 2006



The NVDOC plume center is decreasing in concentration over time.

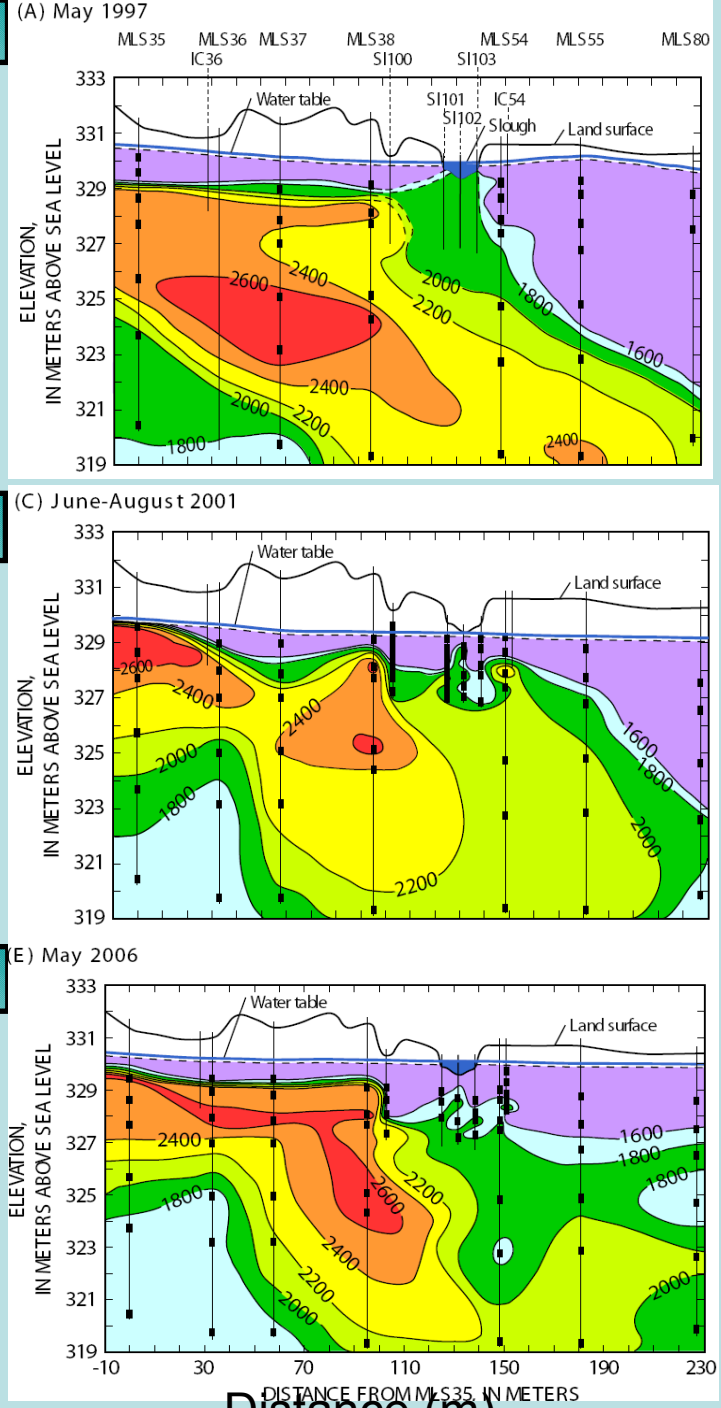
Is this natural attenuation due to biodegradation or dilution?

Comparison with the chloride concentrations over time shows little difference between the NVDOC and conservative compound transport.

Additional lab and field studies are focused on this question of how resistant the NVDOC is t

Cozzarelli et al. unpublished data

biodegradation



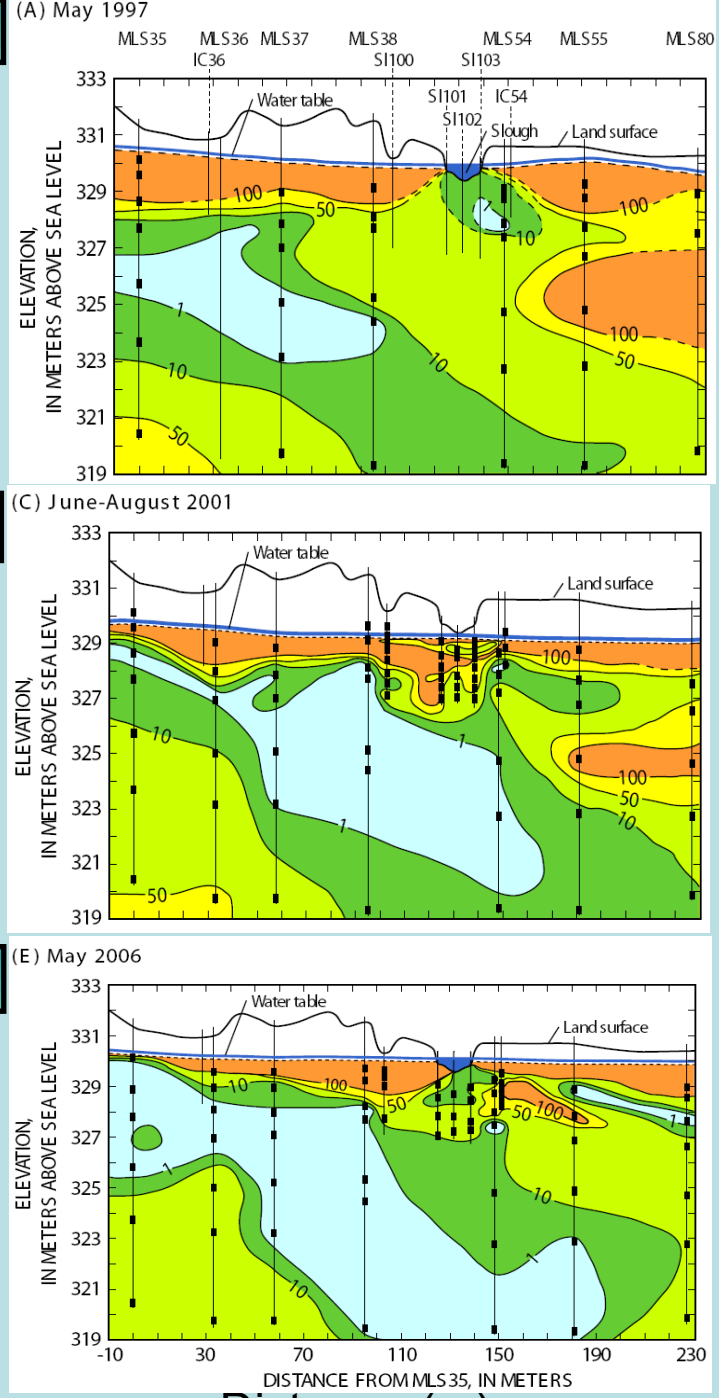
Cross Sectional View Along the A-A' Transect HCO3 (mg/L) 1997 through 2006

Bicarbonate is one of the end product of the oxidation of organic carbon.

While the chloride plume appears to be decreasing in concentration over time, the persistence of high HCO3 concentrations in the core of the plume indicates oxidation of carbon by biodegradation reactions in this reducing environment.

Cozzarelli et al. unpublished data

Cross Sectional View Along the A-A' Transect SO4 (mg/L) 1997 through 2006



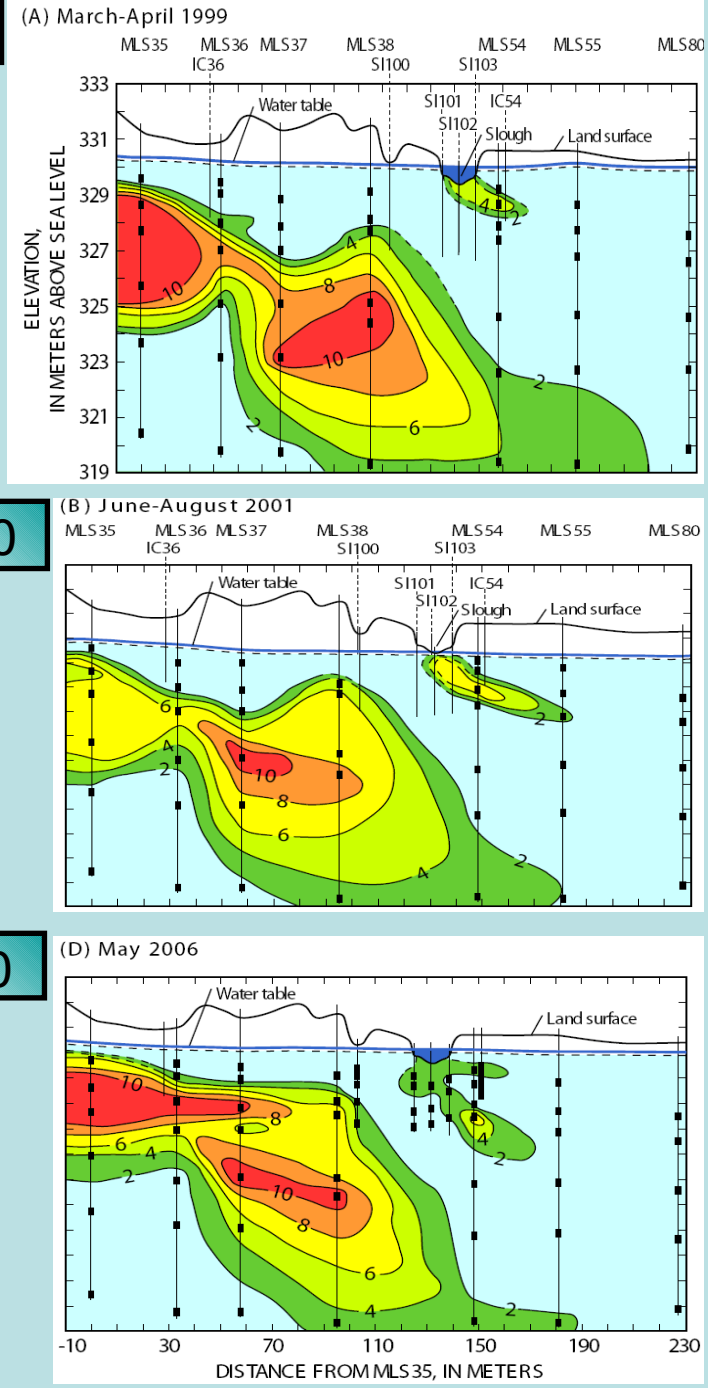
The carbon rich plume is depleted in sulfate.

The sulfate-depleted plume center is expanding over time, increasing in area by more than a factor of 3 over 9 years.

The availability of sulfate at the leading edge of the plume is decreasing as the plume advances.

Cozzarelli et al. unpublished data

Cross Sectional View Along the A-A' Transect CH4 (mg/L) 1999 through 2006



The sulfate-depleted plume center has high methane concentrations

The methane plume has not advanced, indicating retardation mechanisms appear to be balanced by production and transport mechanisms

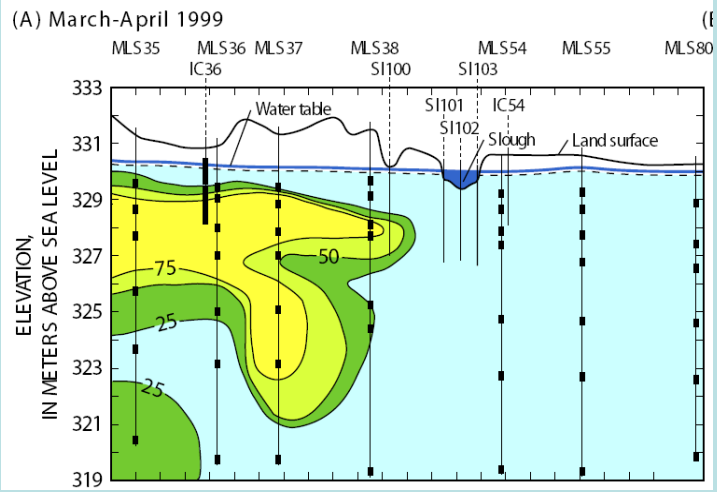
Cozzarelli et al. unpublished data

Cross Sectional View Along the A-A' Transect NH4 (mg/L) 1999 through 2006

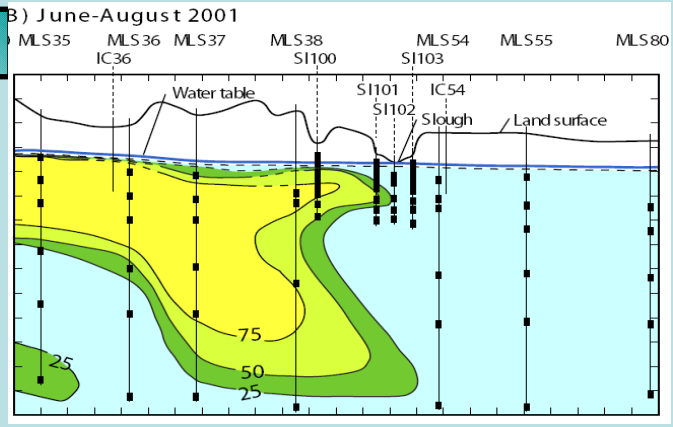
While the chloride and dissolved organic carbon plumes appear to be decreasing in concentration, the ammonium plume is gradually increasing in size

The plume, defined by the 75 mg/L contour, has moved 35 m in 7 years, significantly slower than the estimated average ground-water flow velocity in this region of the aquifer (13 m/yr)

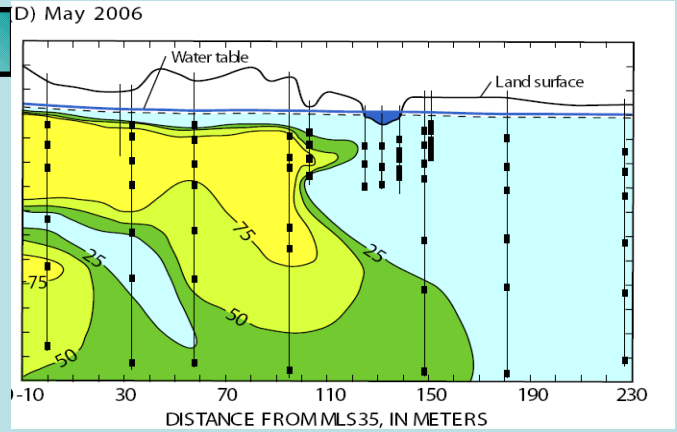
1999



2001



2006



Elevation (m)

Distance (m)

Cozzarelli et al. unpublished data

Plume-Scale Evolution of Reactive Species

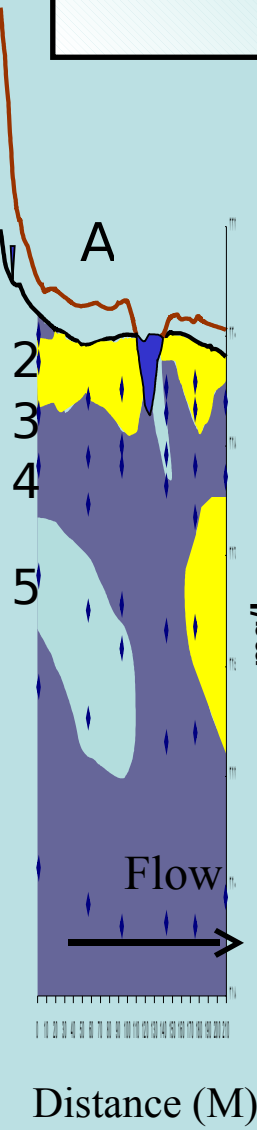
- While the plume is becoming more dilute and the high NVDOC concentrations are decreasing, the carbon load in this system continues to drive oxidation/reduction reactions and reducing conditions persist
- Electron acceptors, such as sulfate, are becoming depleted over time which has implications for the long-term oxidation capacity of the leachate-impacted aquifer
- Persistence of ammonium and methane present long-term concerns from an environmental impact perspective
- Sharp chemical gradients at the plume boundaries indicate biogeochemical reactions may be rapid in these regions of the plume

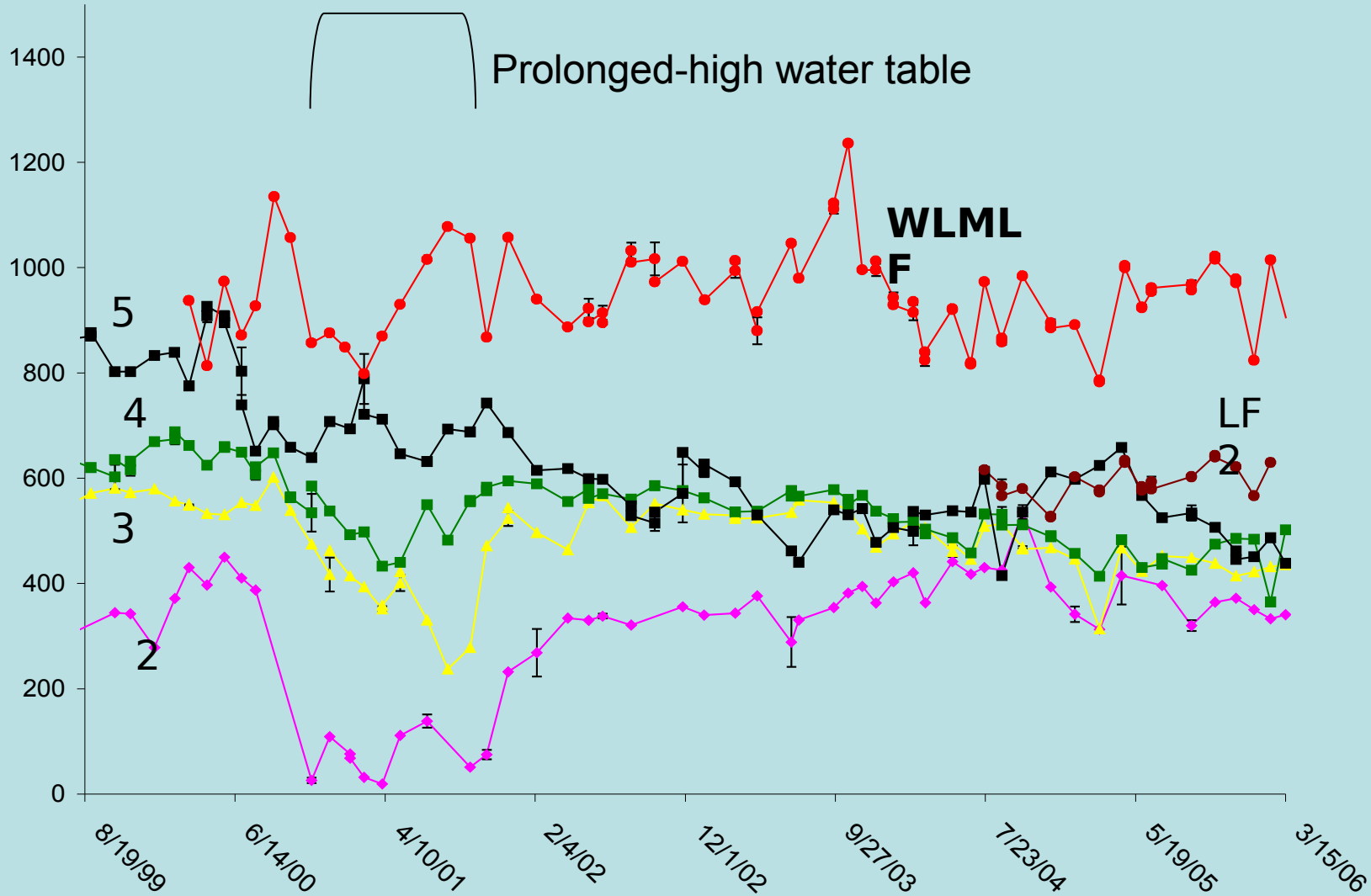
Monthly Water Levels in the Landfill (WLMLF) and at Landfill Edge (35-5)

For the first 5 years of the study the water levels followed a fairly predictable pattern, in the last 4 years, rather unpredictable.

Differences in the magnitude of seasonal variations in water table elevations will affect the degree of mixing and impact processes at this interface.

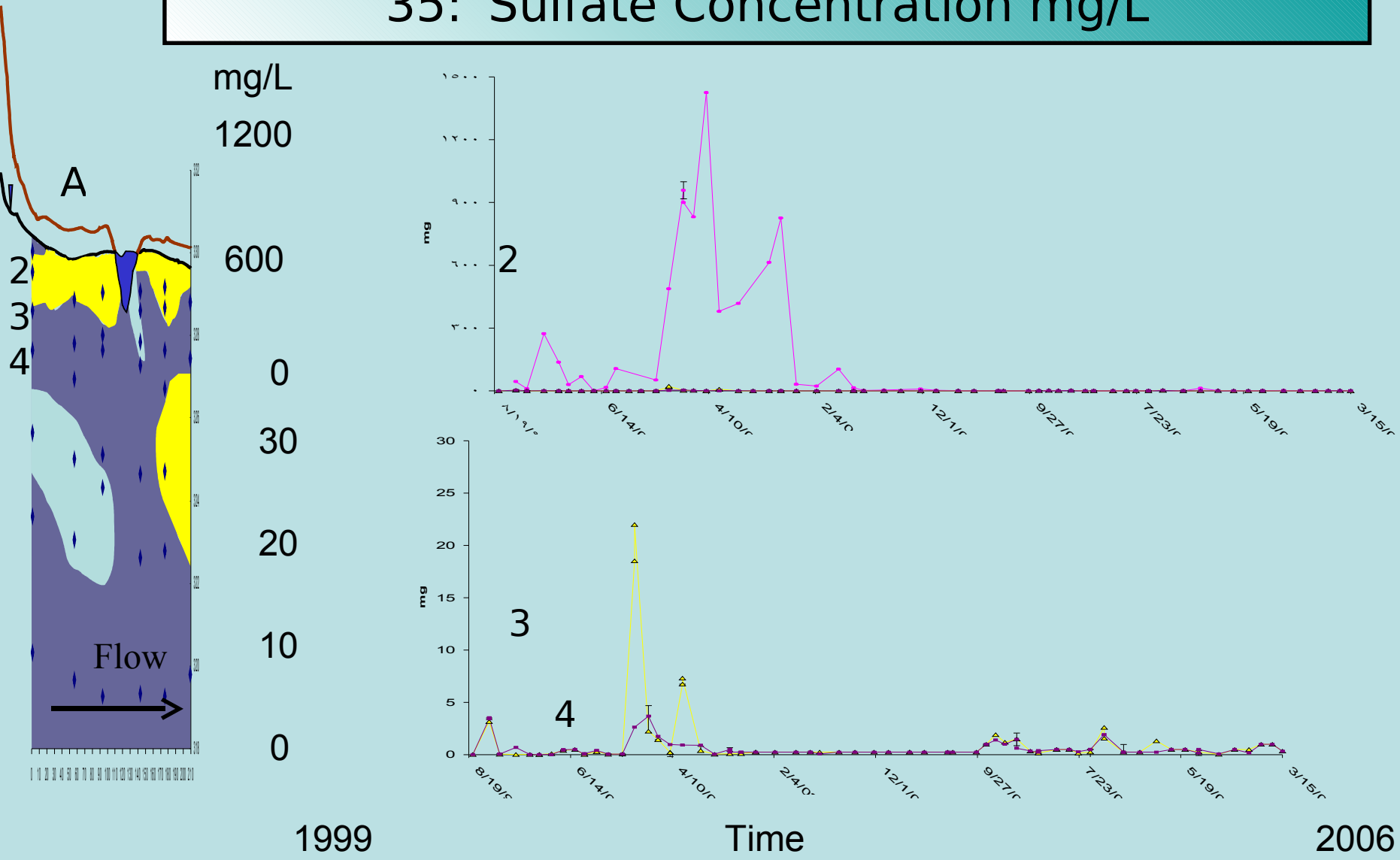
Landfill and Shallow wells at beginning of the plume (MLS 35): Chloride Concentration (mg/L)





Cozzarelli et al. unpublished data

Shallow wells at beginning of the plume at MLS 35: Sulfate Concentration mg/L



Cozzarelli et al. unpublished data

Lessons learned from smaller-scale temporal studies

- The landfill source well does not show significant trends over time and may not be a good indicator of potential plume evolution

- Changes over time at the toe of the landfill (the start of our plume transect) show that the vertical heterogeneity of the plume is diminishing over time as the plume ages and mixing increases

- Reactive species in the plume show greatest temporal variations at the plume boundaries and mixing at these interfaces needs to be assessed in order to understand potential for natural attenuation of contaminants