ADAPTIVE REMEDIATION MANAGEMENT OF A GROUNDWATER CLEANUP PROJECT

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ORICA

PRESENTATION

- Background and history
  - Botany Industrial Park
  - Botany Groundwater Cleanup Project
- Adaptive remediation research
- Adaptive management of the Groundwater Treatment Plant
- Clean-up progress
- Remediation strategy review process
- Note: **M** denotes **million**

BOTANY SITE HISTORY

- First plants: CS_2 in 1942; ChlorAlkali in 1944
- Chlorinated solvents – TCE, PCE, CTC – 1940s to 1991
- PVC (via 1,2-DCA [EDC] and VC as intermediates) – 1950 to 2001
- Others:
  - Olefines and polyolefines – polythene, polypropylene
  - Surfactants and glycols, glycol ethers
  - Silicates, ammonia/urea, rubber chemicals, herbicides, formaldehyde, …
- Business restructure in 1997/8 ICI Australia → Orica → divestment of businesses (J Stening poster)

1955 – three years before first connection to trade waste …

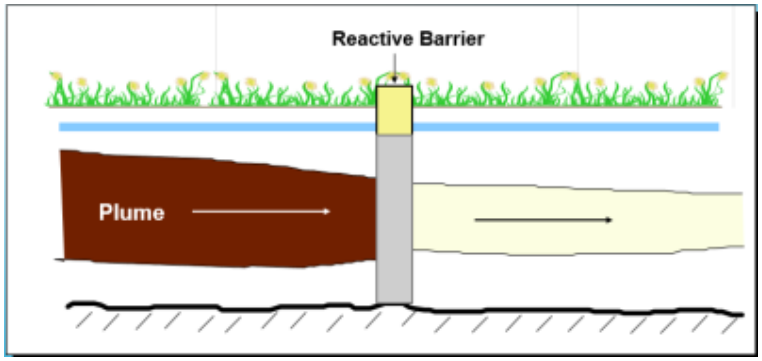
BOTANY INDUSTRIAL PARK

INITIAL ENVIRONMENTAL INVESTIGATIONS

- Stage 1 Survey – 1989-90
  - A snapshot of soil and groundwater contamination
  - Provided basis of scope for more comprehensive investigation
- Stage 2 Survey – 1993-96 (Woodward-Clyde)
  - 9 volume report
  - Soil, groundwater, surface water, marine biota, air
    - central plume source “exacerbated” (J Duran poster)
  - Human health risk assessment
  - Scope for further investigations
  - Remediation options
- Stage 3 ‘Remediation’ – 1997-2003 (WWC/URS)
  - Lined leaking stormwater drain pipes (prevent groundwater ingress)
  - Realigned Springvale Drain and excavated contaminated sediments
  - Remediation options workshop – April 1997
    - identified permeable reactive barrier and bioremediation as options

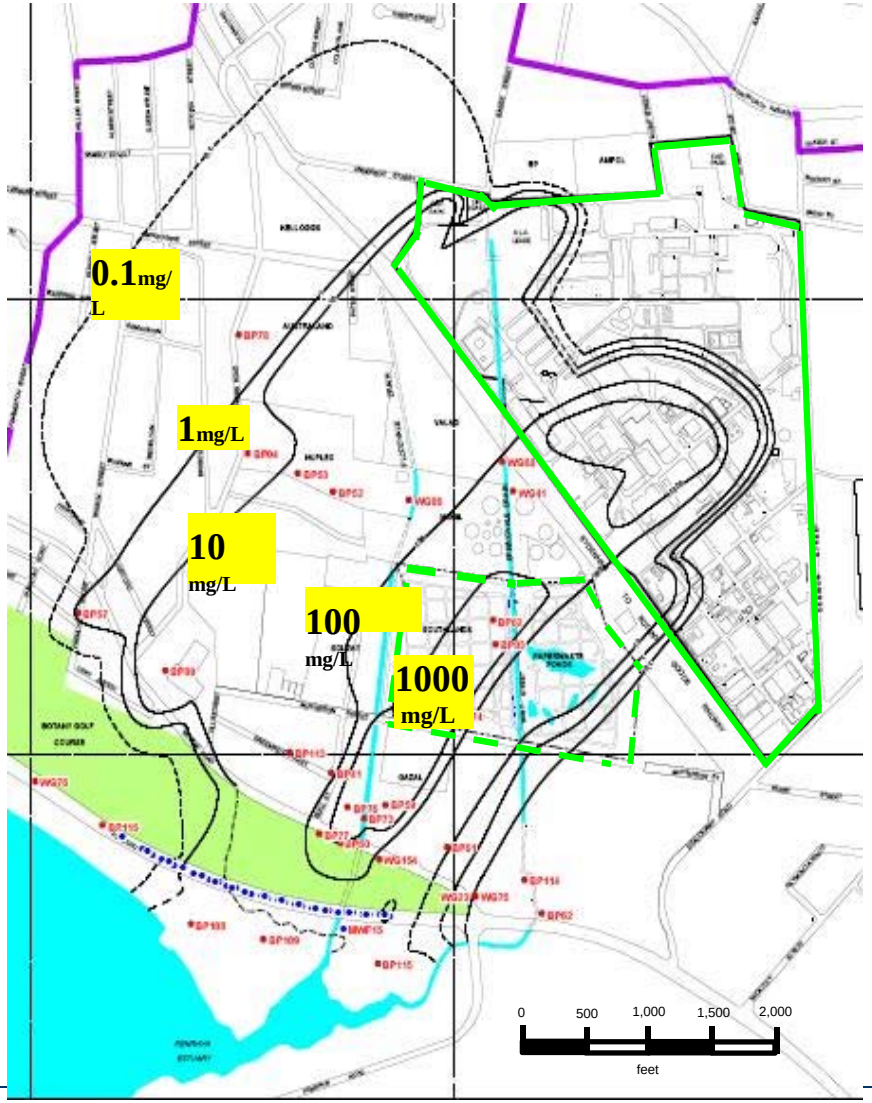
REMEDIATION INVESTIGATIONS

- Permeable reactive iron barrier
  - Laboratory column studies (ETI, Canada)
  - Pilot-scale reactive iron barrier – installed in Feb 1999
  - Good results – 80-90% mass removal
  - Full-scale challenge: 25 m deep in sand
- Bioremediation
  - Laboratory microcosm studies (Uni of Toronto, Canada) – 1999-2000
  - Field trials (Geosyntec) – 2003-05, >$3M
    - › shallow aquifer; passive barrier
      - Emulsified veg oil; calcium oleate
      - 1-2 lb/d CHC degradation
    - › deep aquifer; active barrier
      - Emulsified veg oil; ethanol
      - 13-42 lb/d CHC degradation



BUT TIME WAS RUNNING OUT ...

NB Shows 1,2-DCA Concentration Contours ca 2003

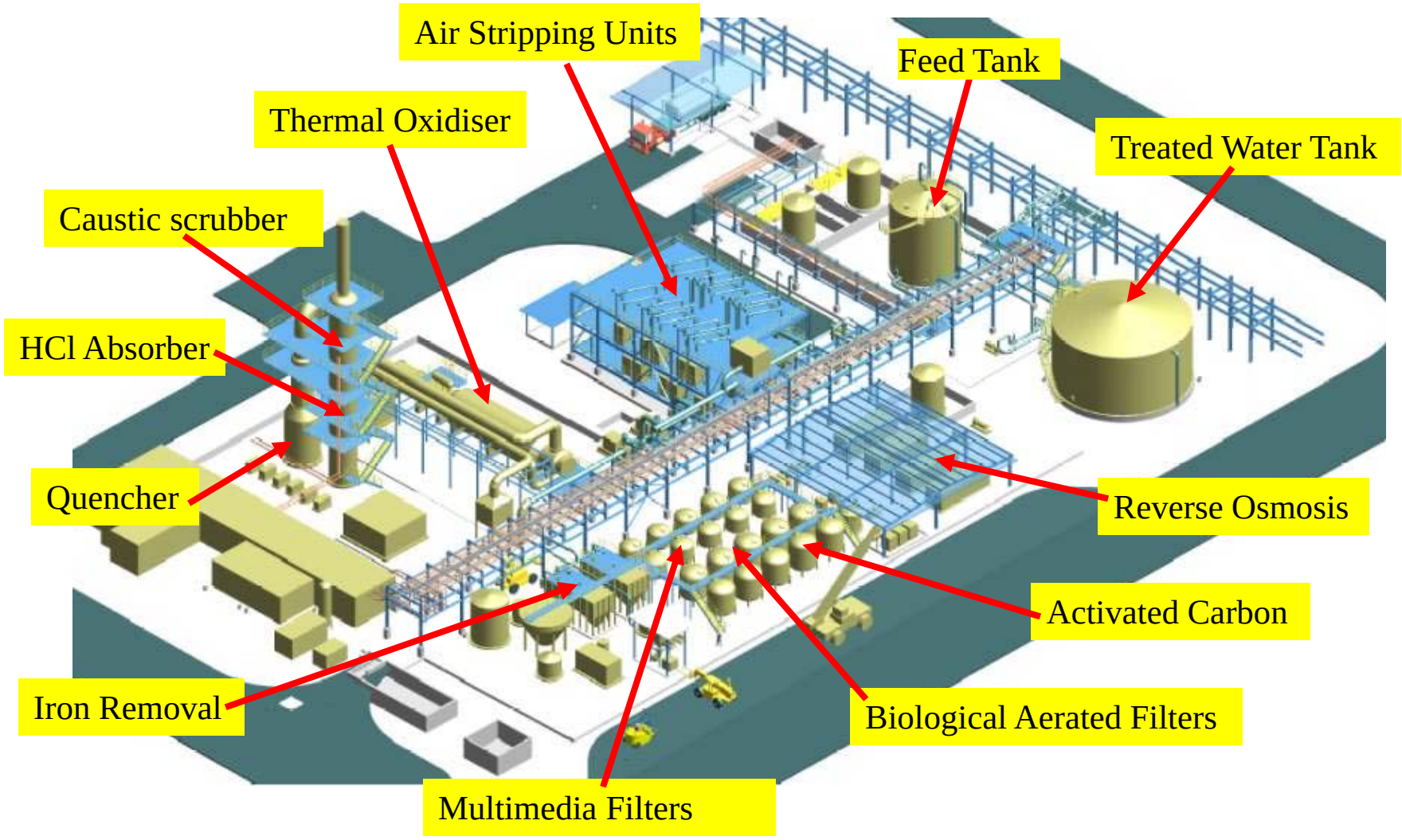


BOTANY INDUSTRIAL PARK

PUMP AND TREAT

- Notice of Clean Up Action issued by NSW EPA in September 2003
  - Required
    - Hydraulic containment
    - Ex situ treatment
    - Source area removal
    - Groundwater cleanup plan
- Groundwater Treatment Plant and hydraulic containment network
  - Construction in 2004 and 2005
  - Groundwater feed in January 2006
  - 3 containment lines; 113 pumping wells
  - ~6 ML/d (~1.6 M USgal/d) treatment, ~4.5 ML/d (~1.2 M USgal/d) treated water for non-potable reuse
- Parallel evaluation of source remediation technologies

GROUNDWATER TREATMENT PLANT



AIR STRIPPING VOC FROM GROUNDWATER

- Counter-current flow of air and water
- Minimum air flow to prevent weeping
- 2 cabinets / 12 stages of separation

AIR STRIPPING VOC FROM GROUNDWATER

- Fungal fouling
  - pH optimisation
  - short run times
- Chlorine dioxide dosing introduced 2009/10
  - longer run times
- >100 mg/L feed
  to
  < 10 ug/L
  volatile CHCs

THERMAL DESTRUCTION OF VOC AND GAS SCRUBBING

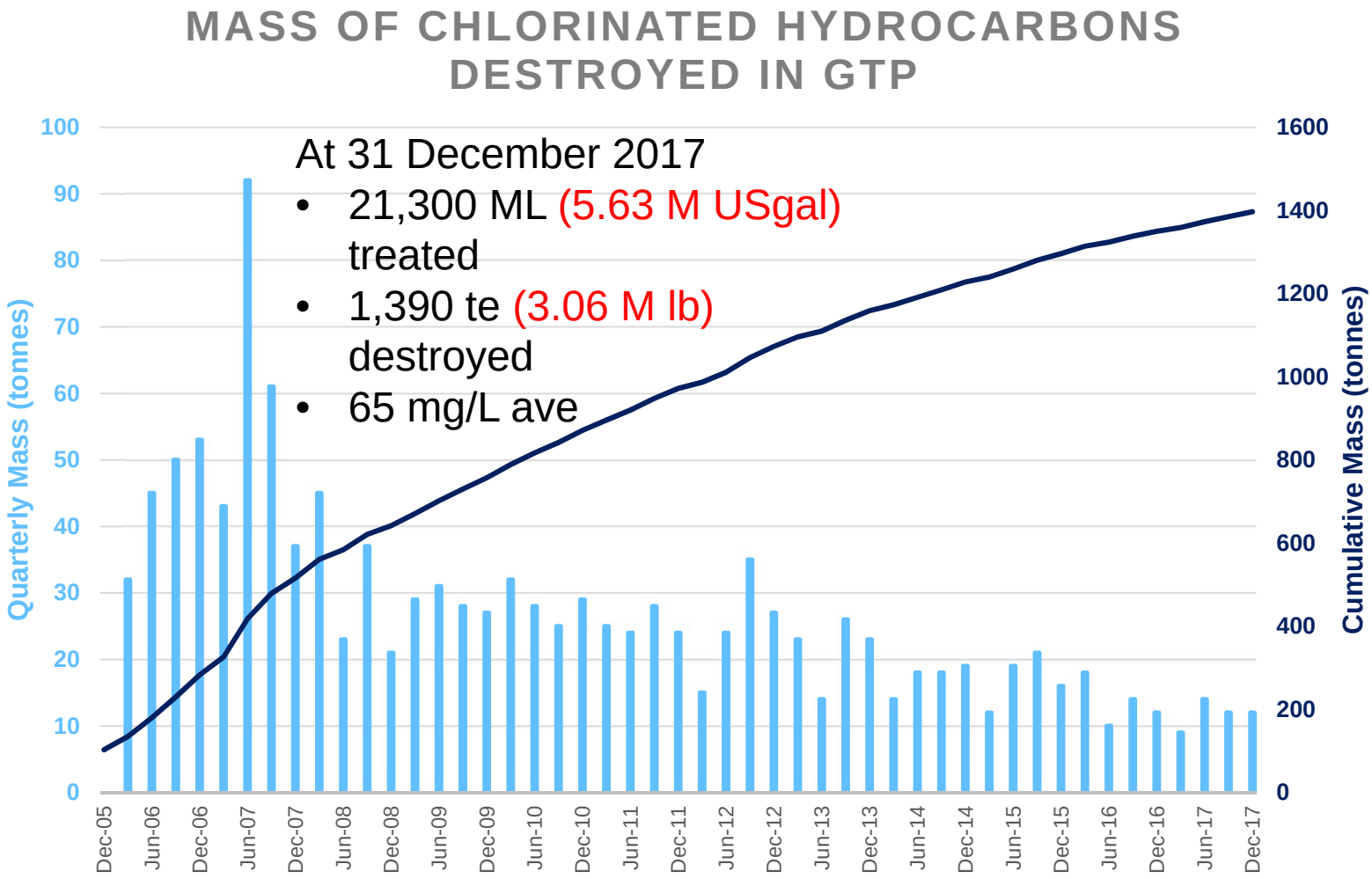
- Refractory damage
  - Liquid droplets in air stripper off-gas contain sodium
  - Introduction of ClO_2
  - Thermal cycling ~ 25 events p.a.
    - improved operations
    - reviewed instrumented trips

- Dioxins
  - Liquid droplets catalysed ‘de novo’ synthesis
  - Removal of top tray from air stripper
  - 12 to 11 stages

STRIPPED WATER TREATMENT – CHLORO-PHENOL REMOVAL

- Granular Activated Carbon (GAC)
  - Downflow configuration, lead/lag
- Biological fouling of downstream filters and RO units
- Adsorption (physical) to biological
- 5 GAC beds converted to Biological Aerated Filters (BAFs)
  - Co-current upflow
  - 30% removal of Cl-phenol
  - 80% removal of acetate
  - Small removal of ammonia
- Backwash and aeration critical
- $Ca(NO_3)_2$ added to control H_2S formation and microbially-induced corrosion

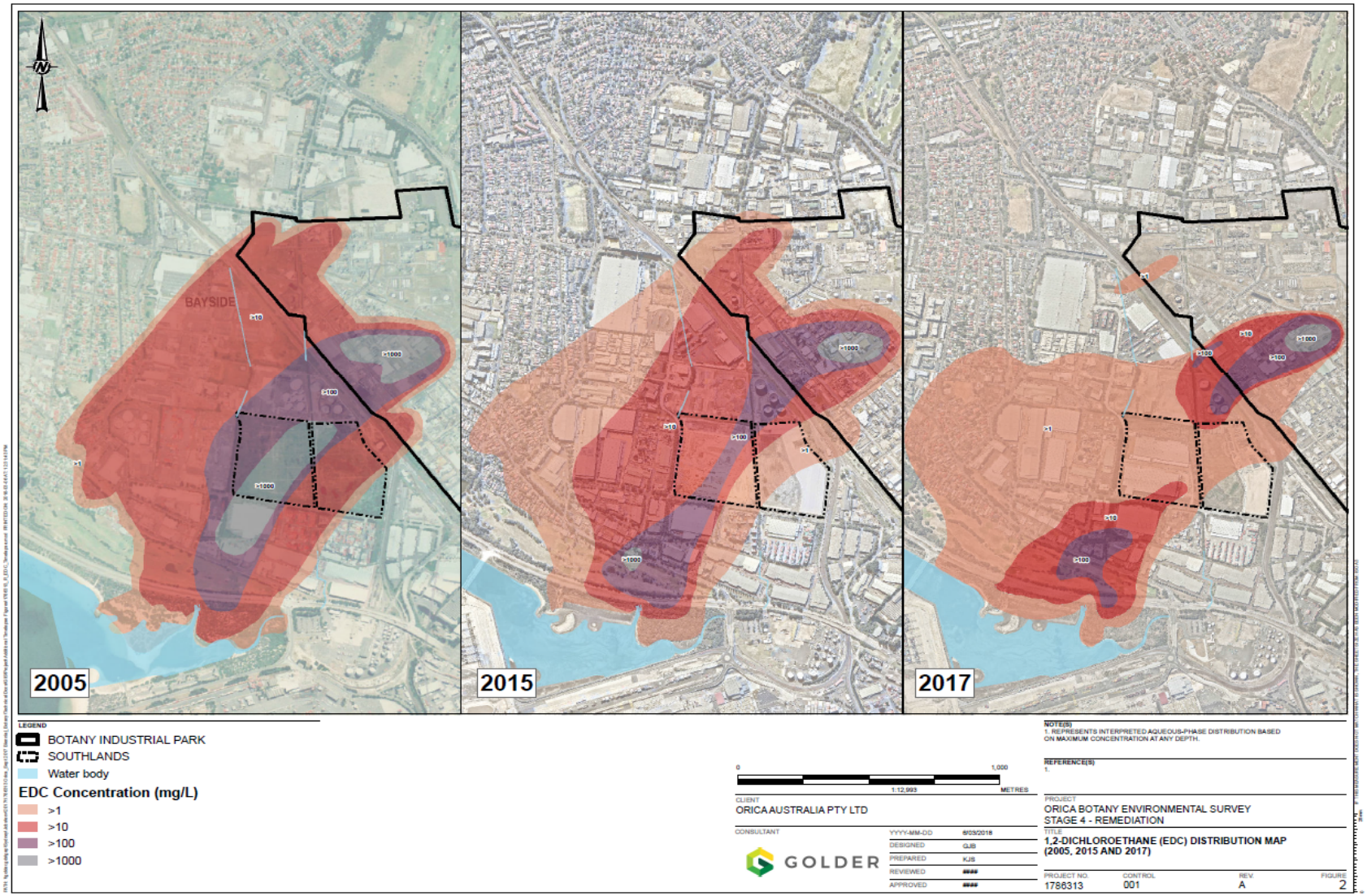
CLEANUP PERFORMANCE - OVERALL



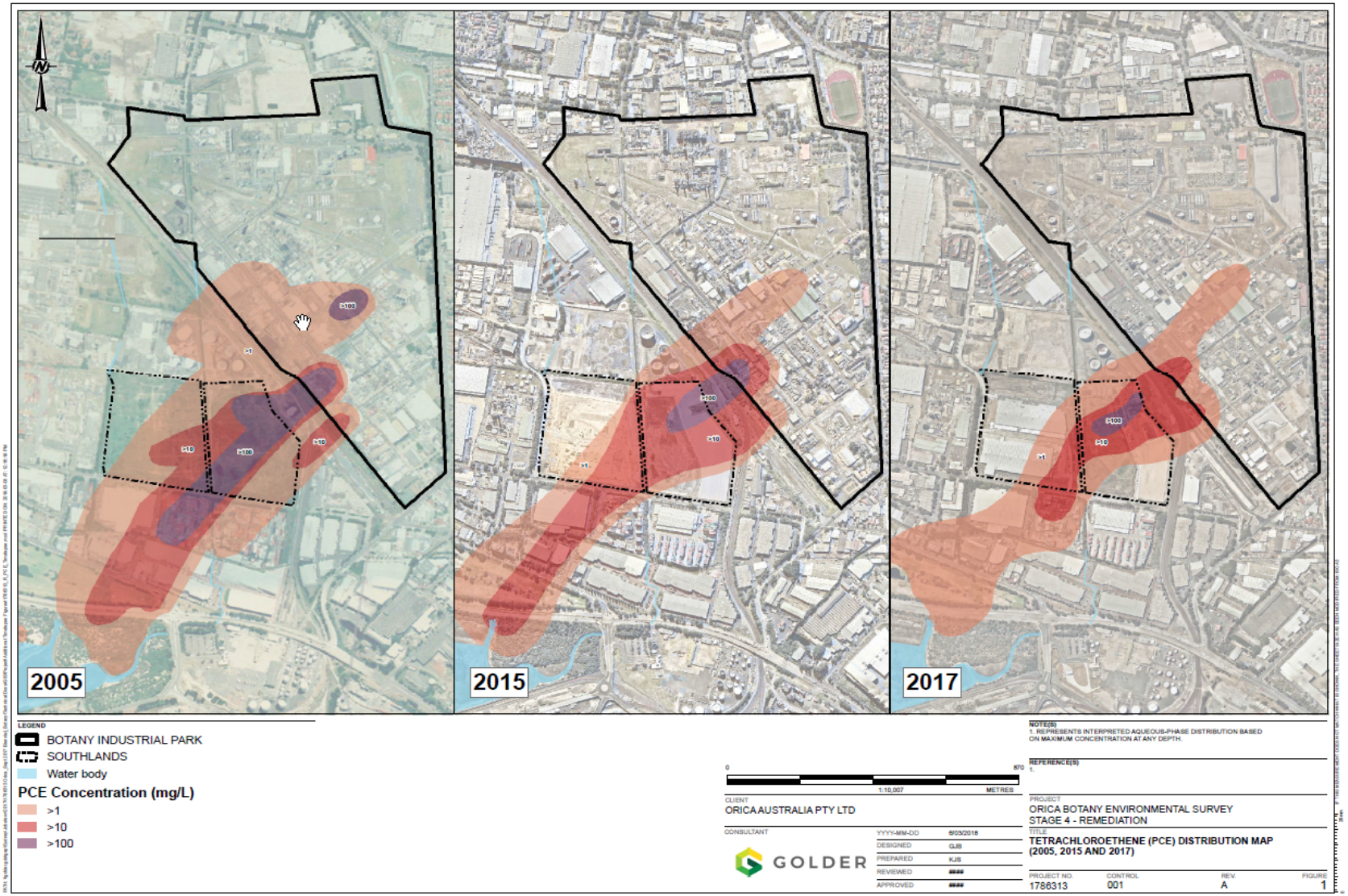
CLEANUP PERFORMANCE – OTHER BENEFITS

- Surface water quality – immediate
- Shallow groundwater – over time
- G Dasey presentation

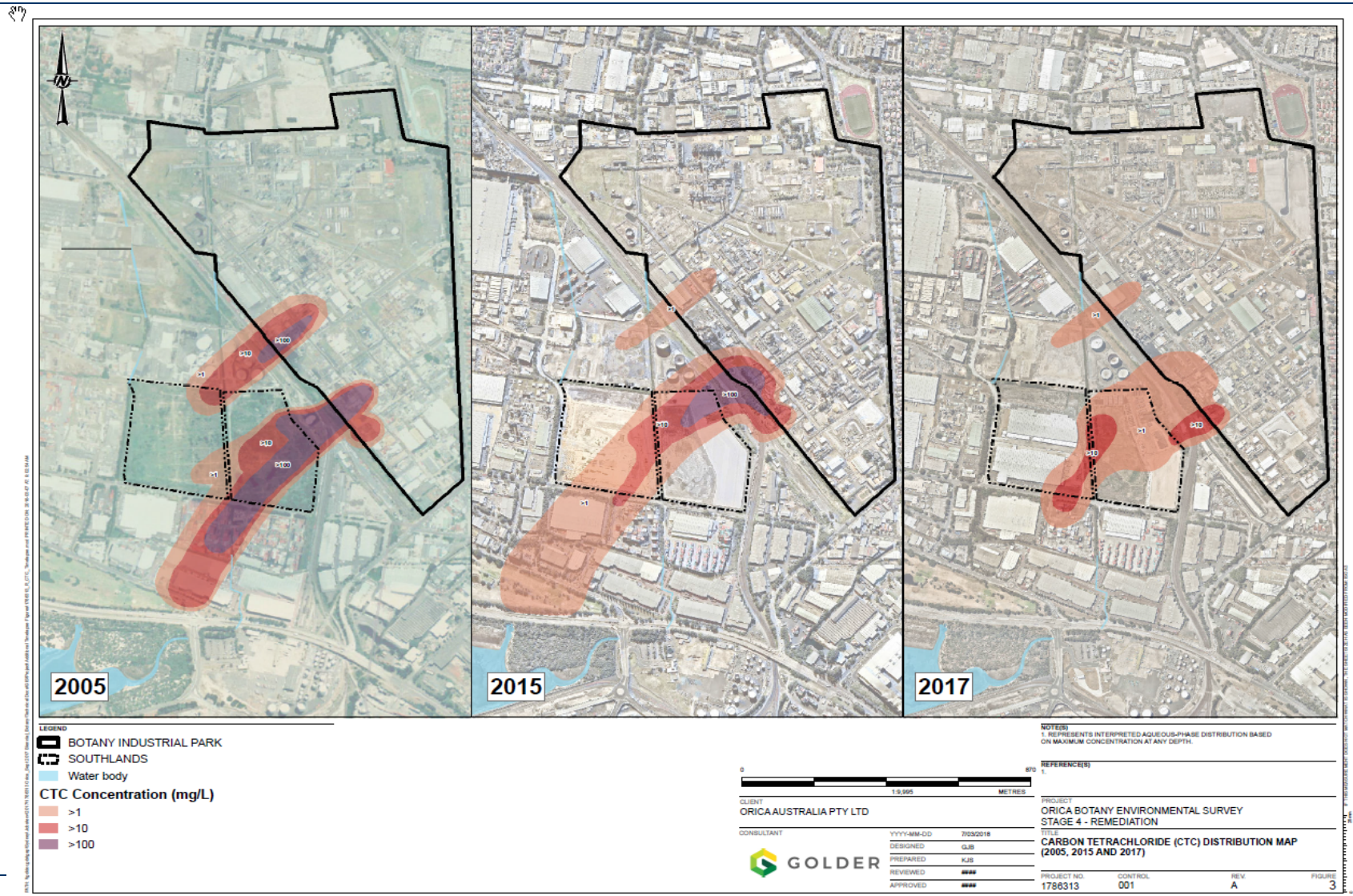
CLEANUP PERFORMANCE – 1,2 DCA (EDC)



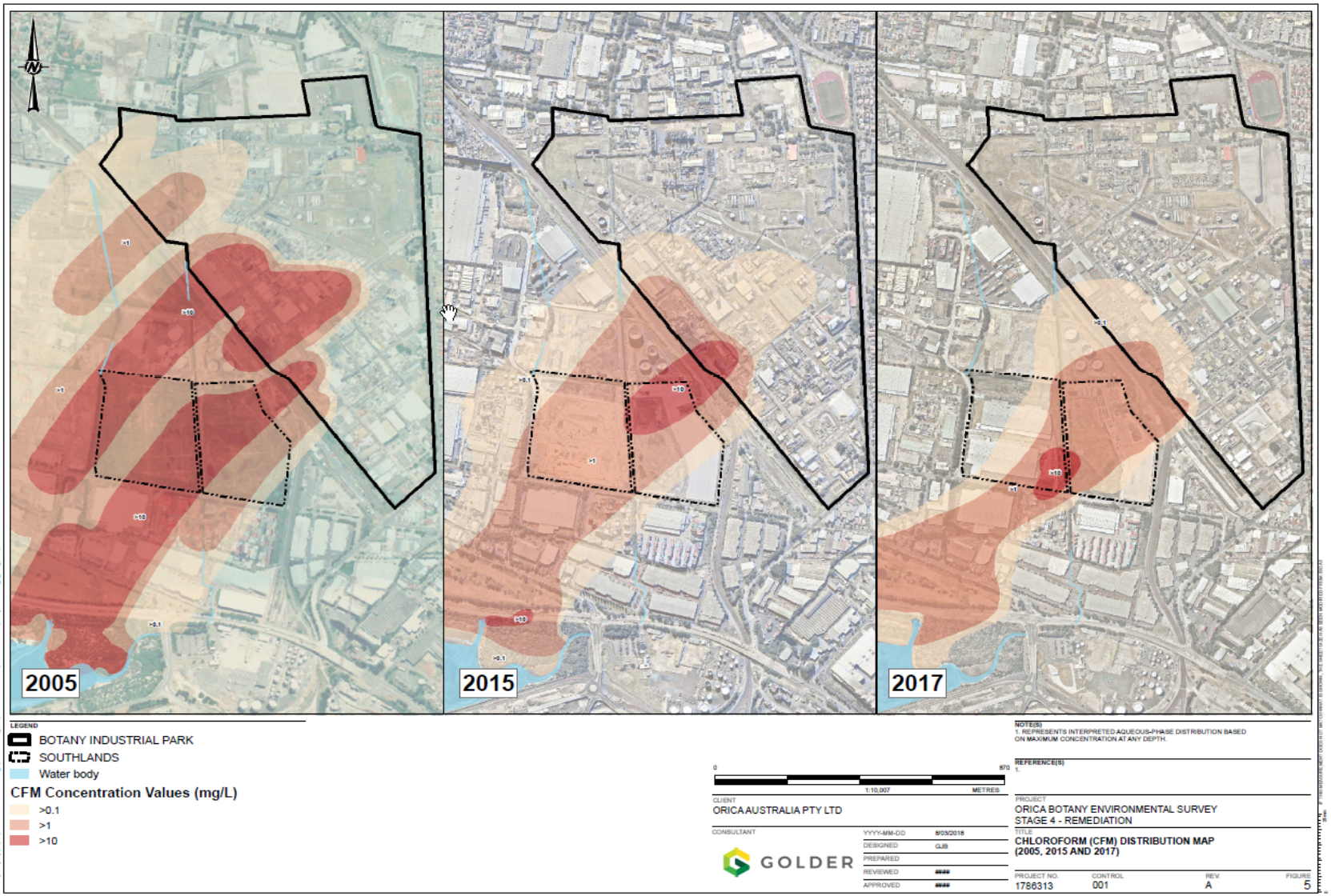
CLEANUP PERFORMANCE – PCE



CLEANUP PERFORMANCE – CTC



CLEANUP PERFORMANCE – CFM



PUMP AND TREAT

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SOURCE REMEDIATION

- Source remediation technologies evaluated:
  - Direct recovery (bailing/pumping)
    - On-site trials → very little free product to recover
  - Hydraulic displacement (flushing)
    - Desktop review → rejected as ineffective
  - Surfactant-enhanced in situ chemical oxidation (SISCO)
    - Laboratory column tests with sodium persulfate and different activation methods
      - surfactant was too effective – the oxidant couldn't keep up with the solubilised contaminants
  - Thermal – steam enhanced extraction (SEE) and thermal conductive heating (TCH)
    - Hydraulic isolation critical to effectiveness

SOURCE REMEDIATION (CONT)

- Remediation technologies proposed for field trials:
  - In situ chemical oxidation (ISCO)
  - Thermal – steam enhanced extraction (SEE) and thermal conductive heating (TCH)
  - Both trials would be very expensive – >$5 million each
- In 2006/7 Orica reviewed the cleanup strategy
  - Mass estimate and solute transport model
    - cleanup duration under a number of scenarios
  - Workshop convened, including international experts
    - doubts expressed about efficacy of both technologies at BIP
  - Independent expert report commissioned:
    - full-scale application of technologies would cost $250-400M
    - scale, technology and access issues mean incomplete removal
    - questionable improvement in estimated cleanup duration
    - adaptive approach better

CURRENT STRATEGY

- Continued extraction and treatment
  - Effective management of all exposure pathways
  - Extensive monitoring and reporting
- Conduct ongoing review of developments in remediation technologies and techniques and their practical applicability
  - Convene a Strategy Review Workshop every three years:
    - a minimum of three international experts in the field, Orica's consultants, NSW EPA and community's monitoring committee
    - review cleanup progress
    - consideration of worldwide developments in technology
      - any current or emerging technologies that are likely to provide a practicable solution and justify the conduct of field trials
      - recommendations into Orica's work plans

CURRENT STRATEGY (CONT)

- To date there have been four Strategy Review Workshops
  - Most recent was in February 2017
  - Key conclusions:
    - “pump and treat” remains the most effective way to manage the groundwater contamination
    - there are currently no other cleanup technologies available that warrant further investigation via field trials
    - more characterisation of the contamination source areas is required → source flux depletion
    - more work to close gaps in understanding fate and transport of contamination

- Feasibility study of Moving Bed Biofilm Reactor (MBBR)
  - lower feed concentrations → smaller equipment sizes
  - replaces air strippers/thermal oxidiser
    - major reduction in gas and electricity usage and greenhouse gas emissions

QUESTIONS?

