An Integrated Approach to

Risk-Based Remediation of a Former Bulk Fuel Storage Facility Adjacent a Marine Environment

Presented by

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Outline

- Site Location and History
- Site Investigation and Conceptual Model
- Remedial Approach
  - Groundwater modeling to assess natural attenuation rate
  - SVE/Bio-venting and Air Sparging/Bio-sparging
- Groundwater Modelling
- Remediation System Detail
- Observations and Lessons Learned

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Site Location and History

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Site Location and History

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Site Location and History

- Bulk fuel storage facility since 1940s
- Catastrophic failure of gasoline tank following a rock fall
- Estimated 0.5 million gallons spilled, ultimately flowing into small boat harbour
- Other historic leaks of both gasoline and diesel fuel have contaminated soil and groundwater
- ASTs decommissioned 1995 to 1996
- Site paved and currently used as a cruise ship dock

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Site Location and History

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Site Location and History

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Site Investigation

- Geotechnical work for the cruise ship dock (1995)
- Environmental investigation (2000+) consisted of:
  - Test-pitting
  - Soil gas survey
  - Sediment sampling
  - Borehole investigation
  - Groundwater sampling
  - Tidal response monitoring

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Conceptual Site Model

- Medium to course sand and gravel fill, underlain by talus deposits and bedrock ($K \sim 3x10^{-4}$)
- Average groundwater velocity 0.5 to 1.5 m/day
- Depth to groundwater at ~6 m below grade on average
- Significant tidal influence
  - Up to 3.5 m variation in groundwater elevation
  - Net groundwater flow direction towards the ocean
- Extensive residual NAPL across site

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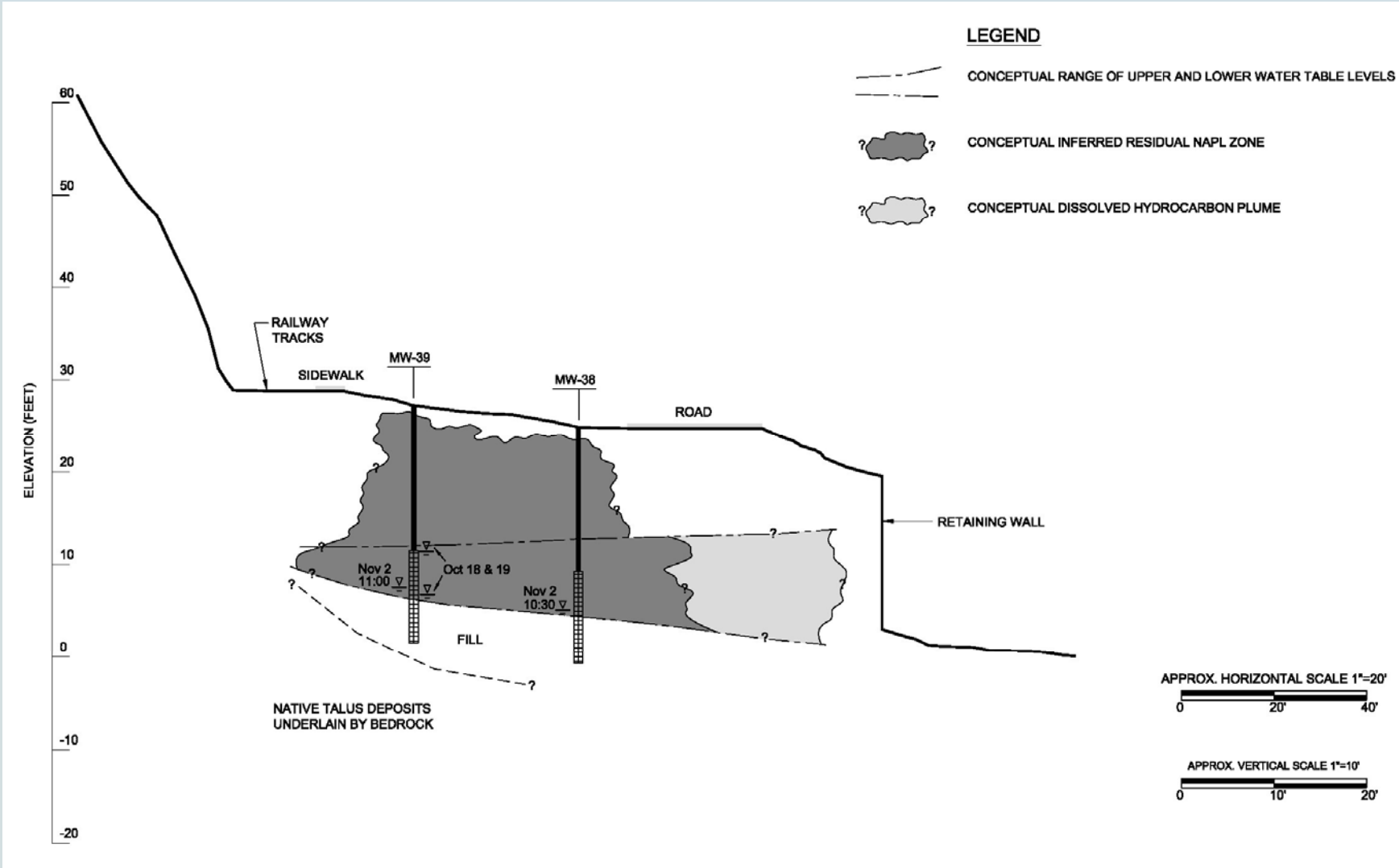
Conceptual Model



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Remedial Approach

- Risk-Based Correction Action Approach
  - Potential risks to aquatic receptors
  - Potential risks to humans due to vapours
  - Limited direct exposure as Site is paved
- Primary Goal:
  - Minimise potential exposure to aquatic receptors by minimising NAPL mobility and dissolved transport of petroleum hydrocarbons

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Remedial Approach

- Remedial Options Screening
  - Excavation limited by geotechnical and physical constraints
  - Hydraulic containment not practical due to high pumping rates required
  - Oxidation not practical due to proximity to ocean and extent of contamination
- SVE / Bioventing and Air Sparging / Biosparging
  - remediate residual NAPL and prevent mobilization
  - to enhance natural attenuation rate

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Groundwater Modelling

- Purpose:
  - to assess attenuation rate
  - to determine remedial targets
- Site Specific Data used for Modeling
  - rising head slug tests
  - tidal survey
  - conservative assumptions used for model
- Model Validation
  - Foreshore reconnaissance and sediment sampling
  - Mini-piezometers installed along shoreline (sampled during falling tide)

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Groundwater Modelling

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Groundwater Modelling

- Modeling
  - Finite element numerical modeling (FEFLOW)
  - Model incorporates tidal fluctuations and the groundwater to seawater interaction
  - Incorporated advection, dispersion, retardation and aerobic biodegradation
  - Calibrated to observed groundwater fluctuations

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Groundwater Modelling

- Modeling Results
  - Predicted time-averaged concentrations at discharge point less than 1% of source concentration
  - Assumed residual NAPL source 10m from retaining wall
  - Predicted that concentration of groundwater at discharge would be below ADEC clean-up levels

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Groundwater Modelling

- Modeling Validation
  - Petroleum hydrocarbons were not detected in pore-water water samples
  - Actual concentrations less than model prediction
- Outcome
  - Demonstration that significant attenuation is occurring
  - ADEC agreement on use of site specific remedial targets

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Remediation System Detail

- SVE / Bioventing and Air Sparging / Biosparging
  - Remediate residual NAPL and prevent mobilization
  - Enhance natural attenuation rate
  - System operation dependent of tidal cycles
- Staged approach
  - System construction and connection to existing wells
  - Additional u/g piping and plumbing for future expansion

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Remediation System Detail

- Current System Components:
  - 13 SVE wells
  - 2 sparge wells
  - Warrick sensors
  - Programmable logic controller with remote monitoring
- Phase 2 Components
  - Additional 7 SVE wells
  - Additional 17 AS Wells

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Remediation System Detail

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System Performance

- System Monitoring / Evaluation
  - Helium tracer tests
  - Weekly field measurements
  - Remote monitoring
  - Bi-annual inspection by Golder
  - Annual groundwater monitoring
- Mass Removed
  - Estimated 4000 kg petroleum hydrocarbons removed after three seasons of operation

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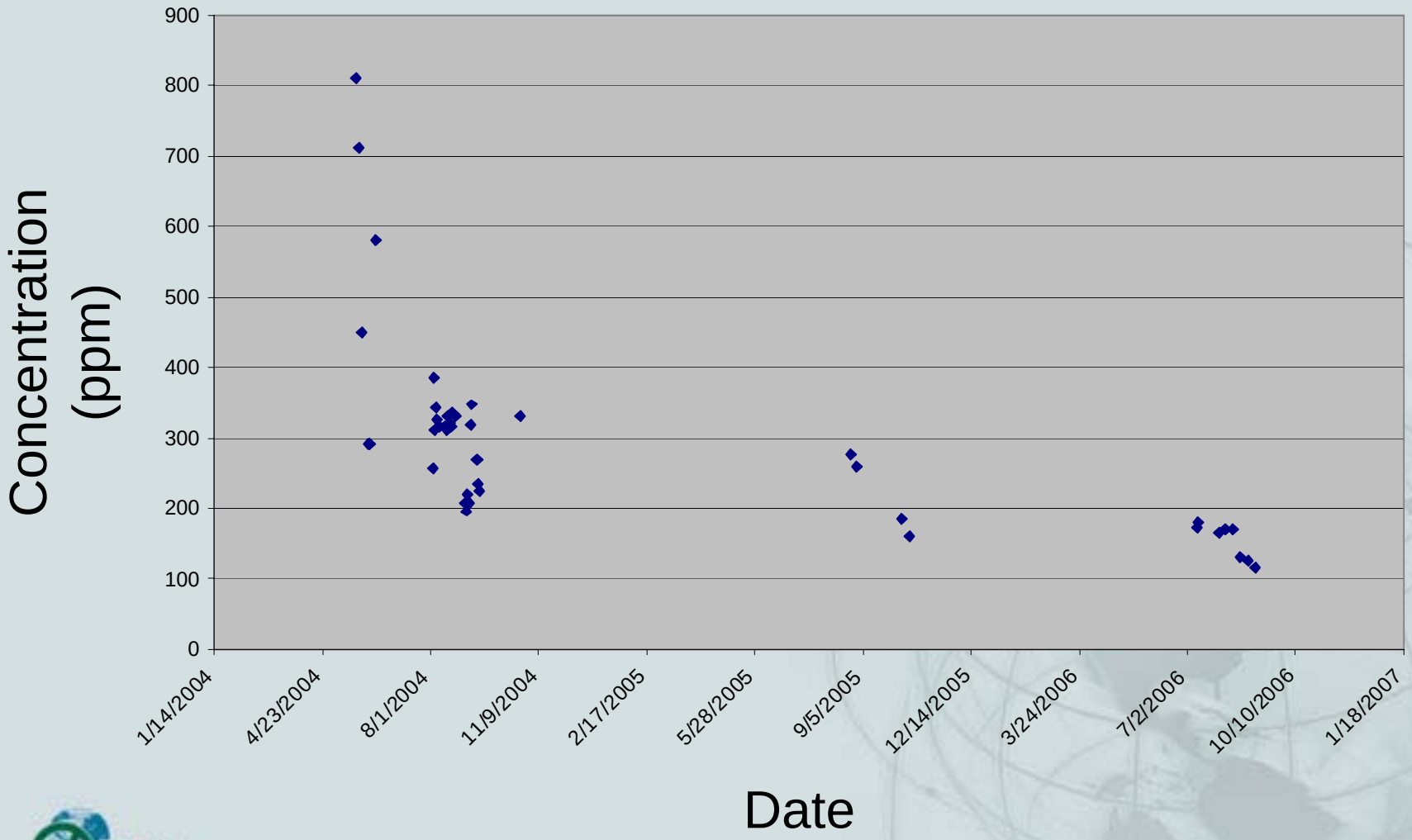
System Performance

Organic Vapour Concentration at Exhaust over Time



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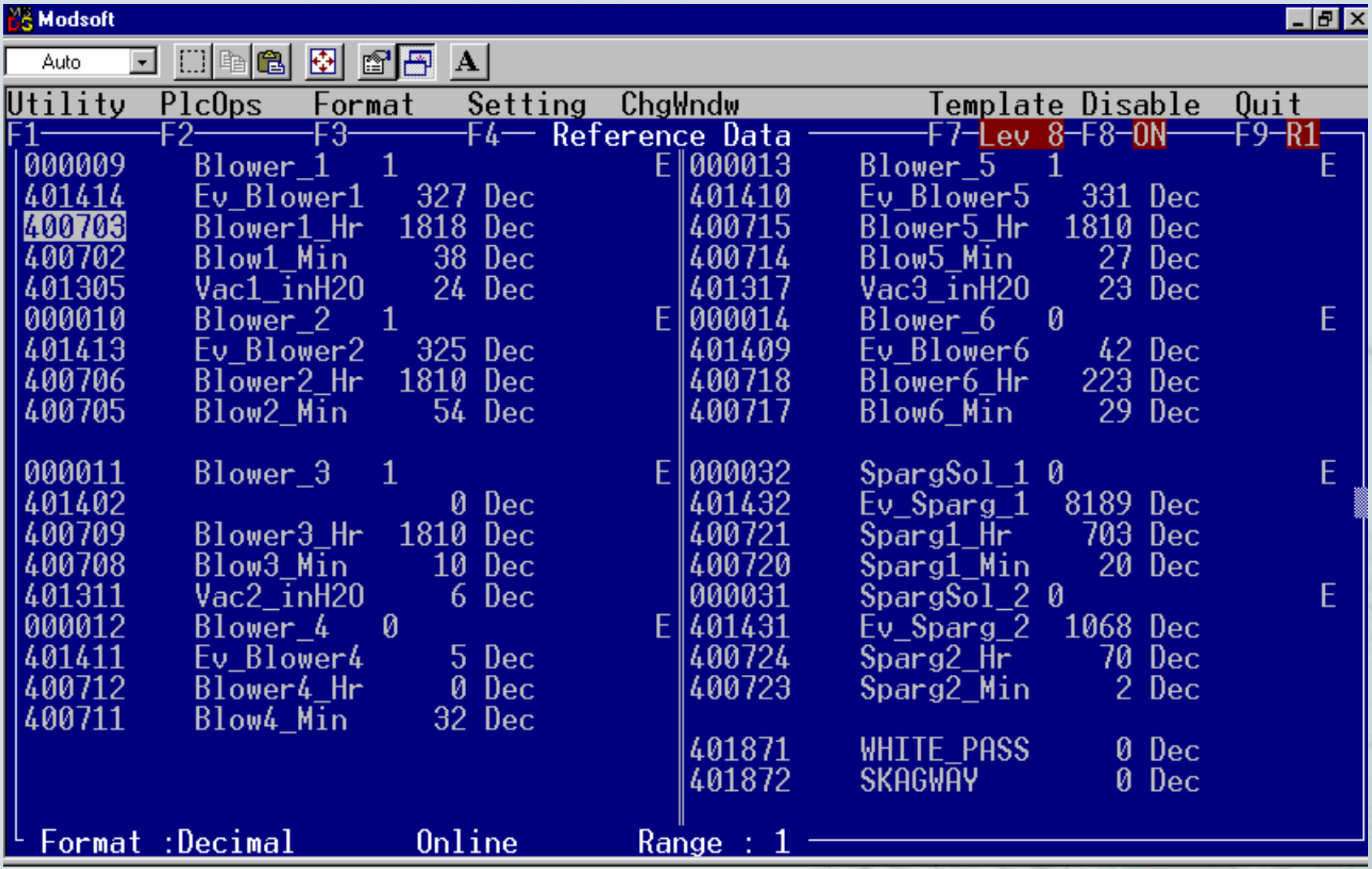
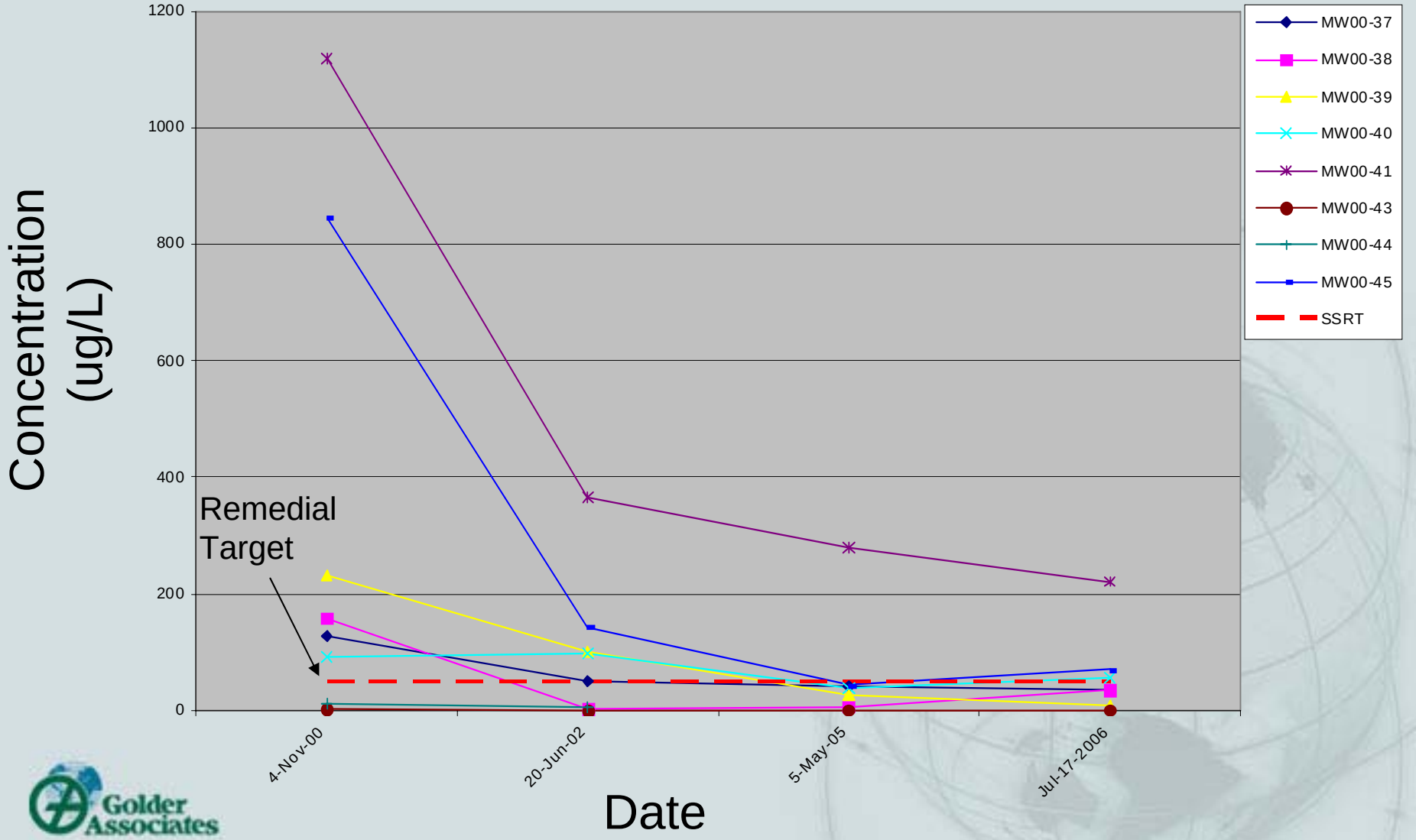
System Performance



System Performance

Concentration on Benzene in Groundwater over Time



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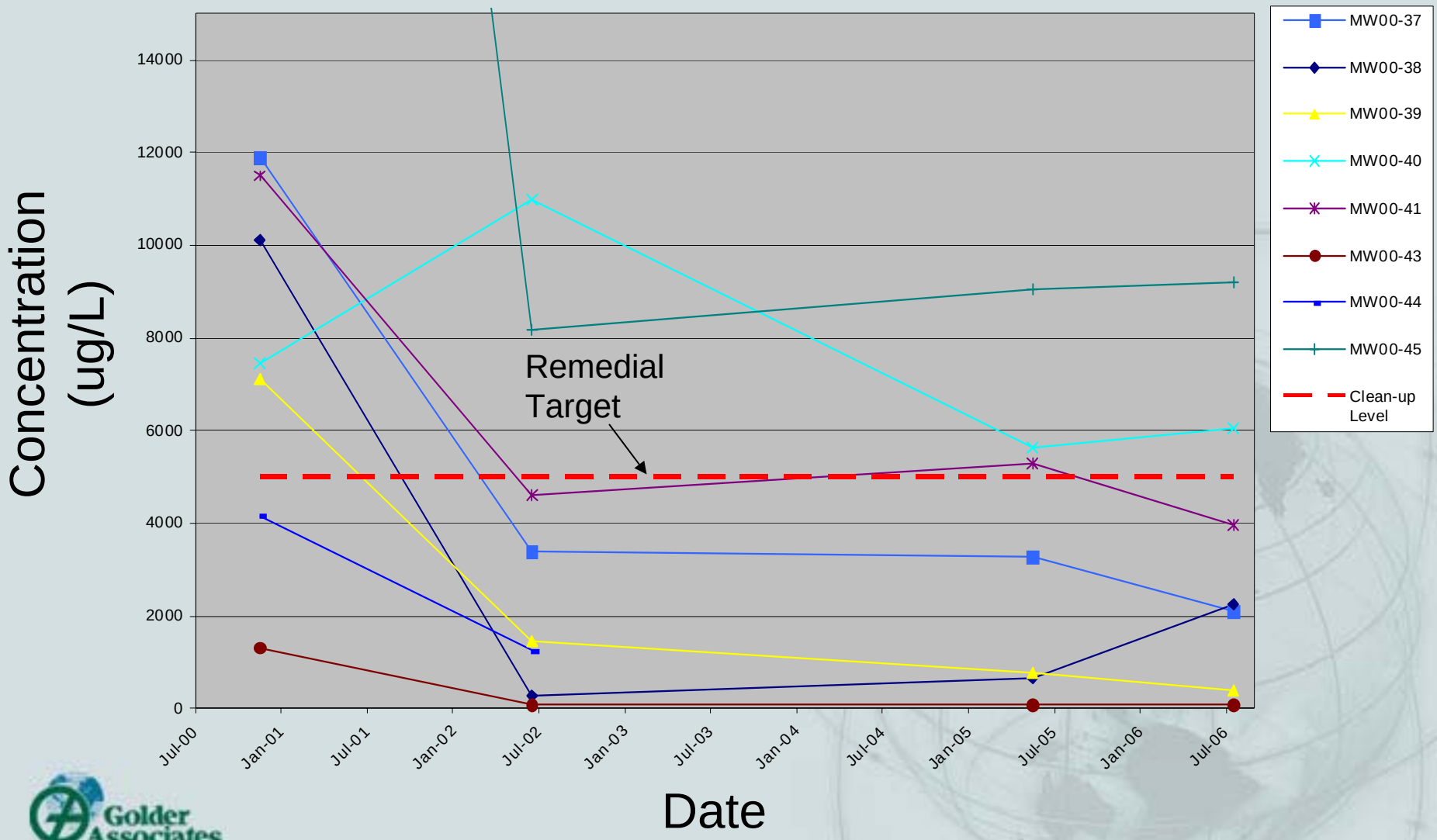
System Performance

Concentration on GRO in Groundwater over Time



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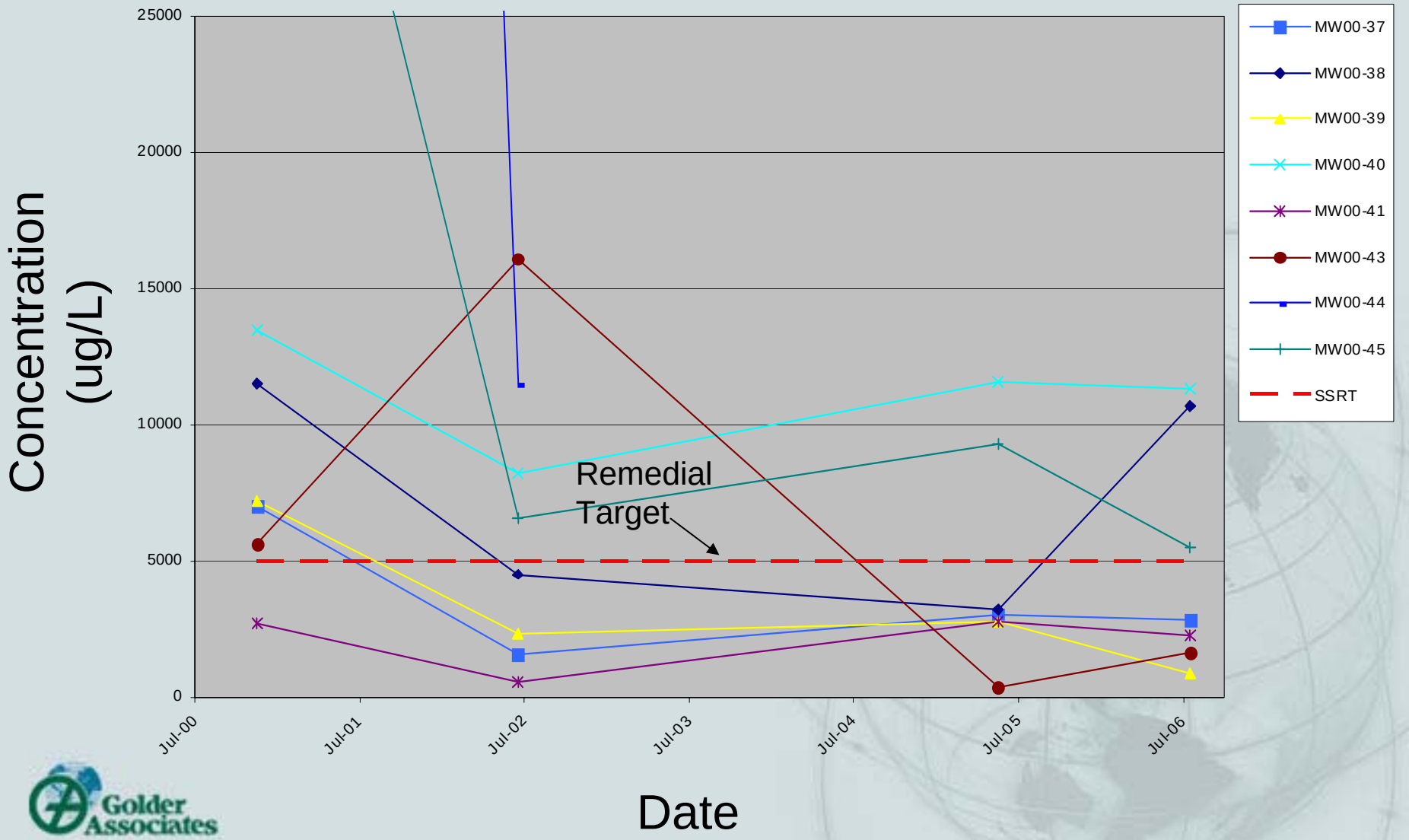
System Performance

Concentration on DRO in Groundwater over Time



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Observations and Lessons Learned

- Demonstration that significant attenuation is occurring
- ADEC regulators accepting of risk-based remedial approach
- Effective mass removal and concentrations decreasing over time
- Warrick sensors/PLC work effectively at controlling system
- Risk-based remedial goals and hydrogeology can change with land use/development

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Questions ?

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