Reykjavik Energy

HVERAHLID POWER STATION
90 MW_e

ENVIRONMENTAL IMPACT STATEMENT
Summary

March 2008

VSO CONSULTING
50 YEARS 1958 – 2008

Summary

General

Reykjavík Energy plans to build a new geothermal power station in Hverahlid. It is estimated that geothermal energy processing in Hverahlid can suffice for the production of 90 MW of electric energy. Reykjavík Energy has a 15-year exploration license for this area, starting on 1 June 2001 and a promise of priority for geothermal energy utilization. The electric energy production at Hverahlid Power Station is scheduled to begin in 2010.

The planned power station is in the Hengill area, more specifically in the area named Hverahlid. The project area of the power station, which is about 320 ha, is located in the Municipality of Olfus. According to the current general plan of Olfus (2002-2014), the planned construction area is defined as an open unsettled area with local protection. The project area is also planned within a far zone of water protection. The Olfus Municipality is working on changing the general plan, and the planned Hverahlid Power Station is in accordance with a proposed amended general plan.
Under the Act on of environmental impact assessment, no. 106/2000, as amended, assessment of the project's environmental impact is obligatory. The assessment was prepared by VSO Consulting under Reykjavík Energy's project management, but numerous experts were also involved in the project.

Purpose

The goal of the power station in Hverahlid is to meet increased demand of the economy for electric energy.

There are prospects for substantial expansion of the electric energy market in Iceland. Agreements have been signed with Nordural and Alcan, and there are ongoing discussions that are far along with parties regarding preparations for a collocation facility as well as a prospective operator of a silicon metal factory. To ensure Reykjavík Energy's customers sufficient security and to service growing demand over the next several years, it is clear that the company must increase its production capacity for electric energy. Further exploration of the geothermal system at Hengill and construction of the Hverahlid and Bitra Power Stations is part of Reykjavík Energy's measures to meet the demand for energy.

The project

Plans call for the fully built geothermal power station in Hverahlid to produce 90 MW of electric energy. In broad terms, a geothermal energy power station operates from geothermal liquid streaming up from boreholes and then being channelled to a separator plant via a steam utility. There the steam is separated from the water and led through supply pipes to the power station's steam turbines where electricity production occurs. For a fully built power station, two 45 MW turbine units are required, with an estimated steam consumption of about 80-85 kg/sec each. An estimated number of 18 production holes must be drilled to achieve this. The water separated by steam separators is led into re-injection wells via a drainage utility.

The main project parts of Hverahlid Power Station are: Boreholes, drilling sites, steam utility, fresh water utility, power plant, cooling towers, drainage utility, roads and tracks in the project area and a connection with a highway, quarrying of material, facilities for contractors and the connection with the Landsnet's energy transport system. Table 2 contains the main key figures of the power station.

In the assessment of the planned geothermal power station in Hverahlid, different locations, arrangements and structural types were investigated, with the goal, among other things, of reducing environmental impact.

Drilling sites, rig locations and boreholes

Drilling sites are demarcated plots where it is deemed most efficient to drill with respect to the yield of geothermal heat for the production of electric energy. Six drilling sites are planned in Hverahlid, marked B1 to B6 on Map 1.

Rig locations, on the other hand, are areas where drilling rigs stand during drilling, and up to 8 rig locations can be situated within a single drilling site.

Plans call for the drilling of 18 production holes for a fully built power station, and holes will be 2000-4000 m deep. Both directional and vertical drilling will be employed. To meet the possible power reduction of older holes, it is anticipated that one hole will have to be drilled every second to fourth year (or 7-15 holes) to maintain full productivity over the next 30 years. It is therefore anticipated that up to 33 holes in the area may have to be drilled.

The planned time for drilling production holes is 1-2 months. After drilling, boreholes are allowed to blow for 3-6 months. During that time necessary measurements and tests are done on the hole, referred to as blow testing. Blow testing primarily revolves around reservoir engineering of the geothermal heat system and the production capacity of the hole. Some noise accompanies the blowing of high-temperature holes, and mufflers are used to reduce the effect of these aspects on the environment. At the conclusion of drilling and blow testing, the hole is prepared for connection with the steam utility.

Drilling in the Hverahlid area will be divided into stages, and plans call for drilling in 2008, 2009 and 2010.

Water utility

Fresh water must be procured for both drilling and the power station. During exploratory drilling in Hverahlid two waterholes were drilled at drilling site B4, and their production capacity is about 100 L per second. The two waterholes will be used for the production of fresh water for drilling as well as the power station itself.

The water required for the drilling of each production hole is estimated to be 30-60 L per second. The estimated water required for each turbine unit of the operating power station is about 40 L per second or about 80 L per second for the fully built power station.

Steam utility

A steam utility will transport geothermal liquid from the top of the hole to the power plant. The main parts of the steam utility are the collection pipes, collection pipe trunks, separator plants, intake pipes, valve house and steam chimneys (Figure 1).

If the blow testing shows that a borehole is sufficiently productive for utilization, it will be connected with a steam utility and utilized as a production hole for the power station. The geothermal liquid from production holes is collected into a steam utility and led to a separator plant where the steam is separated out and led into intake pipes going to the power plant.

To reduce the visual impact, pipes will be hidden or camouflaged, where possible (Table 1). Only a small part of the pipes will be above ground. The pipe layouts for each pipe interval are selected based on several factors, such as the conservation value of the nearby environment, visibility from defined areas, efficiency, maintenance, monitoring, landscape, vegetation and natural features (Map 1).

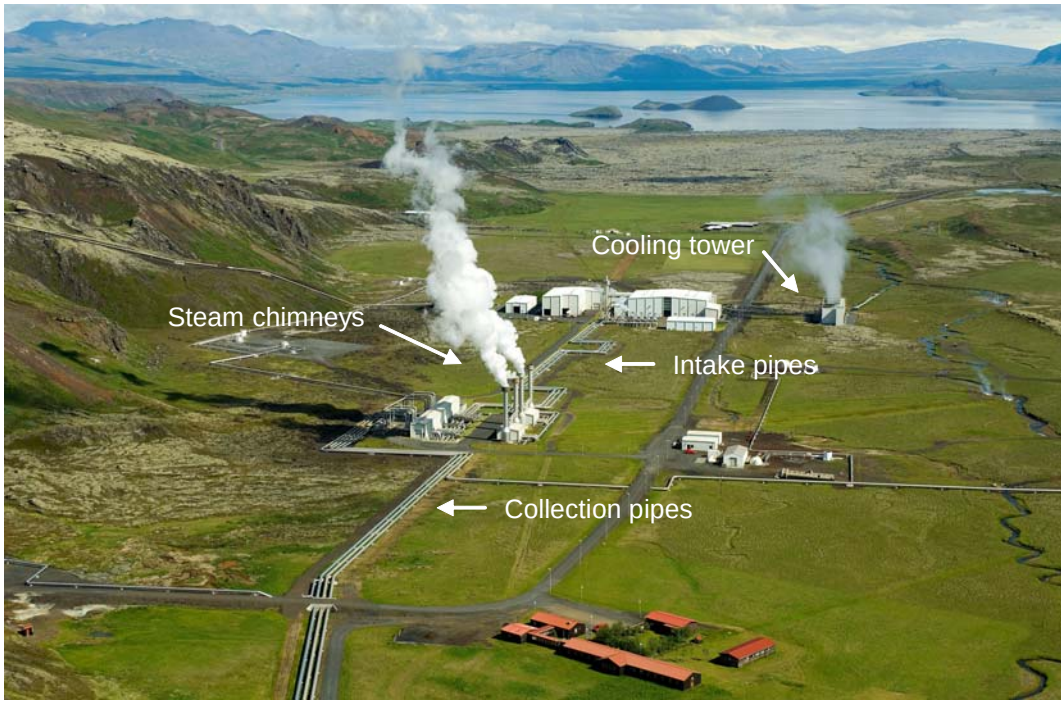


Figure 1. Example of a steam utility. The picture, taken at Nesjavellir, shows collection pipes to a separator plant, steam chimneys and intake pipes to the power plant. The picture also shows four steam chimneys and a cooling tower.

Table 1. Visibility of pipes

Pipe category	Description
Hidden pipes	For the most part, pipes will be buried in the earth or concealed with soil cover so that they cannot be seen on the surface from a certain distance.
Camouflaged pipes	Pipes will be laid above ground, pipe routes chosen for optimal blending with the land's profile, and land is shaped so that pipes will not be very visible.
Traditional aboveground pipes	Pipes will be laid low on the ground, pipe routes chosen for optimal blending with the land's profile.

Power plant and cooling towers

The power plant will house the power station's 90 MW_e generating station. Plans call for the building to have a base level of about 5000 m² and being about 20 m high. Two cooling towers are planned on the power plant's construction plot in Hverahlid (Figure 1). Each of them will have a base level of about 900 m² and be about 20 m high. The cooling tower is part of the cooling water cycle where cooling water at 40°C, coming from condensers, is cooled to 20°C before being pumped again to the condensers, where it absorbs energy during condensation of the steam.

Re-injection utility

The harnessing of geothermal heat creates a need for discharge of the water component of the geothermal liquid that is separated from the steam in the separator plant. The separated water will be piped into 1000-1200 m deep re-injection wells, or deep enough so that there will be no impact

on freshwater. One re-injection well is planned for every two production holes connected with the power station, and the re-injection area will cover about 2 ha (Map 1).

Roads in the project area and connection with a highway

Plans call for improvements to the old Sudurlandsvegur road running to the B5 drilling site from the current Sudurlandsvegur Highway.
A new road will be built to the power plant from the planned intersection to the power plant of the power station. Hverahlid Road from Sudurlandsvegur Highway to the power plant will be about 2.5 km long, with a road width of 6.5 m and a paved surface. The current tracks in the project area and the old road will be used and, if needed, improved. Where there are no tracks, gravel roads 4-6 m wide will be built to the planned drilling sites. All tracks will have minimal build-up.
The proposed communications plan for 2007-2018 provides for enlarging Sudurlandsvegur Highway to a four-lane highway. The Public Roads Administration's plans call for a connecting road to Hverahlid via a grade-separated intersection that will be used jointly by the power stations in Bitra and Hverahlid. The planned location of the intersection will be east of the current road to Gigahnukar. The enlargement of Sudurlandsvegur Highway to a four-lane highway and construction the grade-separated intersection are subject to an environmental impact assessment under Act no. 106/2000, and in that process the Public Roads Administration will present detailed information about the arrangement and assessment of the scope of the impact on the environment.

Quarrying of material

At this stage structures have not been designed, so there is some uncertainty regarding the project's materials requirements. Fill is needed for road construction in the area, building drilling sites, foundations for pipes and building structures. Fill will be brought from licensed operating quarries in the vicinity of the project area. There are also plans to utilize material accumulating from excavation and cutting. The estimated quantity of fill is about 300,000-400,000 m³, assuming compressed, ready-to-use fill.

Contractors' facilities

When construction is at its peak, about 250 people will be working in the area. During the power station's construction period, work camps will be set up. Plans call for work camps to be located on the south side of the construction plot of the power plant in Hverahlid. The possibility of joint work camps because of the Bitra and Hverahlid Power Stations will be investigated.

Connection with the electric energy system

Transport of electric energy from the Hverahlid Power Station will be the responsibility of a transport company in accordance with The Electric Energy Act, no. 65/2003. It is assumed that the power station's generating station will be connected to a substation that will be located at the intersection of Burfell Line 2 and Burfell Line 3, SW of drilling site B6 (Map 1). Landsnet will lay a land line from the power plant to the substation.

Table 2. Key figures for Hverahlid Power Station

			Hverahlid Power Station
Power	*Generating station*		90 MW_e
Steam use			180 kg/s
Project area			320 ha
Roads and tracks	*Main road to power plant*		
		Length:	~2-2.5 km
		Width:	6.5 m
	Work tracks		
		Length:	7-8 km
		Width:	4-6 m
Drilling	*Drilling sites*	Number:	6
		Size:	5 ha
	Boreholes	Number for fully built power station:	18 holes
		Maintenance holes:	7-15 holes
		Depth:	2000-4000 m
Steam utility	*Supply pipes*		
		Total length:	1.5 km
	Collection pipe trunks		
		Total length:	5-7 km
	Separator plants	Number:	2
		Size:	600-750 m^2 for each plant
		Height:	8-10 m
	Valve house	Base level:	160-m2
		Height:	7-8 m
	Steam chimneys	Number:	2
		Height:	20 m
Power plant		Base level:	5000 m^2
		Height:	20 m
Cooling towers		Number:	2
		Base level:	900 m^2 each
		Height:	20 m
Ground water utility		Freshwater requirement:	80 L/s
		Number of freshwater holes:	2 holes
Disposal of waste water		Separated water:	150-550 L/s
		Depth of re-injection wells:	1000-1200 m
		Number of wells:	One re-injection well for per two production holes
Geothermal gases		Released quantity:	27,000 tons/yr
Materials requirement		Fill:	300,000 – 400,000 m^3

Environmental impact of project

During the first stages of the assessment, the environmental factors most likely to be affected by the planned project were defined as well as which parts of the project cause them. Main emphasis was laid on the geothermal system and reservoir engineering, landscape, recreation, the tourism industry and land use. Geological formations, archaeological remains, hydrology, vegetation, birds, gas emissions into the environment and the biosphere of hot springs were also dealt with. The conclusion of the project owner is based on information obtained from specialists' research on the relevant environmental factors.

Geothermal system and reservoir engineering

The project will entail local changes in the resource, including a decrease in pressure, less geothermal mass and energy decrease. According to available information and model calculations, these changes are reversible after the processing of geothermal heat from the system has been stopped. The re-injection of separated water down into the geothermal reservoir will help to maintain pressure in the geothermal system.

There is considerable uncertainty about the effect of the power station on the resource, because of both the short drilling and production time in the area and uncertainty about the behaviour of the resource.

It is the project owner's assessment that the impact of the project on the geothermal reservoir is **insubstantial** but also subject to uncertainty.

Hydrology

There is no surface water in or at the project area of Hverahlid Power Station. Ground water holes in Hverahlid provide potable water at around 100 m below the surface.

The possibility exists that wastewater from drilling and blow testing channelled into a fissure or shallow eddy well will have a temporary effect on the temperature and chemical content of ground water currents in the closest vicinity of the holes. Nevertheless, the great quantity of the ground water currents will result in a high degree of thinning, and the effect is therefore deemed to be insubstantial.

The re-injection area for Hverahlid Power Station will lie at the old Sudurlandsvegur road (Map 1). Running across this area is the Bitra fissure which is planned for the use of drainage. The holes will be deep (1000-1200 m) and lined down below ground water currents. The quality of the ground water in the Selvogur and Ölfus currents should therefore remain unchanged. The effect on ground water currents, in the opinion of the project owner, is insubstantial. It is therefore the assessment of the project owner that the effect on hydrology will be **insubstantial**.

Geology and geological formations

Geological formations in the project area of Hverahlid Power Station are characterized by well-vegetated young lava, pillow lava formations and dolerite buttes that formed in a shield volcano eruption in the last Ice Age. Another characteristic of the region is the geothermal area on the surface in Hverahlid where hot springs bubble and flow. The project will tend to disturb the young lava since the construction is all located on the Hellisheidi lava fields. If geothermal processing has any effect on surface activity, it will be rather to increase it. Young lava and hot springs enjoy special protection under Article 37 of the Nature Conservation Act, no. 44/1999.

It is the assessment of the project owner that the impact of Hverahlid Power Station on geological formations will be **insubstantial**.

Landscape

The main characteristics of the landscape in the vicinity of Hverahlid Power Station are well-vegetated expanses of lava and Hverahlid itself. The landscape is regarded as drear and as having little visual value. The most remarkable feature in the landscape is the old trodden routes lying over Hellisheidi and along Hverahlid, forming a remarkable human landscape. The most important special features in the area are hot springs, Lakahnukar and Lakakrokur (Map 1). The planned project will tend to disturb the lava and impinge on the human landscape of the old routes. If any changes in geothermal surface activity emerge, it will probably increase. The planned project area is near Sudurlandsvegur Highway, and it is therefore deemed that change in people's experience of the landscape will tend to be insubstantial

The value of the landscape in the vicinity of Hverahlid Power Station is regarded as low because of the dreariness of the landscape and considerable disturbance. Under the section on landscape conservation, Article 37 of the Nature Conservation Act, hot springs and lava fields formed within the last 10,000 years enjoy special protection. Hverahlid Power Station will not tend to disturb hot springs but there will be some reduction of lava fields. An attempt has been made to reduce the disturbance of lava as much as possible.

It is the assessment of the project owner that the impact of Hverahlid Power Station on the landscape will be **insubstantial to considerable**. The synergistic effect on the landscape in the Hengill area of Bitra Power Station, Hverahlid Power Station, Hellisheidi Power Station, Nesjavellir Power Station and related high-voltage lines is, nevertheless, deemed to be considerable to substantial because it will impinge on untouched areas.

Air quality

The release of geothermal gases from the fully finished Hverahlid Power Station has been estimated to be about 27,000 tons per year, based on the assumption that the gases will constitute about 0.5% of the steam, which is similar to what has been measured elsewhere in the Hengill area. The emission of geothermal gases during the project period is deemed to have an insubstantial effect since it involves a temporary condition. Increased hot-spring smell can nevertheless be expected in the immediate environment of drilling sites when boreholes blow. According to available documents, the greenhouse gas emissions from Hverahlid Power Station will have insubstantial effect on the overall greenhouse gas emissions in Iceland. Reykjavík Energy plans to remove hydrogen sulphide from the steam. The results of calculations on 99% removal of hydrogen sulphide from the four power stations in the Hengill area indicate negligible chances that the concentration will be so high that the smell will carry to the capital city area.

Increased concentration of hydrogen sulphide (H_2S) in the vicinity of the power plant can be expected after operation starts. Hydrogen sulphide (H_2S) and other kinds of geothermal gases are heavier than the atmosphere and can therefore collect in pits, basements and lava fissures. It is assumed that such accumulation of hydrogen sulphide will have insubstantial impact on people and animals.

The assessment of the project owner is that the effect of Hverahlid Power Station on air quality is deemed **insubstantial**.

Vegetation

The project area is characterized by vegetated dry land (97%), and land with little or no vegetation is only 3%. All high-standing plants and moss species in the construction area of power station are relatively common on a national scale.

The construction will entail direct disturbance of vegetation where structures will be built. The disturbance is confined to the life of the power station, and the effects, over the long run, are

deemed to be reversible. It is the assessment of the project owner that the impact of Hverahlid Power Station on vegetation will be **insubstantial**.

Fauna

There is a rather low density of birds in the project area of Hverahlid Power Station, and the species that are known to have nested in the project area and its vicinity are relatively common elsewhere in Iceland. The impact of the project is temporary and, for the most part, confined to the power station project period when related construction could disturb nesting birds. The effect of the project is fully reversible.

A well-demarcated hot spring area is found in Hverahlid. Hot springs are primarily habitats of microbes although more highly developed animals and plants also have their habitats in and at pools and hot springs. According to available documents, the biosphere of the hot spring area in Hverahlid is very drear, and there is little biological diversity. The project will not tend to directly disturb hot springs but can indirectly affect the activity of hot springs in the project's impact area. It can however be difficult to distinguish these changes from natural fluctuations.

The project owner thinks that the project will have **insubstantial** impact on the fauna in the project's impact area, but some uncertainty prevails about the hot spring organisms since little is known about the biosphere of hot springs before and after harnessing of geothermal areas.

Archaeological remains

Archaeological remains in the planned project area and its vicinity are especially connected with communications routes. Three archaeological remains are at risk of disturbance from the planned project. These are the old protected route over Hellisheidi (721:005) along with a cairn, trodden trails beneath Hverahlid (721:072) in the vicinity of drilling sites B3 and B4 and a trail from the west end of Hverahlid (721:074), going through Smidjulaut near a pipe from drilling site B1 to separator plant S1. It is possible to prevent disturbance of these archaeological remains with mitigating measures in every instance, and in this regard there will be consultation with the National Heritage Agency of Iceland.

Archaeological remains are protected under The National Heritage Act, no. 107/2001.

Taking into consideration mitigating measures, it is the assessment of the project owner that the impact of Hverahlid Power Station on archaeological remains is **insubstantial**.

Noise level profile

The noise level profile in the planned project area is very much characterized by the drone of traffic from Sudurlandsvegur Highway, for the morning traffic on the road is 6000 cars per day, while the summer traffic is just under 8000 cars per day.

Reykjavík Energy has had a precise noise-level profiling map made of the Hverahlid area during the construction period. It is based on the assumption that there would be drilling simultaneously on all of the drilling sites, which is the worst possible scenario with respect to noise level profiling. These calculations include the noise from traffic on Sudurlandsvegur Highway. According to this, the decibel level during the project period will be more than 45 dB(A) at a distance from a drilling site of 800 to 1000 m. According to the calculations, the noise level near Hverahlid will tend to be 50-55 dB(A), and that in Lakakrokar under 45 dB(A). According to the calculations, the noise level at other popular outdoor recreational sites will not exceed 45 dB(A).

Reykjavík Energy has also had a precise noise-level profiling map made of the Hverahlid area during the operational period. These calculations provided for the noise from traffic on Sudurlandsvegur Highway, i.e., over 9000 cars per day. According to a precise noise-level profiling

map, the sound level during operations will usually exceed 45 dB(A) at a distance of 1000 to 1400 m from the steam chimneys. Calculations show that a noise level exceeding 45 dB(A) will tend to be most audible within the power station project area, near Hverahlid 50-55 dB(A) and north of the project area at Orustuholshraun. The noise level profile of the planned Hverahlid Power Station nevertheless clearly shows signs of being located at Sudurlandsvegur Highway.

The impact of the project on the noise level profile will, in the assessment of the project owner, be confined to the lifetime of the power station and will be fully reversible. It is the assessment of the project owner that the impact of Hverahlid Power Station on the noise level profile will be **insubstantial**.

Tourism industry and recreation

The Hverahlid area is used mainly by hikers, horsemen, cross-country skiers and by parties in the tourism industry in small measure. The main advantage of the area is its proximity to the capital city area, which is an advantage today for a rapidly growing group of tourists wanting to go on short trips from the city. The area is not as popular as other parts of the Hengill area, and this may be because of the dreariness of the landscape and proximity to Sudurlandsvegur Highway. The planned project will tend to affect the current tourism industry and outdoor recreation in the area with the advent of structures in previously unsettled land and paths that the project area will overlap.

The planned project will tend to have a direct and irreversible impact on the current tourism industry and outdoor recreation in the area for the next several decades. Taking into account mitigating measures aimed at reducing the visibility of structures and reducing the size of the project area from what was previously planned and the small group of people using the area, it is the assessment of the project owner that the impact of Hverahlid Power Station on the tourism industry and outdoor recreation will be **insubstantial**. The synergy of the planned construction with the structures already in the Hengill area is deemed to be considerable to substantial since the value of the Hengill area as an outdoor recreational area will deteriorate, and the number of nearly untouched areas will decrease considerably.

Conclusion

From an overall point of view, the effect of Hverahlid Power Station on the environment is insubstantial. The impact on particular factors of the environment ranges from insubstantial up to considerable. The factor of the environment that will be most affected in the Hverahlid Power Station project area is the landscape.

The assessment and the preparation of the project have aimed at reducing environmental impact, specifically with respect to the factors of the environment that will be most affected. The measures to reduce impact have been diverse. The most noteworthy include substantially reducing the scope of the project area, reducing the visibility of structures by the choice of locations, increasing the number of boreholes at each drilling site and implementing pipe routes and tracks to minimize disturbance and profiles. Provision has also been made for re-injecting waste liquid down below ground water to avoid polluting it, and hydrogen sulphide will be removed from steam to reduce the effect on air quality. In addition, various other measures will be taken that have been detailed in the initial environmental impact statement.

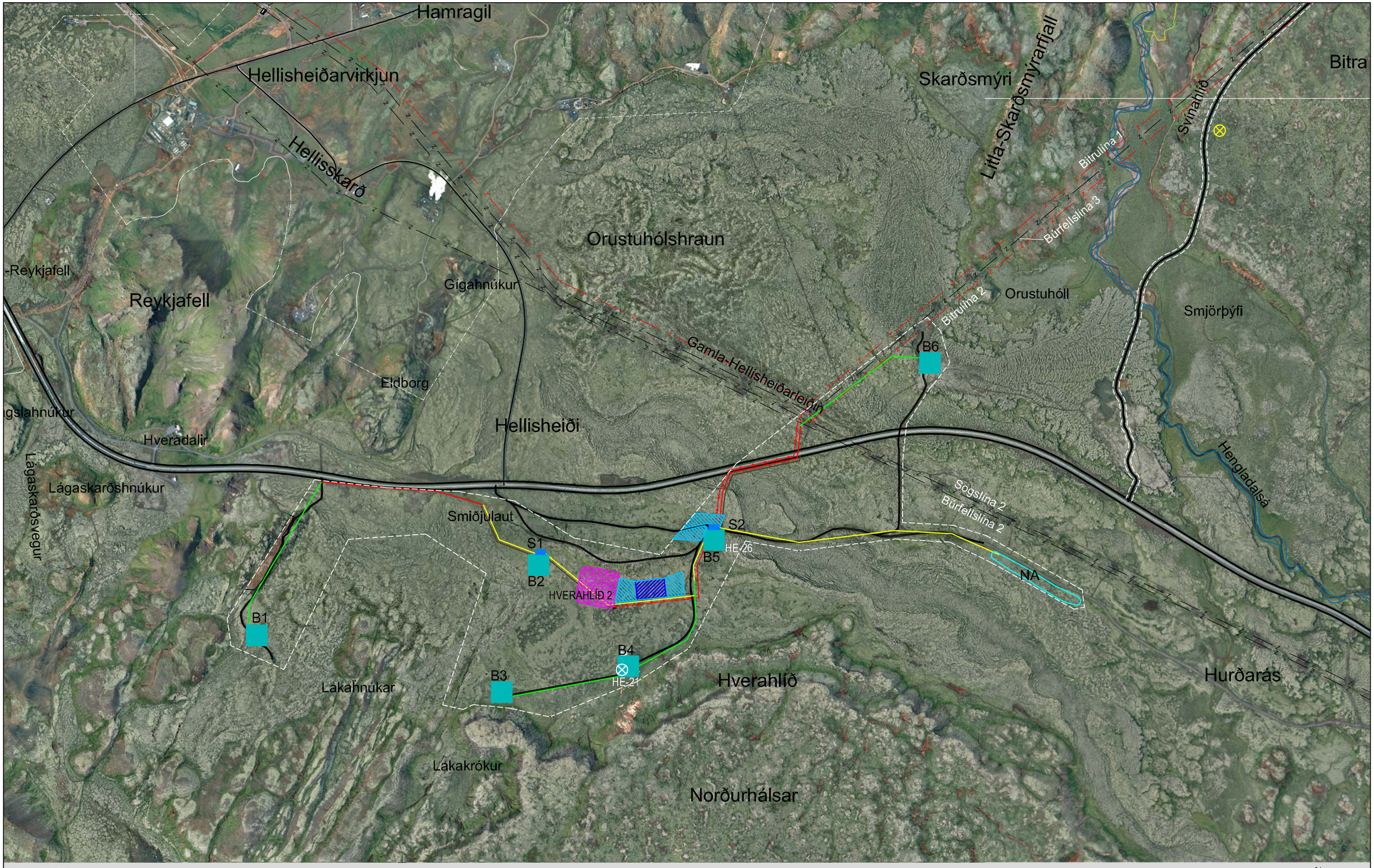
After taking into account construction, mitigating measures, the weight of environmental factors and synergy, it is the assessment of the project owner that the impact of Hverahlid Power Station can be deemed **insubstantial**. All of the necessary information on the environmental consequences of Hverahlid Power Station has been gathered. It is therefore the opinion of the project owner that Hverahlid Power Station is an important project for servicing the demand for electric energy, and

that it will not have significant environmental impact in the meaning of Act no. 106/2000 on the environmental impact assessment.

Table 4. Summary of the environmental impact of Hverahlid Power Station and Bitra Power Station

Environmental factors	Hverahlid Power Station	Bitra Power Station	Combined
Geothermal heat and reservoir engineering	Uncertain/insubstantial	Uncertain/insubstantial	Uncertain/insubstantial
Hydrology	Insubstantial	Insubstantial	Insubstantial
Geology and geological formations	Insubstantial	Insubstantial	Insubstantial
Landscape	Insubstantial/considerable	Considerable	Considerable/substantial*
Air quality	Insubstantial	Insubstantial	Insubstantial
Vegetation	Insubstantial	Insubstantial	Insubstantial
Biosphere of hot springs	Uncertain/insubstantial	Uncertain/insubstantial	Uncertain/insubstantial
Birds	Insubstantial	Insubstantial	Insubstantial
Archaeological remains	Insubstantial	Insubstantial	Considerable
Noise level profile	Insubstantial	Insubstantial/considerable	Insubstantial
Tourism industry and recreation	Insubstantial	Considerable	Considerable/substantial*

*Combined for all power stations in the Hengill area – Bitra Power Station, Hverahlid Power Station, Hellisheidi Power Station, Nesjavellir Power Station and related high-voltage lines.


Hamragil
Hellisheiðarvirkjun
Hellisskarð
Skarðsmýri
Litla-Skarðsmýrarfjall
Bitra
Svínahlíð
Bitrulína 1
Búrfellslína 3
Orustuhólshraun
Gígahnúkur
Reykjafell
Orustuhóll
Bitrulína 2
Smjörþýfi
B6
Gamla-Hellisheiðarleiðin
Eldborg
Hellisheiði
Hengladalsá
Hveradalir
Lágaskarðshnúkur
Lágaskarðsvegur
Sogslína 2
Búrfellslína 2
Smiðjulaut
S1
S2
HE-26
B5
B2
HVERAHLÍÐ 2
NA
B1
B4
HE-21
B3
Lakahnúkar
Hverahlíð
Hurðarás
Lakakrókur
Norðurhálsar
Hidden pipes
Camouflaged pipes
Traditional aboveground pipes
Hydrology
Project site
Re-injection wells
Power house site
Stock site
Work camps
Separator plant
Old quarry
Potable water
Drilling site
Current tracks
Sudurlandsvegur Road
Proposed tracks
Landsnets High Voltage line proposed
Landsnets High Voltage line current
Substation
Landsnets High Voltage underground cable
SCALE 1:20.000
N
MAP 1
HVERAHLID POWER STATION
VSO CONSULTING