REPORT

H-2, Heidarfjall

REMEDIATION PLAN FOR CONTAMINATED SOIL

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Summary

On behalf of Umhverfis- og orkustofnun (UOS), the Norwegian Geotechnical Institute (NGI) has prepared a remediation plan for contaminated soil at H-2 on Heidarfjall, Iceland. The remediation plan is summarized in the table below.

Theme in the remediation plan	Description
Short project description	H-2 is a former U.S. military radar station located on top of Heidarfjall, Langanes, Iceland. This report concerns the remediation of contaminated soil at H-2.
Environmental investigations	Environmental investigations have been conducted by ESG in 2017 and NGI in 2023-2024. A total of 72 soil samples have been analysed for a range of contaminants in addition to water and biota samples. Concentrations above the acceptance criteria in regulation 1400/2020 have been detected for metals, polychlorinated biphenyls (PCB), polycyclic aromatic hydrocarbons (PAH), petroleum hydrocarbons and dioxins. In addition, debris and waste have been found scattered across H-2.
Risk assessment	A risk assessment for human health and contaminant transport has identified hotspots within three subareas which contains contaminant concentrations that exceeds an acceptable risk. This includes: The Dump Area – due to elevated concentrations of lead (Pb). The Tropo Building Area – due to elevated concentrations of PCB. The Catchment Area – due to elevated concentrations of PAH.
Remediation target	The remediation target is defined as *"acceptable risk for human health and contaminant transport for the current land use".* The parameter that causes the exceedance should satisfy the acceptance criteria in regulation 1400/2020 within the subarea after the remediation.
Remediation strategy	The remediation strategy includes excavating the most contaminated soil and delivering it to a waste treatment facility or landfill. For the Dump Area, it is an alternative to cover the soil considered as non-hazardous waste by a minimum of 50 cm of clean soil. The soil considered to be hazardous waste still needs to be excavated and treated at an external facility. Scattered waste and debris across H-2 should be collected, sorted according to waste category and handled according to national regulations.

Theme in the remediation plan	Description
Excavation depth and volumes	The geology at H-2 consists of a thin soil layer over basaltic bedrock. The excavation depth for remediation of contaminated soil is expected to be 2 m or less (typically around 1 m). The volume of contaminated soil in the three areas considered to be hazardous and non-hazardous waste has been estimated as follows: The Dump Area: 920 m^3 / 1830 m^3 The Tropo Building Area: 80 m^3 / 200 m^3 The Catchment Area: - / 15 m^3
Intermediate storage and transport of contaminated soil	Transport can be carried out using either trucks or dumpers. Hazardous and non-hazardous waste should not be mixed during transport or intermediate storage. Intermediate storage should be avoided when possible and take place within the same subarea and in parts with similar (or higher) levels of contaminants.
Follow-up and supplementary environmental investigations	Follow-up of the remediation should be carried out by an environmental engineer. Delimitation of contaminated soil can be carried out prior to remediation by analysing soil samples or, alternatively, during excavation using field test kits (for PCB) and handheld XRF (for heavy metals).
HSE precautions	The soil in some areas of H-2 contains asbestos and high levels of contaminants. All workers should be informed about the potential risks and wear the appropriate PPE. Measured should be taken to reduce the risk of spreading contamination during transport.
Monitoring	It is recommended that PCBs are monitored in Eidisvatn after the remediation on H-2.

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Review and reference page

1 Introduction

On behalf of Umhverfis- og orkustofnun (UOS), the Norwegian Geotechnical Institute (NGI) has prepared a remediation plan for contaminated soil at the former U.S. military radar station, H-2, located on Heidarfjall, Langanes, Iceland. The purpose of the remediation plan is to:

- Be a tool for the project owner, contractor and environmental authorities.
- Decide on the method of disposal of excavated materials.
- Ensure a cost-benefit assessment of the measures, so that the environmental footprint or cost of the measures themselves does not exceed the benefit.
- Ensure that the right measures are implemented in the right sub-areas.
- Ensure correct handling of excavated materials.
- Ensure documentation of material handling and measures carried out.

1.1 Background

1.1.1 Environmental investigations

Environmental site investigations have been carried out by the Environmental Sciences Group (ESG) from the Royal Military College, Kingston, Canada in 2017 (ESG, 2019) and NGI in 2023-2024 (NGI, 2024a). ESG divided H-2 into nine different subareas as shown in Figure 1.

The results from chemical analysis of soil samples taken by ESG (2019) and NGI (2024a) have been classified in NGI (2024a) according to the Icelandic acceptance criteria for soil presented in regulation 1400/2020 (Umhverfis-, orku- og loftslagsráðuneyti, 2020). The contaminants that have been detected in soil samples above the acceptance criteria for the land use category *industrial area* (*Landnoktun atvinnusvæðis)* are summarized in Table 1-1. This category covers all land use other than residential areas, such as business areas, industrial areas, retail and services, airports, ports, open areas, forestry and land reclamation areas, and uninhabited areas. The list reveals that a range of inorganic (As, Cd, Cu, Hg, Pb and Zn) and organic (dioxins, petroleum hydrocarbons, PAHs and ∑PCB-7) contaminants have been detected in soil samples from H-2 above the acceptance criteria. In addition, elevated concentrations of Pb, Zn and ∑PCB-7 were detected in samples of paint and sealants in the Tropo Building. The wall insulation materials may also contain asbestos. However, this has not been confirmed through laboratory analysis.

Figure 1-1 Overview map of H-2 showing the nine different subareas.

Table 1-1 Summary of results from soil investigations conducted at H-2 presented in ESG (2019) and NGI (2024a) by subarea classified according to the Icelandic acceptance criteria for the current land use described in regulation 1400/2020.

Subarea	No. of analysed samples	Contaminants that exceed the Icelandic acceptance criteria for soil
Dump	34	Pb, Cd, Cu, Zn, ∑PCB-7, petroleum hydrocarbons and dioxins
Tropo Building	11	∑PCB-7, Zn
Sewage Outfall	6	As, Pb, Cd, Hg, Cu and Zn
POL	3	-
Garage	1	Pb, Cu and ∑PCB-7
Barracks	1	-
Radome	4	Cd, Cu and Zn
Powerhouse	7	Zn and petroleum hydrocarbons
Catchment	5	Cd, Hg, Cu, Zn, PAHs, ∑PCB-7 and petroleum hydrocarbons

The analysis of water samples, passive samplers (DGT and POM) and biota samples (fish muscle tissue and wild bird eggs) have been reported by NGI (2024a, 2024b). The measured concentrations of inorganic contaminants and dioxins corresponded to “good” and “very good” environmental quality. The POM passive samplers revealed elevated concentrations of ∑PCB-7 in lake Eidisvatn (downstream H-2), while the biota samples showed that fish fillets of Artic char from lake Eidisvatn contains higher concentrations of ∑PCB-7 than samples from a nearby reference lake (NGI, 2024b). However, the fish from both lakes contain lower concentrations of ∑PCB-7 than the maximum levels in food (fishery products and wild fish) recommended in the EU (EC, 2023).

1.1.2 Risk assessment

NGI has conducted a risk assessment for human health and contaminant transport based on the results from the environmental investigations (NGI, 2024c). The results highlight three contaminant hotspots, where the calculations indicate that the risk exceeds an acceptable level (their locations are shown in Figure 1-2):

- **The Dump Area.** Lead (Pb) detected in soil next to weathered battery parts may cause an exceedance of the maximum tolerable daily intake (MTDI) for children. Oral intake of soil is the main exposure mechanism contributing to 70% of the total exposure.
- **The Tropo Building Area.** The levels of ∑PCB-7 detected in soil immediately south of the Tropo Building cause an exceedance of the MTDI for both children and adults. The main exposure mechanism is the consumption of fish from lake Eidisvatn. However, the risk of exposure by skin contact and oral intake also causes an exceedance of the MTDI in the calculations. The transient (time-dependent) contaminant transport model indicates that the ∑PCB-7 concentration in the water and fish downstream H-2 will continue to increase for >1 000 years if no remediation measures are done.
- **The Catchment Area.** The levels of Benzo(a)anthracene (BaA) and Benzo(a)pyrene (BaP) detected in a sediment sample from a small pond in the Catchment Area cause an exceedance of the MTDI for children. The main exposure mechanism is fish consumption. However, water drainage from the Catchment Area is likely towards the north, away from the lake where the landowners catch fish. The sediment sample also showed elevated levels of Cd, Hg, Cu, Zn, PAH, ∑PCB-7, VOC and petroleum hydrocarbons. The cocktail effect of these contaminants has not been assessed.

Asbestos-containing building materials, as well as debris and waste present on Heidarfjall, may represent an additional risk to humans and wildlife. Some is scattered on the surface, while some is buried. The largest concentration of buried waste was encountered in the Dump Area. The Tropo Building is also expected to weather over time. At present, the contaminants in the paint, sealants and tiles etc. are, however, considered less mobile than the contaminants present in the soil.

Figure 1-2 Approximate location of the three contaminant hotspots at H-2 in the Dump, Tropo Building and Catchment areas.

2 Assessment of remediation strategy

2.1 Remediation target

The remediation target describes the desired situation after the remediation is carried out considering the relevant land use (current and/or future).

For the current land use, the landowners and their families eat fish from Eidisvatn. In addition, H-2 is considered a minor tourist attraction. The landowners of Heidarfjall and the Eidi farm (located at the foot of the mountain) have stated that they desire to establish a fish farm in Eidisvatn and have considered letting a third party establish windmills on Heidarfjall. According to UOS, the local municipality considers establishing a National Park on the Langanes peninsula. The area would include Heidarfjell. Apart from that, no specific plans have been expressed regarding the future land use on and around Heidarfjall.

According to the Icelandic food and health authorities, the levels of ∑PCB-7 detected in fish from Eidisvatn satisfies the limit values for ∑PCB-7 in food for human consumption. Based on the available information, they conclude that they will not impose dietary restrictions on the consumption of fish from Eidisvatn or limit the possibility of using Eidisvatn for fish farming.

H-2 covers an area of more than 1 km^2 and contaminant concentrations above the natural background values have been detected across the area. Due to its remote location and the limited number of people at risk of being exposed to the contamination, it cannot be justified economically to remediate the area to satisfy the natural background conditions or the acceptance criteria in regulation 1400/2020. Instead, UOS and NGI have proposed to define the target of the remediation as "*acceptable risk for human health and contaminant transport for the current land use*". Due to the inherent uncertainty of environmental soil sampling, the following remediation plan is prepared with the goal that the concentrations of the parameters that exceed the level of acceptable risk (Pb, ∑PCB-7 and PAHs) will satisfy the acceptance criteria in regulation 1400/2020 in their respective area after the remediation.

2.2 Remediation method alternatives

NGI has identified the following five possible methods that, if applied, can be used to potentially reach the remediation target:

1. Reducing risk of exposure through restrictions
2. In-situ treatment or stabilization
3. Establishing an on-site landfill for contaminated soil
4. Excavating and delivering contaminated soil to a landfill or waste treatment facility
5. Covering contaminated soil

The methods will be described and discussed in the following.

1. **Reducing risk of exposure through restrictions**

The risk of exposure to the contaminants present on Heidarfjall can be reduced by:

- Restricting the access to the specific areas, either by blocking the road leading up to H-2 (to restrict access for tourists) or fencing in smaller areas to restrict access of both tourists and sheep (e.g. the contaminant hotspots).
- Implementation of dietary restrictions on the consumption of fish, sheep, eggs from wild birds and/or groundwater from the area.

The mentioned restrictions would have to be implemented and enforced by the relevant government authorities.

The method does not reduce the spread of contaminants. To reduce the risk of exposure related to activities downstream H-2, such as consuming fish from Eidisvatn, other measures would have to be implemented.

Pros

- Minimal disturbance of contaminated soil that might spread during excavation and/or transport.
- Expected low cost.

Cons

- Restricting access to Heidarfjall or parts of it for any foreseeable future is expected to reduce the value of the area as a tourist attraction as well as for the landowners.
- The method does not deal with the problem (the presence of contaminated soil) and does not reduce the potential spread of contaminants.

2. In-situ treatment or stabilization

The PCB-contaminated soil next to the Tropo building causes the highest exceedance of the MTDI in the risk assessment (NGI, 2024c). A range of methods have been developed for in situ treatment or stabilization of PCB-contaminated soil (Davila, Whitford, & Saylor, 1993). They include:

- Thermal desorption
- Chemical dehalogenation
- Solvent extraction
- Soil washing
- Solidification/Stabilization
- Bioremediation
- Pyrolysis/vitrification

Common for these technologies is that they require testing, verification, specialized equipment not available in Iceland and access to e.g. water and/or electricity on site. Due to the relatively small volume of PCB-contaminated soil at H-2, the cost per treated m^3 of soil is expected to be high. In situ treatment or stabilization can therefore not be recommended as a remediation strategy at H-2.

3. Establishing an on-site landfill for contaminated soil

By establishing an on-site landfill, one can isolate the contaminated soil from humans and the biosphere and at the same time reduce the risk of the contaminants spreading to the environment. The landfill would have to be designed with a low permeability lining at the base and sides. The cover would have to consist of a similar low permeability material and a granular material to protect the top-cover from erosion and cracking due to seasonal freezing and thawing. There is a limited access to natural low permeability sediments like clay near Heidarfjall and in Iceland in general. The low permeability layers would therefore have to consist of either bentonite or HDPE membranes.

It is uncertain whether the most contaminated soil can be placed in a local landfill as it might be classified as hazardous waste. The regulations on landfills for hazardous waste are strict and it is not desirable to establish such a landfill locally. The use of the local landfill(s) would therefore be limited to soil that can be classified as non-hazardous waste.

Possible locations of the landfill(s) could be the abandoned gravel pits northwest of the Dump Area (Figure 2-1), or in the POL Area within the embarkments that surrounded the former fuel storage tank (Figure 2-2).

Pros

- Reduces the risk of exposure to contaminants by skin contact or oral intake.
- Reduces the spread of contaminants from H-2.
- Reduces the need for long-distance transport of contaminated soil to a landfill/treatment facility.

Cons

- Risk of spreading contaminants during excavation and onsite transport by dust and particles.
- Uncertainty regarding the durability and longevity of the low-permeability membranes.
- Unclarified liability and responsibility for maintenance and monitoring of the landfill(s).
- Strict regulations on hazardous waste might limit the possibility to place the most contaminated soil in a local landfill. The most contaminated soil might therefore have to be remediated by other methods.

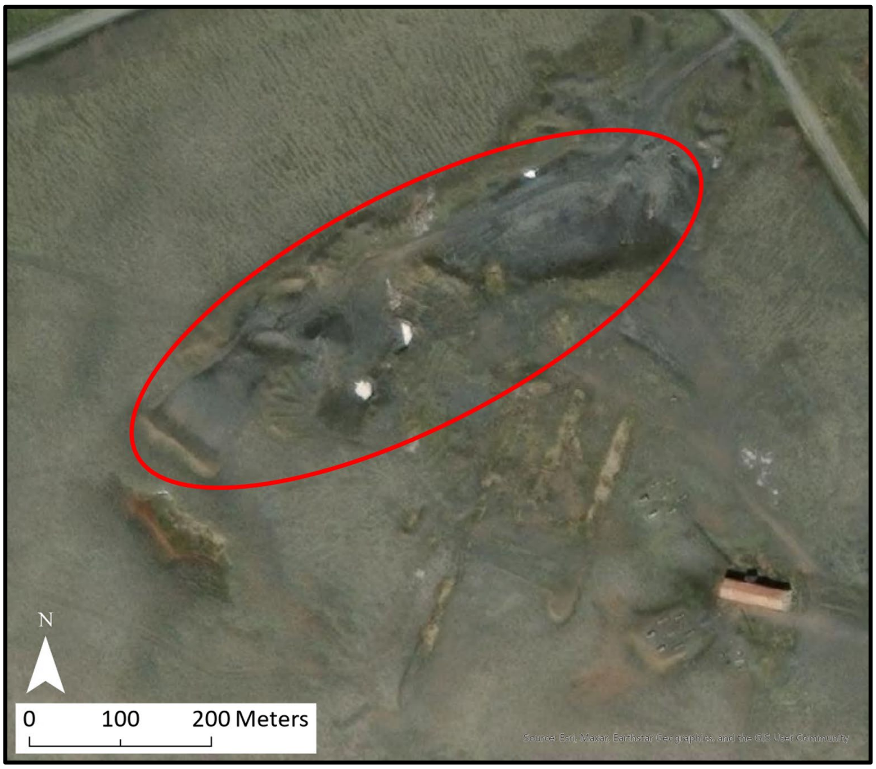

Figure 2-1 Potential location for on-site landfill at H-2: Gravel pits northwest of the Dump Area. The gravel pits cover an area of approximately 5 000 m^2.

Figure 2-2 Potential location for on-site landfill at H-2: Embarkments within the POL Area. The area within the shoulders of the embarkments is approximately 600 m^2.

4. Excavating and delivering contaminated soil to a waste treatment facility

In this alternative, contaminated soil will be excavated and transported to a waste treatment facility or landfill for safe disposal. According to UOS, there are no such facilities near Heidarfjall with permission to receive and treat waste with the contaminant concentrations detected in some of the soil samples at H-2. The excavated contaminated soil would therefore have to be delivered either to one of the landfills close to Reykjavik (8 hours by road or 900 km by the sea) or to a waste treatment facility abroad (at least 1 200 km by boat).

Depending on the amount of contaminated soil, it could be transported by truck to the port in Þórshafnarhreppur (21 km from H-2) and transferred to a ship in either containers or bulk, depending on the volume and transport category. Afterwards, the ship will transport the contaminated soil to the waste treatment facility.

Pros

- Permanently removes the contaminants from Heidarfjall.
- Ensures safe disposal of contaminants.
- Responsibility for the contaminated soil is transferred to the waste treatment facility.
- Reduces the need for maintenance and monitoring after remediation compared to other alternatives.

Cons

- Expected high cost and high CO_2 emissions from excavation, transport and shipment per m^3 of remediated soil.
- The need for backfilling excavation pits.
- The risk of spreading contaminants during excavation and transport by dust and/or particles.
- Potential issues related to transnational shipment of hazardous waste.

5. Covering contaminated soil

In this alternative, a cover will be established on top of the contaminated soil where it is situated. The cover can either consists of locally sourced natural soil or natural soil in combination with a bentonite or HDPE membrane as described for the on-site landfill (alternative no. 3). The purpose is to isolate the contaminated soil from humans and the biosphere. This will reduce the risk of direct exposure through skin contact or oral intake. Using a membrane would in addition reduce the transport of contaminants.

Pros

- Reduces the need for long-distance transport of contaminated soil to a waste treatment facility.
- Reduces the need for excavation of contaminated soil.

Cons

- Large scope if a large area of contaminated soil is to be remediated.
- For a large area of contaminated soil, the material use (soil and membrane) may be higher than for the on-site landfill alternative (alternative no. 3).
- Uncertainty related to whether the membrane-solution can intercept rainwater and groundwater to a satisfactory extent.
- The need to excavate clean, natural soil from the area surrounding H-2. The potential negative effects can be reduced if existing gravel pits are used.

3 Remediation plan

Of the remediation methods that has been evaluated in chapter 2.2, only alternative 4. "*Excavating and delivering contaminated soil to a waste treatment facility*" is considered to reliably reduce the risk related to the contaminated soil present on Heidarfjall. It is also the solution which will put the least number of restrictions on the future land use in the area and be best for the value of the property.

The remediation plan consists of the following activities:

- Excavation of the contaminated soil which causes the risk to exceed an acceptable level and delivering it to a waste treatment facility. This includes:
  - Pb-contaminated soil in the Dump Area.
  - PCB-contaminated soil in the Tropo Building Area.
  - The PAH-contaminated sediments present in the small pond in the Catchment Area.
- Removing any visible waste and debris lying on the surface across H-2. The waste fractions should be sorted according to material and handed in for recycling if possible.

The details of the remediation plan for each subarea are described in the following.

3.1 The Dump Area

High contaminant concentrations and asbestos-containing debris are present in the Dump Area. It is therefore important that the health and safety guidelines described in chapter 4.9 are followed, which includes wearing appropriate personal protection equipment (PPE).

The remediation plan for the Dump Area is described in the following.

Removal of visible waste

A visual inspection of the Dump Area should be carried out prior to any excavation and the location of all visible debris and waste should be recorded. The location of weathered Pb-batteries should be described and georeferenced (e.g. with GPS-equipment). The waste must be collected, sorted according to waste fraction and handed in for recycling (if possible) or as waste. Hazardous waste (such as asbestos and Pb-batteries) must be kept separate from non-hazardous waste. Specific health and safety precautions must be taken when handling asbestos-containing waste.

Soil excavation

Soil represented by the samples that contain Pb-concentrations above the Icelandic acceptance criteria presented in regulation 1400/2020 must be excavated and removed from H-2 (Figure 3-1). It is recommended that soil represented by sample point DA17 is also be removed due to elevated concentrations of ∑PCB-7. Any debris/waste should be separated out before delivering the contaminated soil to a waste treatment facility. The soil must be excavated down to natural soil with no visible waste (expected to be minimum 1 m below terrain) or bedrock. If any Pb-batteries are observed during the visual inspection or during excavation, the soil within a 2 m diameter of the battery parts should be sampled and analysed (for documentation) and removed as well.

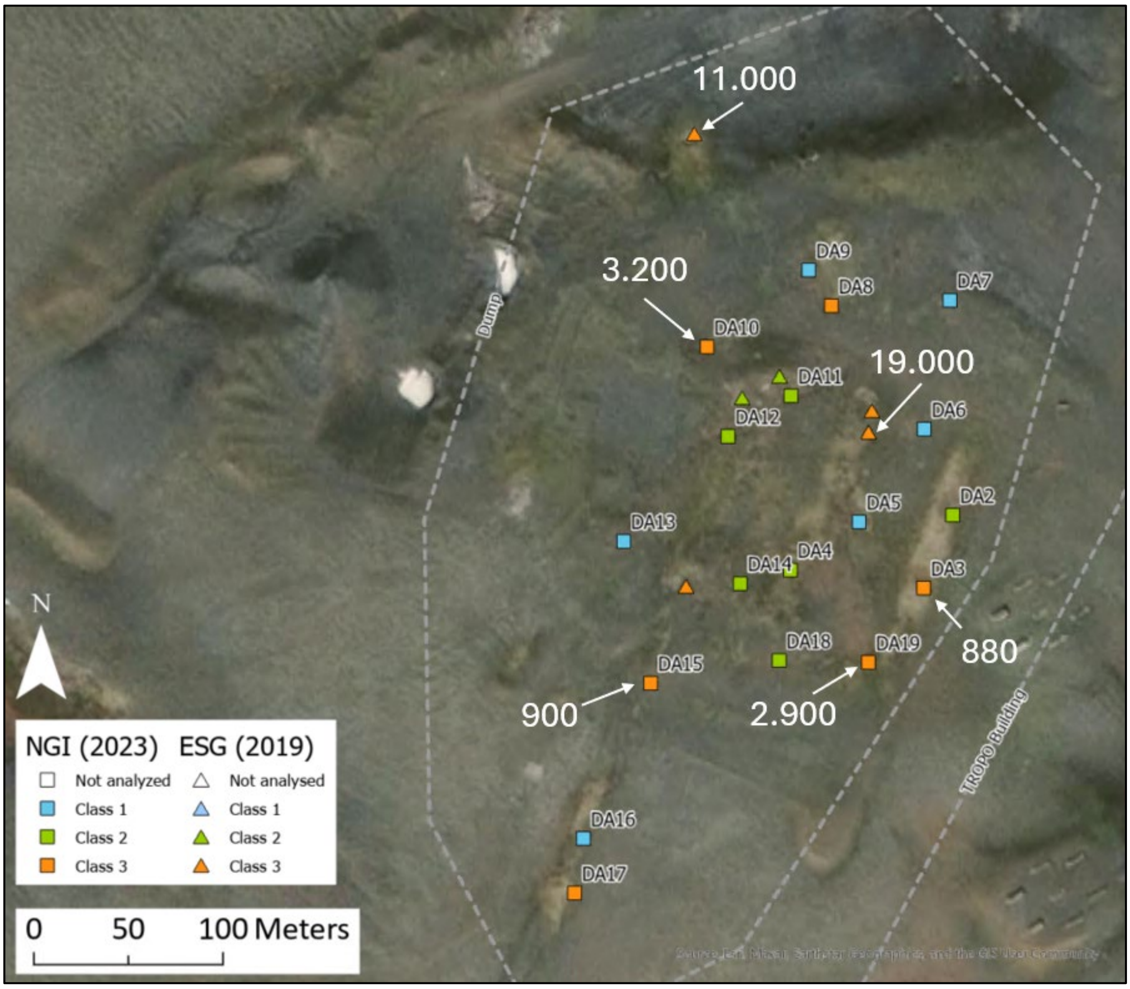

Figure 3-1 The Dump Area. Numbers denote the Pb-concentration (in mg/kg DM) detected in the soil samples. Only concentrations above the Icelandic acceptance criteria for the current land use is shown.

An excavation plan has been prepared based on the analysed soil samples and the geophysical investigations presented in NGI (2024a). The 200 mS/m contour of the electromagnetic (EM) data has been used to delimit the areas to be excavated. The depth and excavation volume has been estimated based on the depth-to-bedrock model created from the ground-penetrating radar (GPR) data. The excavation plan is shown in Figure 3-2, while the expected waste categories (hazardous and non-hazardous waste) and estimated volumes are summarised in Table 3-1. Since the calculations are based on the depth-to-bedrock model, the volumes are expected to represent a maximum estimate. Pb-concentrations in samples from area no. 1 to 4 indicate that the soil can be considered hazardous waste according to the EU waste regulations. The soil within these four areas must be excavated and delivered to a waste treatment facility. The soil within area no. 5 to 8 contain lower levels of contaminants and should either:

A) be excavated and delivered to a waste treatment facility.
B) be covered by a minimum of 50 cm of clean soil from the gravel pit northwest of the Dump Area after removing any waste and levelling the terrain. The purpose is to reduce the risk of humans/animals getting in direct contact with the contaminants.

Alternative B reduces the volume of soil that needs to be transported long distances from H-2 and hence the associated greenhouse gas emissions.

After excavation, the pits should be levelled and/or filled with clean soil from one of the abandoned gravel pits on Heidarfjall.

It is recommended to conduct supplementary soil sampling in the Dump Area before remediation to further delimit the contaminated soil and, possibly, reduce volume of soil that needs to be excavated and handled externally. If the delimitation is carried out during the remediation, samples can be analysed on site using a portable x-ray fluorescence (XRF) analyser.

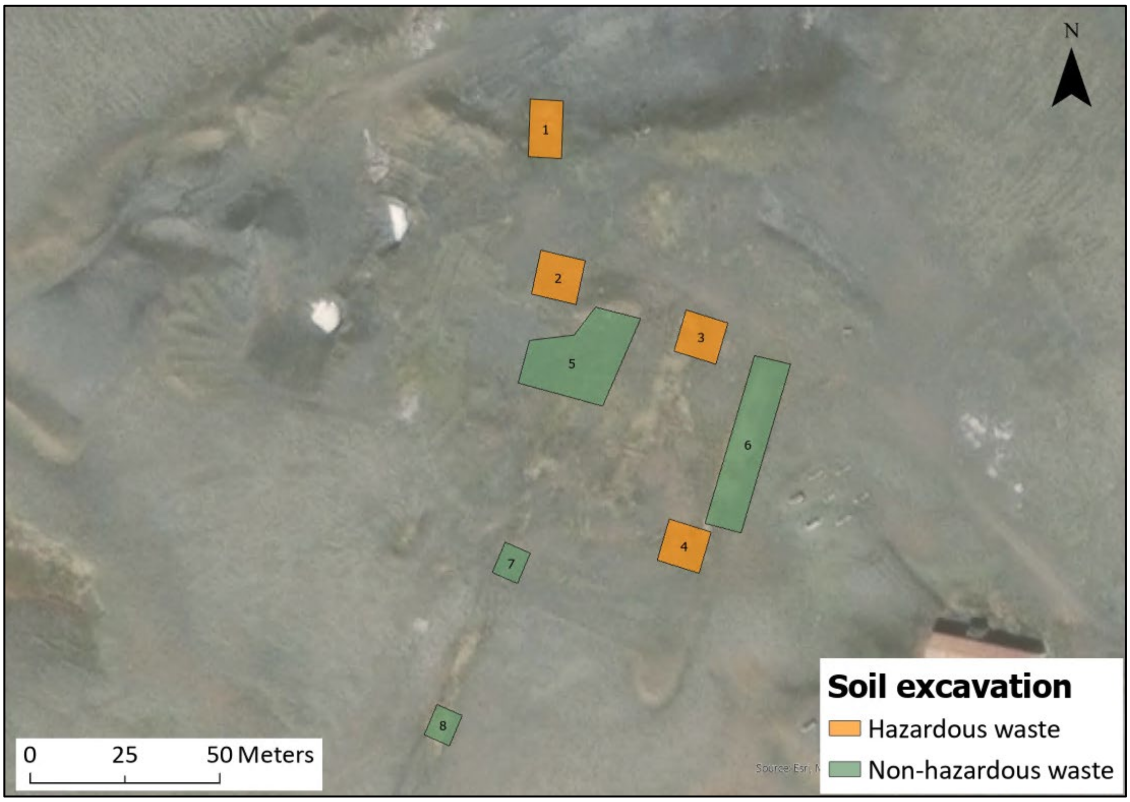

Figure 3-2 Excavation plan for the Dump Area based on expected waste categories.

Table 3-1 Summary of the excavation plan for the Dump Area. Area numbers according to Figure 3-2. Expected waste categories are based on Pb-concentrations. Estimated max. volume is calculated from depth to bedrock-model based on the geophysical investigations.

Area no.	Description	Expected waste category	Area [m^2]	Estimated max. volume [m^3]
1	Pb: 11.000 mg/kg	Hazardous waste	140	280
2	Pb: 3.200 mg/kg		150	300
3	Pb: 19.000 mg/kg		135	135
4	Pb: 2.900 mg/kg		135	200
			Sum	**920**
5	Waste mound A; Batteries	Non-hazardous waste	500	1.000
6	Pb: 880 mg/kg ; Batteries		470	700
7	Pb: 900 mg/kg		65	65
8	∑PCB-7: 8 mg/kg		65	65
			Sum	**1.830**

3.2 The Tropo Building Area

High PCB-concentrations have been measured in soil samples from the Tropo Building Area. It is therefore important that the health and safety guidelines described in chapter 4.9 are followed, which includes wearing appropriate PPE.

Measured ∑PCB-7 concentrations in soil samples are shown in Figure 3-3. The highest concentration (28.000 mg/kg) was measured on a sample of a patch of darkly stained soil next to the building. When handling contaminated soil, ∑PCB-7 concentrations above 50 mg/kg DM are considered hazardous waste according to the EU waste regulations. In addition, elevated concentrations of Pb, Zn and ∑PCB-7 have been detected in construction materials of the Tropo Building itself.

A plan for supplementary soil investigations and a remediation plan for the Tropo Building Area is described in the following.

Figure 3-3 ∑PCB-7-concentrations (in mg/kg DM) detected in soil samples from the Tropo Building Area. Numbers without parenthesis represent topsoil (0 – 0,2 m depth), while numbers in parentheses represent the deeper soil layers (0,2 – 1 m depth).

Supplementary soil investigations

Suggested sampling points for supplementary soil investigations are shown with yellow diamonds in Figure 3-4 alongside the excavation plan. The investigations should distinguish between topsoil (0 – 0,2 m depth) and deeper soil layers (>0,2 m depth). An initial assessment of the PCB-concentrations can be obtained by using field test kits. The kit should have a lower detection limit of 0,5 mg/kg ∑PCB-7 or below, to determine if the concentration satisfies the acceptance criteria in regulation 1400/2020. A number of samples should be verified through analysis by an accredited laboratory.

Soil excavation

The excavation plan for the Tropo Building Area is shown in Figure 3-4. The soil must be excavated down to 1 m below the terrain surface or to bedrock if less than 1 m. The excavation plan should be adjusted based on the results of the supplementary soil investigations. The expected waste categories (hazardous and non-hazardous waste) and estimated volumes are summarised in Table 3-2. After excavation, samples from the bottom of the excavation pit should be collected and analysed for ∑PCB-7. The excavated soil should be replaced by clean soil from one of the abandoned gravel pits on Heidarfjall.

The Tropo Building

The construction materials of the Tropo Building represent a health risk to potential visitors due to their content of contaminants including asbestos. The asbestos-containing building materials must be removed by an approved remediation company and the waste must be packaged in accordance with the national regulations and delivered as asbestos waste to an approved waste handling facility. All entrances to the building (doors, windows and holes) should afterwards be sealed off, e.g. using wooden plates, to prevent public entrance into the building.

Another alternative is to remove the building (including the roof, roof frame and walls) and only leave the concrete foundation. This is what has already been done for e.g. the barracks. Beforehand, chemical analyses of the floor tiles, insulation materials and the wooden roof frame to determine their proper disposal. Analytical results of paint, sealants and concrete are presented in ESG (2019) and NGI (2024a).

Figure 3-4 Suggested sampling points for supplementary soil investigations and excavation plan for the Tropo Building Area.

Table 3-2 Summary of the excavation plan for the Tropo Building Area. The locations of the excavation areas are shown in Figure 3-4. Expected waste categories are based on measured ∑PCB-7 concentrations.

Expected waste category	Description	Estimated volume [m^3]
Hazardous waste	∑PCB-7 >50 mg/kg	80
Non-hazardous waste	∑PCB-7 <50 mg/kg	200

3.3 The Catchment Area

ESG (2019) reported a sediment sample from a small pond in the Catchment Area that contains elevated concentrations of Cd, Hg, Cu, Zn, PAHs, ∑PCB-7 and petroleum hydrocarbons. None of the individual concentrations indicate that it should be classified as hazardous waste. However, the cocktail-effect of multiple contaminants have not been assessed. Contaminant concentrations in samples analysed from other parts of the Catchment Area did not exceed the acceptance criteria in regulation 1400/2020 for the current land use. The pond with the contaminated sediments covers an area of approx. 25 m^2. The boundary between the contaminated sediments and the natural underlying soil has not been determined. In the adjacent dried-out pond, the boundary was encountered 40 cm below the surface (NGI, 2024a).

The remediation plan involves removing the overlying 20-40 cm of water (e.g. by digging a trench and draining it), excavating the contaminated sediments and delivering them to a waste treatment facility. To ensure that sufficient of the contaminated sediments are removed, the pond should be excavated down to 20 cm below the transition into natural soil. The total volume is estimated to be approx. 15 m^3. It is likely that the sediments will have a high water-content, and the contractor must consider choosing an appropriate container for transport.

After excavation, a sample should be collected from the bottom of the pit and analysed for the same contaminants as the samples which has already been collected.

Figure 3-5 Excavation plan for the small pond in the Catchment Area.

3.4 Scattered waste and debris

Scattered waste and debris across H-2 should be collected, sorted according to waste type and handled according to national regulations. The waste includes loose pieces of scrap metal, wires and asbestos-containing building materials like Eternit. Examples are shown in Figure 3-6. Asbestos-containing building materials must be collected, packaged and delivered as asbestos waste to an approved waste handling facility in accordance with national regulations.

Figure 3-6 Examples of pale-yellow fragments of asbestos-containing building materials (top), wood debris and wires (center) and scrap metal, wires and wood (bottom) present on Heidarfjall.

4 Guidelines for execution and documentation

4.1 Intermediate storage and transport of contaminated soil

The following guidelines apply for intermediate storage and transport of contaminated soil:

- The remediation should be planned such that the need for and duration of intermediate storage can be limited as far as possible. This can be achieved e.g. by transferring the soil directly onto the cargo plane of a truck or dumper after excavation and transporting it directly to the external waste treatment facility.
- Soil considered to be hazardous and non-hazardous waste must not be mixed during storage or transport.
- Contaminated soil must be stored within the subarea as it originates from and in parts of it with similar (or higher) levels of contaminants.
- The contractor should implement measures to reduce the risk of contaminants spreading during intermediate storage and transport due to wind/weather.

4.2 Delivering soil to a waste treatment facility

Soil that is transported out of H-2 is considered as waste and must be delivered to a landfill or a waste treatment facility with permission to handle soil with the types and concentrations of contaminants detected at H-2.

According to UOS, there are no landfills or waste treatment facilities in Iceland with permission to handle hazardous waste. Excavated soil classified as hazardous waste must therefore be shipped to a facility abroad. The nearest port is located in Þórshafnarhreppur, 21 km from H-2.

4.3 Handling of contaminated water

Situations may arise where water drains into an excavation pit and might become contaminated. In general, water should then infiltrate into the ground leaving the contaminated particles on the surface. If it is necessary to pump out potentially contaminated water to continue the remediation work, the following general conditions apply:

- The water should be pumped via a sedimentation basin/container to remove particles before discharge. The collected particles should be disposed of in the same way as the contaminated soil from the same area.
- If there is a risk of oil contamination, the water should also be pumped via a mobile oil separator.

4.4 Follow-up by environmental engineer

Follow-up and control must be carried out by an environmental engineer (or a person with equivalent competence or sufficient experience within the field) to ensure that the requirements set by the authorities and described in the remediation plan are followed.

The environmental engineer should delimit the volume of hazardous waste that needs to be excavated and collect the samples needed for analysis and documentation.

4.5 The contractor's internal control

As part of its internal control, the contractor must carry out a risk assessment involving the handling of contaminated soil. Any measures related to health and the surrounding environment, including requirements for protective measures for workers, shall be part of the risk assessment.

It is the contractor's responsibility to call in the environmental engineer if unexpected quantities or types of contaminated soil are encountered or other unexpected events occur.

4.6 Kick-off meeting

A kick-off meeting shall be conducted before the onset of the remediation work with representatives from:

- The contractor, including the people who will carry out the work.
- The project owner (UOS)
- The environmental engineer responsible for following up the remediation.

All personnel involved with the remediation must be present to ensure that those who carry out the work have understood how to act when handling contaminated soil, and that the managers know how to plan, instruct, report and monitor the work. The following themes should be included in the agenda for the kick-off meeting:

- Review of the remediation plan.
- What considerations must be taken when excavating contaminated soil.
- How the excavation work and follow-up should be carried out to meet the requirements set by the environmental authorities.
- Health, safety and environment (HSE).
- Plan for documentation and reporting.

4.7 Timing and tentative schedule

The remediation should be carried out during the summer months, after the spring snowmelt and the topsoil has thawed. According to historical meteorological data, the warmest and driest months in northeast Iceland are May through August.

Based on experience, it should be possible to carry out the remediation plan in 4-8 weeks depending on the number of excavators and trucks involved.

4.8 Health, safety and environment

A detailed Health, safety and environment (HSE) plan must be prepared by the project owner/contractor. This chapter only describes general precautions to be taken in connection with work on contaminated sites. Activities on contaminated soil must be planned:

- To avoid exposure of contaminants to personnel working on the site.
- To reduce the risk of spreading contaminants during excavation, storage and transport.

At H-2, some of the main potential health hazards include excavation of soil that may contain fragments of Eternit (and other asbestos-containing materials) as well as high levels of contaminants.

When excavating contaminated soil, there may be variations in the type and concentration of contaminants. Even after thorough site investigations, unknown contaminants may be encountered during excavation. It is therefore important that precautions for health and safety for personnel are established. The areas where contaminated soil is excavated from or stored are defined as contaminated zones. Workers must have sufficient information about the health hazards that may be associated with the work and be familiar with the rules for working in contaminated areas. The workers should be informed about what personal protection equipment (PPE) to use to protect themselves and the surrounding environment from contamination. Some precautions include avoiding skin contact with the contaminated materials (gloves with high cuffs, rainwear or disposable overalls, safety glasses), changing soiled clothing and washing hands before eating and smoking, etc. During excavation in the Dump Area, all personnel at risk of breathing in asbestos fibers should wear appropriate face masks with asbestos-filters and other PPE in accordance with the national regulations.

Signs should be put up alongside the road to reduce the risk of public entrance into the area during the remediation.

4.9 Documentation and reporting

After the remediation, the work must be described and documented in a report. The report should document:

- How the remediation was carried out.
- How the excavated soil was handled from it was excavated until it reached the waste treatment facility. This includes intermediate storage (if relevant) and transport. Copies of the receipts from the waste treatment facility/facilities should be included in the report.
- The remaining contaminated soil based on previous environmental investigations, and supplementary sampling carried out during the remediation.
- Supplementary sampling of soil and/or water carried out prior to and during the remediation, including reporting of the chemical analysis. It should be described if the results led to any changes in the remediation plan and if so, what changes.
- Mitigation measures that have been implemented to prevent adverse impacts on the environment during the remediation.
- How water in the excavation pits was handled (if relevant).
- Unexpected events and/or deviations from the action plan.

5 Monitoring of PCBs after remediation

The transport and bioaccumulation of PCBs is the primary concern at H-2 (NGI, 2024c). The investigations that have been carried out show that it can be monitored by analysing either polyoxymethylene (POM) passive samplers or biota samples (fish) in Eidisvatn. PCB might be retained in the soil, bedrock and water in and around Heidarfjall. It is therefore expected to take several or even many years before any measurable effect can be detected in water and/or biota samples. Because of the potential long lifespan of Arctic char (they typically live for 6-7 years, but can get as old as 20-30 years), the PCBs measured in biota samples may have accumulated over several years. PCB is reported to have a long biological half-time (>0,5 years for ∑PCB-7, but the half-time depends on fish species and PCB-congener). This makes fish samples less suitable for monitoring over shorter periods (<10 years). POM is therefore the preferred method for monitoring of PCBs in Eidisvatn after the remediation at H-2. It is suggested that monitoring using POM should be carried out 2, 5 and 10 years after the remediation. The results should then be used to evaluate the effect of the remediation and decide whether to continue the monitoring program or not.

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