Soilfix CPD Session

'Treatment Train' Approaches to remediation of organic pollutants in soils & groundwater

Steve Jackson, Director | Soilfix Ltd

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CPD Outline…….

1. Brief introduction to Soilfix
2. Types of Organic Pollutants & General Approaches
3. Types of Remedial Techniques
4. Typical remediation costs
5. Factors influencing Selection of Remediation Technique(s)
6. Case Study Examples

Who are Soilfix?

- A specialist remediation & enabling contractor established in 2004 - based in Bristol, Essex & North Staffs (plan to expand into NW office)
- Projected 2023 turnover of £16M with 50 staff
- Specialise in 'Design & Build' remediation of soil and groundwater using a wide range of technologies. Also, specialist enabling works (earthworks, development platforms etc.), archaeological / ecological support to projects
- Work for a variety of clients in Development, Industrial & Public Sectors
- Active members of CL:AIRE, RemSoc & contribute to various uidelines and Codes of Practice (e.g CAR-Soil, DoWCoP & CIRIA Guidelines)

2022 RoSPA Gold Award

2023 RoSPA Gold Award

ciria

CL:AIRE Principal Member

RemSoc

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Areas of Expertise

Screening / Complex Sorting

Bioremediation

Preparatory Earthworks / Development Platforms

Asbestos in Soils

Stabilisation/Solidification

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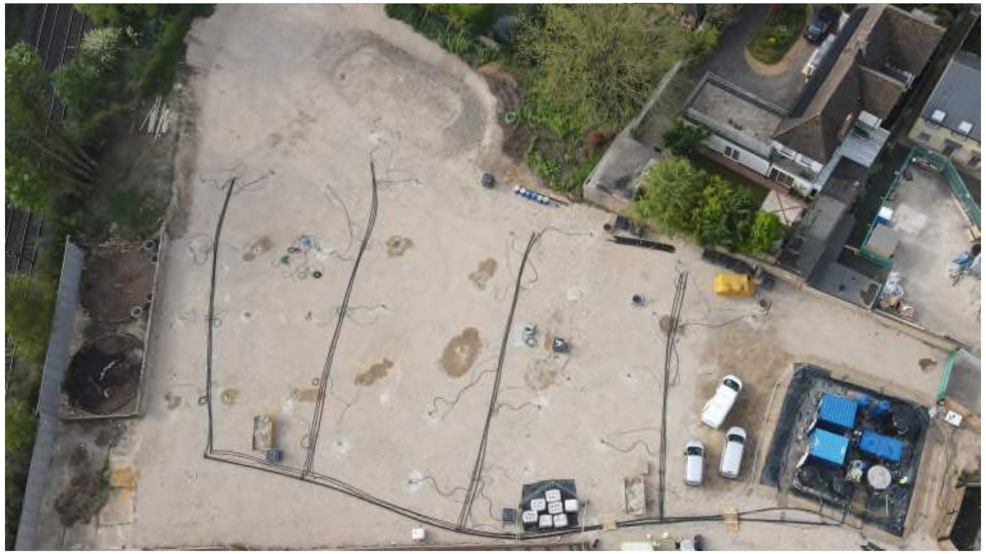
Further Areas of Expertise

In-situ Stabilisation/Solidification

Surfactant-enhanced Product Recovery



Chemox-Stabilisation/Solification (CSS)

Slurry cutoff-barriers

Injected Reactive Barriers / Treatment Zones

Multi-Disciplined….

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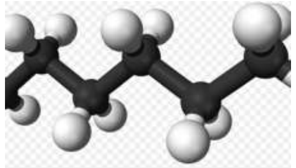
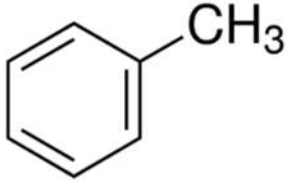
2. Types of Organic Pollutants & Remediation Approaches

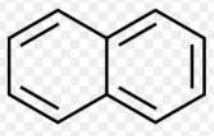
Types of Organic Pollutants……..

- Aliphatic & Aromatic hydrocarbons including BTEX

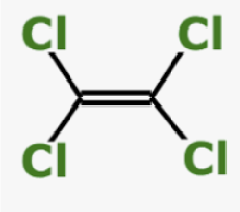




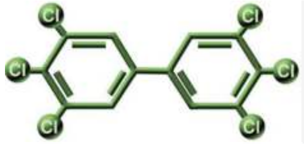
- Coal Tar Derivatives (PAH's)



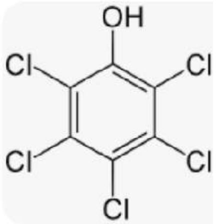
- Chlorinated Solvents (Chlorinated Ethenes such as PCE, TCE & Chlorinated Ethanes such as Chloroform / Carbon Tetrachloride)



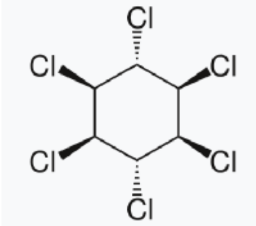
- Complex Organics (e.g. PCB's / Dioxins / Furans)



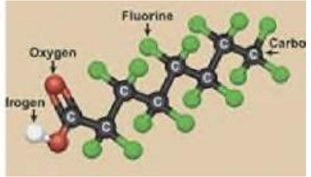
- Phenolics incl. cresols & chlorinated phenols such as Pentachlorophenol



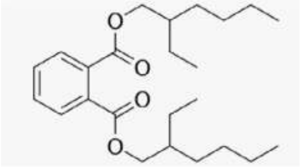
- Organochlorine pesticides / herbicides (e.g. dieldrin, gamma-HCH)



- Per-and Polyfluroalkyl substances (PFAS)



- Others…… organo-tin / organo-mercury compounds / isoflurane / carbon disulphide / amines / phthalates

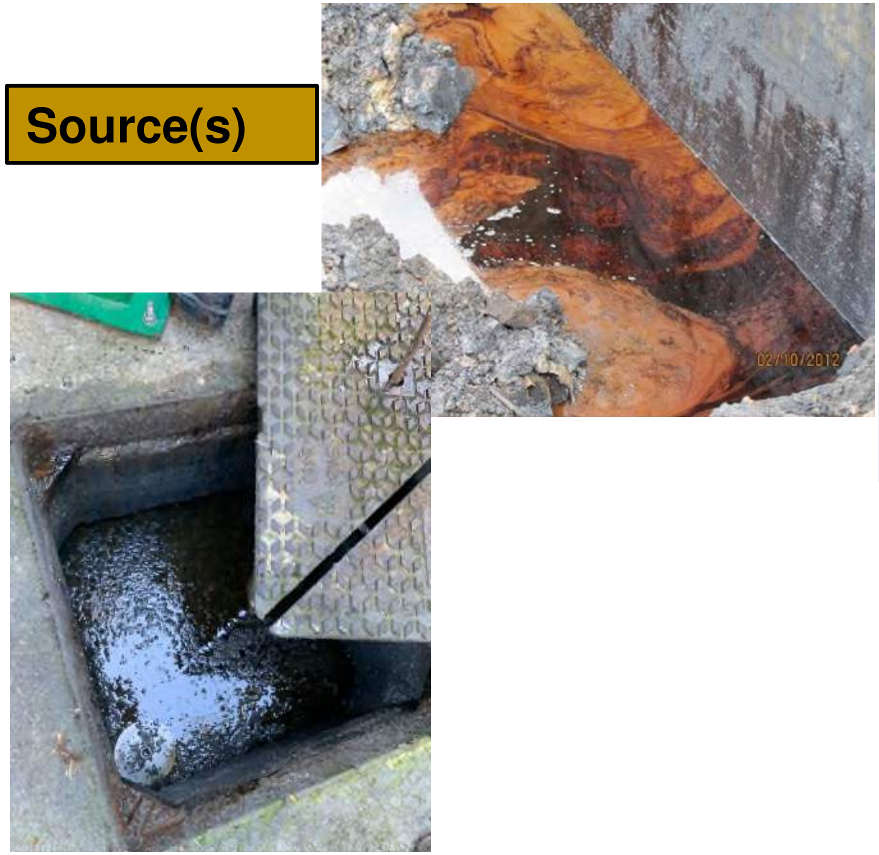


- All highly varied in their chemical composition, volatility, solubility, biodegradability, septicity…….all affect the most appropriate technique(s) for remediation in soil & groundwater

The Site Conceptual Model drives the approach…….

- Remediation is all about the most time / cost effective (and sustainable!) approach to breaking the Pollutant Linkage between **Source – Pathway - Receptor**

Source(s)



Dermal Contact

Ingestion

Inhalation

Pathway(s)

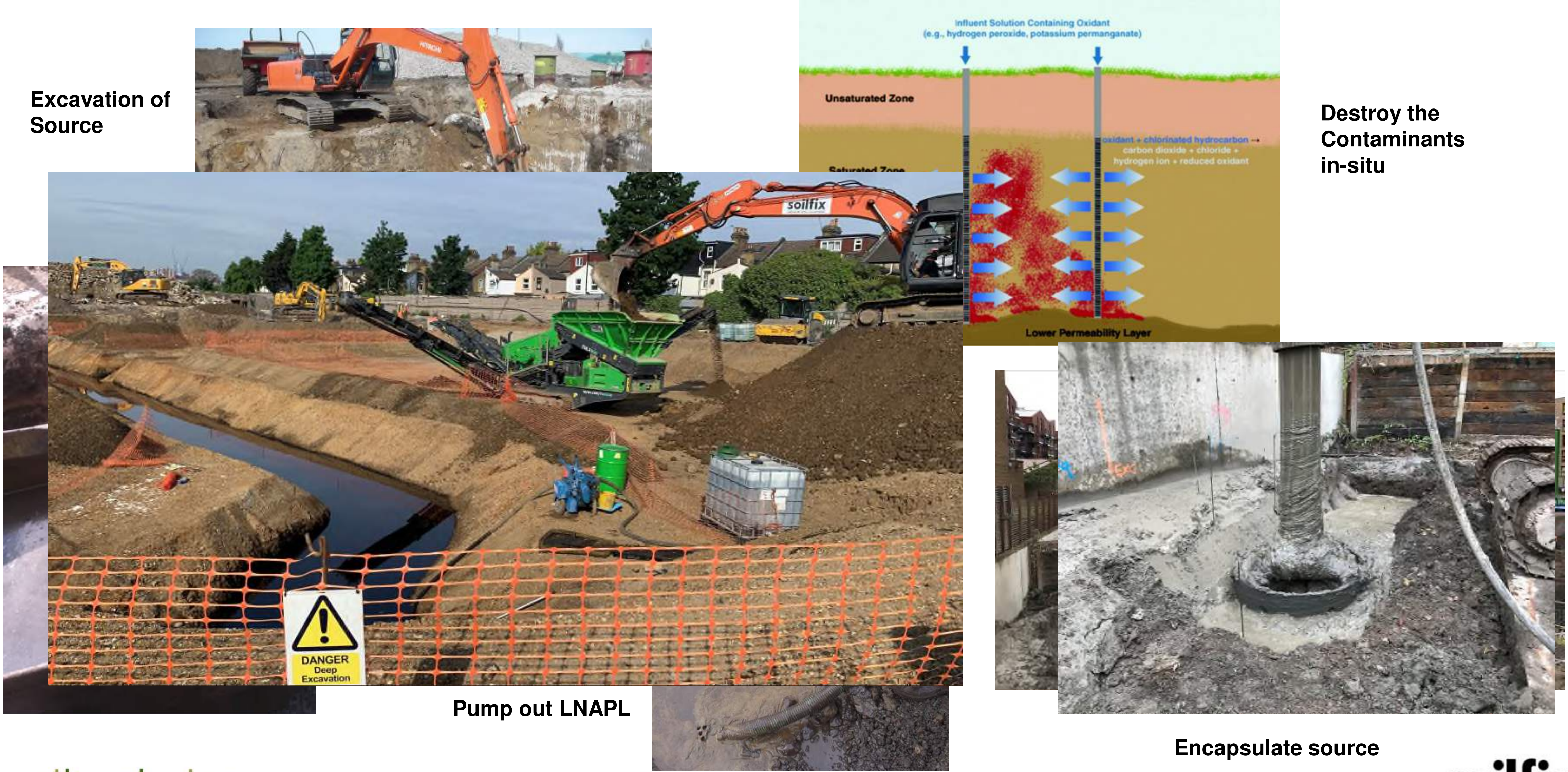
Volatilisation

Groundwater Migration

Surface Water Runoff

Receptors(s)

Dealing with the Source(s)



Excavation of Source

Destroy the Contaminants in-situ

Pump out LNAPL

Encapsulate source

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Modifying / Altering the Pathway

Slurry Wall Cutoff Barrier

Soil Mixed Cutoff Barrier

Permeable Reactive Barrier / Treatment Zone

Clean Cover System

Gas/Vapour Resistant Membrane

Dealing with the Receptor……

__Purchase__ the Receptor(s) e.g. an affected property !!

Change Development Layout

Less sensitive end-use over most contaminated part of site…..

Even a whole row of houses!!

Clean-up the receptor….

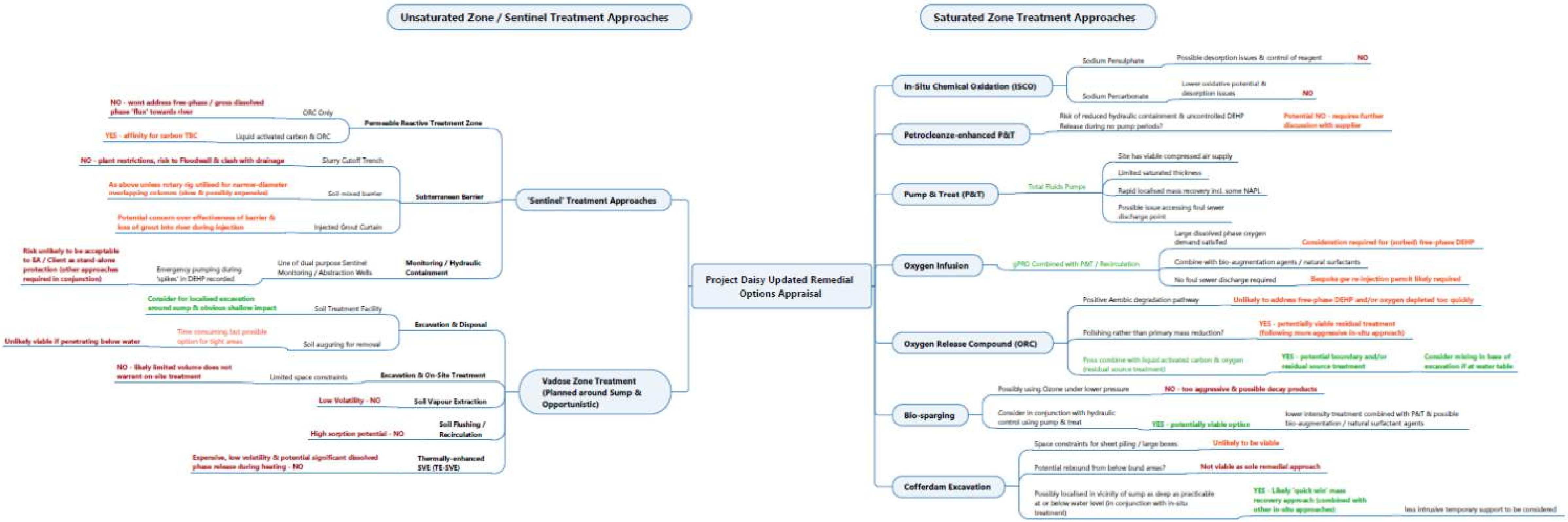
Standards of Remediation……..

- Your remediation objectives, and the standard of remediation required, is reflected by the time and cost you wish (or need) to invest…..
- Imagine dropping a bucket of sand on a carpet, the sand is your contaminant mass……
- You can quite quickly and easily get most of the sand off the carpet with a brush & pan – you'll easily get 70% of the sand out in no time

- Get the hoover on the carpet for 10-15 minutes and you might get around 85-90% of the sand out

- However if you want 98 - 99% of the sand out, you'll need to vacuum for hours (or get yourself an expensive super-vac!)
- In some extreme cases (>99.9% removal) you might have to rip the carpet out and buy a new one!

Options Appraisal – Key Stage of Remediation…….



Project Daisy Updated Remedial Options Appraisal

Unsaturated Zone / Sentinel Treatment Approaches

- **'Sentinel' Treatment Approaches**
  - **Permeable Reactive Treatment Zone**
    - ORC Only – NO - wont address free-phase / gross dissolved phase 'flux' towards river
    - Liquid activated carbon & ORC – YES - affinity for carbon TBC
  - **Subterranean Barrier**
    - Slurry Cutoff Trench – NO - plant restrictions, risk to Floodwall & clash with drainage
    - Soil-mixed barrier – As above unless rotary rig utilised for narrow-diameter overlapping columns (slow & possibly expensive)
    - Injected Grout Curtain – Potential concern over effectiveness of barrier & loss of grout into river during injection
  - **Monitoring / Hydraulic Containment**
    - Use of dual purpose Sentinel Monitoring / Abstraction Wells – Emergency pumping during 'spikes' in DEHP recorded – Risk unlikely to be acceptable to EA / Client as stand-alone protection (other approaches required in conjunction)
- **Vadose Zone Treatment (Planned around Sump & Opportunistic)**
  - **Excavation & Disposal**
    - Soil Treatment Facility – Consider for localised excavation around sump & obvious shallow impact
    - Soil auguring for removal – Time consuming but possible option for tight areas – Unlikely viable if penetrating below water
  - **Excavation & On-Site Treatment**
    - Limited space constraints – NO - likely limited volume does not warrant on-site treatment
  - **Soil Vapour Extraction** – Low Volatility - NO
  - **Soil Flushing / Recirculation** – High sorption potential - NO
  - **Thermally-enhanced SVE (TE-SVE)** – Expensive, low volatility & potential significant dissolved phase release during heating - NO

Saturated Zone Treatment Approaches

- **In-Situ Chemical Oxidation (ISCO)**
  - Sodium Persulphate – Possible desorption issues & control of reagent – NO
  - Sodium Percarbonate – Lower oxidative potential & desorption issues – NO
- **Petrocleanze-enhanced P&T**
  - Risk of reduced hydraulic containment & uncontrolled DEHP Release during no pump periods? – Potential NO - requires further discussion with supplier
- **Pump & Treat (P&T)**
  - Total Fluids Pumps
    - Site has viable compressed air supply
    - Limited saturated thickness
    - Rapid localised mass recovery incl. some NAPL
    - Possible issue accessing foul sewer discharge point
- **Oxygen Infusion**
  - gPRO Combined with P&T / Recirculation
    - Large dissolved phase oxygen demand satisfied – Consideration required for (sorbed) free-phase DEHP
    - Combine with bio-augmentation agents / natural surfactants
    - No foul sewer discharge required – Bespoke gw re-injection permit likely required
- **Oxygen Release Compound (ORC)**
  - Positive Aerobic degradation pathway – Unlikely to address free-phase DEHP and/or oxygen depleted too quickly
  - Polishing rather than primary mass reduction? – YES - potentially viable residual treatment (following more aggressive in-situ approach)
  - Poss combine with liquid activated carbon & oxygen (residual source treatment) – YES - potential boundary and/or residual source treatment – Consider mixing in base of excavation if at water table
- **Bio-sparging**
  - Possibly using Ozone under lower pressure – NO - too aggressive & possible decay products
  - Consider in conjunction with hydraulic control using pump & treat – YES - potentially viable option – lower intensity treatment combined with P&T & possible bio-augmentation / natural surfactant agents
- **Cofferdam Excavation**
  - Space constraints for sheet piling / large boxes – Unlikely to be viable
  - Potential rebound from below bund areas? – Not viable as sole remedial approach
  - Possibly localised in vicinity of sump as deep as practicable at or below water level (in conjunction with in-situ treatment) – YES - Likely 'quick win' mass recovery approach (combined with other in-situ approaches) – less intrusive temporary support to be considered

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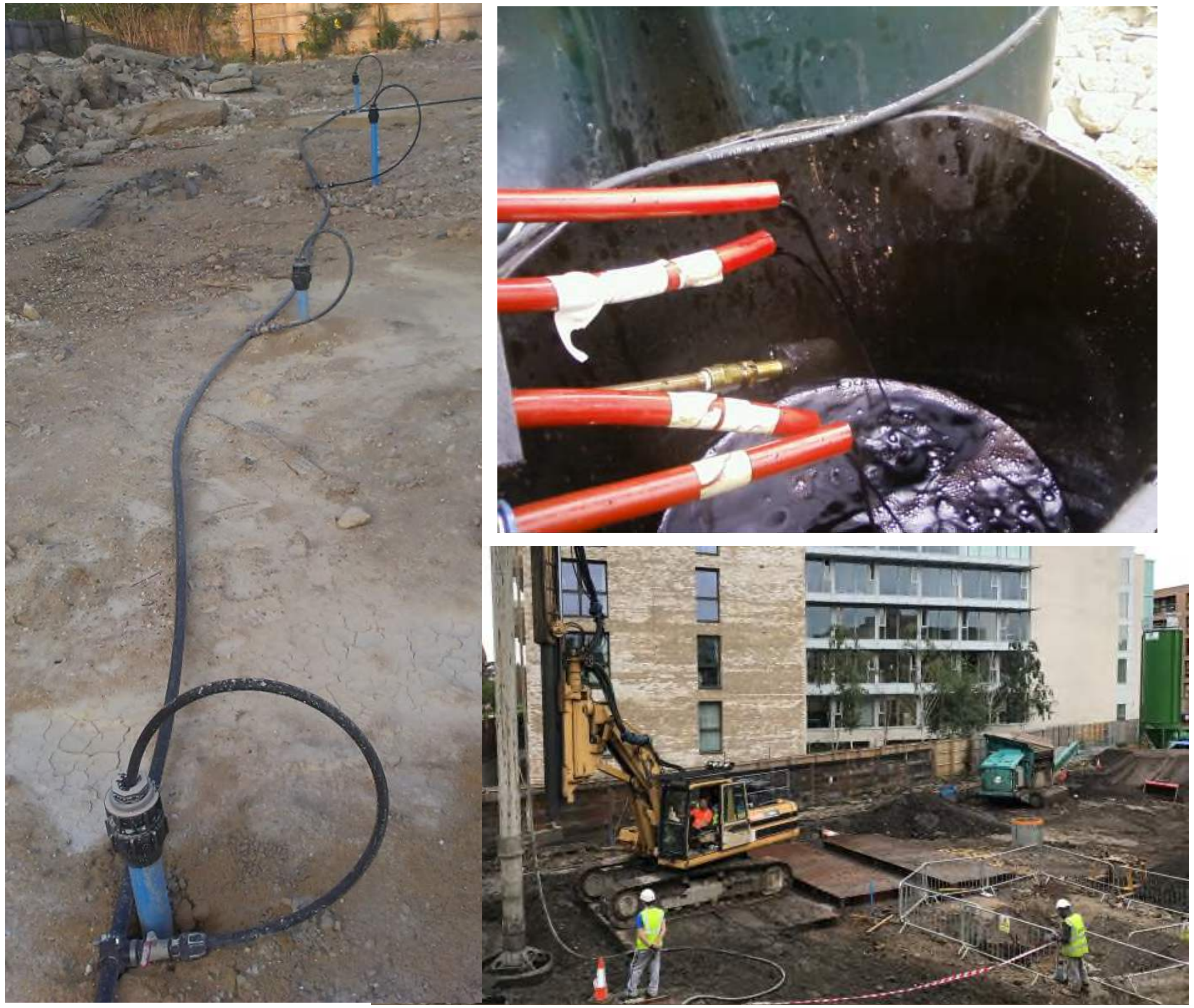
3. Types of Remediation Techniques

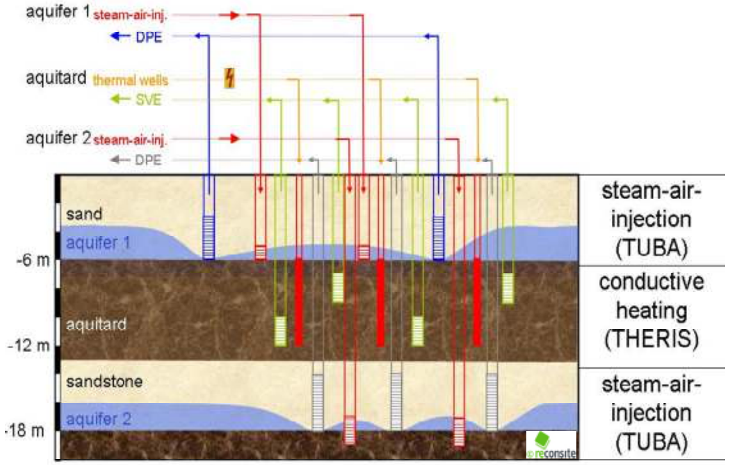
Types of In-Situ Remediation - Physical



- Air Sparging
- Soil Vapour Extraction (often combined with air sparging)
- LNAPL Skimming (can be vacuum-enhanced)
- Multi-phase (high vacuum) Extraction
- In-situ Soil Mixing (for stabilisation / solidification)
- In-situ Thermal Treatment

Thermally-Enhanced Remediation

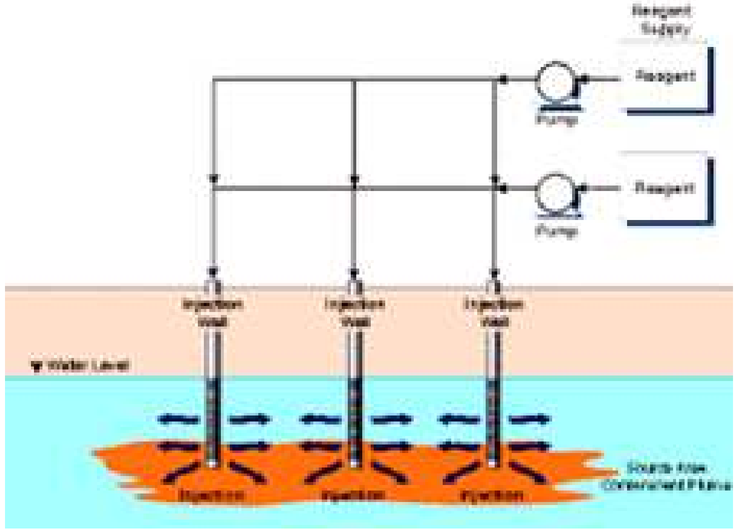
105nr remediation wells installed on a footprint of only 500m^2



In-line vapour, airflow & temperature monitoring systems

Above-ground Treatment systems incl. steam boiler

Types of In-Situ Remediation - Chemical



- In-Situ Chemical Oxidation (ISCO) e.g. sodium persulphate, percarbonate & permanganate
- In-Situ Chemical Reduction (ISCR) e.g. Zero-Valent Iron
- Surfactant flushing for enhanced Free-phase (NAPL) recovery
- In-situ Geochemical Stabilisation (ISGS)

Ex-situ Soil Treatment – Biological & Chemical

- **Bioremediation:** aerobic or anaerobic degradation of contaminants using micro-organisms

- **Stabilisation/Solidification:** Physically and chemically reduce the mobility and availability of contaminants. Also strengthen soils for working platforms

In-Situ Remediation - Biological

- ‘Bio-slurping’ using Multi-phase Extraction systems
- Enhanced aerobic biodegradation – injection of oxygen release compounds / oxygen infusion technologies
- Enhanced anaerobic biodegradation e.g. substrate injection for reductive dechlorination of solvents, pesticides etc.
- Bio-augmentation
- Can be carried out with limited disturbance using direct-push injection-based approaches
- Often biodegradation is a beneficial side-effect of physical treatments, in particular thermal where latent heat takes >2yrs to cool
- Or if you have a large excavation, why not mix amendments in-situ to promote biodegradation……….

Why is In-situ Remediation more of a challenge than Ex-situ?

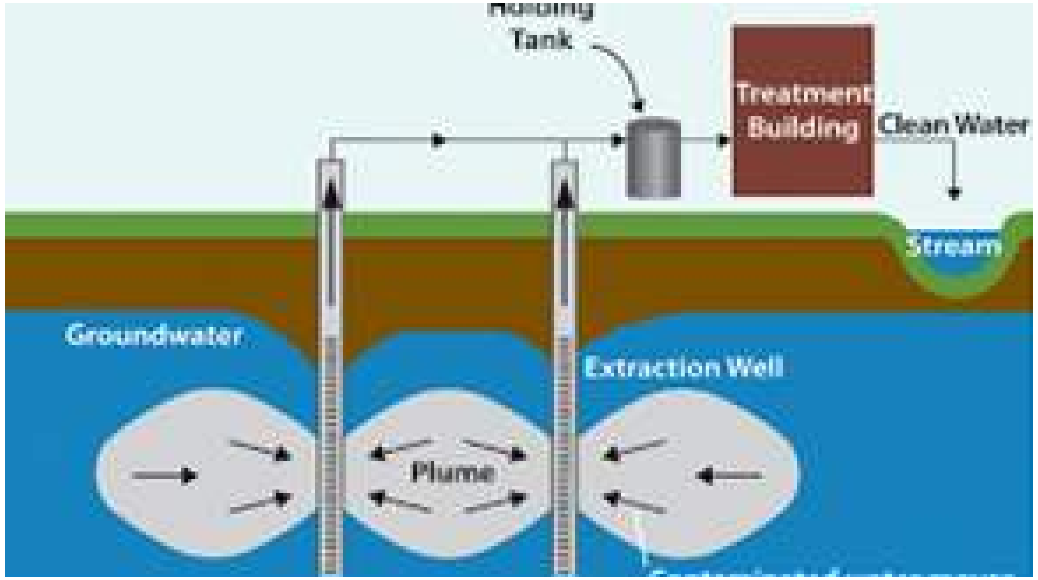
- Dealing with contaminants in the ground you cannot see, feel or smell (most of the time!)
- Often driven by site specific constraints that preclude ‘digging a big hole’ – constrained site, deeper contamination, challenging geology etc.
- Verification & regulatory sign-off typically a more challenging, prolonged process
- Often have impatient clients demanding certainty / results when you often need to hold your nerve
- All of this creates uncertainty and risk
- However that’s what makes in-situ remediation so much more interesting to implement, and rewarding when you get it right…….

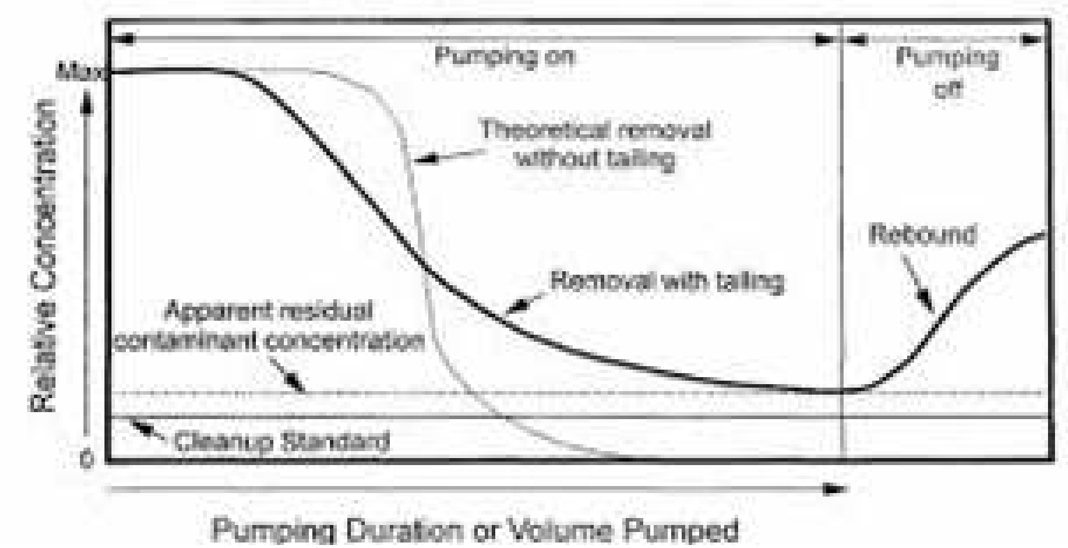
4. Costs of Remedial Techniques

Typical Costs of Remediation Technologies – Ex-Situ

Technology	Contaminants	Timeframe	Set up (£)	Operation (£/m3)	Potential Disadvantages
Bioremediation	TPH, chlorinated Organics, BTEX	>2 months	1,000s	12.50 – 50	Time, space & post remediation re-use
Stabilisation / Solidification	Organics & Inorganics	100m3 - >1,000m3/day	1,000s	11 -100	Space, re-use
Soil Washing	Wide range, metals, organics	50m3 – 500m3/day	10,000s	20-55	Restricted soil type. Size of plant. Filter cake. Elluate
Thermal	Wide range organics	50-200m3/day	100,000s	60-125	Emissions. Energy. Finished product. Size of plant
Dig & dump /treat	Wide range	50-5000m3/day	1,000s	60 – 650 (Landfill / STF) 1000 – 1500 (incineration)	Increasing cost, environmental impact, backfill

Costs of Remediation Technologies – Ex-Situ Pump & Treat



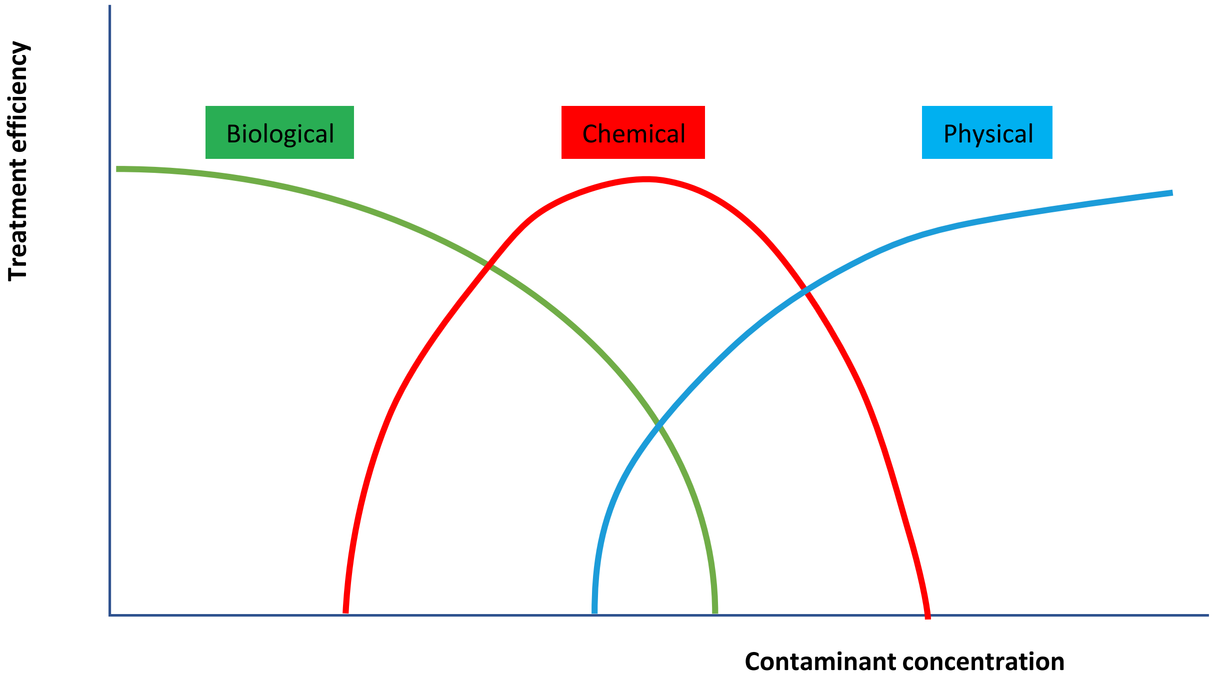


- Reliance upon one technology can be dangerous e.g. pump & treat remediation can cost £££££ over significant timeframes US project (costing $22M quoted $11,000/pound of contaminant mass removed
- Consider as part of a staged treatment approach – e.g. take advantage of initial rapid contaminant mass recovery

Physical/Chemical/Biological

- Which technology to use when?

- Physical e.g. Chemox Surfactant Flushing: LNAPL likely at >10,000ug/l
- ISCO: low mm's LNAPL to 1,000ug/l
- Liquid Activated Carbon: low 00's ug/l to 1,000ug/l
- Biological/ORC: <10,000ug/l



Typical Costs of Remediation Technologies – In-Situ

Technology	Contaminants	Timeframe	Set up (£)	Operation (£/m3)	Potential Disadvantages
In-situ Bioremediation	TPH, Chlorinated Organics, Phenols, BTEX etc.	>2 to 18+ months	1,000s	30 – 75	Timescale, efficacy on more complex / persistent organics, off-gases?
Stabilisation / Solidification (Soil Mixing)	Organics & Inorganics	100m3/day	10,000s	75 -125	Obstructions, restrictions on future construction / disturbance, costly, risk-perception?
Surfactant Flushing	TPH, Phenols, BTEX	3-5 months	10,000s	30-60	Risk to watercourses / off-site migration, uncertainties
In-Situ Thermal	Wide range organics	~2 - 4 months per treatment area	100,000s	95 -135	Technically complex, high cost, Geotechnical impacts, contaminant mobilisation, energy input, cost, significant drilling requirements
Soil Vapour Extraction (SVE)	VOC's, light end TPH incl. BTEX Compounds	4 months +	10,000s	50 - 60	Ineffective in saturated zone (requires additional pumping of groundwater), volatile contaminants only, time, uncertainties

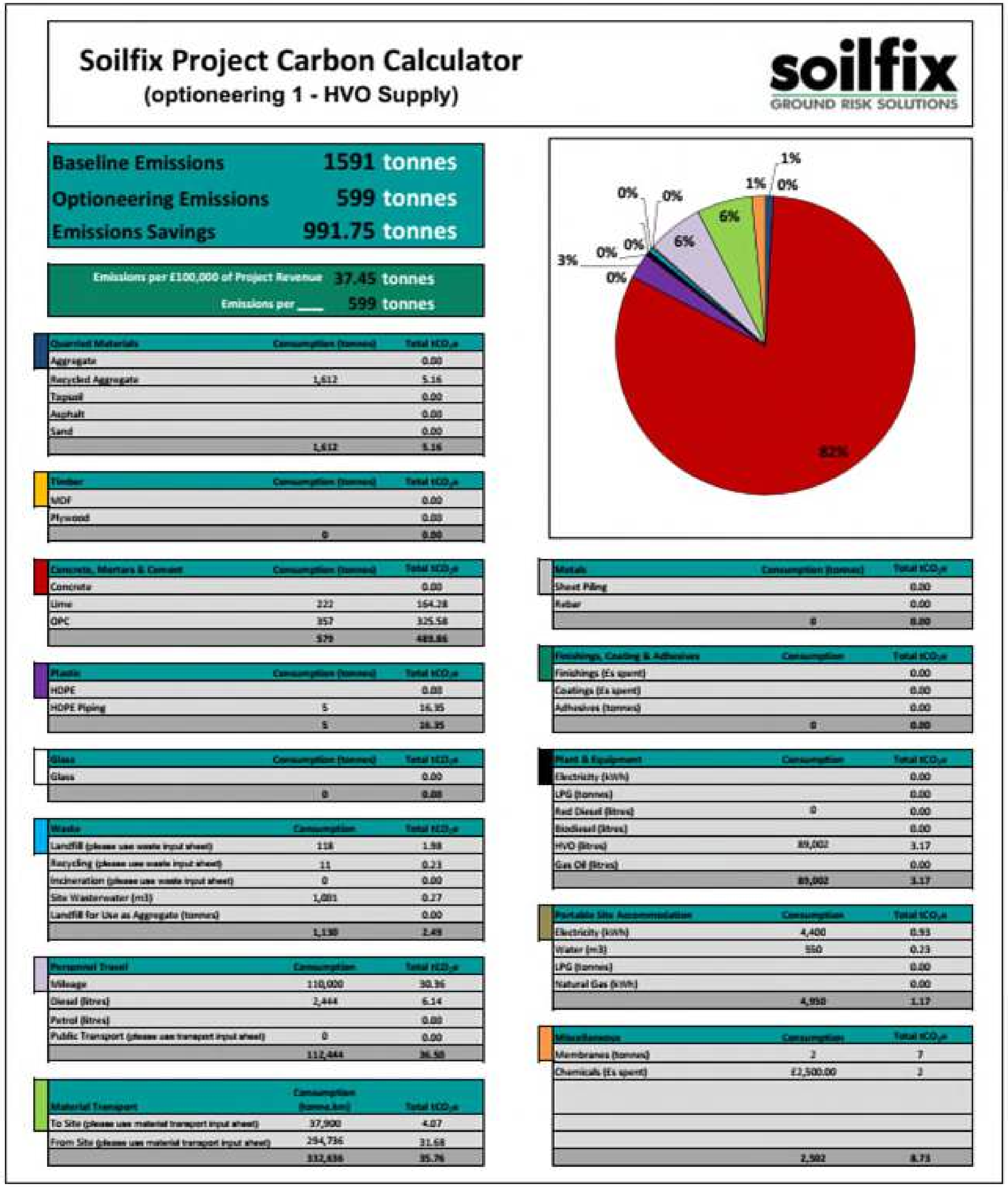
5. Factors influencing Selection of Techniques

Factors Influencing Remediation Design / Approach

- Principal contaminants of concern – Extents, other contaminants within source/plume & effects of daughter products……
- Geology of target strata – Heterogeneity of the ground is an important consideration, cohesive soils often much harder to treat than granular
- In-ground obstructions
- Hydrogeological conditions – often not what you expect !
- Site logistics / constraints (existing & future), also nearby receptors, power / water / gas supply
- Development end-use proposed
- Timescales (client / receptor driven)
- Proven technology – does it actually work?
- **Environmental Permitting requirements !!**

- Potential Greenhouse Gas Emissions (CO2e) – will become an increasing factor in selection of remediation technique(s)

Carbon Calculator Tools to Support Options Appraisal



Soilfix Project Carbon Calculator
(optioneering 1 - HVO Supply)

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Baseline Emissions	1591 tonnes
Optioneering Emissions	599 tonnes
Emissions Savings	991.75 tonnes

Emissions per £100,000 of Project Revenue	37.45 tonnes
Emissions per ____	599 tonnes

Quarried Materials	Consumption (tonnes)	Total tCO$_2$e
Aggregate		0.00
Recycled Aggregate	1,612	5.16
Topsoil		0.00
Asphalt		0.00
Sand		0.00
	1,612	5.16

Timber	Consumption (tonnes)	Total tCO$_2$e
MDF		0.00
Plywood		0.00
	0	0.00

Concrete, Mortars & Cement	Consumption (tonnes)	Total tCO$_2$e
Concrete		0.00
Lime	222	164.28
OPC	357	325.58
	579	489.86

Plastic	Consumption (tonnes)	Total tCO$_2$e
HDPE		0.00
HDPE Piping	5	16.35
	5	16.35

Glass	Consumption (tonnes)	Total tCO$_2$e
Glass		0.00
	0	0.00

Waste	Consumption	Total tCO$_2$e
Landfill (please use waste input sheet)	118	1.98
Recycling (please use waste input sheet)	11	0.23
Incineration (please use waste input sheet)	0	0.00
Site Wastewater (m3)	1,001	0.27
Landfill for Use as Aggregate (tonnes)		0.00
	1,130	2.49

Personnel Travel	Consumption	Total tCO$_2$e
Mileage	110,000	30.36
Diesel (litres)	2,444	6.14
Petrol (litres)		0.00
Public Transport (please use transport input sheet)	0	0.00
	112,444	36.50

Material Transport	Consumption (tonne.km)	Total tCO$_2$e
To Site (please use material transport input sheet)	37,900	4.07
From Site (please use material transport input sheet)	294,736	31.68
	332,636	35.76

Metals	Consumption (tonnes)	Total tCO$_2$e
Sheet Piling		0.00
Rebar		0.00
	0	0.00

Finishings, Coating & Adhesives	Consumption	Total tCO$_2$e
Finishings (£s spent)		0.00
Coatings (£s spent)		0.00
Adhesives (tonnes)		0.00
	0	0.00

Plant & Equipment	Consumption	Total tCO$_2$e
Electricity (kWh)		0.00
LPG (tonnes)		0.00
Red Diesel (litres)	0	0.00
Biodiesel (litres)		0.00
HVO (litres)	89,002	3.17
Gas Oil (litres)		0.00
	89,002	3.17

Portable Site Accommodation	Consumption	Total tCO$_2$e
Electricity (kWh)	4,400	0.93
Water (m3)	550	0.23
LPG (tonnes)		0.00
Natural Gas (kWh)		0.00
	4,950	1.17

Miscellaneous	Consumption	Total tCO$_2$e
Membranes (tonnes)	2	7
Chemicals (£s spent)	£2,500.00	2
	2,502	8.73

- Calculation based on actual requirements for labour, transport, materials, waste removal etc.
- Included portion of surplus clay capping material not required in Phase 1 construction (plus 50% being processed/stabilised for re-use)
- Modular processing & stabilisation of site-won fines, segregated wastes removed for Energy Recovery
- Works programme of 22 weeks

➢ Total **837 tCO2e** emission calculated for Option 2

➢ Largest proportion (59%) now usage of Quicklime / OPC to stabilise processed landfill material

- **NETT** Carbon Reduction of **754 tCO$_2$e** for 'Optioneering' the project (a 47% reduction in GHG emissions) – emissions per £100K of revenue is greater than Option 1 however
- Using **Green Fuel** Supply saves a further **238 tCO$_2$e** Carbon Reduction of **754 tCO$_2$e** for 'Optioneering' the project (a further 16% reduction in GHG emissions)

6. Case Studies

Case Study 1 – Former Tar Works & Ship Breakers Yard, Tipner, Portsmouth

The Problem:

- 8.0Ha derelict site on Tipner Lakes, Portsmouth Harbour, mostly on geotechnically poor reclaimed marshland – former chemical (tar) works, fuels depot, ship breakers yard & Greyhound Track
- Sensitive controlled waters & residents – Tipner Lakes RAMSAR SSSI, primary school & residents sensitive to odours from previous remediation works
- Extensive gross NAPL (mainly tar) contamination associated with former chemical (tar) works & residues, portion subjected to remediation in 2012
- All areas with significant in-ground obstructions & localised areas of exposed chalk aquifer underlying made ground
- Site Preparation & Remediation Strategy agreed with EA & Portsmouth Council
  - Slab/sub-structure breakout & removal / processing;
  - Slurry wall cut-off barrier around 325m of foreshore to 7.0mbgl & permeable reactive sections (granular activated carbon);
  - Excavation & treatment of Made Ground from Tar / NAPL impacted areas across from ~40% of site;
  - NAPL impacted water pumping & treatment;
  - Screening / sorting of fill materials incl. hand-picking of ACM fragments / deleterious materials;
  - Ex-situ bioremediation of gross HC contaminated soils to asymptote & stabilisation/solidification to further reduce leachability; and,
  - Placement of crushed capping layer over hi-vis marker layer.

Case Study 1 – Tipner Regeneration, Portsmouth

Phased Contract over 70 weeks, comprising:

- 55,000m^3 excavation & processing Made Ground
- 20,000m^3 Bioremediation
- 43,000m^3 S/S Treatment
- 7,500m3 ACM in soils
- 2,500m^3 JK impacted soils (hand-picked & encapsulated)
- 100 tonnes segregated tar/silts to be recovered
- 25,000m3 groundwater treated / discharged to date

Case Study 1 – Tipner Regeneration, Portsmouth

Slurry Cutoff Barrier Installation

Groundwater Treatment System

Deep excavation of Made Ground

Bioremediation of Hydrocarbon Contaminated Soils

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Case Study 1 – Tipner Regeneration, Portsmouth

Cement stabilisation of site-won fill

Placement/compaction of S/S Materials

Placement of orange marker geotextile

Completed Development Platform

Case Study 2: Former Bryant & May Match Works, Barking Wharf

The Problem:

- High archaeological interest – one of only 3nr large Saxon Abbey's in UK
- Remediation required to facilitate redevelopment to 4nr multi-storey apartment blocks

- 1.3Ha site, former works had with bulk fuel storage within basement & solvent usage, large area of LNAPL & dissolved TPH plume (~0.4mLNAPL)
- 2nr large TCE source areas within River Terrace Gravels & large dissolved phase plume. TCE impacting off-site to north & potential risk to wider gw body
- Site directly adjacent to River Roding (fortunately no hydraulic continuity)

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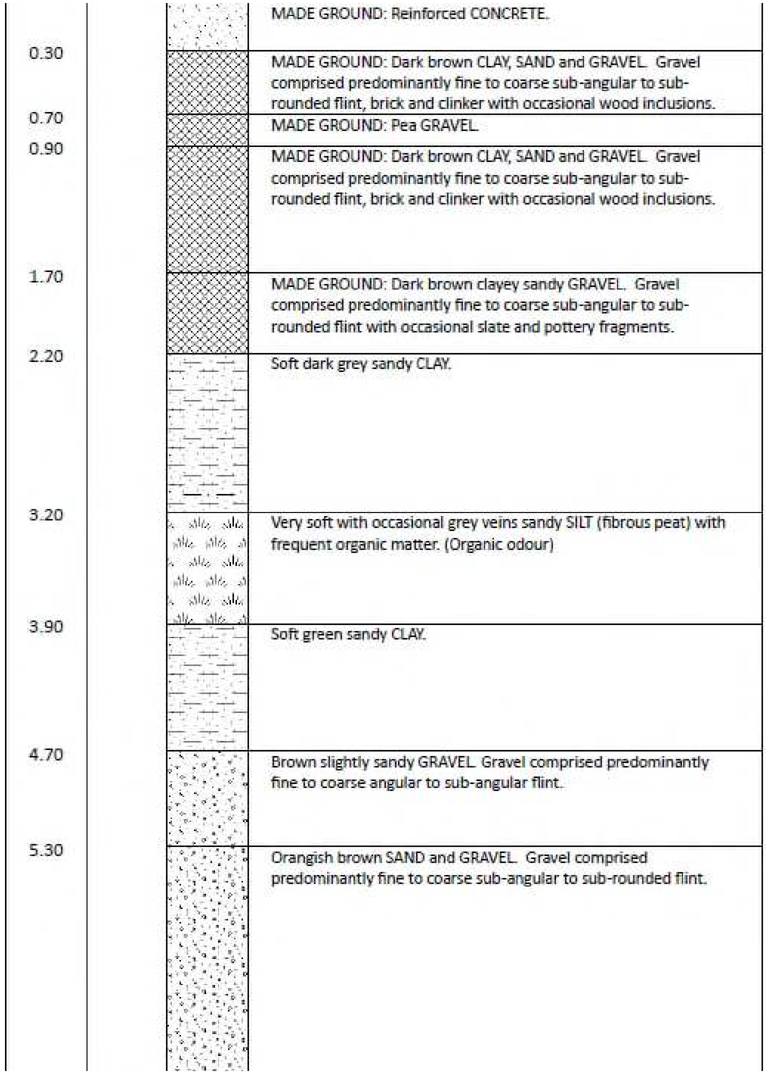
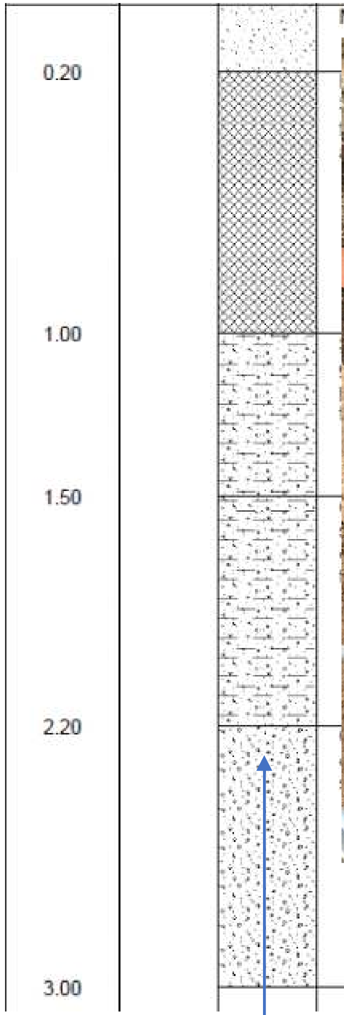
Case Study 2: Former Bryant & May Match Works, Barking Wharf



	MADE GROUND: Reinforced CONCRETE.
0.30	MADE GROUND: Dark brown CLAY, SAND and GRAVEL. Gravel comprised predominantly fine to coarse sub-angular to sub-rounded flint, brick and clinker with occasional wood inclusions.
0.70	MADE GROUND: Pea GRAVEL.
0.90	MADE GROUND: Dark brown CLAY, SAND and GRAVEL. Gravel comprised predominantly fine to coarse sub-angular to sub-rounded flint, brick and clinker with occasional wood inclusions.
1.70	MADE GROUND: Dark brown clayey sandy GRAVEL. Gravel comprised predominantly fine to coarse sub-angular to sub-rounded flint with occasional slate and pottery fragments.
2.20	Soft dark grey sandy CLAY.
3.20	Very soft with occasional grey veins sandy SILT (fibrous peat) with frequent organic matter. (Organic odour)
3.90	Soft green sandy CLAY.
4.70	Brown slightly sandy GRAVEL. Gravel comprised predominantly fine to coarse angular to sub-angular flint.
5.30	Orangish brown SAND and GRAVEL. Gravel comprised predominantly fine to coarse sub-angular to sub-rounded flint.



MADE GROUND: CONCRETE.

0.20

1.00

1.50

2.20

3.00

End of Borehole at 3.00m

3

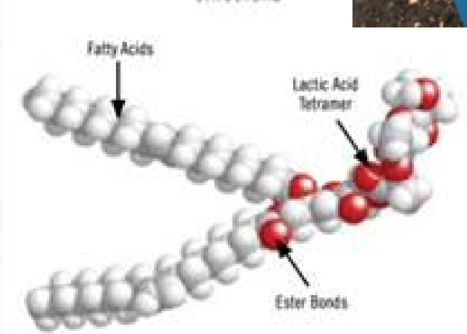
Found an infilled basement structure that likely housed former gas-oil tanks / generator

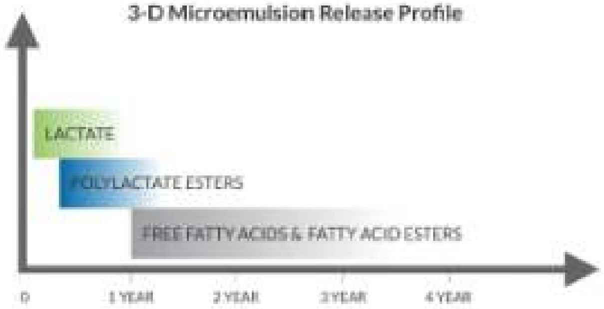
Typically sands & gravels at depth protected by alluvial clays & peats

S&G deposits shallower below LNAPL source area with less protection

Case Study 2: Former Bryant & May Match Works, Barking Wharf

The Solution: Combined In-Situ / Ex-Situ Remediation & Enabling Works





- Betterment-based approach to solvents (>70%) / & no measurable free-phase (LNAPL)
- Primary injection of controlled release organic substrate (3D-Microemulsion – 3DMe) into source areas, using direct push injection
- Extend archaeology excavation to expose natural deposits in LNAPL source zone
- Installation of large LNAPL recovery sumps, with injection wells around perimeter of excavation
- ISCO-enhanced NAPL recovery from RTG formation using RegenOx Petrocleanze^{TM}, ongoing recovery of gross NAPL impacted waters
- Construction of 150m length Permeable Reactive Barrier (reactive treatment zone) around 2nr boundaries through 3DMe injection to protect off-site receptors & mitigate potential ‘rebound’ from residual off-site plume
- Future substrate ‘top-up’ system along boundary to increase longevity of barrier >5yrs
- No measurable LNAPL after 10 weeks injection & pumping & >70% betterment of TCE within 9 months of injection, >95% reduction of TCE & Daughter products within 18 month timeframe

Case Study 2: Former Bryant & May Match Works, Barking Wharf

Direct-push injection of 3DMe Substrate into aquifer (4-7mbgl)

Petrocleanze
Injection into
LNAPL Source
Zone (3-4mbgl)

Groundwater Treatment
Plant

Desorbed
NAPL in
groundwater

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GROUND RISK SOLUTIONS

Case Study 2: Former Match Works, Barking

Drilling 30nr Injection Wells Along Boundary

Injection Well
Manifolded to
HDPE lines

Injection
Lines
grouped in
Chamber for
future access

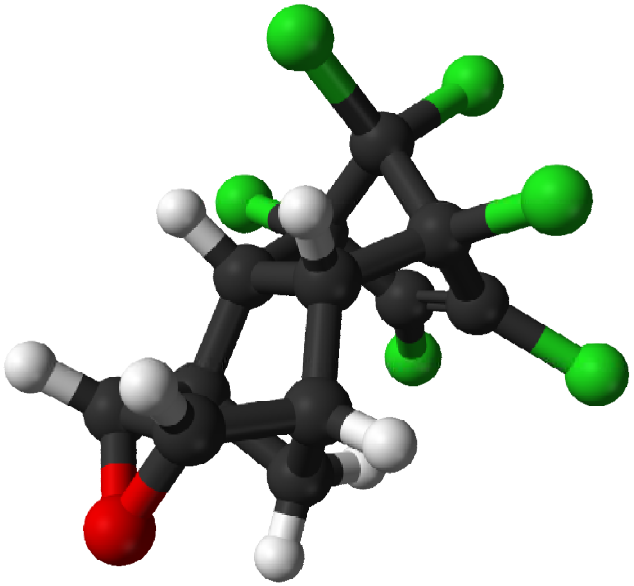
Case Study 3 - Former Timber Treatment Yard, East Anglia

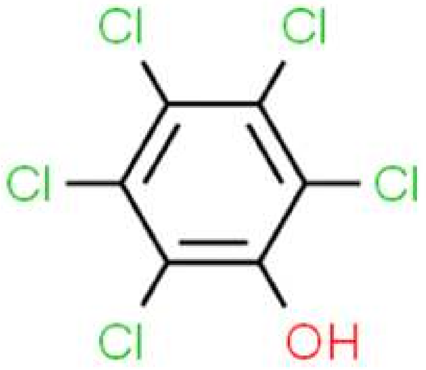
The Problem:

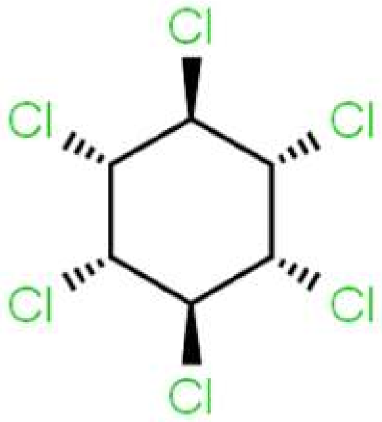
- FTSE-100 Client has long-term lease of site for operation of a data centre, onerous surrender clause related to clean-up of contamination
- No differentiation between historical contamination caused by previous land-uses and lease activities!
- Due diligence identified former timber treatment area on/off-site - some remediation previously carried out for residential development)
- Soils & groundwater below car park contained significantly elevated contamination by petroleum hydrocarbons, VOCs (incl. Benzene) & List 1 organo-chlorine pesticides (PCP, Dieldrin & Lindane)
- Geology comprised superficial deposits of silty sand & gravels underlain by low K head deposits & Newhaven Chalk
- Shallow Secondary ‘A’ aquifer in continuity with River 80m from site – risk based targets derived by DQRA very low for persistent organics
- Chalk aquifer unit Principal Aquifer (Zone SPZ) – Pentachlorophenol & trace Lindane concs detected within chalk groundwater
- Client requires quick solution to surrender lease but not keen on ex-situ remediation of soils & groundwater

Contaminants of Concern

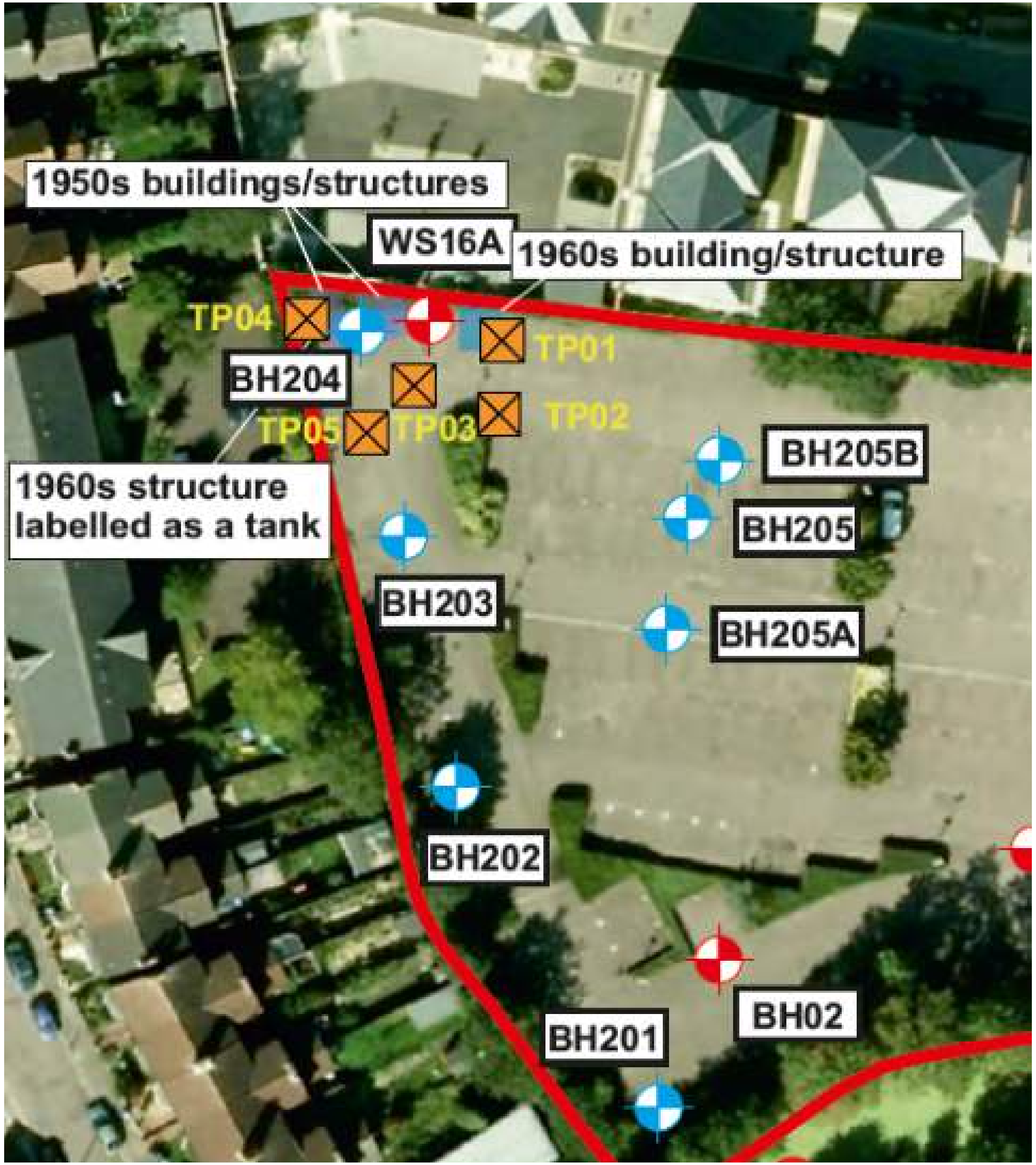
- Petroleum hydrocarbons (1,000 – 6,500ug/l)
- Volatile Organic Compounds (VOCs) incl. Benzene & Trimethyl benzenes (up to 1,135ug/l)
- More complex persistent, List 1 Organo-chlorine pesticides / insecticides – Pentachlorophenol (up to 6,800ug/l), Dieldrin (~18 - 30ug/l), gamma-hexachlorocyclohexane (Lindane) – (~35 - 75ug/l)
- DQRA modelling suggests remedial target concentrations at almost the laboratory limit of detection (<0.1ug/l)………





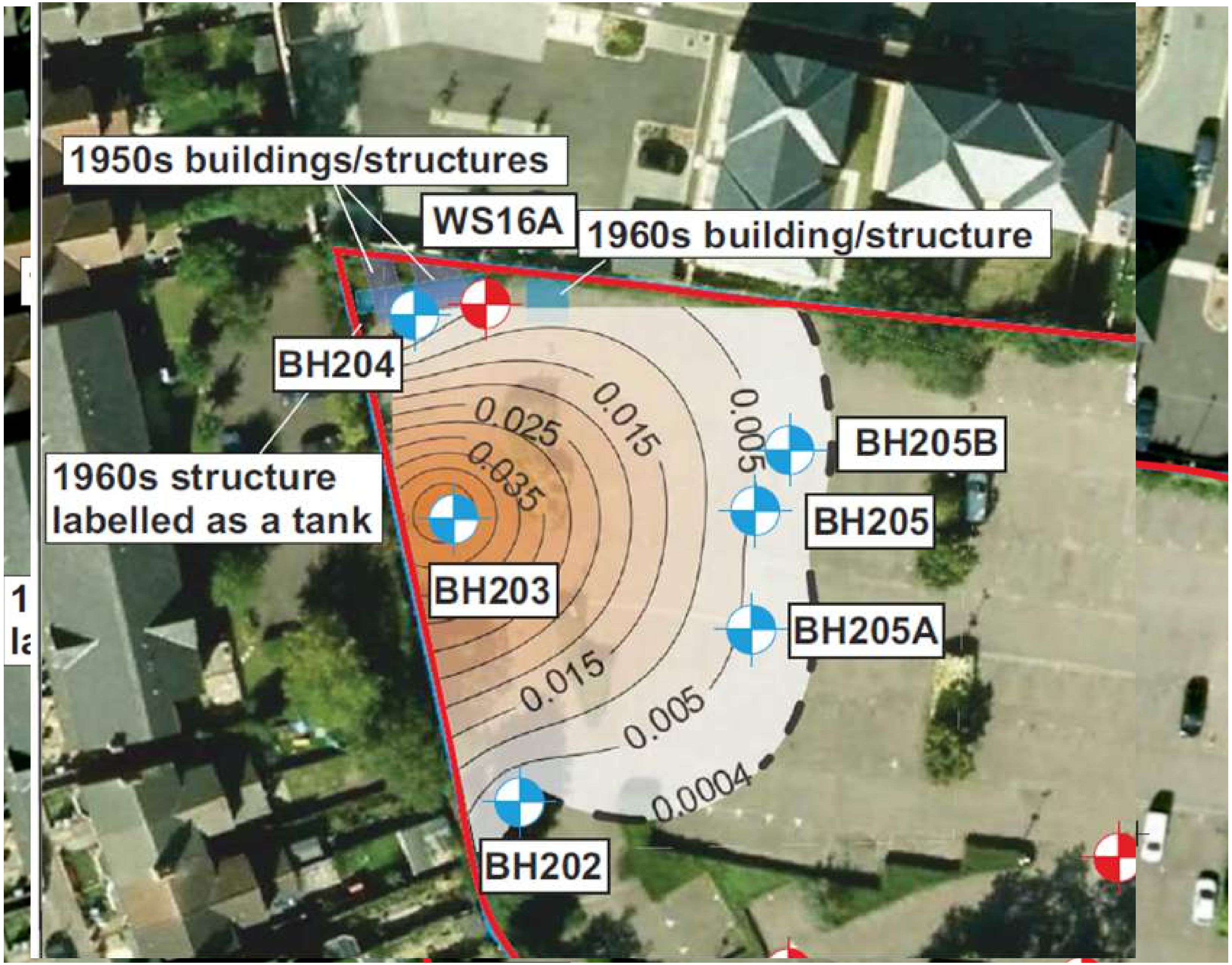


Conceptual Site Model



Inferred TPH Concs in Groundwater

Inferred Pentachlorophenol (PCP) Concs in Groundwater

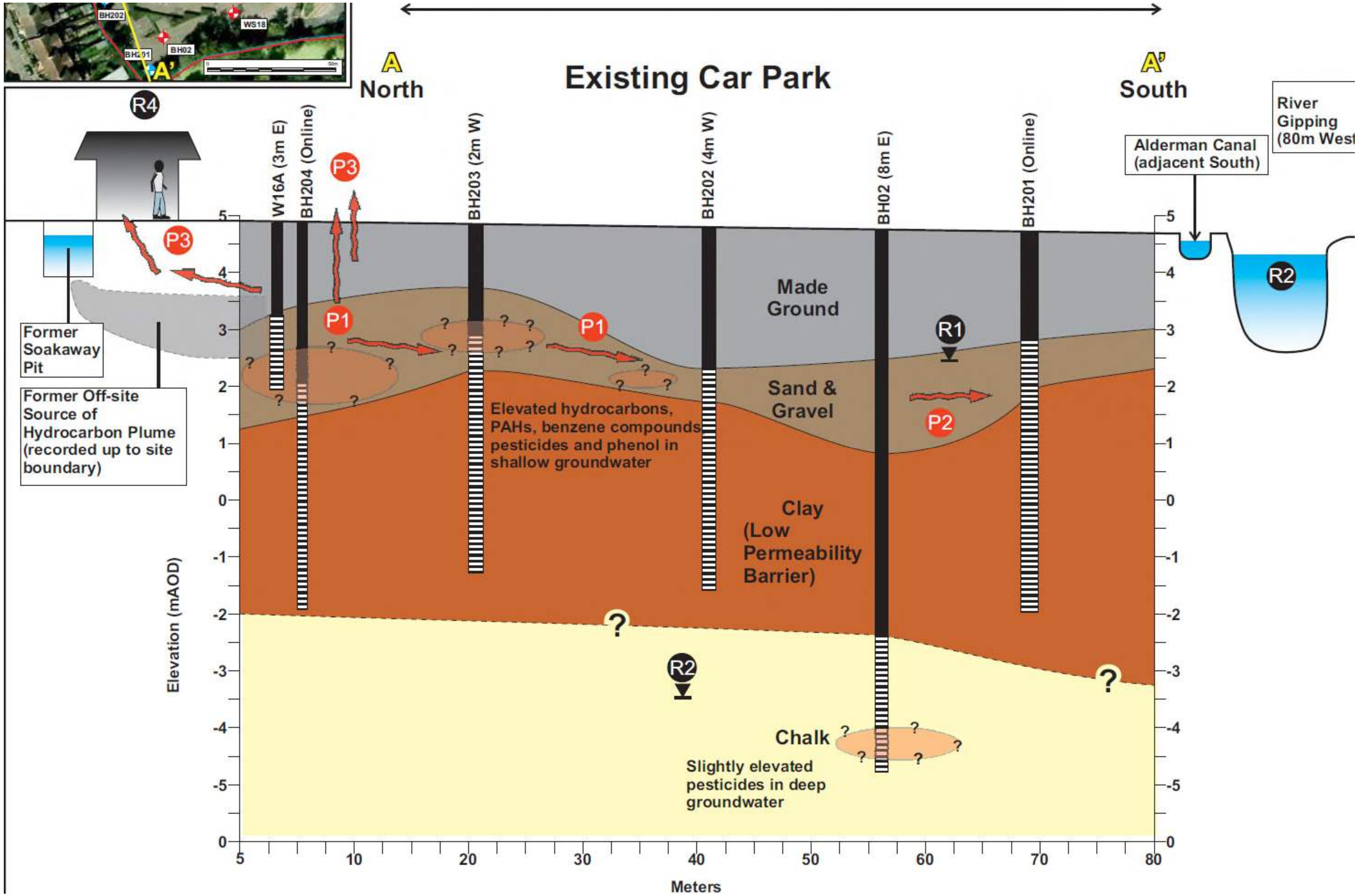


Conceptual Site Model

Potential Pathways

- P1 Lateral Migration of Contaminated Groundwater Impacting Shallow Groundwater
- P2 Lateral Migration of Contaminated Groundwater Impacting Surface Water Receptors
- P3 Hazardous Vapours Impacting Adjacent Residents and Future Site-Users

* The risks to deep groundwater have not been assessed in the DQRA



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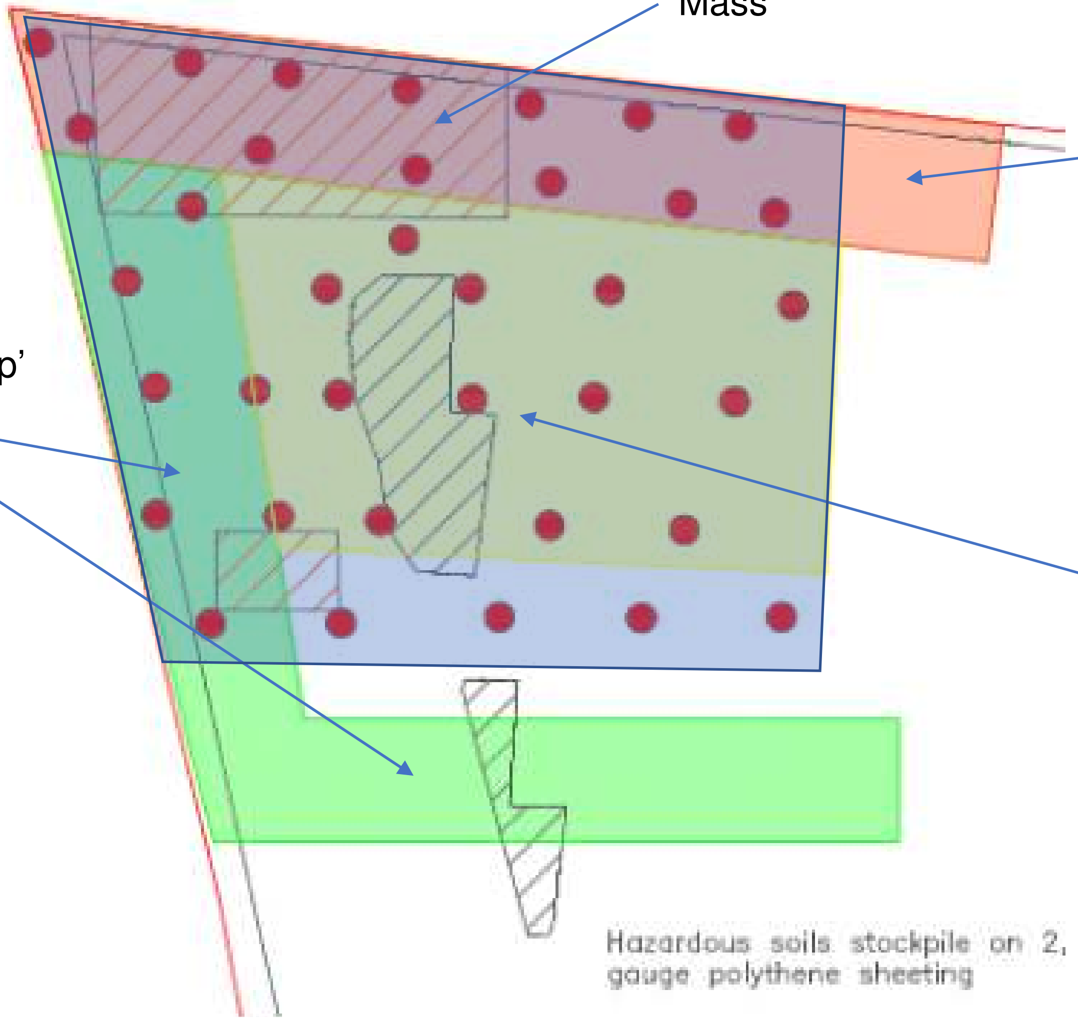
Former Timber Yard, East Anglia

The Solution: Combined In-Situ / Ex-Situ Remediation & Enabling Works

- Betterment-based approach agreed with EA >75% average reduction of CoC's pre-remediation……..
- **Primary Remediation** - Excavation & disposal of 2nr source areas to meet human health criteria in vadose zone & achieve soil/water/NAPL mass removal from main on-site groundwater source
- **Secondary Treatment** - In-situ Chemical Oxidation (ISCO) treatment of groundwater source zone using activated Sodium Persulphate & Sodium Percarbonate below on-site services
- Objective of ISCO to reduce TPH / VOC loading & organochlorine pesticides within shallow RTD aquifer before Tertiary Treatment
- Remediation wellfield utilised for more detailed characterisation of groundwater flow direction & plume extent for targeted treatment
- **Tertiary Treatment** – Direct-push injection of liquid activated carbon (Plumestop^{TM}) & nutrients within RTD with targeted injection of Oxygen Release Compound in areas of residual TPH / PCP mass
- Plumestop forms an in-situ activated carbon vessel within the RTD aquifer for enhanced residual treatment through sorption & biodegradation processes (a colloidal biomatrix)

Case Study 4 – Former Timber Yard, East Anglia

Original Conceptual Design (Pre-Remediation)



ISCO via 30nr injection wells to reduce TPH & Pesticide Mass

Up-gradient 'Plumestop' Treatment Zone (source treatment & protection from off-site source)

Down-gradient 'Plumestop' Treatment Zone

Additional Source Zone 'Plumestop' Treatment to reduce COC loading into down-gradient barrier

Case Study – Former Timber Yard, East Anglia

Targeted excavation of shallow hotspots and pumping of localised LNAPL from groundwater

Rotary Drilling of 30nr Remediation Wells

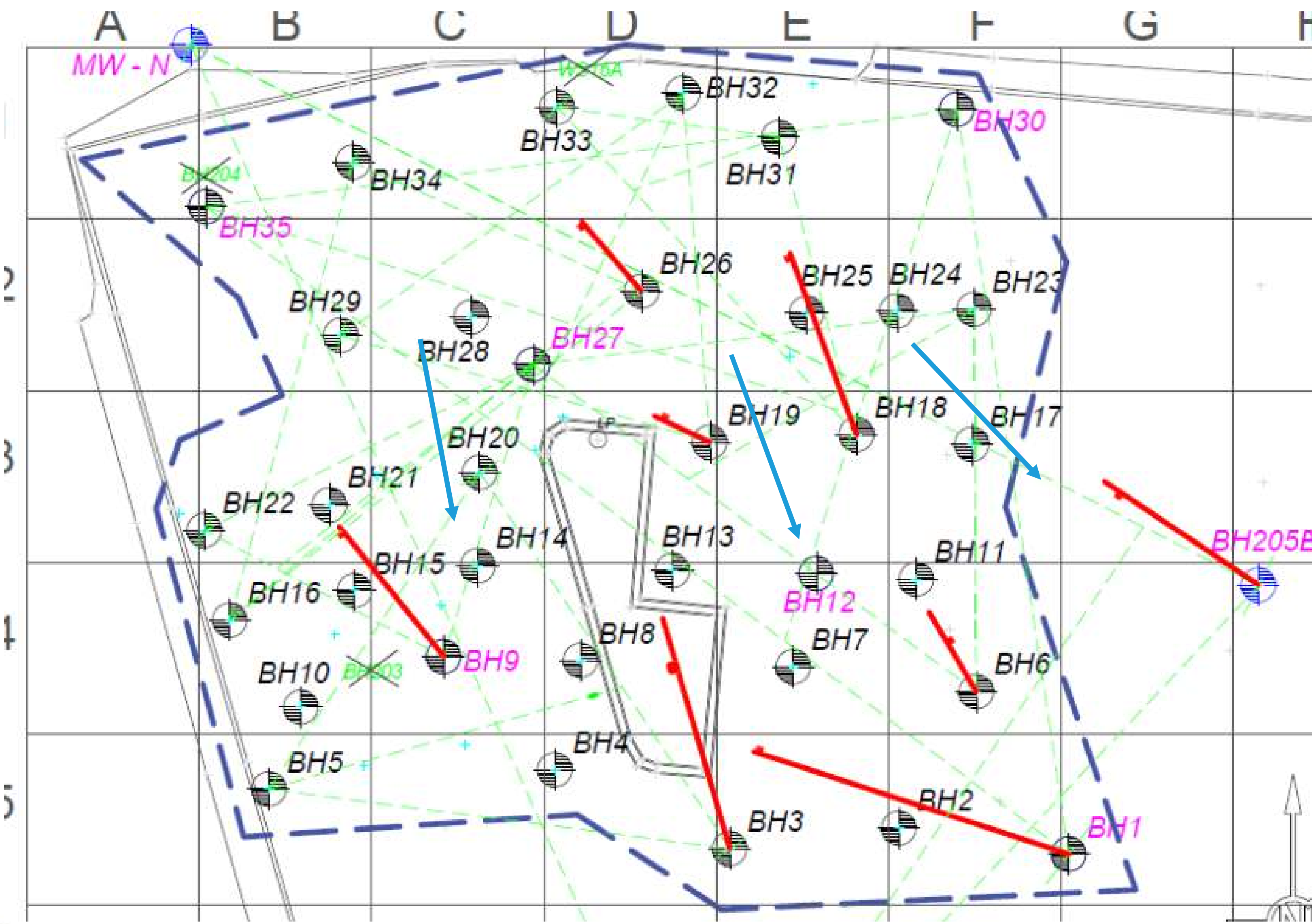
Multi-phase ISCO injection down wells

Former Timber Yard, East Anglia

HCP profiling helped target Plumestop injection in areas of uncertainty

Plumestop batching & injection using direct push points

Former Timber Yard, East Anglia



Groundwater Flow direction complicated & variable due to heterogeneity of RTD

Flow direction & COC concentrations contradict each other!

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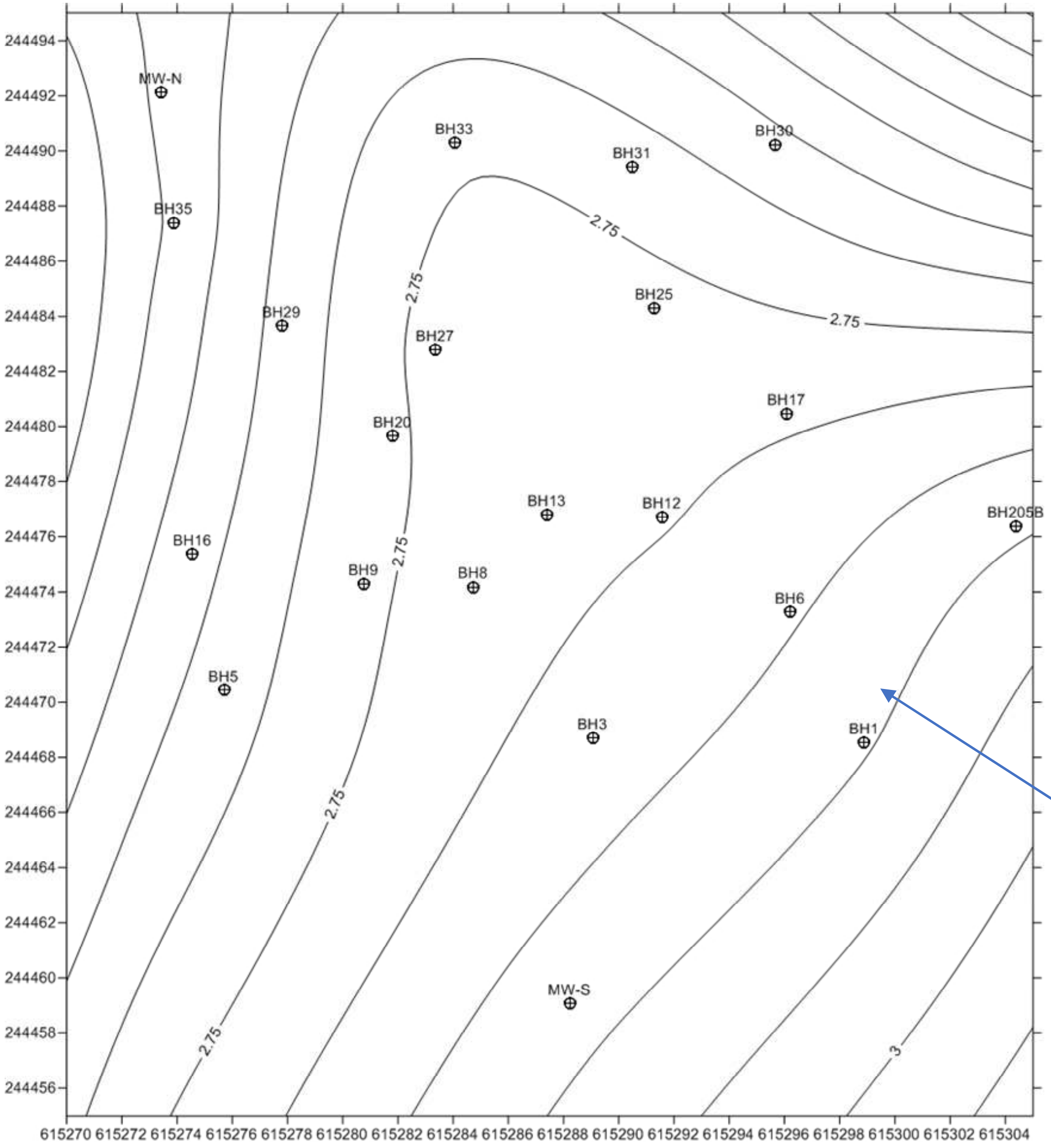

Used Surfer Contour Plots to further assess GW flow direction

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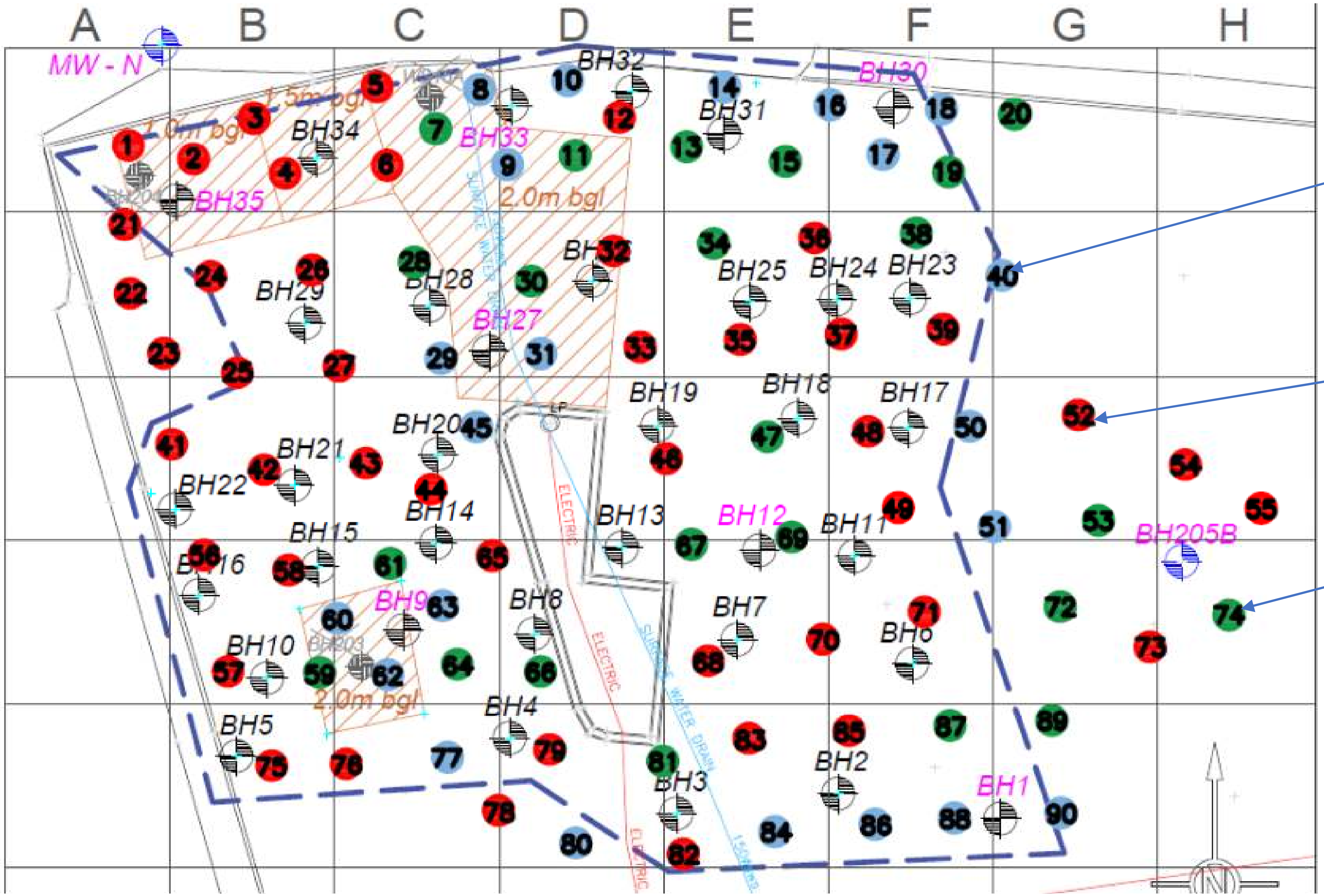


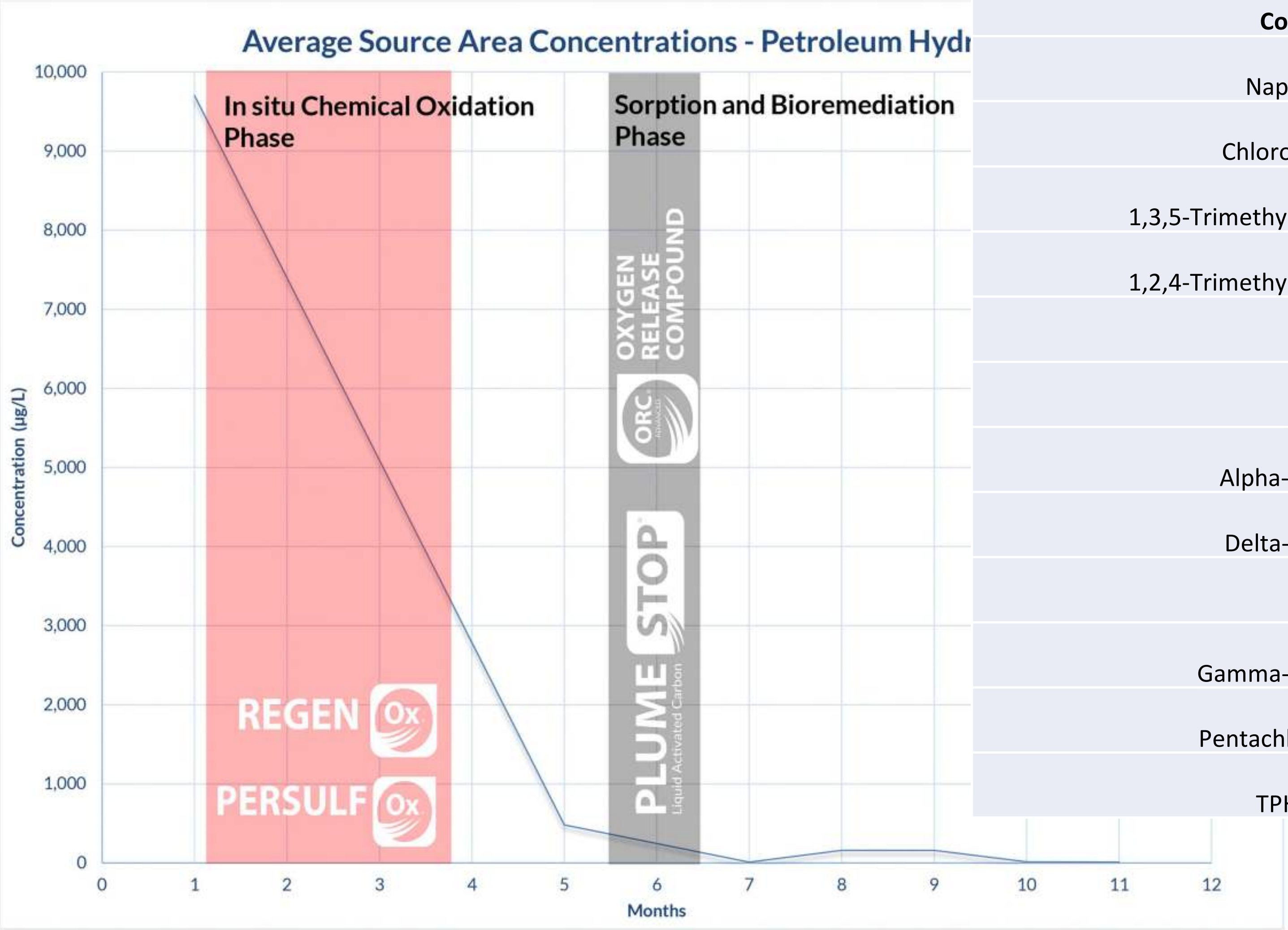
Plumestop, Plumestop "S" & ORC Advanced via direct push points

Plumestop only

Plumestop & ORC Advanced

Almost 20 tonnes Plumestop injected into RTD formation

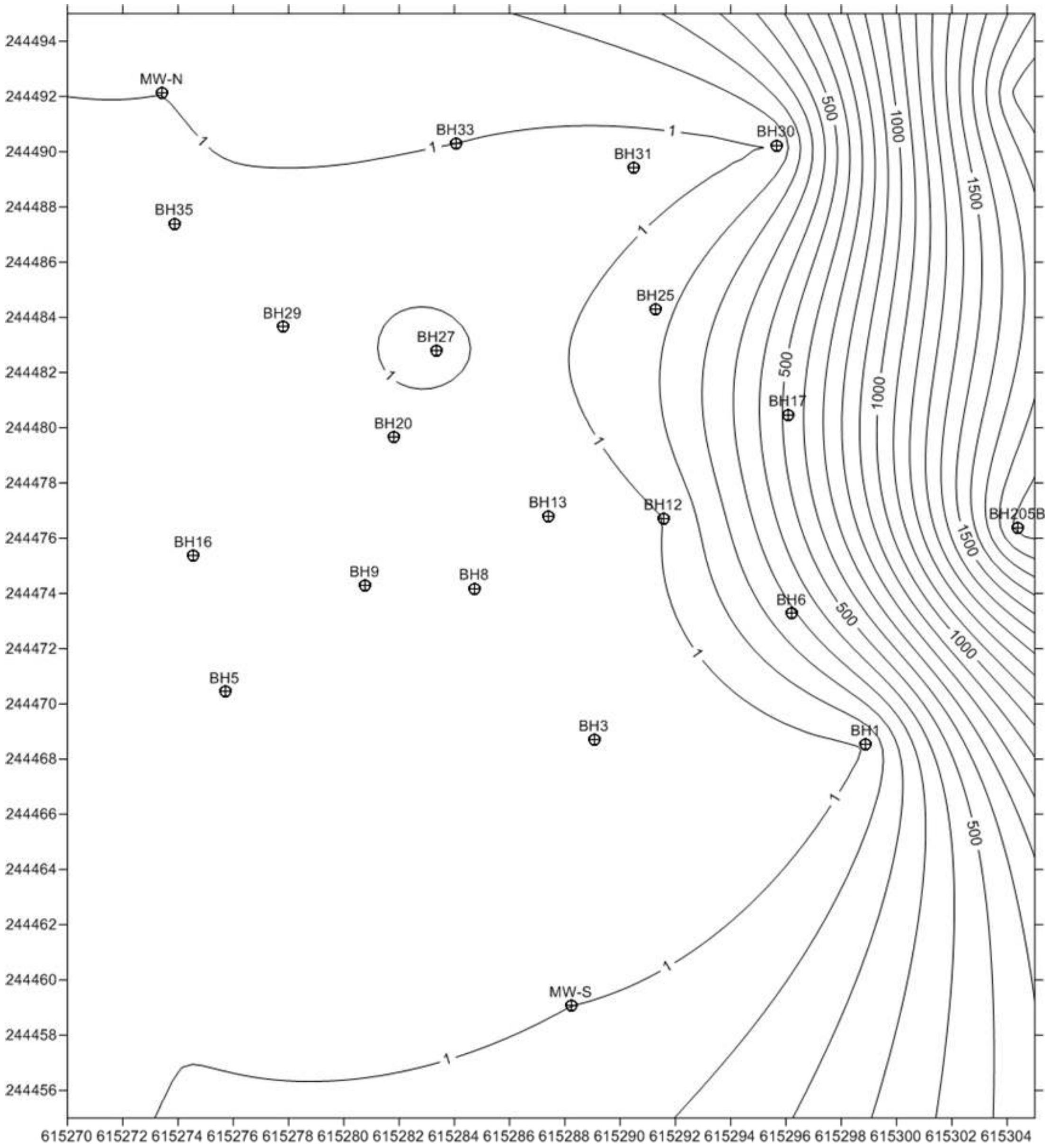
Former Timber Yard, East Anglia



Contaminant	% Reduction
Naphthalene #	99.7%
Chlorobenzene #	98.5%
1,3,5-Trimethylbenzene #	97.3%
1,2,4-Trimethylbenzene #	98.6%
Benzene #	98.0%
Aldrin	94.8%
Alpha-HCH (BHC)	95.7%
Delta-HCH (BHC)	75.8%
Dieldrin	98.9%
Gamma-HCH (BHC)	99.8%
Pentachlorophenol	99.97%
TPH (C5-35) #	99.9%

Former Timber Yard, East Anglia

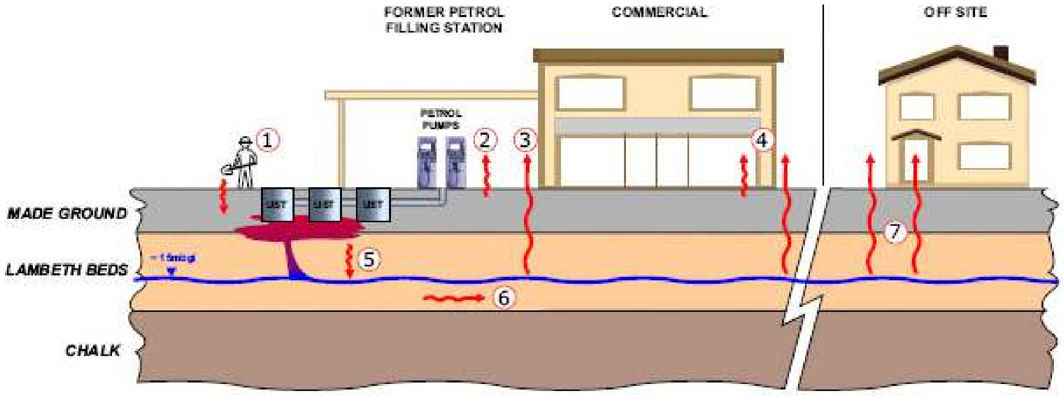
Surfer Plots for Pentachlorophenol:




Thank you
for being
considerate

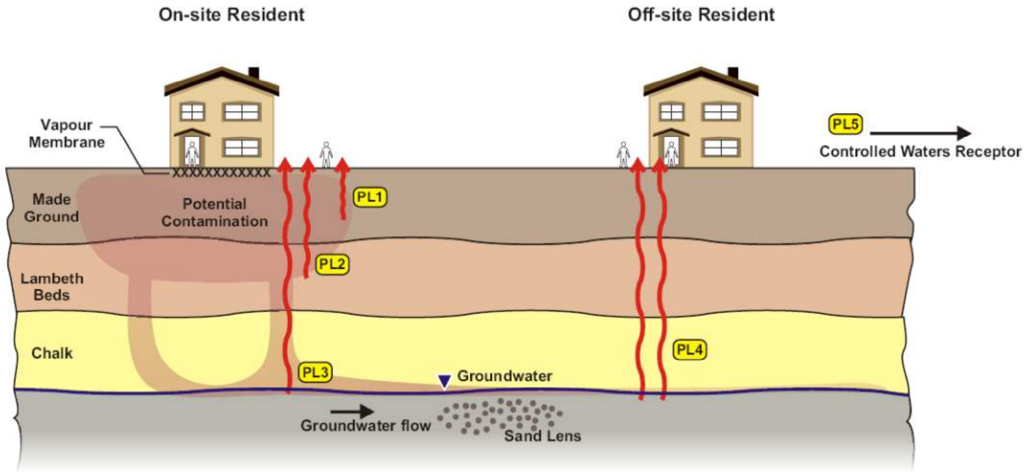
Case Study 5 – Former Petrol Filling Station, Reading

The Problem:



- Redundant former garage with fuel storage tanks historically removed proposed for redevelopment
- LNAPL impacted Chalk Aquifer just up-gradient of Groundwater Source Protection Zone
- Historical LNAPL pumping with long term monitoring did not achieve satisfactory risk reduction (continual rebound)
- Significant proportion of contaminant mass residing in smear zone within weathered chalk & secondary porosity

- Depth of contamination beyond practical / cost effective excavation (>10mbgl)
- No viable foul sewer connection serving site – conventional pump & treat impossible
- More pragmatic betterment-based strategy agreed with EA instead of setting potentially unachievable groundwater criteria (no measurable LNAPL & >50% reduction in dissolved TPH concs in groundwater



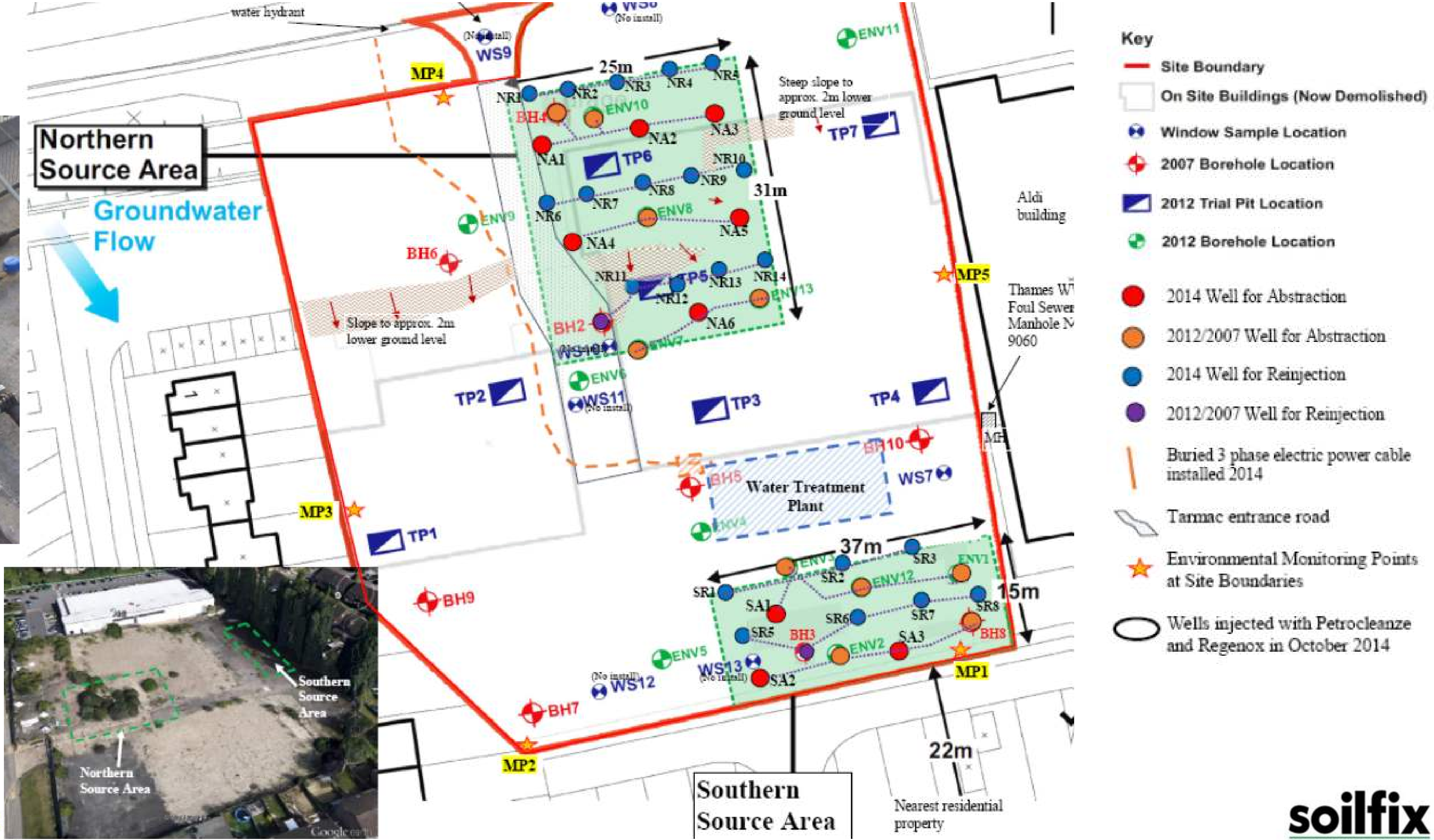
Case Study – Former Petrol Filling Station, Reading

The Solution: Groundwater / LNAPL Pump, Treat & Recirculate with Surfactant Injection, Nutrient Dosing & Oxygen Recirculation

- Further assessment – aquifer testing, pilot trials, optimisation testing (design stage)
- Installation of groundwater injection, abstraction & recirculation wells in two arrays (two plumes areas)
- **<u>Three</u>** permits secured with Environment Agency including abstraction license, waste treatment permit (Soilfix RP3795) and discharge permit (for reinjection of treated water)
- Mobilisation and commissioning of pump, treat and re-injection system
- Three phases of ISCO (RegenOx Petrocleanze^{TM}) injection to promote desorption / flushing of TPH mass for enhanced recovery
- Accelerated natural attenuation phase using Oxygen Infusion technology for O2 supersaturated recirculation water with bio-nutrient amendment with natural surfactant properties

Case Study – Former Petrol Filling Station, Reading

Site Set up:



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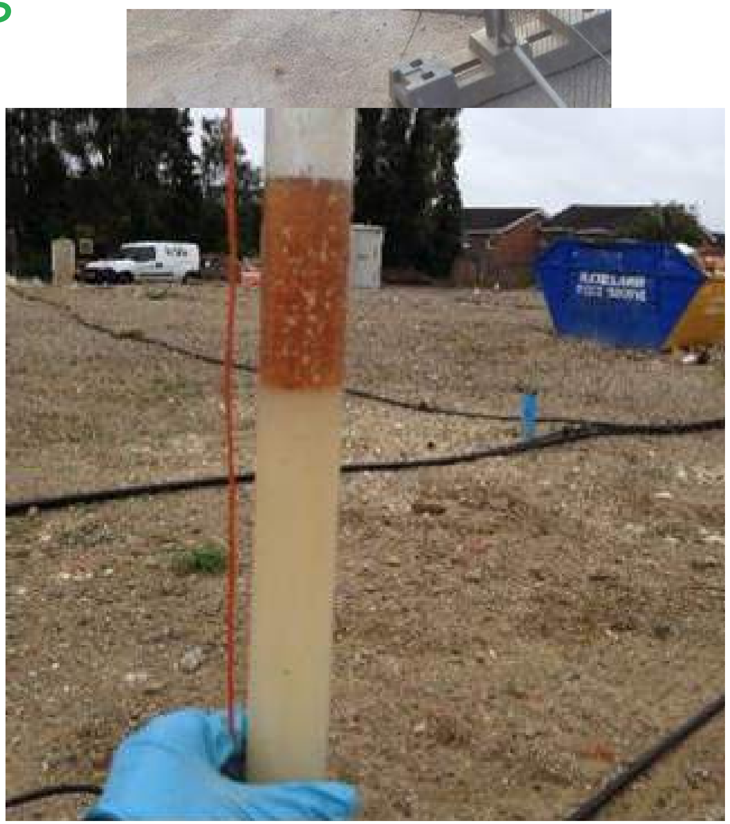
Case Study – Former Petrol Filling Station, Reading

Primary ISCO Injection

Groundwater Pumping & Recirculation



~**20 million litres** of contaminated groundwater abstracted, treated and re-used under bespoke environmental permits. Over **1,000kgs** of hydrocarbons successfully treated and targets agreed with EA achieved

Oxygen Infusion

Bio-nutrient Amendments

Divesture of land completed & residential apartments now constructed by Developer

Thank you!

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