CL:AIRE

SuRF 2
(September 2013)

SuRF-UK bulletin

SuRF-UK bulletins provide examples of carrying out a sustainability assessment whilst undertaking a project.

Upper Heyford - Remediation Options Appraisal

1. INTRODUCTION/NATURE OF ASSESSMENT

RAF Upper Heyford is located 7km northwest of Bicester, in a rural location, within the parishes of Upper Heyford, Somerton and Ardley. The site extends over 505 hectares, and has been designated as a conservation area in view of its heritage as a former airbase.

A live assessment was undertaken as part of the remediation options appraisal during competitive tendering.

The remediation options appraisal was undertaken at Stage B. Detailed planning policy and conditions were already in place for the site. Although the remediation options appraisal was undertaken at Stage B, there were only a few limiting factors to consider as part of the options appraisal which allowed a varied number of options to be considered as part of the SuRF-UK assessment.

The planning policy for the site and planning brief produced by Cherwell District Council, included policies in line with the indicator parameters for sustainable development:

Policy H2 states -

a) Land at RAF Upper Heyford will provide for a new settlement of about 1,000 dwellings and necessary supporting infrastructure, including a primary school and appropriate community, recreational and employment opportunities, as a means of enabling environmental improvements and the heritage interest of the site as a military base with Cold War associations to be conserved, compatible with achieving a satisfactory living environment.

b) Proposals for development must reflect a revised comprehensive planning brief adopted by the district council and demonstrate that the conservation of heritage resources, landscape, restoration, enhancement of biodiversity and other environmental improvements will be achieved across the whole of the former air base in association with the provision of the new settlement.

c) The new settlement should be designed to encourage walking, cycling and use of public transport rather than travel by private car. Improvements to bus and rail facilities and measures to minimise the impact of traffic generated by the development on the surrounding road network will be required.

d) Policy H2 requires the development to be in accordance with a Revised Comprehensive Planning Brief to be adopted by this Council.

2. SITE CONTEXT

This SuRF-UK assessment has been undertaken for the remediation works at RAF Upper Heyford. This assessment is based on the remediation options appraisal undertaken by VertaseFLI and the remediation objectives stipulated by the Client's Consultant, Waterman. The remediation works comprise the decommissioning of the Petrol, Oil and Lubrication dispensing system (POL System).

The POL system comprises a network of circa 13km of pipework and approximately 71 tanks, with a capacity of approximately 30 million litres. Historically, it was used for the storage and distribution of aviation fuel, petrol and diesel. During the 1990s, it is understood that all fuels were removed and the system was filled with water and reportedly an alkaline substance to prevent corrosion. With the exception of isolating the POL system from the UK fuel distribution network little further work was done. "Oily" water is known to be contained within the system and asbestos containing materials are known to remain in parts of the POL system.

The POL system also lies within a conservation area, designated in 2006 due to its cultural and historic association with the Cold War. Parts of the Flying Field are also designated as Low Land Calcareous Grassland and several populations of great crested newts are also present on the site.

2.1 Site Conceptual Model

An extensive site investigation (SI) was carried out in order to assess the contamination status of the area following its historic use. The SI confirmed the geology underlying the site which comprised inter-bedded layers of limestone, sandstone, mudstone and siltstone. At depths of approximately 20 to 25m a significant layer of mudstone was encountered. The SI included taking water samples from the POL system, which indicated that the water contained elevated concentrations of Total Petroleum Hydrocarbons (TPH) and in some cases a layer of free product was also present.

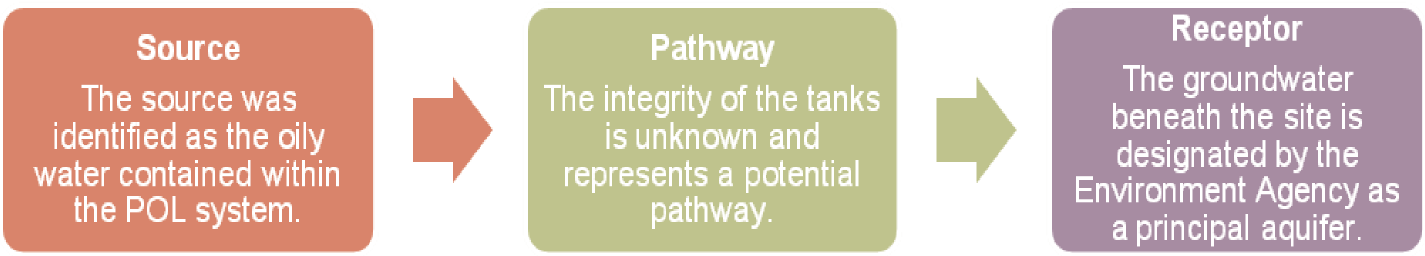

Figure 1: Risk management plan.

A risk management plan was prepared for the POL system based on its current condition and the contents of the decommissioned tanks. The risk management plan identified that the contents of the tanks posed a potential risk to the environment, each tank was given a risk rating dependent on the concentration of hydrocarbons identified and its proximity to groundwater (depth below ground level). The risk management plan concluded that the POL system in its current condition represented an ongoing liability to controlled waters and that a potential source - pathway - receptor linkage was present. TPH contaminated water in the tanks (the source), could leak from the tanks and pipelines and migration through underlying ground (the pathway) leading to impact on the groundwater beneath the site (the receptor) (see Figure 1).

The risk management plan concluded that that in order to remove the residual risk of the POL system it should be 'cleaned and made safe'.

2.2 Planning

The remediation works formed part of the sites wider redevelopment as a new settlement of about 1,000 dwellings and necessary supporting infrastructure, including a primary school and appropriate community, recreational and employment opportunities. As part of the proposal, the opportunity was taken by Cherwell District Council to ensure that environmental improvements and conservation of heritage resources, landscape, restoration, enhancement of biodiversity and other environmental improvements would be achieved across the whole of the former air base in association with the provision of the new settlement.

Cherwell District Council published a Comprehensive Planning Brief in August 1999, this was reviewed and revised in 2007. The brief included a scheme for the airbase to achieve the following:

- to ensure that all risks to public health and safety are removed;
- to remove all military infrastructure which has an adverse impact on the character of the countryside;
- to enable the retention of existing buildings and structures as an element of the structure of the new village where this would be beneficial;
- to minimise the need for off-site disposal of materials arising as a consequence of the demolition and infrastructure removal process.

2.3 Remediation Objectives

The outline remediation objectives for the decommissioning of the POL system were:

- **Objective 1** - The removal of any potential liquid, sludge, emulsion, solid, vapour and gaseous sources of contamination that are currently within and/or associated with the POL system (although soil and groundwater contamination out with the tanks or associated pipework are outside the scope of these works);
- **Objective 2** - Breaking of the internal and external potential pathways for contaminants to enter the environment that exist as a result of the presence of the POL system including the buried pipelines on site; and
- **Objective 3** - Ensuring that the system cannot become a future (defined as a minimum of 12 years duration for the purpose of the contract) source of contamination or a pathway for any contamination, be it contamination either related or unrelated to the existence and/or previous operation of the POL system on site.

There were a number of site constraints which had to be considered when choosing the remediation options, these included:

a) Comply with all restrictions due to the ecological status of the site. The protection of the sensitive grasslands and ecosystems surrounding the POL system.

b) Comply with all restrictions due to the built heritage on site, preserving the heritage of the POL system in accordance with English Heritage's requirements.

c) Ensure that measures are put in place to minimise disruption to other site users and adjacent site users, to the agreement of the Project Manager and the Employer.

d) Comply with all restrictions and recommendations related to the potential for Unexploded Ordnance (UXOs) on site.

3. THE SUSTAINABILITY ASSESSMENT PROCESS

3.1 Objectives

The remediation options appraisal and sustainability assessment was undertaken as part of a competitive tendering process. Its objective was to act as a commercial tool at tender stage to show our understanding of the issues and inform the decision making process. It was also used to demonstrate to regulators that our selection was the most sustainable and supported the choices made. The outcomes resulted in VertaseFLI undertaking the project according to the choices made as part of the assessment i.e. choosing to refine the Pulverised Fuel Ash (PFA) mix, treating water on-site and to discharging treated water to land. The pipelines were foam filled but the tanks decommissioned using PFA.

3.2 Roles

- The tender documents had been prepared by Waterman, the Client's Consultant, whose role it was to appraise the tender submissions for their technical and sustainable merit, as well as commercial value.
- The Client, Dorchester Group, whose role was to appoint their chosen contractor based on the assessment made by Waterman. In addition, they had to consider the management of the works to prevent disruption to the sites current users.
- Other relevant parties whose approval of the proposed strategy was required, including the Environment Agency, English Heritage and Cherwell District Council.
- The assessment was undertaken by VertaseFLI.

3.3 The Assessment

The assessment was undertaken in two stages with both qualitative and semi-quantitative and quantitative elements. The assessment was based on the remediation objectives listed in section 2. These were used as the boundary conditions for the assessment, including timescales and restrictions to ensure protection of environmental and social aspects of the site.

Stage 1 - Initial Remediation Options Appraisal and Semi-Quantitative Sustainability Assessment

The initial stage of the remediation options appraisal was to identify potential remediation options which would meet the criteria for the works, including breaking any source-pathway-receptor pollution linkages present on site. In light of the remediation options being identified, a semi-quantitative assessment was made of the effectiveness and ease of implementation / practicality of the remediation option to meet the objectives.

Table 1: Semi-quantitative sustainability assessment.

(Effectiveness of Remediation Technique X Practical Implementation of Remediation Technique) + Assessment of ENV + Assessment of SOC + Assessment of ECON

Effectiveness of Remediation technique	Practical Implementation of Remediation Technique	Assessment of Sustainability
1. Ineffective, unlikely to meet remedial targets / objectives 2. Partly effective, but still unlikely to meet remedial targets / objectives 3. Effective, likely to meet remedial targets / objectives 4. Very effective, very likely to meet remedial targets /objectives 5. Entirely effective, will meet remedial targets / objectives	1. Impractical, requires significant enabling works significant impacts to cost, programme and the environment. 2. Practical, requires some enabling works, some impacts to cost, programme and the environment. 3. Very practical, with minimal impacts to cost, programme and the environment.	1. Unsustainable (no benefits to the following: ENV, SOC , ECON) 2. Partly Sustainable (benefits one of the following: ENV, SOC , ECON) 3. Sustainable (benefits two of the following: ENV, SOC, ECON) 4. Very Sustainable (benefits three of the following: ENV, SOC , ECON) 5. Extremely Sustainable (significant benefits to all three of the following: ENV, SOC , ECON)

The remediation options were then assessed for their sustainability using the sustainability indicator parameters identified in the SuRF-UK framework. A score was given for each group of parameters Environmental (ENV), Social (SOC) and Economic (ECON). The scoring system is equally distributed between the Effectiveness and Practical Implementation of Remediation Technique vs the Sustainability, with a maximum of 15 being scored for each half of the assessment (see Table 1).

The Stage 1 assessment included a semi-quantitative assessment of 14 of the indicator parameters, see Appendix A of the SuRF-UK Indicator Set for Sustainable Remediation Assessment 2011.

The 15th indicator parameter SOC5: Uncertainties and Evidence was used to qualitatively assess the other 14 indicator parameters as part of the conclusions. For example, for decommissioning the tanks, the main uncertainties considered were associated with the integrity of the tanks and their contents i.e. volume of oil and sludge. The treatment of the water within the tanks was also identified as having a degree of uncertainty; would it be acceptable to discharge treated water to controlled water via spreading it on areas on uncontaminated grassland? It was concluded that additional site investigation data was required to remove this uncertainty.

Stage 2 - Detailed Sustainability Assessment

Following the initial screening, the remediation options with the highest scores were taken to the next level of assessment, this includes a detailed qualitative assessment of the key indicator parameters identified in the initial screening process, including an assessment of the uncertainties identified. A quantitative assessment of the carbon footprint of the different options was undertaken.

As part of this assessment, alternative working methodologies and materials were considered that could improve the sustainability of the project. This was in addition to an assessment of the uncertainties and how additional information could be gathered to improve the effectiveness of the sustainability assessment, and the current assumptions that the project was based on.

Cost benefit analysis

As part of the Stage 2 assessment a basic cost benefit analysis of the remediation options was undertaken, this was mainly based on material costs which exhibited a larger cost difference than operational costs. Operational costs were therefore not calculated as both foamed concrete and off-site disposal were considered to be non viable options based on material / disposal costs.

Carbon Calculations

A basic carbon calculation was undertaken, based on the embodied carbon of the materials (with the exception of Bacel hard foam for which data was not available), fuel consumption of the plant and transport distances for materials. The embodied carbon data was sourced from ICE database, Environment Agency carbon calculator and data sourced from suppliers.

A full life cycle analysis of the options was not undertaken as part of this assessment as reliable information was difficult to find and the assumptions that would have to be made were considered too broad to provide valid data. Based on this several parts of the carbon assessment undertaken have been noted as not having been calculated, including the carbon footprint of off-site water treatment, and sludge recovery. It should be noted that in instances where calculations were not undertaken, a carbon saving was already evident based on comparable data, i.e. on-site treatment had a much lower level of embodied carbon, than the transport alone for off-site treatment. A sensitivity analysis was undertaken for the composition of the grout manufacture; the sensitivity analysis focused on the carbon savings that could be made by reducing the cement content of the grout mix.

4. THE SUSTAINABILITY ASSESSMENT OUTCOMES

4.1 Stage 1 - Results of Initial Remediation Options Appraisal and Semi -Quantitative Sustainability Assessment

Table 2 shows a summary of the scores from the remediation options appraisal and semi-quantitative sustainability assessment. The assessment was divided into three separate remediation processes, (i) decommissioning the tanks (T), (ii) water treatment (W) and (iii) decommissioning the pipelines (P). The options which scored the highest are highlighted in the table. These options were assessed further.

Table 2: Summary of the scores from the remediation options appraisal. (Key: T = Tank, W = Water, P = Pipe).

Remedial Technology Description	Effectiveness	Practical Imp	ENV	SOC	ECON	Overall Score
Option T1 - Clean and vent only	2	2	1	2	2	9
Option T2 - Confirm absence of contamination outside the tanks, 'drill' tanks and allow groundwater equilibrium within tanks	2	2	2	2	2	11
Option T3 - Fill with foamed concrete	5	3	3	4	3	25
Option T4 - Fill with PFA Grout	5	3	5	3	4	27
Option T5 - Break into side of tanks and bulk fill with Fill with Crush	3	2	3	3	3	15
Option T6 - Break into side of tanks and bulk fill with conditioned PFA only	4	2	3	2	4	17
Option T7 - Foam fill (Bacel hard foam)	5	3	2	3	1	21
Option W1 - On-site water treatment and disposal to foul sewer*	5	0	N/A	N/A	N/A	0
Option W2 - Off-site disposal via tanker to treatment facility	5	3	2	2	1	20
Option W3 - On-site water treatment and disposal to controlled waters	5	3	4	4	4	27
Option P1 - Foam fill (Bacel hard foam)	5	3	4	4	4	27
Option P2 - Fill with foamed concrete	4	2	3	3	4	18
Option P3 - Fill with PFA Grout	4	2	4	3	4	24

*Impractical as foul sewer had a very limited capacity and is not located near the POL system.

Example: Option T1 Clean and vent only - overall score 9

(Effectiveness of Remediation Technique 2 X Practical Implementation of Remediation Technique 2) + Assessment of ENV 1 + Assessment of SOC 2 + Assessment of ECON 2

4.2 Stage 2 - Detailed Remediation Options Appraisal

The remediation options appraisal and initial sustainability assessment concluded that the two best options for the decommissioning of the tanks were to fill them with either foamed concrete or PFA grout. Both these options scored equally on their effectiveness to meet the remediation target and also ease of implementation. The detailed sustainability assessment looked at some of the key differences between the two options in relation to ENV, SOC and ECON. Table 3 shows an extract from this assessment for options T1 and T4.

For example further assessment of ENV 1 Air: identified that batching the PFA on-site posed the risk of dust generation impacting on the site users, operatives and potential impact to the sensitive grasslands. However this risk could be easily mitigated by undertaking the batching of the PFA grout within one of the former hardened aircraft shelters, which would mitigate against dust entering the wider environment. The risk of dust to site operatives operating the batching plant could be easily managed using appropriate PPE and working methodologies.

This additional qualitative assessment of each SuRF-UK indicator parameter coupled with quantitative assessments on the carbon footprint and economics of decommissioning the tanks, identified that PFA grout was the most sustainable, cost effective and appropriate solution for the project.

In addition the assessment concluded that there was further opportunity to reduce the carbon footprint of the works by undertaking a site specific bench scale trial to produce a grout mix of less than 4% OPC. This had the potential to save a further 253 tonnes of CO_2 and offered a potentially significant cost saving (see Figure 2).

Key sustainability benefits of using PFA grout over formed concrete were also examined along with investigating the methodologies for providing the grout. It was identified that:

- **SOC 3:** Grout manufacture on-site would reduce the number of vehicle movements by 493 trips, which would reduce the impact on local residents and current site users as well as reducing CO_2 emissions from the transport.
- **ENV 5:** Grout can be manufactured using PFA under the WRAP Quality Protocol as a bound application. Using PFA as the main constituent of the grout not only had the potential to reduce its carbon footprint through a lower cement content but also approximately 8,000 tonnes of PFA could be diverted from landfill.
- **ENV 5:** The PFA could be sourced from a nearby power station which reduced the carbon emissions generated through haulage.

4.3 Water Treatment Elements

The remediation options appraisal and initial sustainability assessment concluded that the two best options for the removal and treatment of the water were either off-site disposal in tankers or on-site treatment. During the initial assessment it was identified that disposal of the treated water to foul sewer was not an option due to the capacity of the

Table 3: Extract from the Semi-Quantitative Sustainability Assessment for decommissioning the tanks (showing Option T1 'Clean and vent only' which scored the lowest compared to Option T4 'Clean and fill with PFA Grout' which scored the highest).

	Option T1 Clean and vent only	Score	Option T4 Clean and fill with PFA grout	Score
Effectiveness	• This approach has been widely and successfully used for gas and vapour remediation design to buildings for over 15 years. • Would require detailed risk assessment and design to ensure venting arrangements were sufficient. • Leaving tanks completely empty will maintain a pathway and potentially allow any contamination from outside the tanks to re-enter the tanks • If tanks are breached possibility of contaminated groundwater re-entering the tanks and replacing the vapour source.	2	• Effective removal of source contaminated water and residual fuel from the tanks. • This approach is based on other grouting applications, an innovative approach to using PFA in a bound application in accordance with WRAP protocol. • If tanks are breached, PFA grout would prevent contaminated groundwater and vapour re-entering the tanks. • Should the tanks be decommissioned in the future concrete is an inert fill material that could be reused to fill the tanks void.	5
Practical Implementation	• Risk Assessment works required to design the venting arrangements. Venting arrangements likely to require regular maintenance & possibly provision of electrical power. • Not suitable for tanks that have been breached, would have to adopt an alternative remedial methodology. • Confined space entry required to clean residual sludge. • Groundwater pressures beneath the tanks are likely to be significantly high enough to attempt to 'lift or float' tanks. Type 1 tanks would be particularly susceptible to this action and may well already have experienced some 'ballooning' on the floor of the tanks which would cause the metal plates to rupture along the joints.	2	• Undertake bench trials to determine a mix design for the PFA grout, measuring strength and setting characteristics. • Trials will determine the optimum Ordinary Portland Cement (OPC) concentration required to achieve a suitable grout. • PFA grout can be batched and produced on site, possibility of using treated tank water as a water supply. • Confined space entry required to clean residual sludge.	3
Environmental	• ENV 1: Air - Long term emissions from the tanks from passive venting to atmosphere. • ENV 2: Soil & Ground Conditions - Long term liability of tanks has not been removed, structural integrity of the tanks may become compromised, resulting in unstable ground conditions. • ENV 3: Groundwater & Surface Water - Tanks below the water table that are breached (or may become breached in the future) may fill with contaminated groundwater. • ENV 4: Ecology - minimal impacts from the works, but long term improvements may be affected by later works to remedy degradation of the tanks. • ENV 5: Natural Resources & Waste - Minimal impacts as tanks would not be filled, (water treatment assessed separately).	1	• ENV 1: Air - Removes long term emissions from the tanks, short term emissions during works. Embodied carbon of PFA dependant on the trial to optimise the cement content currently designed as 4% but could be reduced to 2%. • ENV 2: Soil & Ground Conditions - Long term liability of tanks has been removed. Should tanks be removed in the future PFA can be used as inert fill in the void space. • ENV 3: Groundwater & Surface Water - Long term liability of tanks has been removed, any breached tanks would not fill with contaminated groundwater. • ENV 4: Ecology - minimal impacts from works, long term improvements as part of redevelopment • ENV 5: Natural Resources & Waste - PFA can be used as a recycled waste under WRAP. Could use treated tank water if manufactured on site.	5
Social	• SOC 1: Human Health & Safety - Confined space entry required to clean the tanks, alternative options would not achieve complete removal of the source. On going health and safety risks of venting arrangements during maintenance. • SOC 2: Ethics & Equality - On going liability, potential social blight due to maintenance and monitoring of the venting system. On going risks to future generations. • SOC 3: Neighbourhood & Locality - minimal disruption compared to other options, as works are predominantly cleaning the tanks. • SOC 4: Communities & Community Involvement - Photographic record of tanks made during cleaning and venting can be used in new history centre. • SOC 4: If structural integrity of Type 1 tanks fails, the protected grass mounds which English Heritage wishes to maintain are liable to collapse.	2	• SOC 1 - Human Health & Safety - confined space entry required to clean the tanks, alternative options would not achieve complete removal of the source. • SOC 2: Ethics & Equality - Source of contamination completely removed therefore no risk to further generations. • SOC 3: Neighbourhood & Locality - More disruption to local residents and business on-site due to additional vehicle movements to bring PFA and OPC onto site to mix grout. • SOC 4: Communities & Community Involvement - Photographic record of tanks made during cleaning and venting can be used in new history centre. • SOC 4: In filling the Type 1 tanks with PFA grout will preserve their structural integrity and the protected grass mounds which English Heritage wishes to maintain are liable to collapse.	3
Economic	• ECON 1: Direct Economic Costs & Benefits - Cheapest option as tanks are not filled. Contingency would be required to deal with breached tanks. • ECON 2: Indirect Economic Costs & Benefits - On going maintenance costs, including potential power requirements. Costs of dealing with any tanks that become structurally unsafe. • ECON 3: Employment & Employment Capital - long term maintenance and monitoring contract. Specialist services to design venting and to clean and degas tanks. • ECON 4: Induced Economic Costs & Benefits - N/A • ECON 5: Project Lifespan & Flexibility - On going maintenance and monitoring costs for life time of the tanks does not achieve remediation objectives.	2	• ECON 1: Direct Economic Costs & Benefits - more cost effective than Formed concrete due to lower cement content, trials may reduce this further. Can use treated water from the tanks to mix PFA grout on-site saving costs of water. • ECON 2: Indirect Economic Costs & Benefits - If the tanks are removed in the future, PFA grout can be reused as a fill material saving on disposal and import costs. • ECON 3: Employment & Employment Capital - Short term construction workers / lorry drivers. New innovative approach to tank decommissioning using bound PFA in accordance with the WRAP protocol. • ECON 4: Induced Economic Costs & Benefits - PFA supplier saves on landfill costs as PFA can be used as a product rather than disposed of. • ECON 5: Project Lifespan & Flexibility - Meets project life span objective of 12 years / flexible to change can be reused on-site if the tanks are decommissioned	4
Comments & Overall Score	• SOC 5: Uncertainty & Evidence - Integrity of tanks and groundwater contamination not known. • Alternative option would have to be used if tanks were breached. • Costs of dealing with any tanks that become structurally unsafe. • Disregarded from further consideration as it is does not meet all the remediation objectives, to provide a long term solution.	9	• SOC 5: Uncertainty & Evidence - This approach would readily deal with the uncertainties of the tanks current condition as the PFA Grout will plug any tank breaches and maintain the structural integrity of the tanks. • Further consideration as it meets all the remediation objectives and may be the most sustainable solution for the site due to costs and environmental impacts.	27

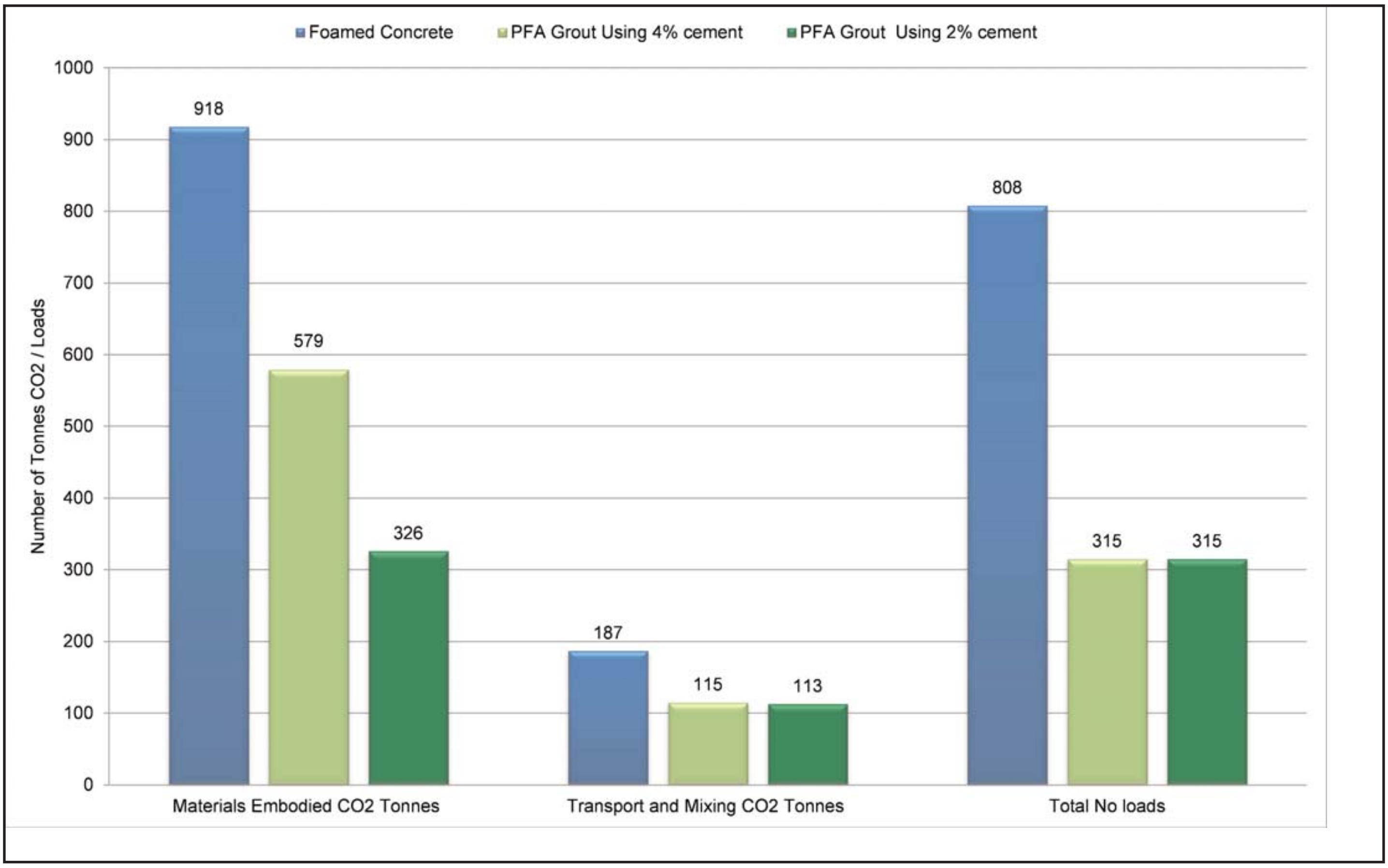

Figure 2: Carbon footprint assessment for decommissioning the tanks with foamed concrete and PFA grout.

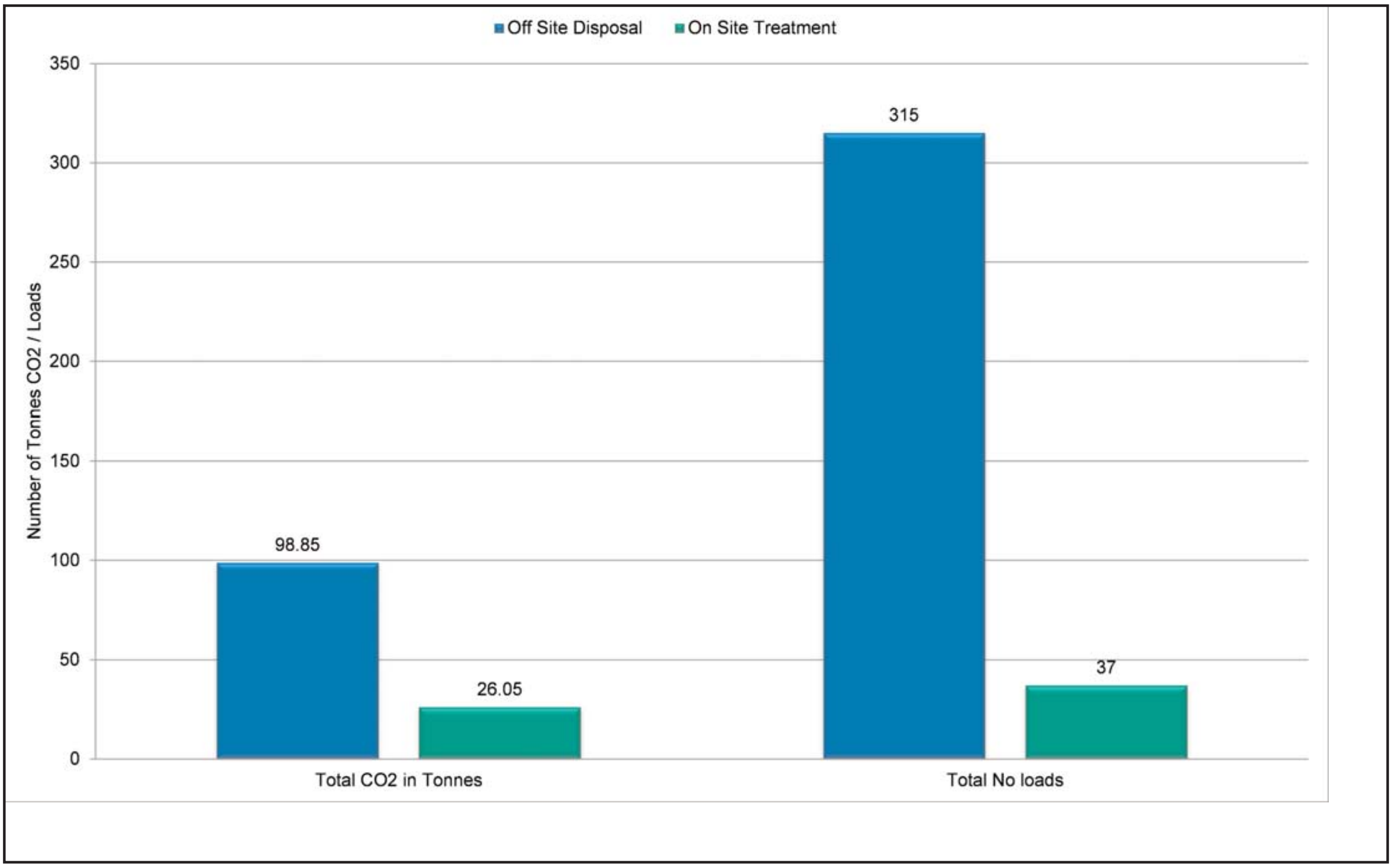

Figure 3: Carbon footprint assessment for water treatment. Comparison of off-site disposal and on-site treatment with discharge to controlled waters.

infrastructure on site. Initial discussions with the EA were held to determine if discharging to controlled water was an option. The EA confirmed that they would consider this option, as the alternative would be to dispose of the water off-site using tankers, which was extremely unsustainable. This sustainability assessment aided the discussions with the EA and formed a major part in them permitting the on-site treatment and subsequent discharge to controlled waters. The primary quantitative assessment used to assess water treatment was the calculation of CO_2 emissions coupled with the number of vehicle movements (see Figure 3).

Key sustainability benefits of using on-site water treatment were that:

- **ENV 5:** Oils and sludges were recovered for off-site recycling, normally as a secondary fuel.
- **SOC 3:** Contaminated tank water would be treated on-site in mobile WWTP units, which would save 630 tanker movements to and from site minimising disruption to surrounding residents, as well as significant disposal costs.
- **ENV 1:** On-site treatment of water saved 84 tonnes of CO_2 emissions, primarily through the reduced number of traffic miles.
- **ENV 5:** Treated tank water was used in the manufacture of grout, saving 2,000m^3 - 3,000m^3 of mains water.
- **ENV 3:** Treated tank water was discharged to land providing recharge to the local aquifer, which is currently depressed due to drought conditions in the area.

4.4 Pipeline decommissioning

The remediation options appraisal and initial sustainability assessment concluded that the two best options for decommissioning the pipeline on-site were either using Bacel hard foam or a PFA grout. The detailed qualitative assessment for these two options identified several disadvantages to using PFA grout as summarised below:

- **ENV 3**: Unlike the tanks which were emptied and confined space entry made to ensure that they were completely cleaned of residual sludges, the pipelines were harder to clean. A key benefit of using foam to decommission the pipeline, is that during injection the Bacel hard foam absorbs all hydrocarbon residues present in the pipeline ensuring that any residual source of contamination is locked in the foam in the pipeline.
- **ENV 4**: In order to fill 13km of pipelines across the site, the injection of Bacel hard foam into the pipes needed to be undertaken every 100 - 150m via a specially excavated access pit to ensure that the pipelines were fully decommissioned. These excavations would need to be undertaken in areas of soft landscaping to minimise the cost of reinstatement and avoid disruption to the site users by excavating roads and parking areas. Approximately 80 - 100 access pits will be required across the site. PFA grout in comparison is more viscous and requires injection every 30 - 50m and approximately 200 - 260 access pits across the site. Therefore PFA would have a greater impact on the sensitive grasslands than foam.
- **ENV 5**: Bacel hard foam is a specialist product manufactured for decommissioning pipeline. Should the pipelines be decommissioned in the future the Bacel hard foam would require disposal to landfill.
- **ECON 1**: PFA grout production is the cheapest material for filling the pipelines. A cost comparison for the material costs of grout and foam shows that foam is 6 to 8 times more expensive per m^3. However when a comparison was made of the operational and programme costs, including the allowance for excavating 2 to 3 times more access pits for grout, the cost difference was reduced.
- When considering the costs the additional benefits and reduction of the risk to the ecology of the site, the benefits of foam over PFA grout significantly outweighed the costs.
- **SOC 1**: The Bacel hard foam is manufactured off-site and delivered as a liquid, personnel would have limited exposure to the liquid. Specialist trained personnel; detailed operational risk assessment, method statement and Control of Substances Hazardous to Health (COSHH) would be required to undertake these works safely. Utilising Bacel hard foam also offered a reduced risk to human health from unexploded ordnance (UXO) as fewer excavations would be required across the site.

Following a review of the qualitative assessment it was concluded that the most sustainable solution for the project was to foam fill the pipelines, as this option both met the remediation objectives and complied with the site constraints.

5. CONCLUSIONS

In summary the most sustainable remediation solution was adopted for the site and the SuRF-UK assessment was essential in aiding and informing these decisions and in communicating them to other stakeholders. As a result of the assessment as well as the sustainability benefits from supporting the use of PFA, the bench scale trials undertaken for the PFA grout concluded that a 2% cement mix achieved the geotechnical strengths and setting properties required to fill the POL system which saved further carbon and lorry movements. The use of on-site water treatment instead of off-site saved lorry movements and provided other environmental benefits. The assessment also identified the fact that the other factors outweighed the economic factors for the pipeline decommissioning, resulting in a more sustainable but more expensive option and ultimately operationally a better solution being applied to this part of the project.

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