Sludge Management at NB Coal 1992-2006

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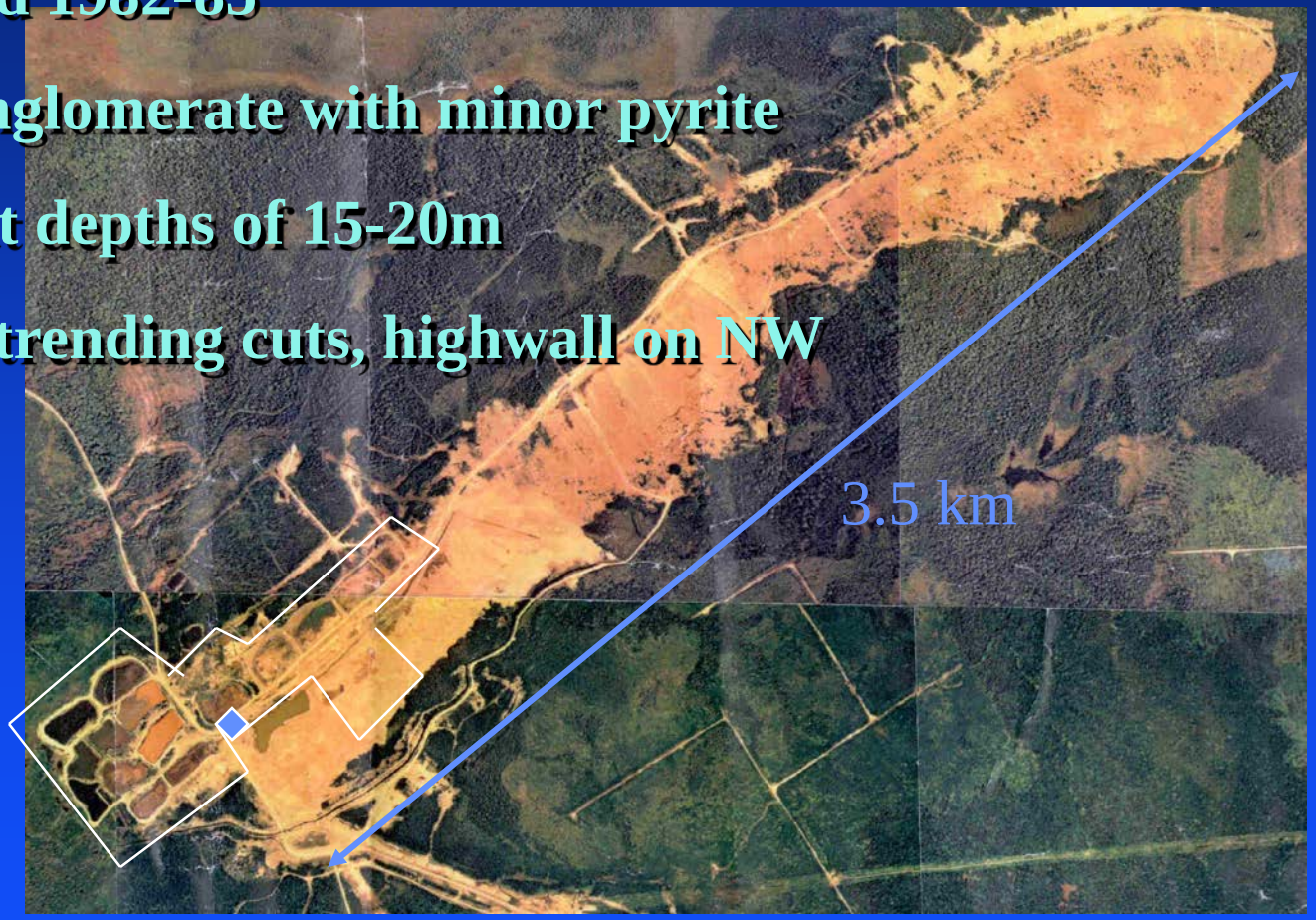
Location of surface coal mine.

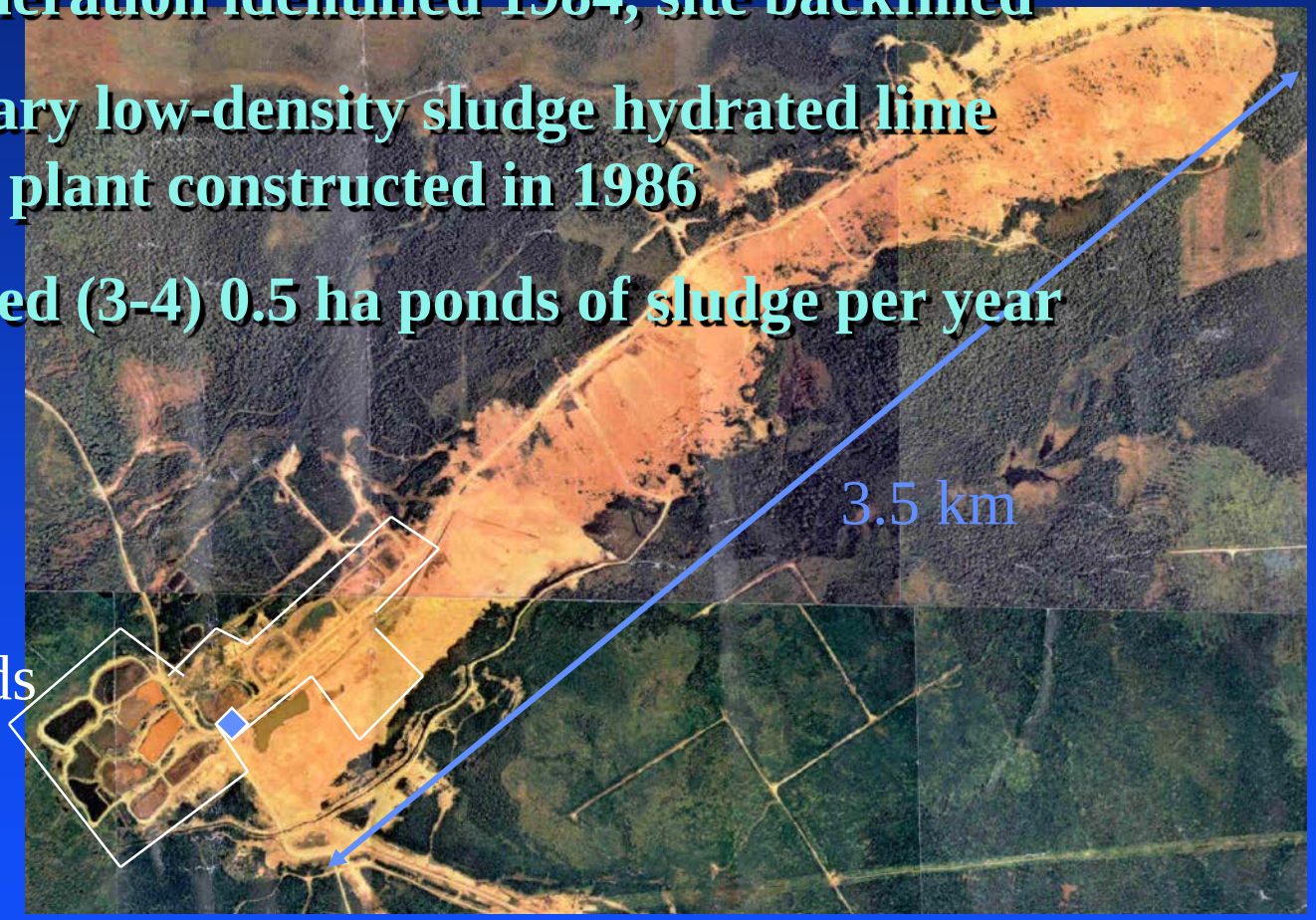
Fire Road Mine

- Operated 1982-85
- Ss & conglomerate with minor pyrite
- 100 ha at depths of 15-20m
- SW/NE trending cuts, highwall on NW



Fire Road Mine

- Acid generation identified 1984, site backfilled
- Temporary low-density sludge hydrated lime treatment plant constructed in 1986
- Generated (3-4) 0.5 ha ponds of sludge per year



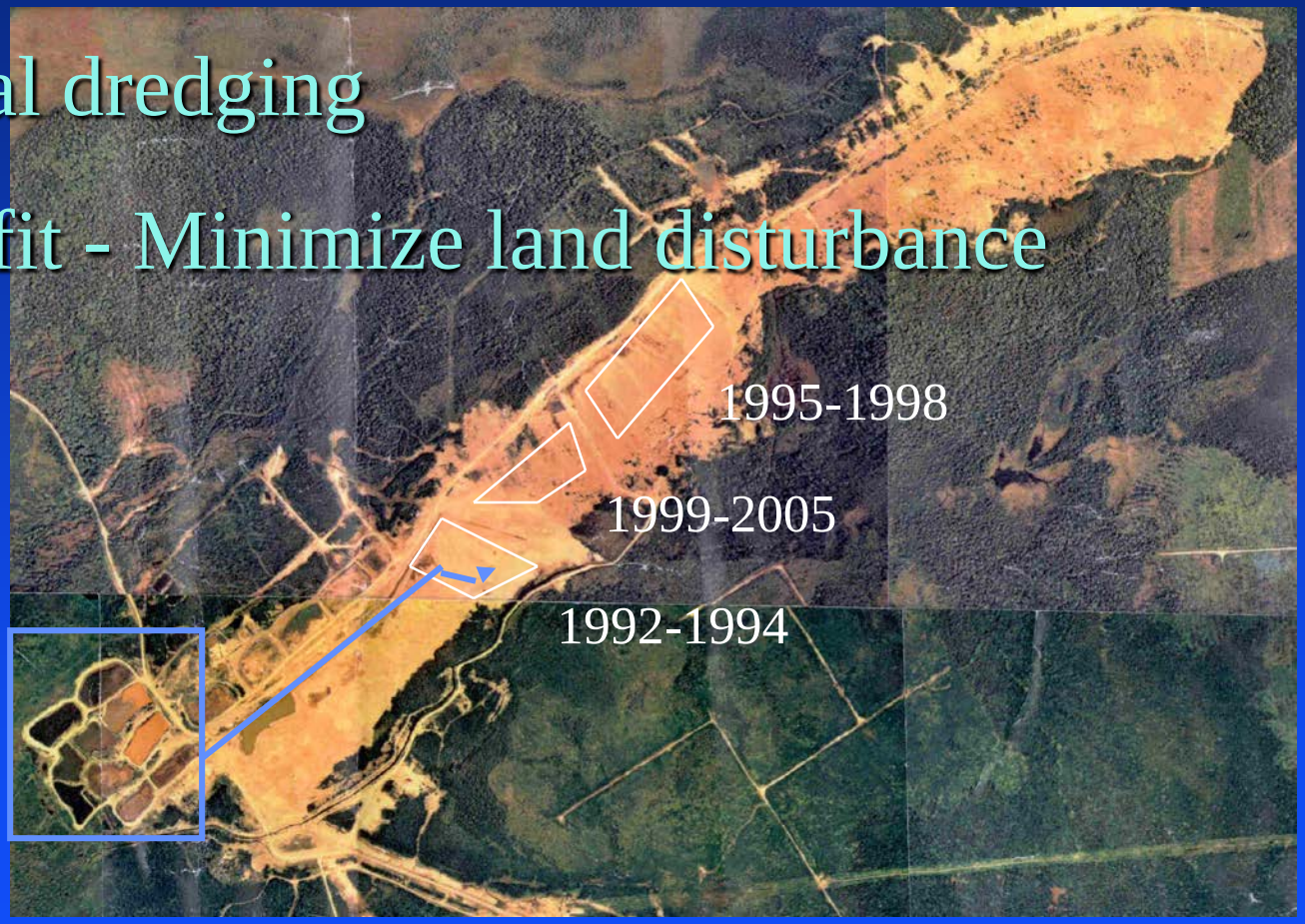
Initial Sludge Management Project Rationale

- Long term plan was to continue with lime treatment.
- After 6 years of treatment, land use became an issue.
- Disposing of lime neutralization sludge into acid generating rock could provide several benefits for reclamation of the mine site including:
  - minimize land disturbance
  - low cost final disposal area for sludge
  - decrease personal liability
  - utilization of the excess alkalinity
  - reduce diffusion of oxygen into the waste rock.

Bathtub layout of mine would contain sludge.

Sludge Depositional Areas

- Annual dredging
- Benefit - Minimize land disturbance



Method of Relocation

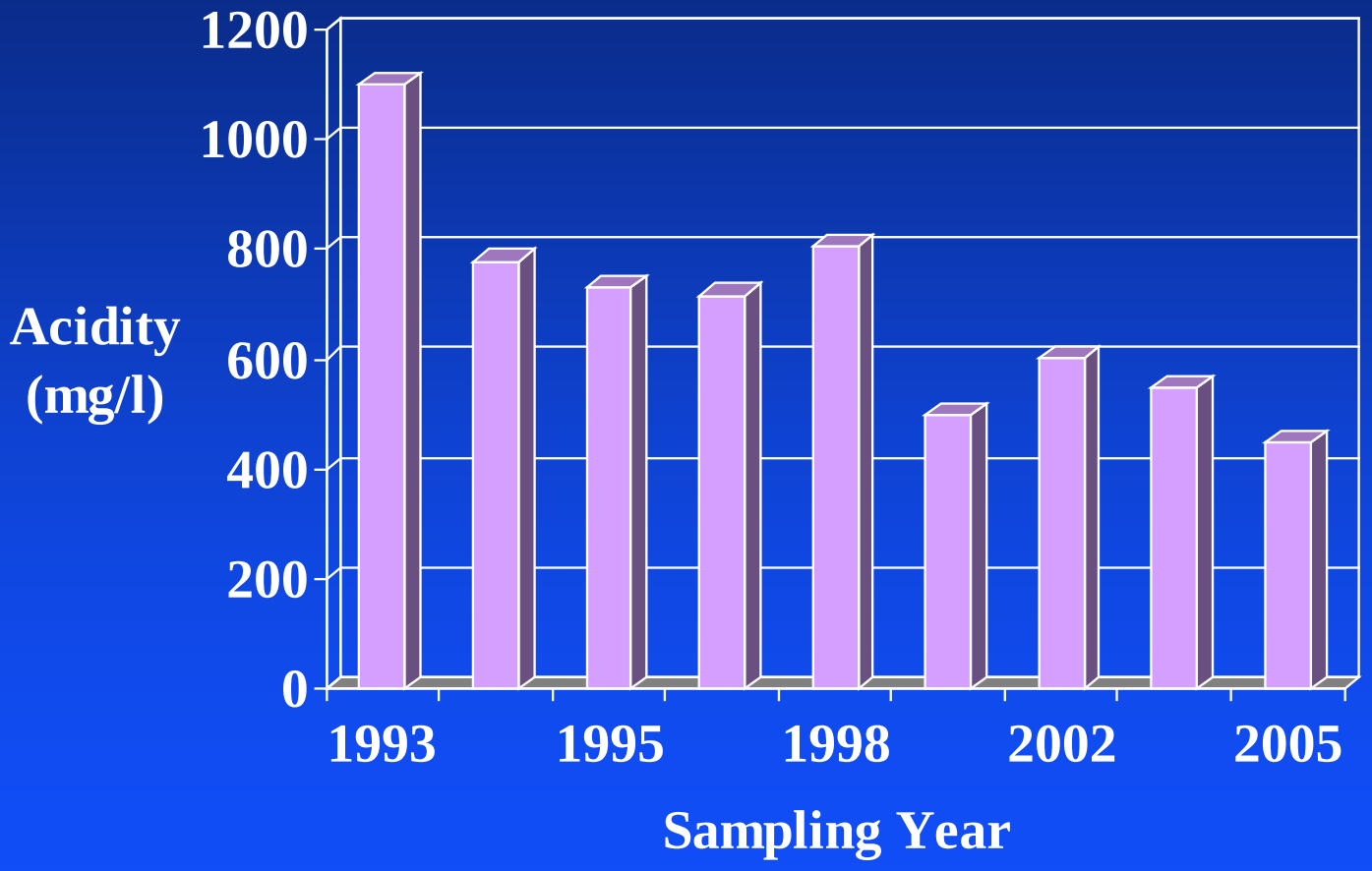
Surface Application

- Adequate disposal method on porous backfill
- Established vegetation not disturbed

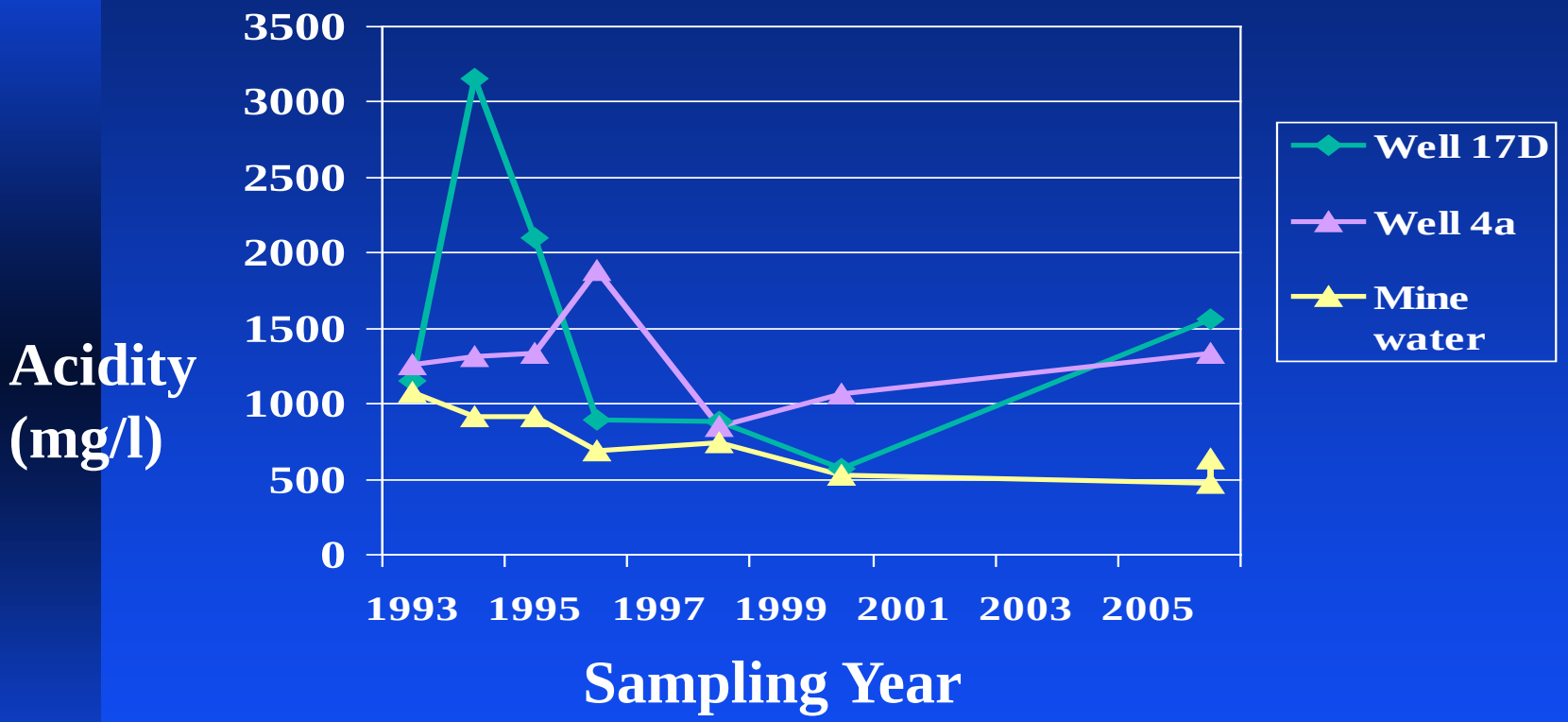
Surface Application

- Most sludge disappears into the waste rock
- Location B after one season of sludge deposition (21,000m^3 of low density sludge)
- Benefits -
  - Low cost final disposal area for sludge
  - Decrease personal liability

Affect on Mine Water Chemistry - Acidity of the mine water pond



Affect on Mine Water Chemistry - mine vs mine water pond



- Benefit - Utilization of the excess alkalinity ? Not as obvious impact in-situ so improvement in mine water pond water quality must be due to other influences.

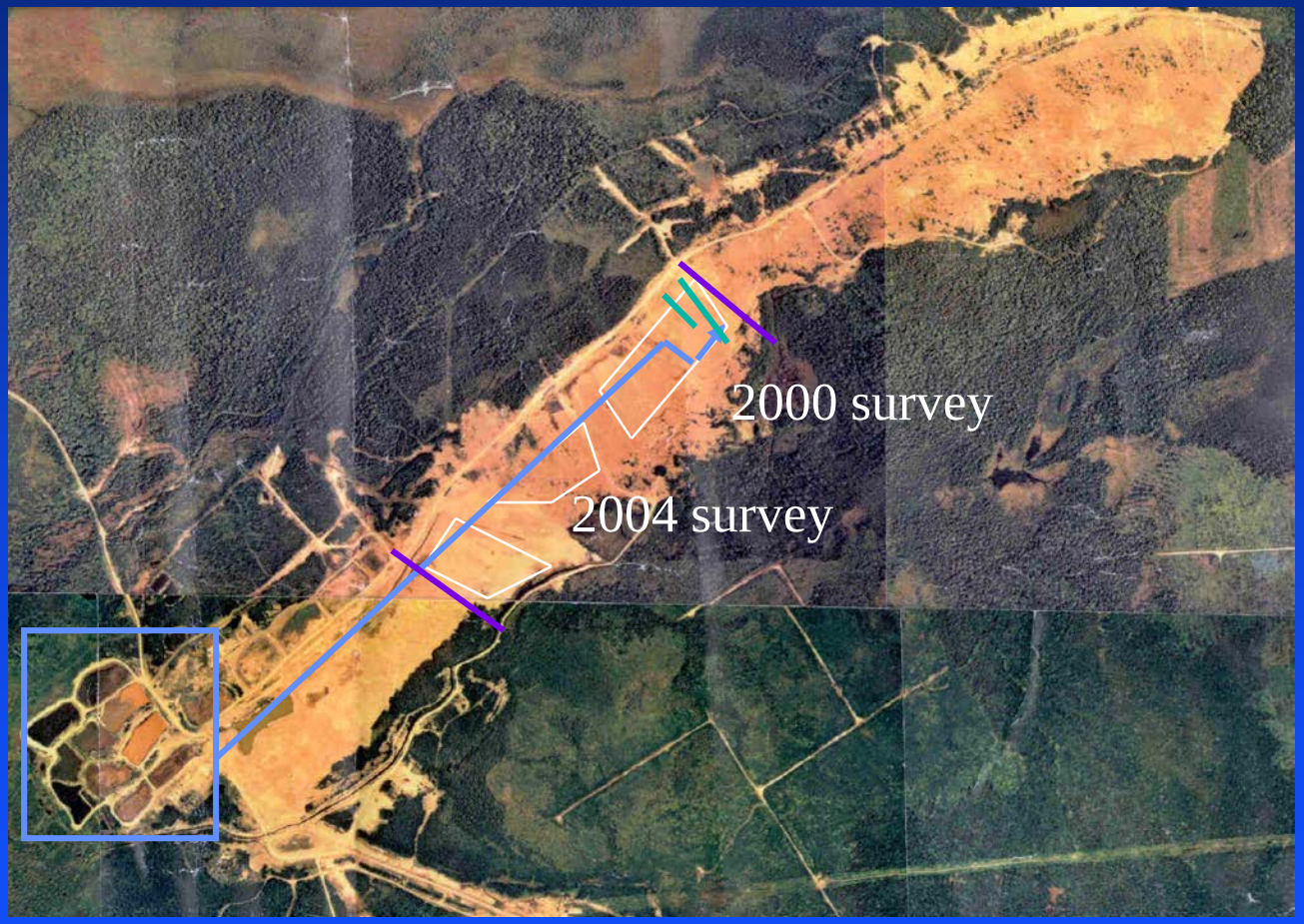
Can AMD be Detected Below the Surface?

- Well analysis indicated acid water was still being generated within the confines of the backfilled mine.
- Is the sludge reducing the diffusion of oxygen?
- Can we use applied resistivity imaging and electromagnetic terrain conductivity (EM34,EM31) investigations to:
  - map lateral variations in AMD content within the mine site.

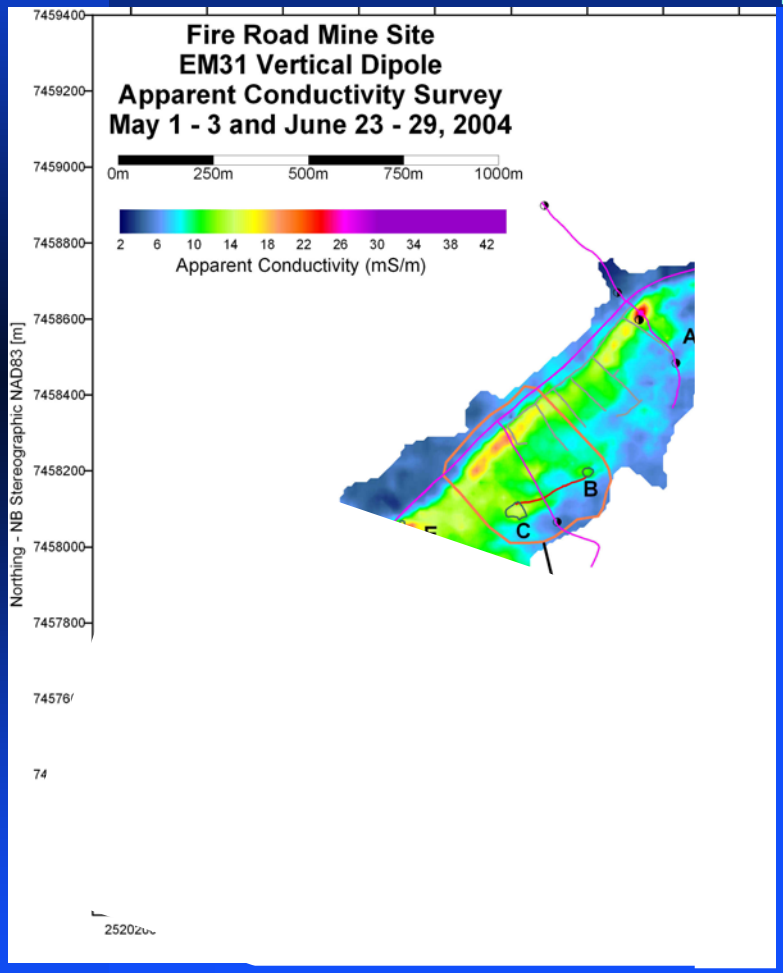
Why Electrical Conductivity?

- Geophysical tools which are commonly used in groundwater investigations.
  - Defines stratigraphy and structures controlling groundwater flow
  - Detects, delineates and monitors conductive plumes of AMD or other sources of contamination.
- Conductivity is proportional to ion concentration, ion valence, and the ion mobilities.
- AMD has high electrical conductivity compared to natural groundwaters

Sludge Depositional Areas EM Mapping Locations



Apparent Conductivity Survey Results - linear anomaly along highwall



- Note the scale.
- Electrical conductivities in waste rock backfill were much higher than outside the pit.
  - Conductivities within the backfill were markedly higher immediately adjacent to highwall.
  - Apparent conductivities within backfill appeared to be subtly dependent on the presence of sludge!

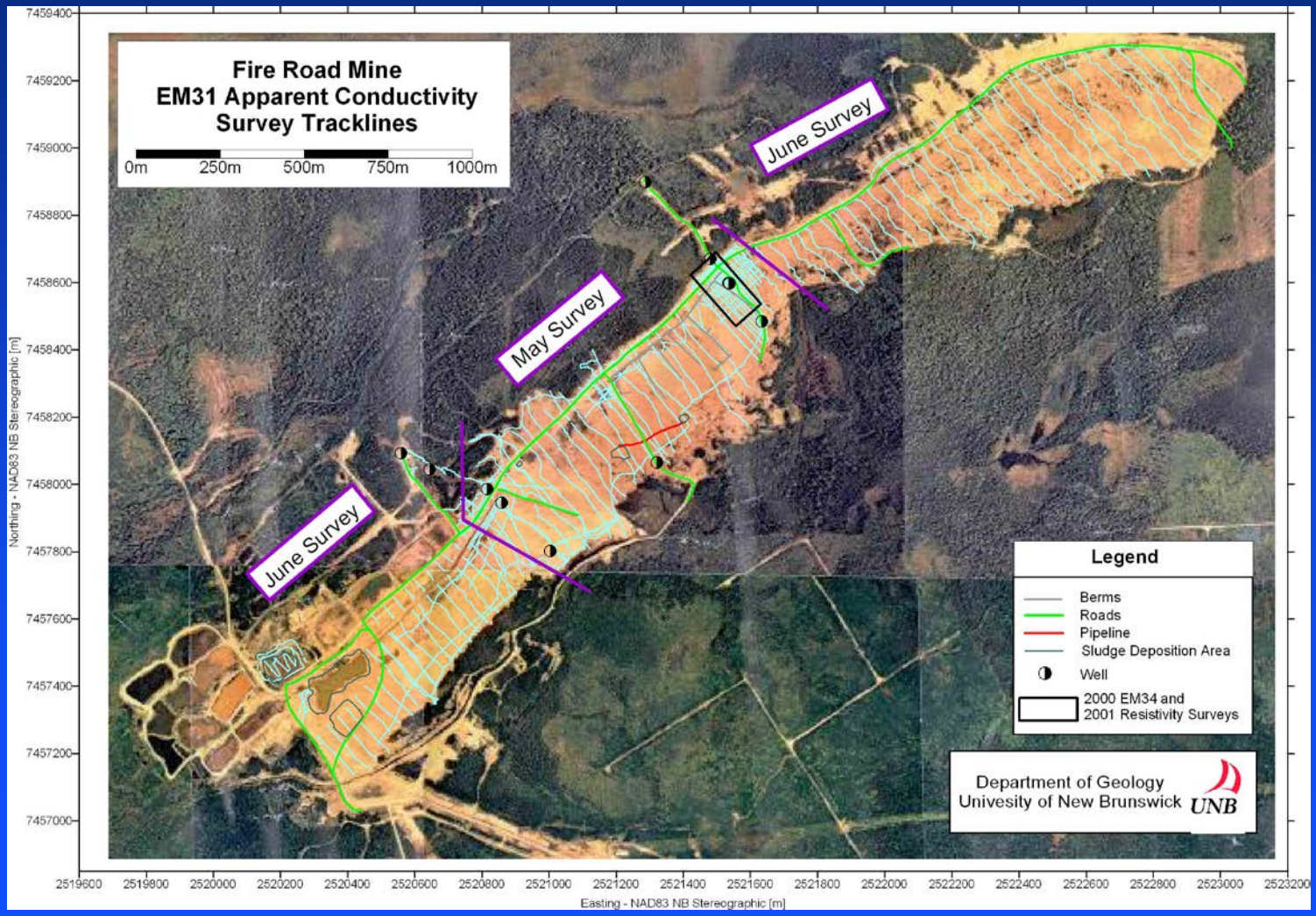
Initial Interpretations (2000, May 2004)

- Could we use Apparent Conductivity Surveys as a sludge management tool to;
  - map the lateral distribution of sludge across the mine?
  - identify where it may be plugging any voids?
  - can it be used to manage placement of sludge to reduce acid generation.
  - And if so, could the plugging
    - reduce diffusion of oxygen into the waste rock.

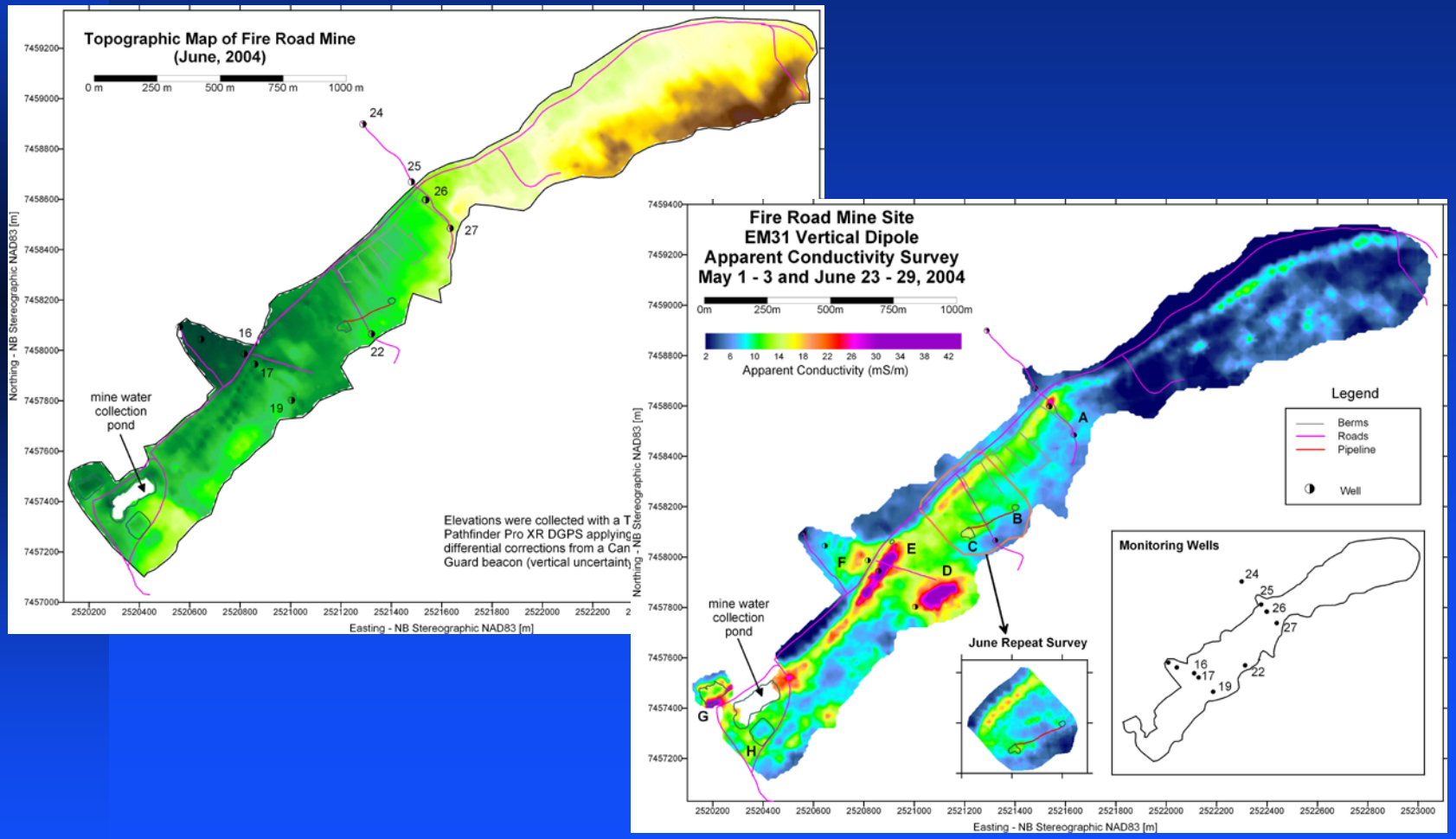
EM31 Apparent Conductivity Survey June 2004

- Covered entire 100 ha site with continuous profiling and integrated DGPS tracking
- Apparent conductivity- is the conductivity weighted to the thickness and conductivity of each layer over the depth of measurement (6 meters).

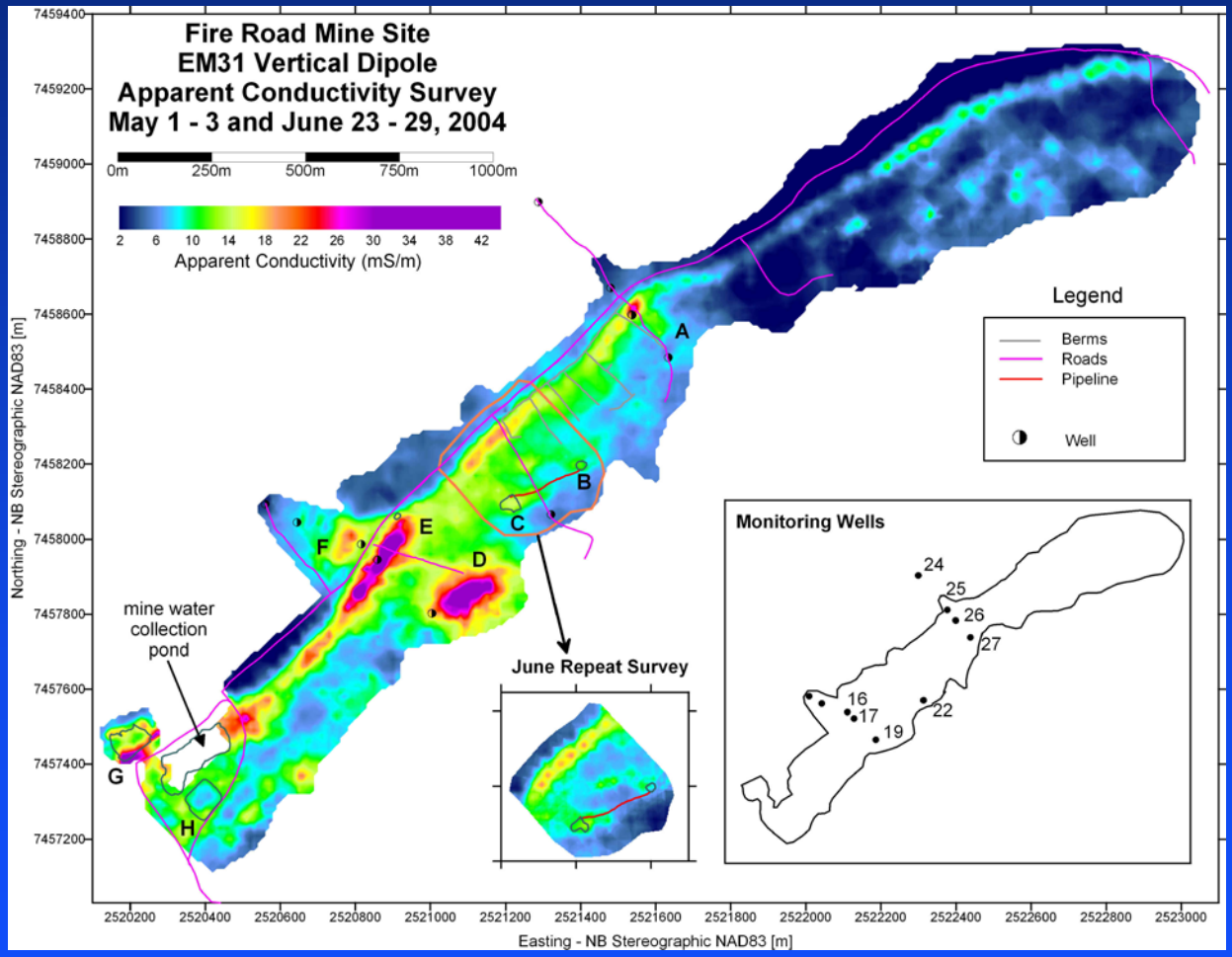
EM 31 Apparent Conductivity Map



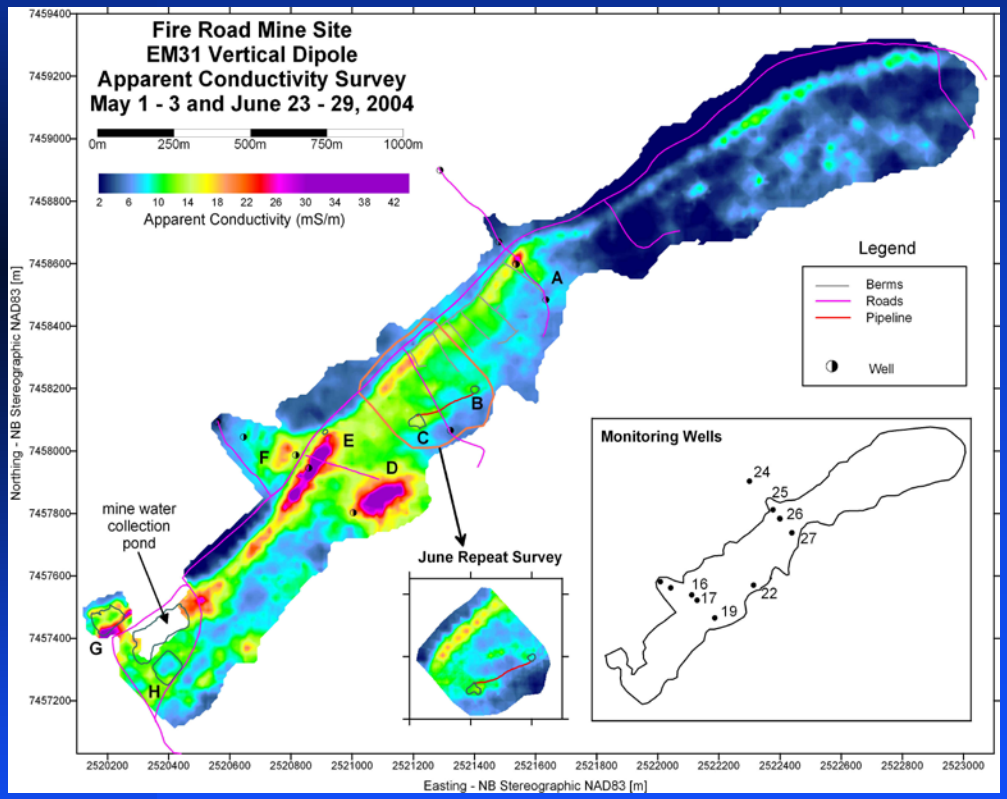
Comparison of Topography and Apparent Conductivity



Apparent Conductivity Survey Results - linear anomaly along highwall



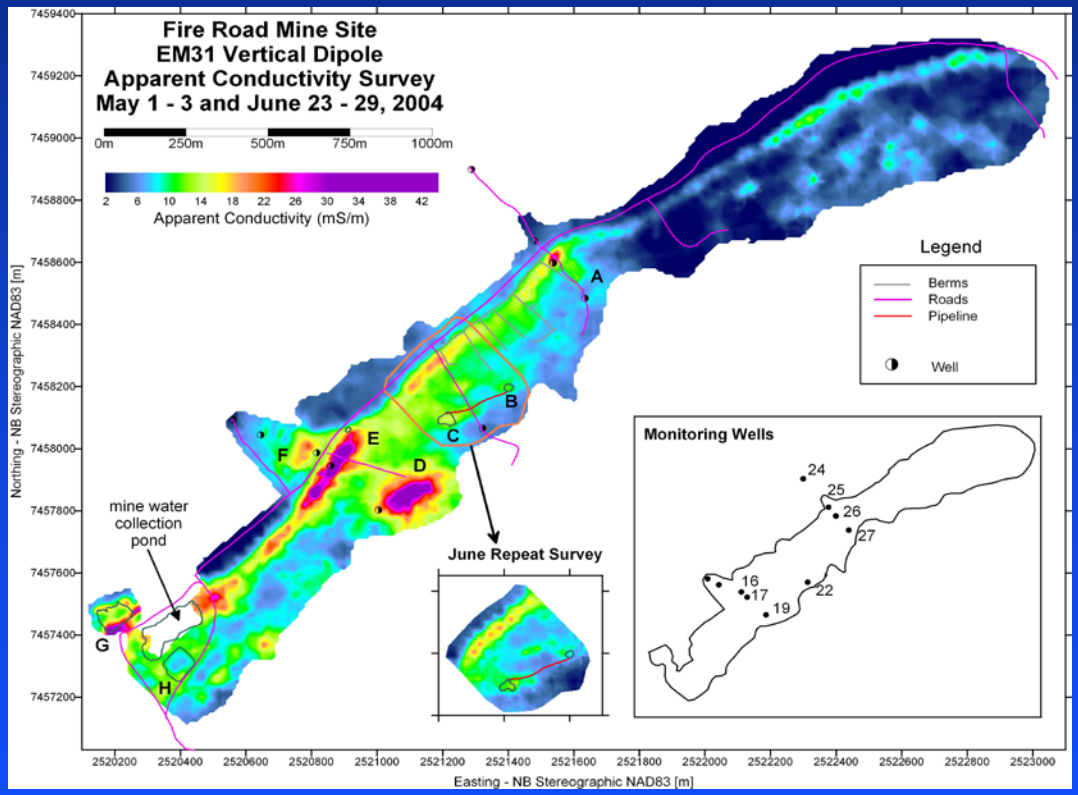
Apparent Conductivity Survey Results - other notable discrete highs



- Conductivity highs at B and C coincide with the discharge location of the sludge pipeline in 2002 and 2003.
- Note seasonal variation.

Apparent Conductivity Survey Results - evidence that sludge is plugging voids in the waste rock

- Large volume of sludge deposited on topographic high between locations E and D.
- Drain constructed to direct flow to mine water holding pond.

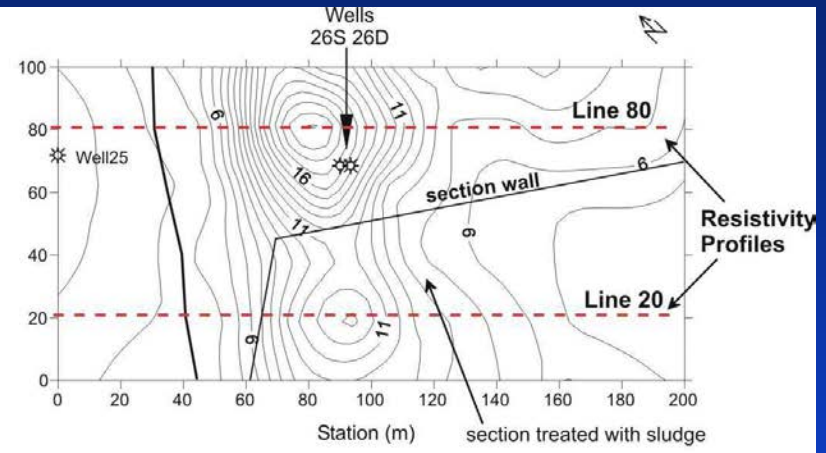


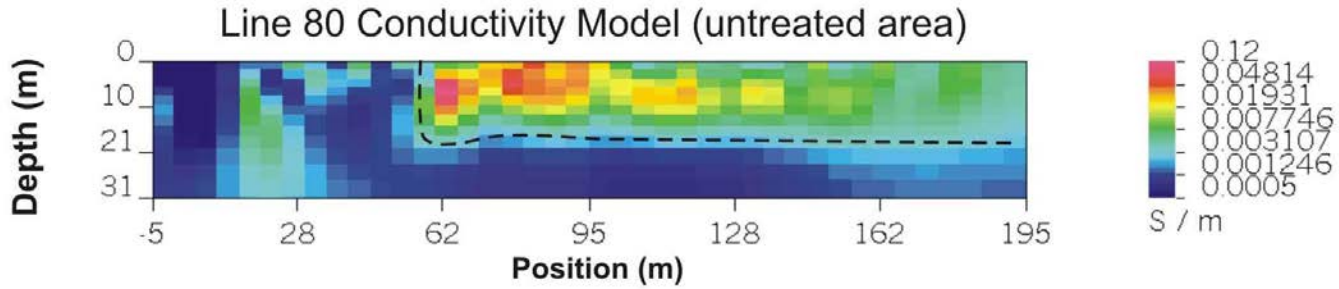
Developing a Mapping Model for Sludge Enhanced Apparent Conductivity

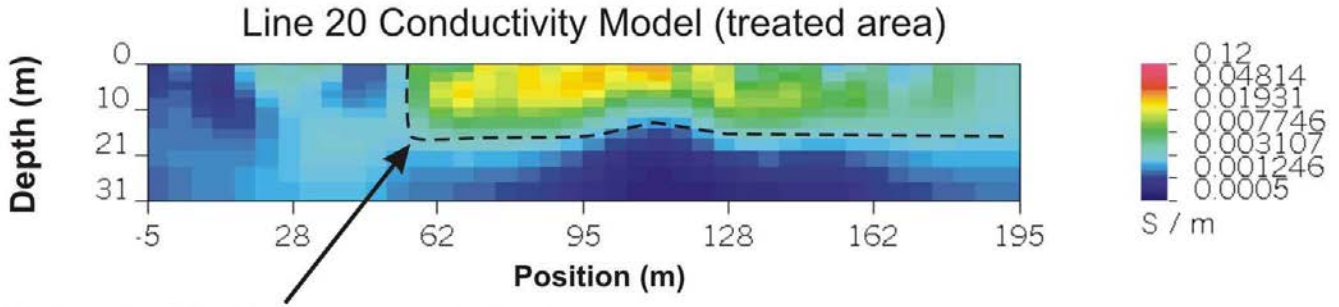
- Elevated conductivities in areas of past sludge deposition are most likely the result of sludge infilling the void space in the waste rock above the water table
  - vadose zone filled with moist sludge would be expected to be more conductive than if filled with air
- What about at depth?
  - What's happening vertically within the waste rock?

Mapping Vertical Distribution of Sludge in the Waste Rock

2D Resistivity Imaging over Untreated (top) and Treated (bottom) waste rock







Challenges of Mapping Sludge Distribution Using Apparent Conductivity

- Since moist sludge had conductivities similar to mine water (Yeomans, T., 2005), the challenges with interpreting the apparent conductivity maps include:
  - Which anomalies are associated with the presence of sludge versus mine water
  - Distinguishing conductive zones with depth--delineating whether the sludge is below or above the water table
- Current investigation to determine optimal time of year
  - when sludge-bearing zones contrast most sharply with surroundings
  - when there may be less interference with determining sludge with the presence of mine water

What is the 2006 Status of the Sludge Management Project?

- The disposing of neutralization sludge into the waste rock had several speculated benefits including:
  - minimize land disturbance
  - low cost final disposal area for sludge
  - decrease personal liability
    - No new ponds.
    - Sludge on the surface is dry.
  - utilization of any excess alkalinity
    - Not much in sludge; short term from the recirculated dredge water.
    - No obvious trend in monitoring wells in backfilled area.
  - reduce diffusion of oxygen into the waste rock
    - Sludge is plugging voids.
    - Sludge in the waste rock has affected the flow pattern of the groundwater through the backfilled site.
    - Use of apparent conductivity mapping could assist in managing sludge deposition locations.

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