D3.1 - Examples of Sustainable Remediation

ASSESSMENT OF A LARGE SCALE IN-SITU THERMAL TREATMENT PROJECT PERFORMED AT A CHLORINATED SOLVENT SITE IN THE UK

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ABSTRACT

In preparation for site remediation, an extensive programme of High Resolution Site Characterisation (HRSC) was carried out at the site, an active manufacturing facility, that identified impact from chlorinated solvents beneath two discrete areas, in particular from cis 1,2-dichloroethene and vinyl chloride. A majority of the contaminant mass was within the matrix of underlying saturated bedrock; the most challenging environment to successfully perform in-situ remediation given the confined and fractured nature of the subsurface.

A number of 'green' remediation schemes have been undertaken in the UK over the last few years, typically focused towards the use of renewable energy or recycling during the operational phase of the project. Whilst the work undertaken here incorporates both of these elements, the sustainability-led strategy developed identified that the greatest opportunity to reduce CO2 emissions was at the design stage by minimizing remedial treatment zones to only include areas of greatest contaminant mass, as determined by the HRSC, for active source treatment; optimizing the works during system operation and agreeing a mass recovery trend endpoint with the regulatory authorities, which was anticipated to be a more sustainable approach than attempting, as is often done at chlorinated solvent sites, to reach a concentration based goal.

The remedial design was therefore intended to apply carbon footprint reduction principals to application of an in-situ technology, which following an options appraisal, the source zone remediation technique comprised a combination of in-situ steam injection and Dual Phase Vacuum Extraction (DPVE). The design comprised 20 DPVE wells, and 23 steam injection locations (screened shallow and deep). Whilst this technique is paradoxically a relatively energy intensive remediation technology, it was identified as the most rapid approach that could achieve an overarching objective of actively removing mass from the bedrock.

The source treatment results demonstrate considerable success of the source treatment works, with the total mass removal calculated at circa 1,000kg together with achievement of asymptotic conditions with respect to mass removal met within 14 weeks.

During the operational phase of the works, the steam injection process was regularly monitored via a network of thermocouples and interpreted using PC based software, with the vapour extraction performance also assessed via regular flow and VOC quantification, this real-time monitoring assisted with the objective of reaching the endpoint more rapidly, hence reducing CO2 emissions.

A preliminary assessment of the works indicates that the thermal remediation carbon footprint was 1,611 tonnes CO2-eq to remove circa 1,100kg of mass. It is considered unlikely that a conventional pump and treat system would have removed >50kg, with the carbon footprint for this approach estimated to be significantly higher at 2,496 tonnes CO2-eq.

INTRODUCTION

A programme of intrusive investigation had identified the presence of soil and groundwater impact at a 8 hectare industrial facility from chlorinated solvents (mainly trichloroethene (TCE) and its degradation compounds cis 1,2-dichloroethene and vinyl chloride), and a remedial strategy based on pump and treat for a number of years was envisaged. The Conceptual Site Model (CSM) at this stage was incomplete and Environmental Resources Management (ERM) was retained to refine the CSM to develop a robust sustainability-led approach to remediation in accordance with UK and European guidance.

The Sustainable Remediation Forum UK (SuRF UK) framework incorporates a two stage approach to apply to sustainable remediation decision making, either at the land use planning design stage and/or the remediation implementation phase (see Figure 1). ERM has adopted a similar life cycle approach for this project (see Figure 2) where sustainability has been an integral consideration from the initial review of the preliminary remedial strategy through to additional site investigation and implementation of remediation, within the boundaries of the overarching client objectives.

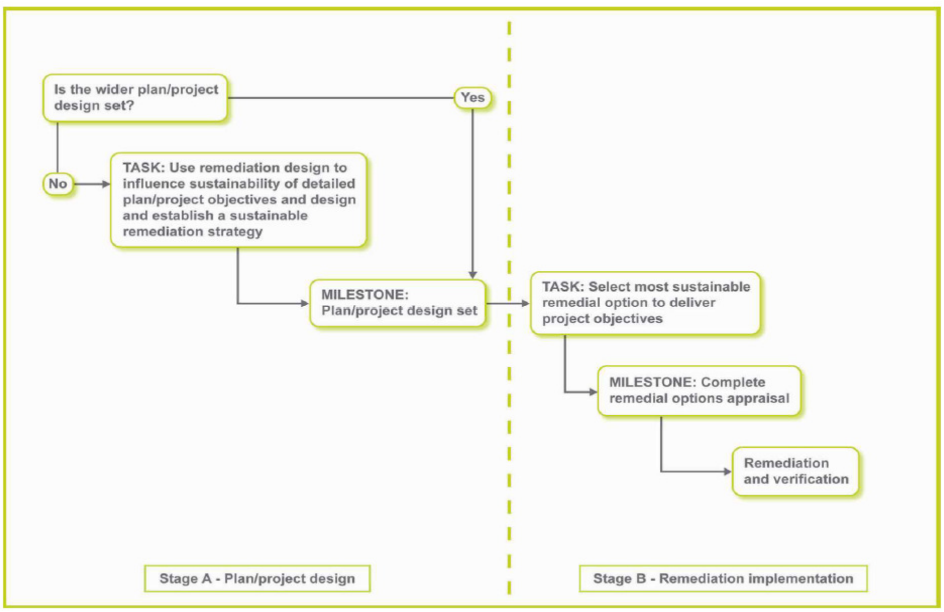

FIGURE 1. The Surf UK Framework.

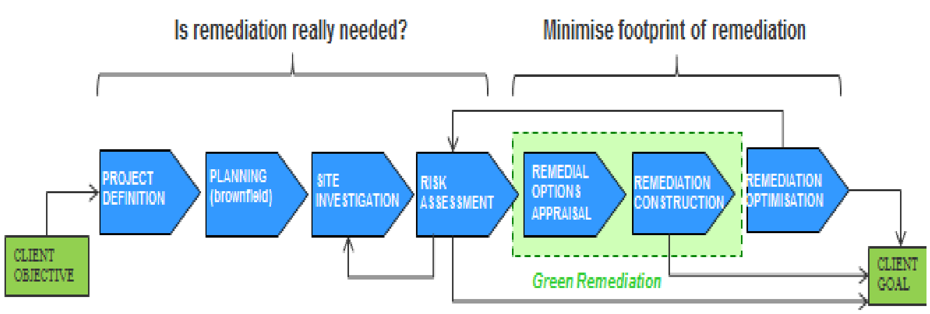

FIGURE 2. ERM's integrated approach to sustainable site investigation and remediation.

In the context of this site a number of environmental economic and social indicators were identified and throughout the investigation and remediation phases, the environmental footprint was quantified.

The metrics recorded were travel to and from site, energy use, materials used, waste generation and disposal route, water use and details of wastewater production & disposal.

HIGH RESOLUTION SITE CHARACTERISATION

The site investigation was completed using Triad principles to complete two phases of works via sequential application of dynamic High Resolution Site Characterization (HRSC) techniques in near surface superficial alluvial deposits and underlying weathered and fractured shale bedrock, the latter including use of a Modified Waterloo Profiler (Figure 3) and ground-breaking Discrete Fracture Network assessment techniques that included on-site extraction and analysis of pore water within fractured rock.

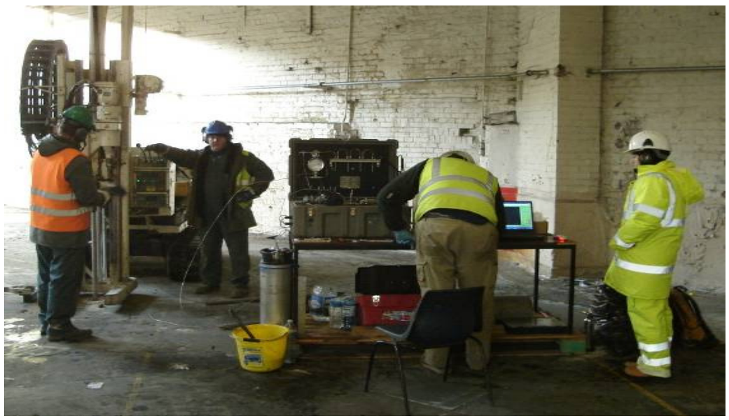

FIGURE 3. Modified Waterloo Profiler Investigation, showing Geoprobe™ and field sampling equipment.

The adoption of HRSC was instrumental in refining and developing a rigorous CSM for the site and enabling the extent of sources zones and mass fluxes to be evaluated. The HRSC also minimised waste generation, eliminated the need for multiple phases of investigation and reduced the carbon footprint of works (it is estimated by circa 13.5 tonnes CO2e compared to a similar scope undertaken using traditional technologies).

REFINED CONCEPTUAL SITE MODEL

The use of the HRSC significantly enhanced the understanding of the site beyond that which was apparent from the conventional site investigation. The subsequent understanding of site geology, contaminant distribution and chemistry provided a sound, technically defensible platform from which to define remedial objectives and is considered a key element of the sustainability led approach shown in Figures 1 & 2.

The revised CSM is presented below (Figure 4). The results indicated the presence of two TCE source zones (one originating via migration through the underlying aquifer, the other caused by preferential flow through drainage runs). Of particular note is the correlation between presence of solvents within the matrix of the weathered shale and absence of solvents within the fresh fractured shale.

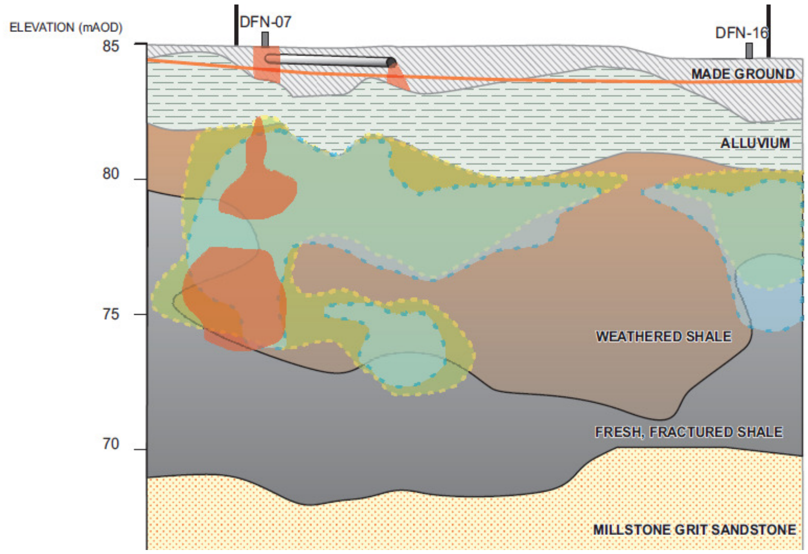

FIGURE 4. Geological cross section/contaminant distribution (scale: approximately 100 m from left to right). The primary TCE source zone is shown near to investigation location DFN-07.

RISK ASSESSMENT

Additionally, the HRSC data was used to accurately define site specific contaminant bulk attenuation factors as part of the development of risk based remedial target criteria.

The results provided a significantly less conservative but defensible assessment of contaminant attenuation than typical half-life values obtained from literature would provide, with the HRSC data-set providing sufficient regulatory confidence that application of a site specific bulk attenuation rate was justified, minimizing remediation extent and enabling the works to focus on the areas of greatest impact.

REMEDIAL OPTIONS APPRAISAL/DESIGN

Given that chlorinated solvent distribution and mass had been clearly defined on the basis of a micro-scale understanding of the geological, hydrogeological and geochemical conditions beneath the site, the remedial strategy was revised from the previously designed long term containment and mass removal approach to one based on focused source reduction.

The HRSC data not only enabled the volume of the originally defined treatment zone to be significantly reduced from that originally anticipated (Figure 5 - The difference in area between the actual treatment zone (blue polygon) and the red rectangle shows how the treatment zone has been minimised post-HRSC), but also identified that a majority of the contaminant mass was present within the bedrock matrix, with 80% of the total contaminant mass in an area representing approximately 40% of the overall treatment zone.

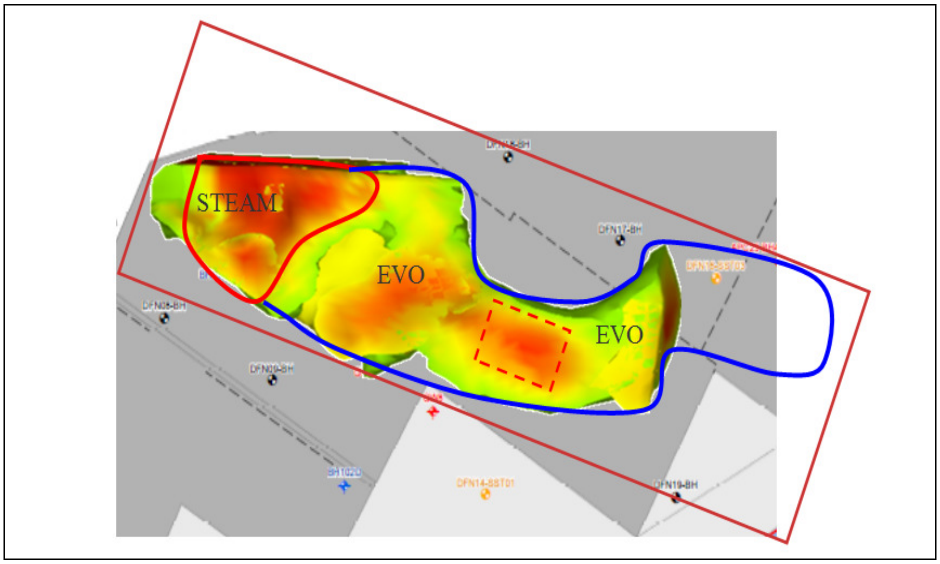

FIGURE 5. Remedial Treatment Zones showing how the HRSC data enabled the overall treatment volume to be reduced and targeting of appropriate techniques relative to mass distribution.

This area was addressed using in-situ steam injection combined with Dual Phase Vacuum Extraction (DPVE), i.e. an approach of using a short-term relatively energy intensive technology in the source zones (initially envisaged to be using surplus steam from factory operations). The area containing the remaining 20% of the contaminant mass (plume) will be treated using biological substrate injection to address mobile contaminants and form a reactive zone downgradient of source zones in the event of any residual impact migration post source treatment. Figure 6 and Figure 7 show the installed remediation system.

FIGURE 6: Above Ground Pipework.

FIGURE 7: Treatment Equipment.

REMEDIATION OPTIMISATION

During the operational phase of the works, thermocouple data was interpreted spatially using PC based software, which together with real time VOC quantification, facilitated reaching the endpoint more rapidly, hence reducing CO2 emissions. Figure 8 provides an example output of the model and Figure 9 illustrates thermocouple devices.

The thermocouple data collected was regularly inputted into the thermal model to verify and if required further refine heating duration prediction.

The data was also used to determine which steam injection wells should be switched on at a given point in time, therefore improving efficiency/carbon footprint reduction of the works undertaken (targeting cooler areas and maintaining minimal injection in warmer areas).

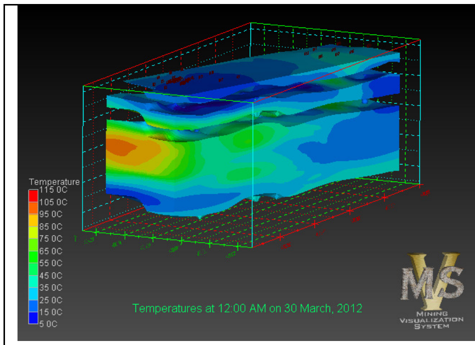

FIGURE 8: Evaluation and Optimization of the Heating Process; Model Output.

FIGURE 9: Thermocouple devices for monitoring.

CARBON FOOTPRINT OF THE WORKS

The carbon footprint was one of the key environmental indicators for the project. ERM collected data on materials used, fuel, travel etc. throughout the lifecycle of the remediation works to provide input data and then calculated the carbon footprint using the Life Cycle Assessment (LCA) software package Simapro and Life Cycle Inventory (LCI) data from the Ecoinvent 2.2 database for all materials, fuels and processes.

ERM then calculated the carbon footprint of the initially proposed pump and treat scheme and compared this to the thermal project actually undertaken.

The results are shown in Figure 10.

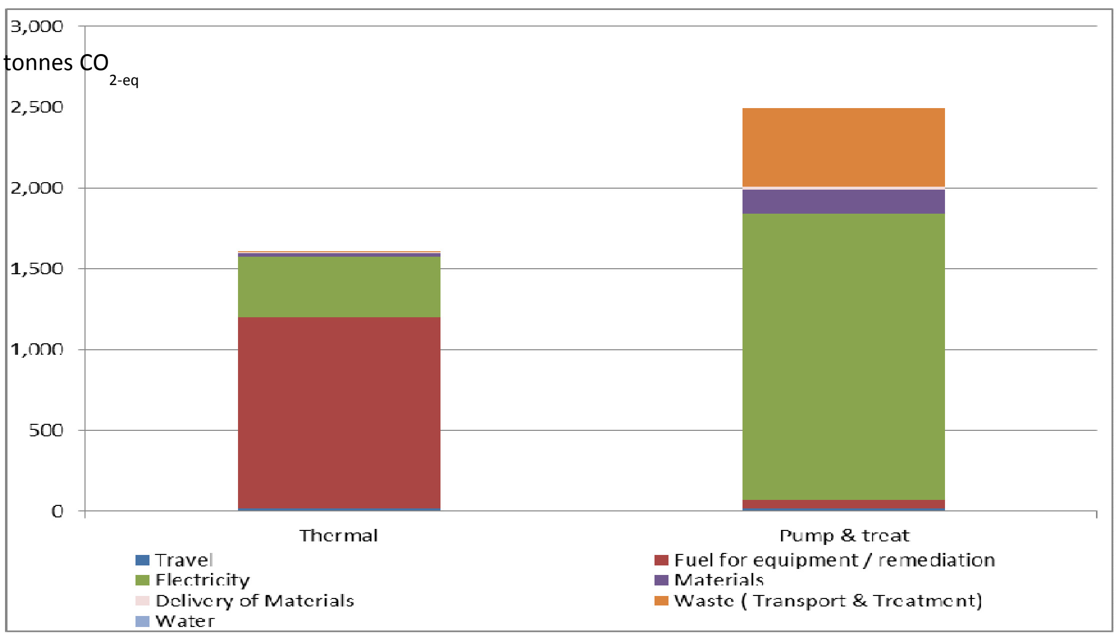

FIGURE 10: Comparison of actual CO2 emissions from the short term in-situ thermal project undertaken against anticipated CO2 emissions that would have been generated by the long term pump and treat scheme.

The carbon footprint for the thermal remediation system was 1,611 tonnes CO2-eq to remove circa 1,100kg of mass. It is considered unlikely that a conventional pump and treat system would have removed >50kg, with the carbon footprint for this approach estimated to be significantly higher at 2,496 tonnes CO2-eq.

The majority of the carbon footprint for the thermal system was from the production of steam from the site boiler accounting for 88% of the total carbon footprint.

CONCLUSIONS

This case study illustrates the benefit of the development of rigorous CSMs early in the life cycle of remediation projects in order that risks can be more clearly understood, the remediation can be undertaken in a sustainable manner from design to implementation, and resources not be wasted through inefficient application of remediation technologies. Sustainability was considered at every stage of project but ultimately had to work within context of overarching project requirements and boundaries.

Following the application of HRSC, the remedial solution was agreed with regulators and delivered for a cost of <£2.5m (compared to previous estimate of £11m), meeting the expectations of all stakeholders.

Whilst several projects have been undertaken in the UK that demonstrate ‘green remediation’ approaches, this project demonstrates that the greatest opportunity to reduce carbon footprint for remediation projects is at the project planning, site characterisation and risk assessment stages.