Quantum Environmental Group
Barrier Wall Presentation
REMTECH 2005
Banff, Alberta

Quantum Environmental Group

DIVISIONS

- *Quantum Hazmat Inc.*
- *Quantum Facilities Inc.*
- *Quantum Remediation Inc.*
- *Quantum Emergency Response Inc.*

PARTNERSHIPS

- *Envirogreen Technologies*
- *Windmill Developments Ltd.*

ALLIANCES

- *Burrard Clean Operations*

Barrier Wall Presentation

Agenda

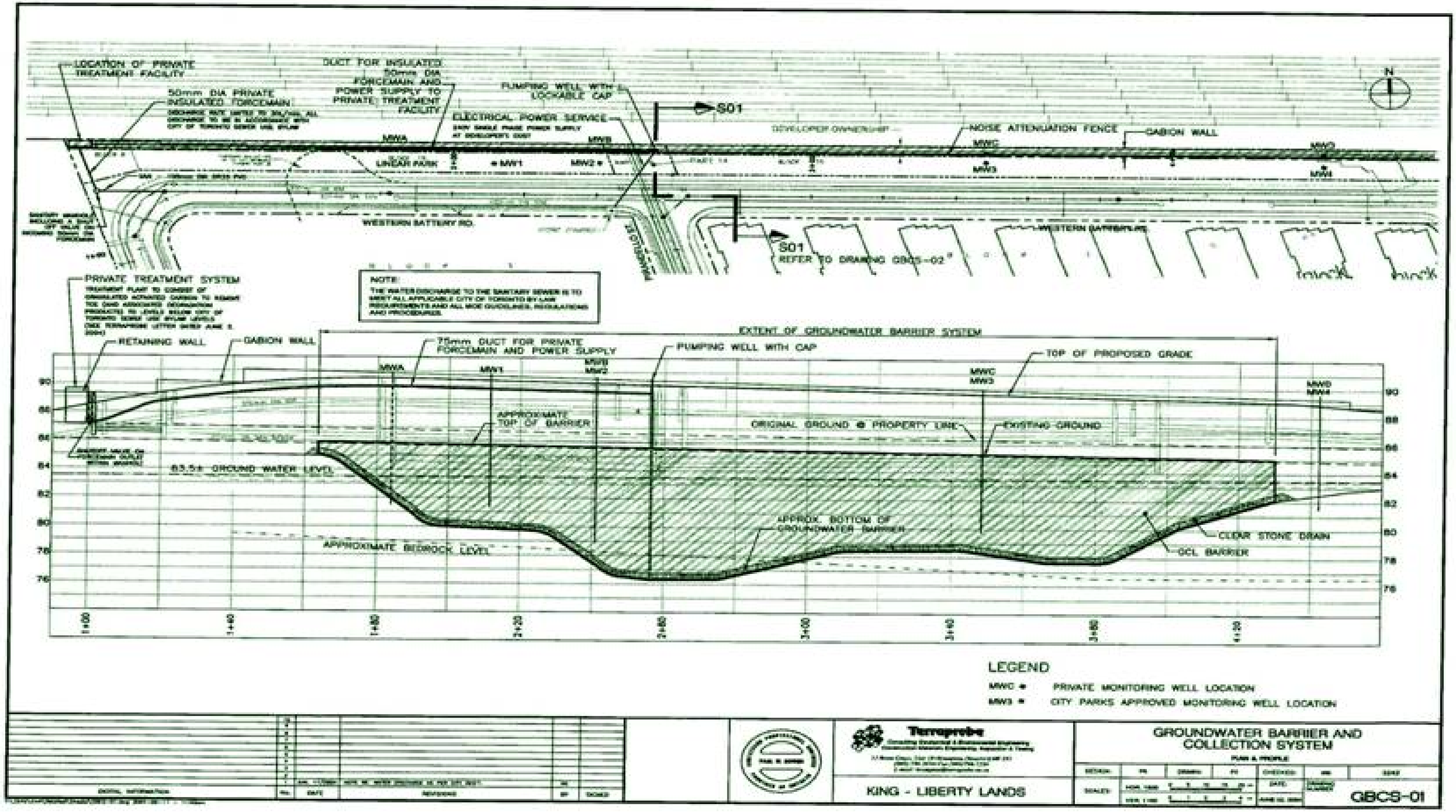
- Clay / Clay Bentomat Barrier Walls
- Soil Bentonite Admixture Barrier Walls
- Waterloo Barrier Walls
- Bentonite Slurry Barrier Walls
- Permeable Reactive Barrier / Jet Grout Barrier Walls
- Slurry Slot Excavation / Low Strength Concrete Barrier Walls
- Caisson Walls

Confidential Site – Toronto, ON
Bentomat Liner Cut-off Wall

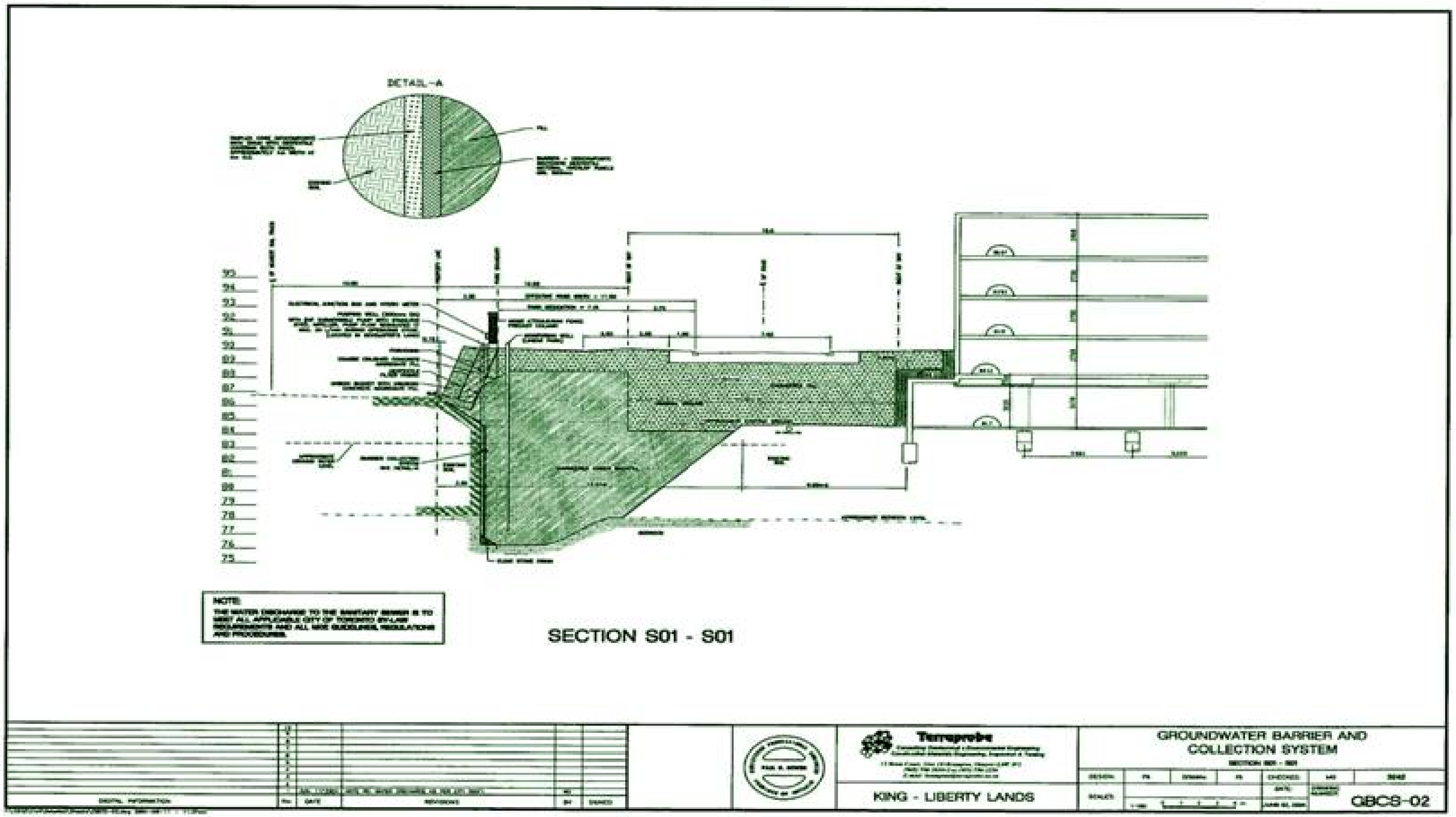
The Challenge

- Install 270lm vertical impermeable barrier at P/L, at depths from 3-10 mbg in a safe manner that minimized geotechnical and employee risk;
- Design permeability had to be <10E-8 m/s;
- Install upgradient drainage and dewatering system

Confidential Site – Toronto, ON
Bentomat Liner Cut-off Wall



Confidential Site – Toronto, ON
Bentomat Liner Cut-off Wall



Confidential Site – Toronto, ON
Bentomat Liner Cut-off Wall

Soil Nailing

- 2m long 3/8” rebar nailed onto vertical excavation face on 2m spacing horizontal and vertical
- Hang 4” steel mesh on protruding rebar
- Tie mesh to rebar and trim protruding rebar

Confidential Site – Toronto, ON
Bentomat Liner Cut-off Wall

Install French Drain and Wick Drain

- 0.5 m wedge of 19mm crush placed in base
- Wick drain material hung from lifeline and draped down vertical face
- Base elevation of barrier graded to a low collection point to reduce upgradient pore pressure

Confidential Site – Toronto, ON
Bentomat Liner Cut-off Wall

Hang Bentomat Liner

- Bentomat Liner composed of 3/8" thick bentonite stitched between 2 woven geofabrics
- Cut liner at depth + 1 m
- Clamped to 4.5 m long 2x6 and hung from material lifeline by excavator
- Liner covers French Drain and 0.6 m overlap on adjacent liners
- Backfilled and compacted with hoepack at base
- Backfilled and compacted to grade using sheeps foot roller

Confidential Site – Toronto, ON
Bentomat Liner Cut-off Wall

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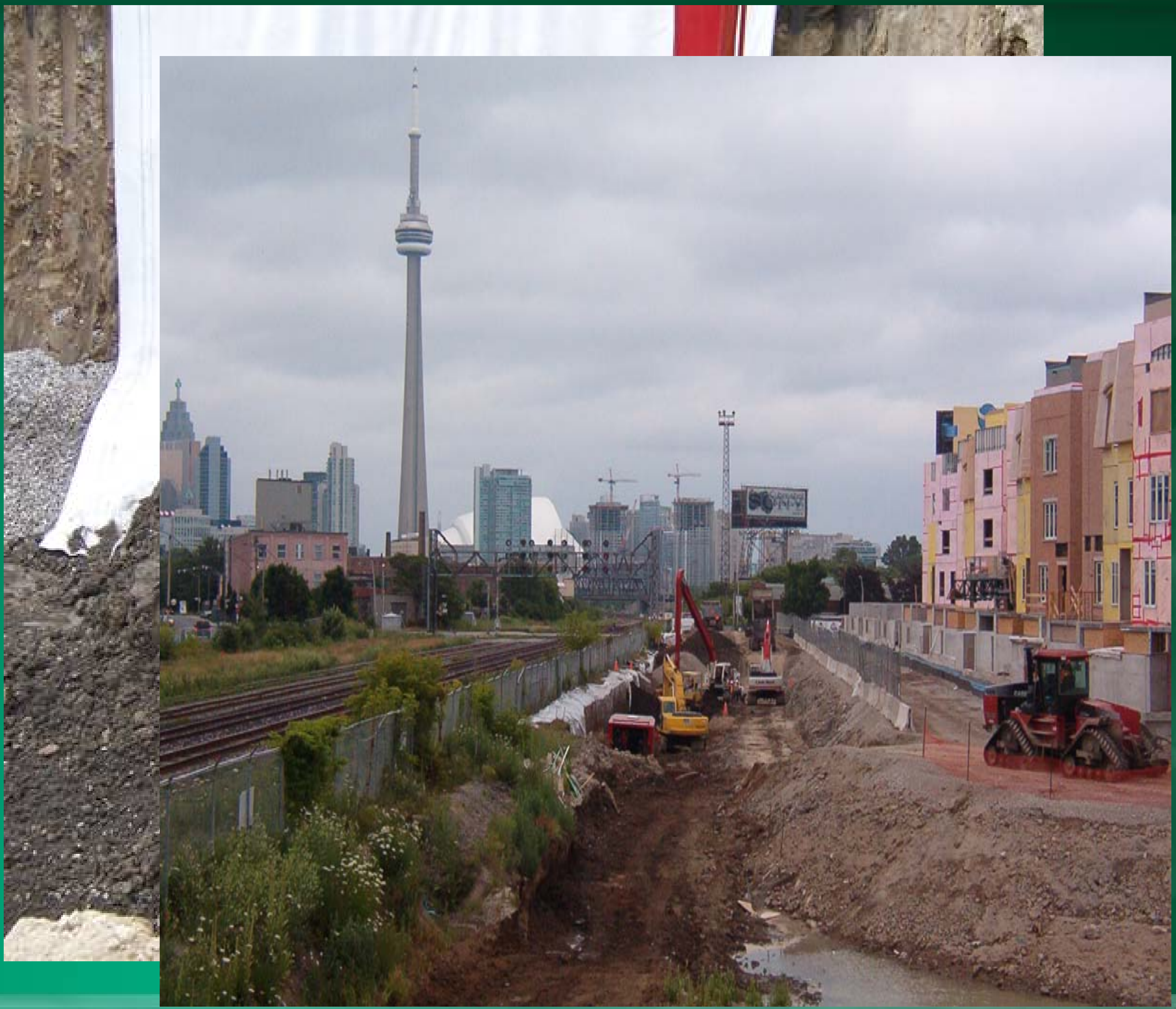
Confidential Site – Toronto, ON
Bentomat Liner Cut-off Wall



Bentomat Liner Cut-off Wall Advantages

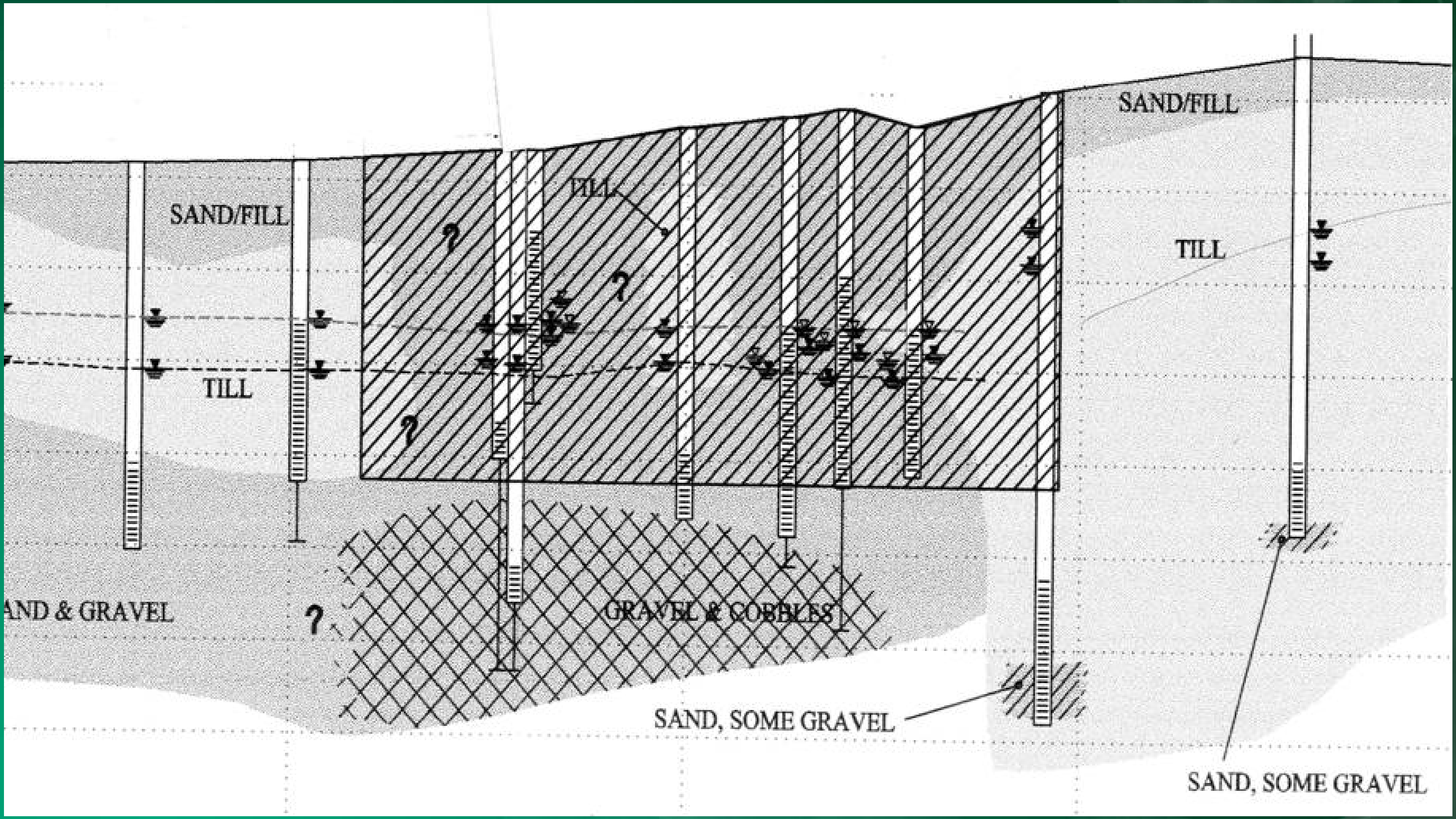
- Allows for variable depth profiles
- Can be manufactured to meet a design permeability up to 10E-12 m/s
- Relatively inexpensive barrier material, no field welding required as overlap and hydration form continuous barrier
- Simple to install on slopes
- Can be installed without specialized equipment

Confidential Site, BC - Design/Build Waterloo Barrier & Insitu LNAPL Collection System

The Challenge

- Design/install an impermeable barrier to 8.5 mbg adjacent to foreshore in very dense till
- Key barrier into low-permeability sediments to prevent short circuiting
- Design/install 13 LNAPL skimmers package in active railyard to collect LNAPL

Confidential Site, BC - Design/Build Waterloo Barrier & Insitu LNAPL Collection System



Confidential Site, BC - Design/Build Waterloo Barrier & Insitu LNAPL Collection System

Solution

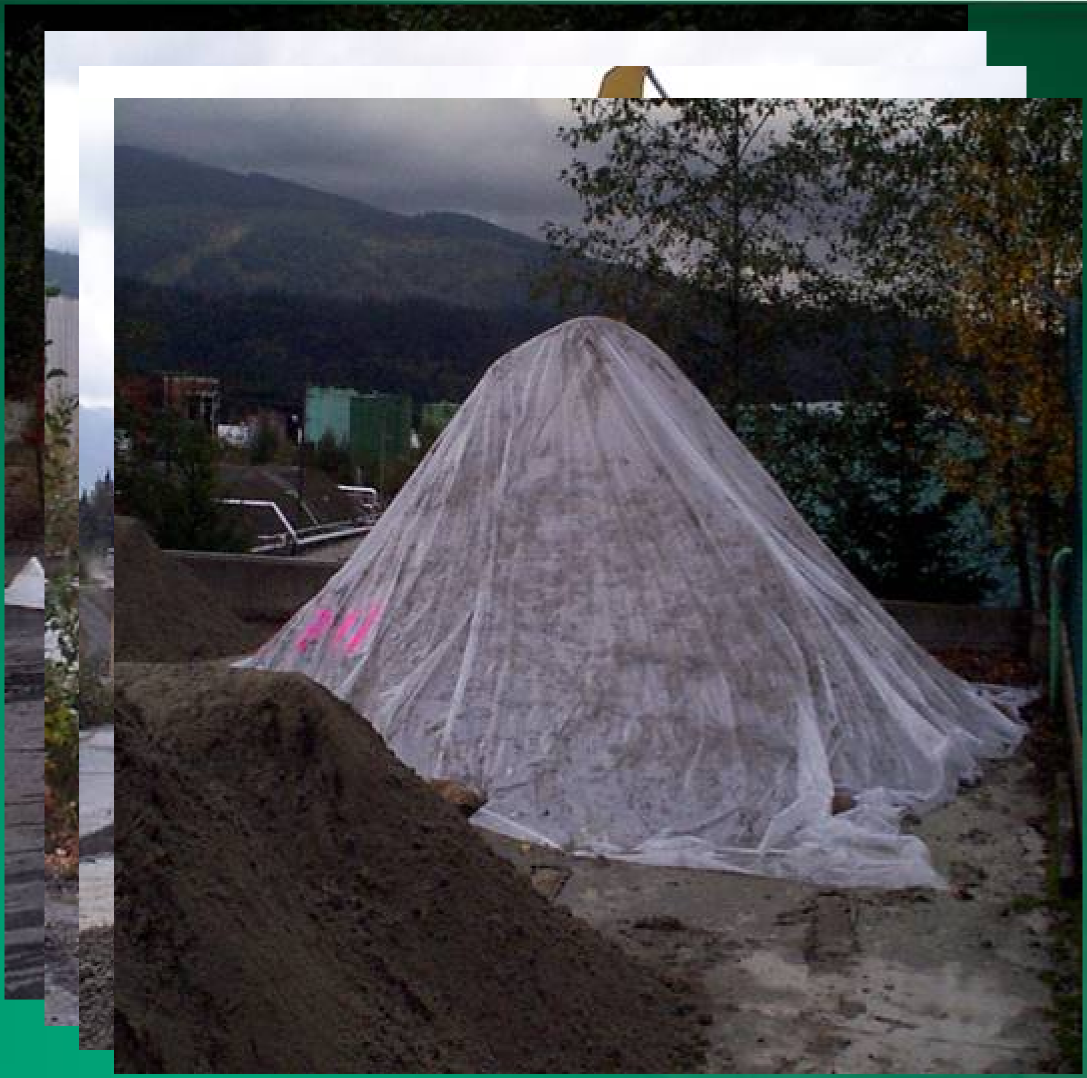
- Dry excavation of an 8.5 m deep, 1.5 m wide trench backfilled with lightly-compacted sand
- Design, testing and placement of an engineered, low-permeability, soil-bentonite admixture to key barrier into till sediments
- Installation Waterloo Barrier sheet pile wall, with joints flushed and grouted
- Advancement of LNAPL recovery wells
- Design, fabrication, installation and commissioning of 13 LNAPL skimmer unit complete with reservoirs and controls

Confidential Site, BC - Design/Build Waterloo Barrier & Insitu LNAPL Collection System

Soil Bentonite Admixture Design and Testing

- Silty sand (fines/silt content >20%)
- Varying amounts of powdered bentonite
- Compactive effort – 90 to 100% SPD
- Moisture content ~10 to 12%
- Constant Head permeability testing
- K values between 10E-8 to 10E-12 m/s

Confidential Site, BC - Design/Build Waterloo Barrier & Insitu LNAPL Collection System



Preparation of Soil-Bentonite Admixture

- Sieve/moisture analysis of sand stockpile
- Weighing and dry mixing of bentonite and sand
- Sieve analysis of several samples from each stockpile to confirm proper mixing and correct material quantities
- Covering of stockpiles to prevent hydration

Confidential Site, BC - Design/Build Waterloo Barrier & Insitu LNAPL Collection System

Confidential Site, BC - Design/Build Waterloo Barrier & Insitu LNAPL Collection System

Admixture Placement

- 5 lm, 8.5 m deep at each end of trench
- Excavation to be kept dry to meet 95% SPD
- Method spec. based on lift thickness (1 m) and compactive effort (sec/m2) field tested through densometer readings
- On-site geotechnical engineer performed QA/QC penetration testing from man bucket

Confidential Site, BC - Design/Build Waterloo Barrier & Insitu LNAPL Collection System

Erect Driving Rack

- Maintains wall alignment and plumb
- Provides safe work area for sheet handler/threader
- Sufficiently stable soils req'd to support rack, particularly during wind events

Confidential Site, BC - Design/Build Waterloo Barrier & Insitu LNAPL Collection System

Threading Sheets

- First sheet advanced to ~50% depth
- Entire rack filled with treaded sheets advanced slightly into formation
- Once entire rack filled, sheet driving begins across entire rack
- Vibratory hammer used to advance sheets

Confidential Site, BC - Design/Build Waterloo Barrier & Insitu LNAPL Collection System

Sheet Driving

- Rack used to drive to ~70% penetration, freely driven for remainder
- Rack re-located for next run
- Plumb checked on each sheet while driving +/– 1% off-plumb tolerance

Confidential Site, BC - Design/Build Waterloo Barrier & Insitu LNAPL Collection System

Joint Jetting and Grouting

- Joint cleaned of soil/rock by advancing high pressure water hose down to bottom of joint
- Joint pumped full of low-permeability grout mixture and allowed to harden
- Provides permeability of 10E-11 m/s

Confidential Site, BC - Design/Build Waterloo Barrier & Insitu LNAPL Collection System

In-situ System Installation

- Advance 100mm diameter recovery wells
- Design, fabricate, install 13 LNAPL skimmer packages
- Install underground electrical to each skimmer
- Skimmers inc. reservoirs, secondary containment and all required electrical controls
- Commission system and prepare operations manual

Confidential Site, BC - Design/Build Waterloo Barrier & Insitu LNAPL Collection System

Engineered Fill Cut-off Walls - Advantages

- Allows for variable depth profiles
- Can be engineered for various design permeabilities (10E-7 to 10E-12 m/s)
    - Sand gradation (> fines content lowers permeability; >20%)
    - Bentonite content
    - Compactive effort (90 to 100 SPD)
- Wall thickness can be designed to meet required flow characteristics
- Allows for post-installation testing of barrier material
- Engineered material is easy to handle and requires no specialized equipment to mix and install.

Confidential Site, BC - Design/Build Waterloo Barrier & Insitu LNAPL Collection System

Waterloo Barrier - Advantages

- Allows for very deep barrier wall (up to 20m)
- Tight continuous interlock filled with grout provides barrier integrity
- Can be driven with conventional pile driving equipment
- Can be removed and reused
- Certified for 1x10E-11 m/s

Confidential Site, BC - Design/Build Bentonite Slurry Wall Barrier

The Challenge

- Install a 125 m long impermeable barrier to 8.5 mbg to mitigate potential migration of impacts into Quesnel River
- Design permeability to be 1x10E-8 m/s
- Barrier to be within 0.6m of an on-site structure
- Barrier located within 3m of riprap bank / river

Confidential Site, BC - Design/Build Bentonite Slurry Wall Barrier

Solution

- Work with consultants to design and subsequently install an 8.5 m deep, 1.5 m wide, 125 m long bentonite slurry wall, backfilled with an engineered, low-permeability soil admixture
- Design and laboratory testing of an engineered, low-permeability, soil-bentonite admixture (trench backfill) to confirm K values
- Design trench slurry mixing and handling plan
- Design of soil admixture (trench backfill) mixing, handling and QA/QC plan
- Design of trench excavation and backfilling plan
- Preparation of Health and Safety Plan

Confidential Site, BC - Design/Build Bentonite Slurry Wall Barrier

Slurry Trench Excavation – Basic Principles

- Trench wall stability is maintained by excess head of bentonite slurry in the trench (slurry level must be continually maintained above existing gw level)
- Excess head maintained by minimizing loss of slurry to formation by:
  - Reduced K at trench interface as bentonite fills voids in formation
  - Monitoring and maintaining viscosity of bentonite slurry in the trench (temp., % bentonite, % sand)
  - Introducing make up slurry
- Bentonite must be completed hydrated in slurry (mixing procedure, pH, temperature, cat ion conc. dependant) to maintain viscosity and remain available to fill voids at interface
- Hydraulic conductivity of formation reduced as a result of the introduction of bentonite

Confidential Site, BC - Design/Build Bentonite Slurry Wall Barrier

Field Preparation of Bentonite Slurry

- Water supply conditioned with soda ash to raise pH
- Dry powdered bentonite mixed with water using shear type pumps (mud mixers)
- Slurry re-circulated in baffled mixing tanks for full hydration
- Tested to meet a minimum Marsh cone standard of 38 seconds (viscosity test)
- Pumped to a holding basin and re-circulated in basin

Confidential Site, BC - Design/Build Bentonite Slurry Wall Barrier

Field Preparation of Soil-Bentonite Admixture (Trench Backfill)

- Weighing and dry mixing of 50% of the required bentonite with sand
- Addition/mixing of the remaining required bentonite in dissolved format (hydration)
- Addition of water to obtain 5”-6” slump test
- Slump test dictates self-placement characteristics of trench backfill

Confidential Site, BC - Design/Build Bentonite Slurry Wall Barrier

Trench Excavation and Backfilling

- 1 m deep bench excavated – control slurry and spoil/attain design depth
- 2 excavators working simultaneously excavating and backfilling
- Slurry maintained at ~1mbg (gw @ 3.5mbg)
- ~15 m of trench open at once
- Trench backfill placed (3H:1V) and self compacting
- Continual depth sounding of trench to confirm depth and backfill location

Confidential Site, BC - Design/Build Bentonite Slurry Wall Barrier

Bentonite Cut-off Walls - Advantages

- Allows for variable (unknown) depth profiles and direction changes
- Can attain significant depths (limited by machine size)
- Ideal for loose formations with cobbles/gravels (precludes driven barriers)
- Trench backfill can be engineered for various design permeabilities (10E-7 to 10E-10 m/s): Sand gradation and bentonite content
- Wall thickness can be designed to meet required flow characteristics, FOS
- Allows for post-installation testing of barrier material
- Engineered trench backfill material is relatively easy to handle and requires limited specialized equipment to mix and install
- Relatively cost-effective option
- Abundance of technical literature – level of confidence for owners/consultants

Confidential Site, BC - Design/Build – Permeable Reactive Barrier

The Challenge

- Remove source of special waste heavy metals contamination through excavation.
- Construct a special waste storage facility to accept special waste metal contaminated soils excavated from the site
- Install an in-ground passive treatment wall to treat metal contaminated water generated on the site prior to discharge to the ocean.

Confidential Site, BC - Design/Build – Permeable Reactive Barrier

Solution

- Install a 750lm, 18m deep, 2m wide PRB to treat contaminated groundwater prior to discharge to the ocean
    - Design guar gum slurry, mixing plant, QA/QC plan
    - Mix proprietary trench media, design QA/QC plan
    - Excavate/backfill trench simultaneously monitoring depth and backfill profile
    - Monitor trench slurry QA/QC to ensure trench stability
    - Clay cap on trench
- Jet grouting in area of GVRD water mains

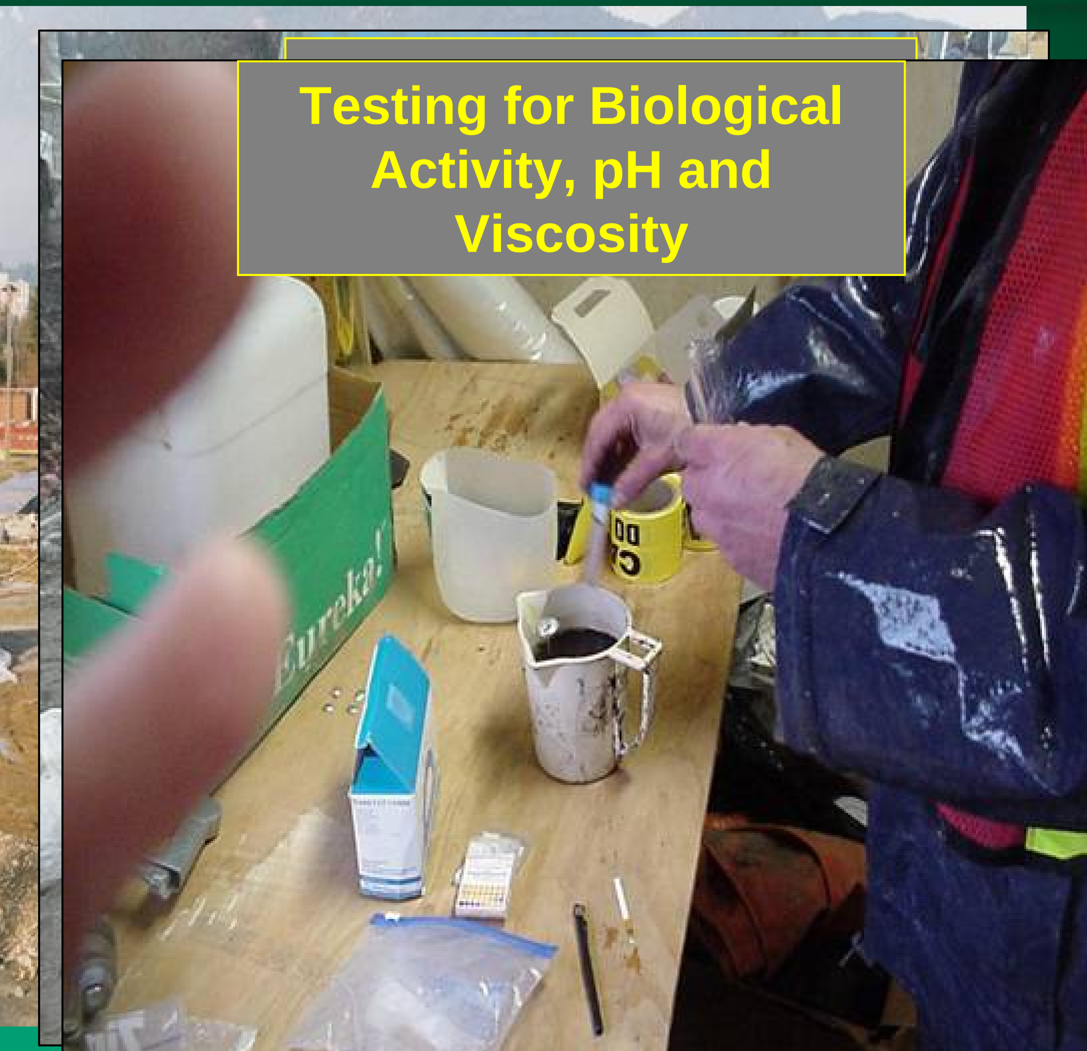
Confidential Site, BC - Design/Build – Permeable Reactive Barrier

Confidential Site, BC - Design/Build – Permeable Reactive Barrier

Filter Media Mixing & Testing

- Media comprised 85% pea gravel, 14% compost, 1% lime
- Numerous samples from each batch mixture were tested by owner
  - Composition
  - K (preferential pathway)
- Mixed using a loader with scale bucket and excavator
- Thorough mixing required to ensure no”dead spots’ in wall

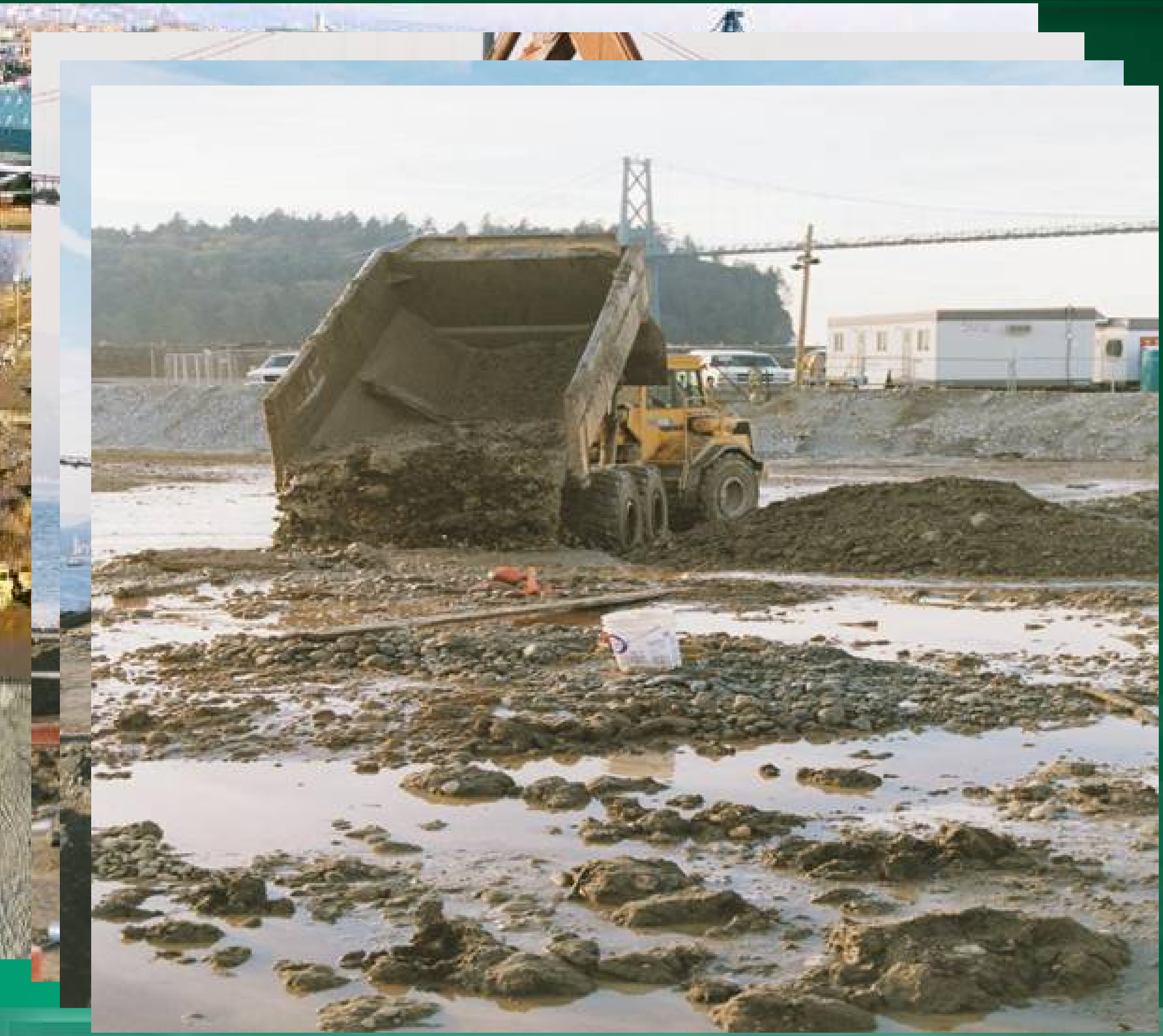
Confidential Site, BC - Design/Build – Permeable Reactive Barrier



Guar Gum Slurry Mixing/ Testing

- Guar gum (a food thickener) used as i degrades over time - PRB
- Guar gum slurry mixed using oil-field mud plant (shear pump) and stored in a 20000 USG tank
- Plant comprised 3 – 20000 USG tanks
- Slurry breaks down in 48 hours at 18C
- Finished and trench slurry tested for pH, viscosity and bacterial count
- Make up slurry always required
- 3m Factor of Safety in slurry trench

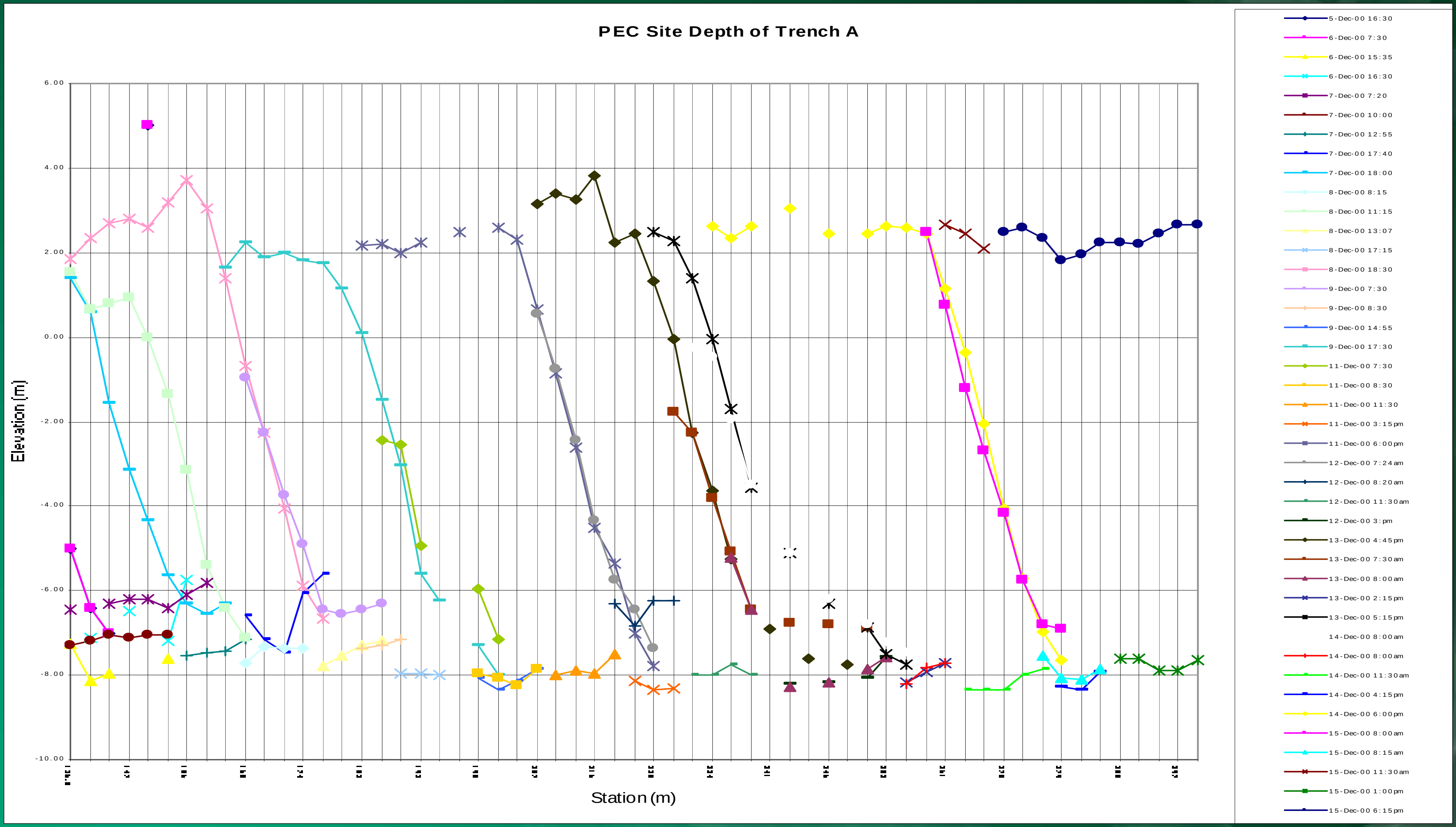
Confidential Site, BC - Design/Build – Permeable Reactive Barrier



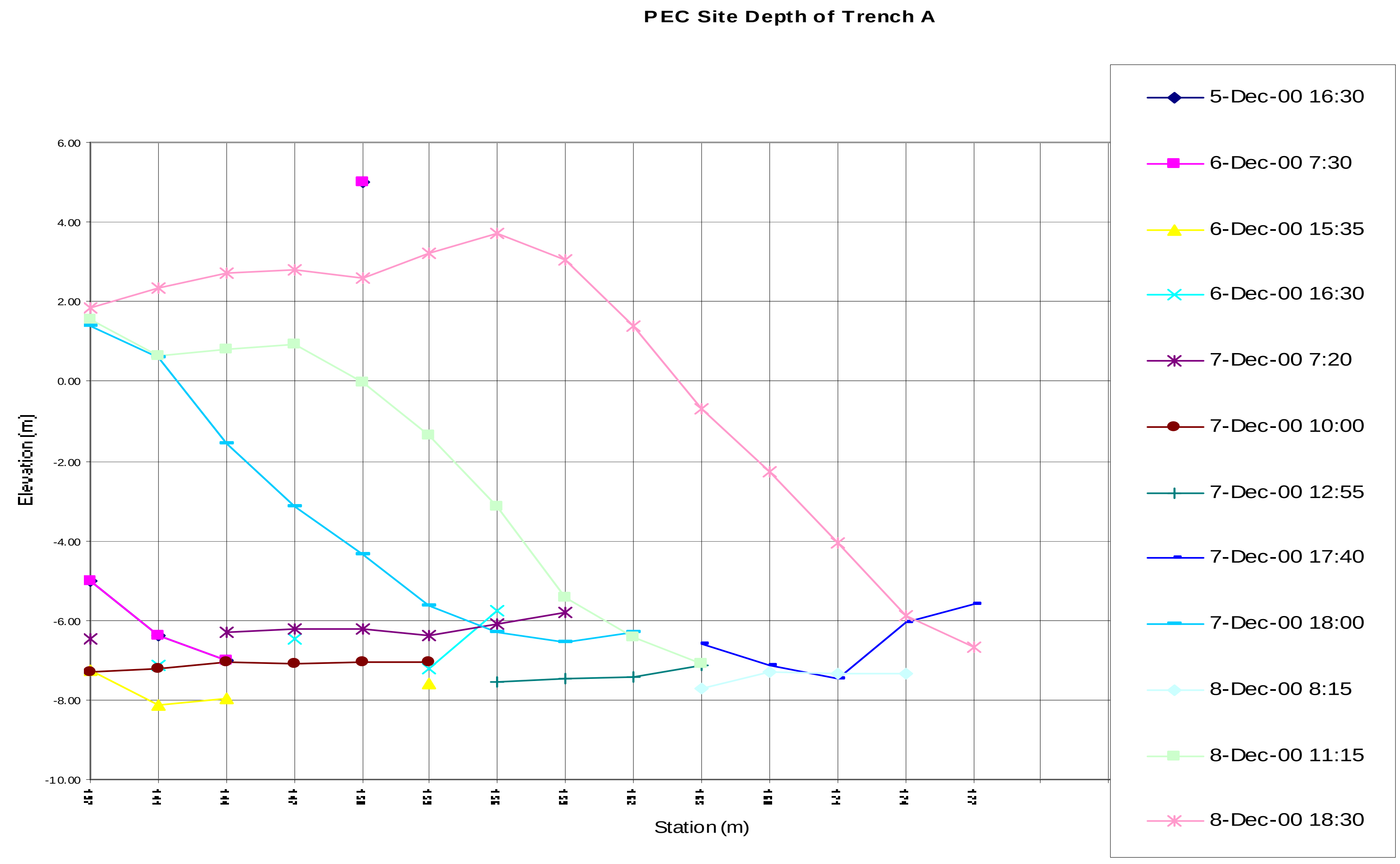
Trench Excavation and Backfilling

- 200T excavator and 125T crane excavating/backfilling simultaneously, 50lm of trench open
- Removal of 20,000m3 of spoil, placement of 18,000m3 of filter media and clay cap
- Real time surveying and monitoring trench depth and backfill profile
- Sheet pile restraint designed for emergency stoppages

Confidential Site, BC - Design/Build – Permeable Reactive Barrier



Confidential Site, BC - Design/Build – Permeable Reactive Barrier



Confidential Site, BC - Design/Build – Permeable Reactive Barrier

Confidential Site, BC - Design/Build – Permeable Reactive Barrier

Gar Gum Slurry Permeable Reactive Barriers - Advantages

- Allows for variable (unknown) depth profiles and direction changes
- Can attain significant depths (limited by machine size)
- Ideal for loose formations with cobbles/gravels (precludes driven barriers)
- Guar gum slurry breaks down (digested by bacteria) over time
    - Does not alter regional hydrogeology
    - Minimal / no deleterious effect on fish/wildlife
- Trench design life can be engineered for varying duration (thickness)
- On-going pump and treat requirement eliminated
- Can be used different contaminants (media specific)
- Ideal for very large sites

Confidential Site, Toronto, ON - Bentonite Slurry, Concrete, Caisson Wall

The Challenge

•Excavate entire site to 11 m below grade – no anchors allowed on City property;

•Shoring mechanism must prevent loss of soil behind shoring wall – compromise off-site utilities

• Install impermeable barrier on 3 property lines from 6 to 11m below grade;

•Hydraulic conductivity to be < 10E-8m/s

Confidential Site, Toronto, ON - Bentonite Slurry, Concrete, Caisson Wall

Solution

- Installation of H-pile to 11mbg and lagging (inc. rakers) to 7mbg to shore excavation wall on N and E P/L
- Slurry slots excavations backfilled with low strength concrete from 7 to 11mbg on N and E P/Ls to remove impacted soil and provide hydraulic barrier
- Installation of caisson wall on W P/L to 11m below grade to support adjacent parade and provide hydraulic barrier
- Slot excavation of impacts at depth along caisson wall, backfilled with low strength concrete
- Wet excavation of entire central portion of site

Confidential Site, Toronto, ON - Bentonite Slurry, Concrete, Caisson Wall

H-Pile and Lagging in North and East Portion of Site

- 760 mm caissons open drilled to 11m, filled with H-pile and low strength concrete (4MPa)
- Waler installed at grade and excavation between H-Piles completed with timber lagging installed to 7 mbg
- Once at 4 mbg, rakers welded and set in 30 MPa concrete footings excavated at 7-9 mbg
- Bulk excavation completed to 7 mbg in north and east portion of site, with waler attached at 6.5mbg.

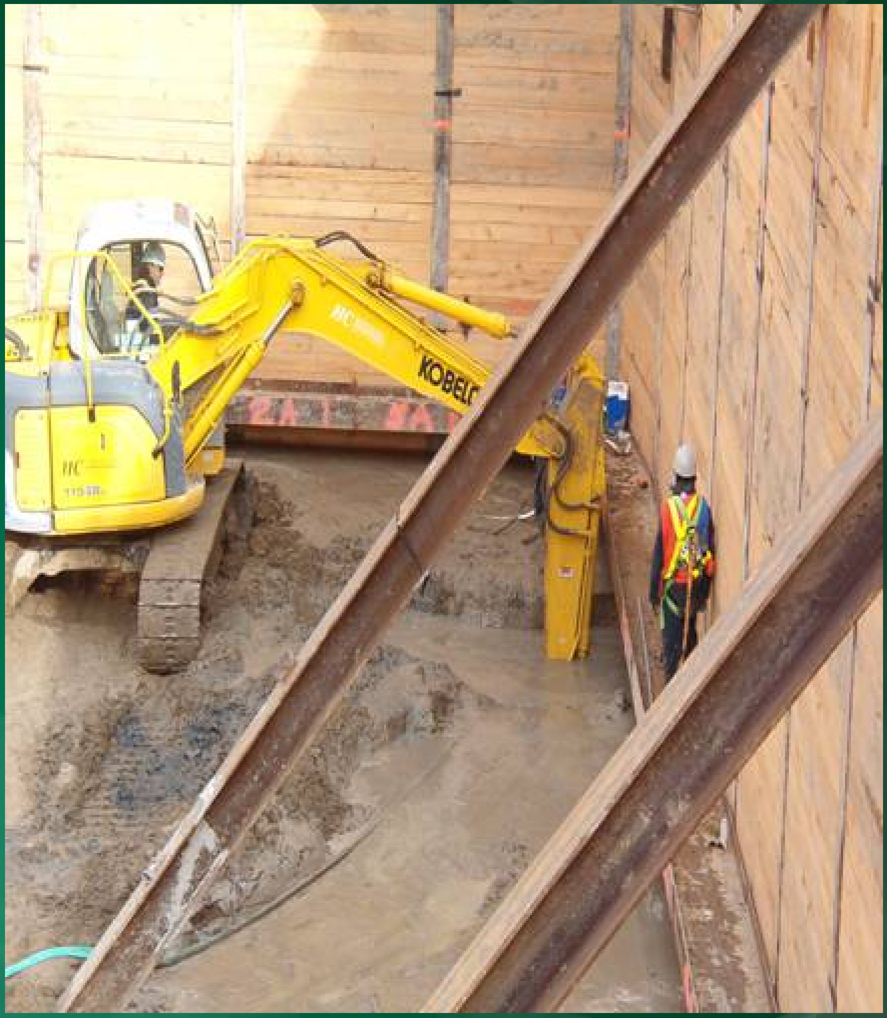
Confidential Site, Toronto, ON - Bentonite Slurry, Concrete, Caisson Wall

Confidential Site, Toronto, ON -
Bentonite Slurry, Concrete, Caisson Wall

Bentonite Slurry/Concrete Wall

- Slots excavated to 11mbg using bentonite slurry to shore excavation wall
- Slot backfilled with low strength concrete to provide impermeable barrier
- Alternating slot technique used with over excavation into adjacent slot to ensure continuous impermeable wall
- Bentonite slurry mixed using shear pump to meet 45 second Marsh Cone viscosity test

Confidential Site, Toronto, ON -
Bentonite Slurry, Concrete, Caisson Wall



Bentonite Slurry/Concrete Cut-off Walls – Advantages

Allows for variable depth profiles

Allows for installation in unconsolidated material

- Can be engineered for various design permeabilities (10E-8 to 10E-12m/s)
  - Concrete additives (bentonite) can lower permeability
- Wall thickness can be designed to meet required flow characteristics
- Low strength concrete provides temporary structural excavation support and re-excavateble.

Confidential Site, Toronto, ON - Bentonite Slurry, Concrete, Caisson Wall

Caisson Wall Barrier Installation

- From 3mbg bench, 13, 915mm dia. open boreholes were drilled on a specified spacing to ~11mbg and filled with an H-Pile and LS concrete to 3 mbg; H-Piles were used in select caissons to construct a shoring support wall
- Subsequently, 3, 864mm dia. ‘filler’ boreholes were advanced between each of the 13 previously drilled, reinforced and filled boreholes
- ‘Filler’ boreholes were drilled with a minimum 0.2m overlap into the adjacent caisson and filled with LS concrete; ’filler’ borehole 2 was drilled first, followed by ‘filler’ boreholes 1 and 3
- A waler was installed at 3.5 mbg (top of caisson wall) to further stabilize the cantilevered caisson wall
- Slot excavations were conducted to ~11mbg, with slots backfilled with LS concrete.

Confidential Site, Toronto, ON -
Bentonite Slurry, Concrete, Caisson Wall

Confidential Site, Toronto, ON - Bentonite Slurry, Concrete, Caisson Wall

Concrete Caisson Barrier Walls - Advantages

Solid structure, cantilevered excavation wall support system

- can be advanced right at property line
- no off-site encroachment or agreements necessary
- no rakers required (simplifies backfilling)

Shoring excavation support and impermeable barrier installed simultaneously

Low strength concrete can be easily excavated for site servicing (vs. pulling H-piles and lagging)