CHALMERS

Environmental footprints and sustainability of contaminated land remediation

Master of Science Thesis in the Master's Programme Geo and Water Engineering

FARZAD FERDOS

Department of Civil and Environmental Engineering
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ABSTRACT

Since the United States Environmental Protection Agency (USEPA) launched its "Green remediation" program and EU member states began to reassess their national regulations for environmental remediation in order to reach a Europe-wide consensus on policy and standards, the need for the sustainable removal of contaminants from brownfields has grown considerably. Concomitantly, the ability to calculate and assess the suitability as well as the environmental footprints and associated risks of a growing number of remediation techniques has become a priority. This thesis aims to evaluate two of the most widely-used free commercial tools for this purpose, SiteWise$^{TMv.1}$ and SRT, for their practicability, quality and range of results and suitability specific to Swedish conditions.

A number of ex-situ and in-situ methods are described in this thesis, a combination of which are then used to model twenty-six remediation scenarios for two documented contaminated sites in the Gothenburg region: the Bohus Varv site on the Götaälv bank and the Hexion site in Mölndal. A wide range of results for these models is presented, compared and analyzed, drawing further comparisons with a previous study and the zero-alternative, which can be used as an example to support sustainable decision making and to advocate the implementation of "gentle" remediation techniques to clear up contaminated sites. Based on the results from the both projects, it is concluded that: i. Remediation techniques requiring long distance residual handling have significant footprints except residual handling by train due to Swedish energy production conditions. ii. Residual handling with ship results in much higher SOx, NOx and particle release compared to the other alternatives. iii. Residual handling with truck results in high accidental risks. Finally, activities powered by electricity result in a reduced footprint compared to activities powered by fossil fuels, considering Swedish energy production conditions.

The thesis concludes with a cross-benefit analysis of SRT and SiteWise$^{TMv.1}$, which recognizes their potential as tools for presenting accurate and reliable Life Cycle Assessment analyses with appropriate system boundary definitions and easy inventory analyses process. Their results provide valuable support to decision makers aiming at more sustainable remediation. The restricted range of remedial technologies with which SRT can model and the crucial adjustments needed to make this tool applicable and effective in Sweden are also evaluated, as are the certain expert knowledge need for modeling and the extensive data need for the SiteWise$^{TMv.1}$ program. The limited practicability of SiteWise$^{TMv.1}$'s final results on their own, with no comprehensive picture of the socio-economic impact of each scenario is also regarded as a shortfall in real-life decision-making processes.

Keywords: Sustainability, Brownfields (Contaminated sites), Remediation, Footprint analysis

Contents

1 Introduction

1.1 Background

Over the last century, industrial development has resulted in huge substantial environmental disturbances and consequently many areas have been contaminated. Although the severity of contamination has decreased over the years due to stricter legislation and a greater general awareness of the consequences of negligent site management, this activity is not yet sustainable and will remain so until industry reconsiders its responsibilities with regard to contamination management and site rehabilitation.

The management and rehabilitation of contaminated sites has become a thorny environmental issue: according to the European Environmental Agency´s (EEA) estimations, there are nearly a quarter of a million contaminated sites in EEA member countries and, concomitantly, the number of potentially polluting activities are growing to nearly three million sites (EEA, 2007). In Sweden alone, more than 80,000 contaminated sites, a large number of which are potentially dangerous to human health and the environment, have been mapped by the Swedish Environmental Protection Agency (SEPA) (SEPA, 2007). Considering the potential impact of contaminants on human health and ecological quality which are, or which may be, present at these sites has led to the implementation of protective legislation to help remediate, rehabilitate and control contaminated sites. The other important factor supporting remedial action is the fact that most of these contaminated sites are economically inactive until remediation has occurred (Lesage et al, 2007). Although such remedial action is a step in the right direction towards sustainable development, this activity, like all human activities, has its own environmental, social and economical impacts. These impacts must be considered within the decision-making process as the needs for remediation are assessed and actions are taken (Morais, Matos, 2010).

Fundamental principles should be followed when selecting remediation technologies. The selection of an appropriate action is a site-specific decision and there may be more than one appropriate technology for a given site. Within this process, it has been the case that the environmental impact of the remediation action itself has been secondary to a preference for familiar, traditional methods for remediation (e.g. Excavation and disposal to landfill). An increasingly more holistic view on remediation has led to significant growth in a branch of research which aims to develop more sustainable remedial technologies, referred to as “gentle” options (Bardos et al, 2008). Although significant progress has been made here, the actual implementation of such techniques is still in its relative infancy. Lack of stakeholder knowledge and confidence in the feasibility or reliability of these methods is a major obstacle and therefore some form of education in the form of decision support is needed to make it possible for site managers to adopt more “gentle” remediation techniques. A range of tools are now available for decision making support with different perspectives and processes (Cundy, 2009). Increasing general knowledge about available tools and developing new ones with sufficient detail will result in a more widespread use and would be followed by a number of new technologies and techniques for sustainable site remediation. It is important to note that the general term “gentle” options not only includes new innovations in remediation, but also the use of current methods in a more environmentally sensitive way.

1.2 Aim

Since the United States Environmental Protection Agency (USEPA) launched its “Green remediation" program, many tools have been developed to estimate the environmental footprint of remedial actions (USEPA, 2010). These tools will be of interest in many parts of the world, including Sweden, where evaluative tests are needed to judge their suitability to Swedish conditions.

Within this research project two of the most widely-used and free tools, SiteWise$^{TMv.1}$ and SRT, are going to be used to evaluate different possible remediation alternatives in order to apply sustainability metrics to a decision making process. The aim of this research is to:

- Assess the availability of the data needed for each method and evaluate how feasible and practical the data collection is
- Review and compare the tools´ results in terms of their suitability for finding a remediation technique and their sustainability, taking into account economical, ecological and socio-cultural dimensions
- Investigate the tools´ capabilities for sensitivity and uncertainty analysis
- Evaluate and recommend revisions and adjustments for application to Swedish conditions.

1.3 Methodology and implementation

The aforementioned tools, which are specifically designed for sustainability evaluation of different remediation techniques, will be reviewed and evaluated using the available data from two case studies of contaminated sites in the Gothenburg region (Bohus Varv in Ale and the Hexion site in Mölndal). By modeling a number of appropriate remediation techniques and comparing their environmental footprints, metrics and effects to the 0-alternative and analysing the results together with other sustainability metrics, this thesis will offer reliable and comprehensive support for decision making.

1.4 Limitations

The project is limited to the system boundary defined by the researcher and the tools, as they are only appropriate for analysing certain aspects of remediation activity i.e. the environmental footprint.

The study does not include any qualitative assessment of performance or effectiveness of different remediation technologies. For each applied technology it is assumed that the technology already fulfils the remediation goals.

This report should not be seen as an overall assessment of remediation activity. The implemented environmental footprint calculations are based on site-specific conditions with available data and assumptions for the case studies. The site-specific results should therefore not be interpreted as generally applicable. However, the recommendations concerning methodological aspects and applications of SiteWise$^{TMv.1}$ and SRT are appropriate for application in other remediation projects to estimate their overall environmental impacts.

2 Case study description

2.1 The Bohus Varv Site

2.1.1 General

The Bohus Varv site is located on the eastern shore of the Göta älv in Ale community, about 15 km upstream of Gothenburg city. As it is illustrated in the Figure 2.1, the site is situated to the north of the Jordfall Bridge and the Eka Chemicals business. To the east it is bordered by railway tracks and the road route 45.The area is about 600 meters long along the river bank with a width ranging between 60 to 110 meters, in total covering around 50,000 square meters.

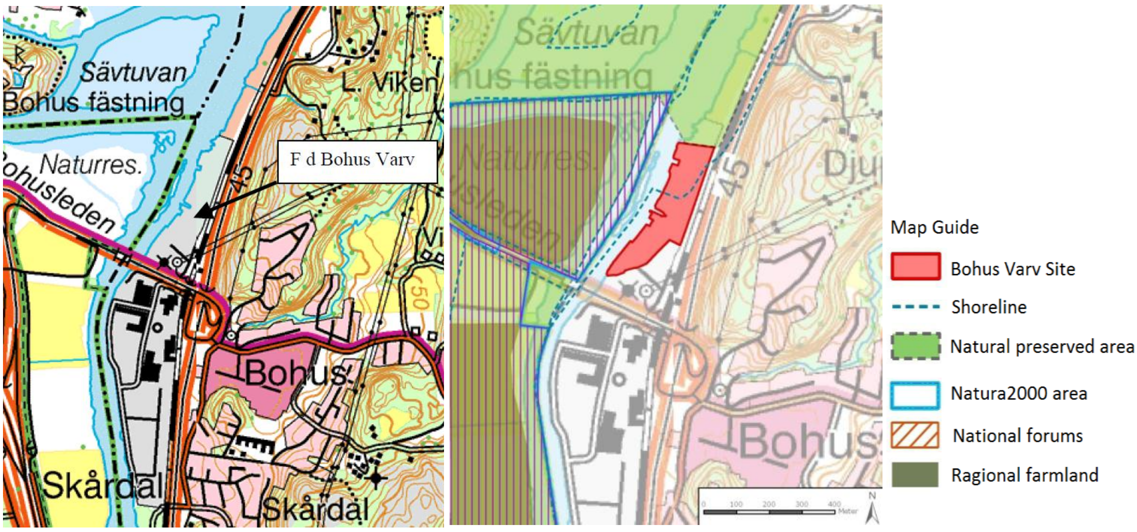


Figure 2.1 The BohusVarv site. A physical map to the left, with land use indicated on the right (Mellin, 2009).

The property has river bank geological formations which were stabilized and widened by laying 0.4 to 4 meters of filling materials (average of 1.7m) on top of the thick layers of glacio-marine clay sediments. The filling materials in the area typically consist of a mixture of soil of differing grain sizes, mostly sand, gravel and boulders. Fillings also include anthropogenic materials, e.g. scrap and building waste. The underlying glacio-marine clays have a very low hydraulic conductivity and the main groundwater flow towards the river therefore occurs in the filling materials. According to the studies done by Swedish Geotechnical Institute (SGI) in 1995, deep clay formation on the Göta älv bank makes the area susceptible to landslides and has uncertain landslide stability condition (SGI, 1995).

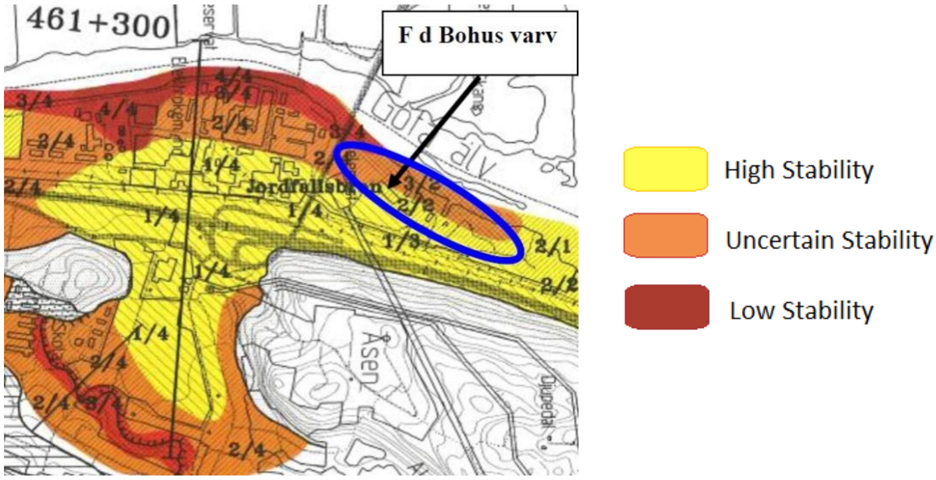


Figure 2.2 Map showing geotechnical stability of the Göta älv bank, including the Bohus Varv site (SGI, 1995).

2.1.2 Site activity background

According to all available information (e.g. reports, municipality visiting notes, local resident interviews and air photos) gathered by SWECO (SWECOVIAK, 2006), the rural river bank was converted to an industrial site by transporting surplus infilling material from Gothenburg city in the early 1900s. The site was gradually developed. Until the late 1980s the site was mainly used for ship building and as a repairing facility. It has been noted that during the end of this period the southern part was used to dump steel and iron scraps. In 1992 Eka Chemicals acquired the property and cleared the area and its buildings (e.g. of seized boats, scrap vehicles, tracked vehicles, tanks, waste oil, paint and batteries) to use for the intermediate storage of nearly 10 000 cubic meters of treated soil. According to the reports, another smaller construction company owned a small portion of the property and used it as a warehouse.

2.1.3 Site contamination situation

Due to previous industrial activity at the Bohus Varv site, it was suspected to be contaminated and potentially dangerous to human health and to the environment. In order to evaluate the situation, a first-round sampling campaign was ordered by the municipality and carried out by Scandia consult (now Ramböll), whose conclusions led to a further and more detailed assessment of the site and an environmental risk analysis (Scandiaconsult, 2001). In 2005, the SWECO consulting company made a detailed investigation of the property, whereby many soil, groundwater and sediment samples were taken and tested. The environmental risk analysis was completed, based on the detailed investigations. According to the analysis, the Bohus Varv site was found to be highly contaminated, primarily by heavy metals (e.g. lead (Pb) and mercury (Hg)) and oil products. As a result, the risk assessment showed that the risks to humans and ecosystems were high and the current situation was not acceptable.

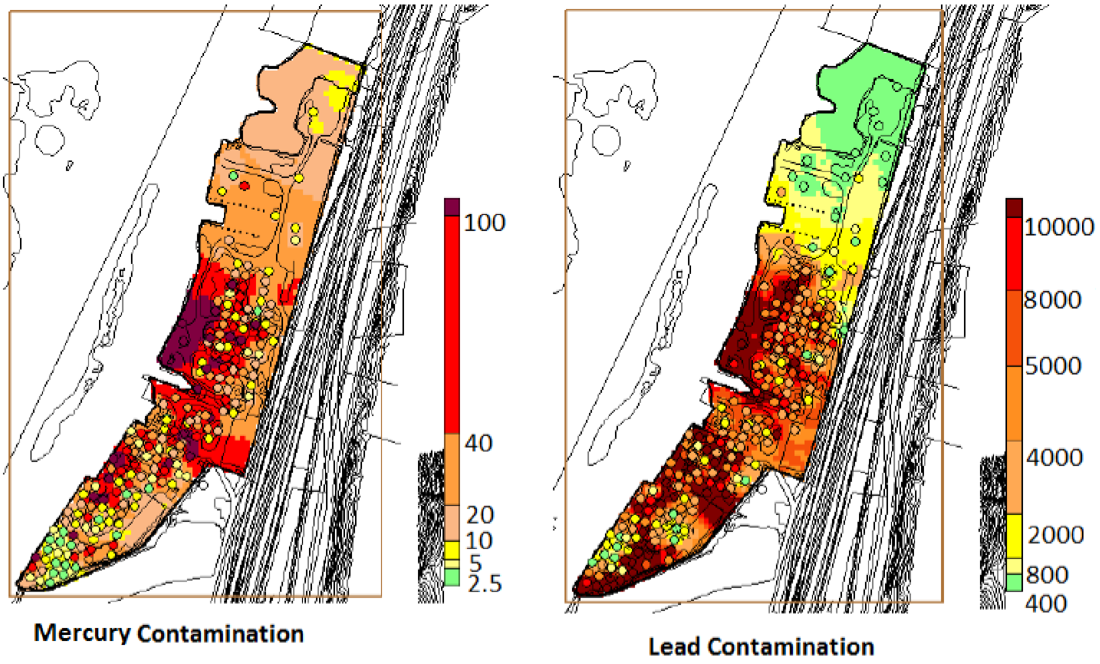


Figure 2.3 *Map showing heavy metal contamination at the Bohus Varv site before remediation. Results are presented as mg/kg of dry soil (Holm, 2006).*

2.2 Hexion Site

2.2.1 General

The Hexion property is an old industrial area covering approximately 35,000 square meters. It is located to the east of Mölndal Centrum. As it is illustrated in the Figure 2.4 below, the site is a triangular area bordered by Borås railway to the north and Måndalsån to the south.

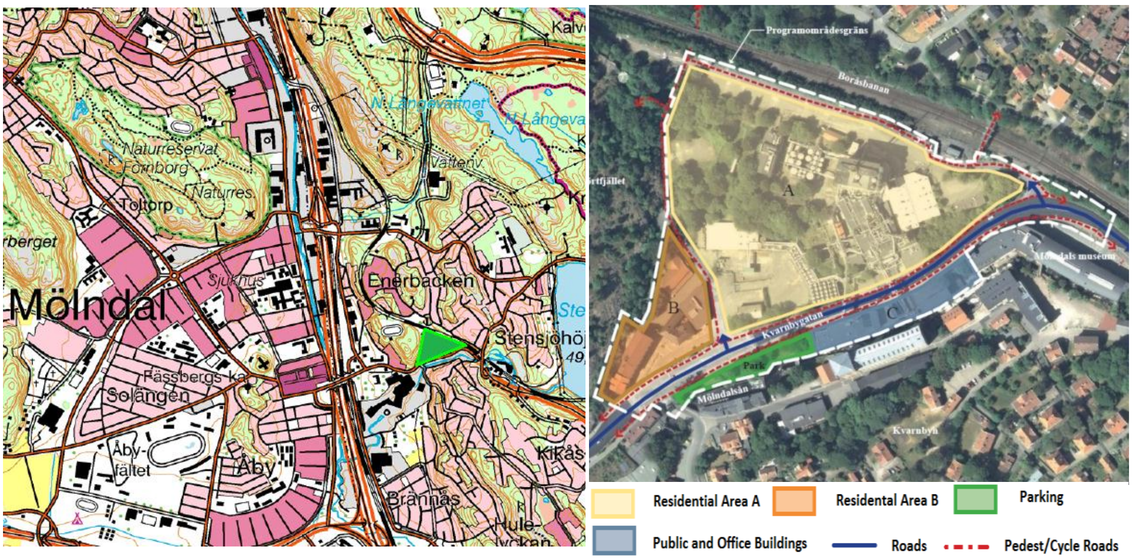


Figure 2.4 *The Hexion site. A physical map to the left (the green triangle indicates the exact location), with a plan for future development to the right (SWECO, 2009a).*

The local geology consists of glacial deposits on the bedrock. Glacial till is characterized by containing an unsorted mixture of different particle sizes from clay to boulders. Glaciofluvial deposits are formed as a result of melting glaciers in the final stages of the last ice age. The deposits comprise boulders, stones, gravel, sand, silt and clay sediments graded by gravity, with the heaviest material at the bottom (Tarbuck & Lutgens, 2008).

A comprehensive soil survey has shown that the natural ground, which has a general soil thickness of between 10-15 meters, has been overlain by large quantities of filling material in order to even out the ground level to provide a site suitable for building industrial buildings. This filling thickness reaches up to 5 meters in some places (see the Figure 2.5 below). Filling material was concluded to be a random fill of mostly gravels, sand, clay, silt, stones and bricks. These filling materials, together with the natural deposits, are very permeable, which resulted in pollution spreading to some parts of the area and endangering the ground water table which is situated 10-20 m below surface level (SWECO, 2009b).

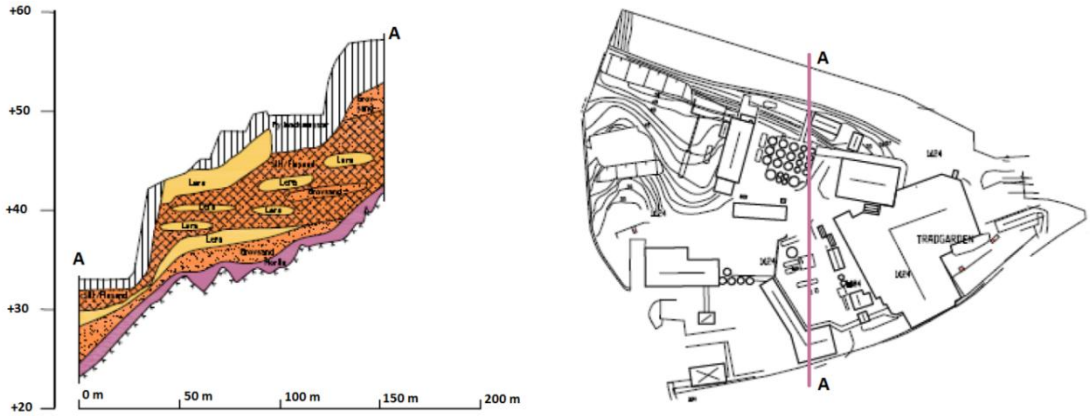


Figure 2.5 Cross section of the Hexion site and its geological condition (SWECO, 2009b).

2.2.2 Site activity background

The first known activity dates back to 1827, when an oil selling facility was founded by Mendel Elias Delbanco, who hoped to take advantage of the hydro power potential of the nearby water stream. This focus continued until the 1940s, when the site was then employed for more diverse industrial use and a wider variety of chemical goods were produced, more recently e.g. Binders for the paint industry. This industry was sustained until April 2007, when Hexion Specialty Chemicals Sweden AB sold the property to NCC Construction Sweden AB in September 2007. NCC purchased the land with the intention of remediating the contaminated site, preventing pollution propagation, reducing the associated health and environmental risks to levels acceptable by SEPA and, in the longer term, converting the land to a residential and commercial area, complete with apartments, houses, a nursery, offices, stores, parking spaces, green space and a town square in the style of modern urban planning. The demolition of the warehouses, laboratories, silos, tanks, pipelines etc, began in 2008 and was completed in late 2009. The development is planned to be completed before 2015 (NCCTeknik, 2007).

2.2.3 Site contamination situation

At the time of purchase in 2007, the site was considered potentially contaminated and was formally restricted to prevent further risk to human health and the environment. Indications of contamination were exposed during demolition works, which eventually called for a complete survey and analysis.

According to the sampling and environmental analysis conducted by NCC in 2007 and 2008, the area was concluded to be contaminated by lead, mercury, phthalates DEHP (plasticizer), aromatics and poly-aromatics (PAHs) and aliphatic hydrocarbons. These pollutants were concentrated in specific areas based on the operation history of the plant, leaving a large part of the area with low concentrations of contamination (SWECO, 2009c). The sampling results' map is presented in Figure 2.6 below.

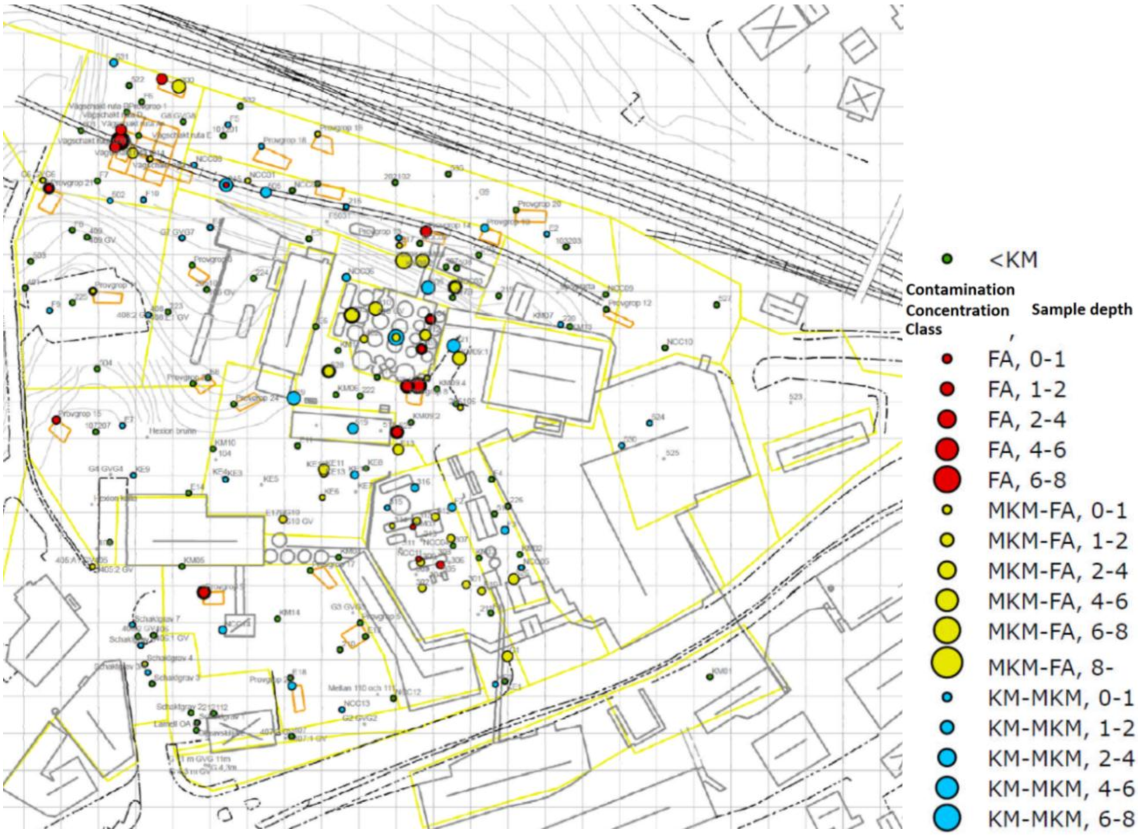


Figure 2.6 Hexion sampling result map. Red stands for very high concentrations, yellow for medium and blue for lower contamination concentrations (SWECO, 2009a).

Based on this analysis and the planned regeneration of the site, it was decided that remediation was necessary, with the following priorities:

- A drastic improvement in the condition of the ecological system for vegetation and soil fauna in the shallow soil layers.
- For the deeper soil layers, a focus to protect and secure the recipient Mölndal water quality rather than the soil environment ecological system.

3 Environmental Remediation

3.1 Introduction

Environmental remediation is generally defined as providing remedy for environmental problems. It involves a number of strategies and techniques to restore contaminated sites and natural resources to an acceptable level which is tolerable to humans and the environmental system. The most common and acceptable way to determine the need for remediation and what measures are to be required is to conduct risk assessment analysis according to SEPA recommendations with identifying generic and/or site-specific guideline values and then defining remediation goals with the aim for reduction of the calculated risk measures.

The remedial action can be done in different ways, depending on the contaminated media (soil, ground water, surface water or air) and contamination type (chemical, radioactive, microbial or physical) (USEPA, 2011). Remedial actions can be categorized into three groups; containment techniques that restrict the contamination in the specific domain and prevent spreading; removal techniques whereby contamination is transferred from an open environment to a controlled environment and treatment techniques that transform the contamination to a non-hazardous form (Brusseau & Maier, 2004).

For ground and soil remediation, the techniques available can be categorized into two major groups: In-situ and ex-situ. Processes that involve excavation of the soil are considered ex-situ and in in-situ techniques attempt to treat the problem without removing the soil. Further remedial applications would be needed on-site or in another facility (off-site) if an ex-situ strategy is implemented. Containment techniques are mainly in-situ; removal techniques are mostly done in an ex-situ manner. Treatment techniques can be implemented in-situ or ex-situ, dependent on the technique used.

In this section, main soil remediation techniques are going to be briefly described.

3.2 Excavation

Excavation is a general term used for ex-situ removal remediation. Within this process the contaminated soil is replaced by a new clean soil and the excavated soil is transported to a disposal or a soil treatment facility. This technique, which is very common, has a very high rate of efficiency because of its relative simplicity and general familiarity in industry. Despite this, there are some clear drawbacks and weaknesses:

- During the activity, site workers can be exposed to any hazardous pollutants present.
- The technique is usually feasible for remediating relatively shallow and localized contaminated sites.
- From a sustainability point of view, the contamination is merely transferred to another location, not eliminated.
- This technique requires a great deal of transportation and earthwork that inevitably contributes to atmosphere pollution end accident exposure(Brusseau & Maier, 2004)

3.3 Soil washing

Soil washing is an umbrella term for a number of techniques, whereby the pollutants are washed away. These treatment techniques can be applied either In-situ or ex-situ and are reliant on the type of contamination, the ground condition and the available technology. Soil washing can be applied for a broad range of contamination types and even a combination of them and are considered "gentler" than excavation methods, as they are treatment-oriented. In-situ (if applicable) and ex-situ on-site techniques are considered "gentle" and sustainable techniques that have low footprints. Soil washing techniques become more difficult and expensive as the fine grain rate of the soil matrix increases (USEPA, 2011).

3.3.1 Ex-situ techniques

Ex-situ soil washing remediation is done by excavating and treating the contaminated soil. Within the treatment process, excavated soil is sieved, washed and floated in basins. During the washing process, fine grades are separated from the soil matrix based on their different settling times. Since the contamination tends to attach to finer grains, this portion is most contaminated and must be separated and be treated as hazardous waste, needed to be handled or treated. Whereas the gravel and sandy portion is separated, rinsed and reused. To increase the efficiency and time necessary for the whole process, water can be adjusted in temperature and pH or specific solvents can be dosed. Ex-situ soil washing can be done on-site at mobile plants or the soil can be transported to a soil washing facility.

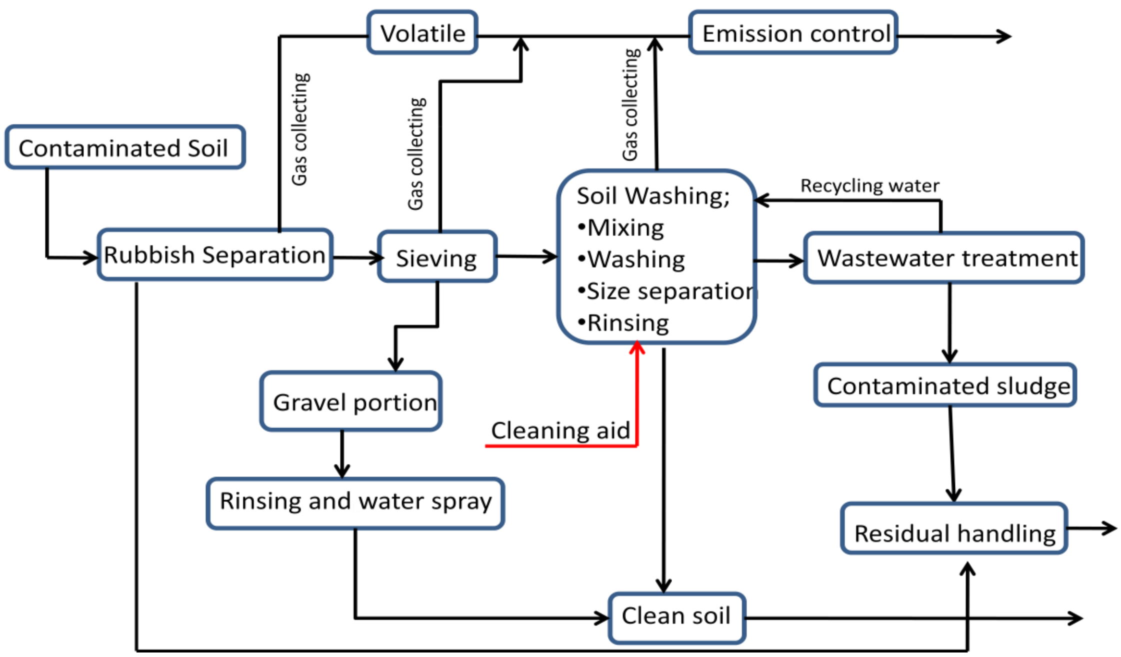


Figure 3.1 Flowchart showing an ex-situ soil washing process, according to a Soil-washing interim guidance report (ORD & SWER, 1991).

Figure 3.2 An ex-situ, on-site soil washing process, by SoilTech™ and Ivey-sol companies (SoilTech, 2011; Ivey-sol, 2010).

3.3.2 In-situ soil washing and sedimentation (ISW)

In-situ soil washing can be done by enclosing smaller areas of contaminated mass, pumping in air and water to blend with the soil and eventually wash out the finer portions. The treatment process is the same as ex-situ techniques with the advantage that the soil does not need to be excavated. However, in order to apply this method, specific conditions are needed:

- The contaminated soil should be shallow
- The soil needs to be on top of a non-permeable surface (on the bed rock or on clay layers)
- The contaminated soil needs to be natural (free from anthropogenic materials, scrap and building wastes)

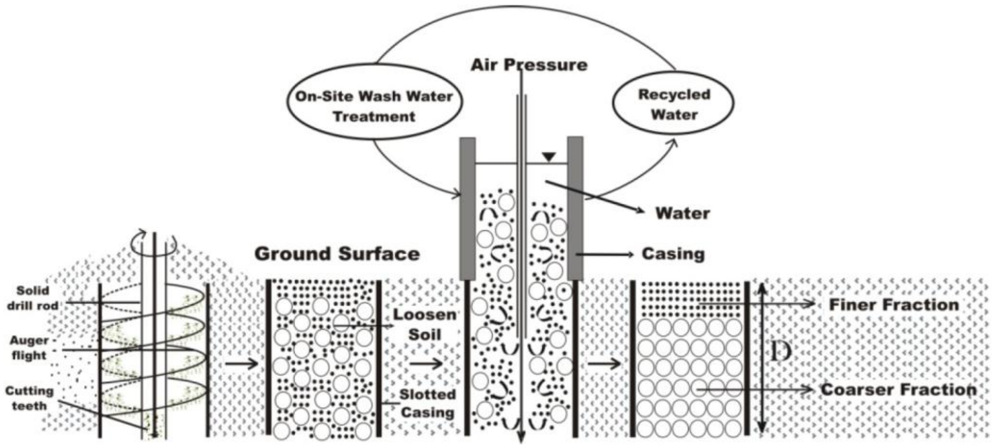


Figure 3.3 An in-situ soil washing technique (Budianta et al., 2010)

3.3.2.1 "Pump and treat"

The "pump and treat" method is a widely used groundwater remediation technique which has the potential to be used to flush out contamination by inducing desorption from the soil media (Brusseau & Maier, 2004). In this process, water (with appropriate adjustments) is infiltrated or pumped through the contaminated media, then treated by a suitable treatment operation. This process is repeated over a determined period of time to reach the acceptable goals. Recent studies show that this technique is very successful in containing contamination plumes and even shrinking them; however, it is not possible to completely remove the subsurface contamination by this technique, as the pollution reduction ratio inevitably decreases over time. This technique, like the previous in-situ technique, is dependent on many in-situ and geological factors that can limit the application or make it not applicable.

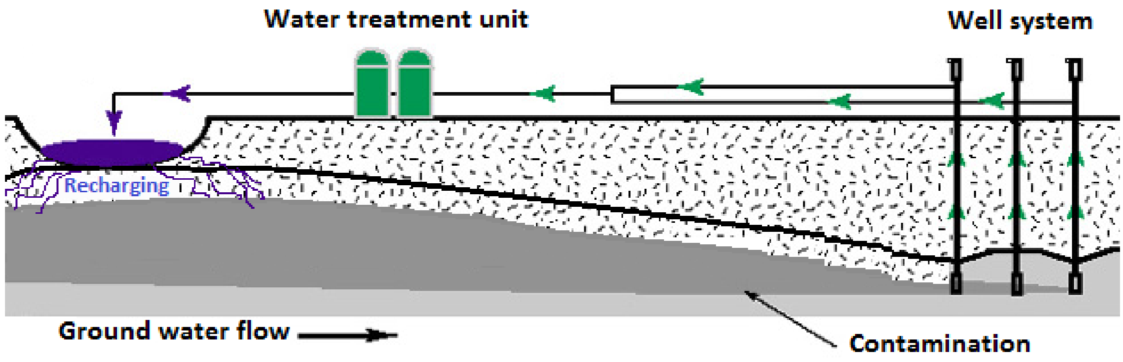


Figure 3.4 In-situ "pump and treat" method (Brookhaven Group, 2000)

3.4 Immobilization techniques

A large number of techniques are available which attempt to immobilize the contamination by fixing them in the soil matrix. This immobilization can be done by solidification-stabilization technologies (S&S), vitrification, capping, cut-off walls and in-situ containment (FRTR, 2011).

3.4.1 Solidification and Stabilization(S&S)

S&S technologies work to chemically bind or encapsulate contaminants and therefore reduce dispersal and overall exposure. S&S techniques can be applied to remediate sites contaminated by metals, organics and radio-nuclides. It can be done by combining cement, pozzolanic, thermoplastic or organic polymerization materials with the contaminated soil (FRTR, 2011). S&S can be applied either by in-situ or ex-situ techniques.

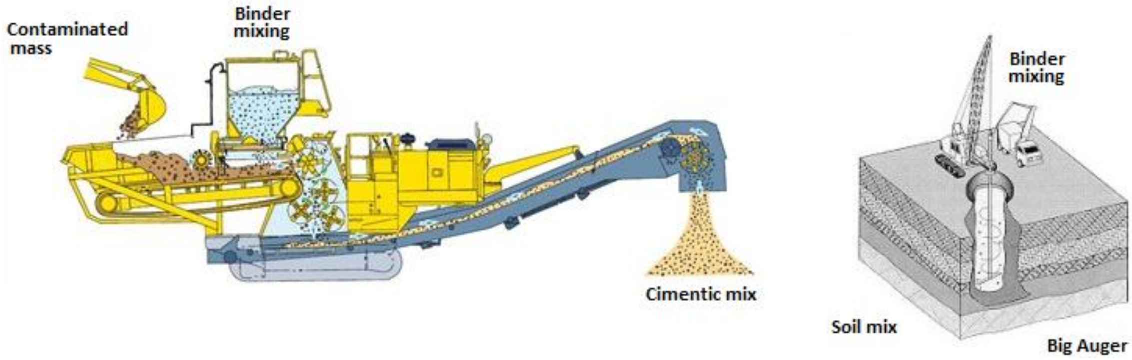


Figure 3.5 Solidification and Stabilization methodology. Ex-situ technique to the left and in-situ technique to the right (Quickfall, 2000).

3.4.2 In-situ Vitrification (ISV)

Vitrification is a process whereby graphite electrodes are planted into the ground and heat is produced by an electric current, which burns or volatilizes any organic compounds, melts and converts the contaminated soil into a stable crystalline solid medium which is contained within the solid matrix. This process has a high immobilization efficiency but is relatively expensive, energy-hungry and the cooling process takes a long time (FRTR, 2011).

3.4.3 Surface capping and vertical barriers (cut-off walls)

Surface capping is a technique used to cover the contaminated area by tight liners and a thin layer of clean soil for extra protection, preventing potentially dangerous exposure of contaminants to human and animals. Capping minimizes infiltration to the contaminated area, eliminates contamination of surface water by coming into contact with the pollutants and removes the risk of contaminated dust spreading to the local area, or indeed the volatilization of contaminants. This technique is a relatively straightforward and time-efficient method to reduce the environmental risk by limiting the exposure pathways; however it demands continued monitoring, is rarely successful without using other preventative methods in parallel and will restrict future land use. Capping techniques are most often used together with vertical impermeable barriers known as cut-off walls. Cut-off walls are mostly built by using slurry materials, steel sheet piling and grouting instead of the liners (FRTR, 2011).

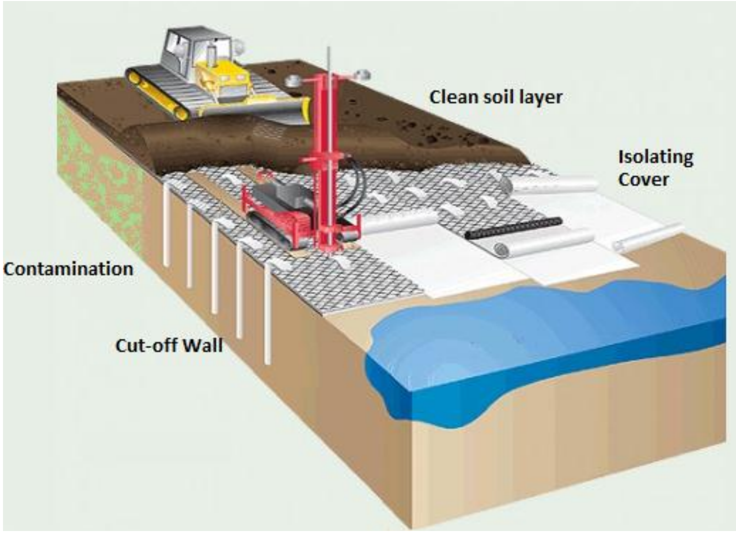


Figure 3.6 Barrier implementation techniques for remediation (WISMUT, 2010).

3.5 Thermal vapour extraction and air sparging

Thermal vapor extraction and air sparging are in-situ treatment techniques. These methods are applied to remediate sites contaminated by volatile and semi-volatile materials and oil remnants. Air (hot air, steam or even gases) is injected into the contaminated zone to volatilize the contaminants which are then captured by a soil venting system at the ground surface which condenses the vapor for further treatment or incineration. The effectiveness of this technique is often limited by the channeling (whereby injected air moves in discrete channels instead of spreading evenly over the zone) and low soil hydraulic conductivity (Brusseau & Maier, 2004).

3.6 Electrokinetic methods

Electrokinetic remediation refers to the extraction of contaminants from the site by inducing an electrical field in the ground. The process works by applying a direct current through electrodes planted in the ground (which should be wet to near saturated). The precise technique and measures used depend on ground condition and the type of contamination (e.g. polar or organic) and are suitable for a considerable number of contaminants. Although electrokinetic methods are energy hungry and comparatively expensive, they are very successful in removing contamination from sites with low water permeability (clay and silty clay soils). These methods are considered "gentle" and sustainable where the electricity source is produced environmentally friendly (USEPA, 1997).

3.7 Biological remediation

Biological remediation can be defined as the use of bacteria, fungi and plants to break down, degrade or transform toxic chemical compounds that have accumulated in the environment. Although less widely used than the methods previously discussed, there has been a great deal of interest in the use of in-situ contaminated land remediation by biological activity recently as they are perhaps the most "gentle" methods of all and pilot tests are showing outstanding results (Cundy, 2009).

3.7.1 Bio-remediation

Bio-remediation is the exploitation of naturally occurring micro-organisms' activity to treat contamination within a specific site. Elements of this microbiological activity are already intrinsically present in the soil, although working at a slower rate, and this can be further stimulated and concentrated by adding oxygen, nutrients and further fertilizing organisms to achieve results more quickly. Bio-remediation can be done onsite or can be applied on the concentrated, extracted contaminations (e.g. sludge, ash and sediment treatment). As more than 90% of hazardous chemical compounds are bio degradable and it is a relatively cheap method of remediation, this technique has plenty of promise and encouraging rates of treatment have been recorded (Zhu et al., 2004). Domestic waste and sewage water treatment is a good example of the efficiency of these systems. However, there is a big uncertainty about the results because these systems are live systems which are very sensitive and unpredictable. Biological activity, degradation and transformation status and outcome are highly dependent on the pollutants´ characteristics, combinative effect and their bioavailability. There is a concern about adverse higher toxic compound formation in specific uncontrolled situations and there is a risk that these micro-organisms could spread to other environmental systems, with unknown effects. This makes the task of recommending and implementing bio-remediation techniques rather complicated without carrying out site-specific, pilot-scale laboratory work. The other drawback is that bio-remediation is less successful at treating metals than chemical compounds, organics and oil remnants (Brusseau & Maier, 2004).

3.7.2 Phyto-remediation

Phyto-remediation is an innovative brand in biological remediation whereby specific plants are sown on polluted sites to remediate contamination, both organic and inorganic hazardous compounds. There are many available plant species that naturally attract, accumulate and degrade toxic compounds in their tissues, or stabilize and fix them in their root region. Phyto-remediation is relatively cheap and environmentally friendly with no significant side effects. The advantages of using bio-accumulating plants as a remediation technique is that organic pollutants are degraded by plant cells and metal pollution can be removed from the site by harvesting the plants after the metals are accumulated in the plant tissues. Stabilization techniques with their specific plants are attractive in the sense that the contamination stays subsurface, which reduces the exposure levels to wildlife and does not require any regular harvesting. However, these stabilization techniques demand continuous monitoring and remediation can take several years and, of course, the remediation is limited to the relatively shallow zone of the plant roots (Environmental Management Support, 1999).

4 Environmental footprint analysis & used tools

4.1 LCA and Footprint analysis

Life-cycle analysis (LCA) is a systematic and step-wise method in which the energy and raw material consumption, different types of emissions and other factors related to a specific activity are measured, analyzed and categorized from an environmental perspective over the activity's life cycle. It attempts to measure the "cradle to grave" impact on the ecosystem (SAIC, 2006). LCA analysis dates back to the early 1970s, when it was used to investigate the energy requirements for different processes; later, emissions and raw materials inventories were added to the process to conduct environmental footprint analyses. Nowadays, LCAs are considered to be the most comprehensive approach to assessing environmental impact (Morais & Matos, 2010).

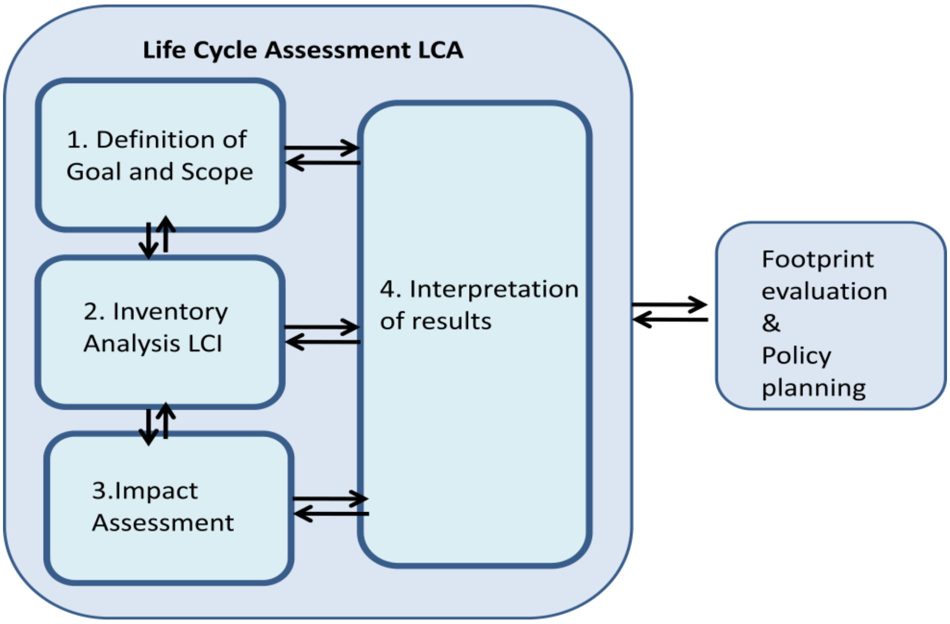


Figure 4.1 Life Cycle Assessment flowchart according to USEPA implementations.

As it is illustrated in the *Figure 4.1* above; The LCA starts with "goal definition and scoping" (description of the activity). It is crucial to establish what purpose the model is meant to serve, what is to be studied, what depth and degree of accuracy is required, and what the decision criteria will be before starting the analysis. System boundaries for space and time as well as the functional units are set in this first phase. After the first step, Inventory analysis (LCI) is carried out, whereby an inventory of the inputs and outputs of all life-cycle processes is determined in terms of material and energy. The process starts by making a process flow-chart covering the events in the activity's life-cycle which are to be considered in the LCA, together with their interrelations. It is followed by a collection of relevant data for each event in terms of emissions from each stage of the process and the resources and materials used. Finally, based on the gathered data, energy balances for each stage of the process are made.

The results from the LCI analysis are crude numbers of mass and energy balance which are then converted to human and ecological impact factors in the impact assessment stage (LCIA). Within the impact assessment, various foot-printing factors are defined by combining and weighting the impact assessment phase results (e.g. GHG from CO_2, CH_4 and N_2O, Eutrofication, Nitrification from NOx, SOx and PO_4 etc emissions). There are different ways to define and weight environmental impacts which have a significant effect on the results. It is important to retain the crude results from the LCI step for better comparison and future impact calculation adaptations and to simply use the LCIA results. The final step in the LCA is data interpretation and evaluation, with consideration of the boundaries of the activity. Decision-making support for a certain process, future improvements and system optimization are some of the major evaluations that can be made here (USEPA, 2011).

Beyond the obvious advantages of LCA, this analysis method is under development and there are still some drawbacks for application of this tool (Morais & Matos, 2010), including:

- System definition and adjusting proper system boundaries for time and space is a demanding, time-consuming and uncertain process.
- It is difficult (if not possible) to define a suitable, representative functional unit for a certain activity for each LCA.
- The inventory step usually takes a great deal of time and effort and mistakes are often in calculations.
- Although some published data on impacts of different materials are available, the data is often inconsistent and not directly applicable due to different goals and scope definition and there is a general lack of solid data about all aspects of a material's life cycle (M.A. Curran).
- There is an infinite amount of data to deal with and numerous decisions to make within each step of LCA analysis which is bound to have an effect on the final results.
- For the Impact assessment step, there are different views on what is environmentally acceptable and approved, and the lack of a consistent standard here is a palpable shortcoming (Morais & Matos, 2010).

In order to make the analysis more acceptable and applicable, tools have been developed that instruct users through the LCA process. Since LCA is case-specific and dependent on the system and defined goals, a number of tools have been developed that are completely different from each other and in most cases can only be used for the specific product/activity that they have been defined for. These tools ease the process of LCA by helping and guiding the user through the steps, proposing the major goal and system boundaries and relevant functional units, facilitating the inventory step by introducing input data menus and minimizing the calculation errors and finally generating presentable, comparable documental results which can be used to support decision making.

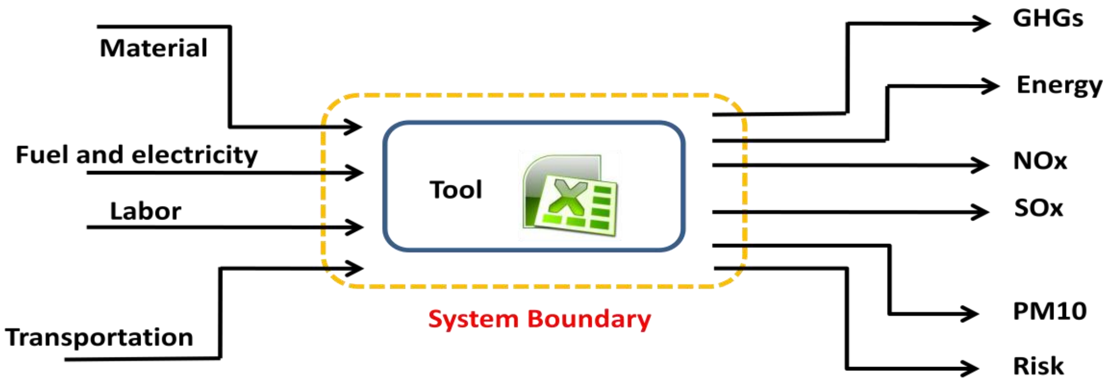


Figure 4.2 Flowchart for LCA analysis and environmental footprint evaluation tools

Below, two recently developed tools for LCA of remediation activities (SiteWise$^{TMv.1}$ and SRT) are going to be described. Their entire analysis process will be evaluated and finally their capacity in footprint estimation, sustainability evaluation, decision making support and data uncertainty coverage will be discussed.

These tools are free and publicly available tools and it is possible to get the tool and the guidance manual from the Green and Sustainable Remediation official website (http://www.ert2.org/t2gsrportal/tools.aspx).

4.2 SiteWise^{TM}, Tool for Green & Sustainable Remediation

4.2.1 Introduction

SiteWise$^{TMv.1}$ is a tool developed for evaluating a range of remediation techniques and comparing alternatives based on their environmental footprints, developed jointly by the United States (US) Navy, United States Army Corps of Engineers (USACE) and Battelle institute (SiteWise$^{TMv.1}$ User Guide, 2010). The tool's first version (SiteWise$^{TMv.1}$) has been available for public use since May 2010 as a tool which can be used free of charge. SiteWise$^{TMv.1}$ has an activity-based approach for footprint analysis, whereby the remediation technology/activity is separated into the individual activities for different phases and the footprint of each activity is calculated separately. The total footprint of the remediation options is finally evaluated by integrating the calculated impacts of each individual action. The data needed to model a certain activity are:

- Material required for the activity

- Transportation of the required materials/ equipment to the site
- All site activities to be performed
- Management of the waste produced by the activity

And calculated footprints are:

- Air emissions of certain pollutants including greenhouse gas (GHG), nitrogen oxides (NOx), sulfur oxides (SOx) emissions, particulate matter (PM) release
- Water consumption
- Energy use
- Work environment safety (exposed risks from transportations and other activities)

This activity-based method of modeling and calculation, where each phase is discrete, allows the user to define all the activities within the applied or planned alternative without limitations, as long as tool is therefore suitable for any phase in remediation technique selection as an aid to decision making. It can also be used to analyze the potential or chosen remedial alternative at any stage in the process (investigation, design, and the operation and/or Long Term Monitoring (LTM) phases), making it well suited to be used as part of environmental footprinting, ecological compensation and optimization studies (SiteWise$^{TMv.1}$ User Guide, 2010).

4.2.2 Tool package and application

SiteWise$^{TMv.1}$ is based on a Microsoft Excel platform in different excel files. The tool package consists of six folders and an overall summary file. Each of the folders includes six excel worksheets for modelling a remedial alternative; a worksheet for data inputting with separate tabs for different remedial activity phases (named SiteWise_Input_Sheet), four inventory analyses for different remedial activity phases (referred to as calculation sheets in the user manual) and a summary worksheet. With the tool package as the default set-up pattern, six different comprehensive alternatives can be modelled simultaneously. The summary results of these alternatives are then gathered in the overall summary file for further comparison. Summary files for each folder as well as the overall summary file include detailed tables of data for each remedial phase in different tabs and have an integrated sum value chart tab for easy comparison.

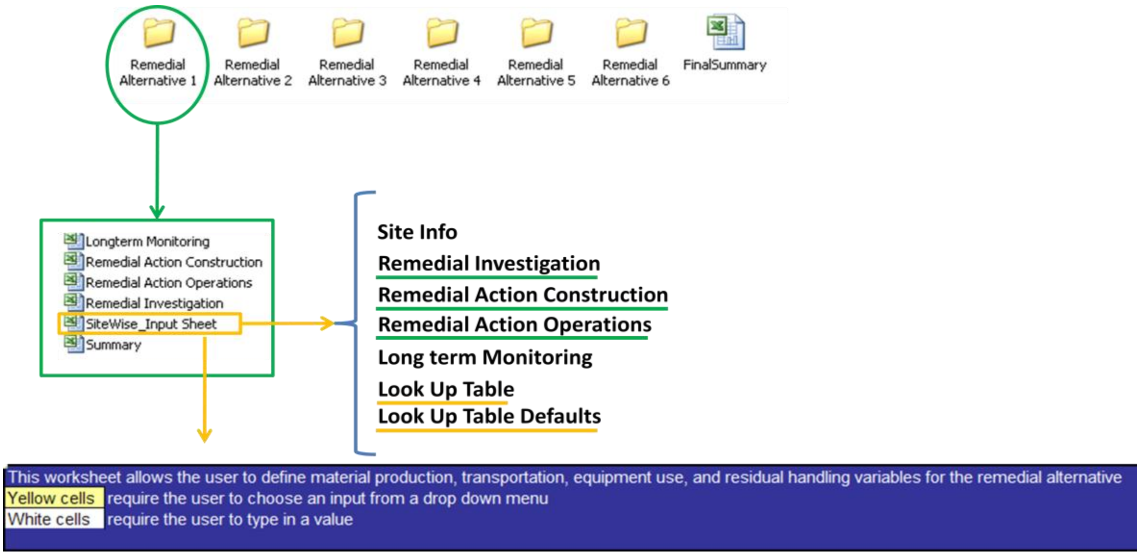


Figure 4.3 SiteWise^{TM} package flowchart, illustrated based on the tool's user-manual.

Modeling begins by copying the tool set into the computer and completing the input worksheet file with the available data for each alternative in its appropriate folder. It should be noted that all macros should be enabled before the input data are entered. All the worksheets are interconnected by the tool, so the input values entered for each phase of each option is used by the tool to conduct inventory analysis and the results are presented in the summary files.

4.2.3 Data requirements

The SiteWise$^{TMv.1}$ input sheet has a very detailed data input registry for a number of possible activities. It is also possible to enter site-specific information by the user, such as the amount of water consumed, site specific emissions, and risk values, in order to cover all the on-site activities. Data input sheets are the same for all different remediation phases in the input sheet tabs. A list of the data requirements are shortly summarized in the Figure 4.2 below.

•**Material Production, consist of:**
- ➢Well material used in the field,
- ➢Material and chemicals used for treatment,
- ➢Construction material (concrete, gravel, etc..)

•**Transportation of:**
- ➢Personnel transportation via road, air or rail
- ➢Equipment transportation via road, air, rail or water

•**Equipment use in terms of:**
- ➢Earth work done by Dozer, Excavator, Loader and /or Scarper
- ➢Drilling work
- ➢Pumping operation,
  - Electric usage,
  - Pumping head
  - Name plate specifications
- ➢Blower, compressor, mixer and other equipments
  - Electric usage,
  - Pumping head
  - Name plate specifications
- ➢Generators
- ➢Agricultural equipments
- ➢Capping equipment
- ➢Mixing equipments

•**Residual handling by:**
- ➢Residue disposal
- ➢Thermal/catalytic oxidizers
- ➢Water consumption
- ➢Landfill methane emissions

•**Other known onside activities**
- ➢Energy and water consumption
- ➢Emissions (CO_2, N_2O, CH_4, NO_x, etc...)
- ➢Risk in terms of injury and/or fatality

Figure 4.4 Input data list for SiteWise^{TM} tool.

The tool uses sets of default values and factors in the data input process to facilitate modeling. The defaults set in the tool are based on the credible sources and their recommended generic values. All default values in the tool can be changed by the user.

For GHG emission footprint calculation, the U.S. EPA Climate Leaders Program (Leaders, 2009) which is a modification of the GHG protocol developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) is used together with the emission factors by Argonne National Laboratory's GREET model, U.S. EPA's Mobile 6 model, and EPA's Non-road model.

Emission factors for consumables are life cycle based with consideration of all energy used and emissions released due to manufacturing of the consumable, production of the electricity and manufacturing, production and transportation of raw materials for manufacturing the consumable obtained from various sources providing life cycle inventories like, the inventory provided by National Renewable Energy Laboratory (SiteWise$^{TMv.1}$ User Guide, 2010). Energy and water consumption are based of the available data from onsite meter readings. Traffic and transportation air emission Inventories are mostly based on the Mobile 6 and Non-road, two computer programs developed by the U.S. EPA's Office of Transportation and Air Quality. Accident risk calculation is based on the developed results of several organizations including Automobile Transport Statistics, Airplane Transport Statistics, Railroad Transport

Statistics, and Labor Statistics for both fatalities and injuries that occur during various activities.

For more detailed information about assumption made, conducted system boundaries for each activity and check of the default data sources it is possible to check the SiteWise$^{TMv.1}$ user manual and the related data appendixes.

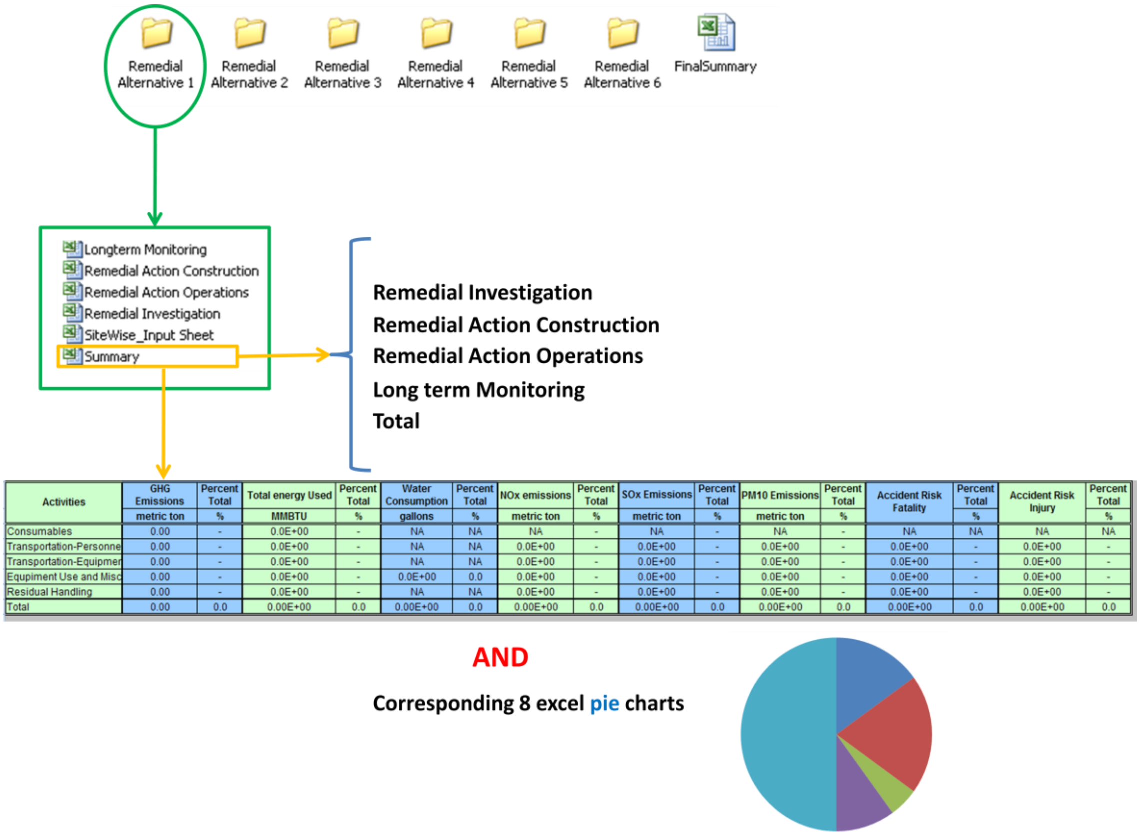
4.2.4 Inventory Analysis

The SiteWise$^{TMv.1}$ inventory calculation process fallows the LCI process of LCA. Inventory calculations in SiteWise$^{TMv.1}$ are based on the input values extracted from the input sheet multiplied and combined by the foot printing factors obtained from the mentioned sources. All the used factors within the inventory process are available in a specific tab in the inventory work sheets named as 'Look-up Tables'. All the foot printing factors and values are editable by the user based on the user's demand and specific available information. The inventory process explanation for each and every of the foot printing metrics is available in the user manual of the SiteWise$^{TMv.1}$ tool. It can be looked up by the user to see the process methodology of multiplication and data combination process of the used sources and released emissions.

SiteWise$^{TMv.1}$ has open Macro codes that enable needed changes and it does not luck the cells. Open cells enable the capability of launching probabilistic analysis tools to the tool (e.g. Crystalball, @Risk, etc). With the aid of theses add-in packages in to the Microsoft based SiteWise$^{TMv.1}$ tool, it is possible to do all type of probabilistic, uncertainty and sensitivity analysis by the tool.

4.2.5 Results

Results of inventory analysis are transferred into the calculation sheets that make it possible to see the environmental footprint of each remedial phase. Every remedial alternative has a summary sheet that has the same function as well.

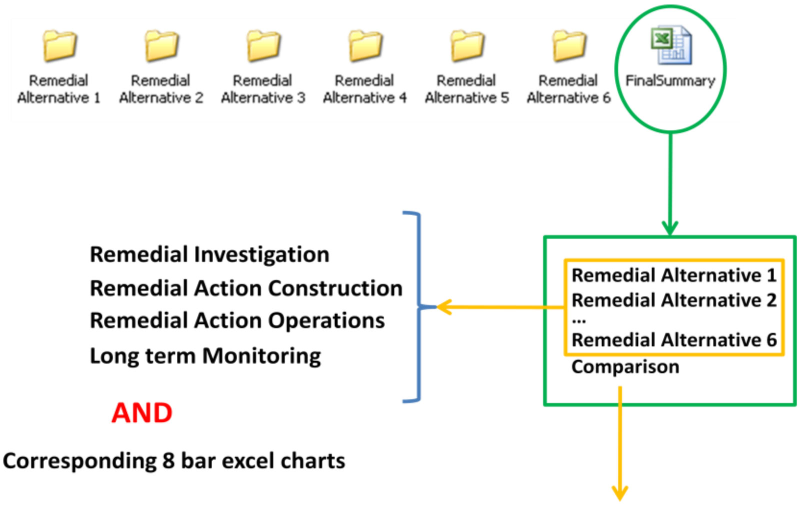


Activities	GHG Emissions	Percent Total	Total energy Used	Percent Total	Water Consumption	Percent Total	NOx emissions	Percent Total	SOx Emissions	Percent Total	PM10 Emissions	Percent Total	Accident Risk Fatality	Percent Total	Accident Risk Injury	Percent Total
	metric ton	%	MMBTU	%	gallons	%	metric ton	%	metric ton	%	metric ton	%		%		%
Consumables	0.00	-	0.0E+00	-	NA	NA	NA	-	NA	-	NA	-	NA	NA	NA	NA
Transportation-Personne	0.00	-	0.0E+00	-	NA	NA	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-
Transportation-Equipmer	0.00	-	0.0E+00	-	NA	NA	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-
Equipment Use and Misc	0.00	-	0.0E+00	-	0.0E+00	0.0	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-
Residual Handling	0.00	-	0.0E+00	-	NA	NA	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-
Total	0.00	0.0	0.00E+00	0.0	0.00E+00	0.0	0.00E+00	0.0	0.00E+00	0.0	0.00E+00	0.0	0.00E+00	0.0	0.00E+00	0.0

Figure 4.5 SiteWise^{TM} result flowchart, an example of tools result for each of the alternatives

The final summary file then combines all the modeled alternative inventory results. This file has the capability to update the information of all the six remedial alternatives in the case of any applied changes by the user through the connection of the worksheets by the tool.

SiteWise$^{TMv.1}$ present graphical excel charts that makes it possible to compare different remedial alternatives on a set of consistent metrics that are goaled and furthermore goes dawn to present the charts separately on the level of activity in every phase of every remedial alternative to determine the activities contribution to the total remediation.



Remedial Alternatives	GHG Emissions metric ton	Total energy Used MMBTU	Water gallons	NO_x emissions metric ton	SO_x Emissions metric ton	PM_{10} Emissions metric ton	Accident Risk Fatality	Accident Risk Injury
Remedial Alternative 1	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Remedial Alternative 2	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Remedial Alternative 3	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Remedial Alternative 4	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Remedial Alternative 5	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Remedial Alternative 6	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

AND

Corresponding 8 bar excel charts

Figure 4.6 SiteWise™ result flowchart, an example of SiteWise™ 's final results.

Result documents from SiteWise™v.1 only contain foot printing metrics of the remedy. In order to make a proper comparison of alternatives in the decision making process, it is crucial to consider other sustainability dimensions also. Therefore additional economic and social analyses are needed to be conducted and then combined with the SiteWise™v.1 results in order to find the most sustainable alternative.

4.3 Sustainable Remediation Tool (SRT)

4.3.1 Introduction

SRT is a tool developed for evaluating remediation techniques and comparing alternatives based on sustainability metrics and make a support on decision making process (US.AFCEE, 2010). It is developed by the United State Air Force Center for Engineering and Environment (AFCEE). The tool is available for public as a free commercial tool for anyone/party to consider sustainability in selection of remediation technology or optimization of an existing ongoing remedy. SRT has a technology based approach for evaluating alternatives. It estimates sustainability metrics for specifically defined remedial technologies. These selected technologies are decided by AFCEE as the most common technologies needed by the Air Force to remediate contaminated sites. More remediation technologies are going to be added to the tool by AFCEE in time. Current available technologies that can be evaluated by the tool are listed below.

For Soil Remediation:

- Excavation
- Soil Vapor Extraction
- Thermal Treatment

For Groundwater Remediation:

- Pump and Treat
- Enhanced Bioremediation
- Permeable Reactive Barrier
- In Situ Chemical Oxidation
- Long-term Monitoring / Monitored Natural Attenuation

4.3.2 Tool package and application

SRT is based on Microsoft Excel platform. Excel was decided based on the widespread availability, familiarity and the transparency for the users. The tool package consists of a excel worksheet with a general input screen, screens for inputting data for different remediation techniques for doing inventory calculations (named as technology screens), ,result screens named as Output screen and one reference tab for the used default values (US.AFCEE, 2010). SRT is structured using analytical “tiers” similar to the tiered structure of the Risk-Based Corrective Action (RBCA) Tool Kit (GSI, 2010). Two tiers are available for modeling a remedy.

- Tier-1; The simpler tier; consider more default values adapted from finished projects. Although a more generic approach and rules of thumb consideration is adapted within tire1 analysis, makes it possible to do a fast and simple evaluation of a remedy at an early stage with no sufficient data available.
- Tier-2; Analysis has a more site specific approach compared to the simple tire. It is possible to put more site specific values instead of the default values considered. It is possible to shift from a simple tier analysis to a more site-specific situation by simply modifying and entering anywhere between 102 and 574 input variables, of the default values used by the tool, if more exclusive data is available.

The modeling process is well illustrated and guided through the analyzing process, from tab to tab. After defining the name of the project in the basic input screen process starts by filling in input data tabs for specific goaled remedy; it continues to the inventory analysis with transparent calculations and finally publishes the results on the results tab for each technology. SRT calculates design elements and materials and consumables needed for each major component based on the rules of thumb or algorithms, allowing the user to adjust the values, and then convey the totals into the output metrics calculations. There is adequate help and guidance available for the user in the tools screen to input correct values and see the concept behind the inventory processes. Tool has a detailed user manual also that makes it possible to the user to get more information about the process, assumptions made and values used in the case of interest.

4.3.3 Data requirements

Based on the contaminated media, the selected remedial technology and the required input data can be different. Since both cases within this thesis study have soil contamination by various volatile and non-volatile (heavy metals) pollutants, only the data requirements for excavation of soil remedy as well as soil vapor extraction technique are presented in this section. For modeling other remedial technologies available in the tool, it is possible to get the data requirement list from the user manual. For environmental footprint analysis of excavation techniques, the following data are needed:

- Personnel transport (distances and number of trips)
- Amount of the soil that needs to be excavated
- The site's surface area
- Dump landfill and clean soil source distances to the site
- Truck size for carrying the contaminated and clean soil
- Other known project metrics (cost, energy, CO_2 emissions, lost working hours and injury risk) to put directly in to consideration

For environmental footprint analysis of SVE, the following data are required:

- Personnel transport (distances and number of trips)
- Amount of the soil that needs to be treated
- Maximum and typical contamination concentration
- Filter type
- Applied technical type and temperature and
- Other known project metrics (cost, energy, CO_2 emissions and risk) to put directly in to consideration

To do a full sustainability analysis, considering the economical perspective and natural resource attenuation, the following information is also required:

- Fuel prices
- Land price
- Technology and Land-filling costs

4.3.4 Inventory Analysis

After entry of basic site data in the Input screen and filling out the Technology screens which contain design and materials and consumables sections, intermediate calculations with LCA approached algorithms are done. Used factors for generating mass and energy balances within the considered boundaries are based on the available trusted source information together with the expert judgment assumptions. Most of the assumed factors are editable by the user in the case of specific available information. Calculated sustainability metrics are carbon emissions, economic cost, energy consumption, safety / accident risk and change in resource service from the evaluated media. These metrics are presented in the output screen as crude metrics.

The SRT worksheet is locked by the developers. This prohibits the possibility of including probabilistic analysis using e.g. Crystalball, @Risk, or other add-in softwares. Therefore it is not possible to do probabilistic, uncertainty and sensitivity analysis. Obtaining the required codes for enabling such analyses could possibly be negotiated by the developers.

4.3.5 Results

SRT has the capacity of combining calculated crude non normalized inventory results in their specific units into a single normalized monetary metric by using convention factors. This normalizing approach brings up the opportunity of summing multi-dimensional sustainability factors in to a singular number that can be used to represent the remedies environmental and economic burden by the tool. It is possible to do sensitivity analysis by SRT considering future hypothetical energy and fuel prices.

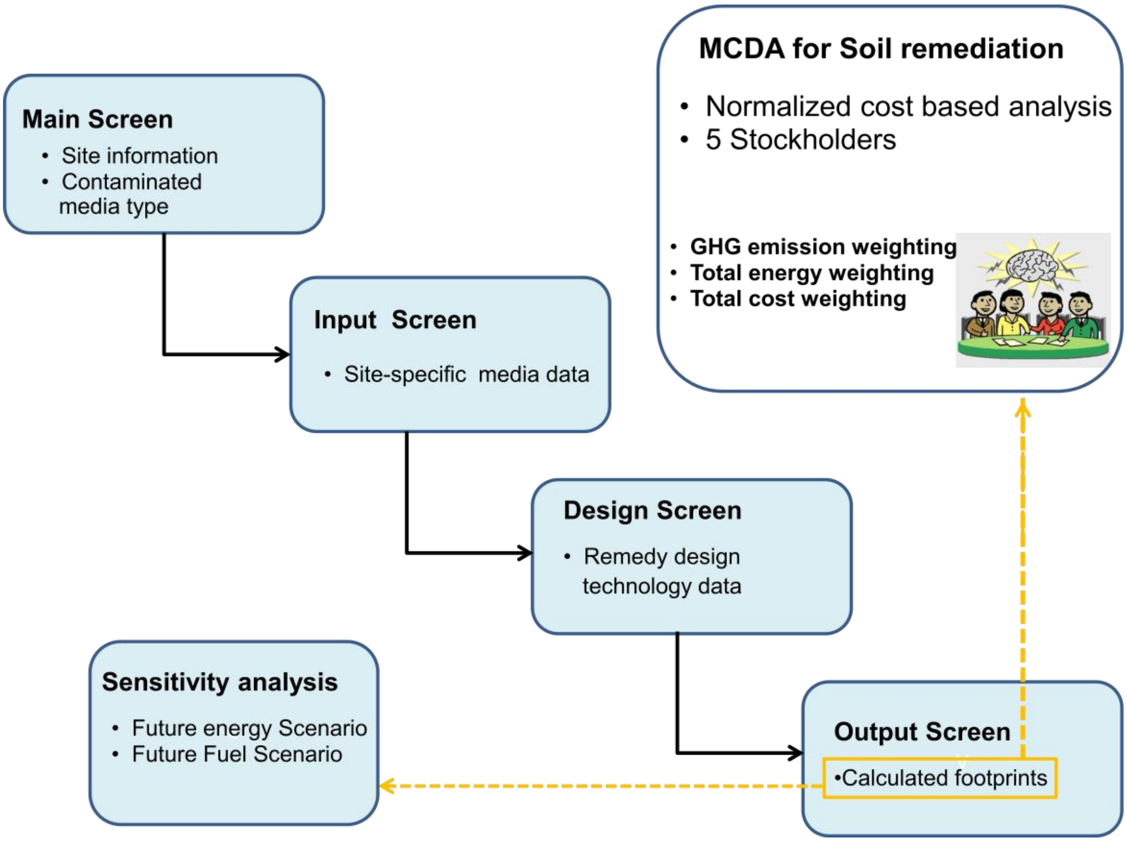


Figure 4.7 Flowchart showing the implementation and results of the Sustainable Remediation Tool (SRT).

SRT has two additional innovative features also. It is possible to make a scenario planning with changed energy and carbon emission offset prices. It can be used to evaluate the sensitivity of the analyzed technology to these metrics. SRT has a virtual meeting room (screen), where different decision-maker scan weigh the importance of different sustainability metrics. This virtual weighting of different aspect of sustainability metrics by the different involved stakeholders brings up the opportunity of making a limited Multi Criteria Decision Analysis (MCDA).based decision making is the preferred method for sustainability evaluation of an activity.

5 Modeling

5.1 Introduction

In this chapter, all the modeled remediation alternatives for both the contaminated sites are presented with descriptions of their LCA system boundaries, site-specific conditions and information and technology implementations.

5.2 BohusVarv Remediation Project

Twelve scenarios for the Bohus Varv remediation project are modeled based on three major remedial technologies. i. Excavation and landfilling, ii. ex-situ, onsite soil washing and iii. stabilization and solidification technologies were chosen as the most appropriate techniques for the site based on the site-specific characteristics, but, due to time restrictions and the relative depth of the contamination in the ground, neither phyto- nor bioremediation was considered effective. Electrokinetic methods were also rejected due to the features of the soil, which was made up of sand and gravel with relatively high permeability. In-situ soil washing by water pumping was also rejected, because of the site´s proximity to the Götaälv and the associated risks of leakage and spread of the contamination. Finally, in-situ encasing soil washing was excluded due to anthropogenic materials present in the ground.

Ten scenarios are modeled using the SiteWise$^{TMv.1}$ tool, but it was not possible to generate more than two scenarios with full excavation and truck transportation using the SRT tool, since it cannot model other chosen remedial technologies, e.g. Soil washing.

The investigation and soil-sampling stage for SiteWise$^{TMv.1}$ analyses is modeled according to the available sampling data and risk analysis reports. It is presumed that a 10 short ton "equipment transport" was needed to establish the stage. All these results are reported as "investigation Stage" in the tables and charts.

To calculate the footprint made by personnel transportation for SiteWise$^{TMv.1}$ models, COWI daily reports of ongoing remediation activity are used and assumed to be the same for all other remediation technologies implemented and reported as "personnel transportation" in the results. An additional 20 short ton road cargo transportation is assumed for all technologies for the site-establishment stage of SiteWise$^{TMv.1}$ models. For all the modeled scenarios by SiteWise$^{TMv.1}$, an internal site work of leach-water treatment and pumping, together with the site shoreline stabilization by metal sheet piling is considered. Site establishment together with the aforementioned in-site activities are reported together as "remedial construction". Intermediate loading and transportation of mass at and around the excavation site before it is taken to landfill is included in the SiteWise$^{TMv.1}$ models.

5.2.1 Scenarios 1 and 2

These two scenarios involve excavation and transfer of the contaminated mass by truck. The amount of soil mass needed to be excavated and landfilled is taken from site-specific reports. Scenario-1 is a full excavation remedy by landfilling the contaminated mass into the Sita centre at Mariestad, 185 kilometers from Bohus Varv. Scenario-2 is the same remedial activity but landfilling in Ragnsell facility which is situated at Värnerborg, 82.5 kilometers from the site.

Excavation and transportation of clean soil to make way for the contaminated mass are taken into consideration. A generic soil fluff factor equal to 1.3 was considered for the in-situ volumes in order to calculate transportable volumes for both SRT and SiteWise$^{TMv.1}$ models. System boundaries are set to be restricted to the remedial activity footprints of the site itself, and the long term landfilling operations as well as long term activity in the clean soil sources are excluded because of the independent nature of the activities at those sites.

System boundaries for scenarios-1 and Scenario-2 as well as the remediation stage activities (excluding personnel transportation, the investigation stage and remedial construction) are illustrated in Figure 5.1 below.

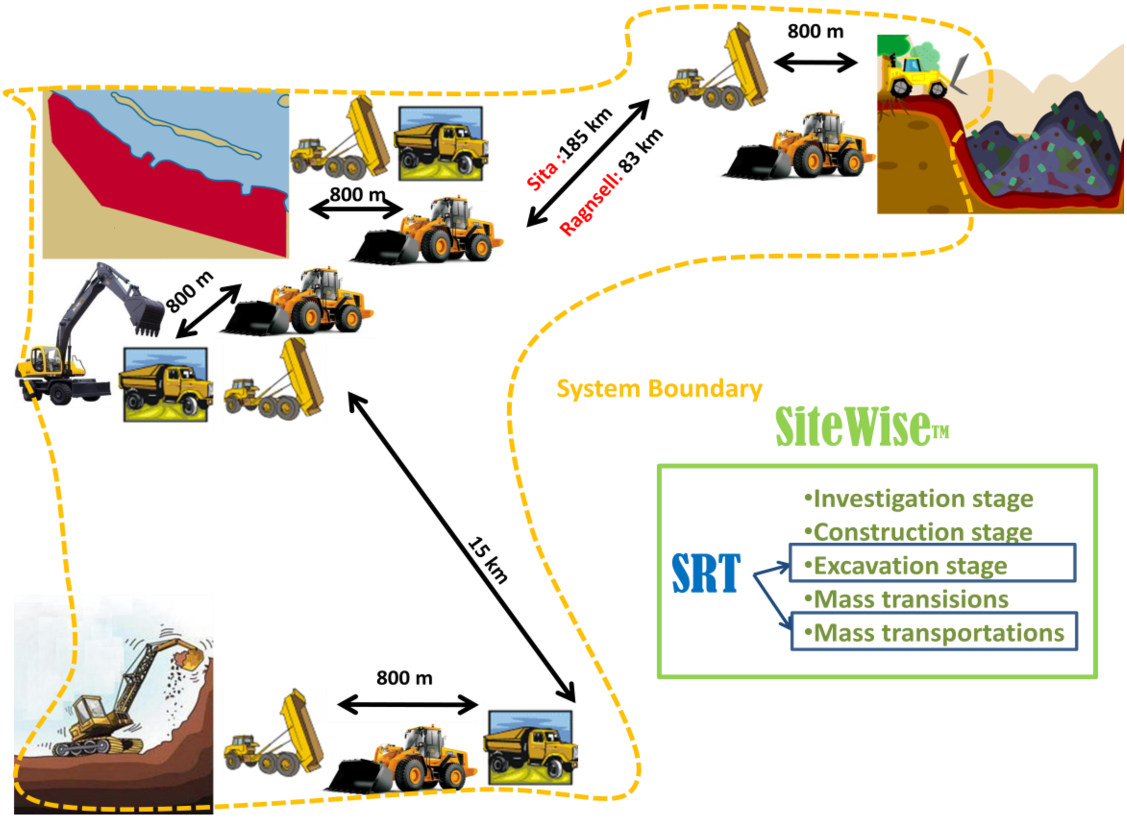


Figure 5.1 Flowchart for Scenarios 1 & 2. The green/blue legend indicates the stages that can be analyzed by SiteWise^{TM} and SRT.

All the values used for modeling these scenarios with both tools can be found in Appendix 1.

5.2.2 Scenarios 3 and 4

Scenarios-3 and Scenario-4 are excavation scenarios and are modeled with the same characteristics as scenarios 1 and 2, except that in Scenario-3, the contaminated soil mass is transported by train to the SAKAB center and in Scenario-4, the mass is transported by boat to Langøya island to the Noah institute. For the train transportation scenario, it is understood that a 300 metric ton cargo capacity train can be used and foot printing metrics for train transportation are adjusted in the SiteWise$^{TMv.1}$ tool for Swedish electricity. For ship transportation, two sets of analysis were performed. The first analysis was performed with SiteWise$^{TMv.1}$ default ship-cargo-impact values. A 2000 metric ton ship cargo capacity was considered. A second round of ship transportation analysis was decided to be necessary due to a large uncertainty of the SiteWise[TMv.1] impact values' reference for NOx, SOx and PM10 on ship cargo transportation and because of the fact that results obtained from the first round were considered unrealistic with respect to SOx, NOx and PM10 emissions. For the second analysis, ship cargo impact values were calculated based on the factors recommended by the Svenska Miljö Emissions Data (SMED) report for ships in Scandinavia (SMED, 2004). For this purpose, a typical medium size ship at relevant speed was assumed to transport the soil and the cargo weight influence on the fuel consumption rate was neglected. All the ship cargo impact values for ship transportation with their assumptions and calculation steps are presented in Appendix 16.

System boundaries for Scenario-3 and Scenario-4 as well as the remediation stage activities (excluding personnel transportation, the investigation stage and remedial construction) are illustrated in Figure 5.2 below.

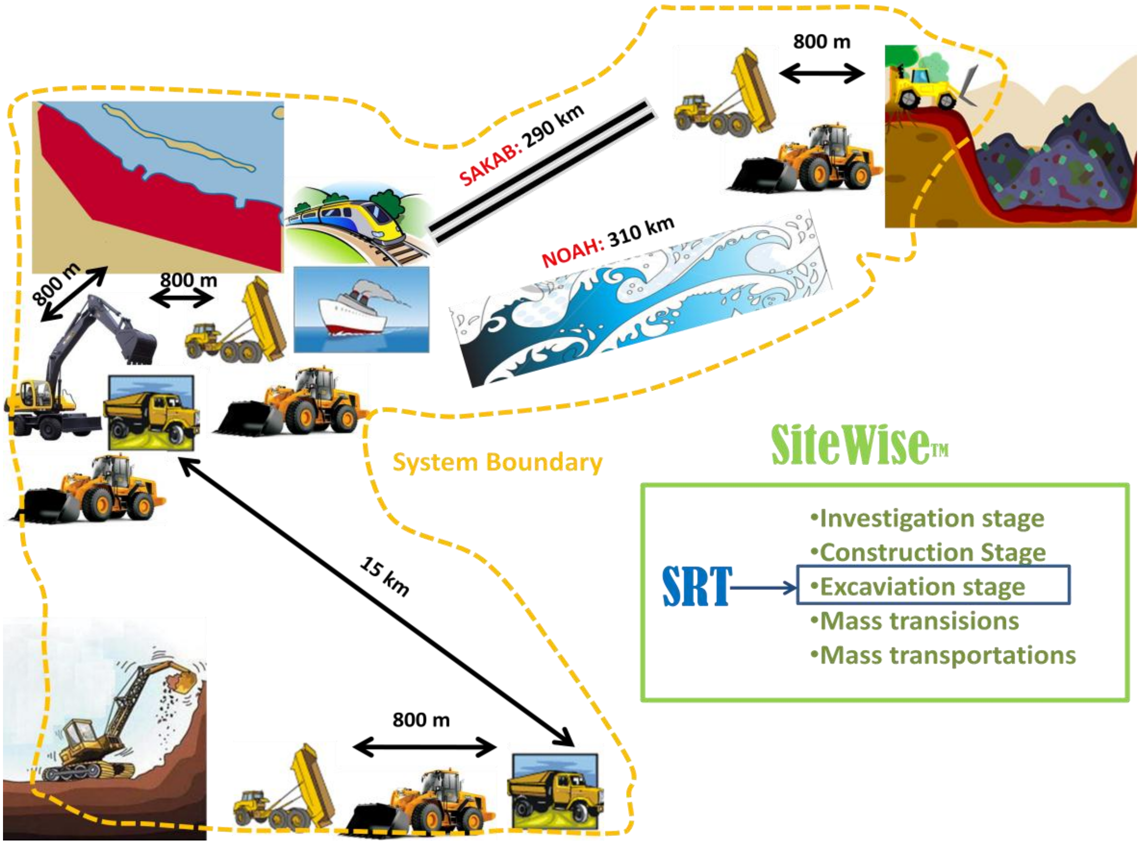


Figure 5.2 Flowchart for Scenario 4. The green/blue legend indicates the stages that can be analyzed by SiteWise™ and SRT.

All the values used for modeling these scenarios with SiteWise™ tool can be found in Appendix 2.

5.2.3 Scenario 5

Scenario-5 is defined as a partial removal and excavation remedy. For this remedial scenario, a 0.5-0.7 meter surface soil layer excavation and landfill is considered. The process is modeled in a similar manner to earlier scenarios with minor relevant adjustments to soil mass, the onsite additional activities and materials needed. The Investigation stages as well as the personnel transport stages are repeated for this scenario. For mass transportation, the reduced mass is transported to the Sita centre, Ragnsell, the SAKAB and Noah facilities accordingly.

All the values used for modeling these scenarios with SiteWise$^{TMv.1}$ tool can be found in Appendix 3.

5.2.4 Scenario 6

Scenario-6 is an ex-situ, on-site soil washing remedy. For this scenario, the investigation stage, on-site additional activity as well as the excavation and internal loading and mass transfer are directly adopted as in previous activities. Instead of a total mass transportation, a 10 percent soil change, to be replaced after the washing process and landfilling the same amount, is assumed. An onsite generic soil washing system, adaptable to available soil washing systems in Sweden (e.g. SoilTech^{TM} Company's presented data) is considered. In this process, any rubbish present in the mass is removed and the processed mass is then sieved and the gravel portion is separated and rinsed. The remaining finer portion is mixed with water in large mixers and the sand part is extracted and rinsed, leaving contaminated slurry, which is de-watered and sent to landfill.

System boundaries for Scenario-6 as well as the remediation stage activities (excluding personnel transportation, the investigation stage and remedial construction) are illustrated in Figures 5.3 and 5.4 below.

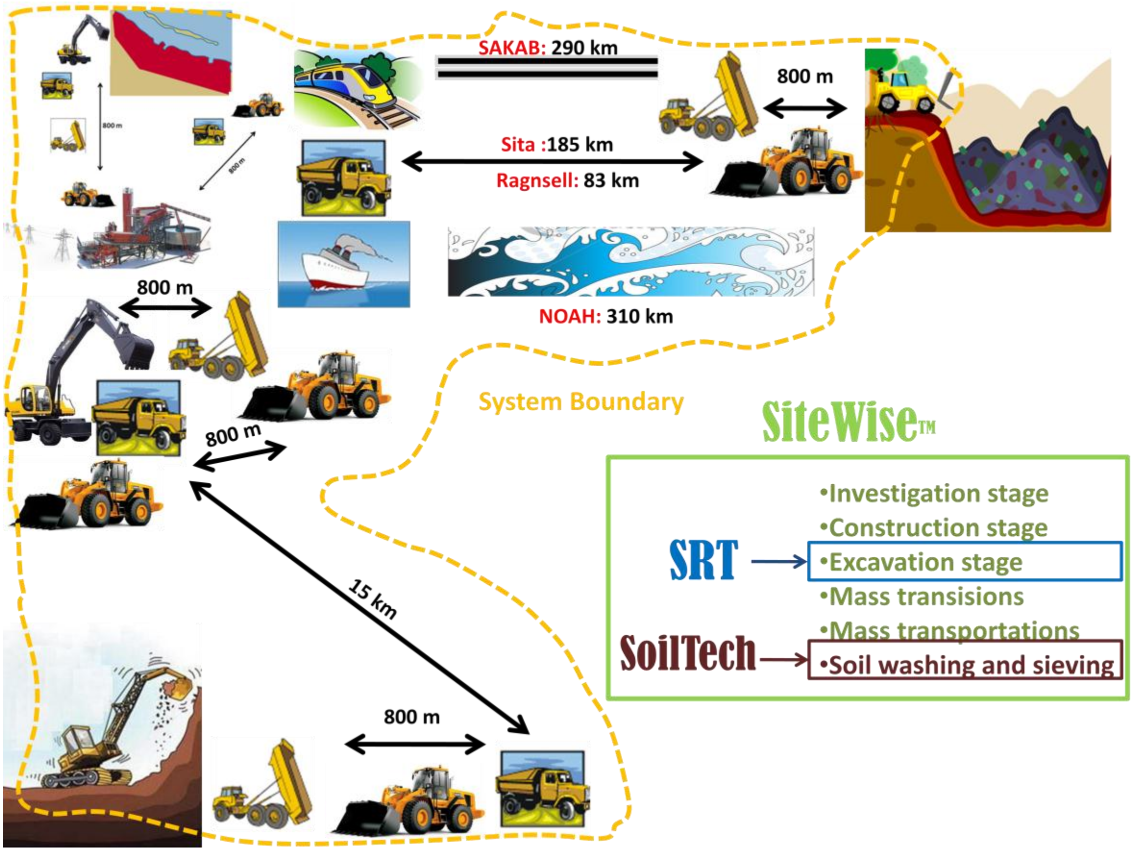


Figure 5.3 Flowchart for Scenario-6. The green/blue legend indicates stages that can be analyzed by SiteWise^{TM} and SRT. Brown legend indicates data source for soil washing.

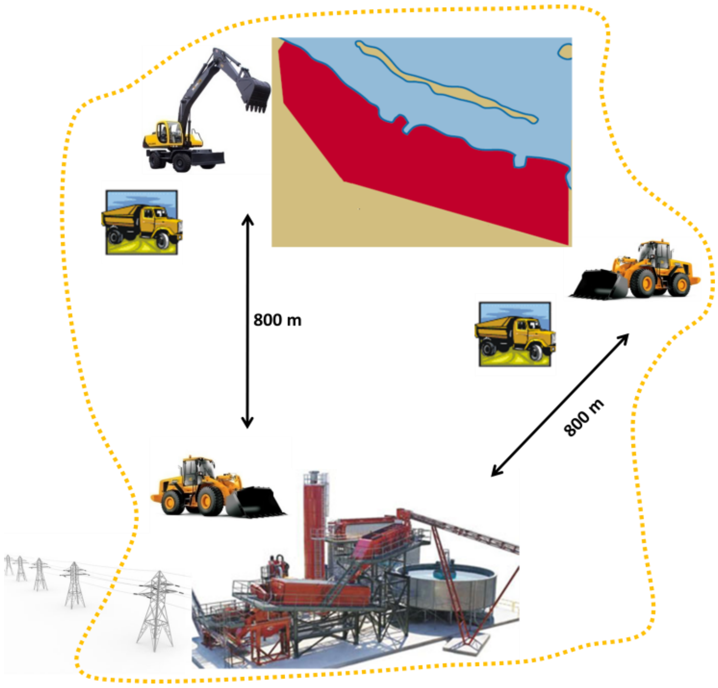


Figure 5.4 Magnification of the soil washing process from Figure5.3.

All the values used for modeling these scenario groups with SiteWise$^{TMv.1}$ tool are available in Appendix 4.

5.2.5 Scenario 7

For this scenario, the S&S containment method is modelled. Cement has been chosen as the binder and solidifier agent for the process with a soil/ cement ratio of 0.175 as recommended (Jesperse & Ryan, 1992).

The same Investigation stage is considered for the scenario as well as personnel transport. However, for on-site additional activity, relevant adaptations are made. To avoid triggering a landslide during the S&S activity, shore-stabilizing by sheet piling is still considered. Neither excavation nor leach water treatment was considered and cement was transported and then mixed with soil by huge augers in-situ.

System boundaries for Scenario-7 as well as the remediation stage activities (excluding personnel transportation, the investigation stage and remedial construction) are illustrated in Figure 5.5 below.

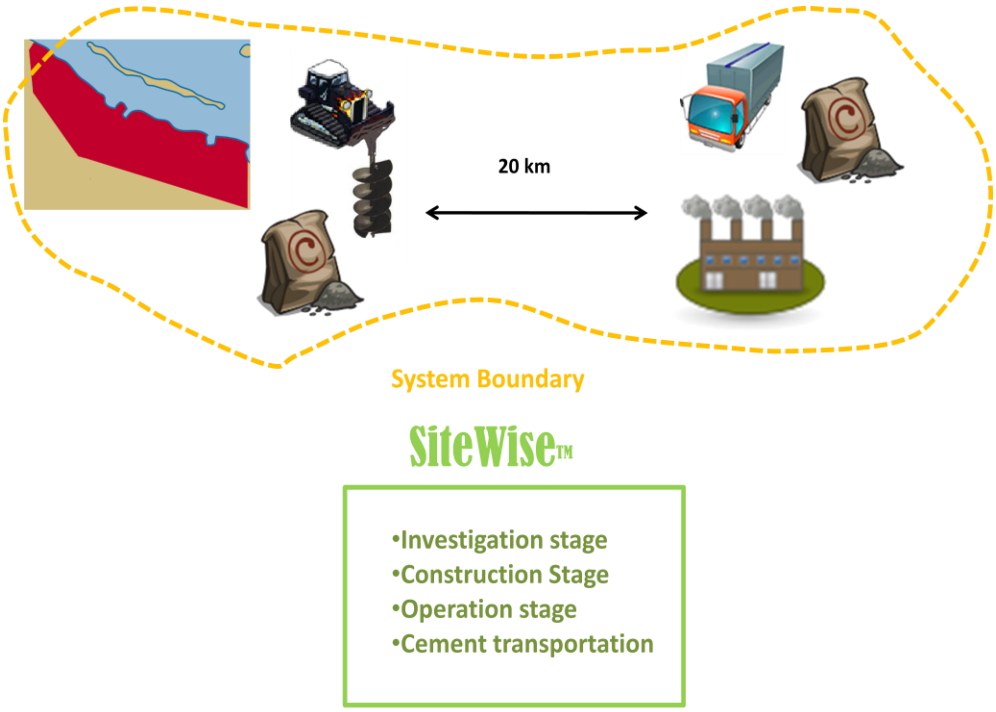


Figure 5.5 BohusVarv S&S techniques modeling flowchart.

All the values used for modeling these scenario groups with both tools are available in Appendix 5.

5.3 Hexion Remediation Project

Hexion´s remediation project is modeled in two phases based on four major remedial technologies. Phase one includes eleven models of six different scenarios (8 SiteWise$^{TMv.1}$ models and 3 SRT models); phase two includes three SiteWise$^{TMv.1}$ models of three different scenarios. Similar to the BohusVarv project, excavation and landfilling, ex-situ, onsite soil washing and solidification were chosen as the most appropriate technologies to be used, but additionally a vapor extraction technology is included, appropriate to site-specific characteristics. (In total fourteen models) Modeling of the first phase is done with data taken from J. Hector’s Master thesis work to facilitate a standard comparison and a clear evaluation of the results. For the second phase, all available data, regardless of the remedial process in question, is used for modeling.

Phyto- and bioremediation scenarios were not considered for the site because of the strict time limitations, imminent plans for development and relatively deep contamination presence in the ground. Electrokinetic methods were not considered proper for the site due to its geology (permeable sand and gravel). In-situ soil washing by water pumping was not adopted due to the deep granular deposits and the risks of contamination spread and leakage into deep layers and the adjacent stream. In-situ encasing washing was not considered as there was no impermeable bottom layer for the case to be positioned on.

As discussed earlier, SRT only models excavation and transportation by truck and vapor extraction among other techniques, so three SRT models have been generated (Two excavation & truck transport models and one vapor extraction model).

Data for the investigation and soil-sampling stages for SiteWise$^{TMv.1}$ models are taken from available sampling results and risk analysis reports. A 10 short ton "equipment transport" is considered for this stage. Footprints of this stage are reported as "Investigation Stage" in the results.

To calculate the footprint made by personnel transportation for SiteWise$^{TMv.1}$ models, generic values were adopted based on those available from the Bohus Varv site and presented as "Investigation Stage" in the results. The same values were used in SRT models as well. An additional 20 short ton road cargo transportation is assumed for all technologies for the site-establishment stage of SiteWise$^{TMv.1}$ models. For all the modeled scenarios by SiteWise$^{TMv.1}$, an internal site work of leach-water treatment is considered. Site establishment together with the aforementioned in-site activities are reported together as "Remedial construction". Intermediate loading and transportation of mass at and around the excavation site before it is taken to landfill is included in the SiteWise$^{TMv.1}$ models.

For water purification, the specific CFO at the site which was constructed for waste water purification was considered. It has the capacity of treating 39 l/s of water flow from the site. This CSO treats leach water using lamella plates and a sand bed filter to separate particles, an oil separator for volatile contaminants and an activated carbon filter for maximizing purification process. This CSO system is connected to the inner wastewater system that purifies the flow before letting it out to the municipality's storm-water system. The system functions by gravitational forces and no pumping is included in the assessments Magnusson & Norin, 2008).

5.3.1 Phase one

For this phase, 49 000 metric tons out of a total 90 000 metric tons of contaminated mass was estimated to have been excavated, which was considered necessary to allow for the new construction. 69% of this is the anthropologic mass generated after the demolition of existing buildings and categorized as non-sievable portion, 35% of which was thought to be reusable within the site and the rest needed to be landfilled.

Figure 5.6 below demonstrates the excavation plan.

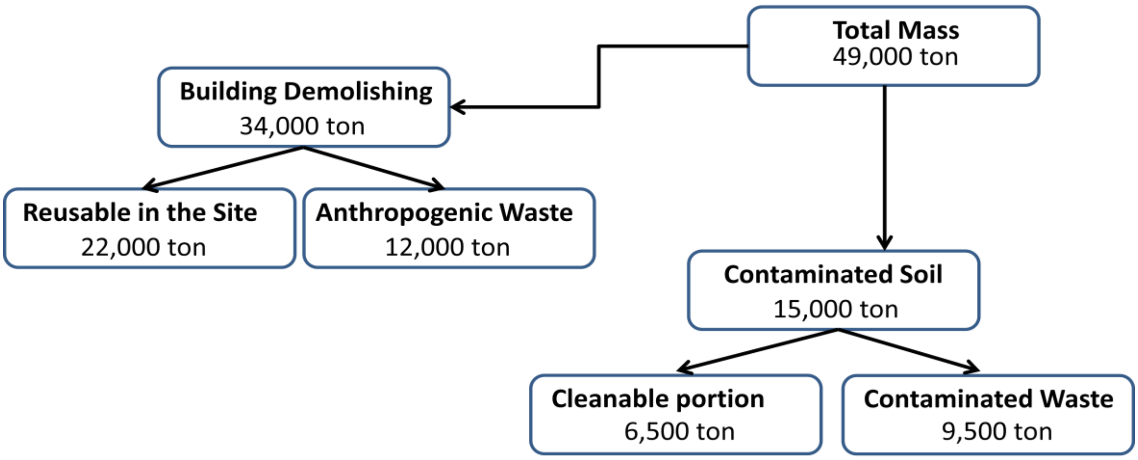


Figure 5.6 Excavation and landfilling plan for Hexion site, used in Phase 1modeling.

5.3.1.1 Scenarios 1 and 2

These two scenarios involve excavation and transportation of contaminated mass by truck. The amount of soil mass needed to be excavated and filled is estimated based on Johanna Hector's Master thesis. Scenario-1 is a full excavation remedy, whereby the contaminated mass was landfilled at RagnsellHeljestorp, 100 kilometers from the site. Scenario-2 is the same remedial activity, but the mass was landfilled at the Kikåstippen facility, situated just two kilometers away from the site.

In opposition to previous scenarios, the excavation and transportation of clean soil to make way for contaminated mass are not taken into account here, as mass excavation was necessary with or without remedial activity. A generic soil fluff factor equal to 1.3 was considered for the in-situ volumes in order to calculate transportable volumes for both SRT and SiteWise$^{TMv.1}$ models. System boundaries are set to be restricted to the remedial activity footprints of the site itself, and the long term landfilling operations are excluded because of the independent nature of the activities at these sites.

This scenario's boundaries as well as the remediation stage activities (excluding personnel transportation and the investigation stage) are illustrated in Figure 5.7. All the values used for modeling these scenario groups with both tools are available in Appendix6 and Appendix 15.

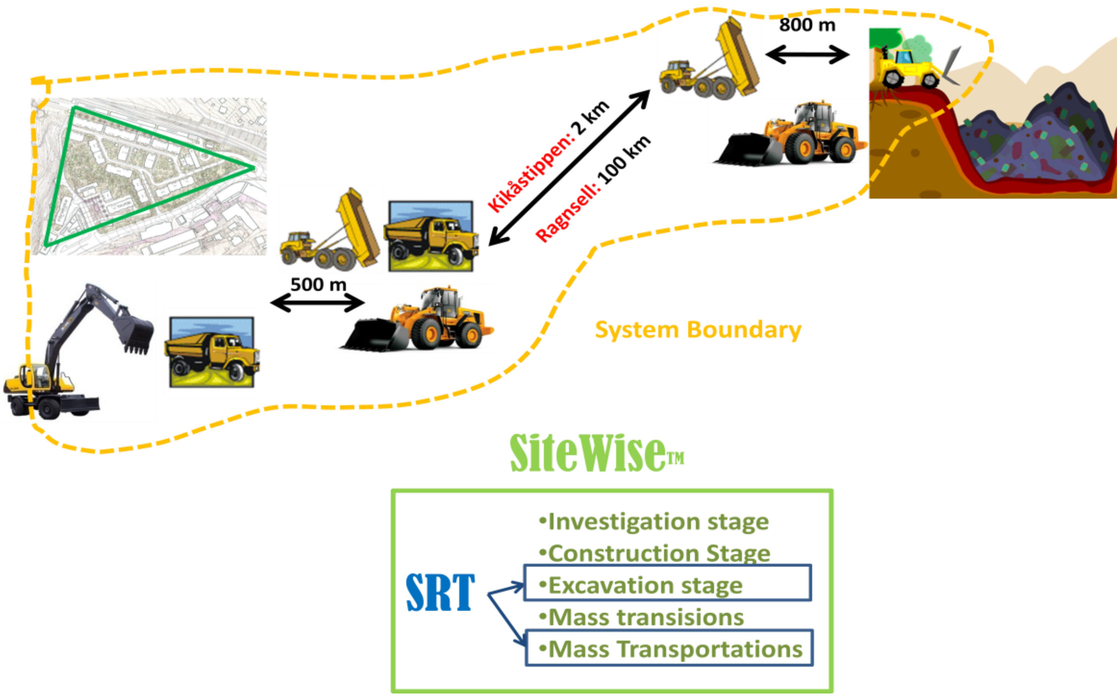


Figure 5.7 Flowchart for scenarios 1 and 2. The green/blue legend indicates the stages that can be analyzed by SiteWise^{TM} and SRT.

5.3.1.2 Scenarios 3 and 4

Scenarios-3 and Scenario-4 are excavation scenarios and have nearly the same characteristics as Scenario-1, except for the fact that in Scenario-4, the excavated contaminated mass is transported by boat to Langøya Island to the Noah institute 270 kilometers from the port, and in Scenario-3, the contaminated mass is transported by train to the SAKAB center, 265 kilometers from the site. For the train transportation scenario, it is understood that a 300 metric ton cargo capacity train can be used and foot printing metrics for train transportation are adjusted in the SiteWise$^{TMv.1}$ tool for Swedish electricity.

For ship transportation, two sets of analysis were performed. The first analysis was performed with SiteWise$^{TMv.1}$ default ship-cargo-impact values. A 2000 metric ton ship cargo capacity was considered. A second round of ship transportation analysis was decided to be necessary due to a large uncertainty of the SiteWise$^{TMv.1}$ impact values' reference for NOx, SOx and PM10 on ship cargo transportation and because of the fact that results obtained from the first round were considered unrealistic with respect to SOx, NOx and PM10 emissions. For the second analysis, ship cargo impact values were calculated based on the factors recommended by the Svenska Miljö Emissions Data (SMED) report for ships in Scandinavia (SMED, 2004). For this purpose, a typical medium size ship at relevant speed was assumed to transport the soil and the cargo weight influence on the fuel consumption rate was neglected. All the ship-cargo-impact values for ship transportation with their assumptions and calculation steps are presented in Appendix 16.

It should also be noted that, for the Langøya case, interconnecting truck transportation of 21 kilometers from the site to the shipping port is also included.

The scenario's system boundaries as well as the remediation stage activities (excluding personnel transportation and the investigation stage) are illustrated in Figures 5.8 and 5.9.

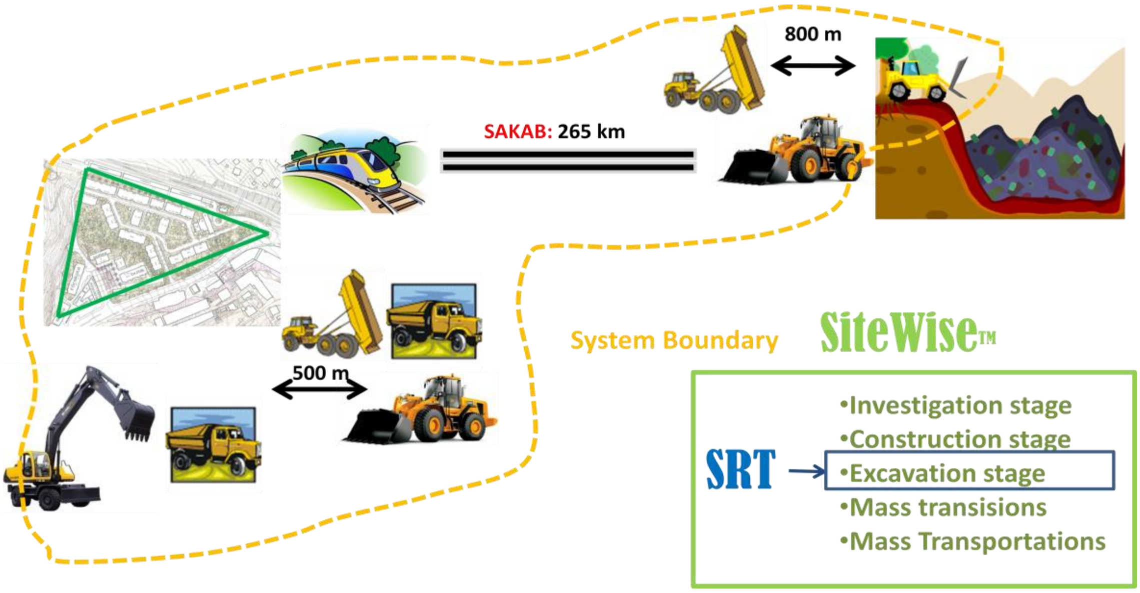


Figure 5.8 Flowchart for Scenario-3. The green/blue legend indicates the stages that can be analyzed by SiteWise^{TM} and SRT.

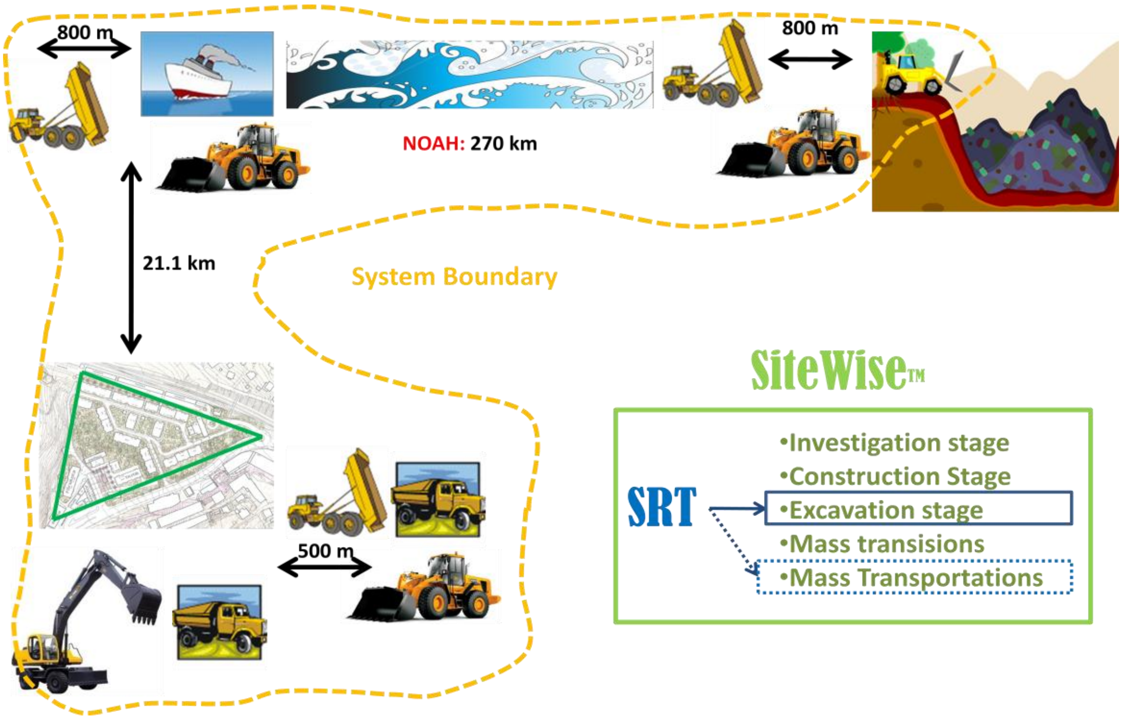


Figure 5.9 Flowchart for Scenario-4. The green/blue legend indicates the stages that can be analysed by SiteWise™ and SRT.

All the values used for modeling these scenario groups with both tools are available in Appendix 7.

5.3.1.3 Scenario 5

Soil vapor extraction for the Hexion site is considered crucial to prevent health risks due to exposure to volatile contaminants after the construction period. Volatile contaminants can seep through the pores of concrete foundations and endanger people's health. In the case of extracting volatile contaminants from the site, the remaining contamination would be composed of heavy metal lead in some restricted portions of the site. This contamination can be isolated by future construction its spread can be prohibited by limiting water infiltration to the ground.

For soil vapor extraction, available data from RGS 90 Company's methodology is applied for footprint analysis.

Long term monitoring stage with wastewater treatment of 20 years and continuous sampling is considered.

The scenario's system boundaries as well as the remediation stage activities (excluding personnel transportation and the investigation stage) are illustrated in Figure 5.10.

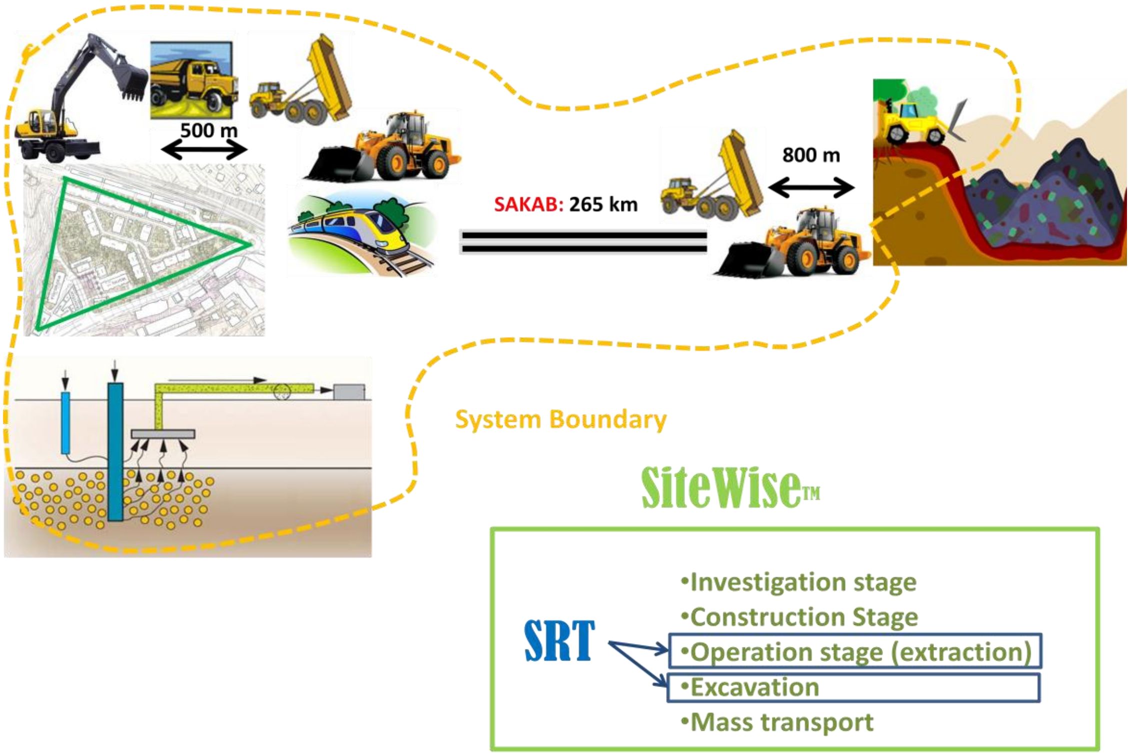


Figure 5.10 Flowchart for vapour extraction implementation. The green/blue legend indicates the stages that can be analyzed by SiteWise™ and SRT.

All the values used for modeling these scenario groups with both tools are available in Appendix 8 and Appendix 15.

5.3.1.4 Scenario 6

Scenario-5 is an ex-situ, on-site soil washing remedy. For this scenario, the excavation phase as well as short distance mass transportation are included as in previous scenarios. According to the available data, it is understood that 57% of sievable soil mass needed to be landfilled and decided to be transferred to SAKAB. The same onsite generic soil washing process, adaptable to available soil washing systems in Sweden, is included.

This scenario's boundaries as well as the remediation stage activities (excluding personnel transportation and the investigation stage) are illustrated in Figure 5.11. The soil washing process is illustrated separately in Figure 5.12.

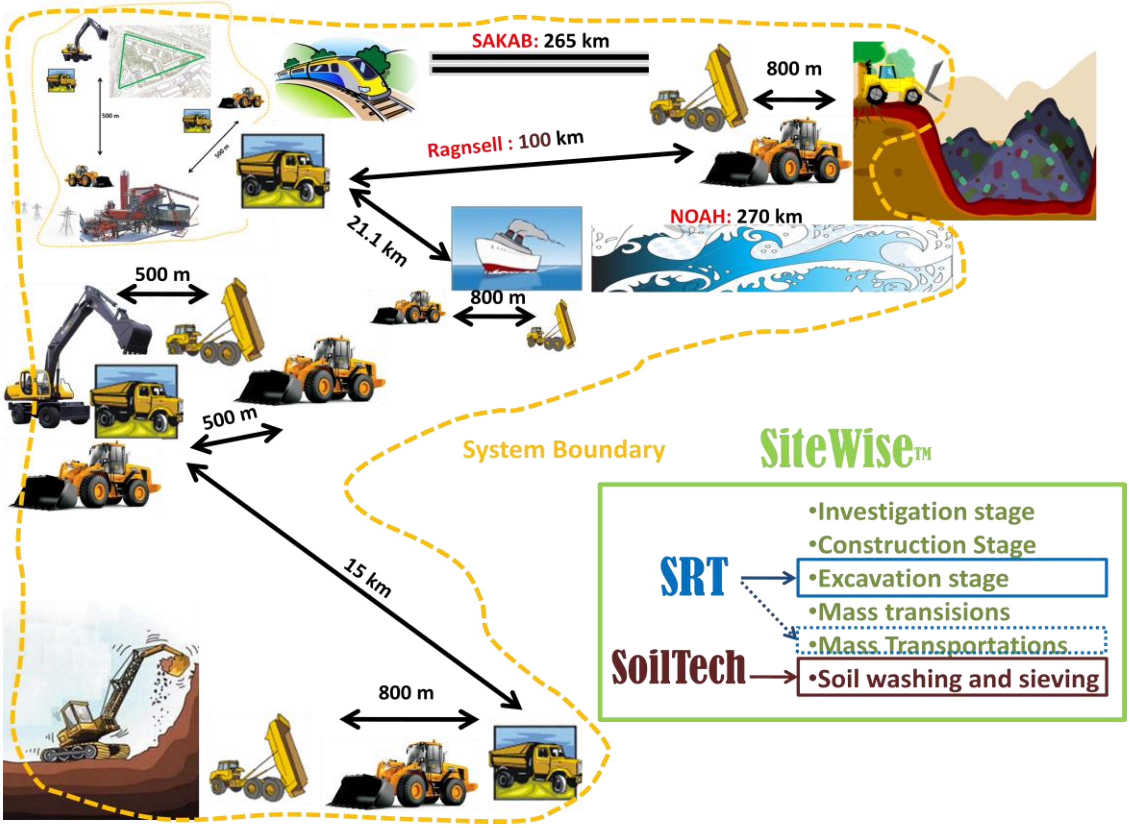


Figure 5.11 Flowchart for Scenario-5. The green/blue legend indicates the stages that can be analyzed by SiteWise^{TM} and SRT. Doted legend indicates partial possibility. Brown legend indicates adapted soil washing metrics' source.

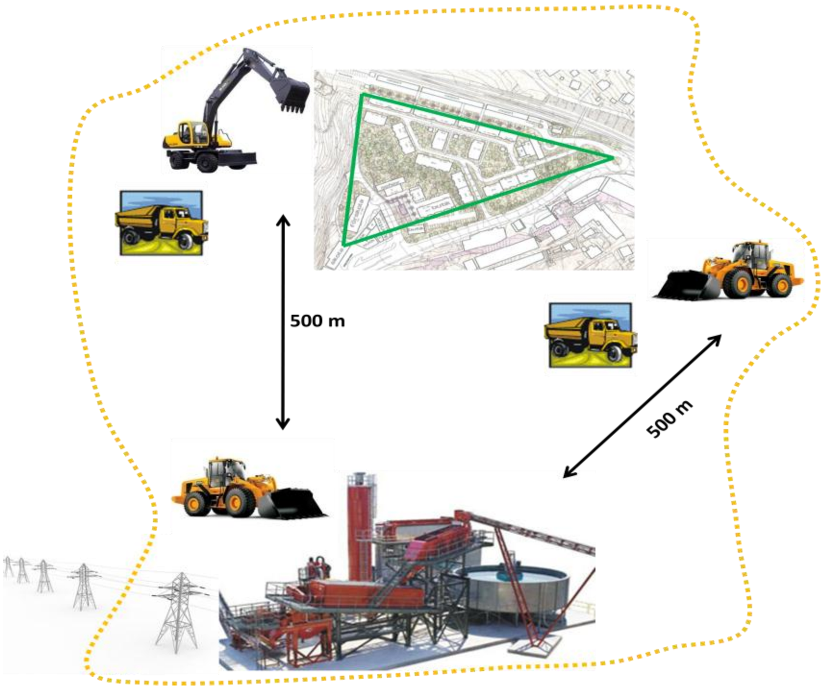


Figure 5.12 Magnification of the soil washing process from Figure 5.11.

All the values used for modeling these scenario groups with SiteWise$^{TMv.1}$ tool are available in Appendix 9 and SRT models input data list are available in Appendix 13.

5.3.2 Phase two

For these scenarios, the total contaminated mass is taken into account, which amounts to an extra 51000 metric tons of contaminated soil from deeper ground layers (4-8 meters depth). For this phase, an optimized excavation and landfilling scenario, soil washing and an S&S technology-based remedy, is modeled.

5.3.2.1 Scenario 7

For this scenario, an excavation remedy with optimized landfilling is considered. Optimization is made based on the different landfilling companies' distances and their requirements for accepting contaminated mass. For the extra 51000 metric tons of soil mass, a filling necessity is assumed and it is understood that the clean soil mass is transported to the site from no further than 20 kilometers.

Similarly to previous excavation scenarios, the excavation and transportation of clean soil to make way for the contaminated mass are taken into consideration. All the values used for modeling these scenario groups with SiteWise$^{TMv.1}$ tool are available in Appendix 10.

5.3.2.2 Scenario 8

This scenario involves an ex-situ, on-site soil washing remedy similar to Scenario-5. In addition to the mass considered in phase one, this scenario includes an extra 51000 metric tons of sievable contaminated soil mass, 20 % of which is substituted with clean soil. It was decided that the contaminated mass be transported to the SAKAB facility and a similar onsite generic soil washing system be included in the model.

All the values used for modeling these scenario groups with SiteWise$^{TMv.1}$ tool are available in Appendix 11.

5.3.2.3 Scenario 9

For this scenario, the S/S containment method is modeled, with cement as the binder and solidifier agent (soil/ cement ratio of 0.175 (Jesperse & Ryan, 1992))

For this scenario, long-term monitoring and treatment of the leach water for twenty years after finishing the project were considered. This process is modeled as an in-situ/ onsite technology, with no extra water treatment taken into account to the current available system. An extra pumping amount is considered for making cement slurry.

The scenario group's system boundaries as well as the remediation stage activities (excluding personnel transportation and the investigation stage) are illustrated in Figure 5.13.

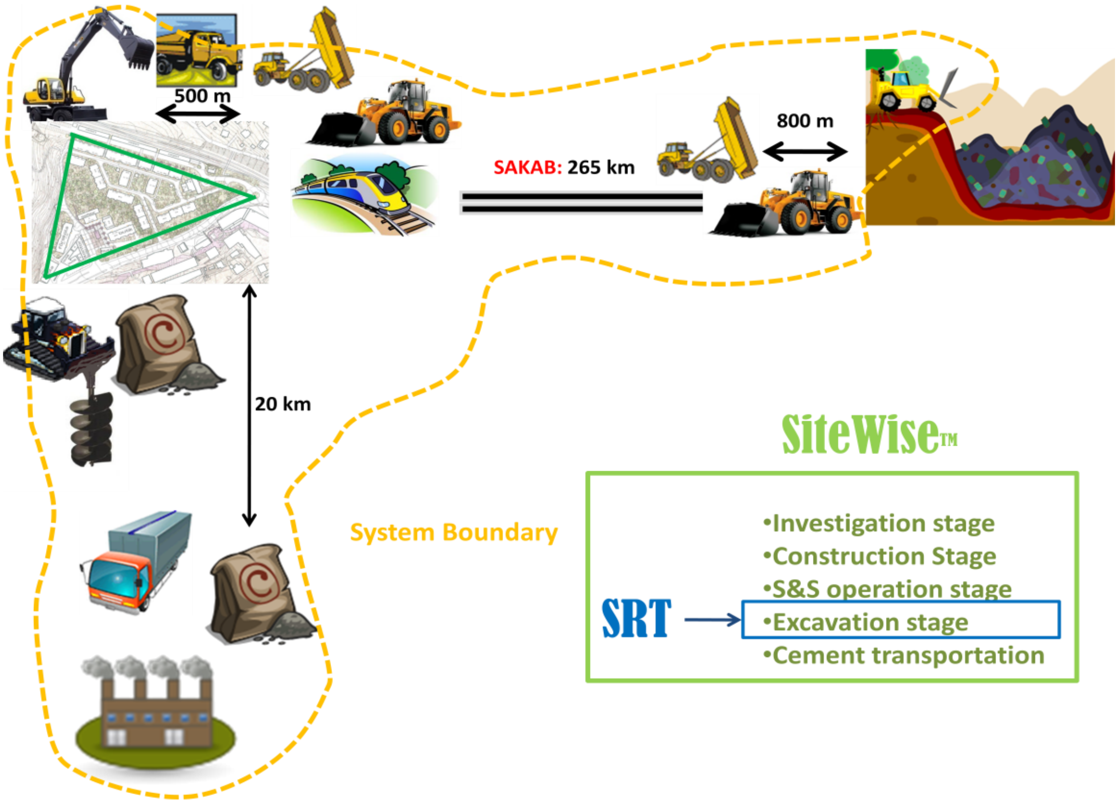


Figure 5.13 Flowchart for S&S implementation at Hexion (Phase 2).The green/blue legend indicates the stages that can be analyzed by SiteWise^{TM} *and SRT.*

All the values used for modeling these scenario groups with both tools are available in Appendix 12.

6 Results

In this chapter, results from all the modeled scenarios for the Bohus Varv and Hexion sites are presented in the tables and charts below. More detailed results for each modeled scenario, with specifications for footprints of each remedial stage, for SiteWise$^{TMv.1}$ tool, are presented in Appendix 14.

6.1 BohusVarv remediation project

The 12 scenarios for remediation activity at the Bohus Varv site are presented below. As previously stated, 10 are SiteWise$^{TMv.1}$ models and 2 were made by the SRT. Footprints and metrics of this analysis are presented in table 6.1 below.

Table 6.1 Results for the 12 remediation scenarios for the Bohus Varv site. The columns in light grey colour show SiteWise$^{TMv.1}$ results and the dark columns show SRT results.

Remedial Alternatives		GHG Emissions	Total energy Used	NO_x emissions	SO_x Emissions	PM_{10} Emissions	Accident Risk Fatality *	Accident Risk Injury**
		metric tons	MMBTU	metric tons	metric tons	metric tons	Num per Project	Num per Project
Full Excavation	Sc1-Sita	6.2E+03	8.2E+04	8.1E+00	1.8E+00	7.3E-01	8.4E-03	1.7E+00
	Sc1-Sita-SRT	2.6E+03	3.6E+04	2.1E+01	2.0E-02	1.0E+00	1.5E+00	7.3E+01
	Sc2-Ragnsell	4.7E+03	6.4E+04	6.4E+00	1.4E+00	4.8E-01	4.4E-03	8.8E-01
	Sc2-Ragnsell-SRT	1.5E+03	2.2E+04	1.3E+01	1.2E-02	5.9E-01	8.8E-01	4.2E+01
	Sc3-SAKAB	3.6E+03	5.6E+04	5.3E+00	1.3E+00	6.1E-01	1.1E-03	2.1E-01
	Sc4-Noah	4.5E+03	6.0E+04	1.9E+03	1.9E+03	2.1E+03	1.2E-03	2.1E-01
Partial Excavation	Sc5a-Sita	4.2E+03	6.8E+04	4.8E+00	1.0E+00	3.1E-01	2.2E-03	4.2E-01
	Sc5b-Ragnsell	3.8E+03	6.4E+04	4.4E+00	9.5E-01	2.5E-01	1.4E-03	2.4E-01
	Sc5c-Sakab	3.6E+03	6.2E+04	4.2E+00	9.1E-01	2.9E-01	6.7E-04	9.8E-02
	Sc5d-Noah	3.8E+03	6.3E+04	4.7E+02	4.7E+02	5.2E+02	6.7E-04	9.8E-02
Onsite Technology	Sc6-Wash	3.3E+03	4.7E+04	5.0E+00	1.4E+00	2.6E-01	6.3E-04	9.5E-02
	Sc7- S&S	1.0E+04	7.2E+04	4.0E+00	8.3E-01	2.0E-01	7.7E-04	1.7E-01

***** For SRT models this represents an injury risk

****** For SRT models, this is a number of lost working hours

As it is seen from the results, Scenario-4 and Scenario-5d show extremely high emissions for NOx, SOx and PM10. This is due to the fact that extremely high default ship cargo-impact values are used by SiteWise$^{TMv.1}$ for NOx, SOx and PM10 impact assessments which have no reliable references. These values are so high that the amount of NOx, SOx and PM10 release are predicted by the model to be higher than the CO_2 release which is normally the major portion of the fuel emissions.

For this reason, the ship cargo-impact values were replaced by the factors recommended by SMED report for ships in Scandinavia. The SMED factors represent fuel consumption factors for a medium size ship at relevant speed. The cargo's weight influence on the consumption rate was neglected here. Ship-cargo-impact values for the ship transportation with all the details and assumptions and calculation steps are presented in appendix 16.

Table 6.2 below shows the new emission values for Scenario-4 and Scenario-5d in comparison to the previous results.

Table 6.2 Results for scenarios involving ship transportation with two different SiteWise™ and SMED inventory values.

Remedial Alternatives	GHG Emissions	Total energy Used	NO_x emissions	SO_x Emissions	PM_{10} Emissions	Accident Risk Fatality *	Accident Risk Injury**
	metric ton	MMBTU	metric ton	metric ton	metric ton	Number	Number
Scenario-4-Noah-SiteWise inventory values	2.3E+03	3.9E+04	1.9E+03	1.9E+03	2.1E+03	1.2E-03	2.1E-01
Scenario-4-Noah-SMED inventory values	1.2E+04	3.8E+04	2.9E+02	8.7E+01	1.3E+01	1.2E-03	2.1E-01
Scenario-5d-Noah-SiteWise inventory values	1.7E+03	4.2E+04	4.7E+02	4.7E+02	5.2E+02	6.7E-04	9.8E-02
Scenario-5d-Noah-SMED inventory values	3.9E+03	4.2E+04	7.5E+01	2.2E+01	3.3E+00	6.7E-04	9.8E-02

***** For SRT models this represents an injury risk

****** For SRT models, this is a number of lost working hours

As shown in table 6.2, the GHG emissions increase significantly when using the new inventory values but NOx, SOx and PM10 emission values decrease with the same significance. Footprints and metrics of analysis of scenarios with the adjusted ship cargo-impact values are presented in Figures 6.1-6.7.

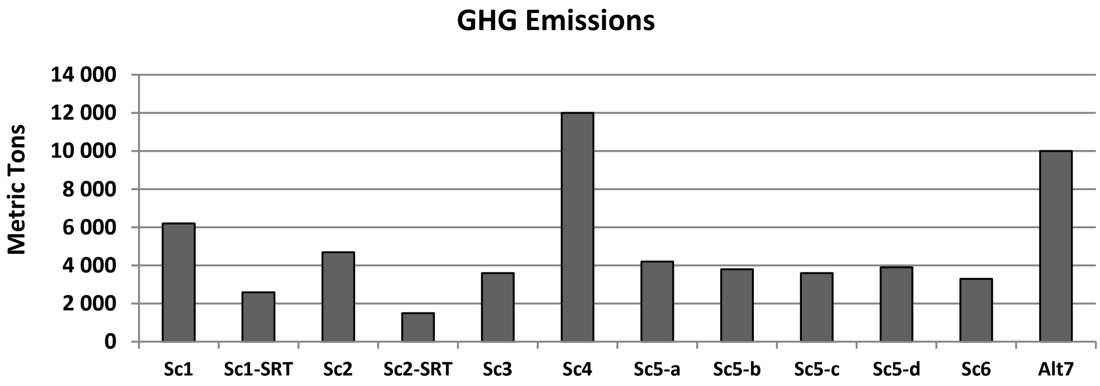


Figure 6.1 *GHG emission results for Bohus Varv remediation scenarios by SiteWise™ and SRT.*

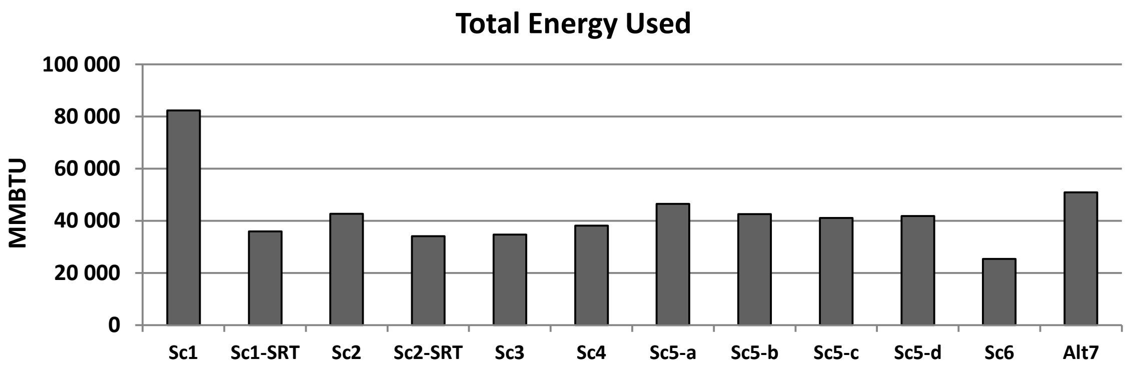


Figure 6.2 *Energy use results for Bohus Varv remediation scenarios by SiteWise™ and SRT.*

As shown in Figures 6.1 and 6.2, Scenario-4 (full mass excavation and landfilling at the Noah center) followed by Scenario-7 (in-situ solidification and stabilization by cement technique) result in the greatest emissions of greenhouse gasses (GHG). Scenario-1 is associated with the third highest emissions. Other scenarios show relatively similar behavior in GHG release.

With 82 GBTU energy usage, Scenario-1 demands nearly three times the SRT model results for energy demand and twice the energy demanded to operate Scenario-6 (onsite, ex-situ soil washing). The remaining scenarios demand relatively similar amounts of energy to operate.

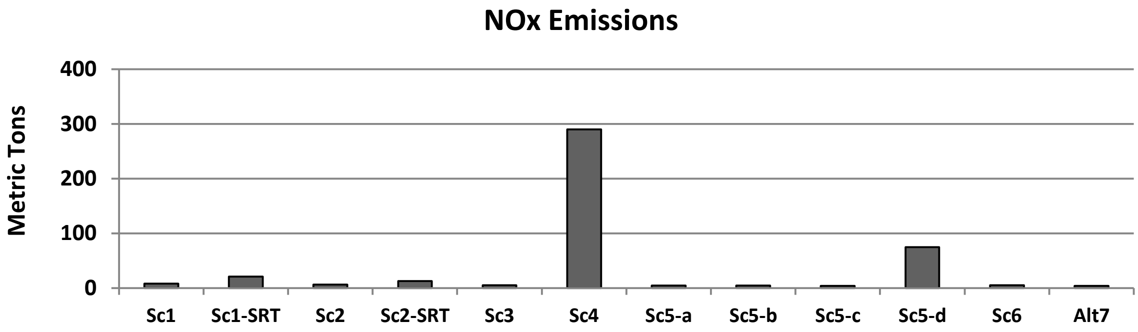


Figure 6.3 *NOx emission results for Bohus Varv remediation scenarios by SiteWise™ and SRT.*

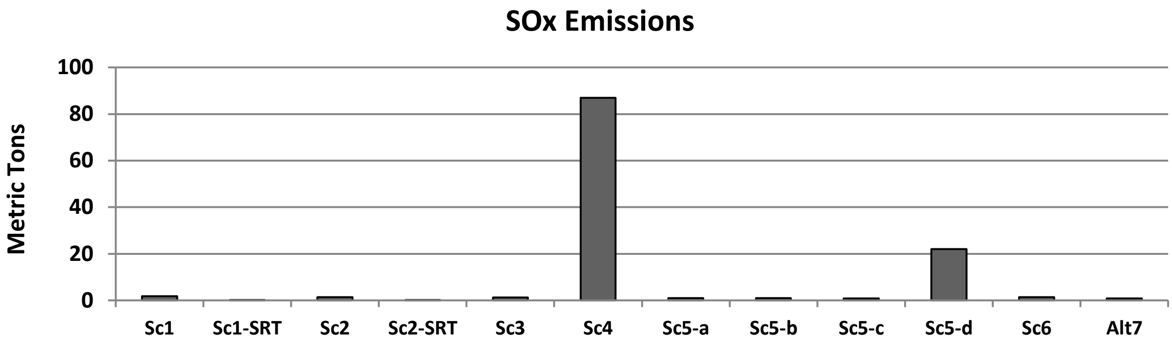


Figure 6.4 *SOx emission results for Bohus Varv remediation scenarios by SiteWise™ and SRT.*

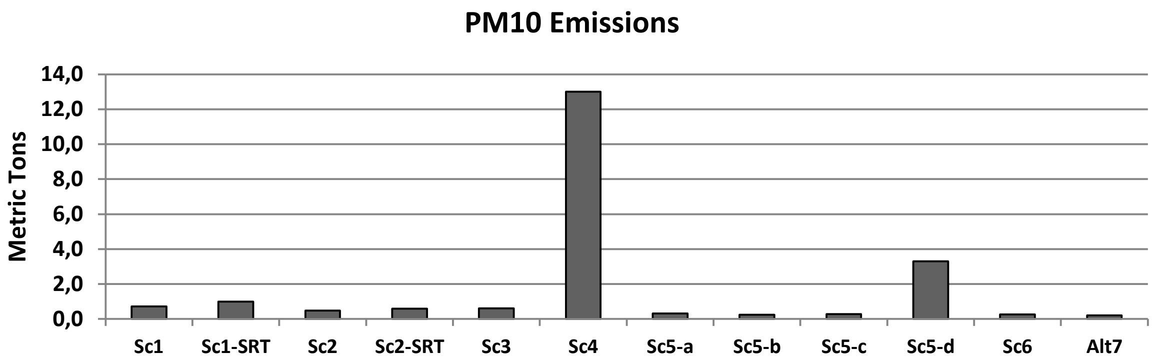


Figure 6.5 *Particle emission results for Bohus Varv remediation scenarios by SiteWise™ and SRT.*

Figures 6.3 to 6.5 show that even with the milder SMED inventory values, Scenarios 4 and 5d, which both rely on transportation by ship, release considerably higher amounts of NOx, SOx and PM10 compared to the other scenarios.

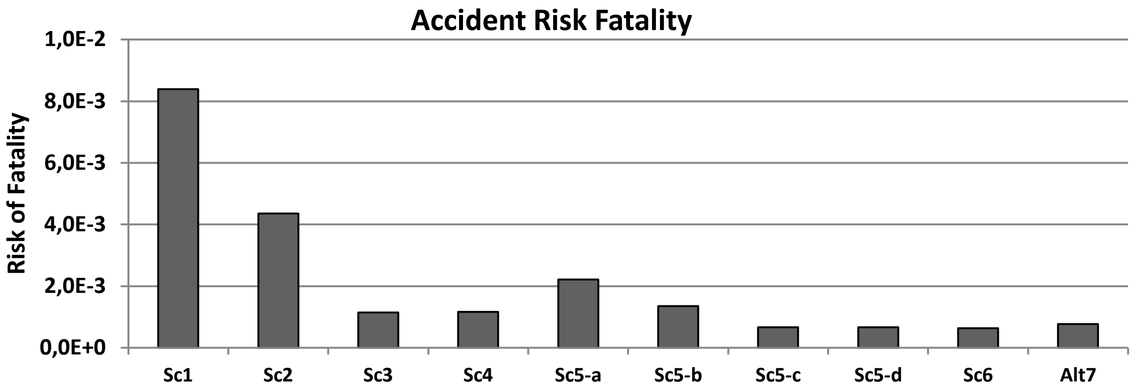


Figure 6.6 Major accident risk results for Bohus Varv remediation scenarios by SiteWise^{TM} models.

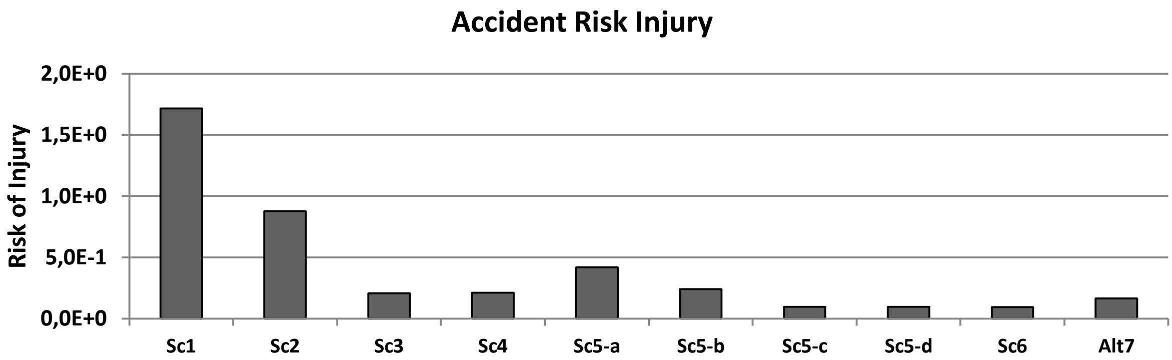


Figure 6.7 Minor accident risk results for Bohus Varv remediation scenarios by SiteWise^{TM} models.

As shown in the above figures, Scenario-1 and Scenario-2, and their adapted Scenario-5a and Scenario-5b, all with substantial dependence on road transportation by truck, show the greatest exposure to accidental risk. It should be noted here that for correct and relevant comparison, the SRT-modeled scenarios are excluded from these tables due to differences in risk definition between the SiteWise$^{TMv.1}$ and SRT models.

6.2 The Hexion site remediation project

The remedial activities at the Hexion site were modeled in 11 scenarios by SiteWise$^{TMv.1}$ and in 3 scenarios by SRT. Footprints and metrics of this analysis are presented in Table 6.3 below. More detailed results for each alternative with specification of footprints of each remedial stage from SiteWise$^{TMv.1}$ tool are presented in Appendix 15.

Table 6.3 Hexion analysis results. Light columns show SiteWise[TMv.1] results and dark columns show SRT results.

Ph	Remedial Alternatives		GHG Emissions	Total energy Used	NO_x emissions	SO_x Emissions	PM_{10} Emissions	Accident Risk Fatality*	Accident Risk Injury**
			metric tons	MMBTU	metric tons	metric tons	metric tons	Num per Project	Num per Project
I	Full Excavation	Sc1- Kik	6.8E+01	8.9E+02	2.8E-01	7.3E-02	1.9E-02	1.7E-04	2.4E-02
		Sc1-Kikå-SRT	1.7E+02	2.4E+03	1.4E+00	3.6E-03	6.3E-02	9.2E-02	4.4E+00
		Sc2-Ragnsell	4.6E+02	5.7E+03	7.1E-01	1.7E-01	8.3E-02	1.2E-03	2.4E-01
		Sc2-Ragnsell-	4.8E+02	6.6E+03	3.8E+00	3.7E-03	1.8E-01	2.7E-01	1.3E+01
		Sc3-SAKAB	9.3E+01	2.5E+03	3.2E-01	1.0E-01	9.6E-02	1.5E-04	2.0E-02
		Sc4-Noah	4.0E+02	4.5E+03	4.5E+02	4.5E+02	5.1E+02	3.7E-04	6.6E-02
	Onsite techniques	Sc5-Vapour	8.5E+01	2.5E+03	2.3E-01	7.4E-02	4.8E-02	1.4E-04	1.6E-02
		Sc5-Vapour-	8.3E+03	4.0E+04	6.4E+00	3.3E+00	7.2E-01	1.4E-02	6.8E-01
		Sc6a-Noah	3.2E+02	3.6E+03	3.5E+02	3.4E+02	3.9E+02	3.2E-04	5.5E-02
		Sc6b-Ragn	3.6E+02	4.5E+03	6.0E-01	1.5E-01	6.7E-02	9.6E-04	1.9E-01
		Sc6c-Sakab	8.5E+01	2.1E+03	3.1E-01	9.5E-02	7.7E-02	1.5E-04	2.0E-02
II	Full Excavation	Sc7-Opti-Excavate	1.9E+02	2.9E+03	9.9E-01	2.6E-01	7.7E-02	2.5E-04	4.8E-02
	Onsite techniques	Sc8-S/S	4.2E+03	2.4E+04	9.5E-01	1.9E-01	1.0E-01	1.8E-04	3.0E-02
		Sc9-Wash-	1.6E+02	3.6E+03	6.7E-01	2.0E-01	1.3E-01	2.1E-04	3.7E-02

* For SRT models this represents an injury risk

** For SRT models, this is a number of lost working hours

As it was mentioned for the Bohus Varv case, the ship transportation inventory analysis factors were replaced with the new adapted factors for this case study also (see appendix 16 for the new inventory factors).

Table 6.4 below shows the new emission values for Scenario-4 and Scenario-6a in comparison with the previous results.

Table 6.4 Results for scenarios involving ship transportation with two different SiteWise and SMED inventory values.

Remedial Alternatives	GHG Emissions	Total energy Used	NO_x emissions	SO_x Emissions	PM_{10} Emissions	Accident Risk Fatality *	Accident Risk Injury**
	metric ton	MMBTU	metric ton	metric ton	metric ton	Number	Number
Scenario-4-Noah-SiteWise inventory values	4.0E+02	4.5E+03	4.5E+02	4.5E+02	5.1E+02	3.7E-04	6.6E-02
Scenario-4-Noah-SMED inventory values	2.6E+03	4.2E+03	6.9E+01	2.1E+01	3.0E+00	3.7E-04	6.6E-02
Scenario-6a-Noah-SiteWise inventory values	3.2E+02	3.6E+03	3.5E+02	3.4E+02	3.9E+02	3.2E-04	5.5E-02
Scenario-6a-Noah-SMED inventory values	2.0E+03	3.4E+03	5.3E+01	1.6E+01	2.3E+00	3.2E-04	5.5E-02

As presented in table 6.4, the GHG emissions increase significantly with SMED inventory values but NOx, SOx and PM10 emission values decrease on the same significance. Footprints and metrics of scenarios with the adjusted ship transportation inventory values are presented in Figures 6.8-6.14.

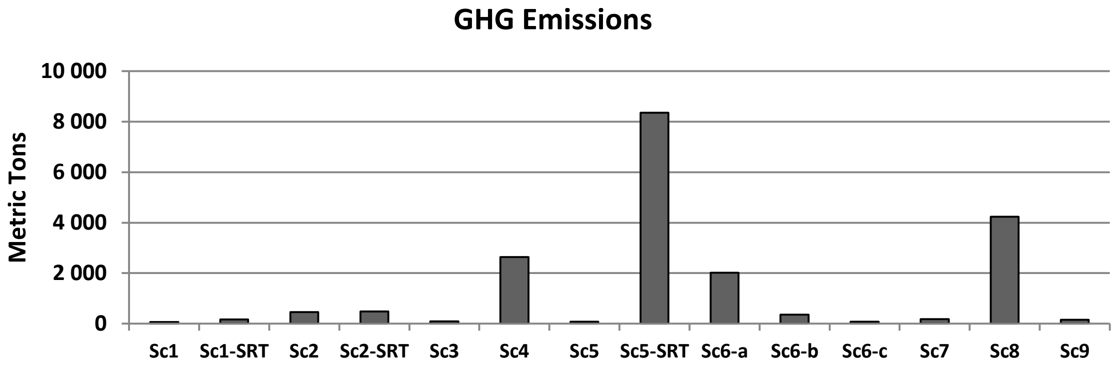


Figure 6.8 GHG emission results for Hexion site remediation scenarios by SiteWise™ and SRT.

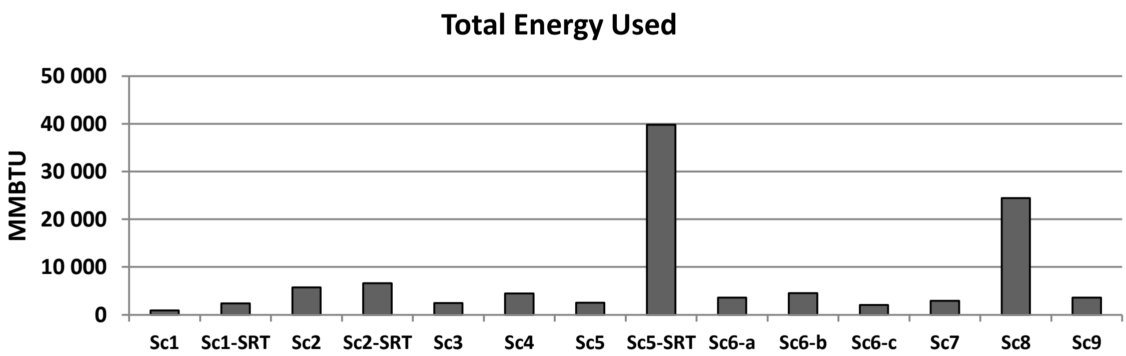


Figure 6.9 Energy usage results for Hexion site remediation scenarios by SiteWise™ and SRT.

As illustrated in Figures 6.8 and 6.9 above, Scenario-5 (in-situ vapor extraction modeled by SRT) and Scenario-8 (in-situ S&S by cement modeled by SiteWise$^{TMv.1}$) with 8300 and 4200 metric tons of CO_2 released respectively have the greatest emissions of GHG, compared to all the other scenarios, where GHG emissions are relatively lower. The same pattern is evident when energy demands are considered.

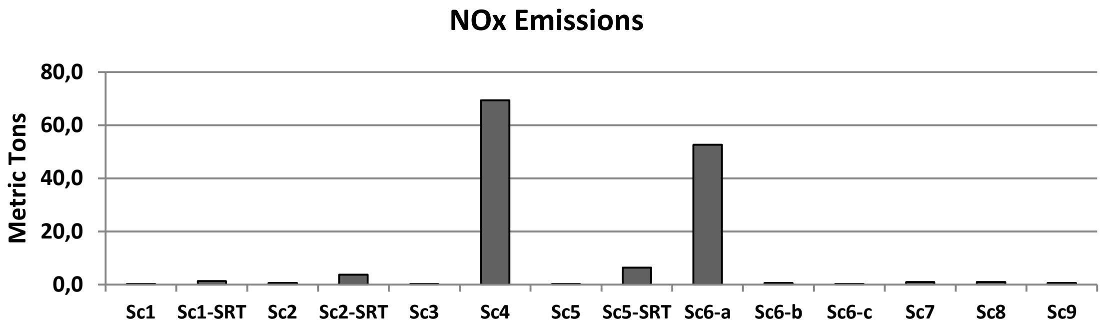


Figure 6.10 NOx emission results for Hexion remediation scenarios by SiteWise^{TM} and SRT.

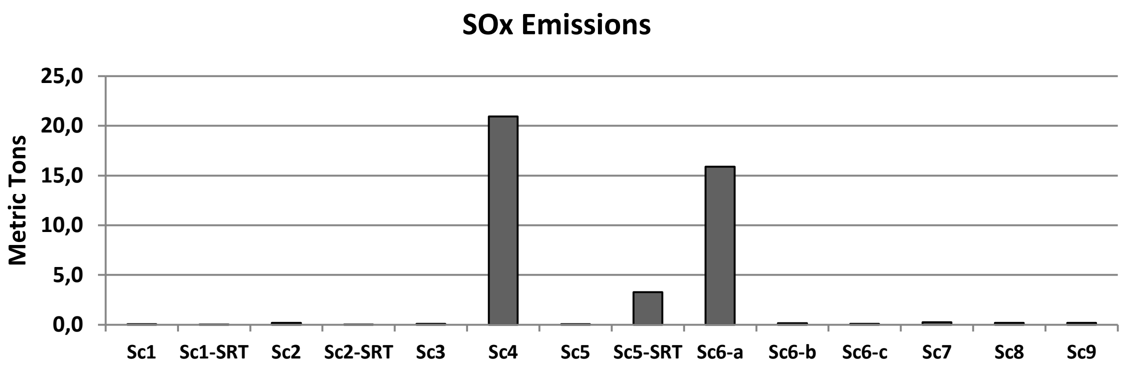


Figure 6.11 SOx emission results for Hexion remediation scenarios by SiteWise^{TM} and SRT.

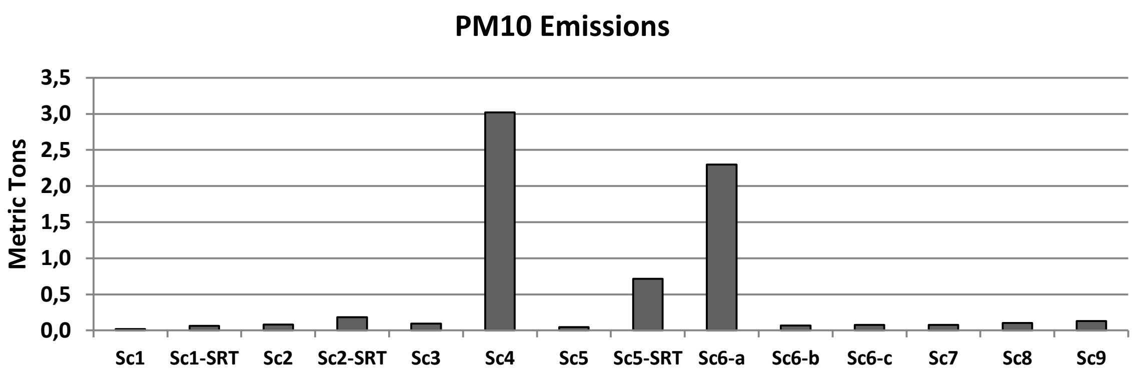


Figure 6.12 Particle emission result for Hexion remediation scenarios by SiteWise^{TM} and SRT.

Figures 6.10 to 6.12 confirm that even with the milder SMED inventory values, Scenario-4 and Scenario-6a, which both rely on ship transportation, release considerably higher amounts of NOx, SOx and PM10 compared to the other alternatives.

Figures 6.13 and 6.14 demonstrate the accidental risk exposure of the Hexion remediation alternatives. Once again, the scenarios dependent on road transportation by truck showed much higher risk values compared to the other scenarios (except Scenario-1 which was defined with very short distance truck transportation. As it was aforementioned, for proper and correct comparison, SRT-modeled scenarios are excluded from these tables due to differences in risk definition between the SiteWise$^{TMv.1}$ and SRT models.

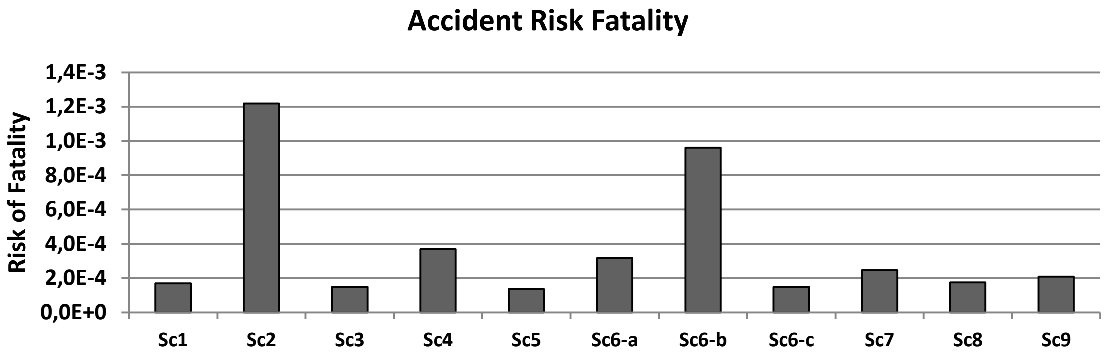


Figure 6.13 Major accident exposure results for Hexion remediation scenarios by SiteWise^{TM} models.

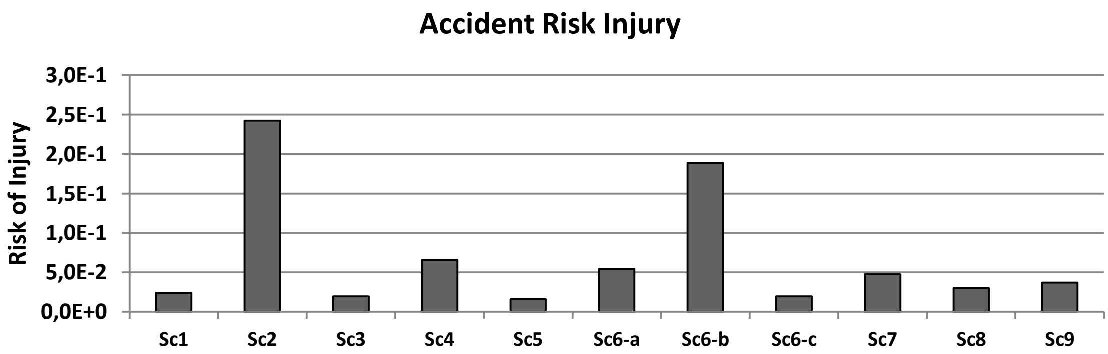


Figure 6.14 Minor accident exposure results for Hexion remediation scenarios by SiteWise^{TM} models.

7 Analysis of the results

In this chapter, an analysis of the results from all the scenarios of the two contaminated sites is presented. It should be noted that this comparative analysis is done regardless of remedial action efficiency of each technique and it is assumed that each defined scenario would result in the adequate environmental and health risk reduction to make the site suitable for its future purpose.

7.1 The Bohus Varv remediation project

7.1.1 Scenario-1 and Scenario-2

These two scenarios are defined as complete excavation of the contaminated media and transportation to the Sita site in Scenario-1 and to the Ragnsell site in Scenario-2. Transports to both sites are made by truck.

According to analysis done by both the tools:

- The SiteWise$^{TMv.1}$ models estimate higher CO_2 and even higher SOx emission releases than the SRT models. The difference in the results is due to the remedial construction stage with sheet-piling activities and steel and plastic usage, which are not included in the SRT models.
- SRT models estimate slightly higher NOx release compared to SiteWise$^{TMv.1}$ models.
- Scenario-1 is calculated to have the highest amount of energy consumption, highest risk of accident and third highest CO_2 release among all the scenarios. Scenario-2 has similar shortcoming in terms of risk of accident and has high value of total energy consumption.
- According to the SRT results, the cost of environmental compensation for GHG release is estimated at 5800 dollars (nearly 37500 SEK) and 5400 dollars (nearly 34800 SEK) for Scenario-1 and Scenario-2 respectively by considering Chicago Climate Exchange Cost recommendations and increases to 116000 and 108000 dollars (0.75 and 0.69 MSEK) considering Bank of America's suggested values.
- According to Swedish traffic administration and Sweden's EPA recommendations, which are calculated based on the rates 1.5 SEK/kg CO_2 release (SIKA, 2009), 20 SEK/kg for SOx release (SIKA, 2005) and 40 SEK/kg for NOx release (SEPA, 2004), Scenario-1 and Scenario-2 emissions cost 9.7 and 7.3 MSEK (1.4 and 1.0 MUS$), respectively. It should be noted that road traffic-related emissions are already compensated for by the tax increase on fuel prices.
- Applying the aforementioned Swedish compensation rates to SRT's results would result in a compensation amount of 4.8 and 2.8 MSEK (0.68 and 0.39 MUS$) for these two scenarios.

7.1.2 Scenario-3

This scenario is defined as complete excavation of the contaminated and transfer of the contaminated mass by train to the SAKAB center.

According to the analysis done by SiteWise$^{TMv.1}$:

- Excluding the SRT model results, this scenario results in the second to lowest CO_2 release and energy usage among all the scenarios.
- NOx and SOx releases as well as the risk of accidents are considerably lower than for Scenario-1 and Scenario-2.
- According to the Swedish compensation values mentioned above, the emissions produced by Scenario-3 would result in a cost of 5.6 MSEK (0.8 MUS$).
- Considering the distances covered by mass transportation in this scenario, the overall footprint is surprisingly low. This is due to the reduced risk of accidents and the smaller environmental footprint associated with Swedish trains.

7.1.3 Scenario-4

This scenario is defined as complete excavation of the contaminated mass and its transfer by ship to the Noah center with SMED based ship-cargo-impact values. According to the analysis done by SiteWise$^{TMv.1}$:

- GHG emission in this scenario is the highest among other scenarios.
- Change in the inventory factors for ship transportation from SiteWise default values to the SMED based factors, result in a significant reduction in NOx, SOx and PM10 but in a substantial increase in GHG emissions.
- This scenario has a significant amount of energy demand.
- Ship mass transportation shows very high NOx, SOx and PM10 release compared to other scenarios even with the milder SMED based factors.
- According to the Swedish compensation values mentioned above, the emissions produced in Scenario-4 would result in a cost of 31 MSEK (4. 5MUS$), which is dramatically higher than all other modeled scenarios.

7.1.4 Scenario group 5

Scenarios 5a, 5b, 5c and 5d are defined as partial excavation and transportation of the contaminated mass to the same destinations adopted in scenarios 1 to 4, in which for the scenario with mass transfer to Noah center SMED based ship-cargo-impact values were used.

According to the analysis done by SiteWise$^{TMv.1}$:

- Having avoided full excavation, this group of scenarios result in a smaller overall environmental footprint.
- This group of scenarios have higher energy consumption rates and concomitant CO_2 emissions at the "remedial action construction" stage compared to earlier full-excavation scenarios due to their extra usage of plastic liners.
- This group of scenarios pose considerably lower risk of accidents compared to the full-excavation scenarios.

- Overall air pollution costs are lower compared to the full excavation scenarios. Scenario-5d show the biggest improvement compared to Scenario-4 followed by Scenario-5a to Scenario-1 , Scenario-5b to Scenario-2 and finally the train transportation scenarios.

7.1.5 Scenario-6

Scenario-6 is an ex-situ, on-site soil-washing remedy with minimum soil mass transfer.

According to the analysis done by SiteWise$^{TMv.1}$:

- This scenario shows the smallest footprint of all the scenarios modeled by SiteWise^{TM} for the Bohus Varv site.
- A big portion of the CO_2 release and energy usage for this scenario comes as a result of the necessary river bank stabilization process and the remedial activity itself, as excavation and on-site washing has a very low impact.
- The SOx, NOx, PM10 and accident risks are mostly remedy oriented.
- According to the Swedish compensation values for air pollution, the CO_2, NOx and SOx emissions produced in this scenario would result in a cost of 5.2 MSEK (0.74 MUS$).

7.1.6 Scenario-7

This is an in-situ stabilization and solidification technique. SiteWise$^{TMv.1}$'s results are as follows:

- This scenario has the second highest CO_2 release and the second highest consumption of energy of all other scenarios.
- The high energy consumption and GHG effect of the scenario are the result of its high cement consumption rate and the fact that cement's life cycle has a considerable environmental impact.
- Scenario-7 involves a higher risk of accidents compared to the scenarios 5c, 5d and 6 due to cement transportation to the site.
- According to the Swedish compensation values mentioned above, the CO2, NOx and SOx emissions produced in this scenario could result in a cost of 15 MSEK(2.2MUS$).

7.2 The Hexion remediation project

Remediation scenarios for the Hexion site were modeled in two phases. The first phase was modeled by 11 scenarios and the second phase is modeled by 3 scenarios.

7.2.1 Phase one

Phase one is modeled in a similar way found in Hector (2009) for this phase, mass excavation and a landfilling stage is considered for all the scenarios. The scenarios are differentiated by the destination of transported contaminated mass and the amount of mass to be landfilled.

7.2.1.1 Scenario-1 and Scenario-2

These two scenarios involve an excavation of the contaminated mass and its transportation by truck to the Kikåstappen site at Scenario-1 and to the Ragnsell site in Scenario-2.

The results from both tools show:

- The SRT models for these two scenarios result in higher footprints for all categories compared to SiteWise$^{TMv.1}$ models, with the exception of the SOx metric.
- Scenario-1 has significantly lower footprints compared to Scenario-2.
- Scenario-2 has the highest accidental risk of all scenarios modeled.
- A major part of these scenarios' impacts occurs in the remedial activity stage.
- According to the SRT results, the cost of environmental compensation for GHG release is estimated to 380 and 1000 dollars (2450 and 6450 SEK) for the Scenario-1 and the Scenario-2 respectively, considering Chicago Climate Exchange Costs, and to 7600 and 20000 dollars (49000 and 400000 SEK), according to the Bank of America suggestions.
- According to the Swedish traffic administration and the Swedish EPA recommendations, which are calculated based on the rates 1.5SEK/kg CO2 release (SIKA, 2009), 20 SEK/kg for SOx release (SIKA, 2005) and 40 SEK/kg for NOx release (SDEPA, 2004), Scenarios 1 and 2's emissions would be associated with a cost of 0.11 and 0.72 MSEK (16,000 and 100,000 US$) respectively. It should be noted that road traffic-related emissions are already compensated by the tax increase on fuel prices.
- Applying the aforementioned Swedish compensation rates to SRT's results would result in a cost of 0.31 and 0.87 MSEK (45,000 and 120,000) for these two scenarios.
- Comparisons of the metrics for each tonne of contaminated soil, from both the tools with Hector (2009) are presented in figures 7.1 for scenario-1 and 7.2 for scenario-2. According to the results, SiteWise$^{TMv.1}$ models reveal a lower footprint than SRT's results and Hector (2009).

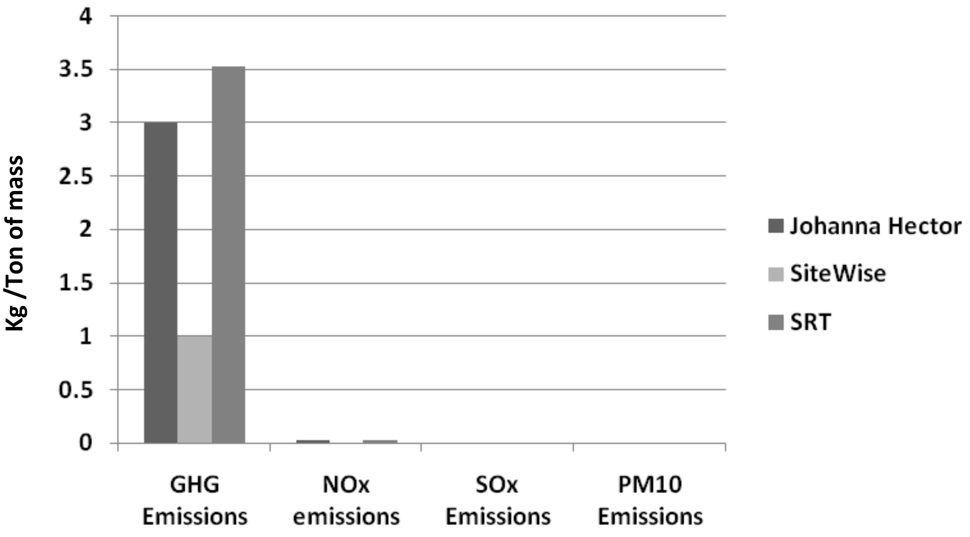


Figure 7.1 Comparison of results for Scenario-1 from SiteWise™, SRT and Hector (2009).

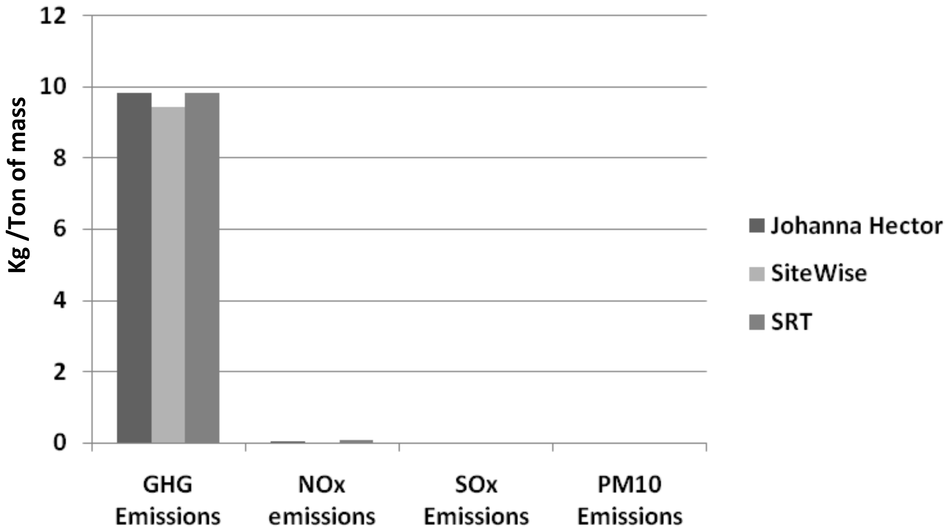


Figure 7.2 Comparison of results for Scenario-2 from SiteWise™, SRT and Hector (2009).

7.2.1.2 Scenario-3

This scenario is an excavation of the contaminated mass and its transfer by train to the SAKAB center.

According to the analysis done by SiteWise$^{TMv.1}$:

- This scenario has a considerably lower footprint in all aspects.
- This scenario shows reduced risk of accidents compared to scenarios with long distance transportation by truck.

- According to the Swedish compensation values mentioned above, the CO_2, NOx and SOx emissions produced in this scenario would result in a cost of 0.15 MSEK (22,000 US$).
- Considering the distances covered by mass transportation in this scenario, the overall footprint is surprisingly low. This is due to the comparatively low risk of accidents and the smaller environmental footprint attributed to Swedish trains.
- Comparisons of the metrics for each tone of contaminated soil, from SiteWise$^{TMv.1}$ tool with Hector (2009) are presented in Figure 7.3 below. According to the results, SiteWise$^{TMv.1}$ models reveal a smaller footprint compared to Hector (2009).

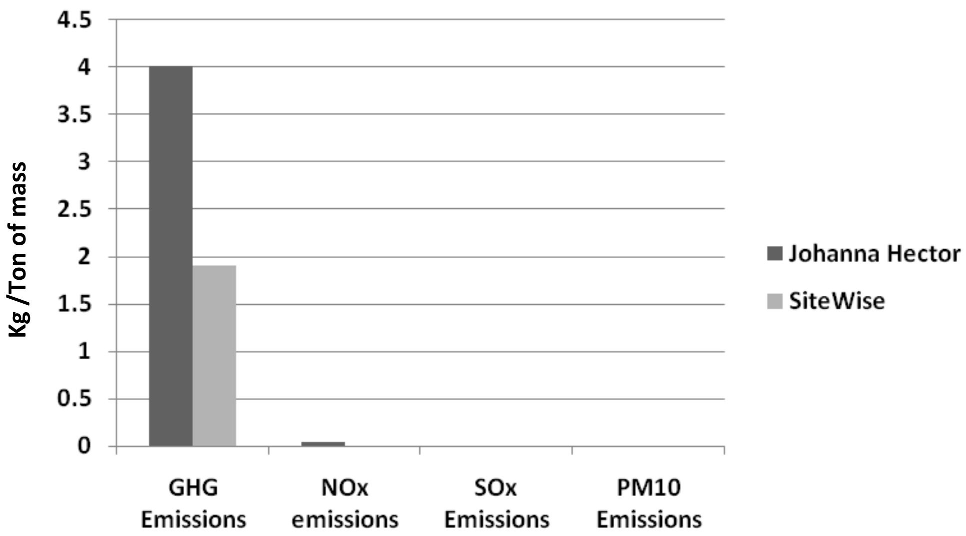


Figure 7.3 Comparison of results for Scenario-3 from SiteWise^{TM}, SRT and Hector (2009).

7.2.1.3 Scenario-4

In this scenario, the contaminated mass is excavated and transported by truck to a port and shipped to the Noah centre at Langøya.

- Ship mass transportation shows very high NOx, SOx and PM10 releases compared to other scenarios, even with the milder SMED based factors.
- Changing of the inventory factors for ship transportation from SiteWise default values to the SMED based factors, result in a significant reduction in NOx, SOx and PM10 but in a substantial increase in GHG emissions.
- According to the Swedish compensation values mentioned above, the CO_2, NOx and SOx emissions produced in this scenario could result in a cost of 7.1 MSEK (1.0MUS$) which is the second highest value for the Hexion case.
- Comparisons of the metrics for each tone of contaminated soil, from the SiteWise$^{TMv.1}$ tool with Hector (2009) are presented in Figure 7.4 below.

According to the results, the footprints for all the emission values are slightly higher in SiteWise$^{TMv.1}$ than in Hector (2009) model. The difference is related to the extra remediation stages considered in the SiteWise$^{TMv.1}$ models but not included in Hector (2009). See Appendix 16 for details.

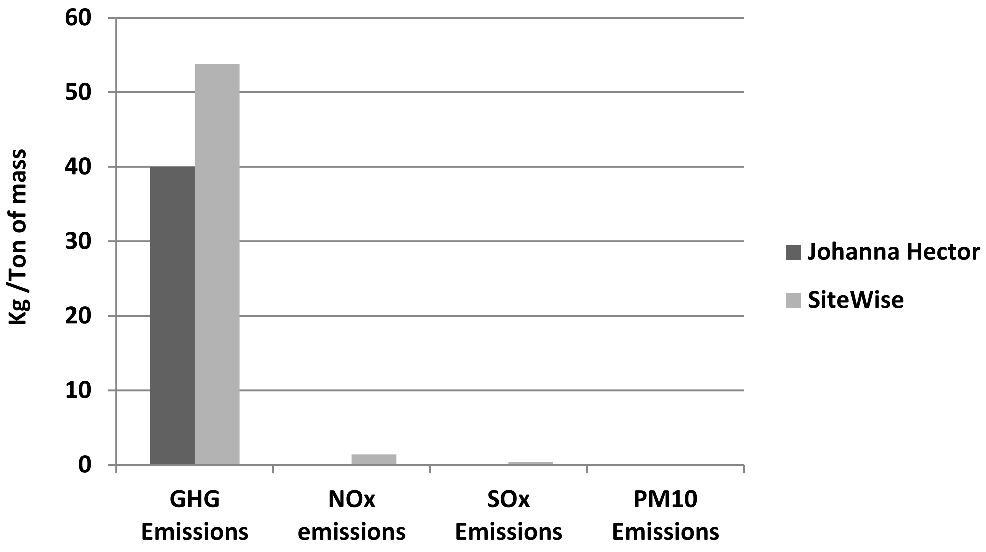


Figure 7.4 Comparison of results for Scenario-4 from SiteWise^{TM}, SRT and Hector (2009).

7.2.1.4 Scenario-5

This scenario involves the vapour extraction of contaminated portions of the site with volatile contaminants combined with excavation of the site for future needs and transfer by train of a quantity of the mass to the SAKAB site.

According to the analysis done by both the tools:

- The SRT model shows the highest GHG emissions and energy use among all the scenarios, though significant differences can be observed in SiteWise$^{TMv.1}$'s estimations. A reason for this variation is that, in the SRT scenario modeling, vapor extraction technology is modeled by Activated Carbon Filtering (GAC) and the US electricity mix is adopted by the tool; on the other hand, in scenario modeling with SiteWise$^{TMv.1}$, the Swedish electricity mix is adapted and the scenario is modeled just as remediation preparation activity (e.g. Well drilling and equipment transport to the site, etc,) and a certain amount of electricity use for the remedy, based on available data.
- Both models show relatively low SOx, NOx and PM10 emissions.
- As a result of reduced transportation, the accident risks are less significant in this scenario.
- According to the SRT results, the cost of environmental compensation for GHG release is estimated at 18000 dollars (0.12 MSEK) for this scenario considering Chicago Climate Exchange Costs and 360000 dollars (2.32 MSEK) according to the Bank of America suggestions.

- The aforementioned recommended Swedish compensation prices for CO_2, NOx and SOx emissions would result in a cost of 0.14 MSEK (20,000US$) for SiteWise$^{TMv.1}$ model and 13 MSEK (1.8MUS$) for the SRT model. Comparisons of the metrics from both the tools to Hector (2009) are presented in Figure 7.5. The SRT models estimate the scenario's emission values to be greater than what had been seen in Hector's work and in the SiteWise$^{TMv.1}$ results, which can be explained by the mentioned simplicity in modelling and differences in electricity mix.

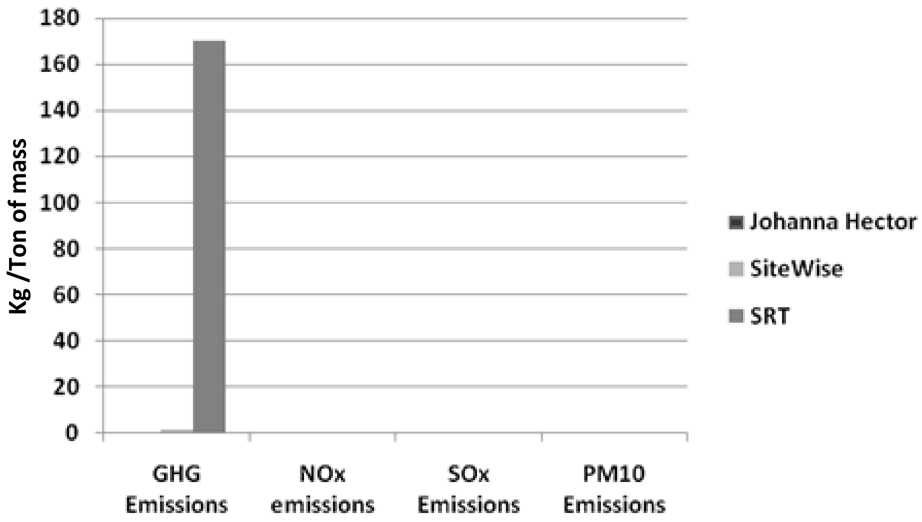


Figure 7.5 Comparison of results from SiteWise^{TM}, SRT and Hector (2009).

7.2.1.5 Scenario group 6

Scenario 6 is defined as an ex-situ, on-site soil-washing remedy, after which reusable portions of the sievable mass is extracted and transferred by boat to the Noah facility at Langøya (6a), to the Ragnsell center by truck (6b) and to the SAKAB by train (6c).

According to the analysis done by SiteWise$^{TMv.1}$:

- This group of scenarios results in lower overall environmental footprint compared to scenarios 4, 3 and 2. This reduction is due to a decrease of 6500 tons of mass needed to be landfilled.
- Scenario-6a with boat transport shows the highest improvement in footprint reduction and Scenario-6c shows the lowest reduction.
- Scenario-6a shows the highest SOx, NOx and PM10 emissions and Senario-6b has the highest risk of accidents of the scenario group.
- In the comparison between this scenario group with Hector (2009), since in both the studies, the SoilTech^{TM} company's values are used for soil washing process, the difference in values follows the difference seen in Scenario-1,2 and 3 between both studies.

7.2.2 Phase two

Phase two was modelled by taking into account the entire contaminated soil mass to be dealt with. For this phase, the same partial mass excavation and landfilling stage, modelled in phase one, is also considered.

7.2.2.1 Scenario-7

This scenario is defined as an excavation of the entire contaminated soil mass and its transfer by truck to Kikåstappen and by train to the SAKAB site, depending on the level of contamination. According to the analysis done by SiteWise$^{TMv.1}$:

- This scenario shows a relatively small footprint.
- Compared to the scenarios modelled in phase one, with partial excavation, full excavation result differences are not very big.
- In this scenario, the entire contaminated soil mass is handled, which results in a larger reduction of risk but a greater demand for land to accommodate landfilling facilities.
- According to the Swedish compensation values mentioned above, the CO_2, NOx and SOx emissions produced in this scenario would result in a cost of 0.33MSEK (47,000 US$).

7.2.2.2 Scenario-8

An in-situ stabilization and solidification technique is modeled by SiteWise$^{TMv.1}$ in this scenario.

According to the analysis:

- This scenario has very high CO_2 emissions and energy usage, second after Scenario-5 (modeled by SRT) and biggest among SiteWise$^{TMv.1}$ models, and has the highest CO_2 emissions and energy usage among SiteWise$^{TMv.1}$models.
- The high energy consumption and GHG effect of the scenario is due to the high cement consumption rate involved. Cement as a material has a considerable footprint, when its full life cycle is taken into consideration.
- According to the Swedish compensation values mentioned above, the NOx and SOx and above all the CO_2 emissions produced in this scenario would result in a cost of 6.4MSEK(0.91 MUS$).

7.2.2.3 Scenario-9

Scenario 9 is an ex-situ, on-site soil-washing remedy, after which the recyclable portion of the sievable mass is excavated, a smaller portion is transported to the SAKAB center by train.

According to the analysis done by SiteWise$^{TMv.1}$:

- This scenario has very low GHG emissions and a relatively low energy demand.
- The footprint of this scenario per ton of contaminated soil to be handled is the lowest among all modeled scenarios in both phases.

- According to the Swedish compensation values mentioned above, the NOx and SOx and above all the CO_2 emissions produced in this scenario would result in a cost of 0.27 MSEK(38,000 US$).

8 Discussions and recommendations

8.1 The Bohus Varv remediation project;

- The footprint made by the studied remediations' investigation stage is negligible.
- Site stabilization activity contributes enormously to each remediation activity's GHG emissions. Sheet-piling, which is included in all the scenarios modeled in this thesis, is considered necessary for the prevention of landslides rather than the remediation itself and could therefore be excluded from the decision making process.
- Activities powered by electricity result in a reduced footprint compared to activities powered by fossil fuels. Within this concept, total energy usage is a crucial metric to be considered. As long as the electricity used at the site is produced with low foot printing (green way), electricity oriented-activities are strongly recommended. Special attention needs to be given to implement low energy-demanding technologies if the electricity mix relies on fossil fuels**.**
- More than any other form of transportation, road transportation results in high risks of accidents. This risk increases, of course, as the distances needed to be travelled and the number of required trucks increases. According to health risk levels estimated by the SADA software, the risks involved in transportation are comparable to the long-term exposure health risks of leaving the site untreated.
- At present, transportation by ship results in very high levels of NOx, SOx and PM10 emissions to the environment relative to other transport types. However, the potential of fuel usage optimization and the improvement of ship fuel quality and emission filtering technologies are currently under extensive investigation, the results of which should be considered if transportation by ship is required in future projects.

8.2 The Hexion site remediation project;

- The footprint made by the studied remediations' investigation stage is negligible.
- Long-term monitoring is included in two of the scenarios, which contributes in a not insignificant way to their overall risk factors and environmental footprint.
- In each scenario, it was considered mandatory to include the excavation of 49,000 metric tons of mass to allow for the necessary demolition and construction of the planned facilities. However, for some remedial scenarios, this extra activity may be excluded.
- For the vapor extraction scenario, only 30 units (each 100 square meters) of the whole sites were included and only well-drilling and electricity usage were considered in the process. With more detailed available data, especially about

the filtering technique used, the final SiteWise$^{TMv.1}$ result could be very different from the calculated and presented values in this report.

- The Solidification and Stabilization activity can be combined with the future planning of the site and considered to be a part of foundation construction. A life cycle assessment with wider boundary conditions, including the future construction plan, could further emphasize the positive side of this scenario.
- More than any other form of transportation, road transportation results in high risks of accidents. This risk increases, of course, as the distances needed to be travelled and the number of required trucks rose. According to health risk data by SADA software, the risks involved in transportation by trucks are comparable to the long-term exposure health risks of leaving the site untreated.

8.3 Tool evaluations:

8.3.1 SRT

- SRT is developed to include the three classic dimensions (ecological, economic and social) of sustainability in remedial decision making (e.g. MCDA & CBA are possible), but all these three dimensions are adaptable in a very specific predefined manner by the developers.
- The defined structure of SRT models for remediation technologies makes it easier to analyze a contaminated site and to consider the sustainability of remediation at an early stage for future decision making. This structure can, on the other hand, limit the user when modeling other relevant technologies.
- To estimate and include specific additional metrics such as individual costs, total energy used, CO_2 emission released and lost hours due to accidents, an additional study is needed.
- In order to use SRT to support decision-making in Sweden, substantial adaptations are needed which are not implemented in this study; e.g. the footprint of the energy mix (which is a combination of different energy source footprints), using Swedish environmental compensation values as well as adaptation of natural resource attenuation definitions. Therefore presented values within this study are estimated based on the tool's original default American data sources.

8.3.2 SiteWise^{TM} (Ver.1)

- SiteWise$^{TMv.1}$ offers a reasonably comprehensive perspective, covering environmental dimensions and some social factors (e.g. the concomitant risks of accidents to society). However, for a truly inclusive, wide-ranging perspective, economic dimensions should also be combined with the results the tool offers.

- SiteWise$^{TMv.1}$ does not have a defined structure for its models and it is therefore adaptable for all kinds of construction activities. This makes it possible to model remedial activities with more precision and fewer deductions, but it requires much more data input in the initial stages and extensive technical understanding and skills.
- SiteWise$^{TMv.1}$ models the activities and presents the results in different remediation stages from Investigation to Monitoring. It allows the user to differentiate between different stages and increases the potential for overall optimization.
- In order to use SiteWise$^{TMv.1}$ to support the decision-making process in Sweden, some adaptations on the inventory values for electricity use, train transportation and ship-cargo transport values are needed, which are all implemented within this study.
- Although it is possible to import metrics directly into the tool, which was already adapted to model the soil-washing process in this study for example, it is much better to model the activity by the SiteWise$^{TMv.1}$ tool instead.
- Default NOx, SOx and PM10 inventory factors used for ship cargo transportation in SiteWise$^{TMv.1}$ tool are very conservative and therefore they result in prediction of extremely high emission release magnitudes, which seem unrealistic and require precise reviews. It is therefore recommended to use inventory factors based on other sources than SiteWise$^{TMv.1}$.

A structured and subjective tool evaluation is presented in the table below. Comparison is made considering the tools' coverage on different categories.

Table 8.1 Qualitative comparison of SRT and SIteWise$^{TMv.1}$.

Considered category		SRT	SiteWise^{TM}
User Friendliness	Help and Guide		
	Manual		
	Clear application		
	Default values		
	Adaptation need for Sweden		
	Easy adaptation application		
	References		
Concept Coverage	Different remediation stages		
	Material Life Cycle consideration		
	Social & Economical coverage		
	Remediation technology		
	Big amount of input data		
Modeling	Data need		
	Modeling time		
	User Familiarity with Remediation		
Result	Clearance		
	Easy to follow		
	Cost Benefit Analysis		
	Multi Criteria Analysis		
	Probabilistic Analysis		
	Comparable diagrams, charts		

NO YES

8.4 Limitations of this thesis and suggestions for future study

- The ability to combine the estimated environmental footprints with comprehensive social and economic data to make full sustainability evaluations of both the projects would be very informative and useful for constructive decision-making
- A discrete classification of fuel usage and electricity bills connected to the project, separate from other financial spending, would allow for more useful analysis.
- Ex-situ and in-situ soil-washing technology models should be generated, which would be more reliable than using generic data.
- A combination of the Remedial Action Cost Engineering and Requirements (RACER™) software with the SiteWise$^{TMv.1}$ tool is recommended.
- To fully exploit SRT's capacity, knowledge of the cost of local technology, environmental compensation values as well natural resource attenuation definition is crucial.
- It would be informative for future studies to work with probabilistic uncertainties, since SiteWise$^{TMv.1}$ has this capacity.
- There is considerable disparity in data regarding the extent to which ships pollute the environment. Research into the reliability of such data, with the aim of establishing accurate metrics for ship transportation, would be valuable.
- Default NOx, SOx and PM10 for ship-cargo-impact values in SiteWise$^{TMv.1}$ are very uncertain. Further communication with the tool's developers in order to get more specific motivation is required. It is recommended to replace the available default values with the project specific inventory factors.

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10 Appendix 1

10.1 Scenario-1, BohusVarv remediation project.

Remedial Investigation		Note
Material Use		
Well Materials		
Number of wells	17	*Available data*
Input depth of wells (ft)	13	*Processed data*
Well diameter (in)	2	*Assumption based*
Material type	PVC	*Assumption based*
Specific material schedule	Schedule 40 PVC	*Assumption based*
TRANSPORTATION		
Personnel transportation-Road		
Choose vehicle type from drop down menu	Car	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	12	*Assumption based*
Number of trips taken	60	*Available data*
Number of travelers	3	*Assumption based*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	12	*Assumption based*
Weight of equipment transported (tons)	10	*Processed data*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	155	*Processed data*
Drilling		
Input number of drilling locations	81	*Available data*
Choose drilling method from drop down menu	Direct Push	*Assumption based*
Input time spent drilling at each location (hr)	1	*Processed data*
Input depth of wells (ft)	13	*Processed data*
Choose fuel type from drop down menu	Diesel	*Available data*
Pump operation-Head is known		
Flow rate (gpm)	40	*Processed data*
Total head (ft)	12	*Assumption based*
Number of pumps operating	1	*Processed data*
Operating time for each pump (hrs)	56	*Processed data*
Pump efficiency times motor efficiency	1/2	*Assumption based*
Specific gravity	1	*Known*

Remedial Construction		Note
Material Use		
Well Materials		
Number of wells	1050	*Processed data*
Input depth of wells (ft)	40	*Processed data*
Well diameter (in)	12	*Processed data*
Material type	Steel	*Available data*
Specific material schedule	Schedule 40	*Assumption based*
GAC		
Weight of GAC used (lbs)	1,000	*Processed data*
Type of GAC	Virgin GAC	*Assumption based*
Construction Material		
Material type	HDPE Liner	*Available data*
Area of material (ft^2)	320	*Processed data*
Depth of material (ft)	12	*Processed data*
EQUIPMENT USE		
Drilling		
Input number of drilling locations	1,050	*Processed data*
Choose drilling method from drop down menu	Direct Push	*Assumption based*
Input time spent drilling at each location (hr)	1	*Assumption based*
Input depth of wells (ft)	20	*Available data*
Choose fuel type from drop down menu	Diesel	*Assumption based*
Pump operetion-Head is known		
Flow rate (gpm)	95	*Processed data*
Total head (ft)	12	*Assumption based*
Number of pumps operating	2	*Available data*
Operating time for each pump (hrs)	1,380	*Processed data*
Pump efficiency times motor efficiency	1/2	*Assumption based*
Specific gravity	1	*Known*

Remedial Operation						Note
TRANSPORTATION						
Personnel transportation-Road						
Choose vehicle type from drop down menu	Cars					*Available data*
Fuel used	Gasoline					*Available data*
Distance traveled per trip (miles)	10					*Assumption based*
Number of trips taken	4960					*Available data*
Number of travelers	1					*Assumption based*
Personnel transportation-Air						
Distance traveled (miles)	1,850					*Available data*
Number of travelers	3					*Available data*
Number of flights taken	1					*Available data*
EQUIPMENT USE						
Earthwork						
Earthwork equipment type	Excavator	Dozer	Loader/Backhoe			*Available data*
Fuel type	Diesel	Diesel	Diesel			*Processed data*
Volume of material to be removed (yd^3)	70390+54149	91513+70390	249078			*Processed data*
RESIDUAL HANDLING						
Disposal transportation-Road						
Weight of the waste transported to landfill (tons)	7	0	14	0	14	*Processed data*
Vehicle type	On-road truck					*Available data*
Fuel used	Gasoline					*Available data*
Total number of trips	43000	8350	6500	6500	8350	*Processed data*
Number of miles per trip	1/2	115	10	10	115	*Processed data*

10.2 Scenario-2, BohusVarv remediation project.

Remedial Investigation		Note
Material Use		
Well Materials		
Number of wells	17	*Available data*
Input depth of wells (ft)	13	*Processed data*
Well diameter (in)	2	*Assumption based*
Material type	PVC	*Assumption based*
Specific material schedule	Schedule 40 PVC	*Assumption based*
TRANSPORTATION		
Personnel transportation-Road		
Choose vehicle type from drop down menu	Car	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	12	*Assumption based*
Number of trips taken	60	*Available data*
Number of travelers	3	*Assumption based*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	12	*Assumption based*
Weight of equipment transported (tons)	10	*Processed data*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	155	*Processed data*
Drilling		
Input number of drilling locations	81	*Available data*
Choose drilling method from drop down menu	Direct Push	*Assumption based*
Input time spent drilling at each location (hr)	1	*Processed data*
Input depth of wells (ft)	13	*Processed data*
Choose fuel type from drop down menu	Diesel	*Available data*
Pump operetion-Head is known		
Flow rate (gpm)	40	*Processed data*
Total head (ft)	12	*Assumption based*
Number of pumps operating	1	*Processed data*
Operating time for each pump (hrs)	56	*Processed data*
Pump efficiency times motor efficiency	1/2	*Assumption based*
Specific gravity	1	*Known*

Remedial Construction		Note
Material Use		
Well Materials		
Number of wells	1050	*Processed data*
Input depth of wells (ft)	40	*Processed data*
Well diameter (in)	12	*Processed data*
Material type	Steel	*Available data*
Specific material schedule	Schedule 40	*Assumption based*
GAC		
Weight of GAC used (lbs)	1,000	*Processed data*
Type of GAC	Virgin GAC	*Assumption based*
Construction Material		
Material type	HDPE Liner	*Available data*
Area of material (ft^2)	320	*Processed data*
Depth of material (ft)	12	*Processed data*
EQUIPMENT USE		
Drilling		
Input number of drilling locations	1,050	*Processed data*
Choose drilling method from drop down menu	Direct Push	*Assumption based*
Input time spent drilling at each location (hr)	1	*Assumption based*
Input depth of wells (ft)	20	*Available data*
Choose fuel type from drop down menu	Diesel	*Assumption based*
Pump operetion-Head is known		
Flow rate (gpm)	95	*Processed data*
Total head (ft)	12	*Assumption based*
Number of pumps operating	2	*Available data*
Operating time for each pump (hrs)	1,380	*Processed data*
Pump efficiency times motor efficiency	1/2	*Assumption based*
Specific gravity	1	*Known*

Remedial Operation						Note
TRANSPORTATION						
Personnel transportation-Road						
Choose vehicle type from drop down menu	Cars					*Available data*
Fuel used	Gasoline					*Available data*
Distance traveled per trip (miles)	10					*Assumption based*
Number of trips taken	4960					*Available data*
Number of travelers	1					*Assumption based*
Personnel transportation-Air						
Distance traveled (miles)	1,850					*Available data*
Number of travelers	3					*Available data*
Number of flights taken	1					*Assumption based*
EQUIPMENT USE						
Earthwork						
Earthwork equipment type	Excavator-Ret	Dozer	Loader/Backhoe			*Available data*
Fuel type	Diesel	Diesel	Diesel			*Processed data*
Volume of material to be removed (yd^3)	70390+54149	91513+70390	249078			*Processed data*
RESIDUAL HANDLING						
Disposal transportation-Road						
Weight of the waste transported to landfill	7	0	14	0	14	*Processed data*
Vehicle type	On-road truck					*Available data*
Fuel used	Gasoline					*Available data*
Total number of trips	43000	8350	6500	6500	8350	*Processed data*
Number of miles per trip	1/2	51	10	10	51	*Processed data*

10.3 Scenario-1&2, SRT input data, BohusVarv

SRT -Sita		
CONTAMINATED MASS		
Soil Source Input*		
Area of effected soil (ft^2)	450,000	*Processed data*
Depth to Top of the Affected soil (ft)	0	*Available data*
Depth to Bottom of the Affected soil (ft)	9	*Available data*
Depth of Groundwater (ft)	2	*Available data*
Natural attenuation		
Calculation of natural resource service	Disabled	-
TRANSPORTATION		
Personnel transportation-Air		
Distance traveled (miles)	1,850	*Available data*
Personnel transportation-Road		
Distance traveled by site workers one-way (miles)	10	*Assumption based*
Number of trips during construction	2,480	*Processed data*
Number of trips after construction	2	*Assumption based*
Distance to disposal one-way (miles)	39.25**	*Processed data*
Type of disposal	Hazardous	*Available data*

* The amount of soil is double calculated in order to cover whole the earthwork
** distance is calculated as weighted average of the distances
for source and landfill 39.25= (10/1.3+114.9*1.3)/2*2

SRT -Ragnsell		
CONTAMINATED MASS		
Soil Source Input*		
Area of effected soil (ft^2)	450,000	*Processed data*
Depth to Top of the Affected soil (ft)	0	*Available data*
Depth to Bottom of the Affected soil (ft)	9	*Available data*
Depth of Groundwater (ft)	2	*Available data*
Natural attenuation		
Calculation of natural resource service	Disabled	-
TRANSPORTATION		
Personnel transportation-Air		
Distance traveled (miles)	1,850	*Available data*
Personnel transportation-Road		
Distance traveled by site workers one-way (miles)	10	*Assumption based*
Number of trips during construction	2,480	*Processed data*
Number of trips after construction	2	*Assumption based*
Distance to disposal one-way (miles)	18.7**	*Processed data*
Type of disposal	Hazardous	*Available data*

* The amount of soil is double calculated in order to cover whole the earthwork
** distance is calculated as weighted average of the distances
for source and landfill 18.7= (10/1.3+51.24*1.3)/2*2

11 Appendix 2

11.1 Scenario-3, BohusVarv remediation project.

Remedial Investigation		Note
Material Use		
Well Materials		
Number of wells	17	*Available data*
Input depth of wells (ft)	13	*Processed data*
Well diameter (in)	2	*Assumption based*
Material type	PVC	*Assumption based*
Specific material schedule	Schedule 40 PVC	*Assumption based*
TRANSPORTATION		
Personnel transportation-Road		
Choose vehicle type from drop down menu	Car	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	12	*Assumption based*
Number of trips taken	60	*Available data*
Number of travelers	3	*Assumption based*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	12	*Assumption based*
Weight of equipment transported (tons)	10	*Processed data*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	155	*Processed data*
Drilling		
Input number of drilling locations	81	*Available data*
Choose drilling method from drop down menu	Direct Push	*Assumption based*
Input time spent drilling at each location (hr)	1	*Processed data*
Input depth of wells (ft)	13	*Processed data*
Choose fuel type from drop down menu	Diesel	*Available data*
Pump operetion-Head is known		
Flow rate (gpm)	40	*Processed data*
Total head (ft)	12	*Assumption based*
Number of pumps operating	1	*Processed data*
Operating time for each pump (hrs)	56	*Processed data*
Pump efficiency times motor efficiency	1/2	*Assumption based*
Specific gravity	1	*Known*

Remedial Construction		Note
Material Use		
Well Materials		
Number of wells	1050	*Processed data*
Input depth of wells (ft)	40	*Processed data*
Well diameter (in)	12	*Processed data*
Material type	Steel	*Available data*
Specific material schedule	Schedule 40	*Assumption based*
GAC		
Weight of GAC used (lbs)	1,000	*Processed data*
Type of GAC	Virgin GAC	*Assumption based*
Construction Material		
Material type	HDPE Liner	*Available data*
Area of material (ft^2)	320	*Processed data*
Depth of material (ft)	12	*Processed data*
EQUIPMENT USE		
Drilling		
Input number of drilling locations	1,050	*Processed data*
Choose drilling method from drop down menu	Direct Push	*Assumption based*
Input time spent drilling at each location (hr)	1	*Assumption based*
Input depth of wells (ft)	20	*Available data*
Choose fuel type from drop down menu	Diesel	*Available data*
Pump operetion-Head is known		
Flow rate (gpm)	95	*Processed data*
Total head (ft)	12	*Assumption based*
Number of pumps operating	2	*Available data*
Operating time for each pump (hrs)	1,380	*Processed data*
Pump efficiency times motor efficiency	1/2	*Assumption based*
Specific gravity	1	*Known*

Remedial Operation					Note
TRANSPORTATION					
Personnel transportation-Road					
Choose vehicle type from drop down menu	Cars				*Available data*
Fuel used	Gasoline				*Available data*
Distance traveled per trip (miles)	10				*Assumption based*
Number of trips taken	4960				*Available data*
Number of travelers	1				*Assumption based*
Personnel transportation-Air					
Distance traveled (miles)	1,850				*Available data*
Number of travelers	3				*Available data*
Number of flights taken	1				*Available data*
EQUIPMENT USE					
Earthwork					
Earthwork equipment type	Excavator	Dozer	Loader/Backhoe		*Available data*
Fuel type	Diesel	Diesel	Diesel		*Available data*
Volume of material to be removed (yd^3)	70390+54149	91513+70390	249078		*Processed data*
RESIDUAL HANDLING					
Disposal transportation-Rail					
Distance traveled (miles)	60,000	60,000			*Processed data*
Weight of load (tons)	330	1			*Processed data*
Disposal transportation-Road					
Weight of the waste transported to landfill (tons)	14	0	14	0	*Processed data*
Vehicle type	On-road truck				*Available data*
Fuel used	Gasoline				*Available data*
Total number of trips	21300	21300	6500	6500	*Processed data*
Number of miles per trip	0.5	0.5	10	10	*Processed data*

11.2 Scenario-4, BohusVarv remediation project.

Remedial Investigation		Note
Material Use		
Well Materials		
Number of wells	17	*Available data*
Input depth of wells (ft)	13	*Processed data*
Well diameter (in)	2	*Assumption based*
Material type	PVC	*Assumption based*
Specific material schedule	Schedule 40 PVC	*Assumption based*
TRANSPORTATION		
Personnel transportation-Road		
Choose vehicle type from drop down menu	Car	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	12	*Assumption based*
Number of trips taken	60	*Available data*
Number of travelers	3	*Assumption based*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	12	*Assumption based*
Weight of equipment transported (tons)	10	*Processed data*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	155	*Processed data*
Drilling		
Input number of drilling locations	81	*Available data*
Choose drilling method from drop down menu	Direct Push	*Assumption based*
Input time spent drilling at each location (hr)	1	*Processed data*
Input depth of wells (ft)	13	*Processed data*
Choose fuel type from drop down menu	Diesel	*Available data*
Pump operetion-Head is known		
Flow rate (gpm)	40	*Processed data*
Total head (ft)	12	*Assumption based*
Number of pumps operating	1	*Processed data*
Operating time for each pump (hrs)	56	*Processed data*
Pump efficiency times motor efficiency	1/2	*Assumption based*
Specific gravity	1	*Known*

Remedial Construction		Note
Material Use		
Well Materials		
Number of wells	1050	*Processed data*
Input depth of wells (ft)	40	*Processed data*
Well diameter (in)	12	*Processed data*
Material type	Steel	*Available data*
Specific material schedule	Schedule 40	*Assumption based*
GAC		
Weight of GAC used (lbs)	1,000	*Processed data*
Type of GAC	Virgin GAC	*Assumption based*
Construction Material		
Material type	HDPE Liner	*Available data*
Area of material (ft^2)	320	*Available data*
Depth of material (ft)	12	*Available data*
EQUIPMENT USE		
Drilling		
Input number of drilling locations	1,050	*Processed data*
Choose drilling method from drop down menu	Direct Push	*Assumption based*
Input time spent drilling at each location (hr)	1	*Assumption based*
Input depth of wells (ft)	20	*Available data*
Choose fuel type from drop down menu	Diesel	*Available data*
Pump operetion-Head is known		
Flow rate (gpm)	95	*Processed data*
Total head (ft)	12	*Assumption based*
Number of pumps operating	2	*Available data*
Operating time for each pump (hrs)	1,380	*Processed data*
Pump efficiency times motor efficiency	1/2	*Assumption based*
Specific gravity	1	*Known*

Remedial Operation					Note
TRANSPORTATION					
Personnel transportation-Road					
Choose vehicle type from drop down menu	Cars				*Available data*
Fuel used	Gasoline				*Available data*
Distance traveled per trip (miles)	10				*Assumption based*
Number of trips taken	4960				*Available data*
Number of travelers	1				*Assumption based*
Personnel transportation-Air					
Distance traveled (miles)	1,850				*Available data*
Number of travelers	3				*Available data*
Number of flights taken	1				*Available data*
EQUIPMENT USE					
Earthwork					
Earthwork equipment type	Excavator-Ret	Dozer	Loader/Backhoe		*Available data*
Fuel type	Diesel	Diesel	Diesel		*Available data*
Volume of material to be removed (yd^3)	70390+54149	91513+70390	249078		*Processed data*
RESIDUAL HANDLING					
Disposal transportation-Water					
Distance traveled (miles)	9,627	9,627			*Processed data*
Weight of load (tons)*	2,200	1			*Processed data*
Disposal transportation-Road					
Weight of the waste transported to landfill (tons)	14	0	14	0	*Processed data*
Vehicle type	On-road truck				*Available data*
Fuel used	Gasoline				*Available data*
Total number of trips	21300	21300	6500	6500	*Processed data*
Number of miles per trip	1/2	1/2	10	10	*Processed data*

*** For the analysis using SMED recommended values, effect of cargo weight on consumption rate is not considered and "weight of load" was set to be 1 ton.**

12 Appendix 3

12.1 Scenario-5a, BohusVarv remediation project.

Remedial Investigation		Note
Material Use		
Well Materials		
Number of wells	17	*Available data*
Input depth of wells (ft)	13	*Processed data*
Well diameter (in)	2	*Assumption based*
Material type	PVC	*Assumption based*
Specific material schedule	Schedule 40 PVC	*Assumption based*
TRANSPORTATION		
Personnel transportation-Road		
Choose vehicle type from drop down menu	Car	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	12	*Assumption based*
Number of trips taken	60	*Available data*
Number of travelers	3	*Assumption based*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	12	*Assumption based*
Weight of equipment transported (tons)	10	*Processed data*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	155	*Processed data*
Drilling		
Input number of drilling locations	81	*Available data*
Choose drilling method from drop down menu	Direct Push	*Assumption based*
Input time spent drilling at each location (hr)	1	*Processed data*
Input depth of wells (ft)	13	*Processed data*
Choose fuel type from drop down menu	Diesel	*Available data*
Pump operetion-Head is known		
Flow rate (gpm)	40	*Processed data*
Total head (ft)	12	*Assumption based*
Number of pumps operating	1	*Processed data*
Operating time for each pump (hrs)	56	*Processed data*
Pump efficiency times motor efficiency	1/2	*Assumption based*
Specific gravity	1	*Known*

Remedial Construction		Note
Material Use		
Well Materials		
Number of wells	1050	*Processed data*
Input depth of wells (ft)	40	*Processed data*
Well diameter (in)	12	*Processed data*
Material type	Steel	*Available data*
Specific material schedule	Schedule 40	*Assumption based*
GAC		
Weight of GAC used (lbs)	250	*Processed data*
Type of GAC	Virgin GAC	*Assumption based*
Construction Material		
Material type	HDPE Liner	*Available data*
Area of material (ft^2)	800	*Processed data*
Depth of material (ft)	12	*Processed data*
EQUIPMENT USE		
Drilling		
Input number of drilling locations	1,050	*Processed data*
Choose drilling method from drop down menu	Direct Push	*Assumption based*
Input time spent drilling at each location (hr)	1	*Assumption based*
Input depth of wells (ft)	20	*Available data*
Choose fuel type from drop down menu	Diesel	*Available data*
Pump operetion-Head is known		
Flow rate (gpm)	95	*Processed data*
Total head (ft)	12	*Assumption based*
Number of pumps operating	2	*Available data*
Operating time for each pump (hrs)	345	*Processed data*
Pump efficiency times motor efficiency	1/2	*Assumption based*
Specific gravity	1	*Known*

Remedial Operation		Note
TRANSPORTATION		
Personnel transportation-Road		
Choose vehicle type from drop down menu	Cars	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	10	*Assumption based*
Number of trips taken	4960	*Available data*
Number of travelers	1	*Assumption based*
Personnel transportation-Air		
Distance traveled (miles)	1,850	*Available data*
Number of travelers	3	*Available data*
Number of flights taken	1	*Available data*

EQUIPMENT USE				
Earthwork				
Earthwork equipment type	Excavator	Dozer	Loader/Backhoe	*Available data*
Fuel type	Diesel	Diesel	Diesel	*Available data*
Volume of material to be removed (yd^3)	17597+13537	22878+17597	62269	*Processed data*

RESIDUAL HANDLING						
Disposal transportation-Road						
Weight of the waste transported to landfill (tons)	7	0	14	0	14	*Processed data*
Vehicle type	On-road truck					*Available data*
Fuel used	Gasoline					*Available data*
Total number of trips	11000	1785	1640	1640	1785	*Processed data*
Number of miles per trip	1/2	115	10	10	115	*Processed data*

12.2 Scenario-5b, Bohus Varv remediationproject.

Remedial Investigation		Note
Material Use		
Well Materials		
Number of wells	17	*Available data*
Input depth of wells (ft)	13	*Processed data*
Well diameter (in)	2	*Assumption based*
Material type	PVC	*Assumption based*
Specific material schedule	Schedule 40 PVC	*Assumption based*
TRANSPORTATION		
Personnel transportation-Road		
Choose vehicle type from drop down menu	Car	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	12	*Assumption based*
Number of trips taken	60	*Available data*
Number of travelers	3	*Assumption based*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	12	*Assumption based*
Weight of equipment transported (tons)	10	*Processed data*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	155	*Processed data*
Drilling		
Input number of drilling locations	81	*Available data*
Choose drilling method from drop down menu	Direct Push	*Assumption based*
Input time spent drilling at each location (hr)	1	*Processed data*
Input depth of wells (ft)	13	*Processed data*
Choose fuel type from drop down menu	Diesel	*Available data*
Pump operetion-Head is known		
Flow rate (gpm)	40	*Processed data*
Total head (ft)	12	*Assumption based*
Number of pumps operating	1	*Processed data*
Operating time for each pump (hrs)	56	*Processed data*
Pump efficiency times motor efficiency	1/2	*Assumption based*
Specific gravity	1	*Known*

Remedial Construction		Note
Material Use		
Well Materials		
Number of wells	1050	*Processed data*
Input depth of wells (ft)	40	*Processed data*
Well diameter (in)	12	*Processed data*
Material type	Steel	*Available data*
Specific material schedule	Schedule 40	*Assumption based*
GAC		
Weight of GAC used (lbs)	250	*Processed data*
Type of GAC	Virgin GAC	*Assumption based*
Construction Material		
Material type	HDPE Liner	*Available data*
Area of material (ft^2)	800	*Processed data*
Depth of material (ft)	12	*Processed data*
EQUIPMENT USE		
Drilling		
Input number of drilling locations	1,050	*Processed data*
Choose drilling method from drop down menu	Direct Push	*Assumption based*
Input time spent drilling at each location (hr)	1	*Assumption based*
Input depth of wells (ft)	20	*Available data*
Choose fuel type from drop down menu	Diesel	*Available data*
Pump operetion-Head is known		
Flow rate (gpm)	95	*Processed data*
Total head (ft)	12	*Assumption based*
Number of pumps operating	2	*Available data*
Operating time for each pump (hrs)	345	*Processed data*
Pump efficiency times motor efficiency	1/2	*Assumption based*
Specific gravity	1	*Known*

Remedial Operation						Note
TRANSPORTATION						
Personnel transportation-Road						
Choose vehicle type from drop down menu	Cars					*Available data*
Fuel used	Gasoline					*Available data*
Distance traveled per trip (miles)	10					*Assumption based*
Number of trips taken	4960					*Available data*
Number of travelers	1					*Assumption based*
Personnel transportation-Air						
Distance traveled (miles)	1,850					*Available data*
Number of travelers	3					*Available data*
Number of flights taken	1					*Available data*
EQUIPMENT USE						
Earthwork						
Earthwork equipment type	Excavator	Dozer	Loader/Backhoe			*Available data*
Fuel type	Diesel	Diesel	Diesel			*Available data*
Volume of material to be removed (yd^3)	17597+13537	22878+17597	62269			*Processed data*
RESIDUAL HANDLING						
Disposal transportation-Road						
Weight of the waste transported to landfill (tons)	7	0	14	0	14	*Processed data*
Vehicle type	On-road truck					*Available data*
Fuel used	Gasoline					*Available data*
Total number of trips	11000	1785	1640	1640	1785	*Processed data*
Number of miles per trip	1/2	51	10	10	51	*Processed data*

12.3 Scenario-5c, BohusVarv remediation project.

Remedial Investigation		Note
Material Use		
Well Materials		
Number of wells	17	*Available data*
Input depth of wells (ft)	13	*Processed data*
Well diameter (in)	2	*Assumption based*
Material type	PVC	*Assumption based*
Specific material schedule	Schedule 40 PVC	*Assumption based*
TRANSPORTATION		
Personnel transportation-Road		
Choose vehicle type from drop down menu	Car	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	12	*Assumption based*
Number of trips taken	60	*Available data*
Number of travelers	3	*Assumption based*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	12	*Assumption based*
Weight of equipment transported (tons)	10	*Processed data*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	155	*Processed data*
Drilling		
Input number of drilling locations	81	*Available data*
Choose drilling method from drop down menu	Direct Push	*Assumption based*
Input time spent drilling at each location (hr)	1	*Processed data*
Input depth of wells (ft)	13	*Processed data*
Choose fuel type from drop down menu	Diesel	*Available data*
Pump operetion-Head is known		
Flow rate (gpm)	40	*Processed data*
Total head (ft)	12	*Assumption based*
Number of pumps operating	1	*Processed data*
Operating time for each pump (hrs)	56	*Processed data*
Pump efficiency times motor efficiency	1/2	*Assumption based*
Specific gravity	1	*Known*

Remedial Construction		Note
Material Use		
Well Materials		
Number of wells	1050	*Processed data*
Input depth of wells (ft)	40	*Processed data*
Well diameter (in)	12	*Processed data*
Material type	Steel	*Available data*
Specific material schedule	Schedule 40	*Assumption based*
GAC		
Weight of GAC used (lbs)	250	*Processed data*
Type of GAC	Virgin GAC	*Assumption based*
Construction Material		
Material type	HDPE Liner	*Available data*
Area of material (ft^2)	800	*Processed data*
Depth of material (ft)	12	*Processed data*
EQUIPMENT USE		
Drilling		
Input number of drilling locations	1,050	*Processed data*
Choose drilling method from drop down menu	Direct Push	*Assumption based*
Input time spent drilling at each location (hr)	1	*Assumption based*
Input depth of wells (ft)	20	*Available data*
Choose fuel type from drop down menu	Diesel	*Available data*
Pump operetion-Head is known		
Flow rate (gpm)	95	*Processed data*
Total head (ft)	12	*Assumption based*
Number of pumps operating	2	*Available data*
Operating time for each pump (hrs)	345	*Processed data*
Pump efficiency times motor efficiency	1/2	*Assumption based*
Specific gravity	1	*Known*

Remedial Operation					Note
TRANSPORTATION					
Personnel transportation-Road					
Choose vehicle type from drop down menu	Cars				*Available data*
Fuel used	Gasoline				*Available data*
Distance traveled per trip (miles)	10				*Assumption based*
Number of trips taken	4960				*Available data*
Number of travelers	1				*Assumption based*
Personnel transportation-Air					
Distance traveled (miles)	1,850				*Available data*
Number of travelers	3				*Available data*
Number of flights taken	1				*Available data*
EQUIPMENT USE					
Earthwork					
Earthwork equipment type	Excavator	Dozer	Loader/Backhoe	*Available data*	
Fuel type	Diesel	Diesel	Diesel	*Available data*	
Volume of material to be removed (yd^3)	17597+13537	22878+17597	62269	*Processed data*	
RESIDUAL HANDLING					
Disposal transportation-Rail					
Distance traveled (miles)	15,000	15,000	*Processed data*		
Weight of load (tons)	330	1	*Processed data*		
Disposal transporttaion-Road					
Weight of the waste transported to landfill (tons)	14	0	14	0	*Processed data*
Vehicle type	On-road truck				*Available data*
Fuel used	Gasoline				*Available data*
Total number of trips	5350	5350	1625	1625	*Processed data*
Number of miles per trip	0.5	0.5	10	10	*Processed data*

12.4 Scenario-5d, BohusVarv remediation project.

Remedial Investigation		Note
Material Use		
Well Materials		
Number of wells	17	*Available data*
Input depth of wells (ft)	13	*Processed data*
Well diameter (in)	2	*Assumption based*
Material type	PVC	*Assumption based*
Specific material schedule	Schedule 40 PVC	*Assumption based*
TRANSPORTATION		
Personnel transportation-Road		
Choose vehicle type from drop down menu	Car	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	12	*Assumption based*
Number of trips taken	60	*Available data*
Number of travelers	3	*Assumption based*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	12	*Assumption based*
Weight of equipment transported (tons)	10	*Processed data*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	155	*Processed data*
Drilling		
Input number of drilling locations	81	*Available data*
Choose drilling method from drop down menu	Direct Push	*Assumption based*
Input time spent drilling at each location (hr)	1	*Processed data*
Input depth of wells (ft)	13	*Processed data*
Choose fuel type from drop down menu	Diesel	*Available data*
Pump operation-Head is known		
Flow rate (gpm)	40	*Processed data*
Total head (ft)	12	*Assumption based*
Number of pumps operating	1	*Processed data*
Operating time for each pump (hrs)	56	*Processed data*
Pump efficiency times motor efficiency	1/2	*Assumption based*
Specific gravity	1	*Known*

Remedial Construction		Note
Material Use		
Well Materials		
Number of wells	1050	*Processed data*
Input depth of wells (ft)	40	*Processed data*
Well diameter (in)	12	*Processed data*
Material type	Steel	*Available data*
Specific material schedule	Schedule 40	*Assumption based*
GAC		
Weight of GAC used (lbs)	250	*Processed data*
Type of GAC	Virgin GAC	*Assumption based*
Construction Material		
Material type	HDPE Liner	*Available data*
Area of material (ft^2)	800	*Processed data*
Depth of material (ft)	12	*Processed data*
EQUIPMENT USE		
Drilling		
Input number of drilling locations	1,050	*Processed data*
Choose drilling method from drop down menu	Direct Push	*Assumption based*
Input time spent drilling at each location (hr)	1	*Assumption based*
Input depth of wells (ft)	20	*Available data*
Choose fuel type from drop down menu	Diesel	*Available data*
Pump operetion-Head is known		
Flow rate (gpm)	95	*Processed data*
Total head (ft)	12	*Assumption based*
Number of pumps operating	2	*Available data*
Operating time for each pump (hrs)	345	*Processed data*
Pump efficiency times motor efficiency	1/2	*Assumption based*
Specific gravity	1	*Known*

Remedial Operation					Note
TRANSPORTATION					
Personnel transportation-Road					
Choose vehicle type from drop down menu	Cars				*Available data*
Fuel used	Gasoline				*Available data*
Distance traveled per trip (miles)	10				*Assumption based*
Number of trips taken	4960				*Available data*
Number of travelers	1				*Assumption based*
Personnel transportation-Air					
Distance traveled (miles)	1,850				*Available data*
Number of travelers	3				*Available data*
Number of flights taken	1				*Available data*
EQUIPMENT USE					
Earthwork					
Earthwork equipment type	Excavator	Dozer	Loader/Backhoe	*Available data*	
Fuel type	Diesel	Diesel	Diesel	*Available data*	
Volume of material to be removed (yd^3)	17597+13537	22878+17597	62269	*Processed data*	
RESIDUAL HANDLING					
Disposal transportation-Water					
Distance traveled (miles)	2,400	2,400	*Processed data*		
Weight of load (tons) *	2,200	1	*Processed data*		
Disposal transportation-Road					
Weight of the waste transported to landfill (tons)	14	0	14	0	*Processed data*
Vehicle type	On-road truck				*Available data*
Fuel used	Gasoline				*Available data*
Total number of trips	5350	5350	1625	1625	*Processed data*
Number of miles per trip	0.5	0.5	10	10	*Processed data*

*** For the analysis using SMED recommended values, effect of cargo weight on consumption rate is not considered and "weight of load" was set to be 1 ton.**

13 Appendix 4,

13.1 Scenario-6, BohusVarv remediation project.

Remedial Investigation		Note
Material Use		
Well Materials		
Number of wells	17	*Available data*
Input depth of wells (ft)	13	*Processed data*
Well diameter (in)	2	*Assumption based*
Material type	PVC	*Assumption based*
Specific material schedule	schedule 40 PVC	*Assumption based*
TRANSPORTATION		
Personnel transportation-Road		
Choose vehicle type from drop down menu	Car	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	12	*Assumption based*
Number of trips taken	60	*Available data*
Number of travelers	3	*Assumption based*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	12	*Assumption based*
Weight of equipment transported (tons)	10	*Processed data*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	155	*Processed data*
Drilling		
Input number of drilling locations	81	*Available data*
Choose drilling method from drop down menu	Direct Push	*Assumption based*
Time spent drilling at each location (hr)	1	*Processed data*
Input depth of wells (ft)	13	*Processed data*
Choose fuel type from drop down menu	Diesel	*Available data*
Pump operetion-Head is known		
Flow rate (gpm)	40	*Processed data*
Total head (ft)	12	*Assumption based*
Number of pumps operating	1	*Processed data*
Operating time for each pump (hrs)	56	*Processed data*
Pump efficiency times motor efficiency	1/2	*Assumption based*
Specific gravity	1	*Known*

Remedial Construction		Note
Material Use		
Well Materials		
Number of wells	1050	*Processed data*
Input depth of wells (ft)	40	*Processed data*
Well diameter (in)	12	*Processed data*
Material type	Steel	*Available data*
Specific material schedule	Schedule 40	*Assumption based*
GAC		
Weight of GAC used (lbs)	1,000	*Processed data*
Type of GAC	Virgin GAC	*Assumption based*
Construction Material		
Material type	HDPE Liner	*Available data*
Area of material (ft^2)	320	*Available data*
Depth of material (ft)	12	*Available data*
EQUIPMENT USE		
Drilling		
Input number of drilling locations	1,050	*Processed data*
Choose drilling method from drop down menu	Direct Push	*Assumption based*
Input time spent drilling at each location (hr)	1	*Assumption based*
Input depth of wells (ft)	20	*Available data*
Choose fuel type from drop down menu	Diesel	*Assumption based*
Pump operetion-Head is known		
Flow rate (gpm)	95	*Processed data*
Total head (ft)	12	*Assumption based*
Number of pumps operating	2	*Available data*
Operating time for each pump (hrs)	1,380	*Processed data*
Pump efficiency times motor efficiency	1/2	*Assumption based*
Specific gravity	1	*Known*

Remedial Operation					Note
TRANSPORTATION					
Personnel transportation-Road					
Choose vehicle type from drop down menu	Cars	*Available data*			
Fuel used	Gasoline	*Available data*			
Distance traveled per trip (miles)	10	*Assumption based*			
Number of trips taken	4960	*Available data*			
Number of travelers	1	*Assumption based*			
Personnel transportation-Air					
Distance traveled (miles)	1,850	*Available data*			
Number of travelers	3	*Available data*			
Number of flights taken	1	*Available data*			
Equipment transportation-Road					
Fuel used	Diesel	*Available data*			
Distance traveled (miles)	40	*Assumption based*			
Weight of equipment transported (tons)	10	*Assumption based*			
EQUIPMENT USE					
Earthwork					
Earthwork equipment type	Excavator	Dozer	Loader/Backhoe	*Available data*	
Fuel type	Diesel	Diesel	Diesel	*Available data*	
Volume of material to be removed (yd^3)	70390+5414	91513+9000	116000	*Processed data*	
RESIDUAL HANDLING					
Disposal transportation-Rail					
Distance traveled (miles)	6,000	6,000	*Processed data*		
Weight of load (tons)	330	1	*Processed data*		
Disposal transportation-Road					
Weight of the waste transported to landfill (tons)	14	0	14	0	*Processed data*
Vehicle type	On-road truck				*Available data*
Fuel used	Gasoline				*Available data*
Total number of trips	10000	10000	650	650	*Processed data*
Number of miles per trip	0.5	0.5	10	10	*Processed data*
Other known onsite activities					
CO_2 emission (metric ton)	7.6E+01	*Available data*			
NOx emission (metric ton)	4.6E-04	*Available data*			
SOx emission (metric ton)	4.6E-04	*Available data*			

14 Appendix 5

14.1 Scenario-7, BohusVarv remediation project.

Remedial Investigation		Note
Material Use		
Well Materials		
Number of wells	17	*Available data*
Input depth of wells (ft)	13	*Processed data*
Well diameter (in)	2	*Assumption based*
Material type	PVC	*Assumption based*
Specific material schedule	schedule 40 PVC	*Assumption based*
TRANSPORTATION		
Personnel transportation-Road		
Choose vehicle type from drop down menu	Car	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	12	*Assumption based*
Number of trips taken	60	*Available data*
Number of travelers	3	*Assumption based*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	12	*Assumption based*
Weight of equipment transported (tons)	10	*Processed data*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	155	*Processed data*
Drilling		
Input number of drilling locations	81	*Available data*
Drilling method	Direct Push	*Assumption based*
Time spent drilling at each location (hr)	1	*Processed data*
Depth of wells (ft)	13	*Processed data*
Fuel type	Diesel	*Available data*
Pump operetion-Head is known		
Flow rate (gpm)	40	*Processed data*
Total head (ft)	12	*Assumption based*
Number of pumps operating	1	*Processed data*
Operating time for each pump (hrs)	56	*Processed data*
Pump efficiency times motor efficiency	1/2	*Assumption based*
Specific gravity	1	*Known*

Remedial Construction		Note
Material Use		
Well Materials		
Number of wells	1050	*Processed data*
Input depth of wells (ft)	40	*Processed data*
Well diameter (in)	12	*Processed data*
Material type	Steel	*Available data*
Specific material schedule	Schedule 40	*Assumption based*
EQUIPMENT USE		
Drilling		
Input number of drilling locations	1,050	*Processed data*
Drilling method	Direct Push	*Assumption based*
Time spent drilling at each location (hr)	1	*Assumption based*
Depth of wells (ft)	20	*Available data*
Fuel type	Diesel	*Available data*

Remedial Operation			Note
Material Use			
Construction Material			
Material type	Typical Cement	*Processed data*	
Area of material (ft^2)	20,500	*Processed data*	
Depth of material (ft)	10	*Processed data*	
TRANSPORTATION			
Personnel transportation-Road			
Vehicle type	Cars	*Available data*	
Fuel used	Gasoline	*Available data*	
Distance traveled per trip (miles)	10	*Assumption based*	
Number of trips taken	4960	*Available data*	
Number of travelers	1	*Assumption based*	
Personnel transportation-Air			
Distance traveled (miles)	1,850	*Available data*	
Number of travelers	3	*Available data*	
Number of flights taken	1	*Available data*	
Equipment transportation-Road			
Fuel used	Diesel		*Available data*
Distance traveled (miles)	4,375	4,375	*Processed data*
Weight of equipment transported (tons)	40	0	*Processed data*
EQUIPMENT USE			
Drilling			
Input number of drilling locations	3,900	*Processed data*	
Drilling method	Direct Push	*Assumption based*	
Time spent drilling at each location (hr)	1	*Assumption based*	
Depth of wells (ft)	13	*Processed data*	
Fuel type	Diesel	*Available data*	

15 Appendix 6

15.1 Scenario-1, Hexion remediation project.

Remedial Investigation		Note
Material Use		
Well Materials		
Number of wells	11	*Available data*
Input depth of wells (ft)	26	*Processed data*
Well diameter (in)	2	*Assumption based*
Material type	PVC	*Assumption based*
Specific material schedule	Schedule 40 PVC	*Assumption based*
TRANSPORTATION		
Personnel transportation-Road		
Vehicle type	Cars	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	4	*Assumption based*
Number of trips taken	60	*Processed data*
Number of travelers	3	*Assumption based*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	12	*Assumption based*
Weight of equipment transported (tons)	10	*Processed data*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	50	*Processed data*
Drilling		
Input number of drilling locations	19	*Available data*
Drilling method	Direct Push	*Assumption based*
Time spent drilling at each location (hr)	1	*Processed data*
Input depth of wells (ft)	13	*Processed data*
Fuel type	Diesel	*Available data*

Remedial Construction		Note
Material Use		
GAC		
Weight of GAC used (lbs)	65	*Available data*
Type of GAC	Virgin GAC	*Assumption based*
Construction Materials		
Material type from drop down menu	General Concrete	*Available data*
Area of material (ft2)	500	*Processed data*
Depth of material (ft)	2+1	*Processed data*
Material type from drop down menu	Sand	*Available data*
Applied diameter (in)	16	*Processed data*
Depth of material (ft)	10	*Processed data*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	4	*Assumption based*
Weight of equipment transported (tons)	20	*Assumption based*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	60	*Processed data*

Remedial Operation					Note
TRANSPORTATION					
Personnel transportation-Road					
Vehicle type	Cars				*Available data*
Fuel used	Gasoline				*Available data*
Distance traveled per trip (miles)	4				*Assumption based*
Number of trips taken	500				*Processed data*
Number of travelers	6				*Assumption based*
EQUIPMENT USE					
Earthwork					
Earthwork equipment type	Excavator	Dozer	Loader/Backhoe	*Available data*	
Fuel type	Diesel	Diesel	Diesel	*Processed data*	
Volume of material to be removed (yd^3)	33933	24307	68421	*Processed data*	
RESIDUAL HANDLING					
Disposal transportation-Road					
Weight of the waste transported to landfill (tons)	14	0	14	0	*Processed data*
Vehicle type	On-road truck				*Available data*
Fuel used	Gasoline				*Available data*
Total number of trips	6333	6333	2250	2250	*Processed data*
Number of miles per trip	0.40	0.40	1.20	1.20	*Processed data*

15.2 Scenario-2, Hexion remediation project.

Remedial Investigation		Note
Material Use		
Well Materials		
Number of wells	11	*Available data*
Input depth of wells (ft)	26	*Processed data*
Well diameter (in)	2	*Assumption based*
Material type	PVC	*Assumption based*
Specific material schedule	Schedule 40 PVC	*Assumption based*
TRANSPORTATION		
Personnel transportation-Road		
Vehicle type	Cars	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	4	*Assumption based*
Number of trips taken	60	*Processed data*
Number of travelers	3	*Assumption based*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	12	*Assumption based*
Weight of equipment transported (tons)	10	*Processed data*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	50	*Processed data*
Drilling		
Input number of drilling locations	19	*Available data*
Drilling method	Direct Push	*Assumption based*
Time spent drilling at each location (hr)	1	*Processed data*
Input depth of wells (ft)	13	*Processed data*
Fuel type	Diesel	*Available data*

Remedial Construction		Note
Material Use		
GAC		
Weight of GAC used (lbs)	65	*Available data*
Type of GAC	Virgin GAC	*Assumption based*
Construction Materials		
Material type from drop down menu	General Concrete	*Available data*
Area of material (ft2)	500	*Processed data*
Depth of material (ft)	2+1	*Processed data*
Material type from drop down menu	Sand	*Available data*
Applied diameter (in)	16	*Processed data*
Depth of material (ft)	10	*Processed data*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	4	*Assumption based*
Weight of equipment transported (tons)	20	*Assumption based*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	60	*Processed data*

Remedial Operation					Note
TRANSPORTATION					
Personnel transportation-Road					
Vehicle type	Cars				*Available data*
Fuel used	Gasoline				*Available data*
Distance traveled per trip (miles)	4				*Assumption based*
Number of trips taken	500				*Processed data*
Number of travelers	6				*Assumption based*
EQUIPMENT USE					
Earthwork					
Earthwork equipment type	Excavator	Dozer	Loader/Backhoe	*Available data*	
Fuel type	Diesel	Diesel	Diesel	*Processed data*	
Volume of material to be removed (yd^3)	33933	24307	68421	*Processed data*	
RESIDUAL HANDLING					
Disposal transportation-Road					
Weight of the waste transported to landfill (tons)	14	0	14	0	*Processed data*
Vehicle type	On-road truck				*Available data*
Fuel used	Gasoline				*Available data*
Total number of trips	6333	6333	2250	2250	*Processed data*
Number of miles per trip	0.40	0.40	63.00	63.00	*Processed data*

16 Appendix 7

16.1 Scenario-3, Hexion remediation project.

Remedial Investigation		Note
Material Use		
Well Materials		
Number of wells	11	*Available data*
Input depth of wells (ft)	26	*Processed data*
Well diameter (in)	2	*Assumption based*
Material type	PVC	*Assumption based*
Specific material schedule	Schedule 40 PVC	*Assumption based*
TRANSPORTATION		
Personnel transportation-Road		
Vehicle type	Cars	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	4	*Assumption based*
Number of trips taken	60	*Processed data*
Number of travelers	3	*Assumption based*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	12	*Assumption based*
Weight of equipment transported (tons)	10	*Processed data*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	50	*Processed data*
Drilling		
Input number of drilling locations	19	*Available data*
Drilling method	Direct Push	*Assumption based*
Time spent drilling at each location (hr)	1	*Processed data*
Input depth of wells (ft)	13	*Processed data*
Fuel type	Diesel	*Available data*

Remedial Construction		Note
Material Use		
GAC		
Weight of GAC used (lbs)	65	*Available data*
Type of GAC	Virgin GAC	*Assumption based*
Construction Materials		
Material type from drop down menu	General Concrete	*Available data*
Area of material (ft2)	500	*Processed data*
Depth of material (ft)	2+1	*Processed data*
Material type from drop down menu	Sand	*Available data*
Applied diameter (in)	16	*Processed data*
Depth of material (ft)	10	*Processed data*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	4	*Assumption based*
Weight of equipment transported (tons)	20	*Assumption based*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	60	*Processed data*

Remedial Operation				Note
TRANSPORTATION				
Personnel transportation-Road				
Vehicle type	Cars			*Available data*
Fuel used	Gasoline			*Available data*
Distance traveled per trip (miles)	4			*Assumption based*
Number of trips taken	500			*Processed data*
Number of travelers	6			*Assumption based*
EQUIPMENT USE				
Earthwork				
Earthwork equipment type	Excavator	Dozer	Loader/Backhoe	*Available data*
Fuel type	Diesel	Diesel	Diesel	*Processed data*
Volume of material to be removed (yd^3)	33933	24307	68421	*Processed data*
Disposal transportation-Rail				
Distance traveled (miles)	14,800	14,800	*Processed data*	
Weight of load (tons)	330	1	*Processed data*	
Disposal transportation-Road				
Weight of the waste transported to landfill (tons)	14	0	*Processed data*	
Vehicle type	On-road truck		*Available data*	
Fuel used	Gasoline		*Available data*	
Total number of trips	6333	6333	*Processed data*	
Number of miles per trip	0.40	0.40	*Processed data*	

16.2 Scenario-4, Hexion remediation project.

Remedial Investigation		Note
Material Use		
Well Materials		
Number of wells	11	*Available data*
Input depth of wells (ft)	26	*Processed data*
Well diameter (in)	2	*Assumption based*
Material type	PVC	*Assumption based*
Specific material schedule	Schedule 40 PVC	*Assumption based*
TRANSPORTATION		
Personnel transportation-Road		
Vehicle type	Cars	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	4	*Assumption based*
Number of trips taken	60	*Processed data*
Number of travelers	3	*Assumption based*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	12	*Assumption based*
Weight of equipment transported (tons)	10	*Processed data*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	50	*Processed data*
Drilling		
Input number of drilling locations	19	*Available data*
Drilling method	Direct Push	*Assumption based*
Time spent drilling at each location (hr)	1	*Processed data*
Input depth of wells (ft)	13	*Processed data*
Fuel type	Diesel	*Available data*

Remedial Construction		Note
Material Use		
GAC		
Weight of GAC used (lbs)	65	*Available data*
Type of GAC	Virgin GAC	*Assumption based*
Construction Materials		
Material type from drop down menu	General Concrete	*Available data*
Area of material (ft2)	500	*Processed data*
Depth of material (ft)	2+1	*Processed data*
Material type from drop down menu	Sand	*Available data*
Applied diameter (in)	16	*Processed data*
Depth of material (ft)	10	*Processed data*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	4	*Assumption based*
Weight of equipment transported (tons)	20	*Assumption based*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	60	*Processed data*

Remedial Operation					Note
TRANSPORTATION					
Personnel transportation-Road					
Vehicle type	Cars				*Available data*
Fuel used	Gasoline				*Available data*
Distance traveled per trip (miles)	4				*Assumption based*
Number of trips taken	500				*Processed data*
Number of travelers	6				*Assumption based*
EQUIPMENT USE					
Earthwork					
Earthwork equipment type	Excavator	Dozer	Loader/Backhoe	*Available data*	
Fuel type	Diesel	Diesel	Diesel	*Processed data*	
Volume of material to be removed (yd^3)	33933	24307	68421	*Processed data*	
RESIDUAL HANDLING					
Disposal transportation-Water					
Distance traveled (miles)	2,346	2,346	*Processed data*		
Weight of load (tons) *	2,200	1	*Processed data*		
Disposal transportation-Road					
Weight of the waste transported to landfill (tons)	14	0	14	0	*Processed data*
Vehicle type	On-road truck				*Available data*
Fuel used	Gasoline				*Available data*
Total number of trips	6333	6333	2250	2250	*Processed data*
Number of miles per trip	0.40	0.40	13	13	*Processed data*

*** For the analysis using SMED recommended values, effect of cargo weight on consumption rate is not considered and "weight of load" was set to be 1 ton.**

17 Appendix 8

17.1 Scenario-5, Hexion remediation project.

Remedial Investigation		Note
Material Use		
Well Materials		
Number of wells	11	*Available data*
Input depth of wells (ft)	26	*Processed data*
Well diameter (in)	2	*Assumption based*
Material type	PVC	*Assumption based*
Specific material schedule	Schedule 40 PVC	*Assumption based*
TRANSPORTATION		
Personnel transportation-Road		
Vehicle type	Cars	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	4	*Assumption based*
Number of trips taken	60	*Processed data*
Number of travelers	3	*Assumption based*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	12	*Assumption based*
Weight of equipment transported (tons)	10	*Processed data*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	50	*Processed data*
Drilling		
Input number of drilling locations	19	*Available data*
Drilling method	Direct Push	*Assumption based*
Time spent drilling at each location (hr)	1	*Processed data*
Input depth of wells (ft)	13	*Processed data*
Fuel type	Diesel	*Available data*

Remedial Construction		Note
Material Use		
GAC		
Weight of GAC used (lbs)	65	*Available data*
Type of GAC	Virgin GAC	*Assumption based*
Construction Materials		
Material type from drop down menu	General Concrete	*Available data*
Area of material (ft2)	500	*Processed data*
Depth of material (ft)	2+1	*Processed data*
Material type from drop down menu	Sand	*Available data*
Applied diameter (in)	16	*Processed data*
Depth of material (ft)	10	*Processed data*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	4	*Assumption based*
Weight of equipment transported (tons)	20	*Assumption based*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	60	*Processed data*

Remedial Operation				Note
Material Use				
Well Materials				
Number of wells	180			*Processed data*
Input depth of wells (ft)	26			*Processed data*
Well diameter (in)	4			*Processed data*
Material type	Steel			*Available data*
Specific material schedule	Schedule 40 Steel			*Assumption based*
TRANSPORTATION				
Personnel transportation-Road				
Vehicle type	Cars			*Available data*
Fuel used	Gasoline			*Available data*
Distance traveled per trip (miles)	4			*Assumption based*
Number of trips taken	500			*Available data*
Number of travelers	6			*Assumption based*
Equipment transportation-Road				
Fuel used	Diesel			*Available data*
Distance traveled (miles)	20			*Assumption based*
Weight of equipment transported (tons)	20			*Assumption based*
Electricity usage				
Equipment electrical usage, if known (KWh)	100000			*Available data*
Electricity region	Swedish elmix			*Available data*
EQUIPMENT USE				
Earthwork				
Earthwork equipment type	Excavator	Dozer	Loader/Backhoe	*Available data*
Fuel type	Diesel	Diesel	Diesel	*Available data*
Volume of material to be removed (yd^3)	23545	10000	34348	*Processed data*
RESIDUAL HANDLING				
Disposal transportation-Rail				
Distance traveled (miles)	6,583	6,583	*Processed data*	
Weight of load (tons)	330	0	*Processed data*	
Disposal transportation-Road				
Weight of the waste transported to landfill (tons)	14	0	*Processed data*	
Vehicle type	On-road truck		*Available data*	
Fuel used	Gasoline		*Available data*	
Total number of trips	3833	3833	*Processed data*	
Number of miles per trip	0.40	0.40	*Processed data*	

Remedial Monitoring		Note
TRANSPORTATION		
Personnel transportation-Road		
Vehicle type	Cars	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	5	*Assumption based*
Number of trips taken	240	*Available data*
Number of travelers	2	*Assumption based*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	10	*Assumption based*
Weight of equipment transported (tons)	5	*Assumption based*

18 Appendix 9

18.1 Scenario-6a, Hexion remediation project.

Remedial Investigation		Note
Material Use		
Well Materials		
Number of wells	11	*Available data*
Input depth of wells (ft)	26	*Processed data*
Well diameter (in)	2	*Assumption based*
Material type	PVC	*Assumption based*
Specific material schedule	Schedule 40 PVC	*Assumption based*
TRANSPORTATION		
Personnel transportation-Road		
Vehicle type	Cars	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	4	*Assumption based*
Number of trips taken	60	*Processed data*
Number of travelers	3	*Assumption based*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	12	*Assumption based*
Weight of equipment transported (tons)	10	*Processed data*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	50	*Processed data*
Drilling		
Input number of drilling locations	19	*Available data*
Drilling method	Direct Push	*Assumption based*
Time spent drilling at each location (hr)	1	*Processed data*
Input depth of wells (ft)	13	*Processed data*
Fuel type	Diesel	*Available data*

Remedial Construction		Note
Material Use		
GAC		
Weight of GAC used (lbs)	65	*Available data*
Type of GAC	Virgin GAC	*Assumption based*
Construction Materials		
Material type from drop down menu	General Concrete	*Available data*
Area of material (ft2)	500	*Processed data*
Depth of material (ft)	2+1	*Processed data*
Material type from drop down menu	Sand	*Available data*
Applied diameter (in)	16	*Processed data*
Depth of material (ft)	10	*Processed data*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	4	*Assumption based*
Weight of equipment transported (tons)	20	*Assumption based*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	60	*Processed data*

Remedial Operation					Note
TRANSPORTATION					
Personnel transportation-Road					
Vehicle type	Cars				*Available data*
Fuel used	Gasoline				*Available data*
Distance traveled per trip (miles)	4				*Assumption based*
Number of trips taken	500				*Processed data*
Number of travelers	6				*Assumption based*
EQUIPMENT USE					
Earthwork					
Earthwork equipment type	Excavator	Dozer	Loader/Backhoe		*Available data*
Fuel type	Diesel	Diesel	Diesel		*Processed data*
Volume of material to be removed (yd^3)	33933	24307	68421		*Processed data*
RESIDUAL HANDLING					
Disposal transportation-Water					
Distance traveled (miles)	1,780	1,780			*Processed data*
Weight of load (tons) *	2,200	1			*Processed data*
RESIDUAL HANDLING					
Disposal transportation-Road					
Weight of the waste transported to landfill (tons)	14	0	14	0	*Processed data*
Vehicle type	On-road truck				*Available data*
Fuel used	Gasoline				*Available data*
Total number of trips	6333	6333	1708	1708	*Processed data*
Number of miles per trip	0.40	0.40	13.00	13.00	*Processed data*
Other known onsite activities					
CO_2 emission (metric ton)	1.3E+01				*Available data*
NOx emission (metric ton)	7.6E-05				*Available data*
SOx emission (metric ton)	7.6E-05				*Available data*

*** For the analysis using SMED recommended values, effect of cargo weight on consumption rate is not considered and “weight of load” was set to be 1 ton.**

18.2 Scenario-6b, Hexion remediation project.

Remedial Investigation		Note
Material Use		
Well Materials		
Number of wells	11	*Available data*
Input depth of wells (ft)	26	*Processed data*
Well diameter (in)	2	*Assumption based*
Material type	PVC	*Assumption based*
Specific material schedule	Schedule 40 PVC	*Assumption based*
TRANSPORTATION		
Personnel transportation-Road		
Vehicle type	Cars	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	4	*Assumption based*
Number of trips taken	60	*Processed data*
Number of travelers	3	*Assumption based*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	12	*Assumption based*
Weight of equipment transported (tons)	10	*Processed data*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	50	*Processed data*
Drilling		
Input number of drilling locations	19	*Available data*
Drilling method	Direct Push	*Assumption based*
Time spent drilling at each location (hr)	1	*Processed data*
Input depth of wells (ft)	13	*Processed data*
Fuel type	Diesel	*Available data*

Remedial Construction		Note
Material Use		
GAC		
Weight of GAC used (lbs)	65	*Available data*
Type of GAC	Virgin GAC	*Assumption based*
Construction Materials		
Material type from drop down menu	General Concrete	*Available data*
Area of material (ft2)	500	*Processed data*
Depth of material (ft)	2+1	*Processed data*
Material type from drop down menu	Sand	*Available data*
Applied diameter (in)	16	*Processed data*
Depth of material (ft)	10	*Processed data*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	4	*Assumption based*
Weight of equipment transported (tons)	20	*Assumption based*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	60	*Processed data*

Remedial Operation					Note
TRANSPORTATION					
Personnel transportation-Road					
Vehicle type	Cars				*Available data*
Fuel used	Gasoline				*Available data*
Distance traveled per trip (miles)	4				*Assumption based*
Number of trips taken	500				*Processed data*
Number of travelers	6				*Assumption based*
EQUIPMENT USE					
Earthwork					
Earthwork equipment type	Excavator	Dozer	Loader/Backhoe	*Available data*	
Fuel type	Diesel	Diesel	Diesel	*Processed data*	
Volume of material to be removed (yd^3)	33933	24307	68421	*Processed data*	
RESIDUAL HANDLING					
Disposal transportation-Road					
Weight of the waste transported to landfill (tons)	14	0	14	0	*Processed data*
Vehicle type	On-road truck				*Available data*
Fuel used	Gasoline				*Available data*
Total number of trips	6333	6333	1708	1708	*Processed data*
Number of miles per trip	0.40	0.40	63	63	*Processed data*
Other known onsite activities					
CO_2 emission (metric ton)	1.3E+01				*Available data*
NOx emission (metric ton)	7.6E-05				*Available data*
SOx emission (metric ton)	7.6E-05				*Available data*

18.3 Scenario-6c, Hexion remediation project.

Remedial Investigation		Note
Material Use		
Well Materials		
Number of wells	11	*Available data*
Input depth of wells (ft)	26	*Processed data*
Well diameter (in)	2	*Assumption based*
Material type	PVC	*Assumption based*
Specific material schedule	Schedule 40 PVC	*Assumption based*
TRANSPORTATION		
Personnel transportation-Road		
Vehicle type	Cars	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	4	*Assumption based*
Number of trips taken	60	*Processed data*
Number of travelers	3	*Assumption based*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	12	*Assumption based*
Weight of equipment transported (tons)	10	*Processed data*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	50	*Processed data*
Drilling		
Input number of drilling locations	19	*Available data*
Drilling method	Direct Push	*Assumption based*
Time spent drilling at each location (hr)	1	*Processed data*
Input depth of wells (ft)	13	*Processed data*
Fuel type	Diesel	*Available data*

Remedial Construction		Note
Material Use		
GAC		
Weight of GAC used (lbs)	65	*Available data*
Type of GAC	Virgin GAC	*Assumption based*
Construction Materials		
Material type from drop down menu	General Concrete	*Available data*
Area of material (ft2)	500	*Processed data*
Depth of material (ft)	2+1	*Processed data*
Material type from drop down menu	Sand	*Available data*
Applied diameter (in)	16	*Processed data*
Depth of material (ft)	10	*Processed data*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	4	*Assumption based*
Weight of equipment transported (tons)	20	*Assumption based*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	60	*Processed data*

Remedial Operation				Note
TRANSPORTATION				
Personnel transportation-Road				
Vehicle type	Cars	*Available data*		
Fuel used	Gasoline	*Available data*		
Distance traveled per trip (miles)	4	*Assumption based*		
Number of trips taken	500	*Processed data*		
Number of travelers	6	*Assumption based*		
EQUIPMENT USE				
Earthwork				
Earthwork equipment type	Excavator	Dozer	Loader/Backhoe	*Available data*
Fuel type	Diesel	Diesel	Diesel	*Processed data*
Volume of material to be removed (yd^3)	33933	24307	68421	*Processed data*
RESIDUAL HANDLING				
Disposal transportation-Rail				
Distance traveled (miles)	11,247	11,247	*Processed data*	
Weight of load (tons)	330	1	*Processed data*	
Disposal transportation-Road				
Weight of the waste transported to landfill (tons)	14	0	*Processed data*	
Vehicle type	On-road truck		*Available data*	
Fuel used	Gasoline		*Available data*	
Total number of trips	6333	6333	*Processed data*	
Number of miles per trip	0.40	0.40	*Processed data*	
Other known onsite activities				
CO_2 emission (metric ton)	1.3E+01	*Available data*		
NOx emission (metric ton)	7.6E-05	*Available data*		
SOx emission (metric ton)	7.6E-05	*Available data*		

19 Appendix 10

19.1 Scenario-7, Hexion remediation project.

Remedial Investigation		Note
Material Use		
Well Materials		
Number of wells	11	*Available data*
Input depth of wells (ft)	26	*Processed data*
Well diameter (in)	2	*Assumption based*
Material type	PVC	*Assumption based*
Specific material schedule	Schedule 40 PVC	*Assumption based*
TRANSPORTATION		
Personnel transportation-Road		
Vehicle type	Cars	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	4	*Assumption based*
Number of trips taken	60	*Processed data*
Number of travelers	3	*Assumption based*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	12	*Assumption based*
Weight of equipment transported (tons)	10	*Processed data*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	50	*Processed data*
Drilling		
Input number of drilling locations	19	*Available data*
Drilling method	Direct Push	*Assumption based*
Time spent drilling at each location (hr)	1	*Processed data*
Input depth of wells (ft)	13	*Processed data*
Fuel type	Diesel	*Available data*

Remedial Construction		Note
Material Use		
GAC		
Weight of GAC used (lbs)	65	*Available data*
Type of GAC	Virgin GAC	*Assumption based*
Construction Materials		
Material type from drop down menu	General Concrete	*Available data*
Area of material (ft2)	500	*Processed data*
Depth of material (ft)	2+1	*Processed data*
Material type from drop down menu	Sand	*Available data*
Applied diameter (in)	16	*Processed data*
Depth of material (ft)	10	*Processed data*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	4	*Assumption based*
Weight of equipment transported (tons)	20	*Assumption based*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	60	*Processed data*

Remedial Operation					Note
TRANSPORTATION					
Personnel transportation-Road					
Choose vehicle type from drop down menu	Cars	*Available data*			
Fuel used	Gasoline	*Available data*			
Distance traveled per trip (miles)	4	*Assumption based*			
Number of trips taken	500	*Processed data*			
Number of travelers	6	*Assumption based*			
EQUIPMENT USE					
Earthwork					
Earthwork equipment type	Excavator	Dozer	Loader/Backhoe	*Available data*	
Fuel type	Diesel	Diesel	Diesel	*Processed data*	
Volume of material to be removed (yd^3)	33933	24307	68421	*Processed data*	
RESIDUAL HANDLING					
Disposal transportation-Road					
Weight of the waste transported to landfill (tons)	14	0	14	0	*Processed data*
Vehicle type	On-road truck				*Available data*
Fuel used	Gasoline				*Available data*
Total number of trips	6333	6333	2250	2250	*Processed data*
Number of miles per trip	0.40	0.40	1.20	1.20	*Processed data*
TRANSPORTATION					
Personnel transportation-Road					
Distance traveled per trip (miles)	10	*Assumption based*			
Number of trips taken	4960	*Available data*			
Number of travelers	1	*Assumption based*			
Equipment transportation-Road					
Fuel used	Diesel	*Available data*			
Distance traveled (miles)	40	*Assumption based*			
Weight of equipment transported (tons)	10	*Assumption based*			
EQUIPMENT USE					
Earthwork					
Earthwork equipment type	Excavator	Dozer	Loader/Backhoe	*Available data*	
Fuel type	Diesel	Diesel	Diesel	*Available data*	
Volume of material to be removed (yd^3)	62327+47000	78000+60000	158500	*Processed data*	
RESIDUAL HANDLING					
Disposal transportation-Rail					
Distance traveled (miles)	2,613	2,613	*Processed data*		
Weight of load (tons)	330	1	*Processed data*		
Disposal transportation-Road					
Weight of the waste transported to landfill (tons)	14	0	14	0	*Processed data*
Vehicle type	On-road truck				*Available data*
Fuel used	Gasoline				*Available data*
Total number of trips	19100	19100	2000	2000	*Processed data*
Number of miles per trip	0.40	0.40	1.20	1.20	*Processed data*

20 Appendix 11,

20.1 Scenario-8, Hexion remediation project.

Remedial Investigation		Note
Material Use		
Well Materials		
Number of wells	11	*Available data*
Input depth of wells (ft)	26	*Processed data*
Well diameter (in)	2	*Assumption based*
Material type	PVC	*Assumption based*
Specific material schedule	Schedule 40 PVC	*Assumption based*
TRANSPORTATION		
Personnel transportation-Road		
Vehicle type	Cars	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	4	*Assumption based*
Number of trips taken	60	*Processed data*
Number of travelers	3	*Assumption based*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	12	*Assumption based*
Weight of equipment transported (tons)	10	*Processed data*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	50	*Processed data*
Drilling		
Input number of drilling locations	19	*Available data*
Drilling method	Direct Push	*Assumption based*
Time spent drilling at each location (hr)	1	*Processed data*
Input depth of wells (ft)	13	*Processed data*
Fuel type	Diesel	*Available data*

Remedial Construction		Note
Material Use		
GAC		
Weight of GAC used (lbs)	65	*Available data*
Type of GAC	Virgin GAC	*Assumption based*
Construction Materials		
Material type from drop down menu	General Concrete	*Available data*
Area of material (ft2)	500	*Processed data*
Depth of material (ft)	2+1	*Processed data*
Material type from drop down menu	Sand	*Available data*
Applied diameter (in)	16	*Processed data*
Depth of material (ft)	10	*Processed data*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	4	*Assumption based*
Weight of equipment transported (tons)	20	*Assumption based*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	60	*Processed data*

Remedial Operation		Note
Material Use		
Well Materials		
Number of wells	500	*Processed data*
Input depth of wells (ft)	26	*Processed data*
Well diameter (in)	2	*Assumption based*
Material type	Steel	*Assumption based*
Specific material schedule	Schedule 40 PVC	*Assumption based*
Construction Materials		
Material type from drop down menu	Typical Cement	*Available data*
Area of material (ft2)	11,522	*Processed data*
Depth of material (ft)	10	*Processed data*
TRANSPORTATION		
Personnel transportation-Road		
Choose vehicle type from drop down menu	Cars	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	4	*Assumption based*
Number of trips taken	500	*Processed data*
Number of travelers	6	*Assumption based*

Equipment transportation-Road				
Fuel used	Gasoline	Gasoline	Gasoline	*Available data*
Distance traveled (miles)	20	2500	2500	*Assumption based*
Weight of equipment transported (tons)	10	40	0	*Assumption based*
EQUIPMENT USE				
Earthwork				
Earthwork equipment type	Excavator	Dozer	Loader/Backhoe	*Available data*
Fuel type	Diesel	Diesel	Diesel	*Processed data*
Volume of material to be removed (yd^3)	23545	10800	21606	*Processed data*

Drilling		
Input number of drilling locations	500	*Processed data*
Drilling method	Air Rotary	*Assumption based*
Time spent drilling at each location (hr)	1	*Processed data*
Input depth of wells (ft)	16	*Processed data*
Fuel type	Diesel	*Available data*

RESIDUAL HANDLING Disposal transportation-Road					
Weight of the waste transported to landfill (tons)	14	0	14	0	*Processed data*
Vehicle type	On-road truck				*Available data*
Fuel used	Gasoline				*Available data*
Total number of trips	6333	6333	2250	2250	*Processed data*
Number of miles per trip	0.40	0.40	1.20	1.20	*Processed data*

RESIDUAL HANDLING Disposal transportation-Rail			
Distance traveled (miles)	6,583	6,583	*Processed data*
Weight of load (tons)	330	0	*Processed data*

21 Appendix 12,

21.1 Scenario-9, Hexion remediation project.

Remedial Investigation		Note
Material Use		
Well Materials		
Number of wells	11	*Available data*
Input depth of wells (ft)	26	*Processed data*
Well diameter (in)	2	*Assumption based*
Material type	PVC	*Assumption based*
Specific material schedule	Schedule 40 PVC	*Assumption based*
TRANSPORTATION		
Personnel transportation-Road		
Vehicle type	Cars	*Available data*
Fuel used	Gasoline	*Available data*
Distance traveled per trip (miles)	4	*Assumption based*
Number of trips taken	60	*Processed data*
Number of travelers	3	*Assumption based*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	12	*Assumption based*
Weight of equipment transported (tons)	10	*Processed data*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	50	*Processed data*
Drilling		
Input number of drilling locations	19	*Available data*
Drilling method	Direct Push	*Assumption based*
Time spent drilling at each location (hr)	1	*Processed data*
Input depth of wells (ft)	13	*Processed data*
Fuel type	Diesel	*Available data*

Remedial Construction		Note
Material Use		
GAC		
Weight of GAC used (lbs)	65	*Available data*
Type of GAC	Virgin GAC	*Assumption based*
Construction Materials		
Material type from drop down menu	General Concrete	*Available data*
Area of material (ft2)	500	*Processed data*
Depth of material (ft)	2+1	*Processed data*
Material type from drop down menu	Sand	*Available data*
Applied diameter (in)	16	*Processed data*
Depth of material (ft)	10	*Processed data*
Equipment transportation-Road		
Fuel used	Diesel	*Available data*
Distance traveled (miles)	4	*Assumption based*
Weight of equipment transported (tons)	20	*Assumption based*
EQUIPMENT USE		
Earthwork		
Earthwork equipment type	Excavator	*Available data*
Fuel type	Diesel	*Available data*
Volume of material to be removed (yd^3)	60	*Processed data*

Remedial Operation				Note
TRANSPORTATION				
Personnel transportation-Road				
Vehicle type	Cars			*Available data*
Fuel used	Gasoline			*Available data*
Distance traveled per trip (miles)	4			*Assumption based*
Number of trips taken	500			*Processed data*
Number of travelers	6			*Assumption based*
Equipment transportation-Road				
Fuel used	Diesel			*Available data*
Distance traveled (miles)	20			*Assumption based*
Weight of equipment transported (tons)	10			*Assumption based*
EQUIPMENT USE				
Earthwork				
Earthwork equipment type	Excavator	Dozer	Loader/Backhoe	*Available data*
Fuel type	Diesel	Diesel	Diesel	*Processed data*
Volume of material to be removed (yd^3)	62327+16117	20900+27233	158500	*Processed data*
RESIDUAL HANDLING				
Disposal transportation-Rail				
Distance traveled (miles)	16,843	16,843	*Processed data*	
Weight of load (tons)	330	1	*Processed data*	
Disposal transportation-Road				
Weight of the waste transported to landfill (tons)	14	0	*Processed data*	
Vehicle type	On-road truck		*Available data*	
Fuel used	Gasoline		*Available data*	
Total number of trips	19100	19100	*Processed data*	
Number of miles per trip	0.40	0.40	*Processed data*	
Other known onsite activities				
CO_2 emission (metric ton)	1.3E+01	*Available data*		
NOx emission (metric ton)	7.6E-05	*Available data*		
SOx emission (metric ton)	7.6E-05	*Available data*		

22 Appendix 13

22.1 Scenario-1, 2 and 5, SRT input data, Hexion

SRT -Kikåstappen		
CONTAMINATED MASS		
Soil Source Input*		
Area of effected soil (ft^2)	110,250	*Processed data*
Depth to Top of the Affected soil (ft)	0	*Available data*
Depth to Bottom of the Affected soil (ft)	9	*Available data*
Depth of Groundwater (ft)	5	*Available data*
Natural attenuation		
Calculation of natural resource service	Disabled	-
TRANSPORTATION		
Personnel transportation-Air		
Distance traveled (miles)	1,850	*Available data*
Personnel transportation-Road		
Distance traveled by site workers one-way (miles)	5	*Assumption based*
Number of trips during construction	1,550	*Processed data*
Number of trips after construction	2	*Assumption based*
Distance to disposal one-way (miles)	1.2**	*Processed data*
Type of disposal	Hazardous	*Available data*
* The amount of soil is directly calculated since no clean soil fill is considered		
** Direct distance from landfill site is considered		

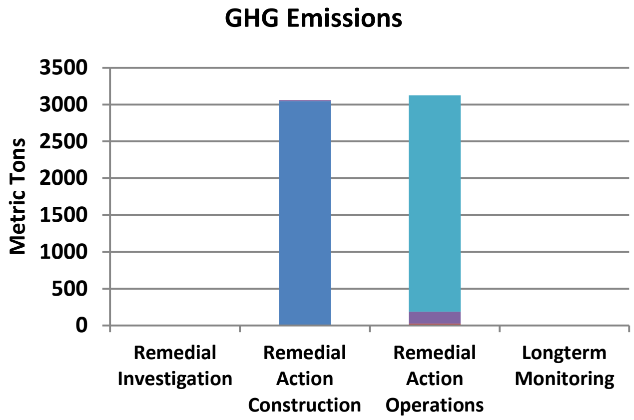
SRT -Ragnsell		
CONTAMINATED MASS		
Soil Source Input*		
Area of effected soil (ft^2)	110,250	*Processed data*
Depth to Top of the Affected soil (ft)	0	*Available data*
Depth to Bottom of the Affected soil (ft)	9	*Available data*
Depth of Groundwater (ft)	5	*Available data*
Natural attenuation		
Calculation of natural resource service	Disabled	-
TRANSPORTATION		
Personnel transportation-Air		
Distance traveled (miles)	1,850	*Available data*
Personnel transportation-Road		
Distance traveled by site workers one-way (miles)	5	*Assumption based*
Number of trips during construction	1,550	*Processed data*
Number of trips after construction	2	*Assumption based*
Distance to disposal one-way (miles)	28.23**	*Processed data*
Type of disposal	Hazardous	*Available data*
* The amount of soil is directly calculated since no clean soil fill is considered		
** Direct distance from landfill site is considered		

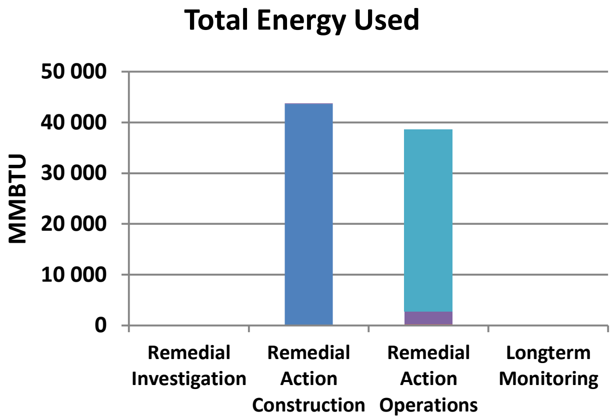
SRT -Vapour extraction		
CONTAMINATED MASS		
Soil Source Input*		
Area of effected soil (ft^2)	110,250	*Processed data*
Depth to Top of the Affected soil (ft)	0	*Available data*
Depth to Bottom of the Affected soil (ft)	9	*Available data*
Depth of Groundwater (ft)	5	*Available data*
Natural attenuation		
Calculation of natural resource service	Disabled	-
TRANSPORTATION		
Personnel transportation-Air		
Distance traveled (miles)	1,850	*Available data*
Personnel transportation-Road		
Distance traveled by site workers one-way (miles)	5	*Assumption based*
Number of trips during construction	1,550	*Processed data*
Number of trips after construction	2	*Assumption based*
Treatment process		
Duration (years)	1	Processed data
Vapor treatment method	Activated Carbon	*Assumption based*
Efficiancy	1.0	*Assumption based*
* The amount of soil is directly calculated since no clean soil fill is considered		

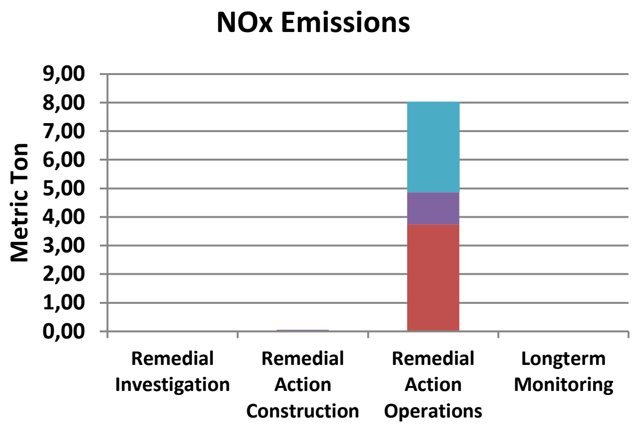
23 Appendix 14

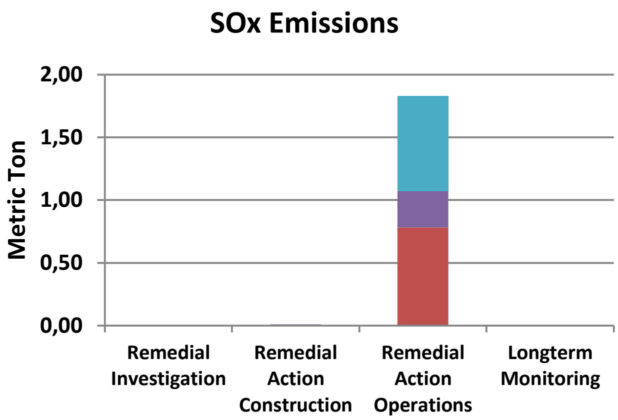
23.1 Scenario-1, BohusVarv:

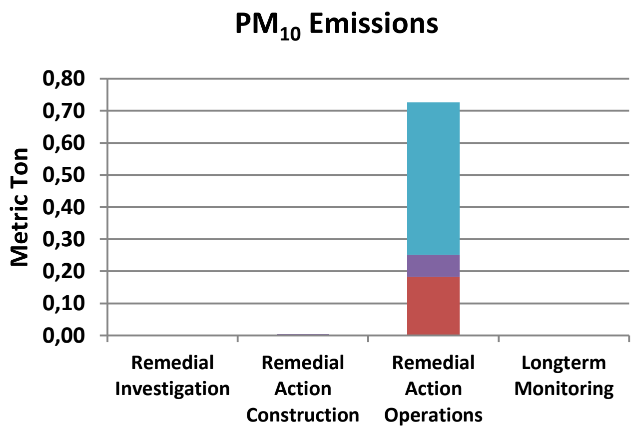
23.1.1 Full excavation & landfilling at Sita

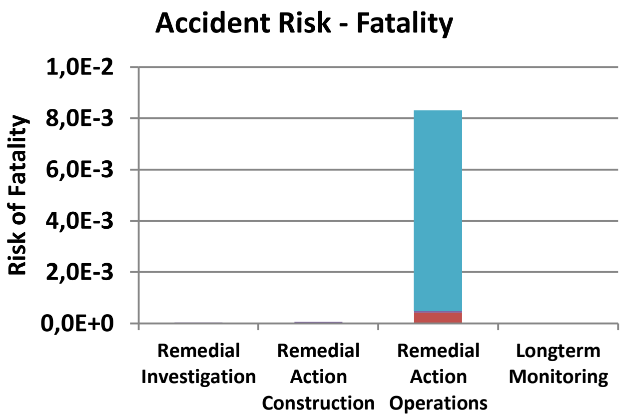


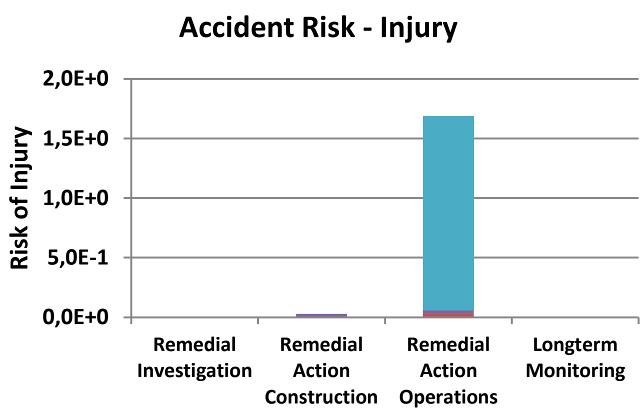


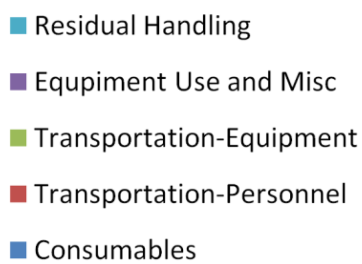








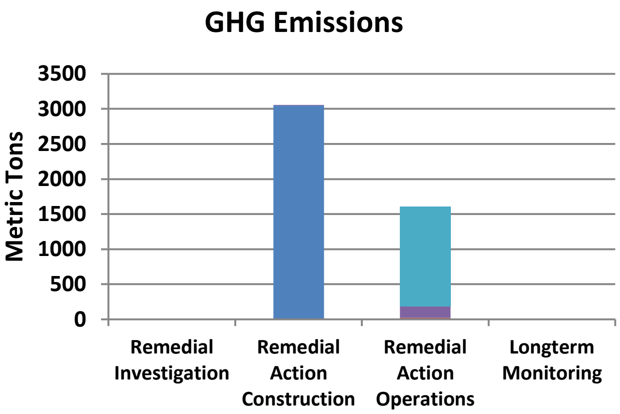


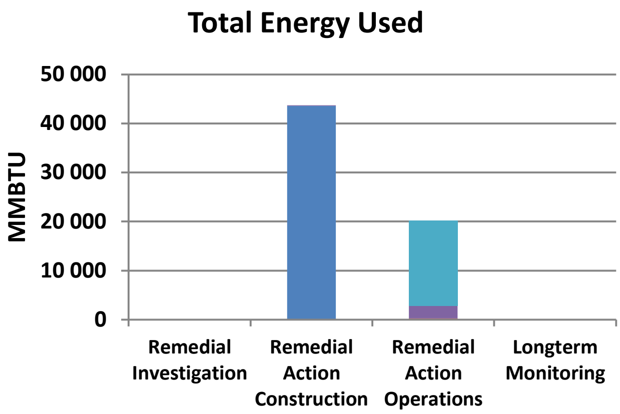


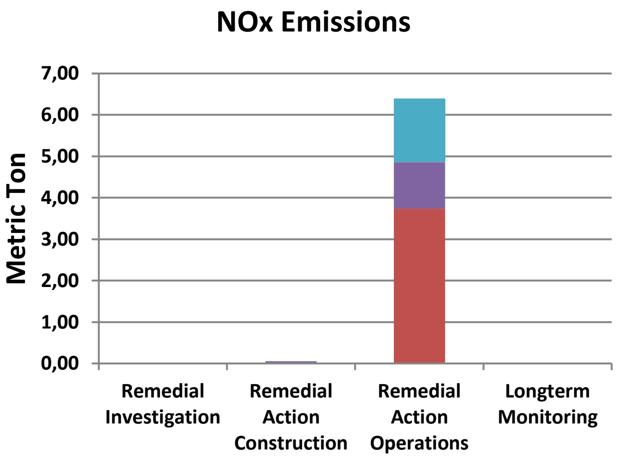
Phase	Activities	GHG Emissions (metric ton)	Total energy Used (MMBTU)	Water Consumption (gallons)	NOx emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.21	4.4E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.34	3.7E+00	NA	2.7E-04	8.9E-05	6.0E-05	1.8E-05	1.3E-03
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.73	1.0E+01	5.5E+00	4.3E-03	7.6E-04	3.2E-04	5.0E-06	2.1E-03
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	1.30	1.84E+01	5.49E+00	4.58E-03	8.48E-04	3.86E-04	2.33E-05	3.45E-03
Remedial Action Construction	Consumables	3,048.79	4.4E+04	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	9.26	1.3E+02	5.9E+02	5.2E-02	9.1E-03	3.9E-03	6.4E-05	2.7E-02
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	3,058.05	4.37E+04	5.93E+02	5.23E-02	9.06E-03	3.86E-03	6.35E-05	2.73E-02
Remedial Action Operations	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	25.17	2.7E+02	NA	3.7E+00	7.8E-01	1.8E-01	4.2E-04	3.0E-02
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	161.14	2.5E+03	0.0E+00	1.1E+00	2.9E-01	6.9E-02	6.6E-05	2.8E-02
	Residual Handling	2,936.29	3.6E+04	NA	3.2E+00	7.6E-01	4.7E-01	7.8E-03	1.6E+00
	Sub-Total	3,122.60	3.87E+04	0.00E+00	8.02E+00	1.83E+00	7.25E-01	8.30E-03	1.69E+00
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		6.2E+03	8.2E+04	6.0E+02	8.1E+00	1.8E+00	7.3E-01	8.4E-03	1.7E+00

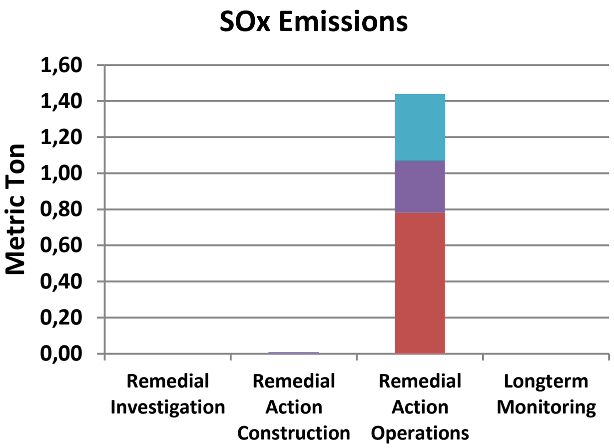
23.2 Scenario-2, BohusVarv:

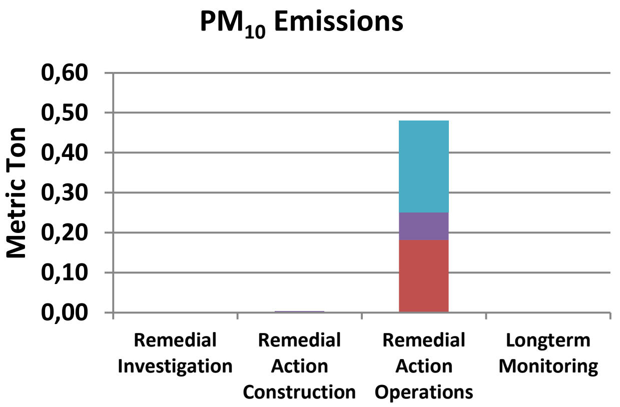
23.2.1 Full excavation & landfilling at Ragnsell

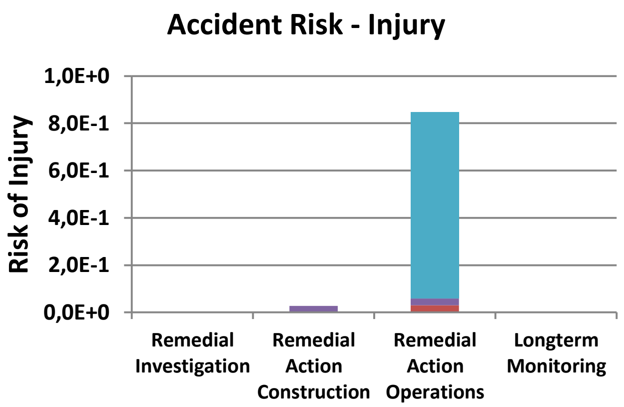


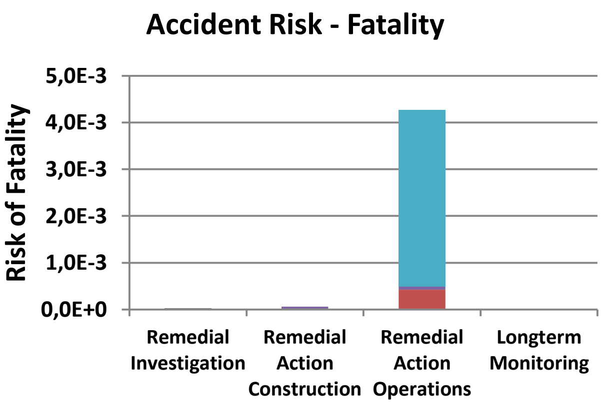


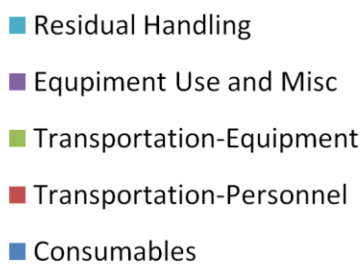








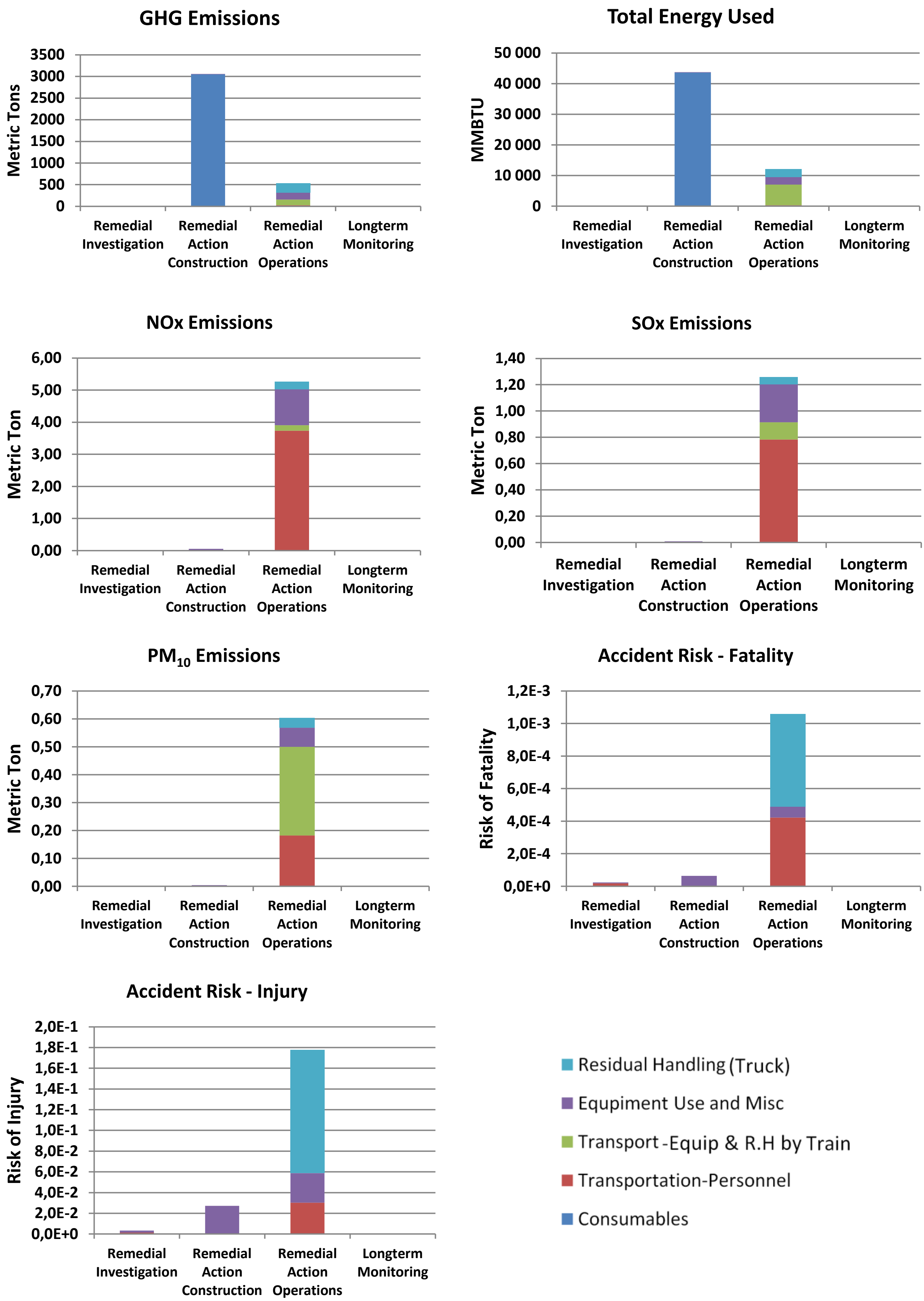




Phase	Activities	GHG Emissions (metric ton)	Total energy Used (MMBTU)	Water Consumption (gallons)	NOx emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.21	4.4E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.34	3.7E+00	NA	2.7E-04	8.9E-05	6.0E-05	1.8E-05	1.3E-03
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.73	1.0E+01	5.5E+00	4.3E-03	7.6E-04	3.2E-04	5.0E-06	2.1E-03
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	1.30	1.84E+01	5.49E+00	4.58E-03	8.48E-04	3.86E-04	2.33E-05	3.45E-03
Remedial Action Construction	Consumables	3,048.79	4.4E+04	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	9.26	1.3E+02	5.9E+02	5.2E-02	9.1E-03	3.9E-03	6.4E-05	2.7E-02
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	3,058.05	4.37E+04	5.93E+02	5.23E-02	9.06E-03	3.86E-03	6.35E-05	2.73E-02
Remedial Action Operations	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	25.17	2.7E+02	NA	3.7E+00	7.8E-01	1.8E-01	4.2E-04	3.0E-02
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	161.14	2.5E+03	0.0E+00	1.1E+00	2.9E-01	6.9E-02	6.6E-05	2.8E-02
	Residual Handling	1,421.66	1.7E+04	NA	1.5E+00	3.7E-01	2.3E-01	3.8E-03	7.9E-01
	Sub-Total	1,607.97	2.02E+04	0.00E+00	6.39E+00	1.44E+00	4.80E-01	4.27E-03	8.47E-01
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		4.7E+03	6.4E+04	6.0E+02	6.4E+00	1.4E+00	4.8E-01	4.4E-03	8.8E-01

23.3 Scenario-3, BohusVarv:

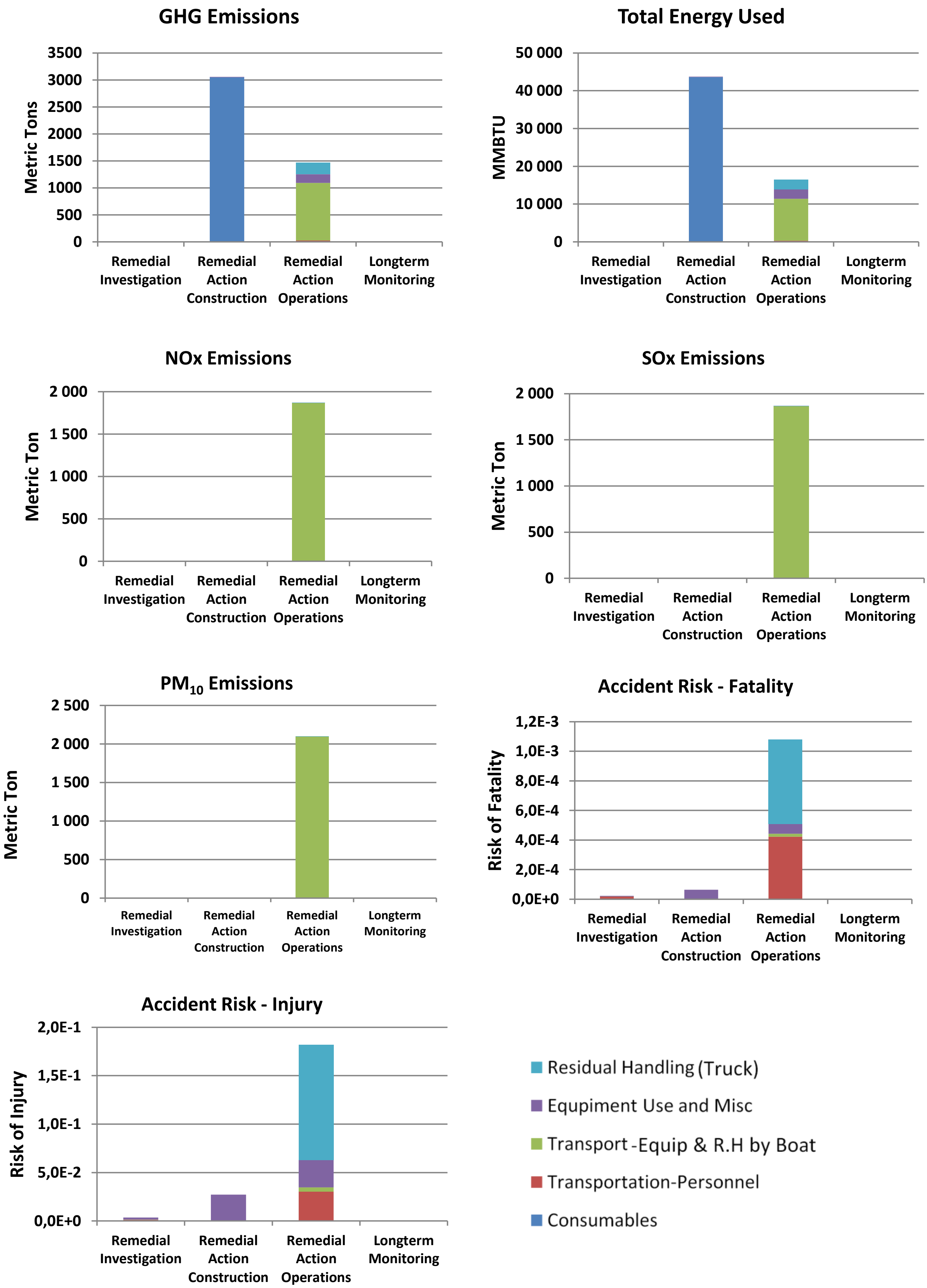
23.3.1 Full excavation & landfilling at SAKAB



Phase	Activities	GHG Emissions (metric ton)	Total energy Used (MMBTU)	Water Consumption (gallons)	NOx emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.21	4.4E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.34	3.7E+00	NA	2.7E-04	8.9E-05	6.0E-05	1.8E-05	1.3E-03
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.73	1.0E+01	5.5E+00	4.3E-03	7.6E-04	3.2E-04	5.0E-06	2.1E-03
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	1.30	1.84E+01	5.49E+00	4.58E-03	8.48E-04	3.86E-04	2.33E-05	3.45E-03
Remedial Action Construction	Consumables	3,048.79	4.4E+04	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	9.26	1.3E+02	5.9E+02	5.2E-02	9.1E-03	3.9E-03	6.4E-05	2.7E-02
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	3,058.05	4.37E+04	5.93E+02	5.23E-02	9.06E-03	3.86E-03	6.35E-05	2.73E-02
Remedial Action Operations	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	25.17	2.7E+02	NA	3.7E+00	7.8E-01	1.8E-01	4.2E-04	3.0E-02
	Transportation-Equipment	133.92	6.8E+03	NA	1.7E-01	1.3E-01	3.2E-01	0.0E+00	0.0E+00
	Equipment Use and Misc	161.14	2.5E+03	0.0E+00	1.1E+00	2.9E-01	6.9E-02	6.6E-05	2.8E-02
	Residual Handling	214.41	2.6E+03	NA	2.3E-01	5.5E-02	3.5E-02	5.7E-04	1.2E-01
	Sub-Total	534.63	1.22E+04	0.00E+00	5.26E+00	1.26E+00	6.03E-01	1.06E-03	1.78E-01
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		3.6E+03	5.6E+04	6.0E+02	5.3E+00	1.3E+00	6.1E-01	1.1E-03	2.1E-01

23.4 Scenario-4, BohusVarv:

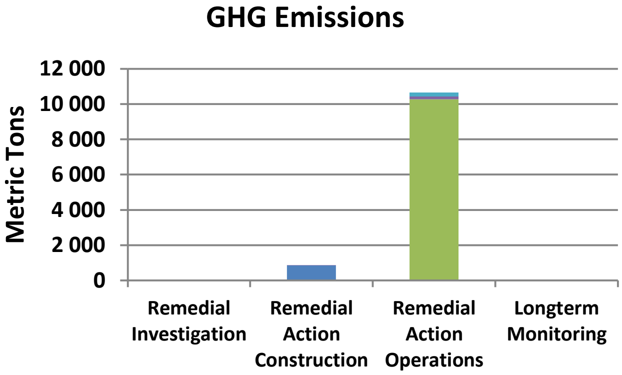
23.4.1 Full excavation & landfilling at Noah, SiteWise default ship

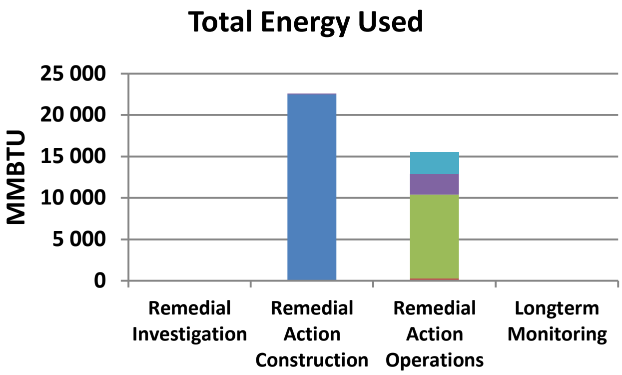


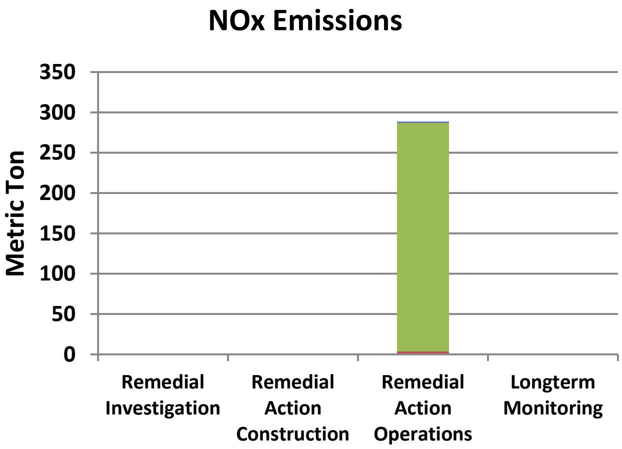
Phase	Activities	GHG Emissions (metric ton)	Total energy Used (MMBTU)	Water Consumption (gallons)	NOx emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.21	4.4E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.34	3.7E+00	NA	2.7E-04	8.9E-05	6.0E-05	1.8E-05	1.3E-03
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.73	1.0E+01	5.5E+00	4.3E-03	7.6E-04	3.2E-04	5.0E-06	2.1E-03
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	1.30	1.84E+01	5.49E+00	4.58E-03	8.48E-04	3.86E-04	2.33E-05	3.45E-03
Remedial Action Construction	Consumables	3,048.79	4.4E+04	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	9.26	1.3E+02	5.9E+02	5.2E-02	9.1E-03	3.9E-03	6.4E-05	2.7E-02
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	3,058.05	4.37E+04	5.93E+02	5.23E-02	9.06E-03	3.86E-03	6.35E-05	2.73E-02
Remedial Action Operations	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	25.17	2.7E+02	NA	3.7E+00	7.8E-01	1.8E-01	4.2E-04	3.0E-02
	Transportation-Equipment	1,064.69	1.1E+04	NA	1.9E+03	1.9E+03	2.1E+03	2.1E-05	4.4E-03
	Equipment Use and Misc	161.14	2.5E+03	0.0E+00	1.1E+00	2.9E-01	6.9E-02	6.6E-05	2.8E-02
	Residual Handling	214.55	2.6E+03	NA	2.3E-01	5.5E-02	3.5E-02	5.7E-04	1.2E-01
	Sub-Total	1,465.55	1.65E+04	0.00E+00	1.87E+03	1.87E+03	2.10E+03	1.08E-03	1.82E-01
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		4.5E+03	6.0E+04	6.0E+02	1.9E+03	1.9E+03	2.1E+03	1.2E-03	2.1E-01

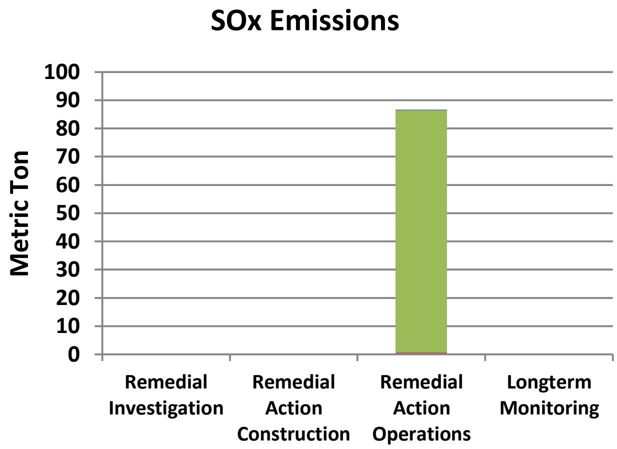
23.5 Scenario-4, BohusVarv:

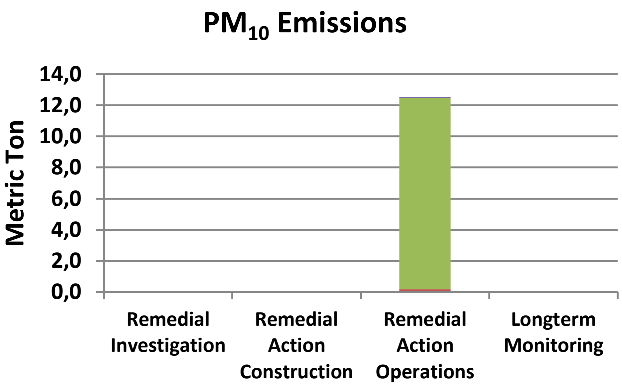
23.5.1 Full excavation & landfilling at Noah, SMED values for ship

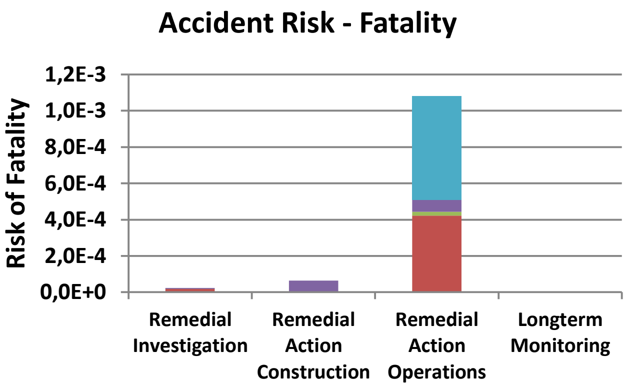


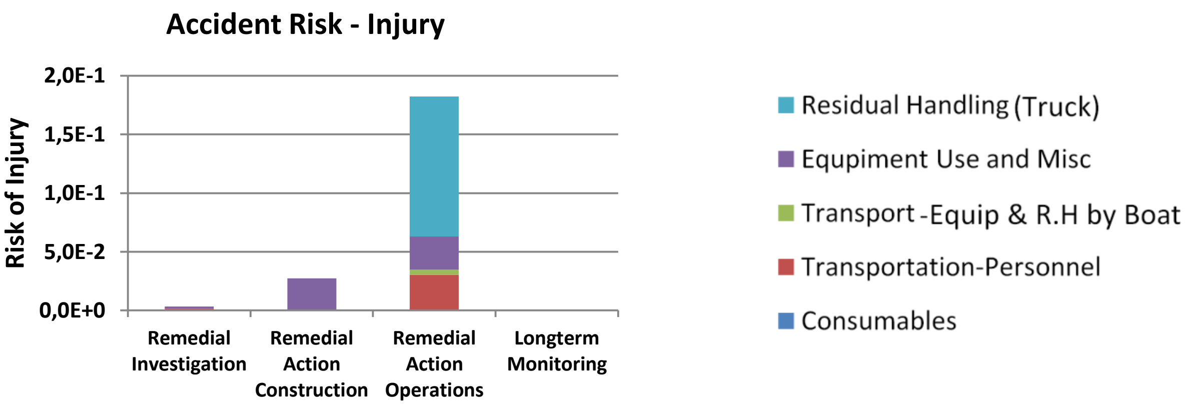








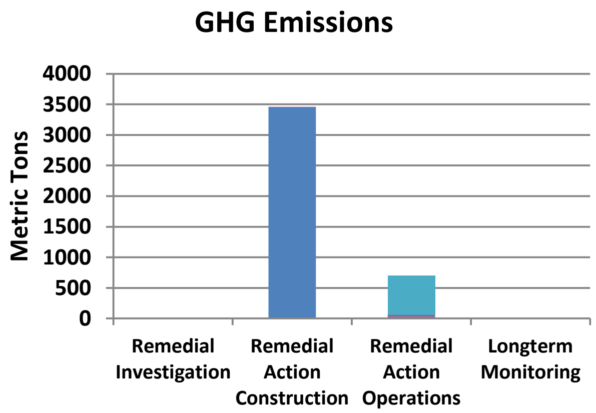


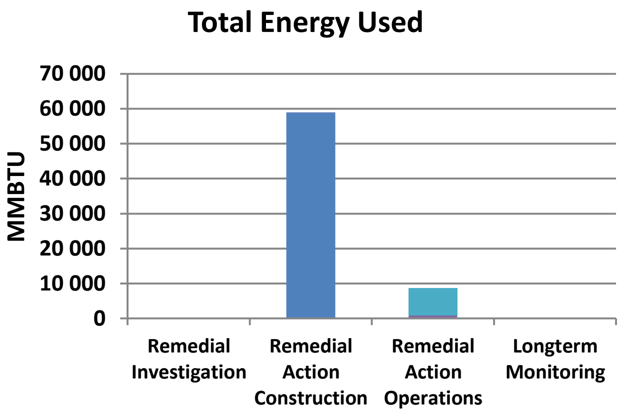


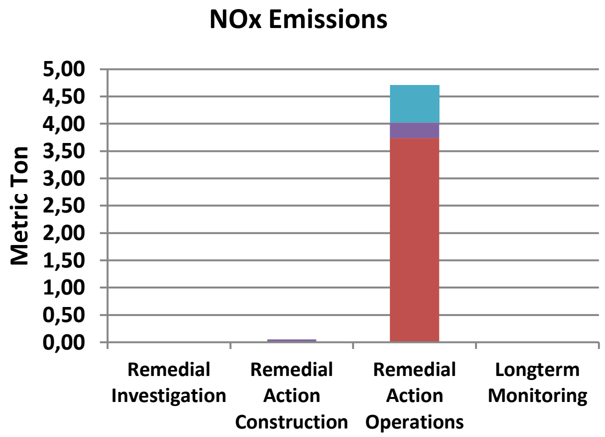
Phase	Activities	GHG Emissions	Total energy Used	Water Consumption	NOx emissions	SOx Emissions	PM10 Emissions	Accident Risk Fatality	Accident Risk Injury
		metric ton	MMBTU	gallons	metric ton	metric ton	metric ton		
Remedial Investigation	Consumables	0.21	4.4E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.34	3.7E+00	NA	2.7E-04	8.9E-05	6.0E-05	1.8E-05	1.3E-03
	Transportation-Equipment	0..02	2..4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.73	1.0E+01	5.5E+00	4.3E-03	7.6E-04	3.2E-04	5.0E-06	2.1E-03
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	1.30	1.84E+01	5.49E+00	4.58E-03	8.48E-04	3.86E-04	2.33E-05	3.45E-03
Remedial Action Construction	Consumables	865.58	2.2E+04	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	9.26	1.3E+02	5.9E+02	5.2E-02	9.1E-03	3.9E-03	6.4E-05	2.7E-02
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	874.83	2.26E+04	5.93E+02	5.23E-02	9.06E-03	3.86E-03	6.35E-05	2.73E-02
Remedial Action Operations	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	25.17	2.7E+02	NA	3.7E+00	7.8E-01	1.8E-01	4.2E-04	3.0E-02
	Transportation-Equipment	10 252.57	1.0E+04	NA	2.8E+02	8.6E+01	1.2E+01	2.1E-05	4.4E-03
	Equipment Use and Misc	161.14	2.5E+03	0.0E+00	1.1E+00	2.9E-01	6.9E-02	6.6E-05	2.8E-02
	Residual Handling	214.55	2.6E+03	NA	2.3E-01	5.5E-02	3.5E-02	5.7E-04	1.2E-01
	Sub-Total	10 653.43	1.55E+04	0.00E+00	2.88E+02	8.67E+01	1.26E+01	1.08E-03	1.82E-01
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		1.2E+04	3.8E+04	6.0E+02	2.9E+02	8.7E+01	1.3E+01	1.2E-03	2.1E-01

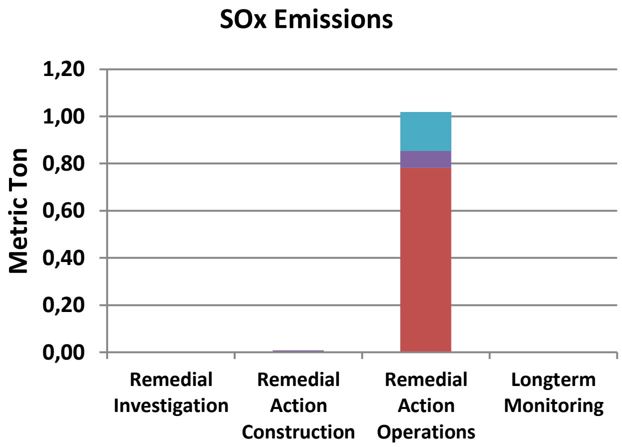
Scenario-5a, BohusVarv:

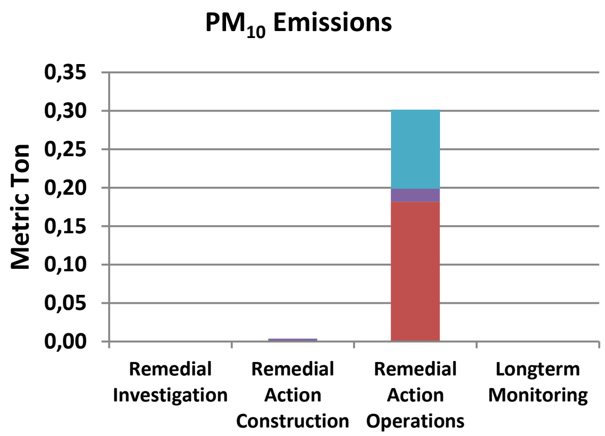
23.5.2 Partial excavation &and landfilling at Sita

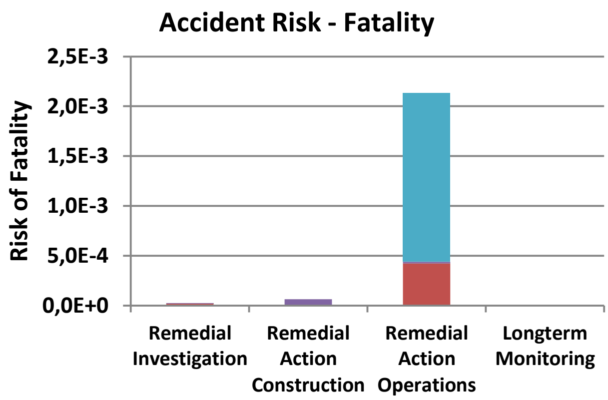


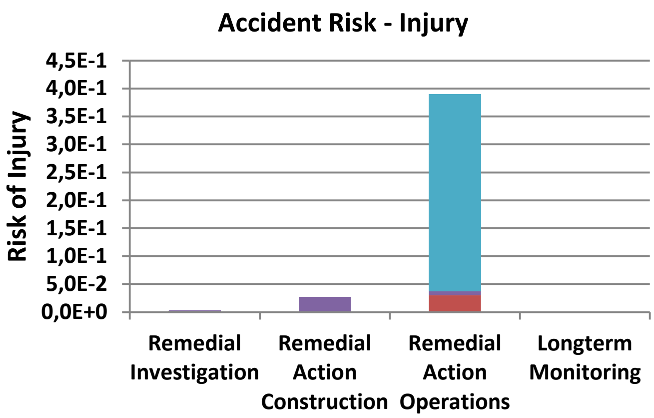


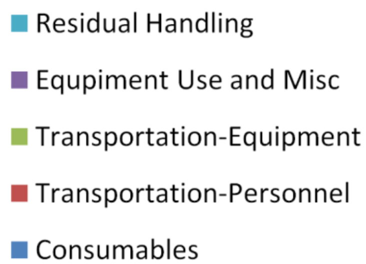








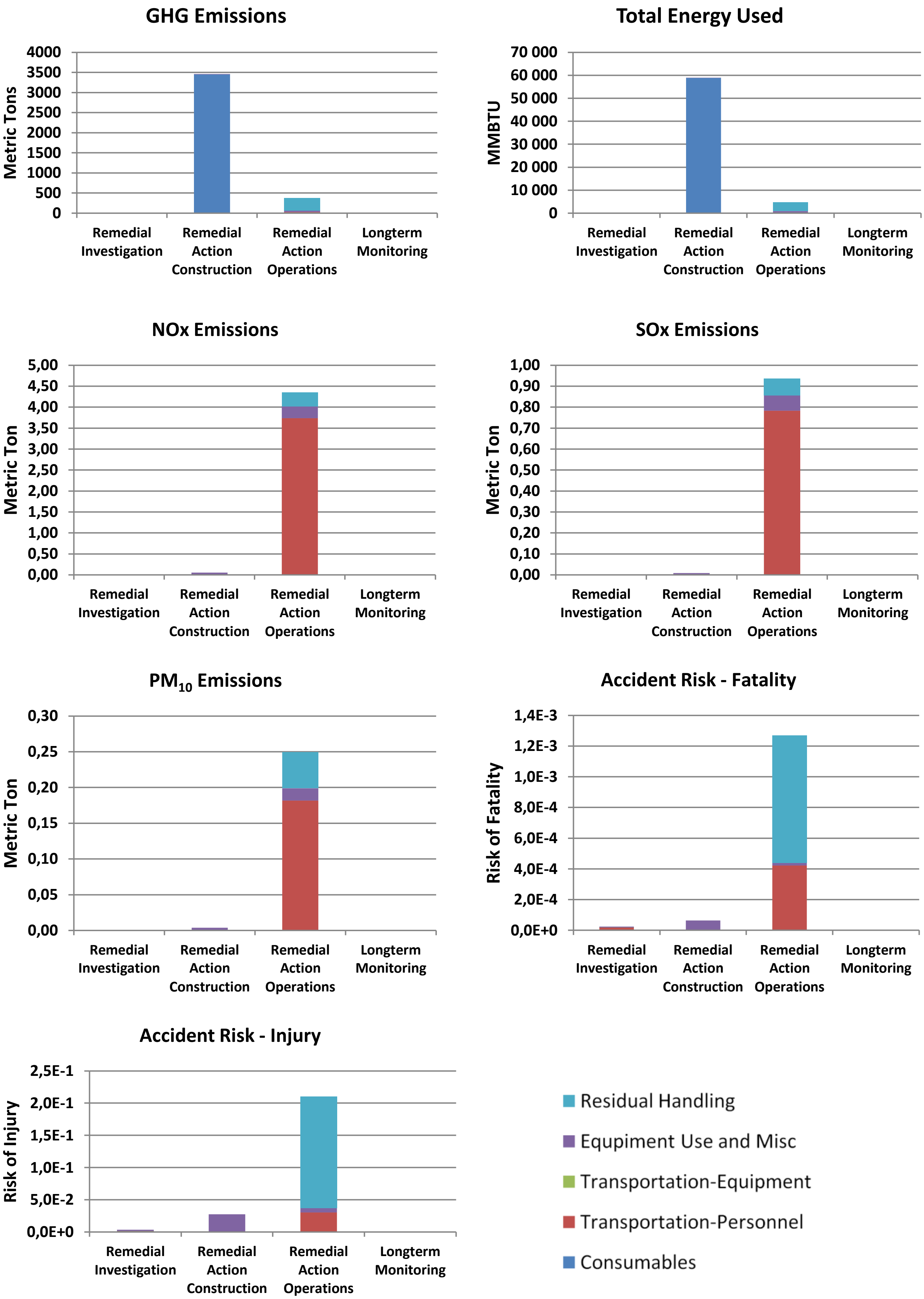




Phase	Activities	GHG Emissions (metric ton)	Total energy Used (MMBTU)	Water Consumption (gallons)	NOx emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.21	4.4E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.34	3.7E+00	NA	2.7E-04	8.9E-05	6.0E-05	1.8E-05	1.3E-03
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.73	1.0E+01	5.5E+00	4.3E-03	7.6E-04	3.2E-04	5.0E-06	2.1E-03
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	1.30	1.84E+01	5.49E+00	4.58E-03	8.48E-04	3.86E-04	2.33E-05	3.45E-03
Remedial Action Construction	Consumables	3,451.25	5.9E+04	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	8.77	1.2E+02	1.5E+02	5.1E-02	8.6E-03	3.9E-03	6.4E-05	2.7E-02
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	3,460.02	5.90E+04	1.48E+02	5.13E-02	8.58E-03	3.86E-03	6.35E-05	2.73E-02
Remedial Action Operations	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	25.17	2.7E+02	NA	3.7E+00	7.8E-01	1.8E-01	4.2E-04	3.0E-02
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	40.28	6.3E+02	0.0E+00	2.8E-01	7.2E-02	1.7E-02	1.7E-05	7.1E-03
	Residual Handling	636.08	7.8E+03	NA	6.8E-01	1.6E-01	1.0E-01	1.7E-03	3.5E-01
	Sub-Total	701.53	8.68E+03	0.00E+00	4.70E+00	1.02E+00	3.02E-01	2.13E-03	3.90E-01
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		4.2E+03	6.8E+04	1.5E+02	4.8E+00	1.0E+00	3.1E-01	2.2E-03	4.2E-01

23.6 Scenario-5b, BohusVarv:

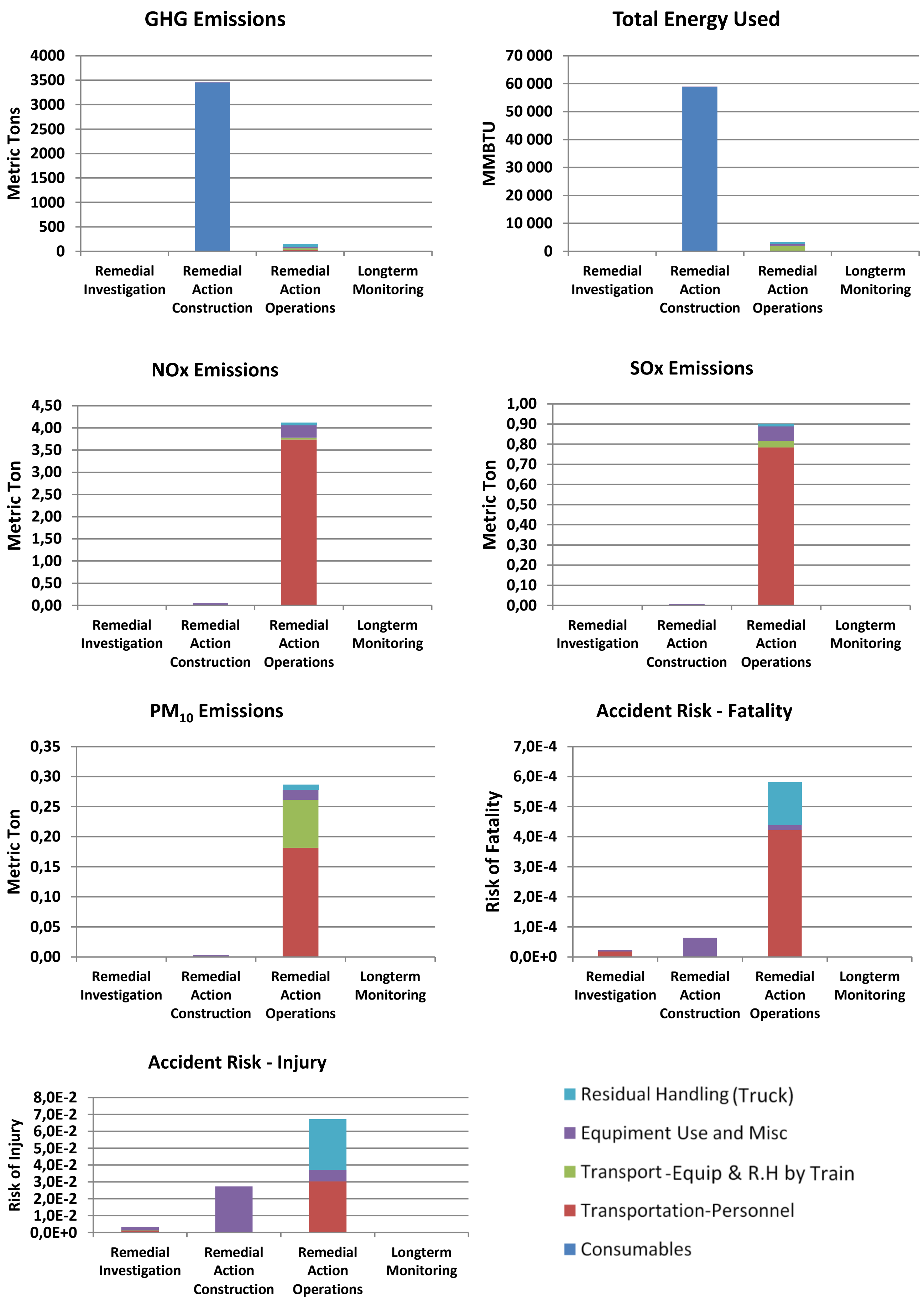
23.6.1 Partial excavation & landfilling at Ragnsell



Phase	Activities	GHG Emissions (metric ton)	Total energy Used (MMBTU)	Water Consumption (gallons)	NOx emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.21	4.4E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.34	3.7E+00	NA	2.7E-04	8.9E-05	6.0E-05	1.8E-05	1.3E-03
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.73	1.0E+01	5.5E+00	4.3E-03	7.6E-04	3.2E-04	5.0E-06	2.1E-03
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	1.30	1.84E+01	5.49E+00	4.58E-03	8.48E-04	3.86E-04	2.33E-05	3.45E-03
Remedial Action Construction	Consumables	3,451.25	5.9E+04	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	8.77	1.2E+02	1.5E+02	5.1E-02	8.6E-03	3.9E-03	6.4E-05	2.7E-02
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	3,460.02	5.90E+04	1.48E+02	5.13E-02	8.58E-03	3.86E-03	6.35E-05	2.73E-02
Remedial Action Operations	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	25.17	2.7E+02	NA	3.7E+00	7.8E-01	1.8E-01	4.2E-04	3.0E-02
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	40.28	6.3E+02	0.0E+00	2.8E-01	7.2E-02	1.7E-02	1.7E-05	7.1E-03
	Residual Handling	312.29	3.8E+03	NA	3.4E-01	8.1E-02	5.0E-02	8.3E-04	1.7E-01
	Sub-Total	377.74	4.72E+03	0.00E+00	4.35E+00	9.36E-01	2.49E-01	1.27E-03	2.10E-01
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		3.8E+03	6.4E+04	1.5E+02	4.4E+00	9.5E-01	2.5E-01	1.4E-03	2.4E-01

23.7 Scenario-5c, BohusVarv:

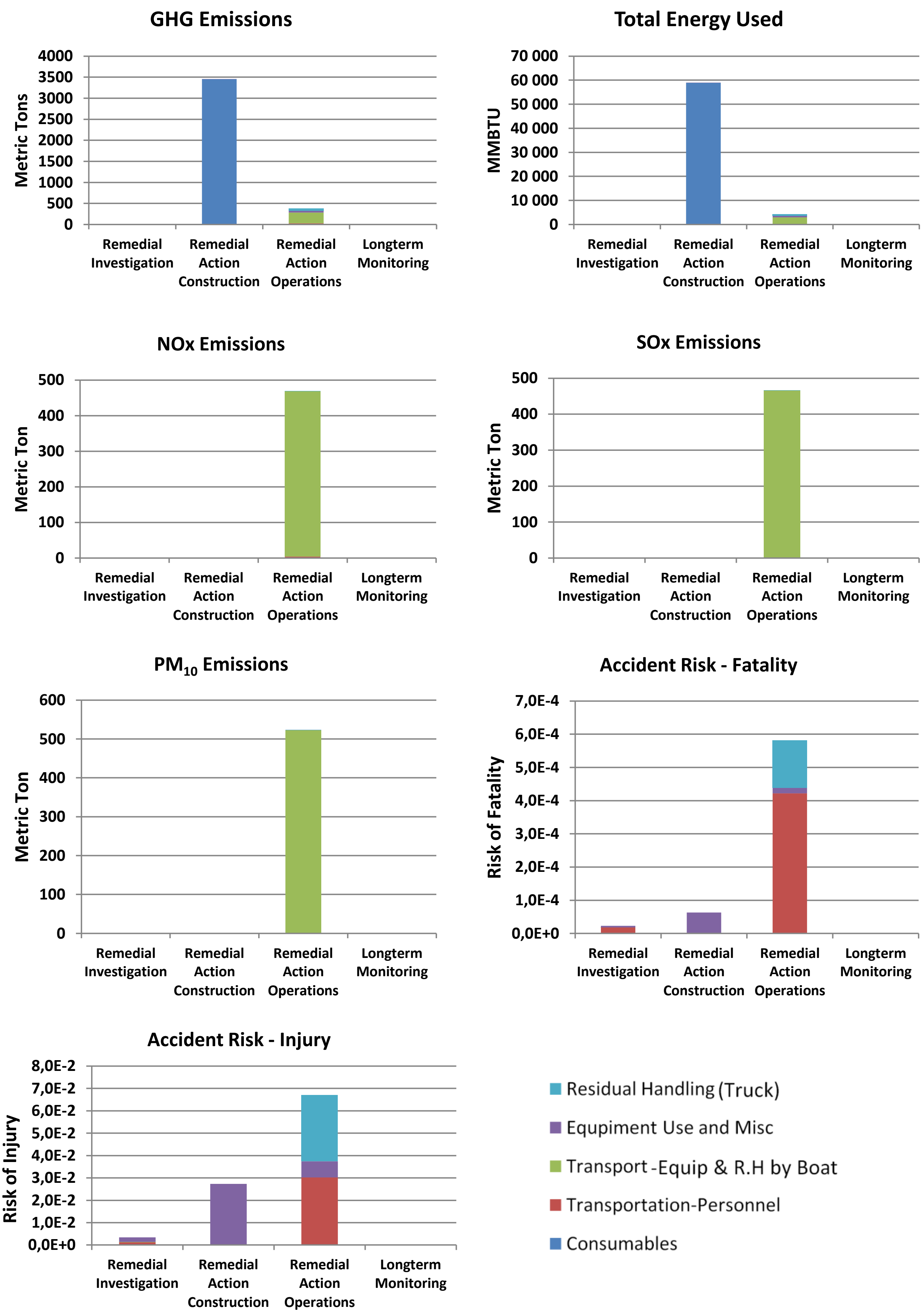
23.7.1 Partial excavation & landfilling at SAKAB



Phase	Activities	GHG Emissions (metric ton)	Total energy Used (MMBTU)	Water Consumption (gallons)	NOx emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.21	4.4E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.34	3.7E+00	NA	2.7E-04	8.9E-05	6.0E-05	1.8E-05	1.3E-03
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.73	1.0E+01	5.5E+00	4.3E-03	7.6E-04	3.2E-04	5.0E-06	2.1E-03
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	1.30	1.84E+01	5.49E+00	4.58E-03	8.48E-04	3.86E-04	2.33E-05	3.45E-03
Remedial Action Construction	Consumables	3,451.25	5.9E+04	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	8.77	1.2E+02	1.5E+02	5.1E-02	8.6E-03	3.9E-03	6.4E-05	2.7E-02
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	3,460.02	5.90E+04	1.48E+02	5.13E-02	8.58E-03	3.86E-03	6.35E-05	2.73E-02
Remedial Action Operations	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	25.17	2.7E+02	NA	3.7E+00	7.8E-01	1.8E-01	4.2E-04	3.0E-02
	Transportation-Equipment	33.48	1.7E+03	NA	4.2E-02	3.3E-02	7.9E-02	0.0E+00	0.0E+00
	Equipment Use and Misc	40.28	6.3E+02	0.0E+00	2.8E-01	7.2E-02	1.7E-02	1.7E-05	7.1E-03
	Residual Handling	53.64	6.6E+02	NA	5.8E-02	1.4E-02	8.7E-03	1.4E-04	3.0E-02
	Sub-Total	152.57	3.25E+03	0.00E+00	4.12E+00	9.02E-01	2.87E-01	5.81E-04	6.71E-02
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		3.6E+03	6.2E+04	1.5E+02	4.2E+00	9.1E-01	2.9E-01	6.7E-04	9.8E-02

23.8 Scenario-5d, BohusVarv:

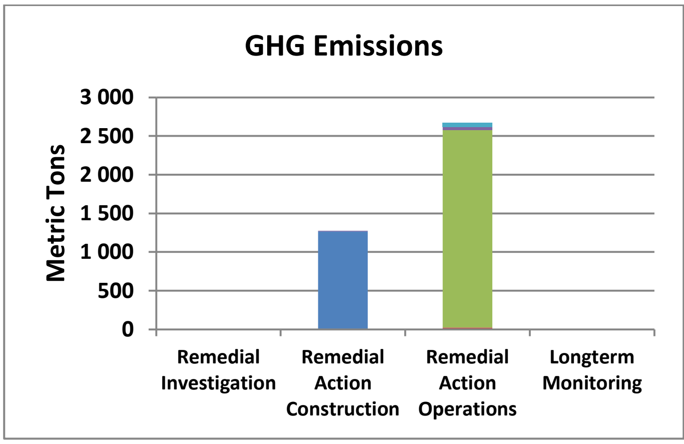
23.8.1 Partial excavation & landfilling at Noah, SiteWise default ship

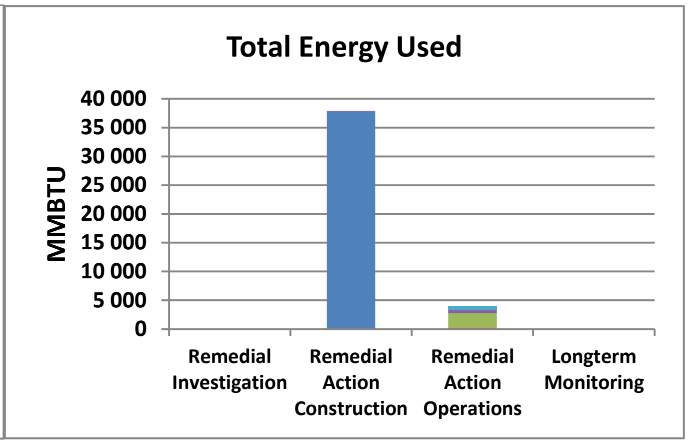


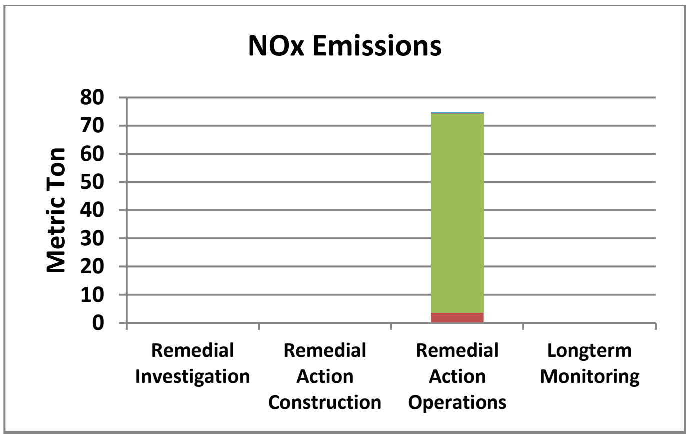
Phase	Activities	GHG Emissions (metric ton)	Total energy Used (MMBTU)	Water Consumption (gallons)	NOx emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.21	4.4E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.34	3.7E+00	NA	2.7E-04	8.9E-05	6.0E-05	1.8E-05	1.3E-03
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.73	1.0E+01	5.5E+00	4.3E-03	7.6E-04	3.2E-04	5.0E-06	2.1E-03
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	1.30	1.84E+01	5.49E+00	4.58E-03	8.48E-04	3.86E-04	2.33E-05	3.45E-03
Remedial Action Construction	Consumables	3,451.25	5.9E+04	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	8.77	1.2E+02	1.5E+02	5.1E-02	8.6E-03	3.9E-03	6.4E-05	2.7E-02
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	3,460.02	5.90E+04	1.48E+02	5.13E-02	8.58E-03	3.86E-03	6.35E-05	2.73E-02
Remedial Action Operations	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	25.17	2.7E+02	NA	3.7E+00	7.8E-01	1.8E-01	4.2E-04	3.0E-02
	Transportation-Equipment	260.42	2.7E+03	NA	4.6E+02	4.6E+02	5.2E+02	0.0E+00	0.0E+00
	Equipment Use and Misc	40.28	6.3E+02	0.0E+00	2.8E-01	7.2E-02	1.7E-02	1.7E-05	7.1E-03
	Residual Handling	53.64	6.6E+02	NA	5.8E-02	1.4E-02	8.7E-03	1.4E-04	3.0E-02
	Sub-Total	379.51	4.27E+03	0.00E+00	4.69E+02	4.66E+02	5.23E+02	5.81E-04	6.71E-02
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		3.8E+03	6.3E+04	1.5E+02	4.7E+02	4.7E+02	5.2E+02	6.7E-04	9.8E-02

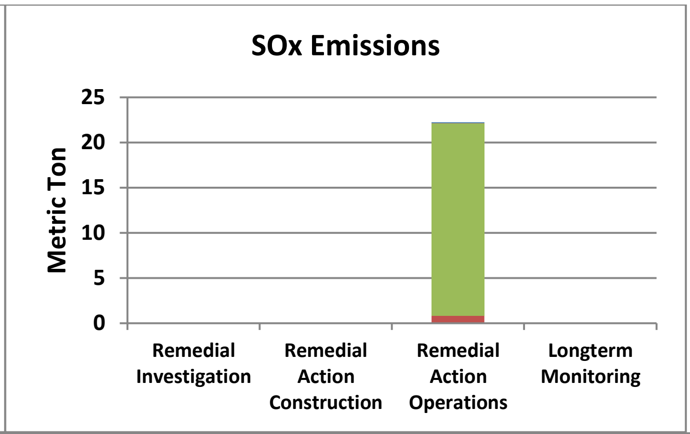
23.9 Scenario-5dx, BohusVarv:

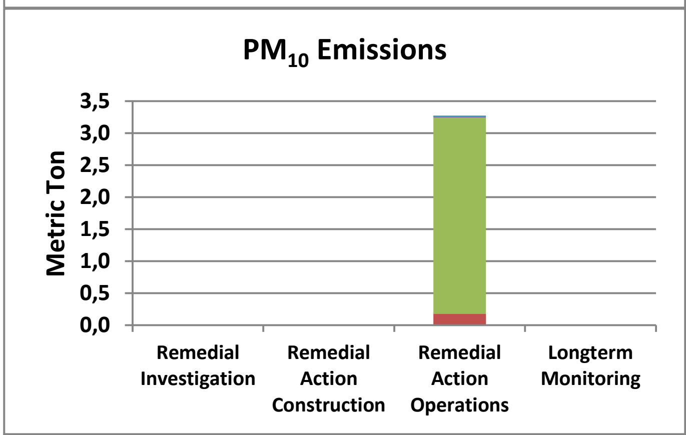
23.9.1 Partial excavation & landfilling at Noah, SMED values for ship

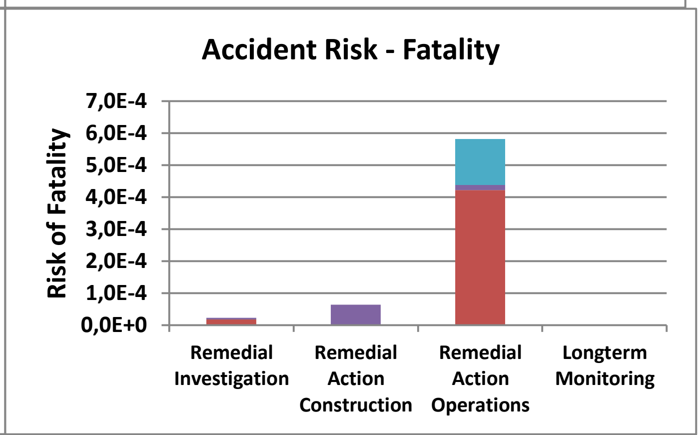


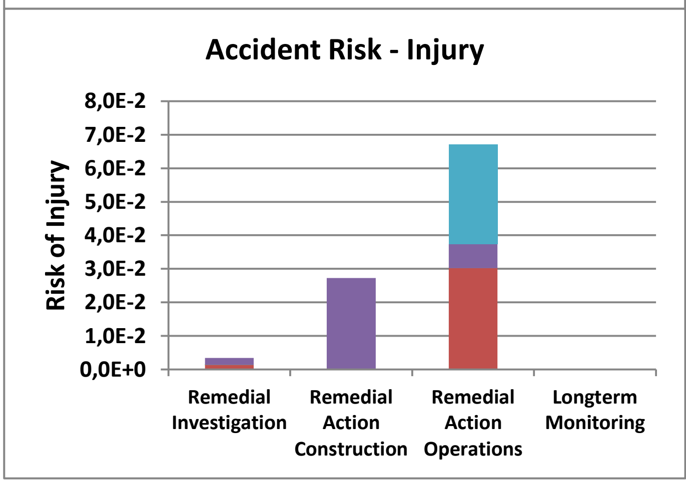


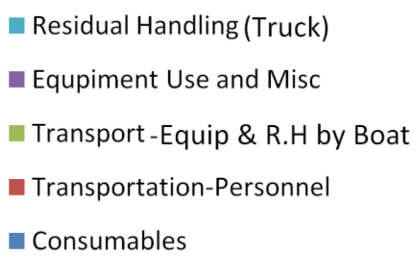








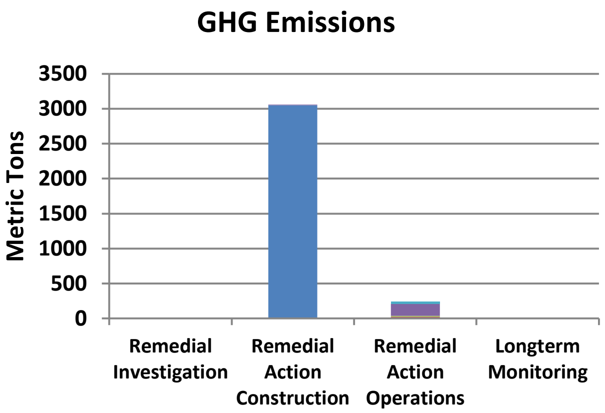


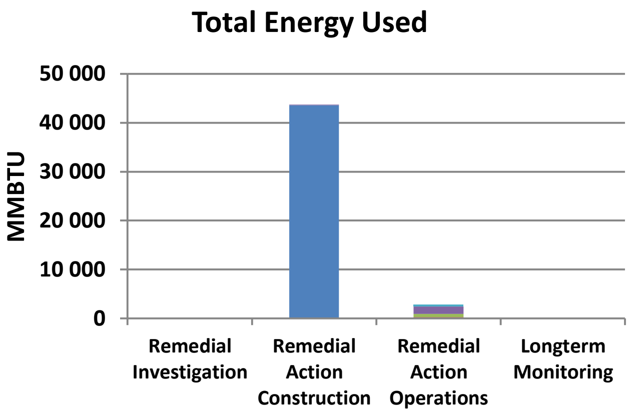


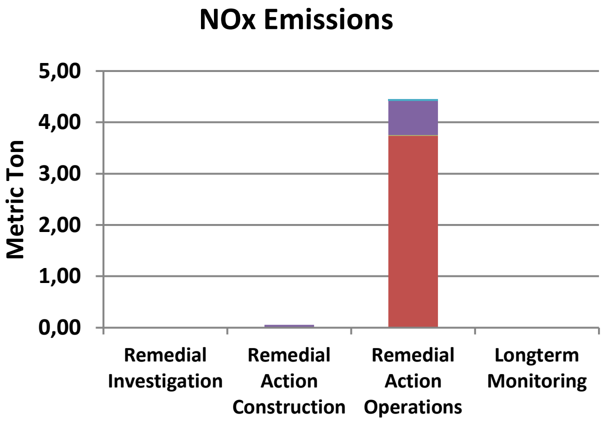
Phase	Activities	GHG Emissions	Total energy Used	Water Consumption	NOx emissions	SOx Emissions	PM10 Emissions	Accident Risk Fatality	Accident Risk Injury
		metric ton	MMBTU	gallons	metric ton	metric ton	metric ton		
Remedial Investigation	Consumables	0.21	4.4E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.34	3.7E+00	NA	2.7E-04	8.9E-05	6.0E-05	1.8E-05	1.3E-03
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.73	1.0E+01	5.5E+00	4.3E-03	7.6E-04	3.2E-04	5.0E-06	2.1E-03
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	1.30	1.84E+01	5.49E+00	4.58E-03	8.48E-04	3.86E-04	2.33E-05	3.45E-03
Remedial Action Construction	Consumables	1 268.03	3.8E+04	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	8.77	1.2E+02	1.5E+02	5.1E-02	8.6E-03	3.9E-03	6.4E-05	2.7E-02
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	1 276.80	3.79E+04	1.48E+02	5.13E-02	8.58E-03	3.86E-03	6.35E-05	2.73E-02
Remedial Action Operations	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	25.17	2.7E+02	NA	3.7E+00	7.8E-01	1.8E-01	4.2E-04	3.0E-02
	Transportation-Equipment	2 550.95	2.5E+03	NA	7.1E+01	2.1E+01	3.1E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	40.28	6.3E+02	0.0E+00	2.8E-01	7.2E-02	1.7E-02	1.7E-05	7.1E-03
	Residual Handling	53.64	6.6E+02	NA	5.8E-02	1.4E-02	8.7E-03	1.4E-04	3.0E-02
	Sub-Total	2 670.04	4.02E+03	0.00E+00	7.46E+01	2.22E+01	3.27E+00	5.81E-04	6.71E-02
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		3.9E+03	4.2E+04	1.5E+02	7.5E+01	2.2E+01	3.3E+00	6.7E-04	9.8E-02

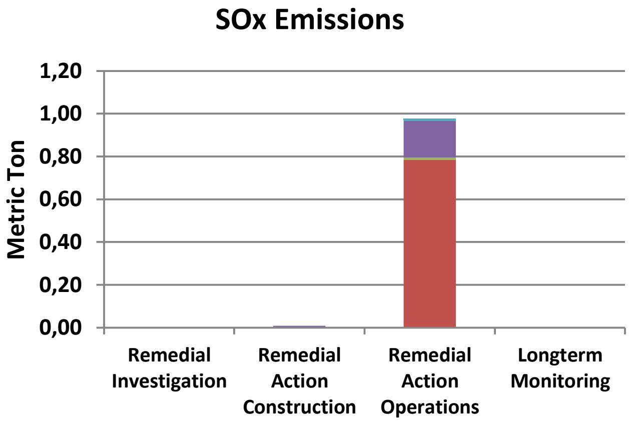
Scenario-6, BohusVarv:

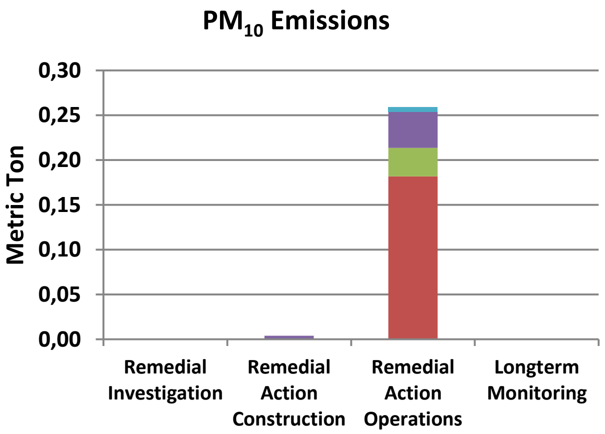
23.9.2 Soil-washing & landfilling remnants at SAKAB

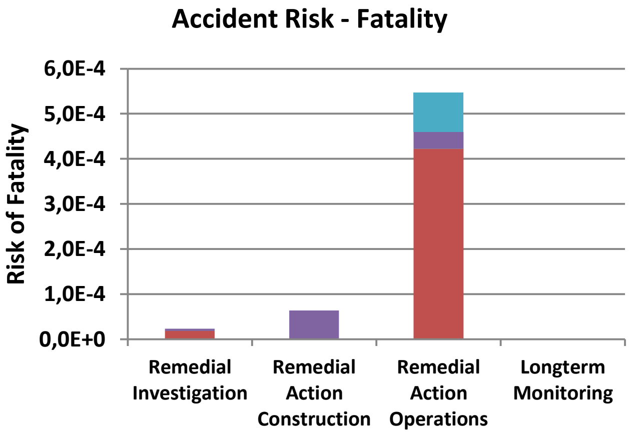


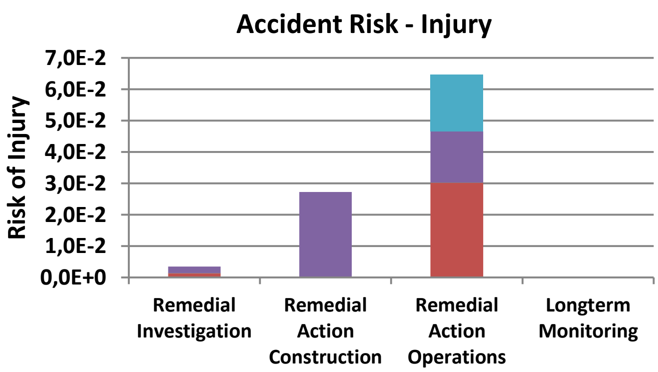


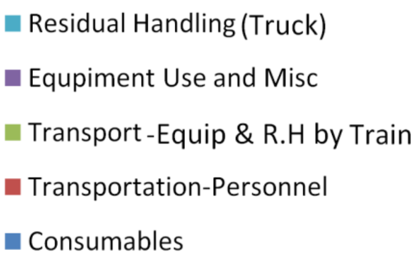








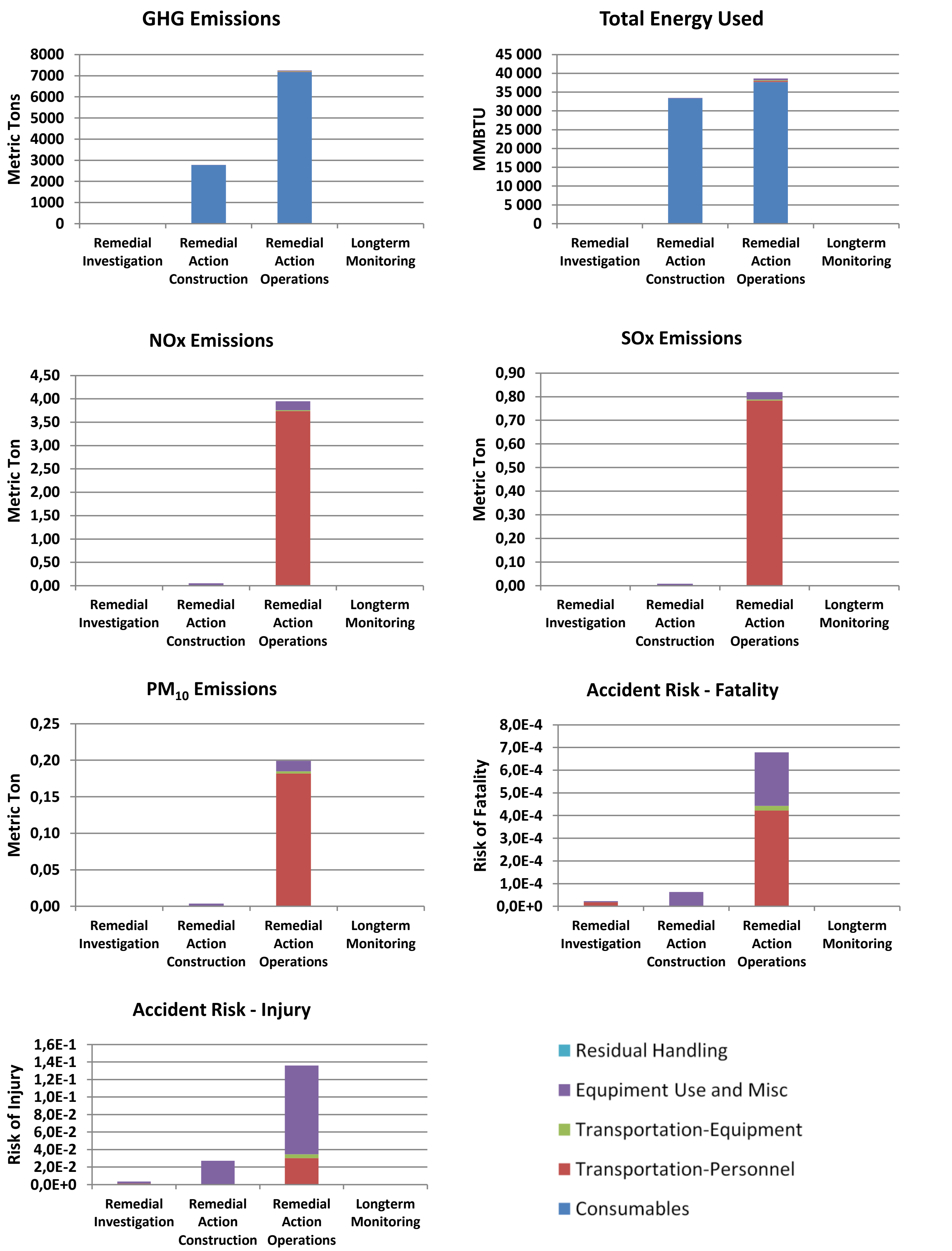




Phase	Activities	GHG Emissions (metric ton)	Total energy Used (MMBTU)	Water Consumption (gallons)	NOx emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.21	4.4E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.34	3.7E+00	NA	2.7E-04	8.9E-05	6.0E-05	1.8E-05	1.3E-03
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.73	1.0E+01	5.5E+00	4.3E-03	7.6E-04	3.2E-04	5.0E-06	2.1E-03
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	1.30	1.84E+01	5.49E+00	4.58E-03	8.48E-04	3.86E-04	2.33E-05	3.45E-03
Remedial Action Construction	Consumables	3,048.79	4.4E+04	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	9.26	1.3E+02	5.9E+02	5.2E-02	9.1E-03	3.9E-03	6.4E-05	2.7E-02
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	3,058.05	4.37E+04	5.93E+02	5.23E-02	9.06E-03	3.86E-03	6.35E-05	2.73E-02
Remedial Action Operations	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	25.17	2.7E+02	NA	3.7E+00	7.8E-01	1.8E-01	4.2E-04	3.0E-02
	Transportation-Equipment	13.46	6.8E+02	NA	1.7E-02	1.3E-02	3.2E-02	9.6E-08	2.0E-05
	Equipment Use and Misc	171.08	1.5E+03	0.0E+00	6.6E-01	1.7E-01	4.0E-02	3.8E-05	1.6E-02
	Residual Handling	32.59	4.0E+02	NA	3.5E-02	8.4E-03	5.3E-03	8.7E-05	1.8E-02
	Sub-Total	242.30	2.84E+03	0.00E+00	4.45E+00	9.76E-01	2.59E-01	5.47E-04	6.46E-02
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		3.3E+03	4.7E+04	6.0E+02	4.5E+00	9.9E-01	2.6E-01	6.3E-04	9.5E-02

23.10 Scenario-7,BohusVarv:

23.10.1 In-situ S&S remedy

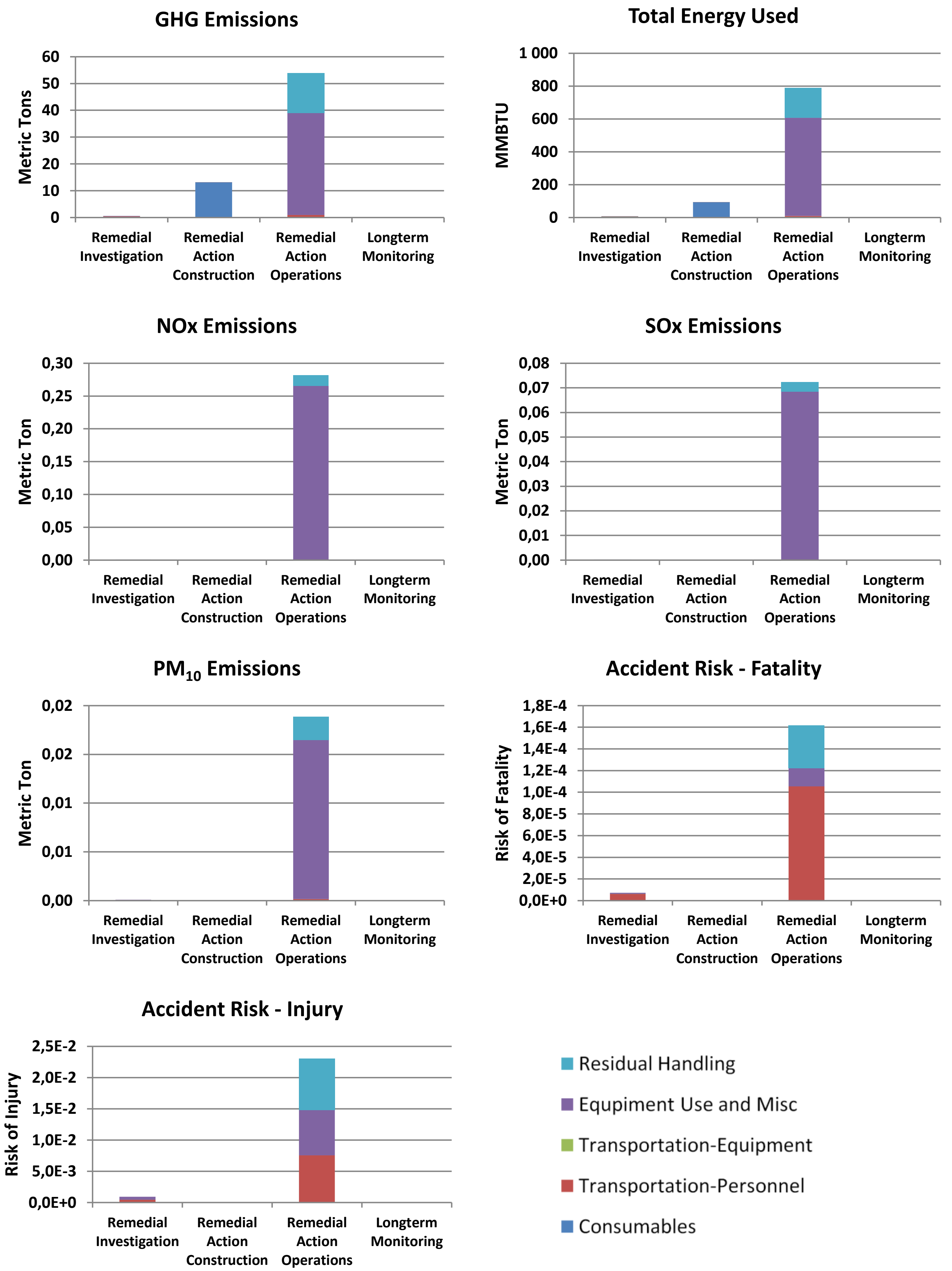


Phase	Activities	GHG Emissions metric ton	Total energy Used MMBTU	Water Consumption gallons	NOx emissions metric ton	SOx Emissions metric ton	PM10 Emissions metric ton	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.21	4.4E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.34	3.7E+00	NA	2.7E-04	8.9E-05	6.0E-05	1.8E-05	1.3E-03
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.73	1.0E+01	5.5E+00	4.3E-03	7.6E-04	3.2E-04	5.0E-06	2.1E-03
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	1.30	1.84E+01	5.49E+00	4.58E-03	8.48E-04	3.86E-04	2.33E-05	3.45E-03
Remedial Action Construction	Consumables	2,776.10	3.3E+04	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	8.60	1.2E+02	0.0E+00	5.1E-02	8.4E-03	3.9E-03	6.4E-05	2.7E-02
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	2,784.70	3.34E+04	0.00E+00	5.10E-02	8.42E-03	3.86E-03	6.35E-05	2.73E-02
Remedial Action Operations	Consumables	7,174.89	3.8E+04	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	25.17	2.7E+02	NA	3.7E+00	7.8E-01	1.8E-01	4.2E-04	3.0E-02
	Transportation-Equipment	20.07	2.2E+02	NA	2.2E-02	5.2E-03	3.2E-03	2.1E-05	4.4E-03
	Equipment Use and Misc	31.96	4.3E+02	0.0E+00	1.9E-01	3.1E-02	1.4E-02	2.4E-04	1.0E-01
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	7.252.08	3.86E+04	0.00E+00	3.95E+00	8.20E-01	1.99E-01	6.79E-04	1.36E-01
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		1.0E+04	7.2E+04	5.5E+00	4.0E+00	8.3E-01	2.0E-01	7.7E-04	1.7E-01

24 Appendix 15

24.1 Scenario-1, Hexion:

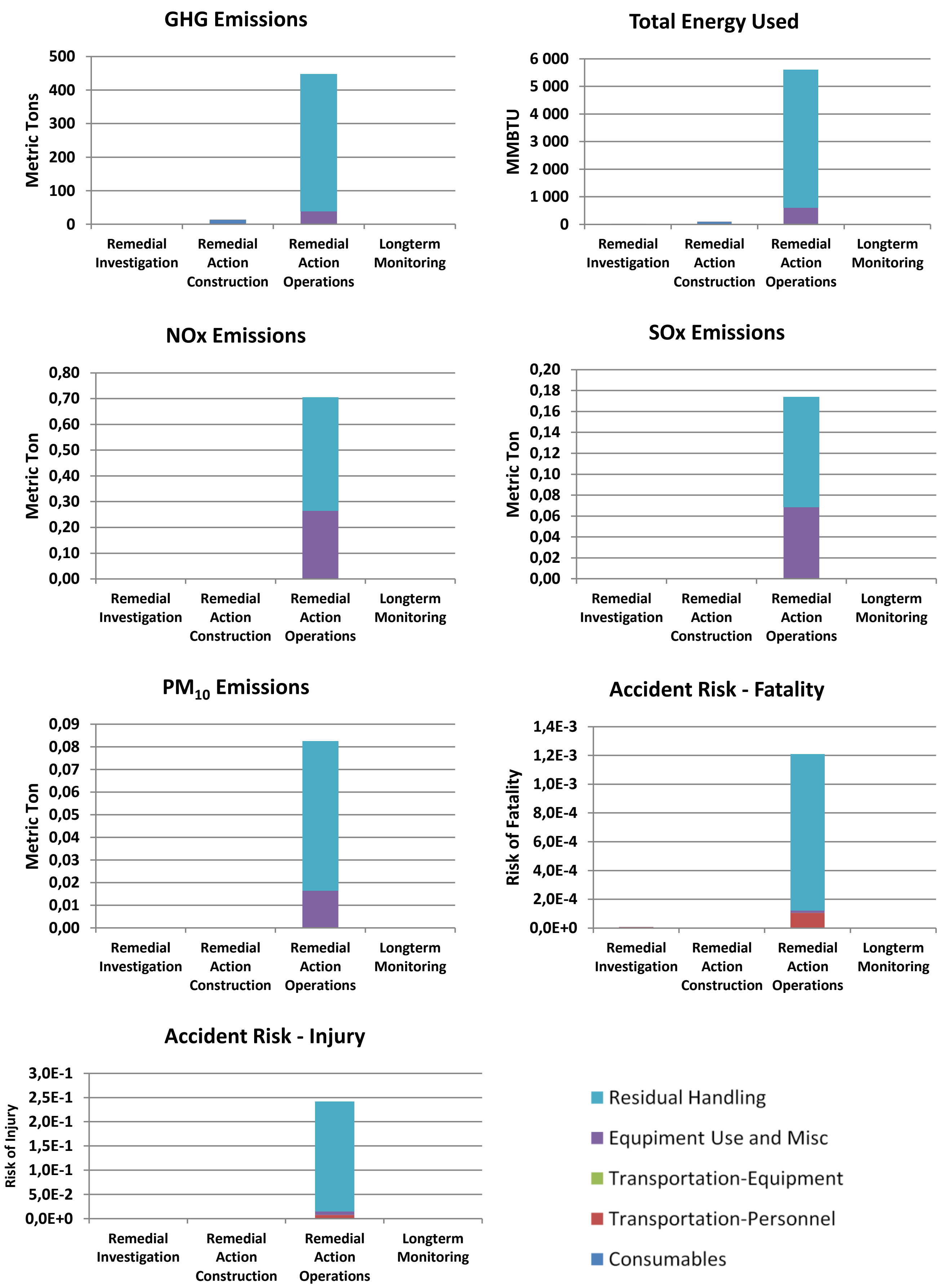
24.1.1 Excavation & landfilling at Kikåstappen



Phase	Activities	GHG Emissions (metric ton)	Total energy Used (MMBTU)	Water Consumption (gallons)	NOx emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.27	5.6E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.11	1.2E+00	NA	9.0E-05	3.0E-05	2.0E-05	6.1E-06	4.4E-04
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.17	2.4E+00	0.0E+00	1.0E-03	1.8E-04	7.8E-05	1.2E-06	5.0E-04
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.58	9.56E+00	0.00E+00	1.14E-03	2.18E-04	1.00E-04	7.32E-06	9.47E-04
Remedial Action Construction	Consumables	13.14	9.3E+01	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.01	9.6E-02	NA	7.5E-06	1.4E-06	7.0E-07	9.6E-09	2.0E-06
	Equipment Use and Misc	0.02	3.9E-01	0.0E+00	1.4E-04	3.9E-05	1.0E-05	2.1E-08	9.1E-06
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	13.17	9.36E+01	0.00E+00	1.44E-04	4.04E-05	1.09E-05	3.09E-08	1.11E-05
Remedial Action Operations	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.95	1.0E+01	NA	7.5E-04	2.5E-04	1.7E-04	1.1E-04	7.6E-03
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	38.07	6.0E+02	0.0E+00	2.6E-01	6.8E-02	1.6E-02	1.7E-05	7.2E-03
	Residual Handling	14.83	1.8E+02	NA	1.6E-02	3.8E-03	2.4E-03	3.9E-05	8.2E-03
	Sub-Total	53.85	7.88E+02	0.00E+00	2.81E-01	7.23E-02	1.89E-02	1.62E-04	2.30E-02
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		6.8E+01	8.9E+02	0.0E+00	2.8E-01	7.3E-02	1.9E-02	1.7E-04	2.4E-02

24.2 Scenario-2, Hexion:

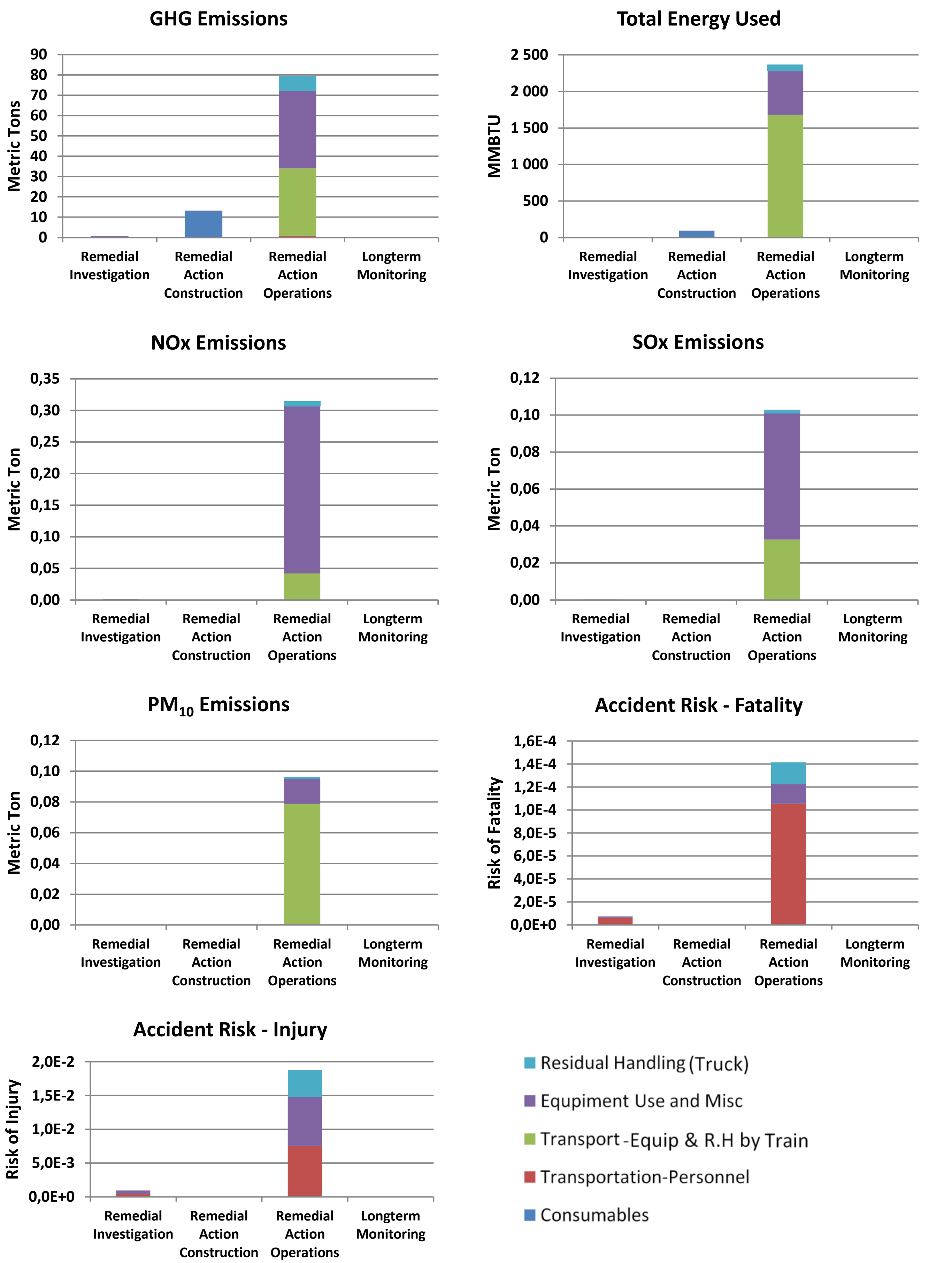
24.2.1 Excavation & landfilling at Ragnsell



Phase	Activities	GHG Emissions (metric ton)	Total energy Used (MMBTU)	Water Consumption (gallons)	NOx emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.27	5.6E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.11	1.2E+00	NA	9.0E-05	3.0E-05	2.0E-05	6.1E-06	4.4E-04
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.17	2.4E+00	0.0E+00	1.0E-03	1.8E-04	7.8E-05	1.2E-06	5.0E-04
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.58	9.56E+00	0.00E+00	1.14E-03	2.18E-04	1.00E-04	7.32E-06	9.47E-04
Remedial Action Construction	Consumables	13.14	9.3E+01	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.01	9.6E-02	NA	7.5E-06	1.4E-06	7.0E-07	9.6E-09	2.0E-06
	Equipment Use and Misc	0.02	3.9E-01	0.0E+00	1.4E-04	3.9E-05	1.0E-05	2.1E-08	9.1E-06
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	13.17	9.36E+01	0.00E+00	1.44E-04	4.04E-05	1.09E-05	3.09E-08	1.11E-05
Remedial Action Operations	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.95	1.0E+01	NA	7.5E-04	2.5E-04	1.7E-04	1.1E-04	7.6E-03
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	38.07	6.0E+02	0.0E+00	2.6E-01	6.8E-02	1.6E-02	1.7E-05	7.2E-03
	Residual Handling	408.94	5.0E+03	NA	4.4E-01	1.1E-01	6.6E-02	1.1E-03	2.3E-01
	Sub-Total	447.96	5.61E+03	0.00E+00	7.05E-01	1.74E-01	8.25E-02	1.21E-03	2.42E-01
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		4.6E+02	5.7E+03	0.0E+00	7.1E-01	1.7E-01	8.3E-02	1.2E-03	2.4E-01

24.3 Scenario-3, Hexion:

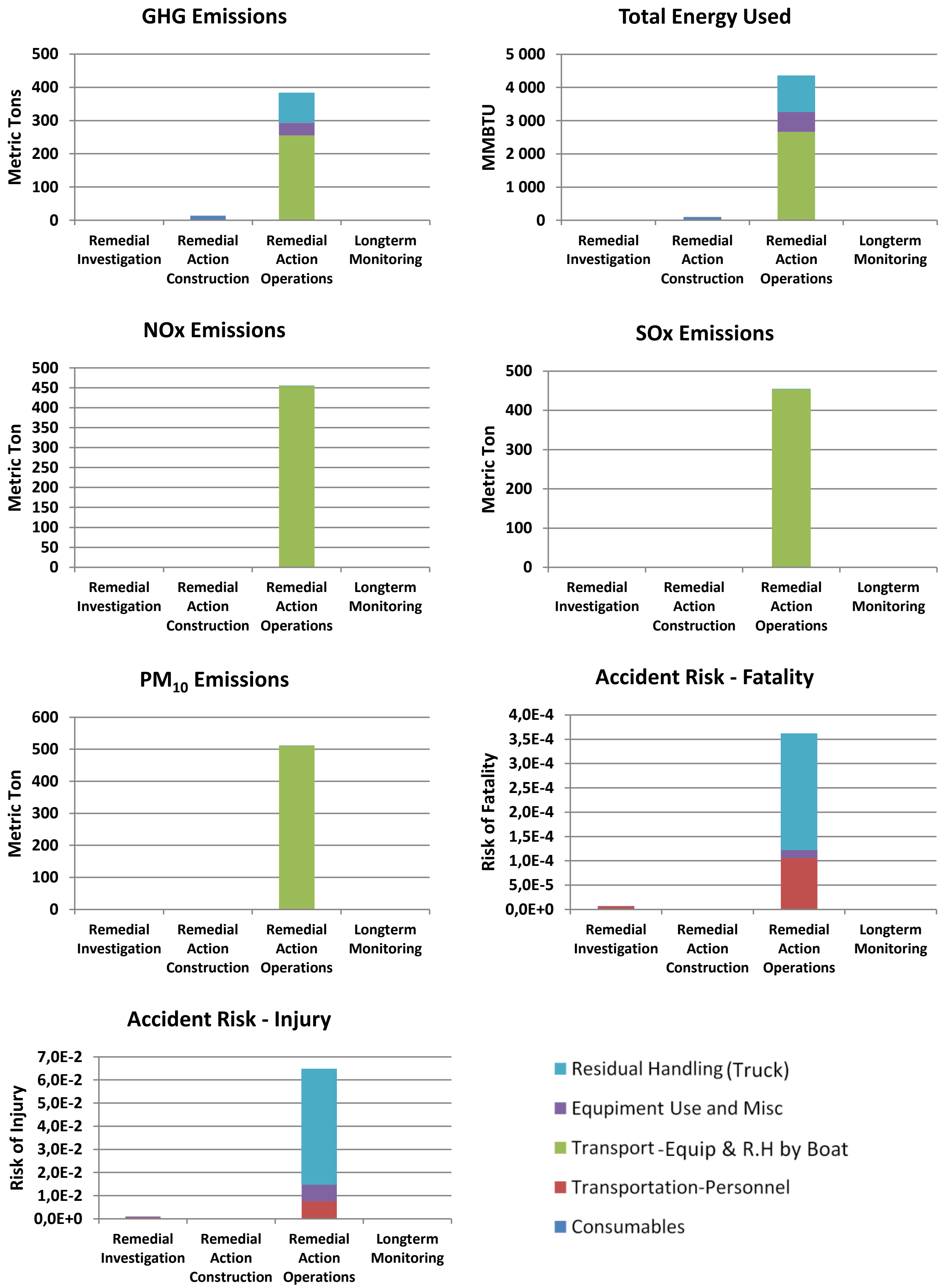
24.3.1 Excavation & landfilling at SAKAB



Phase	Activities	GHG Emissions (metric ton)	Total energy Used (MMBTU)	Water Consumption (gallons)	NOx emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.27	5.6E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.11	1.2E+00	NA	9.0E-05	3.0E-05	2.0E-05	6.1E-06	4.4E-04
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.17	2.4E+00	0.0E+00	1.0E-03	1.8E-04	7.8E-05	1.2E-06	5.0E-04
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.58	9.56E+00	0.00E+00	1.14E-03	2.18E-04	1.00E-04	7.32E-06	9.47E-04
Remedial Action Construction	Consumables	13.14	9.3E+01	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.01	9.6E-02	NA	7.5E-06	1.4E-06	7.0E-07	9.6E-09	2.0E-06
	Equipment Use and Misc	0.02	3.9E-01	0.0E+00	1.4E-04	3.9E-05	1.0E-05	2.1E-08	9.1E-06
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	13.17	9.36E+01	0.00E+00	1.44E-04	4.04E-05	1.09E-05	3.09E-08	1.11E-05
Remedial Action Operations	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.95	1.0E+01	NA	7.5E-04	2.5E-04	1.7E-04	1.1E-04	7.6E-03
	Transportation-Equipment	33.03	1.7E+03	NA	4.1E-02	3.2E-02	7.8E-02	0.0E+00	0.0E+00
	Equipment Use and Misc	38.07	6.0E+02	0.0E+00	2.6E-01	6.8E-02	1.6E-02	1.7E-05	7.2E-03
	Residual Handling	7.18	8.8E+01	NA	7.7E-03	1.9E-03	1.2E-03	1.9E-05	4.0E-03
	Sub-Total	79.23	2.36E+03	0.00E+00	3.14E-01	1.03E-01	9.60E-02	1.41E-04	1.88E-02
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		9.3E+01	2.5E+03	0.0E+00	3.2E-01	1.0E-01	9.6E-02	1.5E-04	2.0E-02

24.4 Scenario-4, Hexion:

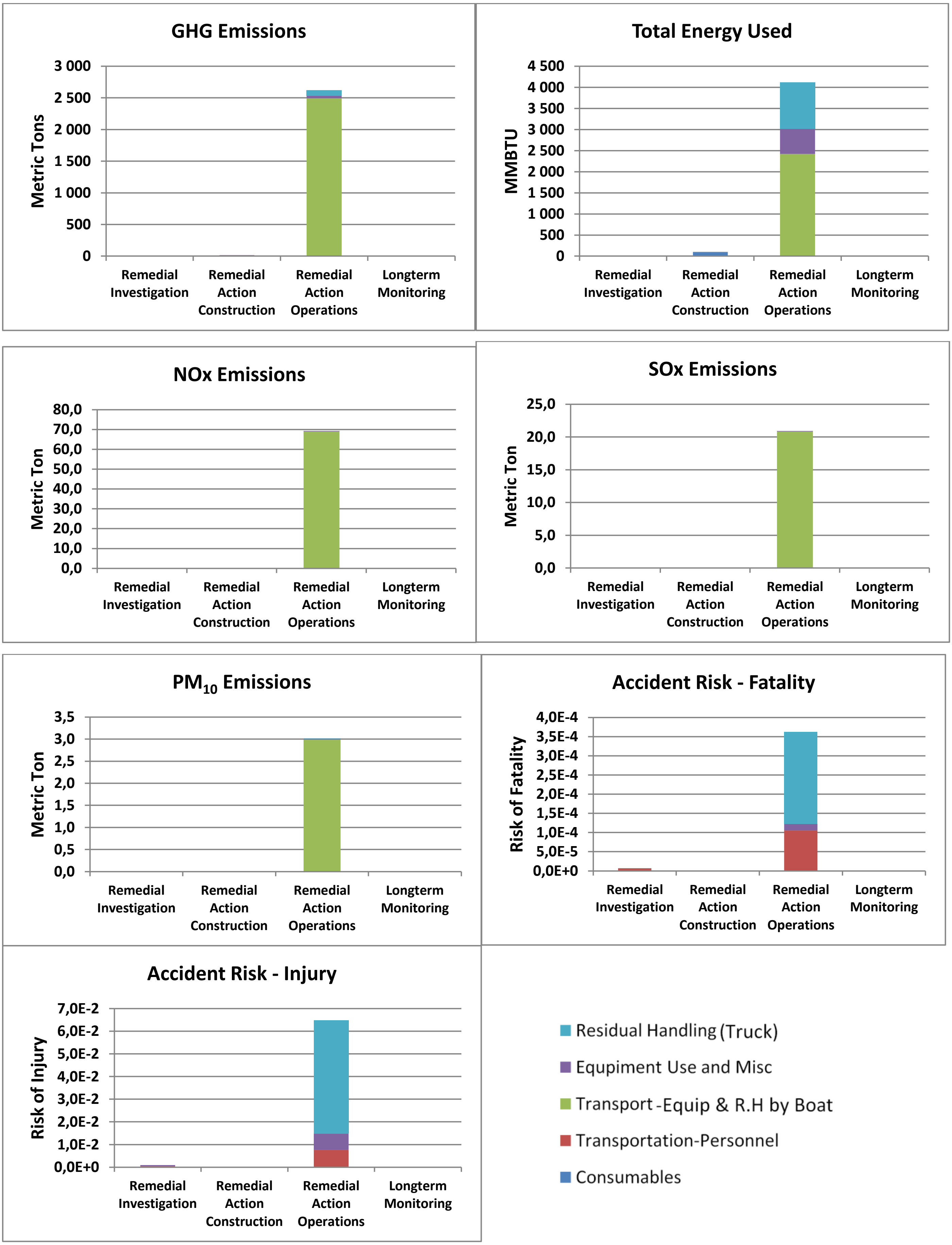
24.4.1 Excavation & landfilling at Noah, SiteWise default ship



Phase	Activities	GHG Emissions metric ton	Total energy Used MMBTU	Water Consumption gallons	NOx emissions metric ton	SOx Emissions metric ton	PM10 Emissions metric ton	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.27	5.6E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.11	1.2E+00	NA	9.0E-05	3.0E-05	2.0E-05	6.1E-06	4.4E-04
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.17	2.4E+00	0.0E+00	1.0E-03	1.8E-04	7.8E-05	1.2E-06	5.0E-04
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.58	9.56E+00	0.00E+00	1.14E-03	2.18E-04	1.00E-04	7.32E-06	9.47E-04
Remedial Action Construction	Consumables	13.14	9.3E+01	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.01	9.6E-02	NA	7.5E-06	1.4E-06	7.0E-07	9.6E-09	2.0E-06
	Equipment Use and Misc	0.02	3.9E-01	0.0E+00	1.4E-04	3.9E-05	1.0E-05	2.1E-08	9.1E-06
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	13.17	9.36E+01	0.00E+00	1.44E-04	4.04E-05	1.09E-05	3.09E-08	1.11E-05
Remedial Action Operations	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.95	1.0E+01	NA	7.5E-04	2.5E-04	1.7E-04	1.1E-04	7.6E-03
	Transportation-Equipment	254.56	2.7E+03	NA	4.5E+02	4.5E+02	5.1E+02	0.0E+00	0.0E+00
	Equipment Use and Misc	38.07	6.0E+02	0.0E+00	2.6E-01	6.8E-02	1.6E-02	1.7E-05	7.2E-03
	Residual Handling	90.08	1.1E+03	NA	9.7E-02	2.3E-02	1.5E-02	2.4E-04	5.0E-02
	Sub-Total	383.67	4.36E+03	0.00E+00	4.55E+02	4.54E+02	5.11E+02	3.62E-04	6.48E-02
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		4.0E+02	4.5E+03	0.0E+00	4.5E+02	4.5E+02	5.1E+02	3.7E-04	6.6E-02

24.5 Scenario-4, Hexion:

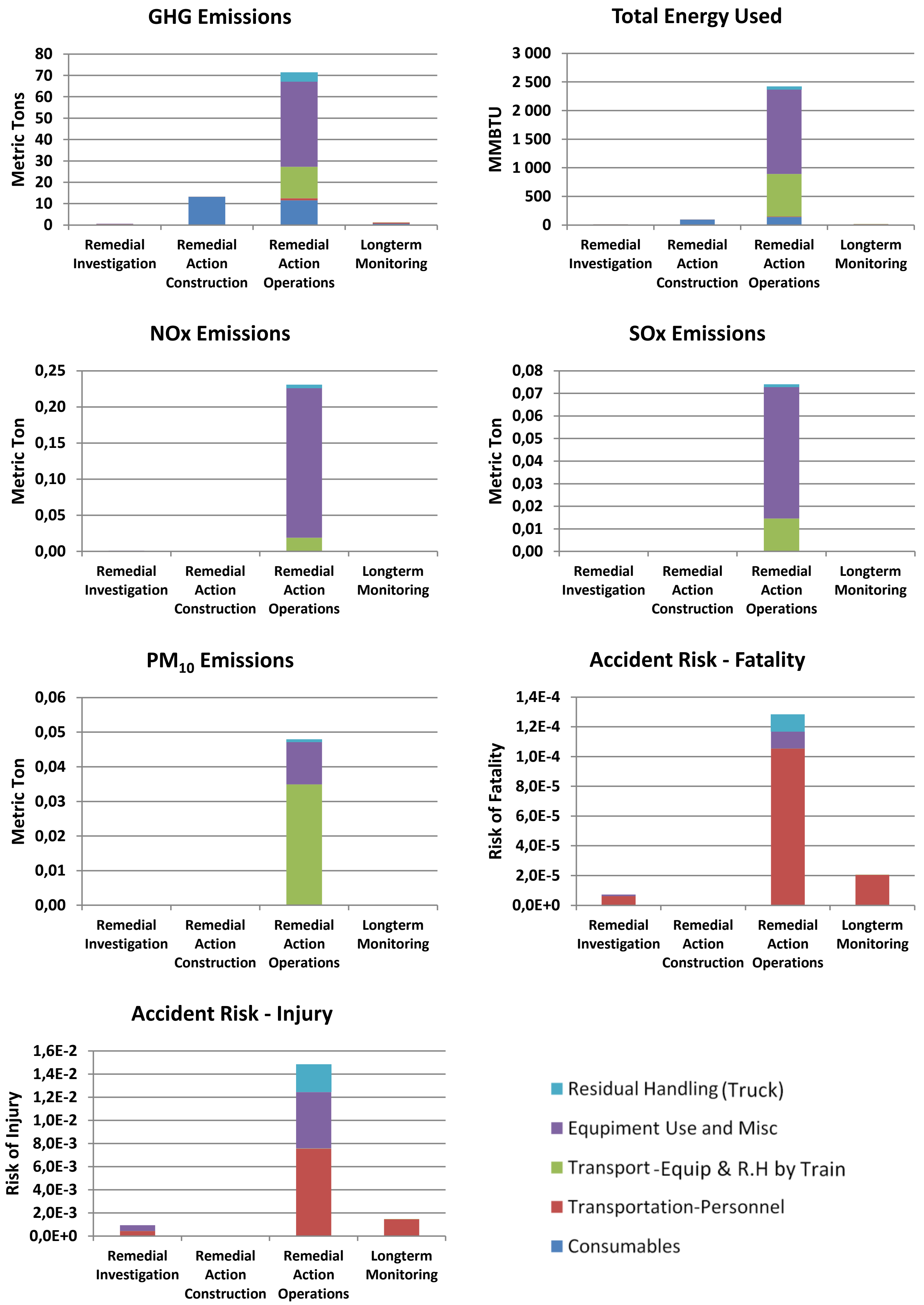
24.5.1 Excavation & landfilling at Noah, SMED vales for ship



Phase	Activities	GHG Emissions (metric ton)	Total energy Used (MMBTU)	Water Consumption (gallons)	NOx emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.27	5.6E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.11	1.2E+00	NA	9.0E-05	3.0E-05	2.0E-05	6.1E-06	4.4E-04
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.17	2.4E+00	0.0E+00	1.0E-03	1.8E-04	7.8E-05	1.2E-06	5.0E-04
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.58	9.56E+00	0.00E+00	1.14E-03	2.18E-04	1.00E-04	7.32E-06	9.47E-04
Remedial Action Construction	Consumables	13.14	9.3E+01	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.01	9.6E-02	NA	7.5E-06	1.4E-06	7.0E-07	9.6E-09	2.0E-06
	Equipment Use and Misc	0.02	3.9E-01	0.0E+00	1.4E-04	3.9E-05	1.0E-05	2.1E-08	9.1E-06
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	13.17	9.36E+01	0.00E+00	1.44E-04	4.04E-05	1.09E-05	3.09E-08	1.11E-05
Remedial Action Operations	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.95	1.0E+01	NA	7.5E-04	2.5E-04	1.7E-04	1.1E-04	7.6E-03
	Transportation-Equipment	2 493.55	2.4E+03	NA	6.9E+01	2.1E+01	3.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	38.07	6.0E+02	0.0E+00	2.6E-01	6.8E-02	1.6E-02	1.7E-05	7.2E-03
	Residual Handling	90.08	1.1E+03	NA	9.7E-02	2.3E-02	1.5E-02	2.4E-04	5.0E-02
	Sub-Total	2 622.66	4.12E+03	0.00E+00	6.93E+01	2.09E+01	3.02E+00	3.62E-04	6.48E-02
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		2.6E+03	4.2E+03	0.0E+00	6.9E+01	2.1E+01	3.0E+00	3.7E-04	6.6E-02

Scenario-5, Hexion:

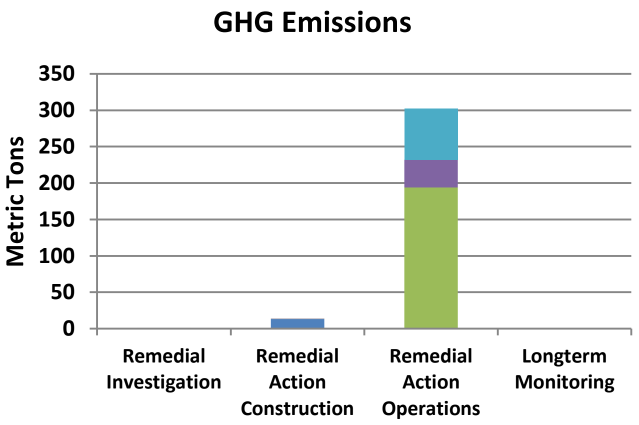
24.5.2 Vapour extraction & landfilling at SAKAB

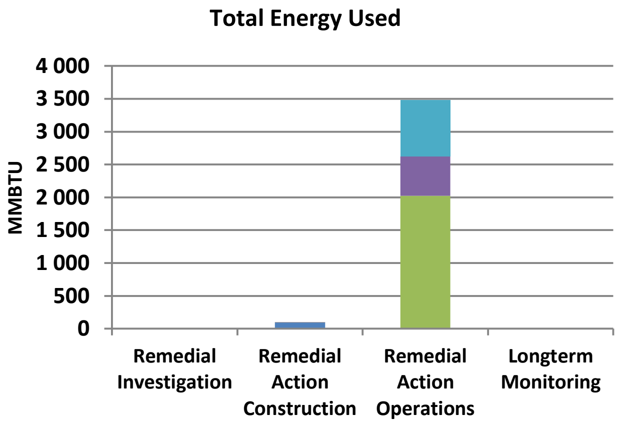


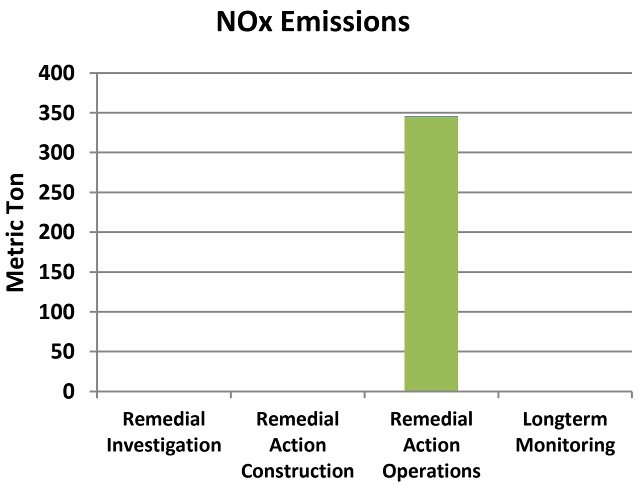
Phase	Activities	GHG Emissions (metric ton)	Total energy Used (MMBTU)	Water Consumption (gallons)	NOx emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.27	5.6E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.11	1.2E+00	NA	9.0E-05	3.0E-05	2.0E-05	6.1E-06	4.4E-04
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.17	2.4E+00	0.0E+00	1.0E-03	1.8E-04	7.8E-05	1.2E-06	5.0E-04
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.58	9.56E+00	0.00E+00	1.14E-03	2.18E-04	1.00E-04	7.32E-06	9.47E-04
Remedial Action Construction	Consumables	13.14	9.3E+01	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.01	9.6E-02	NA	7.5E-06	1.4E-06	7.0E-07	9.6E-09	2.0E-06
	Equipment Use and Misc	0.02	3.9E-01	0.0E+00	1.4E-04	3.9E-05	1.0E-05	2.1E-08	9.1E-06
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	13.17	9.36E+01	0.00E+00	1.44E-04	4.04E-05	1.09E-05	3.09E-08	1.11E-05
Remedial Action Operations	Consumables	11.60	1.4E+02	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.95	1.0E+01	NA	7.5E-04	2.5E-04	1.7E-04	1.1E-04	7.6E-03
	Transportation-Equipment	14.69	7.4E+02	NA	1.8E-02	1.4E-02	3.5E-02	4.8E-08	1.0E-05
	Equipment Use and Misc	39.84	1.5E+03	5.1E+04	2.1E-01	5.8E-02	1.2E-02	1.1E-05	4.9E-03
	Residual Handling	4.35	5.3E+01	NA	4.7E-03	1.1E-03	7.0E-04	1.2E-05	2.4E-03
	Sub-Total	71.43	2.42E+03	5.10E+04	2.31E-01	7.40E-02	4.79E-02	1.28E-04	1.48E-02
Longterm Monitoring	Consumables	0.57	1.0E+01	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.57	6.2E+00	NA	4.5E-04	1.5E-04	1.0E-04	2.0E-05	1.5E-03
	Transportation-Equipment	0.02	1.7E-01	NA	1.6E-05	3.9E-06	2.5E-06	2.4E-08	5.0E-06
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	1.16	1.65E+01	0.00E+00	4.65E-04	1.52E-04	1.02E-04	2.04E-05	1.47E-03
Total		8.6E+01	2.5E+03	5.1E+04	2.3E-01	7.4E-02	4.8E-02	1.6E-04	1.7E-02

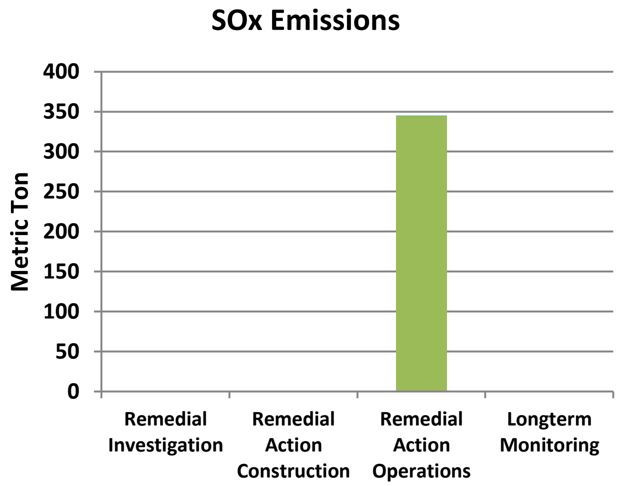
24.6 Scenario-6a, Hexion:

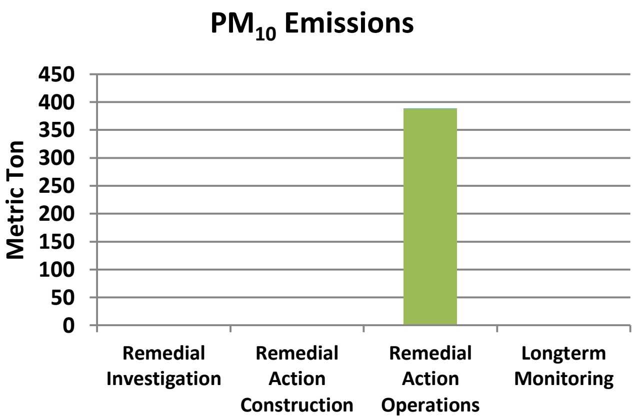
24.6.1 Onsite soil-washing & landfilling at Noah, SiteWise default ship

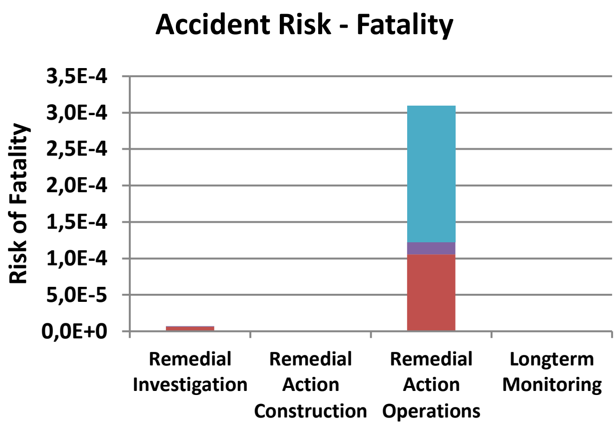


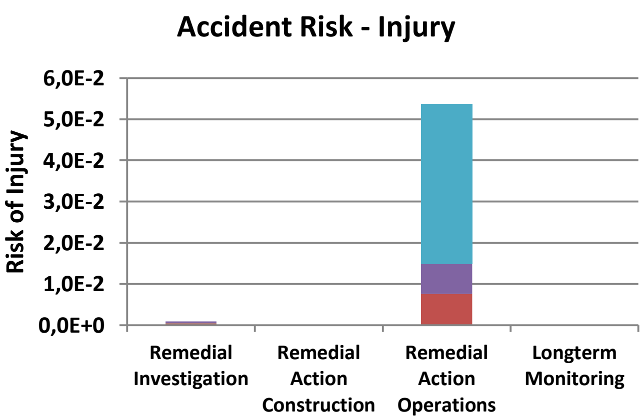


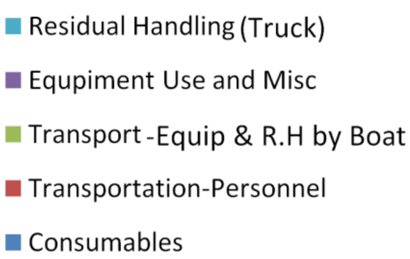








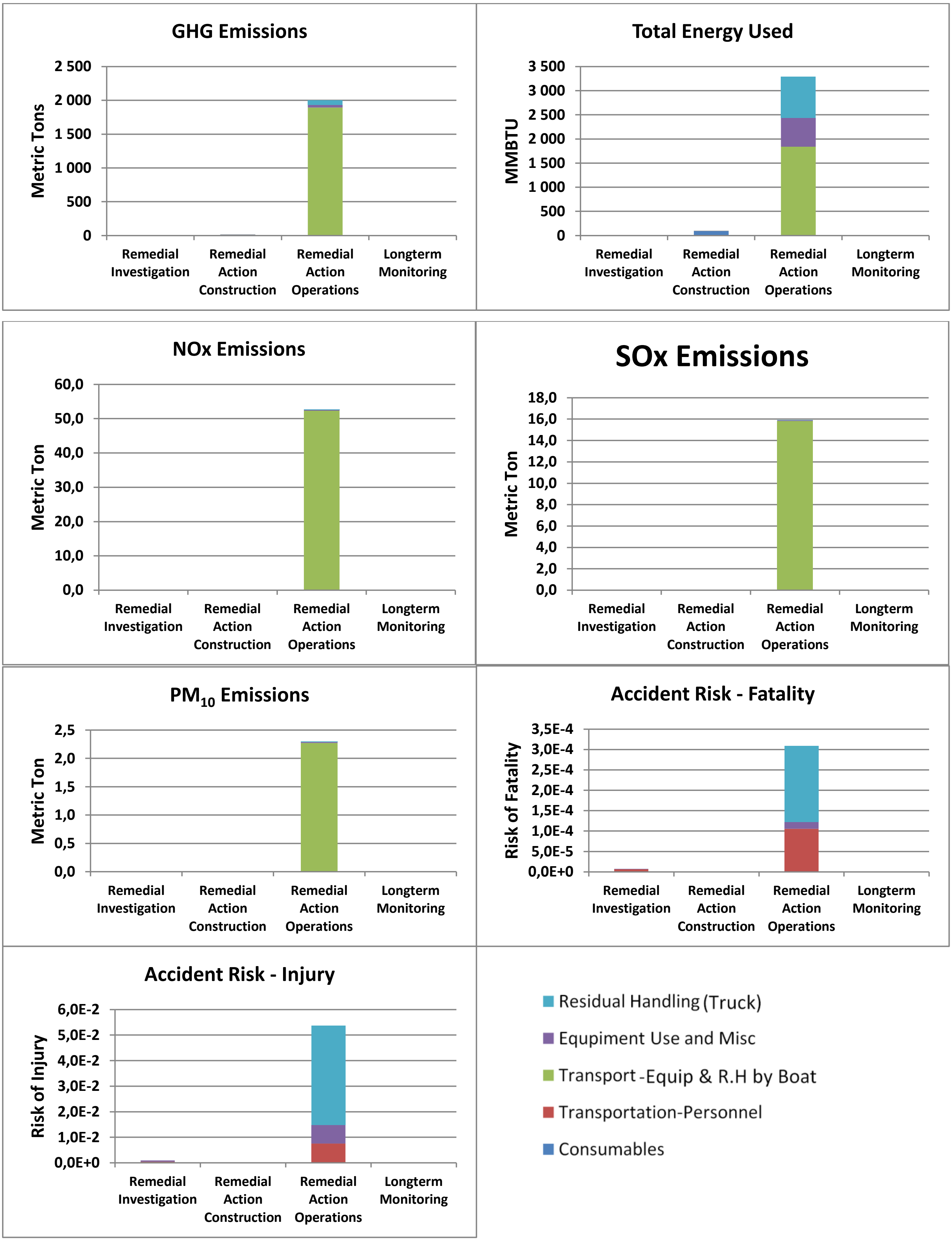




Phase	Activities	GHG Emissions (metric ton)	Total energy Used (MMBTU)	Water Consumption (gallons)	NOx emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.27	5.6E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.11	1.2E+00	NA	9.0E-05	3.0E-05	2.0E-05	6.1E-06	4.4E-04
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.17	2.4E+00	0.0E+00	1.0E-03	1.8E-04	7.8E-05	1.2E-06	5.0E-04
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.58	9.56E+00	0.00E+00	1.14E-03	2.18E-04	1.00E-04	7.32E-06	9.47E-04
Remedial Action Construction	Consumables	13.14	9.3E+01	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.01	9.6E-02	NA	7.5E-06	1.4E-06	7.0E-07	9.6E-09	2.0E-06
	Equipment Use and Misc	0.02	3.9E-01	0.0E+00	1.4E-04	3.9E-05	1.0E-05	2.1E-08	9.1E-06
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	13.17	9.36E+01	0.00E+00	1.44E-04	4.04E-05	1.09E-05	3.09E-08	1.11E-05
Remedial Action Operations	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.95	1.0E+01	NA	7.5E-04	2.5E-04	1.7E-04	1.1E-04	7.6E-03
	Transportation-Equipment	193.15	2.0E+03	NA	3.4E+02	3.4E+02	3.9E+02	0.0E+00	0.0E+00
	Equipment Use and Misc	38.07	6.0E+02	0.0E+00	2.6E-01	6.8E-02	1.6E-02	1.7E-05	7.2E-03
	Residual Handling	70.11	8.6E+02	NA	7.5E-02	1.8E-02	1.1E-02	1.9E-04	3.9E-02
	Sub-Total	302.28	3.48E+03	0.00E+00	3.45E+02	3.45E+02	3.88E+02	3.09E-04	5.37E-02
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		3.2E+02	3.6E+03	0.0E+00	3.5E+02	3.4E+02	3.9E+02	3.2E-04	5.5E-02

24.7 Scenario-6a, Hexion:

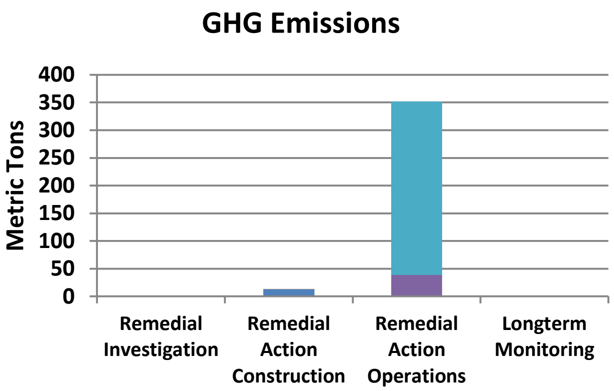
24.7.1 Onsite soil-washing & landfilling at Noah, SMED vales for ship

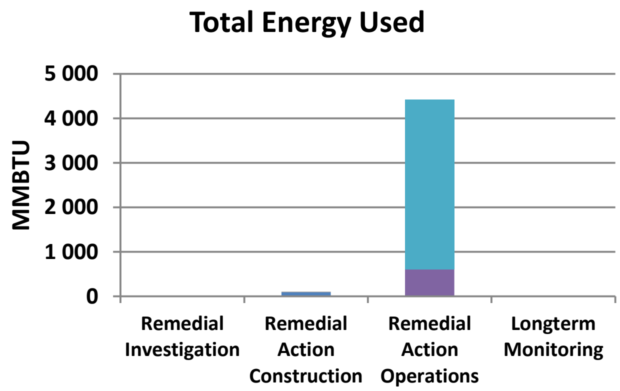


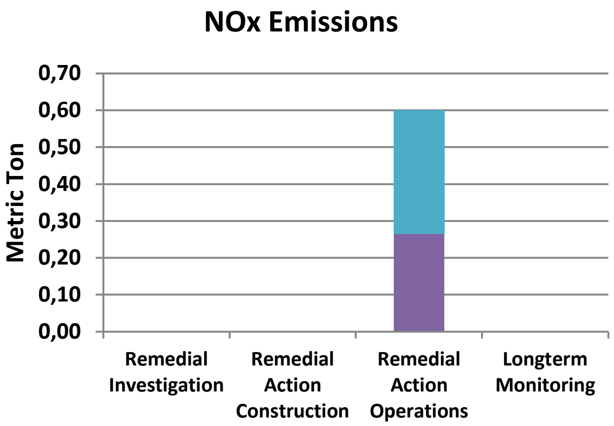
Phase	Activities	GHG Emissions (metric ton)	Total energy Used (MMBTU)	Water Consumption (gallons)	NOx emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.27	5.6E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.11	1.2E+00	NA	9.0E-05	3.0E-05	2.0E-05	6.1E-06	4.4E-04
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.17	2.4E+00	0.0E+00	1.0E-03	1.8E-04	7.8E-05	1.2E-06	5.0E-04
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.58	9.56E+00	0.00E+00	1.14E-03	2.18E-04	1.00E-04	7.32E-06	9.47E-04
Remedial Action Construction	Consumables	13.14	9.3E+01	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.01	9.6E-02	NA	7.5E-06	1.4E-06	7.0E-07	9.6E-09	2.0E-06
	Equipment Use and Misc	0.02	3.9E-01	0.0E+00	1.4E-04	3.9E-05	1.0E-05	2.1E-08	9.1E-06
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	13.17	9.36E+01	0.00E+00	1.44E-04	4.04E-05	1.09E-05	3.09E-08	1.11E-05
Remedial Action Operations	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.95	1.0E+01	NA	7.5E-04	2.5E-04	1.7E-04	1.1E-04	7.6E-03
	Transportation-Equipment	1 891.96	1.8E+03	NA	5.2E+01	1.6E+01	2.3E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	38.07	6.0E+02	0.0E+00	2.6E-01	6.8E-02	1.6E-02	1.7E-05	7.2E-03
	Residual Handling	70.11	8.6E+02	NA	7.5E-02	1.8E-02	1.1E-02	1.9E-04	3.9E-02
	Sub-Total	2 001.09	3.29E+03	0.00E+00	5.27E+01	1.59E+01	2.30E+00	3.09E-04	5.37E-02
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		2.0E+03	3.4E+03	0.0E+00	5.3E+01	1.6E+01	2.3E+00	3.2E-04	5.5E-02

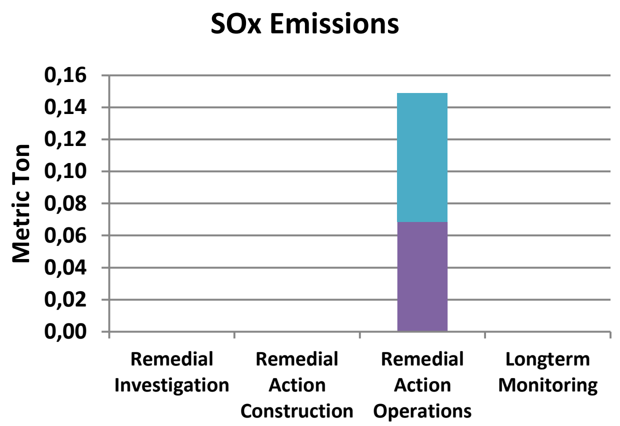
24.8 Scenario-6b, Hexion:

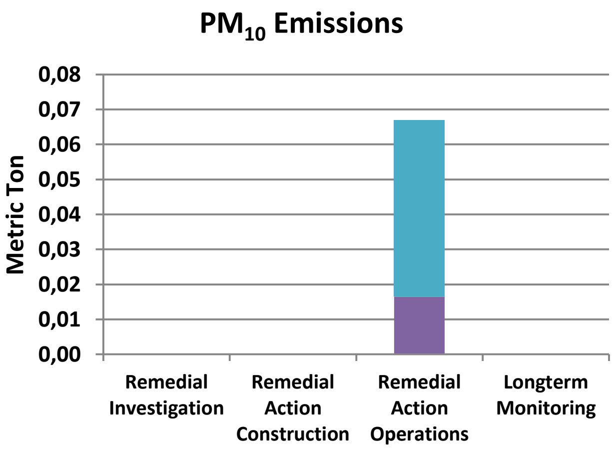
24.8.1 Onsite soil-washing & landfilling at Ragnsell

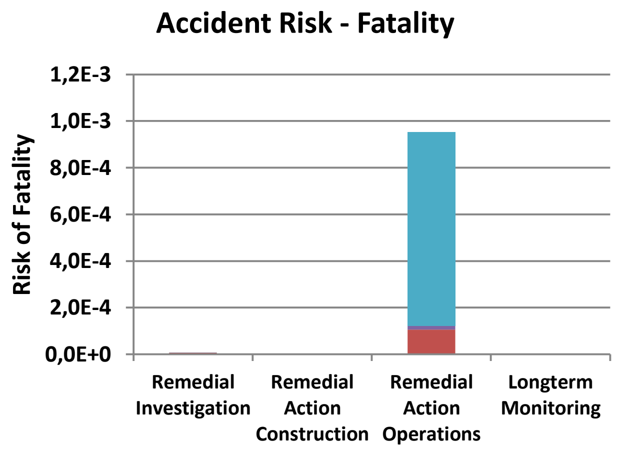


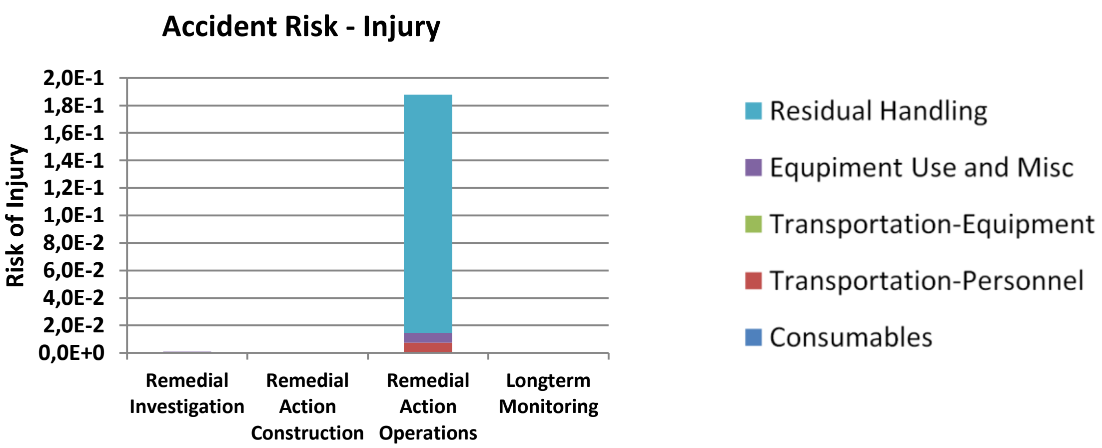








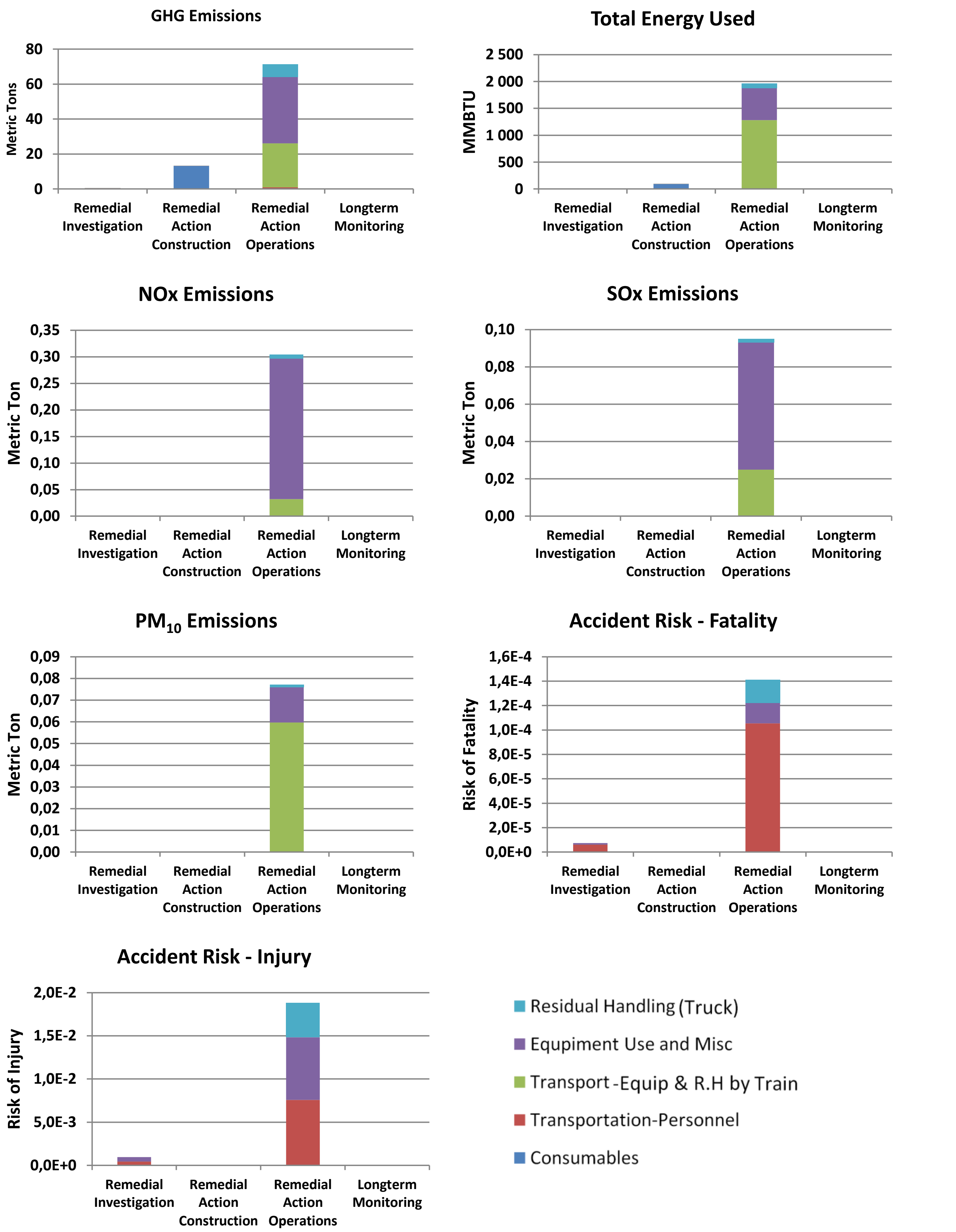




Phase	Activities	GHG Emissions (metric ton)	Total energy Used (MMBTU)	Water Consumption (gallons)	NOx emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.27	5.6E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.11	1.2E+00	NA	9.0E-05	3.0E-05	2.0E-05	6.1E-06	4.4E-04
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.17	2.4E+00	0.0E+00	1.0E-03	1.8E-04	7.8E-05	1.2E-06	5.0E-04
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.58	9.56E+00	0.00E+00	1.14E-03	2.18E-04	1.00E-04	7.32E-06	9.47E-04
Remedial Action Construction	Consumables	13.14	9.3E+01	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.01	9.6E-02	NA	7.5E-06	1.4E-06	7.0E-07	9.6E-09	2.0E-06
	Equipment Use and Misc	0.02	3.9E-01	0.0E+00	1.4E-04	3.9E-05	1.0E-05	2.1E-08	9.1E-06
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	13.17	9.36E+01	0.00E+00	1.44E-04	4.04E-05	1.09E-05	3.09E-08	1.11E-05
Remedial Action Operations	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.95	1.0E+01	NA	7.5E-04	2.5E-04	1.7E-04	1.1E-04	7.6E-03
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	38.07	6.0E+02	0.0E+00	2.6E-01	6.8E-02	1.6E-02	1.7E-05	7.2E-03
	Residual Handling	312.16	3.8E+03	NA	3.4E-01	8.1E-02	5.0E-02	8.3E-04	1.7E-01
	Sub-Total	351.18	4.42E+03	0.00E+00	6.01E-01	1.49E-01	6.68E-02	9.53E-04	1.88E-01
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		3.6E+02	4.5E+03	0.0E+00	6.0E-01	1.5E-01	6.7E-02	9.6E-04	1.9E-01

24.9 Scenario-6c, Hexion:

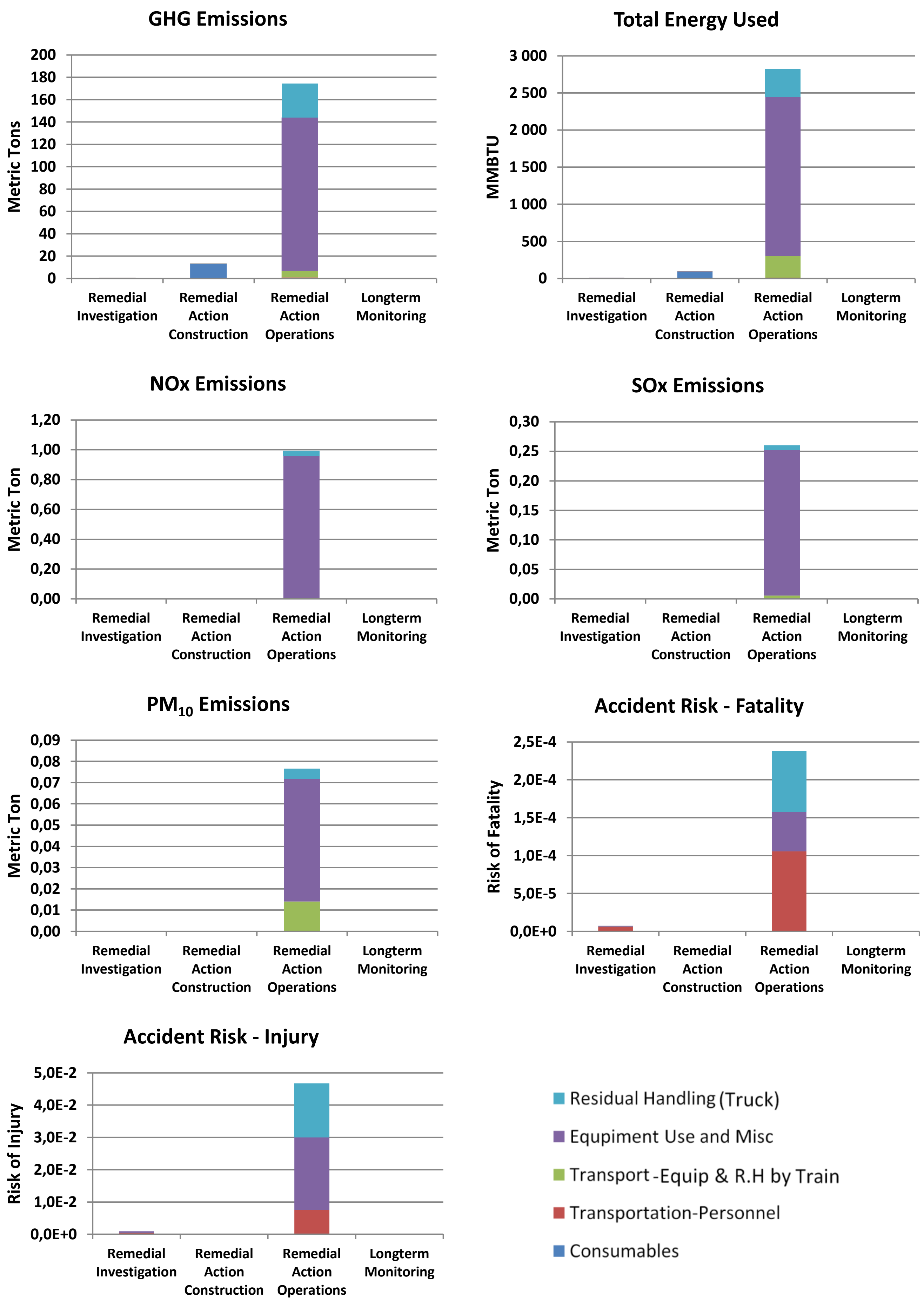
24.9.1 Onsite soil-washing & landfilling at SAKAB



Phase	Activities	GHG Emissions (metric ton)	Total energy Used (MMBTU)	Water Consumption (gallons)	NOx emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.27	5.6E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.11	1.2E+00	NA	9.0E-05	3.0E-05	2.0E-05	6.1E-06	4.4E-04
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.17	2.4E+00	0.0E+00	1.0E-03	1.8E-04	7.8E-05	1.2E-06	5.0E-04
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.58	9.56E+00	0.00E+00	1.14E-03	2.18E-04	1.00E-04	7.32E-06	9.47E-04
Remedial Action Construction	Consumables	13.14	9.3E+01	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.01	9.6E-02	NA	7.5E-06	1.4E-06	7.0E-07	9.6E-09	2.0E-06
	Equipment Use and Misc	0.02	3.9E-01	0.0E+00	1.4E-04	3.9E-05	1.0E-05	2.1E-08	9.1E-06
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	13.17	9.36E+01	0.00E+00	1.44E-04	4.04E-05	1.09E-05	3.09E-08	1.11E-05
Remedial Action Operations	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.95	1.0E+01	NA	7.5E-04	2.5E-04	1.7E-04	1.1E-04	7.6E-03
	Transportation-Equipment	25.10	1.3E+03	NA	3.1E-02	2.5E-02	6.0E-02	0.0E+00	0.0E+00
	Equipment Use and Misc	38.07	6.0E+02	0.0E+00	2.6E-01	6.8E-02	1.6E-02	1.7E-05	7.2E-03
	Residual Handling	7.18	8.8E+01	NA	7.7E-03	1.9E-03	1.2E-03	1.9E-05	4.0E-03
	Sub-Total	71.30	1.96E+03	0.00E+00	3.04E-01	9.50E-02	7.72E-02	1.41E-04	1.88E-02
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		8.5E+01	2.1E+03	0.0E+00	3.1E-01	9.5E-02	7.7E-02	1.5E-04	2.0E-02

24.10 Scenario-7, Hexion:

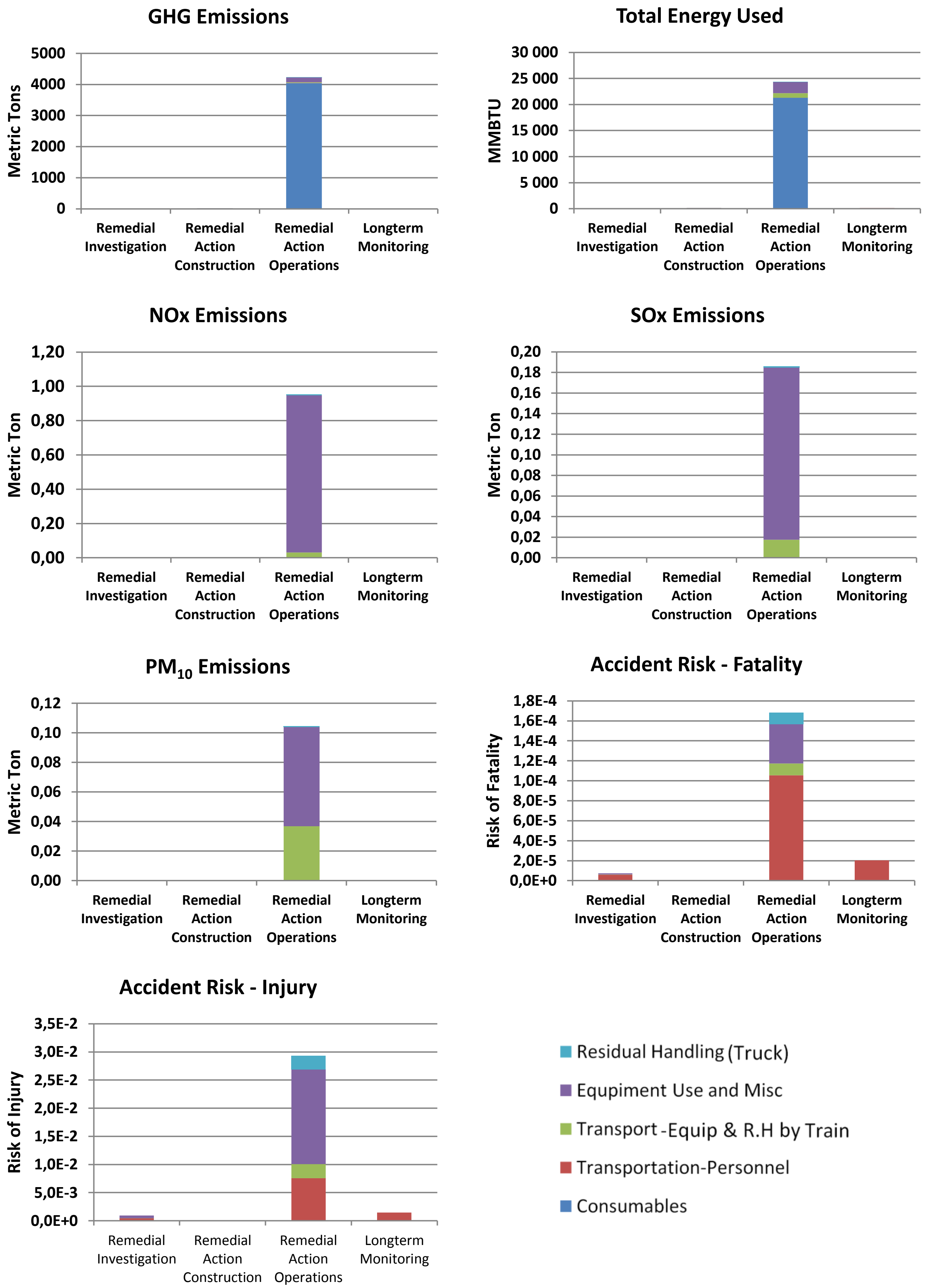
24.10.1 Complete excavation & optimized landfilling



Phase	Activities	GHG Emissions (metric ton)	Total energy Used (MMBTU)	Water Consumption (gallons)	NOx emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.27	5.6E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.11	1.2E+00	NA	9.0E-05	3.0E-05	2.0E-05	6.1E-06	4.4E-04
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.17	2.4E+00	0.0E+00	1.0E-03	1.8E-04	7.8E-05	1.2E-06	5.0E-04
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.58	9.56E+00	0.00E+00	1.14E-03	2.18E-04	1.00E-04	7.32E-06	9.47E-04
Remedial Action Construction	Consumables	13.14	9.3E+01	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.01	9.6E-02	NA	7.5E-06	1.4E-06	7.0E-07	9.6E-09	2.0E-06
	Equipment Use and Misc	0.02	3.9E-01	0.0E+00	1.4E-04	3.9E-05	1.0E-05	2.1E-08	9.1E-06
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	13.17	9.36E+01	0.00E+00	1.44E-04	4.04E-05	1.09E-05	3.09E-08	1.11E-05
Remedial Action Operations	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.95	1.0E+01	NA	7.5E-04	2.5E-04	1.7E-04	1.1E-04	7.6E-03
	Transportation-Equipment	5.83	2.9E+02	NA	7.3E-03	5.7E-03	1.4E-02	0.0E+00	0.0E+00
	Equipment Use and Misc	137.19	2.1E+03	0.0E+00	9.5E-01	2.5E-01	5.8E-02	5.2E-05	2.2E-02
	Residual Handling	30.16	3.7E+02	NA	3.2E-02	7.8E-03	4.9E-03	8.0E-05	1.7E-02
	Sub-Total	174.14	2.82E+03	0.00E+00	9.93E-01	2.60E-01	7.66E-02	2.38E-04	4.67E-02
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		1.9E+02	2.9E+03	0.0E+00	9.9E-01	2.6E-01	7.7E-02	2.5E-04	4.8E-02

24.11 Scenario-8, Hexion:

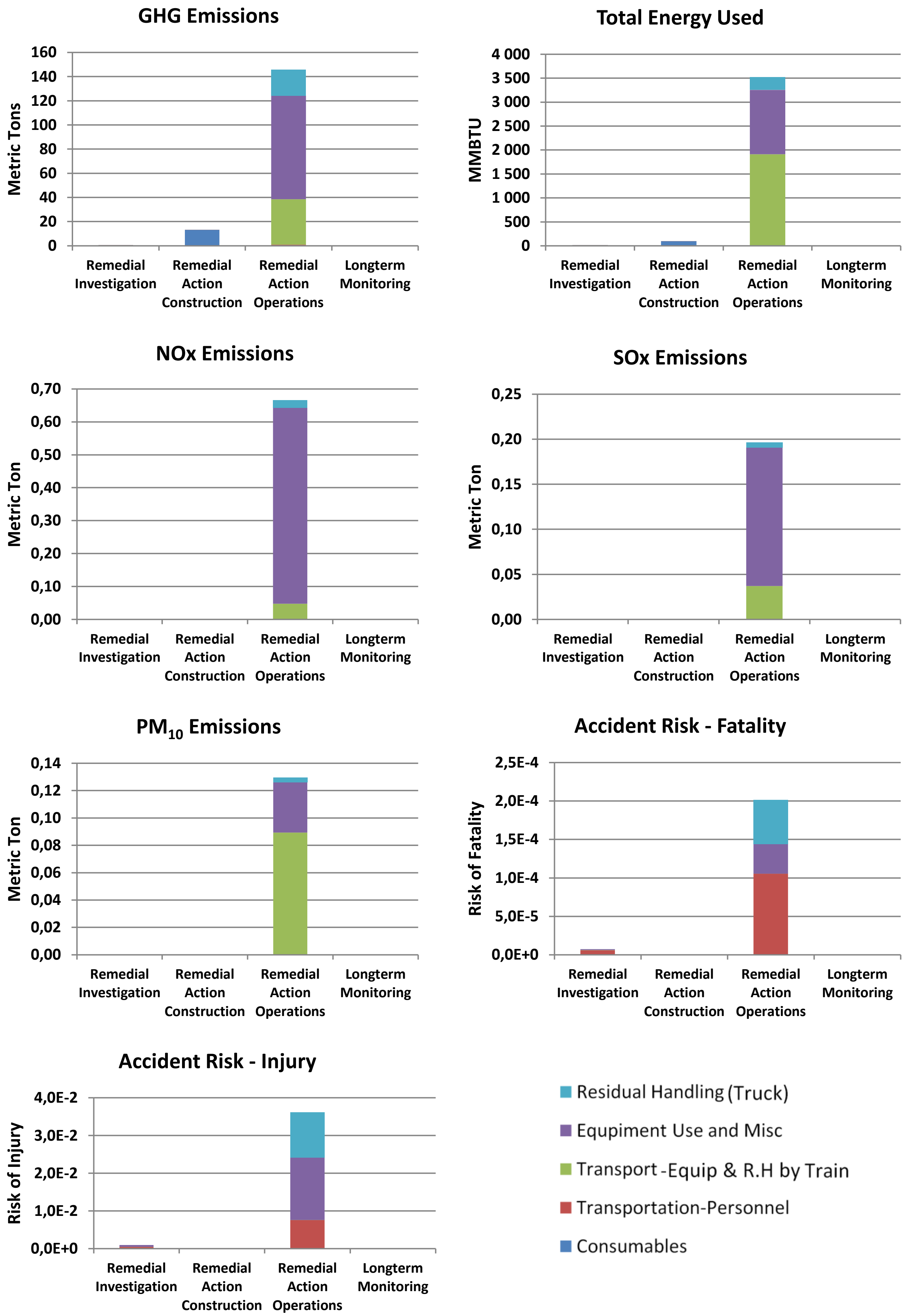
24.11.1 S&S remedy & remnants landfilling at SAKAB



Phase	Activities	GHG Emissions (metric ton)	Total energy Used (MMBTU)	Water Consumption (gallons)	NOx emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.27	5.6E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.11	1.2E+00	NA	9.0E-05	3.0E-05	2.0E-05	6.1E-06	4.4E-04
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.17	2.4E+00	0.0E+00	1.0E-03	1.8E-04	7.8E-05	1.2E-06	5.0E-04
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.58	9.56E+00	0.00E+00	1.14E-03	2.18E-04	1.00E-04	7.32E-06	9.47E-04
Remedial Action Construction	Consumables	13.14	9.3E+01	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.01	9.6E-02	NA	7.5E-06	1.4E-06	7.0E-07	9.6E-09	2.0E-06
	Equipment Use and Misc	0.02	3.9E-01	0.0E+00	1.4E-04	3.9E-05	1.0E-05	2.1E-08	9.1E-06
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	13.17	9.36E+01	0.00E+00	1.44E-04	4.04E-05	1.09E-05	3.09E-08	1.11E-05
Remedial Action Operations	Consumables	4,043.54	2.1E+04	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.95	1.0E+01	NA	7.5E-04	2.5E-04	1.7E-04	1.1E-04	7.6E-03
	Transportation-Equipment	26.15	8.7E+02	NA	3.1E-02	1.7E-02	3.7E-02	1.2E-05	2.5E-03
	Equipment Use and Misc	151.35	2.1E+03	0.0E+00	9.2E-01	1.7E-01	6.7E-02	3.9E-05	1.7E-02
	Residual Handling	4.35	5.3E+01	NA	4.7E-03	1.1E-03	7.0E-04	1.2E-05	2.4E-03
	Sub-Total	4,226.33	2.44E+04	0.00E+00	9.53E-01	1.86E-01	1.04E-01	1.68E-04	2.93E-02
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	1.5E+02	NA	0.0E+00	0.0E+00	0.0E+00	2.0E-05	1.5E-03
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	1.49E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.04E-05	1.46E-03
Total		4.2E+03	2.5E+04	0.0E+00	9.5E-01	1.9E-01	1.0E-01	2.0E-04	3.2E-02

24.12 Scenario- 9, Hexion:

24.12.1 Full Soil-wash & remnants landfilling at SAKAB



Phase	Activities	GHG Emissions (metric ton)	Total energy Used (MMBTU)	Water Consumption (gallons)	NOx emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	0.27	5.6E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.11	1.2E+00	NA	9.0E-05	3.0E-05	2.0E-05	6.1E-06	4.4E-04
	Transportation-Equipment	0.02	2.4E-01	NA	1.9E-05	3.6E-06	1.8E-06	2.9E-08	6.0E-06
	Equipment Use and Misc	0.17	2.4E+00	0.0E+00	1.0E-03	1.8E-04	7.8E-05	1.2E-06	5.0E-04
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.58	9.56E+00	0.00E+00	1.14E-03	2.18E-04	1.00E-04	7.32E-06	9.47E-04
Remedial Action Construction	Consumables	13.14	9.3E+01	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.01	9.6E-02	NA	7.5E-06	1.4E-06	7.0E-07	9.6E-09	2.0E-06
	Equipment Use and Misc	0.02	3.9E-01	0.0E+00	1.4E-04	3.9E-05	1.0E-05	2.1E-08	9.1E-06
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	13.17	9.36E+01	0.00E+00	1.44E-04	4.04E-05	1.09E-05	3.09E-08	1.11E-05
Remedial Action Operations	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.95	1.0E+01	NA	7.5E-04	2.5E-04	1.7E-04	1.1E-04	7.6E-03
	Transportation-Equipment	37.63	1.9E+03	NA	4.7E-02	3.7E-02	8.9E-02	4.8E-08	1.0E-05
	Equipment Use and Misc	85.63	1.3E+03	0.0E+00	6.0E-01	1.5E-01	3.7E-02	3.9E-05	1.7E-02
	Residual Handling	21.65	2.6E+02	NA	2.3E-02	5.6E-03	3.5E-03	5.8E-05	1.2E-02
	Sub-Total	145.86	3.52E+03	0.00E+00	6.66E-01	1.96E-01	1.30E-01	2.02E-04	3.61E-02
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personnel	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Transportation-Equipment	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Residual Handling	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Sub-Total	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total		1.6E+02	3.6E+03	0.0E+00	6.7E-01	2.0E-01	1.3E-01	2.1E-04	3.7E-02

25 Appendix 16

Ship cargo transfer impact values. Swedish available data (Cooper & Gustafsson, 2004) used in Hector (2009) are presented in left and default values used in SiteWise^{TM} to the right (Leaders, 2008).

Ship Cargo footprint *		
C02	3179	kg/ton marin diesel
NOx	63.22	kg/ton marin diesel
CH4	0.20	kg/ton marin diesel
NMVOC	0.97	kg/ton marin diesel
SO2	8.00	kg/ton marin diesel
N2O	0.15	kg/ton marin diesel
Partiklar	0.98	kg/ton marin diesel

*Swedish Methodology for Environmental Data, 2004

Water transportation*	
kg CO_2/ton mile	4.80E-02
g N_2O /ton mile	4.10E-03
g CH_4/ton mile	1.40E-03
g NOx /ton mile	8.80E+01
g SOx /ton mile	8.80E+01
g PM_{10} /ton mile	9.90E+01
BTU /ton mile	5.14E+02

* Table 2g from SiteWise^{TM} for impact values

New ship cargo transport impact values which were used for the second round of analysis are presented below. Ship fuel consumption rates were picked from Notteboom and Carriou (2009). SMED (2004) values were used to calculate emission impact factors.

Ship Fuel consumption						
Speed		Size	Fuel consumption			
Knots	km/hr		tons/day	tons/hr	tons/km	tons/mile
18.00	33.34	Small	50.00	2.08	0.06	0.10
20.00	37.05	Small	65.00	2.71	0.07	0.12
22.00	**40.75**	**Small**	**100.00**	**4.17**	**0.10**	**0.16**
24.00	44.46	Small	150.00	6.25	0.14	0.23

Source :T, Notteboom and P, Carriou, 2009

Ship transportation impact values(g/ton fuel)												
Engine Type	Fuel type	Main Pollutants					Particulate Matter			Greenhouse Effect		
		NOx	CO	NMVOC	SOx	NH3	TSP	PM10	PM2,5	CO2	CH4	N2O
SSD*	Md[a]	91561	2703	1622	8000	16	1081	1081	1081	3.18E+06	3.24E+01	1.68E+02
	RO[b]	87136	2545	1525	46000	27	6667	6667	6667	3.18E+06	3.08E+01	1.59E+02
	Average	8.93E+04	2.62E+03	1.57E+03	2.70E+04	2.15E+01	3.87E+03	3.87E+03	3.87E+03	3.18E+06	3.16E+01	1.64E+02

Source: SMED, 2004

* Slow Speed Engine [a] Marine Distillates [b] Residual Oils

Ship transportation impact values (g/km) and (g/mile)											
For 22 knots- g/km:	9.14E+03	2.68E+02	1.61E+02	2.76E+03	2.20E+00	3.96E+02	3.96E+02	3.96E+02	3.25E+05	3.23E+00	1.67E+01
For 22 knots- g/mile:	1.47E+04	4.32E+02	2.59E+02	4.44E+03	3.54E+00	6.37E+02	6.37E+02	6.37E+02	5.23E+05	5.20E+00	2.69E+01

Train cargo impact values. EPA Climate Leaders values and Railway association of Canada used by SiteWise$^{TMv.1}$ adaptation and replacement to Swedish condition (Leaders, 2008) and (RAC, 2001).

Rail cargo transportation lifecycle impact*	
kg CO2/ton mile a	2.52E-02
g N2O /ton mile a	6.00E-04
g CH4/ton mile a	2.00E-03
g NOx /ton mile b	6.44E-01
g SOx /ton mile b	3.22E-02
g PM10 /ton mile b	1.60E-02
BTU /ton mile c	3.41E+02

* Table 2f from SiteWise^{TM} for impact values

Swedish El-mix*				
C02	0.107748	kg/kwh	2.38E+02	Ibs/MWh
NOx	0.000137	kg/kwh	3.02E-01	Ibs/MWh
CH4	8.33E-05	kg/kwh	1.84E-01	Ibs/MWh
NMVOC	7.56E-06	kg/kwh	1.67E-02	Ibs/MWh
SO2	0.000108	kg/kwh	2.38E-01	Ibs/MWh
N2O	1.68E-06	kg/kwh	3.70E-03	Ibs/MWh
Partiklar	1.64E-05	kg/kwh	3.62E-02	Ibs/MWh

*Svensk elmix, 2002 The European Commission's Joint Research Centre

Rail cargo transportation lifecycle impact*						
Energy use		Train capacity		El use		
0.042	kwh/tonne.km	300	tonne/trip	12.6	kwh/km	
Inventory analysis						
C02	0.107748	kg/kwh	4.53E-03	kg/tonne.km	0.0066039	kg/ton.mile
NOx	0.000137	kg/kwh	5.754E-06	kg/tonne.km	0.0083968	g/ton.mile
CH4	8.33E-05	kg/kwh	3.50E-06	kg/tonne.km	0.0051055	g/ton.mile
NMVOC	7.56E-06	kg/kwh	3.18E-07	kg/tonne.km	0.0004634	g/ton.mile
SO2	0.000108	kg/kwh	4.536E-06	kg/tonne.km	0.0066194	g/ton.mile
N2O	1.68E-06	kg/kwh	7.06E-08	kg/tonne.km	0.000103	g/ton.mile
Partiklar	1.64E-05	kg/kwh	6.89E-07	kg/tonne.km	0.0010052	g/ton.mile

*Adopted and replaced train transport impact values with Swedish electricity mix