ORKUSTOFNUN
National Energy Authority

HRAUNEYJAFOSS

GEOLOGICAL REPORT

By

Haukur Tómasson

geologist NEA

Prepared for
LANDSVIRKJUN
The National Power Company
Marz 1971

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Chapter 1

General Geology

1.1 Introduction

The Hrauneyjafoss Hydroelectric Project is located on the Tungná river, the main tributary to Thjorsá, and is the lowest project site on the river above its confluence with Kaldakvísl. The project area proper is less than 10 km^2, but in connection with construction materials a somewhat larger area has been investigated. The Project site is about 30 km from The Búrfell Hydro-electric Project Plant, which is the nearest habitation, and 165 km fram the capital of Iceland, Reykjavík. For location see Exh. 1.01.

Hrauneyjafoss has for a long time been under some study as a potential power site on the Tungná river. Under consideration has been utilizing a head, at Hrauneyjafoss, of between 65 and 103 meters. The present Project will utilize approximately 85 meters of head. The average flow of Tungná at this site is a little over 100 m^3/sec., and to this will be added a diverted flow of Þórisós and Kaldakvísl of about 50 m^3/sec. Proposed installed capacity is 160 MW.

Geological investigation has been going on occasionally for more than a decade. The first work was carried out in 1959, being drilling, geological reconnaissance and mapping. The field work was continued in 1965, ´66 and ´67 with some additional drilling. This investigation was all carried out by the State Electricity Authority and its successor Orkustofnun (the National Energy Authority, NEA). The investigation carried out in 1970, which will be the main subject of this report, was ordered by Landsvirkjun (The National Power Company) and has been performed by NEA personnel in co-operation with and under the supervision of the Associated Firms Harza Engineering Company International, and Thoroddsen and Partners, (Verkfræðistofa Sigurðar Thoroddsen s.f.)

The Project site at Hrauneyjafoss can be divided into three areas: 1) The reservoir site, which is partly on the postglacial lava flows upstream of Fossalda at an approximate elevation of 420-425 m. 2) The Fossalda ridge, which at its western end is not much higher than the lava fields upstream, but a part of it reaches an elevation of above 500 m. The Project will utilize a low pass through the Fossalda ridge for a diversion canal and 3) The Þóristungur area lying at approximately 350-320 m elevation. This will be the site of the powerhouse and tailrace canal.

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Subsurface exploration, drilling and geophysical work has been as follows:

1) In 1959 one hole was drilled in the lava fields upstream of Fossalda. At that time extensive drilling was done at Sigalda, the next site upstream on the river. These holes were drilled in the postglacial formation.

2) In the years 1965 and ´66 12 boreholes were drilled. They are scattered in the lava fields from upstream of Sigalda down to the Búrfell area, which was investigated mostly in 1962. This drilling mapped the groundwater table and groundwater aquifer in the lava fields of the Tungná lavas. One of these holes, TH-9, is in the immediate vicinity of Hrauneyjafoss.

3) In the latter year, 1966, 2 holes, called HR-1 and HR-2, were drilled with view of the Hrauneyjafoss Project. Both were drilled in the lava fields west of Fossalda.

4) In 1967 the first drilling was done in the Móberg formation in the Fossalda/Sporðalda area. In that year two holes, HR-3 and HR-4, were drilled.

5) In 1970 very extensive drilling was carried out both in Fossalda, down in Þóristungur and on the lava fields. Altogether 33 holes were drilled in that year. Some Borro-sounding was also carried out in Þóristungur and along the canal sites and damsite. Finally seismic sounding was carried out on the canal sites, the diversion canal in Fossalda and tailrace canal in Þóristungur. Many bulldozers and smaller trenches were done, partly for stratigraphic purposes, but mainly in the search for construction materials. Total drilling up to date at Hrauneyjafoss is as follows:

Rock and core drilling	38	holes	total	depth	1363 m
Borro sounding	119	"	"	"	450 m
Piezometer driving	2	"	"	"	58 m

Location map of drillholes, piezometers and Borro soundings is on Exh. 3.01, graphic core logs on Exh. 3.02 to 3.09, Borro soundings on Exh. 3.10 to 3.15 and piezometers on Exh. 3.16.

Besides these conventional methods of investigation in connection with hydro-power projects experiments with the sealing properties of the Tungná water have also been accomplished in this area. The experiment, known as Langölduveita, was started in late fall 1966 and was kept running through the summers of ´67, ´68 and ´69 and extended with a relatively large dam in 1970. Its experimental fields give valuable information of the initial vertical permeability of lava fields, on the tightening capacity of the glacial meltwater of Tungná and the trap efficiency of these relatively small lakes for the sediments of Tungná. This experiment also has given information about groundwater behaviour. A report on the Langölduveita will not be included, but results from these experiments will be used in calculating the waterloss from the reservoir at Hrauneyjafoss.

1.2 Geography

The main trend of landscape in the middle course of Tungná, from Bjallar down to Kaldakvísl, is móberg ridges running approximately north-east. These ridges may be interpreted as flanking the east side of the valley of Kaldakvísl and the main trend of the Tungná river is a flow towards Kaldakvísl, which is at the bottom of the valley. But where crossing the ridges the course of the river is usually very irregular and a substantial drop in elevation occurs between the two sides of the ridges. These are therefore the sites for power plants on the Tungná river. In this middle course there are three sites which have been anticipated for hydro-power production, whereof Hrauneyjafoss is the lowest one.

The móberg ridges which interfere with the course of Tungná are outrunners of the móberg massif around lake Þórisvatn and are generally lower the further to the west.

Lowest of these ridges and also oldest and most eroded is the Fossalda/Langalda ridge, which is the power site at Hrauneyjafoss. The highest part of the Fossalda/Langalda ridge is 540 m, but at Þórisvatn it reaches 630 m. To the west of Tungná this ridge is generally at only about 400 m elevation. The ridge next to the south of this one is 510 - 560 m high and the lava field in between usually 425 - 400 m high.

The drainage of Tungná is very simple as Tungná is, for the most part, a trunk river flowing far above the groundwater level. Inflow into the river is mainly through springs and spring fed rivers which are always very short. Between Sigalda and Fossalda there is no surface inflow except near the base of Sigalda. At many places are seen water courses which are always dry during summer. Some of these water courses were made by branches of Tungná before it stabilized its course in the present one.

Others are made by winter floods, as in winter, when the ground is frozen, there can be surface runoff both in the lava fields and in the móberg area. One of the courses is formed by a historic river which was dammed up by a lava flow in 1913 and found a new totally different course afterwards. In Þóristungur there is a network of spring fed streams originating at elevation between 360 - 350 m and flowing into Kaldakvísl.

A cover of vegetation is widespread in Þóristungur and also along the west bank of Tungná up to Hrauneyjafoss and in many of the islands in the river on Hrauneyjar. On all the hills east of Hrauneyjar and also in the lava fields to the west of them vegetation cover is lacking and drifting sand is common. Rock outcrops are common in the Tungná canyons; in the valley of Kaldakvísl rock outcrops are also frequent. In the ridges the bedrock is usually covered with moraine or some mixture of eolian sand and rock fragments. The lava is very irregular at the surface and lava blocks outcrop, but in between is eolian sand filling depressions with abundant lava fragments mixed in.

1.3 Stratigraphy

The Hrauneyjafoss area was built up by volcanic products during the last two glacials, an interglacial in between, and postglacial time. On the geological map, Exh. 1.02, the main bedrock formations are shown and the schematic geological section, Exh. 1.03, shows the relationship between the geological formations.

The geological formations can be divided into two main groups, i.e. móberg formations and the lava flows. On the schematic profile the móberg formations get younger proceeding the closer to the present volcanic belt. Some of the móberg formations in Þóristungur are from the last but one glaciation as this formation is covered by a lava flow, flowed in an interglacial. The youngest móberg formations close to the postglacial volcanic belt are probably from the end of the last glaciation and the postglacial volcanic activity, which has mainly produced lava flows, is a direct continuation of the móberg formations.

According to above the rock in the Tungná reach can be divided into the following groups:

1. The móberg group, which ranges in age from the last but one glaciation to the end of the last glaciation.

2. The Kaldakvísl grey basalt formation, which is a lava formation from the last interglacial.

3. The Postglacial lava formation, which is mainly lava flows erupted during the interval of 2000 - 8000 years B.P. This subdivision is shown on the geological map, Exh. 1.02, and the schematic profile, Exh. 1.03.

On the more detailed geological map, Exh. 1.04, the formations around Hrauneyjafoss are subdivided. These formations are:

a) The Kaldakvísl grey basalt formation. This is a rather coarse-grained basalt usually cube jointed or even with a pillow structure and was in a former report interpreted as a móberg formation. This basalt has been a lava flow flowing down the valley of Kaldakvísl in the last interglacial. It is apparent from the geological section, Exh. 1.08 that this grey basalt formation lies on top of the móberg formation.

b) The Móberg group. The age relationship between the different móberg formations is not at all clear except in a few cases. The indication of the age is just as much morphological, supported by a higher seismic velocity for the older formations than the younger ones. This depends on better consolidation and precipitation of some material to fill cavities and cracks in the rock. This also causes the older formations to be less permeable than the younger ones. On the map, Exhibit 1.04, are shown 5 different formations of the móberg group. The oldest one is the low-lying much-levelled and flattened-out móberg formation called the levelled old Móberg formation. This really may be a mixture of many formations, the petrography is very similar for all the rock in this area - most of it being dark to grey basalt rock with a few small phenocrysts of feldspar.

The oldest part of this formation is older than the Kaldakvísl grey basalt and therefore dates from the last but one glaciation. Part of this formation is at Sigalda termed Si_3, but at Hrauneyjafoss this formation is termed Hr_2 and is the older of the two móberg formations there.

On the top of Hr_2 in Þóristungur is the Fossalda móberg formation and Langalda is probably a continuation of the formation towards the west. Between the Fossalda/Langalda formation and the Hr_2 is a tillite layer intercepted in drillhole Hr_4 and shown on sections D-D and I-I, Exh. 3.24 and 1.08. This tillite is a very well indurated and strong rock. In Fossalda at the Project site the Fossalda formation is indicated with the letter Hr_1.

The age relationship between the next two formations is uncertain although from topographical or morphological reasons it is supposed that the Sigalda formation, Si_2, and Miðalda is older than the Hrauneyjafell móberg formation. All the formations hitherto mentioned are mainly pillow lavas. The bulk of the rock is pillow lava or pillow breccia to breccia, but Hrauneyjafell, on the other hand, is mainly tuff or very tuff rich breccia. This indicates that Hrauneyjafell is formed in eruptions fairly close to the surface and is the only formation in this area which shows these characteristics.

The Sigalda formation Si_1 is clearly younger than Si_2 and Miðfell as it lies on top of it as found from drilling at Sigalda. It is mainly móberg breccia and pillow lava.

On top of the oldest formations such as Fossalda/Langalda and Hr_1 there is often a thick layer of moraine and tillite. On the younger formations this type of material is mostly absent. This moraine or tillite can reach a thickness of several tens of meters but the móberg formation is probably several hundred meters thick, but thinning out towards Kaldakvísl.

c) The Postglacial lava flows. They range in age from 2000 - 8000 years B.P. and most of them originated in a volcanic belt, the so-called Heljargjá-Vatnaöldur graben area. This volcanic belt is seen on the general geologic map, Exh. 1.02, and the schematic geologic profile Exh. 1.03, also shows the westernmost part of it. From there ten major lava flows have flowed down the valley of Tungná and through passes in the móberg ridges during this interval. Gradually these flows have decreased the relief and more or less levelled out the landscape. Yet the highest ridges are still sticking through the lava flows. In connection with this, the course of Tungná has changed many times. Each lava flow has changed the course more or less, but the main trend of the change in Tungná courses has been towards the east to follow the margin of the lava flows as Tungná today does.

The oldest three of these lava flows do not influence the Hrauneyjafoss area. They flow through lava pass number 1 down to the lowlands and one, the second oldest, is the biggest lava flow in postglacial time in Iceland. In Exh. 1.05 are shown the main characteristics of the different lava flows and tephra layers and other marker beds which have been used for dating. The most important marker beds are the light colored ash layers from Hekla designated H_1 to H_5 which all have been dated by C method. These lava flows have a very characteristic petrography, which is quite different from that of the móberg areas. They all have big phenocrysts of feldspar and also some of olivine. The number of phenocrysts has been used for identification of the different lava flows together with the marker beds mentioned above and shown in Exh. 1.05. These lava flows are called Tungná lava flows and are marked with TH and an index a for the oldest flow and J for the youngest one. The first of these lavas flowing into the Hrauneyjafoss area is TH_d and TH_e. All the still younger flows have reached the Hrauneyjafoss area except TH_g which is not found so far downstream. Most of these flows except TH_g and TH_j have flowed all the way down to the lowlands near Búrfell, but TH_g has only reached the Hrauneyjafoss area and ends 2 km downstream of the falls.

Besides the above mentioned Tungná lavas a postglacial volcanism has occured in the neighbourhood of Hrauneyjafoss in a volcanic belt which is a continuation of the Hekla fissure which has its summit crater 30 km away from Hrauneyjafoss. From Hekla extends a scattered crater row and small lava flows all the way to the corner of the geological map whereof one crater can be seen surrounded by the Þjórsá lava flow TH_i. The age of this crater is 3-4000 years.

1.4 Superficial deposits

Loose materials or overburden are of various origins: glacial, alluvial, lacustrine, eolian and directly volcanic, i.e. tephra. At many places these deposits form thick beds up to several tens of meters thick. On the map, Exh. 1.09, are shown the types of loose materials covering the bedrock and generally reaching a few meters in thickness.

In Þóristungur loessy soil, peat and a mixture of both cover extensive areas. The loess consists of windblown material of grain sizes from fine sand to silt and in many places is mixed with the airborne volcanic material tephra sandwiched in between loess layers. In the peat are found the same ash layers. Most of these ash layers are from Hekla or Katla and some also from the Heljargjá graben area. The thickness of loess and peatmaterial varies from 1 m up to 3 or 4 m. Where it is thickest it can be expected to consist to a large extent of peat.

Sand-filled depressions are upstream of the Fossalda ridge and between that ridge and Sigalda is a depression probably filled with a thick layer of sand. The thickness is known to be several tens of meters. The origin of the sand may be mixed, but it is likely that a part of it is flood deposits from the end of the glaciation but now covered with eolian sand or some mixture of eolian and alluvial sand. Also mixed into this unit may be truly alluvial deposits from the Tungná river at an earlier stage before the last lava flow raised its level.

Lake deposits are considered to be along Tungná in areas where Tungná usually floods at a high water level. This area is covered with silty material and may extend and be mixed with the preceding unit. The distinction is mainly done from the surface characteristics.

Alluvial deposits are found along Tungná and Kaldakvísl. Between Sigalda and Fossalda the alluvial deposits are very closely related to the lake deposits and the sand-filled depression deposits. It is at many places very fine grained, but where it is coarsest it is sand and some gravel.

In Kaldakvísl on the other hand the grain size is much more varying from very coarse gravel and cobbles to gravel and sand. The thickness of the deposits is mostly unknown, but ranges from 1 or 2 m to several m.

A special type of alluvial deposits is at the mouth of the Sigalda canyon. These deposits are caused by a sudden emptying of the Króksvatn lake, which existed for more than 1000 years in the basin upstream of Sigalda. This alluvial deposit is characterized by the way it is sorted. The grading is more or less horizontal with the coarsest material near the Sigalda canyon and the finer material in the direction downstream towards the Ferjugljúfur canyon. The coarsest material consists of blocks of a half to one meter in diameter.

Flood deposits cover some depressions along the Kaldakvísl river and form some terraces there also. The thickness of these deposits varies very much, but often forms terraces 5 m thick or more. These deposits mostly consist of medium to coarse sand and many of the grains are crystals of feldspar and olivine. The origin is an eruption under the glacier in the mountain Brandur at the middle of the east coast of Þórisvatn. This was at the end of the last glaciation when the Þórisvatn basin was glacier filled and partly the mountains surrounding the basin. The sand is essentially volcanic products which have been carried down to the valley by a hugh flood caused by ice melted by the eruption. Some of the material classified as sand-filled depressions is probably also from the same source as it was discovered during the investigation in 1970 that the flood from the Brandur eruption actually found outlets at the low passes at the south coast of Þórisvatn just as along the western and north-western end of Þórisvatn where the main outlet probably was.

The postglacial lava flows are here classified as superficial deposits because all the lava has similar surface characteristics. The surface of the lava is mostly broken and partly scoriaceous lava and filled with eolian and some alluvial sand. Along the river there may also be silt and clay in the depressions. Typical thickness of the top layer of the lava is 2 or 3 meters and in it is everywhere mixed blocks of lava fragments. The blocks are lifted by frost action towards the surface.

In the postglacial lava flows are water courses in many places now usually dry during summer. They are either formed 1) by prehistoric braches of the Tungná river, 2) by some rivers which now have been diverted to another course of 3) by winter floods, which can be substantial. 4) Some of the courses near Langalda/Fossalda are probably formed by the flood when Króksvatn was emptied. In that part of the lava flows the material on the top of the lavas is more alluvial than eolian.

Moraine covered bedrock is at many places along Fossalda/Langalda. The moraine is at many places sandy and the term moraine is used more as an indication of the origin of the material than a description of it. The thickness of the moraine varies considerably. Where the moraine is thick the lower part of it is usually so well indurated and hard that it is classified as rock and will be called tillite in further discussions. Moraine together with

tillite can be 20-30 m thick altogether whereof 5-7 m can usually be worked with heavy bulldozers.
Frequently, 1 or 2 m are quite loose.

The younger móberg formations have usually no cover of moraine. The surface is often pillow fragments, bedded in eolian sand or, where rock outcrops, the surface is so-called pseudomóberg which is reworked móberg by the glacier and is very often hard and dense. This reworked material may have the colour of tillite, but often the material has the same colour as tuff. These materials mentioned here are thin where they are marked on the map as móberg formation without cover.

Basalt formations slightly covered or without cover are found near Kaldakvísl. Here the Kaldakvísl grey basalt formation outcrops. The reason for the many outcrops of this formation is the catastrophic flood from Brandur already mentioned. A former cover of moraine has been washed away.

1.5 Tectonics

The regional tectonics in the Hrauneyjafoss area are shown on the geological map, Exh. 1.04. In respect to tectonic features this area seems to be a transition zone between the móberg areas, where tectonic features are not prominent and do not guide drainage systems, and the so-called Hreppar series supposed to be west of Kaldakvísl where very strongly developed tectonic features usually guide all the erosional features. This supports the already mentioned conclusion in the stratigraphic section that this rock is older than at Sigalda and further towards south.

There are many systems of fault directions in the Fossalda area as shown on the map. Some of these systems are probably strike-slip faults; others may be normal faults. Usually the dislocation of these faults is not know as there is no such rock where dislocation can be easily recognized in the Fossalda. The most prominent direction of faults is probably north 60° - 70° east and north 20° - 30° east. Other faults have some intermediate direction, but these two seem to have the strongest tendency to develop. The first direction is, in the Búrfell area, a slip strike fault. There are also a few faults with a completely different direction, that is north 40° - 50° west. Generally this direction is not stronly developed in southern Iceland.

The móberg ridges and móberg mountains in general are formed in subglacial eruptions under a glacier cover, usually in fissure eruptions. These fissure eruptions in this part of Iceland have probably followed a direction north 60° - 70° east as that is the main trend of the long axes of the ridges. In connection with the volcanism graben tectonics have probably been active as is now in the volcanic belt and in the youngest móberg formations.

All such graben tectonics are now inactive and there is no indication of recent movement of any of the faults in the area. None of the faults can be traced in the postglacial lava flows and are therefore older. Probably the last time these faults have been active was at the end of the last glaciation or beginning of postglacial time.

1.6 Geologic history and geomorphology

The geologic history of the middle Tungná area is marked by a general southeastward movement of the volcanic belt during the last 700.000 years or so. This movement of the active volcanic belt is best illustrated in the schematic profile, Exh. 1.03, where the móberg ridges overlap each other and are generally younges towards southeast. At present the volcanic belt is mainly the Heljargjá graben system, but one crater belonging to that system is seen at the edge of the schematic section.

The oldest móberg formation, Hr_2, is in Fossalda dating from the last but one glaciation, or about 300.000 years old, while the youngest formations are formed just before the end of the last glaciation 10.000 years ago. Then the Bjallar and Dyngjuhorn ridges were formed. All the móberg formations have a normal magnetic polarity which establishes that they are of a lower age than 700.000 years. Probably the Hr_1 móberg is from the last but one glaciation as Hr_2. During the following interglacial there were lavas flowing down the valley of Kaldakvísl in a similar manner as lavas have been flowing down the valleys of Tungná in postglacial time. This is the Kaldakvísl grey basalt formation.

In the latter half of the last glaciation the most active volcanic belt was just east of Þórisvatn or along the east coast of it. One eruption, the Brandur eruption, which occurred when the Þórisvatn basin was filled by ice, caused a big flood going through all the low passes at the rim of Þórisvatn. This flood has both eroded the valley of Kaldakvísl and deposited thick layers of flood sediments, mostly ash from the eruption.

The finiglacial topography at the end of the last glaciation was, in the middle reach of Tungná, much rougher than to-day. Valleys have been in between the móberg ridges; the deepest of these was the Kaldakvísl valley, which is still more or less in existence, but south of Sigalda there was a deep valley and again to the south of Bjallar. This valley system had no contact with the Kaldakvísl valley at that time. The drainage system has been different as Tungná was flowing straight down to the lowlands along Dyngjur og Valafell and its confluence with Þjórsá was east of Búrfell. Kaldakvísl has been a direct tributary to Þjórsá and its confluence with it probably not far from where the Tungná - Þjórsá confluence is now.

This finiglacial topography did not last very long because the volcanism continued in the Heljargjá graben area in postglacial time and gradually filled the valleys, especially the southern ones. The Heljargjá graben has produced 10 major lava flows during the time interval of 8000-2000 years before present. The 3 oldest have not reached the area north of the Sigalda ridge. Of the remaining seven, six have passed through some of the lava passes in Sigalda and are present in the Hrauneyjafoss area.

The postglacial lava flows have had a tendency to divert Tungná towards north along the margin of the lava flows. In this connection marginal lakes have often been formed and dammed up by the lava flows and the móberg ridges. Such marginal lake has certainly existed many times in the area between Fossalda and Sigalda, but now none is in existence; the last one is certainly silted up. Upstream of Sigalda much bigger lakes have been formed, the so-called Króksvatn. Króksvatn was a big lake for approximately 1.500 years and was emptied in a hugh flood about 3.000 years before present. In that flood probably 150-200 Gl. of water were emptied from the lake in a very short time, possibly a day or so.

Chapter 2

Sediment load

2.1 Investigations

Investigations on the sediment load of Tungná and Þjórsá have been going on for more than two decades, but the main work has been done since 1962 as at that time sampling with American type supended sediment samplers was started and a laboratory was furnished to make it possible to measure the quantity and grain size of the sediment load. Since then sampling in Tungná and Þjórsá has been accomplished as shown in Table 1. The samples are generally of two types, so-called S-samples, taken with sediment samplers of American type and F-samples, which are collected into an ordinary glass bottle without a sampler. The S-samples, which are integrated samples usually taken at three verticals in each section, are much more reliable and calculations are as a rule based on the S-samples only. F-samples are usually taken at one bank of the river. F-samples are available further back than 1962, even as far back as 1949. For the finer grained sediment load the difference between F-samples and S-samples either is very small or non-existent, but for the sandy part of the suspended sediment load the F-samples can show quite different results from the S-samples. Altogether there are now available 543 samples from Þjórsá and Tungná with tributaries of Tungná. By correlation and calculation of stage discharge relationship for the sediment these investigations can be used to get a fairly accurate picture of the sediment load of Tungná at Hrauneyjafoss, especially as 102 of the samples are from Tungná at Hald and 60 are from Tungná at Hrauneyjar.

Bedload measurements and calculations have not been done for Tungná, but have been done for Þjórsá, downstream of Búrfell, and for Hvítá. Therefore bedload of Tungná can only be roughly estimated from comparison between Tungná and Þjórsá. For Hald it has been assumed to be 15% of the average suspended load and 7 1/2 % at Hrauneyjar.

The available samples are not evenly distributed throughout the year. Most of them date from the summertime and winter samples are underrepresented. As the majority of the discharge occurs during summer and at the same time the majority of the sediment load also occurs during summer this handicap is not as serious as would else be the case. The reason for the few samples during winter is mainly due to technical difficulties in obtaining samples in winter time as then the river is frequently full of frazil ice and the samplers get clogged when put into the water.

2.2 Results

The results of the sediment discharge investigations prior to 1966 are published in a report "Skýrsla um aurburðarrannsóknir 1965 - 1966", by H. Tómasson and S. Pálsson with an english summary by P. Ingólfsson.

Since that time considerable data have been obtained, and new calculations of the relationship between the sediment load and discharge have been done. Exh. 2.01 shows the relationship between discharge and sediment load for Tungná at Hald as calculated in 1967. The available data collected since then show no important change, but they are not plotted on the graph Exh. 2.01.

The available samples from Hald are from the years 1965 to 1970 and the suspended sediment load has been calculated for each year during the period. The samples from Hrauneyjar are from the period 1967 to 1969 mainly, and the calculated sediment load is for the years 1968 - 1970. The results of these calculations are illustrated in Table 2.

The three years series for Hrauneyjar has been extended to six years by correlation with Hald. This is also in Table 2. The sediment load has been converted into volume by assuming specific weight 1.4 for deposited sediments. Finally estimated bedload was added and total load in Gl per year calculated.

The limit between fine and coarse sediment load is at grain size 0.02 mm, i.e. between fine silt and coarse silt. As seen in the table the total sediment load at Hrauneyjar could amount to a sedimentation of roughly 1 Gl/year. The trap efficiency of the reservoir is not known, but in the Langalda reservoir a trap efficiency of approx. 50% was experienced. In Bjarnalón at Búrfell a trap efficiency of 50% also seems to be the case. The reservoir at Hrauneyjafoss is certainly larger compared to the inflow than both the mentioned cases so a higher trap efficiency should be expected. With a trap efficiency of 70% the decrease in volume will be 0.8 Gl/year. A continuous blanket of fine grained silt should be formed over all the reservoir bottom thickening several cm per year.

This quantity of sediment would fill the reservoir in about 30 - 40 years on the basis of unchanged trap efficiency. In fact the trap efficiency will certainly change from 70% in the beginning to less than 50% when the reservoir is practically filled.

The deposition of sediments in the Hrauneyjafoss reservoir would be decreased greatly with Sigalda reservoir in existence either built first or following soon after. It should be expected that the sediment carried into the reservoir at Hrauneyjafoss would be decreased to one tenth of the quantity it would receive without Sigalda reservoir. In that case the sediment deposition will not at all be a problem at Hrauneyjafoss.

In Exh. 2.02 are shown grain size curves for the sediment of Tungná, one for each season. There is a marked difference especially between the grain size curves for the summer season as compared to the other seasons. In summer the sediment samples contains less sand and more of coarse and medium sized silt than during the other seasons. In the winter and autumn, especially winter, the fine grained sediments are in very small quantities. In spring and autumn they are in larger quantities than in the winter, but much less than in the summer time.

TAFLA 1

TABLE 1

FJÖLDI AURBURÐARSÝNISHORNA Í TUNGNAÁ OG ÞJÓRSÁ NEÐAN TUNGNAÁR

NUMBER OF SEDIMENT LOAD SAMPLES IN TUNGNAÁ AND ÞJÓRSÁ DOWNSTREAM OF TUNGNAÁ

Vatnsfall og tökustaður River and locality	Ár Year	S-Sýnishorn S-Sample	F-Sýnish. F-Sample	Samtals Total
Þjórsá Urriðafoss	1962	3	1	4
	1963	24	2	26
	1964	9	14	23
	1965	27	5	32
	1966	21	1	22
	1967	17		17
	1968	3		3
	1970	32	1	33
Samtals, Total	1962-70	136	24	160
Þjórsá Þjórsárholt	1962		5	5
	1963		2	2
Samtals, Total	1962-63		7	7
Þjórsá Skriðufell	1962	2		2
	1963	1		1
Samtals, Total	1962-63	3		3
Þjórsá Búrfell	1963	1		1
	1964	1	3	4
	1965	3	3	6
	1967	2		2
	1968	23		23
	1969	9		9
	1970	15		15
Samtals, Total	1963-70	54	6	60
Tungaá Ármótafoss	1967	1		1
Tungnaá Hald	1962	1		1
	1963	1	1	2
	1964	3	1	4
	1965	16	1	17
	1966	17		17
	1967	17		17
	1968	23		23
	1969	11		11
	1970	13		13
Samtals, Total	1962-70	102	3	105
Langölduveita Þéttingartilraun tigtening test	1966	1		1
	1967	29		29
	1968	25		25
	1969	46		46
Samtals, Total	1966-69	101		101

Vatnsfall og tökustaður River and locality	Ár year	S-Sýnish. S-Sample	F-Sýnish. F-Sample	Samt. Total
Tungnaá Hrauneyjar	1964	2		2
	1965	4		4
	1966	6		6
	1967	18		18
	1968	17		17
	1969	12		12
	1970	1		1
Samtals, Total	1964-70	60		60
Tungnaá Vatnaöldur	1962	2		2
	1963	2		2
	1964	1	1	2
Samtals, Total	1962-64	5	1	6
Tungnaá Gnapi	1965	1		1
	1966	9		9
	1967	39		39
Samtals, Total	1965-67	49		49
Tungnaá Jökulkrókur	1967	90		90
Kaldakvísl ármót við Tungnaá Confluence with Tungnaá	1965	1		1
	1967	3		3
	1968	1		1
	1969	9		9
	1970	3		3
Samtals, Total	1965-70	17		17
Kaldakvísl ofan Brúar-gljúfurs	1966	7		7
Kaldakvísl Sauðafell	1962	2		2
Systrakvísl	1967	17		17
Samtals Þjórsá neðan Tungnaár	1962-70	193	37	230
Samtals Tungnaá	1962-70	307	4	311
" Kaldakvísl	1962-70	26		26
" Systrakvísl	1967	17		17
Alls/Total	1962-70	644	41	685
Þjórsá Búrfell Þéttingartilraun tigtening test	1963	19		19

TAFLA

TABLE 2

Aurburður í Tungná

Sediment load in Tungná

		HALD			HRAUNEYJAR		
		Grófur Coarse	Fínn Fine	Samtals Total	Grófur Coarse	Fínn Fine	Samtals Total
	Ár/Year						
Svifaur á ári	1965	1.142	400	1.504			
í þús. tonna	1966	1.406	519	1.795			
Suspended load	1967	1.227	448	1.584	(80)*	(25)*	(111)*
per year	1968	2.353	979	2.844	1.988	872	2.284
in thousand tons	1969	1.910	738	2.396	1.490	617	1.767
	1970	1.103	388	1.443	1.736	259	941
Meðaltal Average	1968-1970	1.789	701	2.228	1.405	583	1.664
Meðaltal Average	1965-1970	1.524	579	1.928	1.196	481	1.440
Rúmmál 1000 m^3 Volume M.tal Av.	1965-70	1.088	413	1.377	854	343	1.029
Áætlað botnskrið 1000 m^3 Estimated bedload M.tal Av.	1965-70	207		207	77		77
Aurburður, samtals Total sediment load	Gl	1,251	0,475	1,584	0,918	0,369	1,106

* þrír síðustu mán. ársins/The last three months of the year.

Chapter 3

Engineering Geology

3.1 Groundwater and Permeability

The fairly high permeability of the young rock formations in the Tungná reach was already at an early stage of studies of these hydro potentials considered a major problem. Groundwater has therefore been studied to some degree in this area from 1959, especially after 1965 when more drillholes became available for studying the groundwater behaviour in the postglacial lava formation. Later the groundwater in the móberg formations was also studied; then it became obvious that in many places there is a marked difference in groundwater level in the móberg formations on one hand and in the postglacial lava flows on the other. This difference is due to heterogeneity in permeability between the móberg group on one hand and the postglacial lava formation on the other hand. This heterogeneity is especially at the surface of the móberg formation, which often is covered with a relatively impermeable moraine or pseudomóberg blanket with a much lower permeability than either of the two formations. In connection with permeability studies the postglacial lava formation can be looked upon as having the same permeability all over. The móberg group on the other hand is considerably diversified in age, so the youngest móberg has substantially higher permeability than the oldest one.

The postglacial lava flows have by far the highest permeability. Their permeability is also heterogeneous for different parts of a particular lava flow. The highest permeability is in the horizontal direction at the base of the lava flow, or at the contact between the two lava flows.

This permeability is higher than a k-value of 1 cm/sec, probably in the range of 1-10 cm/sec. The permeability through the dense part of a lava flow is much less, probably of the order of 10^{-2} to 10^{-1} cm/sec. Through the dense part of the lava flow water percolates vertical, often hexagonal joints. The vertical permeability is higher than the horizontal one in the dense part of the flow, due to much shorter leakage paths downwards than around the columns. Vertical permeability is often decreased to a considerable degree by the blanket of loose material of sand and silt sizes brought into the upper surface of a lava flow by wind or water. This material may even cause perched groundwater to exist at some places in the postglacial lava formation. The most important of these loose materials to decrease vertical permeability is the one now forming the surface of the lavaflows. This material will decrease the vertical permeability from the proposed reservoir at Hrauneyjafoss. The interbed material is always the least permeable part of the postglacial lava formation.

The móberg formation has a much more uniform permeability than the postglacial lava formation because it is not divided into horizontal layers as the lavaflows, but rather form thick mounds probably hundreds of meters thick, but of rather small areal extension. This makes the permeability of the whole móberg formation much more homogeneous than that of the postglacial lavas. This permeability is considerably lower than that of the lavas. In Fossalda the water pressure indicated permeability of the value 10^{-4} to 10^{-3} cm/sec for the móberg, see Exh. 3.15.

The moraine and tillite on top of the móberg formation have certainly still lower permeability than the móberg itself. From the pressure tests we get a wider range of permeability for this unit, but as it is often tested very close to the surface the accuracy of the tests may be questionable because of unconfined conditions. But it is fairly certain that it has lower permeability than the móberg. The sand in the depressions seems to have a higher permeability than the moraine, but much lower than the postglacial lava formation.

On Exh. 3.16 is shown the elevation of the groundwater in the Hrauneyjafoss area. The groundwater in the lavas is higher than in the móberg except at the toe of Sigalda and again below the Fossalda-Langalda ridge. Everywhere in between the lava groundwater is higher. Inflow of groundwater into the lava formation between Sigalda and Fossalda is from two sources. One is probably lava groundwater coming through lava pass number II, along the same route as the lavaflows have reached the area. This aquifer is very much hypotical. No drillholes are along this route. There are only drillholes upstream of Sigalda and again downstream of it. Another source of groundwater into the lava is at the toe of Sigalda where springs in Ferjugljúfur and vicinity probably extend underneath the lavaflows and cause substantial inflow of groundwater to the lavas in that area. The hole HR-1 is drilled in the old canyon of Tungná cut through the Fossalda-Langalda ridge. In this old canyon the relatively tight cover of moraine is lacking and in that area the potential between the lava groundwater and the móberg groundwater seems to be levelled out. The móberg groundwater, which issues out in springs in Þóristungur in great quantities has a fairly even gradient. It flows from Þórisvatn and the area east of it. The groundwater issuing at the powerhouse site in Þóristungur is probably from the east of Þórisvatn. The springs issued further north are probably much more direct leakage from the lake Þórisvatn. The total discharge of the springs in Þóristungur is 8 m^3/sec whereof 1,1 m^3/sec flows into Sporðöldukvísl, which drains the powerhouse site.

Exhibits 3.17 and 3.18 show variations in groundwater level in drillholes in the postglacial lava formation. It is obvious from these Exhibits that the variations are relatively small or of the order of 3 m between the extreme high and the extreme low groundwater level. The biggest changes are due to diversions of water which will be discussed in the next chapter, and are therefore not changes from natural conditions. In the móberg areas there are not available long series of groundwater observations, but apparently the variations are still smaller there than in the lavaflows.

3.2 Reservoir leakage

On Exh. 3.19 is a map of the reservoir at Hrauneyjafoss divided into subareas, each of which will have a different mode of leakage. This map also contains a table giving the size of the different areas.

Area 1 is mostly sand and silt on surface. The groundwater is at surface. No leakage is expected from this area.

Area 2 is moraine on surface. Excessive leakage should not be expected through this formation.

Area 3 is pillow-lava or móberg at surface. The permeability of this unit should be higher than for the moraine, but this area is small.

Area 4 is sand-filled depression. The permeability of the sand can be rather high, but the depression is probably underlain by moraine which will restrict the leakage. The sand can also leak into the lavas. The actual waterloss from this area is very difficult to predict because of these two facts.

Area 5 is lake deposits. They are silty on surface and should have low permeability. The waterloss from the area is small.

Area 6 is alluvial deposits, mostly sand, gravel and silt. The waterloss from this area is also supposed to be small.

Area 7 is lavaflow which at present is not flooded by the river at normal stage. Previously, before the river stabilized its course, it flooded this area. For this area it is difficult to predict the waterloss. Pressure tests show high permeability, but experience from Langölduveita shows low permeability. It is expected that this area will not have excessive waterloss.

Area 8 is the main problem area. It has not been flooded by the river and is therefore not tightened by alluvial sediments. On the other hand the area is more or less covered with eolian sand. Experience from Langölduveita and from Búrfell indicates that leakage from such an area, not tightened by the river, is of the order of 300-400 l/sec/ha. Similar magnitude should be expected for this area as initial leakage.

Area 9 is pseudo-craters. These are made of scoriae and may be scoriaceous all through the uppermost lavaflow down to the first contact. The leakage in this area is of the same order as in area 8. If the sandy material which has accumulated in the scoriae is coarse enough to have a filter criteria for the scoriae it may be less. But as this is not likely this area has probably to be protected by a blanket of filter material which has a filter criteria against the scoria to prevent swallow holes to form there.

Area 10 is the river itself. It is probably practically impermeable.

The initial leakage from the reservior will not last very long because of the sediment load of the river. In Exhibit 3.20 is a diagram showing the probable way in which the reservoir will be tightened by the sediment load. These calculations are based on the experience from Langölduveita, where a layer 1 mm thick is formed in one week with vertical permeability in k-value of 10^{-7} cm/sec. Over the lake bottom will be formed such a tight blanket with at least the same permeability as the one formed in Langölduveita. This will very soon decrease the initial leakage, as shown on the graph. Besides the carpet tightening, which is created through a formation of a layer of silt on the surface we will also have a tightening inside the lava. Area 8, especially, and probably also area 9 will not have a complete filter criteria for the sediment load, so there we will in the beginning have a formation of swallow-holes, and through the swallow-holes the sediments will go further down into the lava and cause tightening there. In the graph 3.20 it is estimated that tightening of area 8 will be slower in the beginning because of the swallow holes. It may even become neceassary to put filter in some of the swallow holes to stop eccessive leakage.

Experience from Langölduveita shows that swallow holes in the middle of the lava field did not do any harm. It was leaking for a short time and became tight in 6-8 weeks. On the other hand swallow holes at the lavafronts and probably also swallow holes in the pseudo-craters can last very long and have to be filtered. As shown on Exhibit 2.03,a grain size curve for the sediment load of Tungná, much more silt is transported in the water during summer than in other seasons. The most effective sealing will therefore be during summer, and it is probably necessary to fill the lake in early summer to get it tightened during the first summer.

The tightening calculations are based on the Hrauneyjafoss reservoir as being the uppermost on the Tungná river when the reservoir is filled. If the Sigalda reservoir is in existence before the Hraun-eyjafoss lake the sealing by impervious blanket will be much slower. On Exhibit 3.20 is shown a line for the tightening based on the assumption that the Sigalda reservoir will have a trap efficiency of 80% for the sediment load of Tungná and the Hrauneyjafoss reservoir will have a trap efficiency of 50% of the remaining load. As shown on the graph the tightening is much slower under that condition. But as the trap efficiency of the Sigalda reservoir is not known and neither the trap efficiency of the Hrauneyjafoss reservoir for the remaining sediment load, this calculation must be assumed a crude approximation.

Influence from the leakage water on the groundwater level is indicated by the ground water fluctuations represented in Exhibit 3.17 and 3.18. All the holes selected are near either the Langölduveita or near Þjórsá at Búrfell. Only TH-8 is far away from either of these sites. Hole BD-11 is near Búrfell and shows a sudden rise, 1,5 m, when the diversion was put into operation at Búrfell in August 1969. Since then the groundwater level has been dropping. But compared to TH-8, where the groundwater had an upward trend during the same time, we can conclude that the leakage at Búrfell has now practically ceased. All the other holes are near Langöldu-veita and they show a rise in groundwater table in May 1967, which may be due to that diversion. At that time the leakage from Langölduveita was over 2 m^3/sec into the lava. Langölduveita has since then had very little effect on hole HR-1, which indicates that the leakage does not go into the old canyon of Tungná, but through a pass west of the canyon. HR-2 is close to the big lake which came into existence in 1970. In that lake the normal leakage during the summer of 1970 was 2-3 m^3/sec, but at flood peaks it could amount to 6-7 m^3/sec. The creation of this lake also affected TH-9 which is located close to it. The inflow of great quantities of water certainly raises the groundwater level for a short time, but it levels out again very soon as shown on the graph. The lava aquifer can therefore take great quantities of water for a short time, which may be necessary if the lake is filled very rapidly, but due to the rapid sealing it is not probable that the lava formation will be saturated up to the surface so that a piping condition will be created under the dams.

3.3 The Damsite

A part of section D-D runs along the damsite while sections A-A, B-B and C-C cover the contact of the postglacial lavas with the móberg formation. These sections are shown on Exhibits 3.24 and 3.23. Most of the dam will be founded on the postglacial lava formation which along the damside consists of several different flows, up to five in one section. The thickness of the lavaflows varies, but the uppermost is on the whole 10-15 m thick.

The uppermost flow consists on top of a mixture of broken lava and eolian sand, but even big broken blocks of solid lava can reach the surface. This hetero-geneous upper surface of the lava has a thickness varying from 0 to 3 or even 4 m. Below this surface layer is dense lava often with a thickness of about 10 m or slightly less. The dense lava is columnar jointed and the contraction cracks along the jointing constitute leakage paths through the dense lava. Leakage through this part of the lava is therefore mainly vertical as the vertical permeability is higher than the horizontal one. Under the dense part a scoriaceous layer again ensues, the lower contact zone. This is an extremely permeable zone for horizontal leakage. At present the uppermost contact zone is dry. The groundwater is farther down under the dam. The main active aquifer for horizontal groundwater discharge under the dam is therefore the second contact zone.

The impervious core along with concrete structures have to be founded on the dense core of the lava. In the area where no tightening by the river has occured, area 8 on Exhibit 3.19, the leakage under the dam will be vertical. Grout curtain will therefore not prevent any leakage, and the only use of a grout curtain is an extra safety for the core of the dam. In Langölduveita the small dams built there have all been stable without any grout curtain in an area, where no tightening had taken place previously.

In area 7 the river has at former times flooded the lava flows. In this area danger of horizontal leakage under the base of the dam exists. Experience from Langölduveita showed a tendency for piping at the base of the small dams in the area previously tightened by the river. A grout curtain must therefore secure that horizontal leakage can not take place under the dam in this part of the foundation.

At the contact with Fossalda there are thick interbeds of sand between the lavas and Fossalda; this sand interfingers with the lower lava fronts. In the fall of 1970 this interbed contained higher ground-water table than either the lava flows on one side or the móberg on the other. This sandy interbed seems to be the only place along the dam axis where a danger of piping can be foreseen. It is therefore proposed to make a grout curtain into the front of the second lava flow. When the second lava is reached, the vertical permeability is so high that an excellent drainage is obtained. The right abutment of the dam will be founded on tillite or moraine. The tillite is a strong rock, as will be discussed in the next chapter and constitutes a good foundation. Grouting has to be done in the tillite to prevent short path horizontal leakage under the impervious core.

3.4 Diversion Canal

A section along the diversion canal D-D on Exh. 3.24 shows that the diversion canal is in three different units. These are: 1) On top, moraine, 6-8 m thick except at the river where it is lacking.
2) Beneath it is tillite, varying in thickness from 0-16 m, and
3) The lowest is the pillow lava breccia and basaltic veins of the móberg formation Hr_1, which reaches far below the zone of interest.

The moraine is usually rather hard, but the uppermost 1-2 m can be quite loose and weathered. This uppermost part has a seismic sound velocity of 0,7 km/sec up to 1,1 km/sec. The lower part of the moraine has seismic sound velocity of at least 1,5 km/sec and even up to 2 km/sec. It can be worked with heavy bulldozers by ripping, but it is a fairly hard material, which does not break down into individual grains.

The tillite should be considered as rock. The seismic sound velocity is over 2 km/sec and it has an unconfined compressive strength between 250-450 kg/cm^2. If this is compared to the rock at the newly finished hydro-power plant at Búrfell the compressive strength of this material is of the same order as that of the tuff on which the powerhouse was founded at Búrfell. Freezing and thawing experiments have shown a piece of core from this tillite to withstand 200 cycles without breaking down. Yet another piece of the tillite did only withstand 40 cycles. Tillite taken from an excavation on the nearby Langalda did withstand 200 cycles of freezing/thawing without any disintegration. These experiments prove that the tillite can be looked upon as rock, and a fairly steep slope in it should be stable. Waterfalls in tillite in Tungná also prove that it is resistant to erosion. The tillite is not rippable and has to be blasted.

The móberg formation Hr_1 mostly consists of pillow lava or pillow breccia, and it has a seismic sound velocity of over 2 km/sec. Experiments have shown that it is difficult to rip or even non-rippable for heavy bull-dozers. The rock should be able to stand at a steep slope as cementation is fairly good. Existing slopes seen in the Tungná canyon also indicate very steep stable slopes in this rock type. Results from pressure tests in drillholes, shown on Exh. 3.17 show that the permeability of the rock in the approach canal is of the order of k = 10^{-4} to 10^{-3} cm/sec. An average value should be 6 or 7x10^{-4} cm/sec. If this value is used for calculating the expected waterloss from the canal by an equation taken from the book "Groundwater and seepage" by Harr pp. 239-240, we get a waterloss of 0.4 m^3/sec for a k-value $6x10^{-4}$ cm/sec and an upper limit of 0.7 m^3/sec for k-value 10^{-3} cm/sec. This is initial leakage, which will decrease rapidly because of silting and also due to gradual decrease in hydraulic gradient as the rock becomes saturated.

3.5 Powerhouse and tailrace canal

The powerhouse excavation will be cut into moraine and tillite for the most part and down to underlying móberg belonging to Hr_1. What has been said about these units in the section on the approach canal is also valid here. The only change in condition is that the powerhouse is situated below the groundwater table and the inflow of groundwater will be considerable. The total amount of water in springs in the area surrounding the powerhouse is about 1,1 m^3/sec. This may be an upper limit of the possible inflow into the powerhouse excavation. This excavation will be a major drainage of groundwater from around, as it goes 30 m or more below the groundwater table. How much the actual inflow will be still depends on the mode of excavation, i.e. on how much of the tailrace canal is done at an early stage to take as much of the inflow as possible. In any case the inflow of several hundred l/sec may be expected. As a foundation the móberg will be quite adequate and the inflow will not cause foundation problems. The tailrace canal will be excavated into loessial and silty overburden materials filling the depression at the toe of the Fossalda ridge. Also, some of it will be excavated in moraine and even in tillite. Penstocks will be founded on moraine or cut into moraine which covers the slopes above the powerhouse.

T A F L A

T A B L E 3

STAÐSETNING OG DÝPI KJARNAHOLA OG PÍSOMETRA
LOCATION AND DEPTH OF CORE DILLHOLES AND PIEZOMETERS

Hola Nr. Hole No	Hnit Co-ordinates X	Y	Toppur fóðurrörs, m y.s. Top of casing, el.	Dýpi Depth m	Botn holu m y.s. Bottom of hole, el.
HP-1	560,215	411,080	430,01	97,0	333,0
HP-2	560,273	411,529	357,12	28,7	328,4
HP-3	560,283	410,410	438,29*	86,0	352,3
HP-4	(560,152)	(409,725)	418,02	34,5	383,2
HP-9	561,703	410,518	387,38	41,9	345,5
HP-10	560,730	410,097	428,06	33,3	394,8
HP-14	558,749	409,011	419,85	51,7	368,2
HP-15	559,742	408,245	429,56	35,7	393,9
HP-16	560,936	410,967	391,08*	44,0	387,1
HP-20	556,684	412,416	431,58	51,1	380,5
HP-21	559,881	410,928	431,02	31,0	400,0
HP-22	560,964	410,769	363,05	23,5	339,6
HP-23	559,769	410,641	435,85	30,9	405,0
HP-24	559,680	410,427	421,58	16,5	405,1
HP-25	559,749	410,309	423,95	13,7	410,3
HP-26	560,169	411,356	387,35	23,2	364,2
HP-27	560,159	411,548	357,09	29,0	328,1
HP-28	560,153	411,705	349,53	20,2	329,3
HP-29	560,176	411,228	422,44	22,5	399,9
HP-30	560,068	411,135	428,42	22,5	405,9
HP-31	560,105	411,479	363,42	31,6	331,8
HP-32	560,016	411,000	429,30	5,7	423,6
HP-33	559,811	410,801	428,89	10,2	418,7
HP-34	559,671	410,333	417,48	28,7	388,8
HP-35	559,629	410,276	417,98*	26,2	391,8

Hola Nr. Hole No	Hnit Co-ordinates X	Y	Toppur fóðurrörs, m y.s. Top of casing, el.	Dýpi Depth m	Botn holu m y.s. Bottom of hole, el.
HP-37	559,517	409,912	417,91*	42,9	375,0
HP-38	559,382	409,402	420,15	27,4	392,8
HP-39	559,251	408,936	420,24	18,0	402,2
HP-41	(558,635)	(408,098)	428,24	19,0	409,2
HP-42	(559,750)	(410,550)	430,43	11,5	418,9
HP-46	560,167	411,448	367,28	30,0	337,3
HP-47	560,169	411,107	430,32	20,0	410,3
HP-48	559,671	410,334	417,50	19,4	398,1
P-23	556.495	411.071	423,2+	30,0	391,6
P-24	557.860	470.465	420,6+	28,3	390,7
HR-1	561,727	410,180	395,6*	61,5	334,1
HR-2	563,238	408,540	394,3*	67,0	327,3
HR-3	410.085	560.185	418,7	101,4	317,3
HR-4	411.210	561.225	368,2	59,6	308,6
X	560,283	409,056	420,0	46,0	374,0
BD-11	(585.175	402.428)	241,8	17,7	224,1
TH-8	568,152	405,615	378,6*	60,6	318,0
TH-9	564,307	406,988	393,5*	37,0	356,5

*Písameterrör í holunni
Piezometer pipe in the hole

+Hæð á toppi písarörs, sjá Exh. 3.14.
Elevation on top of piezometer pipe, see Exh. 3.14.

TAFLA 4

TABLE

STAÐSETNING OG DÝPI BORROHOLA

LOCATION AND DEPTH OF BORRO SOUNDINGS

Hola Nr. Hole No	Hnit Co-ordinates X	Hnit Co-ordinates Y	Hæð yfirb. m y.s. Surface el.	Dýpi Depth m	Hæð botns m y.s. Bottom of hole, el.	Hola Nr. Hole No	Hnit Co-ordinates X	Hnit Co-ordinates Y	Hæð yfirb. m y.s. Surface el.	Dýpi Depth m	Hæð botns m y.s, Bottom of hole, el.
BP-1	556.719	412.341	435,2	2,0	433,2	BP-30E	559.575	409.908	417,6	0,9	416,7
BP-2	616	391	431,8	1,2	430,6	BP-31	.564	.882	417,8	4,7	413,1
BP-3	712	441	432,5	1,4	431,1	BP-31B	.564	.859	417,9	2,6	415,3
BP-4	708	491	435,2	0,6	434,6	BP-31C	.564	.850	417,7	2.5	415,2
BP-5	672	525	432,6	0,4	432,2	BP-32	.572	.765	418,8	3.3	415,5
BP-6	636	559	430,9	1,3	429,6	BP-33	.483	.696	417,5	2,3	415,2
BP-7	599	593	433,5	0,8	432,7	BP-34	.458	.641	417,1	2,9	414,2
BP-8	562	627	434,2	0,5	433,7	BP-34B	.487	.658	417,1	2,2	414,9
BP-9	526	661	434,9	0,6	434,3	BP-35	.432	.579	417,4	1,3	416,1
BP-10	467	674	432,4	1,7	430,7	BP-36	.408	.528	417,8	2,6	415,2
BP-11	429	688	432,2	0,7	431,5	BP-37	.342	.378	418,8	0,7	418,1
BP-12	381	702	432,7	0,8	431,9	BP-38	.257	.180	418,8	1,0	417,8
BP-13	333	715	433,3	0,7	432,6	BP-39	.232	.123	418,9	1,0	417,9
BÐ-14	285	728	433,7	0,9	432,8	BP-40	.200	.047	419,2	3,3	415,9
BP-15	240	704	435,1	0,8	434,3-	BP-51	.401	410.763	432,4	0,8	431,6
BP-16	196	781	436,1	1,0	435,1	BP-52	391	724	431,5	1,6	429,9
BP-17	152	658	436,9	0,6	436,3	BP-53	375	680	431,0	1,5	429,5
BP-18	640	335	435,4	0,6	434,8	BP-54	352	761	436,6	1,0	435,6
BP-19	720	399	431,1	1,6	429,5	BP-90	560.246	412.600	332,2	14,8	317,4
BP-20	801	463	430,6	0,7	429,9	BP-91	270	507	336,2	6,2	330,0
BP-21	882	528	430,9	6,7	424,2	BP-92	291	410	338,3	3,0	335,3
BP-22	464	627	431,5	1,8	429,7	BP-93	311	310	338,8	4,7	334,1
BP-23	416	640	430,3	1,3	429,0	BP-101	.173	.487	338,4	3,7	334,7
BP-24	368	654	430,3	2,1	428,2	BP-101B	.183	.430	339,9	4,7	335,2
BP-25	556.320	412.667	433,2	0,9	432,3	BP-102	.193	.388	341,0	4,0	337,0
						BP-102B	560.203	412.340	341,5	6,4	335,1

T A F L A

T A B L E 4 cont'd.

STAÐSETNING OG DÝPI BORROHOLA

LOCATION AND DEPTH OF BORRO SOUNDINGS

Hola Nr. Hole No.	Hnit Co-ordinates		Hæð yfirb. m y.s. Surface el.	Dýpi Depth	Hæð botns m y.s. Bottom of hole, el.	Hola Nr. Hole No	Hnit Co-ordinates		Hæð yfirb. m y.s. Surface el.	Dýpi Depth	Hæð botns m y.s. Bottom of hole, el.
	X	Y		m			X	Y		m	
BP-103	560.212	412.292	337,7	4,9	332,8	BP-201	559.979	412.450	344,7	8,8	335,9
BP-103B	.223	.240	338,7	5,8	332,9	BP-202	998	350	343,9	4,1	339,8
BP-104	.233	.192	338,7	3,4	335,3	BP-203	.015	250	343,6	6,0	337,6
BP-104B	.243	.143	343,6	5,2	338,4	BP-204	560.036	.151	341,8	8,1	333,7
BP-105	.253	.095	344,0	5,2	338,8	BP-204B	.042	.103	344,0	16,5	327,5
BP-105B	.262	.044	345,1	6,0	339,1	BP-205	055	055	343,8	19,0	324,8
BP-106	.272	.000	346,0	5,6	340,4	BP-205B	062	005	344,0	5,2	338,8
BP-108	312	411.803	350,4	4,9	345,5	BP-205C	007	045	345,5	5,5	340,0
BP-110	350	605	354,2	4,5	349,7	BP-206	074	958	343,8	2,8	341,0
BP-112	390	416	371,4	0,5	370,9	BP-207	092	862	346,9	5,9	341,0
BP-151	.076	412.472	342,2	4,7	337,5	BP-208	113	763	349,8	6,5	343,3
BP-152	096	370	343,2	5,9	337,3	BP-209	133	667	351,5	5,4	346,1
BP-153	118	271	343,3	5,7	337,6	BP-210	.152	411.567	356,7	6,5	350,2
BP-153B	.127	.220	342,8	10,4	332,5	BP-211	174	.470	363,4	0,6	362,8
BP-154	136	171	340,4	5,3	335,1	BP-212	.192	.878	383,0	0,6	382,4
BP-154B	.146	.122	339,8	1,3	338,5	BP-214	.233	.180	423,7	1,0	422,7
BP-155	157	074	345,7	12,2	333,5	BP-215	251	085	428,0	1,1	426,9
BP-155B	.166	.025	346,1	6,2	339,9	BP-216	157	046	432,6	0,5	432,1
BP-155C	.104	.065	342,4	15,5	326,9	BP-217	064	001	432,9	0,6	432,3
BP-156	173	411.977	346,4	5,7	340,7	BP-218	982	970	431,2	0,7	430,5
BP-157	196	878	346,9	9,6	337,3	BP-219	559.883	410.923	431,6	0,9	430,7
BP-158	214	781	346,8	5,8	341,0	BP-220	828	840	433,2	1,3	431,9
BP-159	235	682	350,0	5,3	344,7	BP-221	.783	.750	432,5	1,1	431,4
BP-160	253	584	354,4	5,4	349,0	BP-222	.759	.652	435,8	0,4	435,4
BP-161	560.274	411.490	359,9	1,0	358,9	BP-223	559.736	410.556	428,0	1,1	426,9

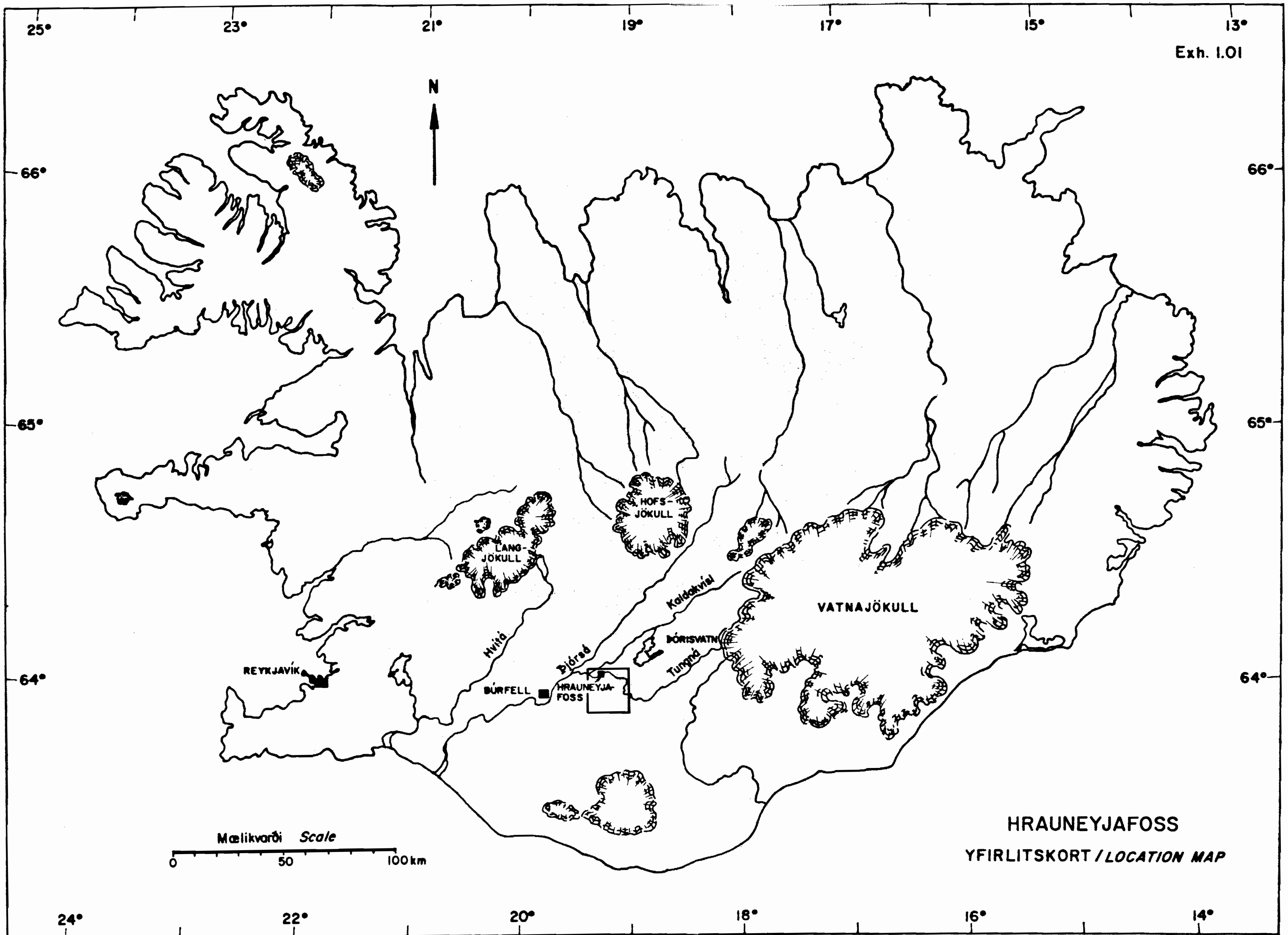
T A F L A 4 cont´d.

T A B L E

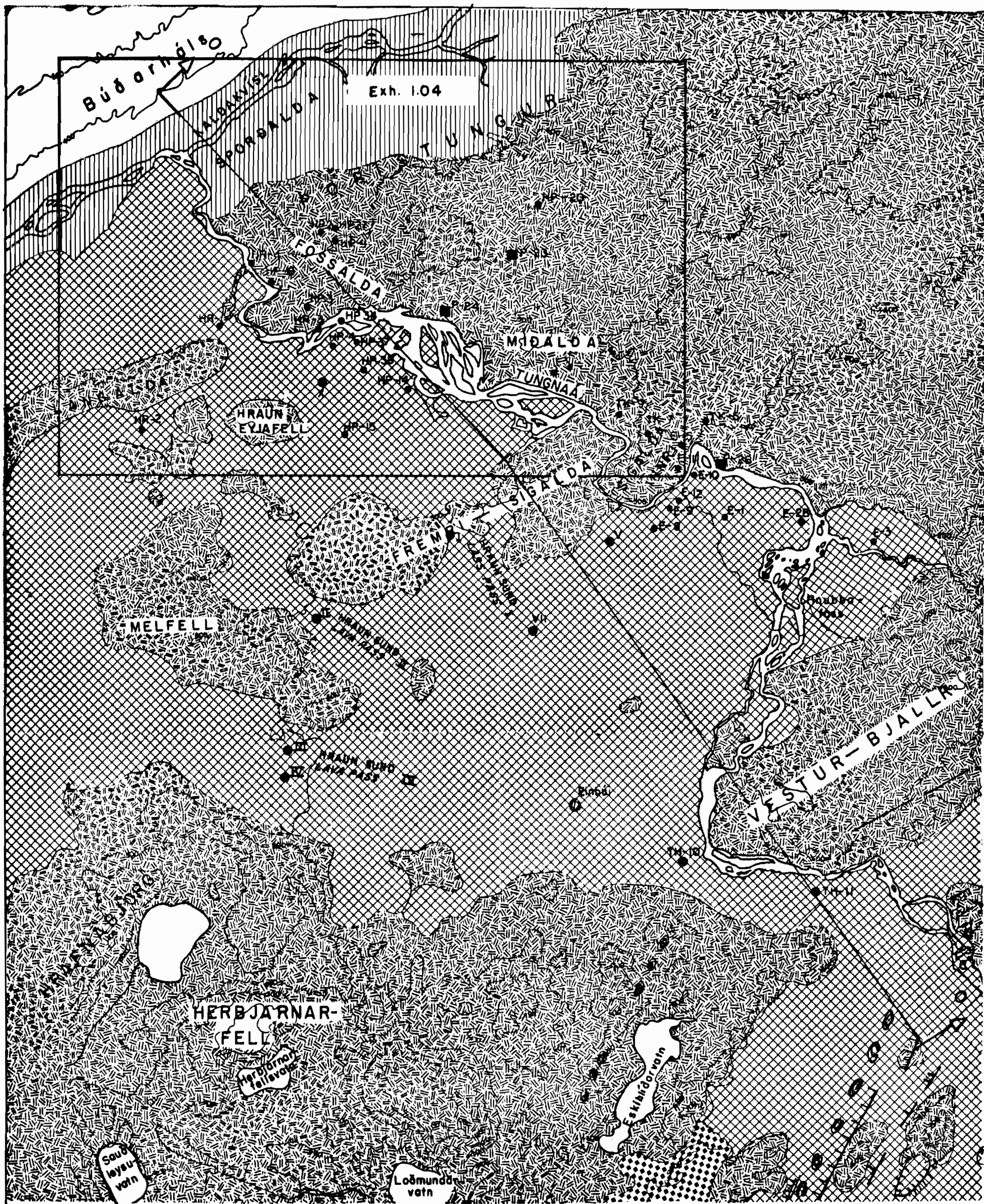
STAÐSETNING OG DÝPI BORROHOLA

LOCATION AND DEPTH OF BORRO SOUNDINGS

Hola Nr. Hole No.	Hnit Co-ordinates X	Y	Hæð yfirb. m y.s. Surface el.	Dýpi Depth m	Hæð botns m y.s Bottom of hole, el.	Hola Nr. Hole No.	Hnit Co-ordinates X	Y	Hæð yfirb. m y.s. Surface el.	Dýpi Depth m	Hæð botns m y.s. Bottom of hole, el.
BP-224	559.712	410.460	423,3	0,9	422,4						
BP-225	690	638	435,6	0,8	434,8						
BP-251	880	412.432	343,7	8,0	333,7						
BP-252	897	330	343,9	6,6	337,3						
BP-253	918	230	344,3	6,5	337,8						
BP-254	937	133	343,5	10,6	332,9						
BP-254B	948	411.083	345,9	4,5	341,4						
BP-255	958	035	346,1	4,5	341,6						
BP-256	976	411.939	346,0	4,1	341,9						
BP-257	998	411.159	348,7	7,4	341,0						
BP-259	560.036	645	354,6	5,5	349,1						
BP-260	054	546	358,3	2,0	356,3						
BP-261	074	400	367,8	0,6	367,2						
BP-302	559.302	412.310	343,3	1,9	341,4						
BP-304	340	412.111	345,6	4,5	341,1						
BP-306	381	411.420	347,8	4,0	343,8						
BP-308	422	411.720	352,5	6,0	346,5						
BP-310	559.759	411.526	368,1	0,5	367,6						


Exh. 1.01
N
HOFS-
JÖKULL
LANG-
JÖKULL
VATNAJÖKULL
Kaldakvísl
ÞÓRISVATN
Tungná
Þjórsá
Hvítá
BÚRFELL
HRAUNEYJA-
FOSS
REYKJAVÍK
Mælikvarði Scale
0
50
100 km
HRAUNEYJAFOSS
YFIRLITSKORT / LOCATION MAP
25°
23°
21°
19°
17°
15°
13°
24°
22°
20°
18°
16°
14°
66°
65°
64°

Exh. 102



Skýringar *Legend*

(cross-hatch)	Tungnaárhraun *Tungnaa lava flow*	(symbol)	Heljargjár sigdæld *Heljargja graben area*
(stipple)	Sigöldu móberg *Sigalda Moberg*	●	Borholur *Boreholes*
(vertical lines)	Köldukvíslargrágrýti *Kaldakvisl Gray Basalt*	■	Písómetri *Piezometer*
(dots)	Líparít Rhyolite	(symbol)	Jarðlagasnið, megindrættir, O - O *Schematic geol. section, O- O* Exh. I.03

0 1 2 3 4 km

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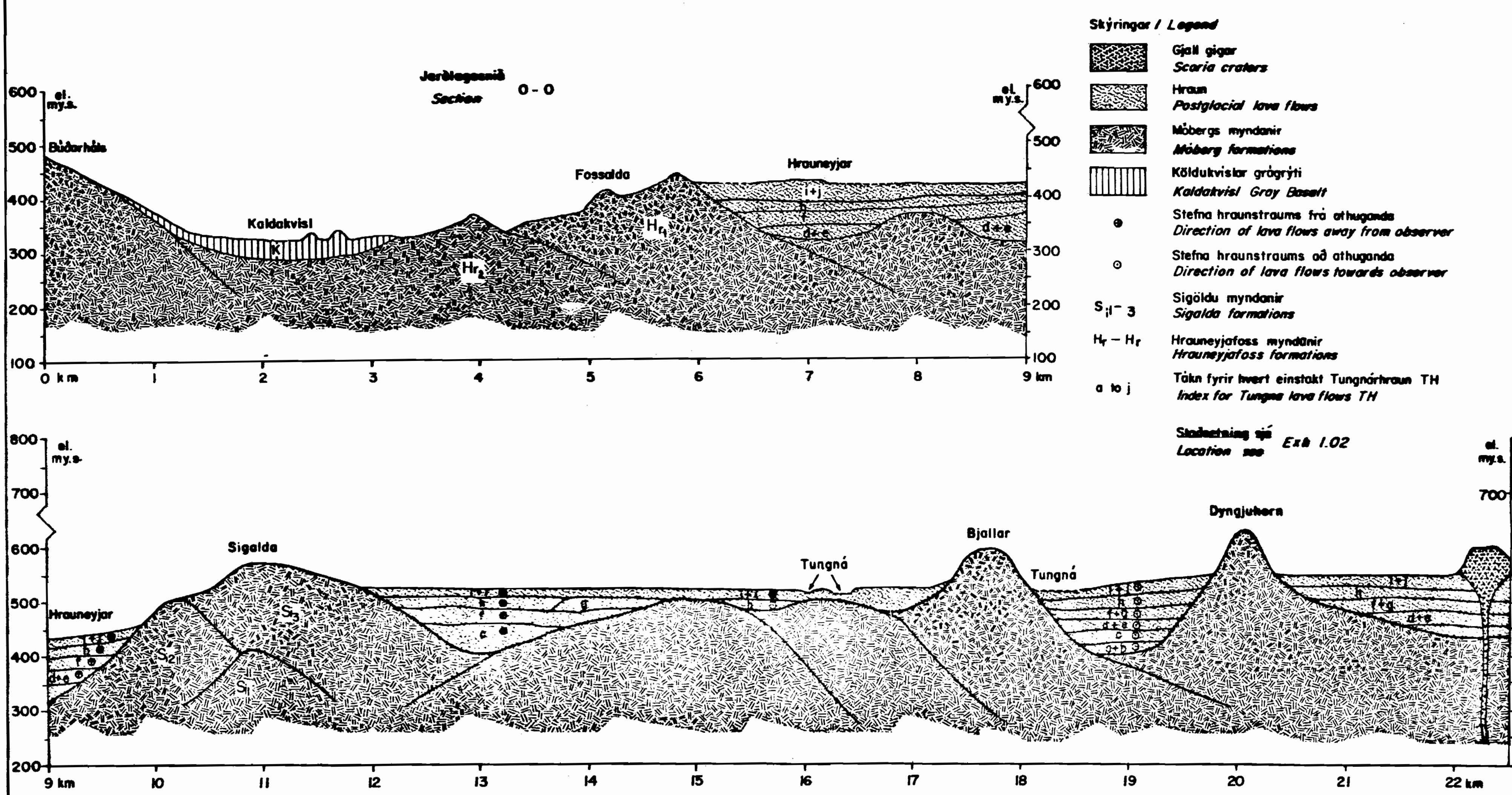
Thoroddsen and Partners
ORKUSTOFNUN
HRAUNEYJAFOSS
Yfirlits jarðfræði
General Geology

28.I.'71	H.T / PJ	Thr. 2 5 7	Fnr. 9 7 2 1
		B – 332	

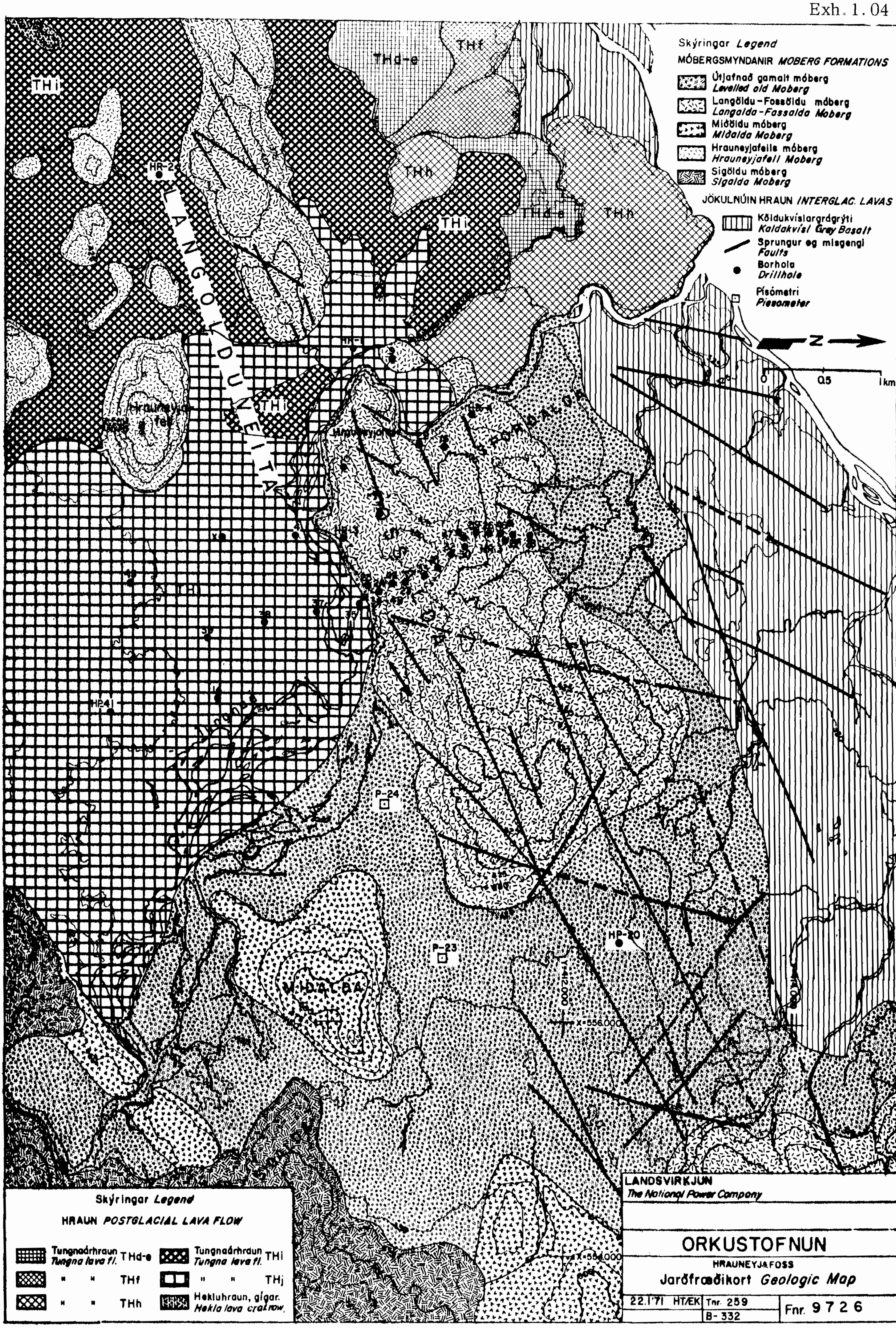
Exh. 1.03



Jarðlagasnið sem sýnir höfuðdrætti jarðfræðinnar frá eldgosabeltinu að Búðarhálsi.
Það sýnir afstöðu móbergsmyndananna hverrar til annarrar og hraun runnin fyrir og eftir síðustu ísöld.
Öll hraun eftir ísöld hafa runnið um skarðið milli Dyngjuhorns og Bjalla, gígur í Heljargjár eldgosabeltinu sést yzt til hægri.

Schematic geologic section from the volcanic belt to Búðarháls. It shows the anticipated stratigraphic relationship between the different móberg formations and the lava flows. All the Postglacial lava flows have flown through the pass between Dyngjuhorn and Bjallar. A crater in the Heljargja volcanic belt is seen at the extreme right.

LANDSVIRKJUN The National Power Company	
ORKUSTOFNUN	
HRAUNEYJAFOSS Jarðlagasnið, megindrættir Schematic geologic section 0-0	
11.1 '70 H.T/O Tnr. 244 B-332	Fnr. 9650


Skýringar Legend
MÓBERGSMYNDANIR MOBERG FORMATIONS
Útjafnað gamalt móberg
Levelled old Moberg
Langöldu-Fossöldu móberg
Langalda-Fossalda Moberg
Miðöldu móberg
Miðalda Moberg
Hrauneyjafells móberg
Hrauneyjafell Moberg
Sigöldu móberg
Sigalda Moberg
JÖKULNÚIN HRAUN INTERGLAC. LAVAS
Köldukvíslargrágrýti
Kaldakvísl Grey Basalt
Sprungur og misgengi
Faults
Borhola
Drillhole
Písómetri
Piesometer
Z
0
0.5
1 km
THi
THd-e
THf
THh
HR-2
LANGÖLDUVEITA
Hrauneyjafell
P-24
P-23
HP-20
HP-41
MIÐALDA
Skýringar Legend
HRAUN POSTGLACIAL LAVA FLOW
Tungnaárhraun THd-e
Tungna lava fl.
Tungnaárhraun THi
Tungna lava fl.
" " THf
" " THj
" " THh
Hekluhraun, gígar.
Hekla lava crat.row.
LANDSVIRKJUN
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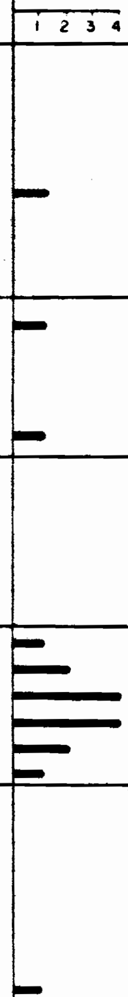
HRAUNEYJAFOSS
Jarðfræðikort Geologic Map
22.1.'71 HT/EK
Tnr. 259
B-332
Fnr. 9726

Exh. 1.05

Age in years	Tephra layers and C^{14} datings	Tungná lavas		Number of phenocrysts per cm² (1 2 3 4)	Length km	Area km²	Volume km³	Main production centres for the Tungná lavas
0								
	H_1							
1000								
2000		TH_j	Tjörvahraun		20	63.2	0.6	Crater row west of Tjörvafell
	H_3							
3000		TH_i	Búrfellshraun		70	282	4.2	Vatnaöldur crater rows
		TH_h	Þjórsárdalshraun		55	135	25	
4000	H_4							
5000								
	Plant remains in Króksvatn	TH_g	Hnubbahraun		15	25	05	Heljargjá crater rows
		TH_f	Kvíslahraun		65	185	20	
		TH_e			80	400	20	
6000		TH_d			80	400	60	
		TH_c			60	135	2.0	
		TH_b	Flóahraun		150	735	15.0	?
	H_5							
7000								
8000	Peat at Thjórsábridge	TH_a			120	455	70	?
							41 8	



Note:
All cited tephra layers originate from Hekla.

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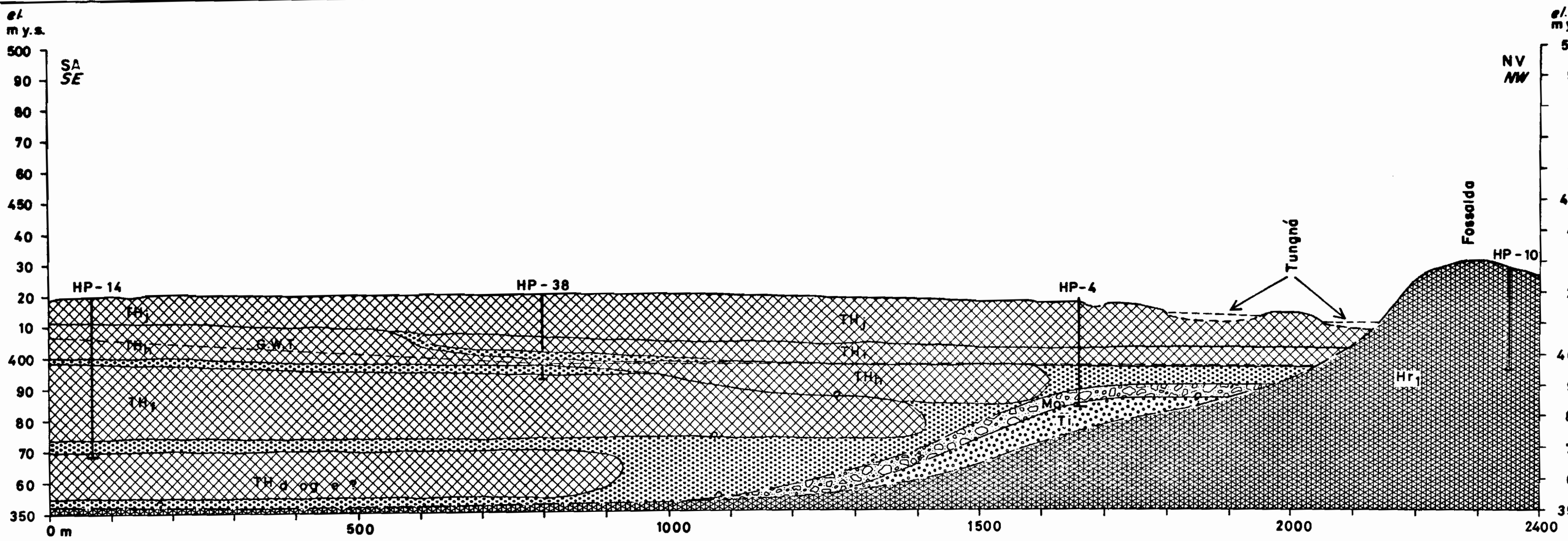
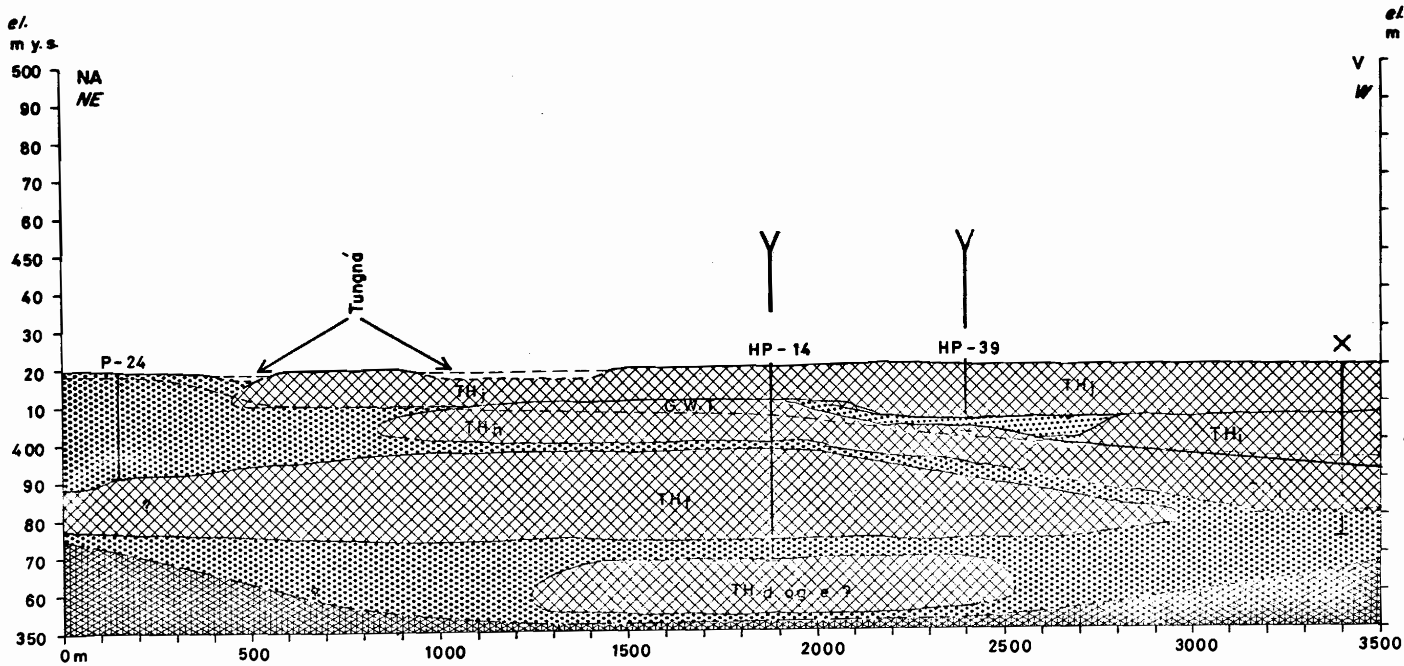
HRAUNEYJAFOSS
AÐALEINKENNI TUNGNÁRHRAUNA
MAIN CHARACTERIST. OF TUNGNÁ LAVA FORM.
Febr. '69 EGV/Gyð Tnr. 262 B-332 Fnr. 8825

Exh.1.06



E - E



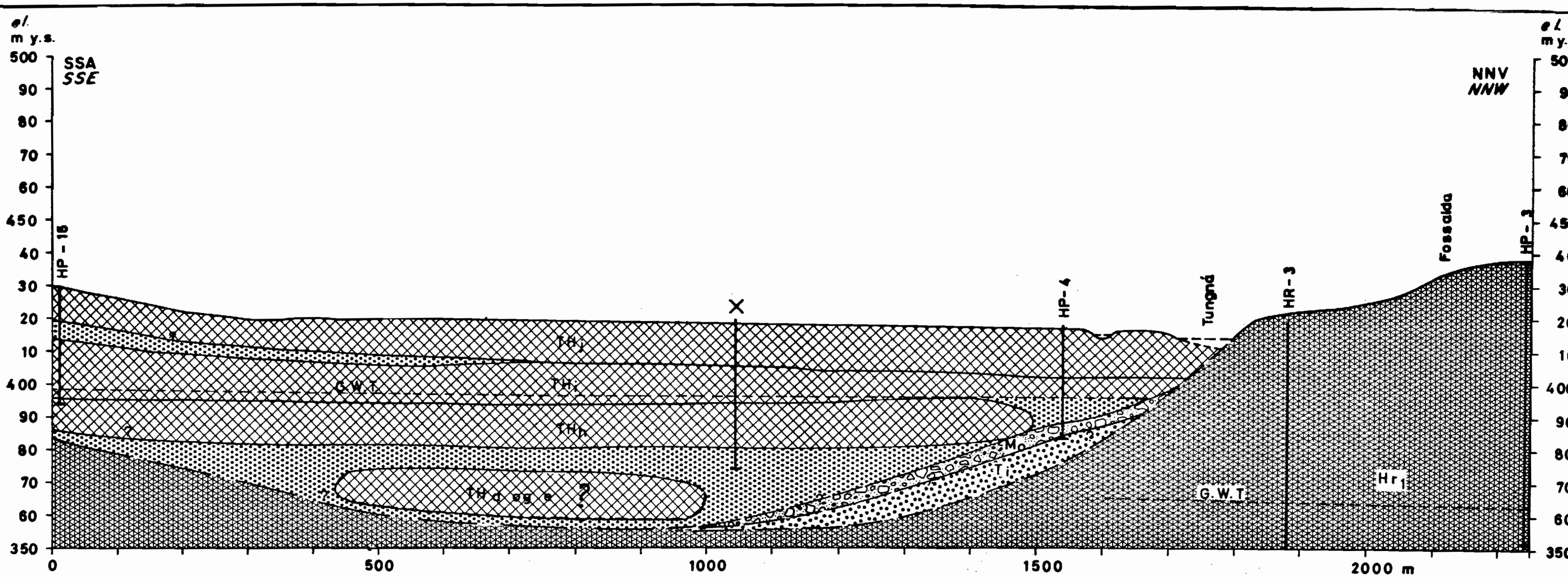
F - F

Skýringar sjá *Legend see* Exh. 1.08

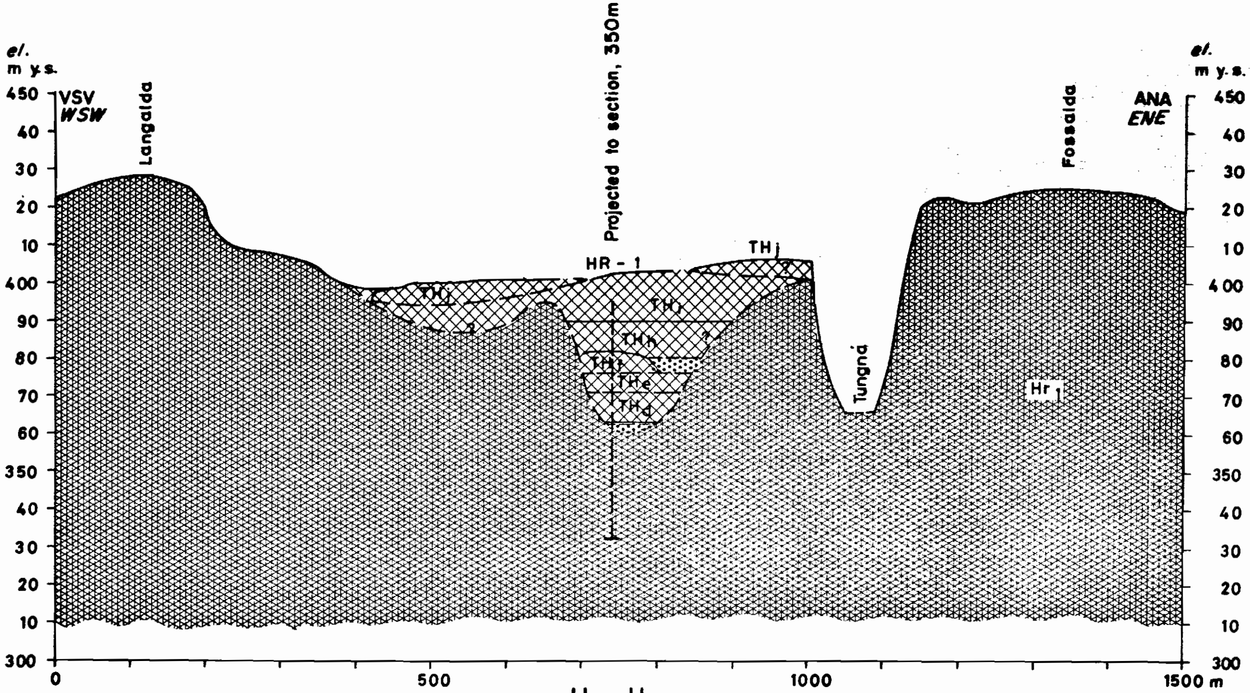
Staðsetning sjá *Location see* Exh. 3.21

LANDSVIRKJUN *The National Power Company*	
ORKUSTOFNUN	
HRAUNEYJAFOSS Jarðlagasnið EE-FF *Geological sections EE-FF*	
Jan.1971 HT / Tnr. 267	Fnr. 9734
Blað 3 af 5 B-332	

Exh. 1.07



G - G



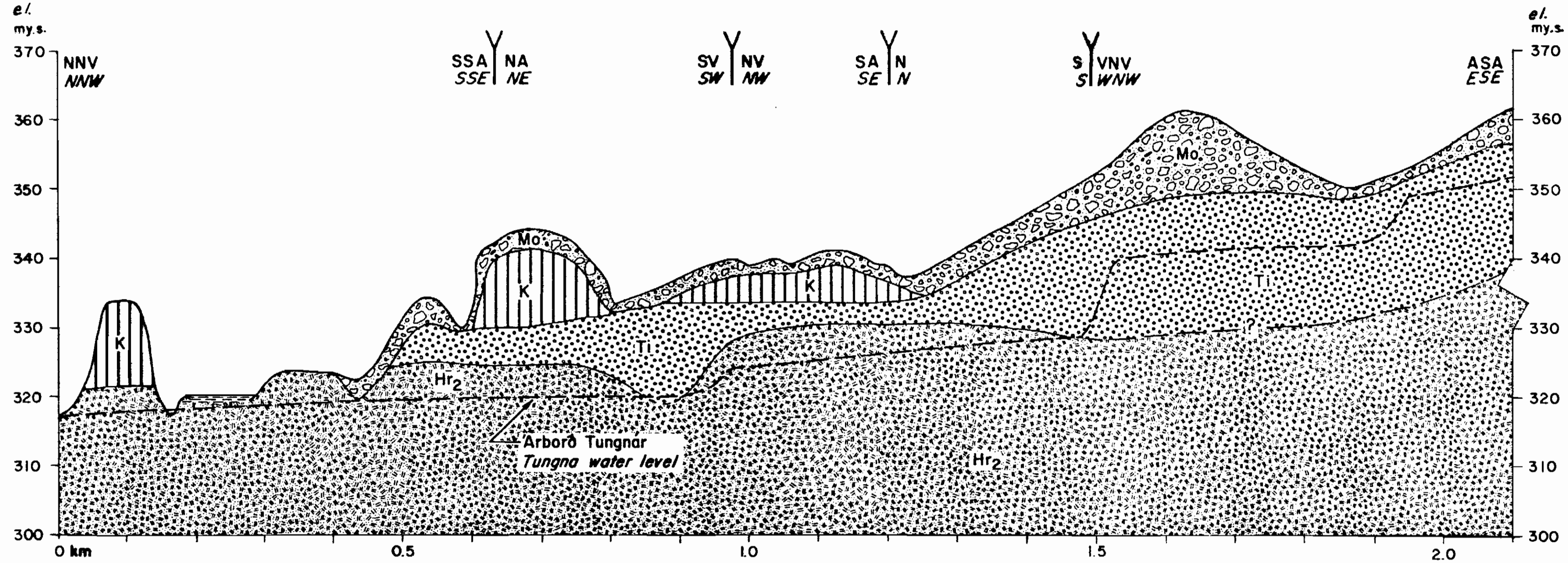
H - H

Skýringar sjá
Legend see Exh. 1.08

Staðsetning sjá
Location see Exh. 3.21

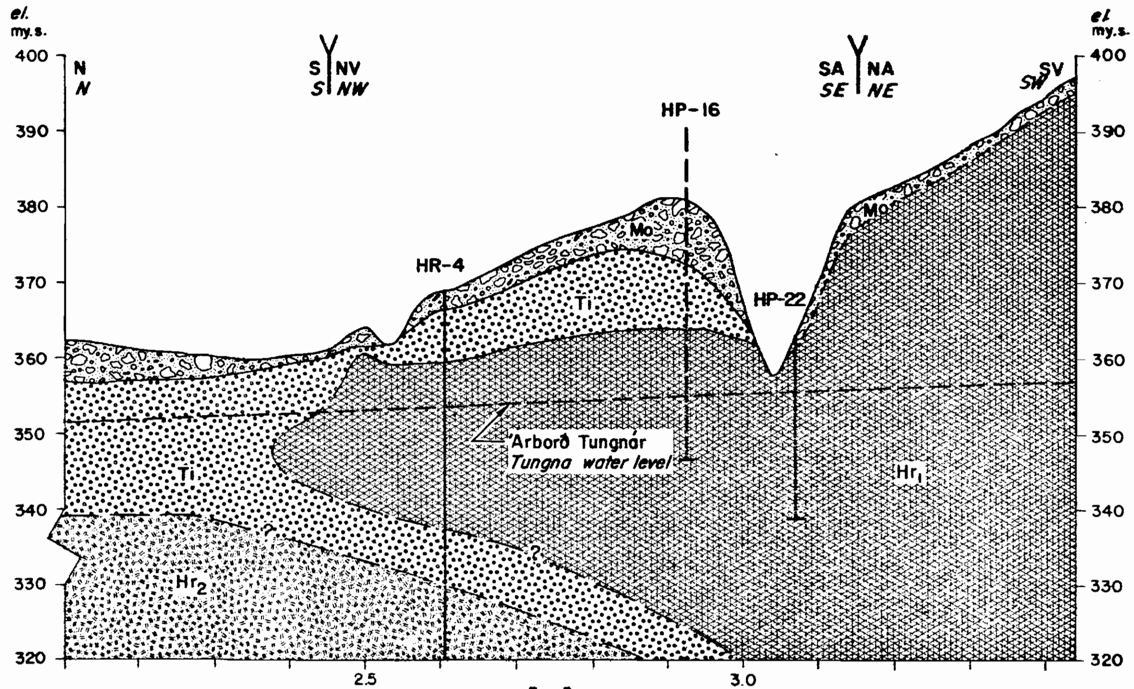
LANDSVIRKJUN *The National Power Company*	
ORKUSTOFNUN	
HRAUNEYJAFOSS Jarðlagasnið GG-HH *Geological sections GG-HH*	
Jan.1971 / Blað 4 af 5	Tnr.268 / B-332
Fnr. 9735	

Exh. 1.08



I – I

Staðsetning sjá
Location see Exh. 3.21



I – I

SKÝRINGAR:
LEGEND:

- Laust yfirborð og millilög, sand- og gjallkennd — *Overburden and interbeds, sandy and scoriaceous*
- TH — Tungnárhraun, stórdílótt basalt — *Tungná lavas, porphyritic basalt*
- Mo/Ti — Mórena og jökulberg undir — *Moraine and tillite beneath*
- Hr_1/Hr_2 — Hrauneyjafossmóberg — *Hrauneyjafoss Móberg Formations*
- Si_2 — Sigöldumóberg — *Sigalda Móberg Formation*
- K — Köldukvíslargrágrýti — *Kaldakvísl Gray Basalt*
- Borhola — *Drillhole*
- Snið breytir stefnu — *Section turns*
- Óviss jarðlagaskil — *Uncertain rock contacts*
- A-A — Snið skerast — *Sections intersect*
- G.W.T — Jarðvatnsborð — *Ground Water Table*

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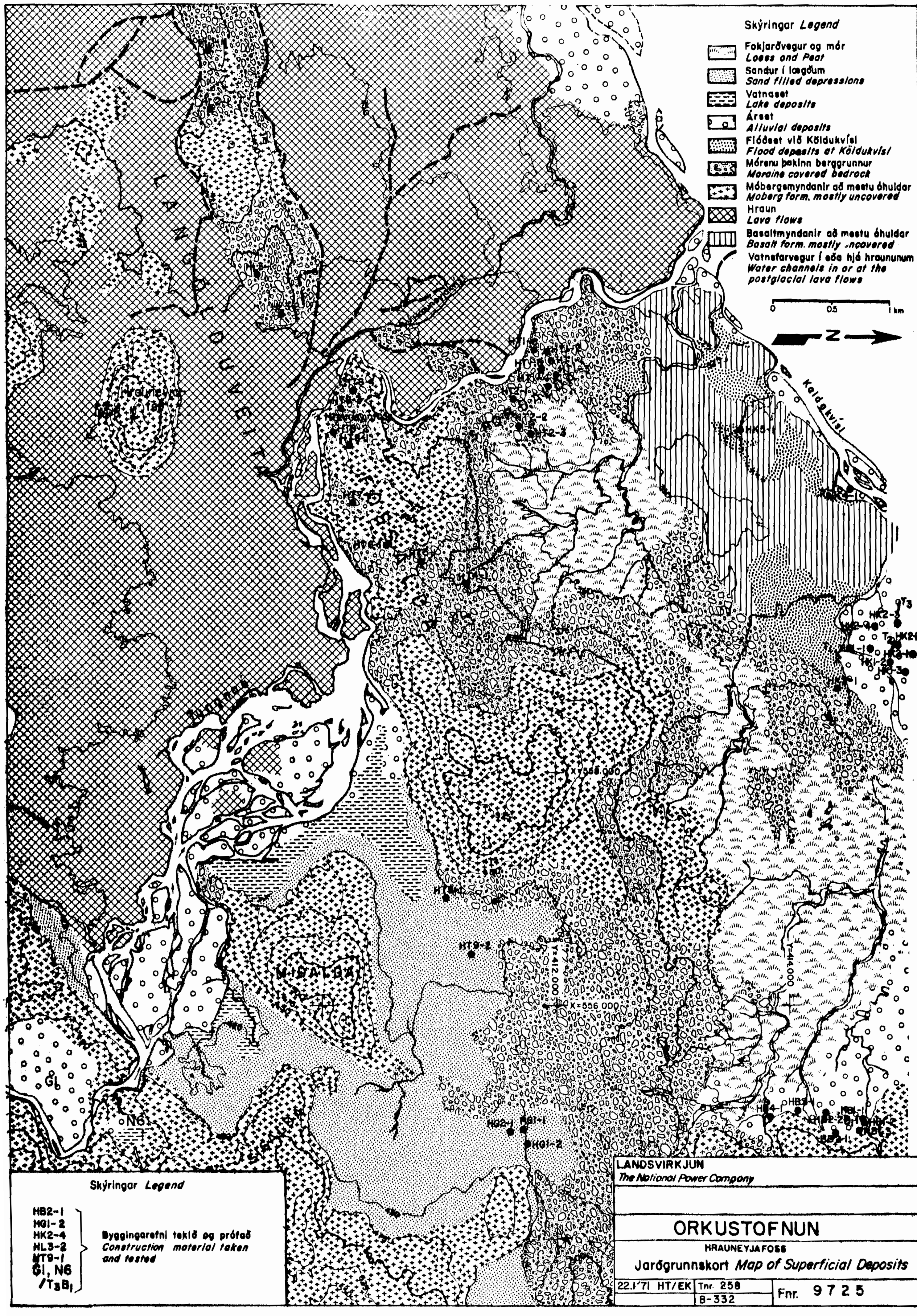
ORKUSTOFNUN

HRAUNEYJAFOSS
Jarðlagasnið I-I
Geological Section I-I

Febr. 1971 HT/Gyða	Tnr. 264	Fnr. 9731
Blað 5 af 5	B. 770	

Exh. 1.09


Skýringar Legend
Fokjarðvegur og mór
Loess and Peat
Sandur í lægðum
Sand filled depressions
Vatnaset
Lake deposits
Árset
Alluvial deposits
Flóðset við Köldukvísl
Flood deposits at Köldukvísl
Mórenu þakinn berggrunnur
Moraine covered bedrock
Móbergsmyndanir að mestu óhuldar
Moberg form. mostly uncovered
Hraun
Lava flows
Basaltmyndanir að mestu óhuldar
Basalt form. mostly uncovered
Vatnsfarvegur í eða hjá hraununum
Water channels in or at the postglacial lava flows
0
0.5
1 km
Z
Köldukvísl
Skýringar Legend
HB2-1
HG1-2
HK2-4
HL3-2
HT9-1
Gl, N6
/T3B1
Byggingarefni tekið og prófað
Construction material taken and tested
LANDSVIRKJUN
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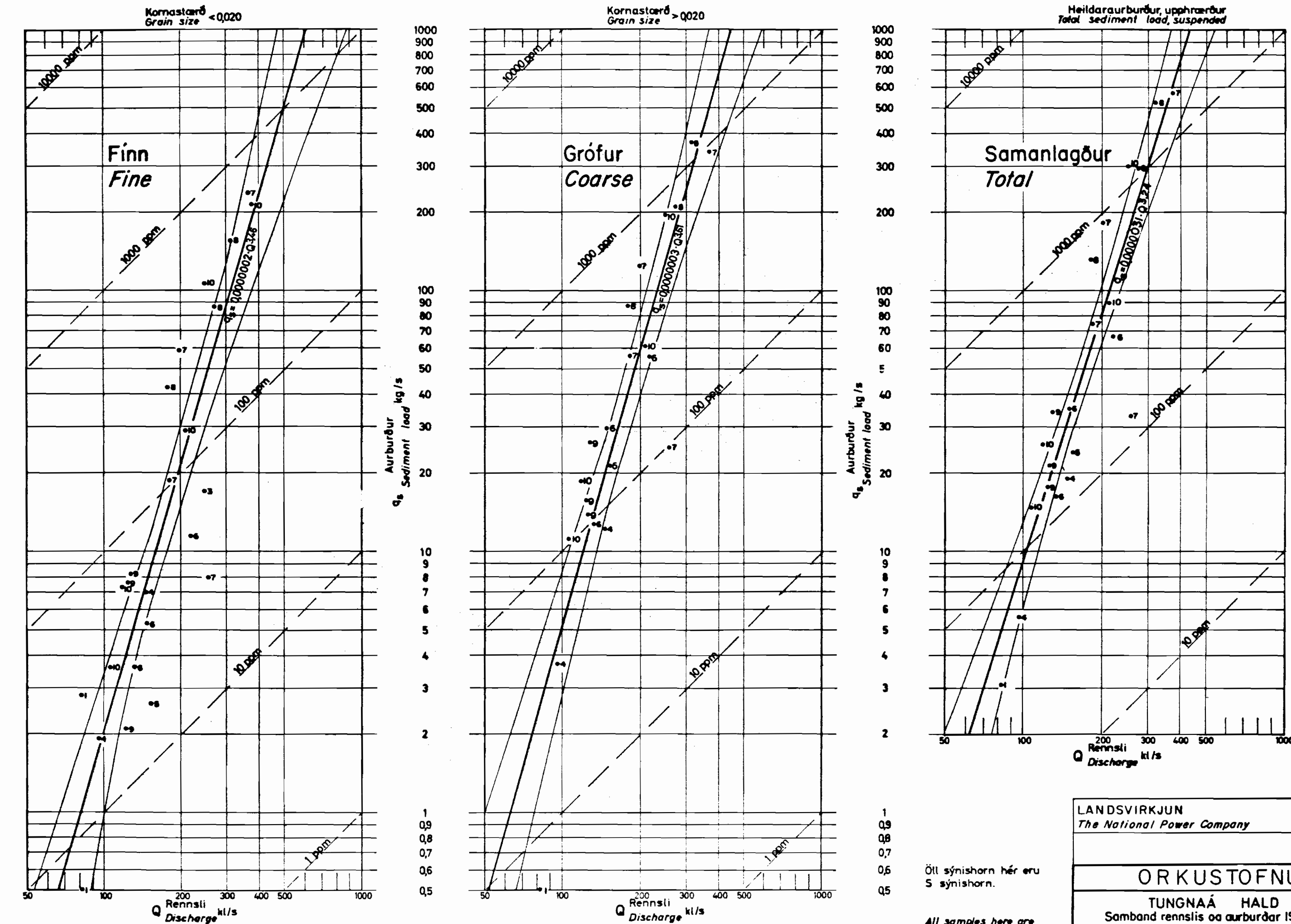
ORKUSTOFNUN
HRAUNEYJAFOSS
Jarðgrunnskort Map of Superficial Deposits
22.1.'71 HT/EK
Tnr. 258
B-332
Fnr. 9725

Exh. 2.01

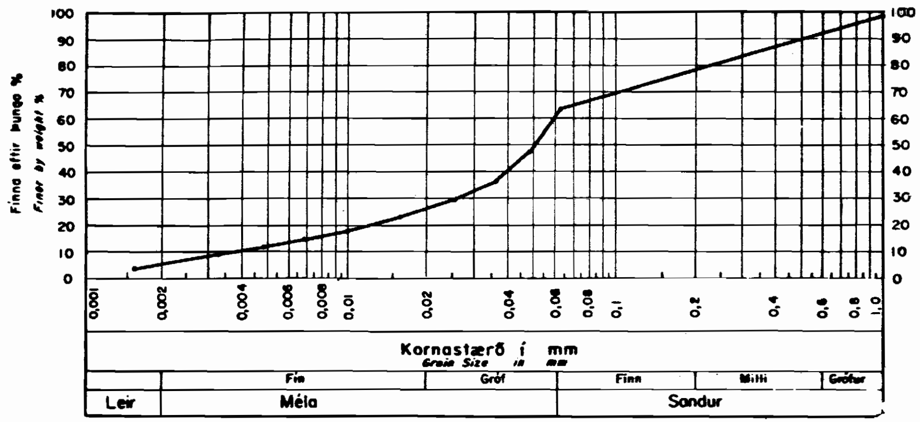


Öll sýnishorn hér eru S sýnishorn.

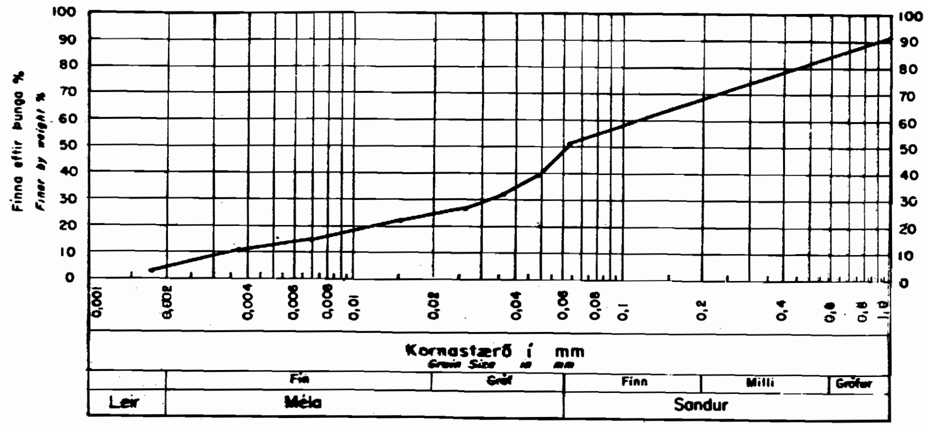
All samples here are S samples.

LANDSVIRKJUN *The National Power Company*	
ORKUSTOFNUN	
TUNGNAÁ HALD Samband rennslis og aurburðar 1962 — 65 *Correlation betw. discharge and sedim. load during 1962-65.*	
13.6.66 HT/HF | B-277	Fnr. 7489
Bl. 3 af 5 | Tnr. 591	

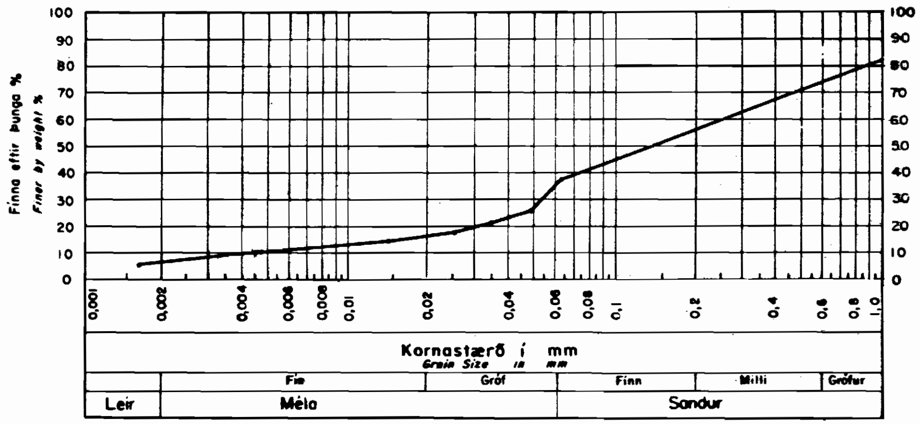
EXHIBIT NO. 2.02



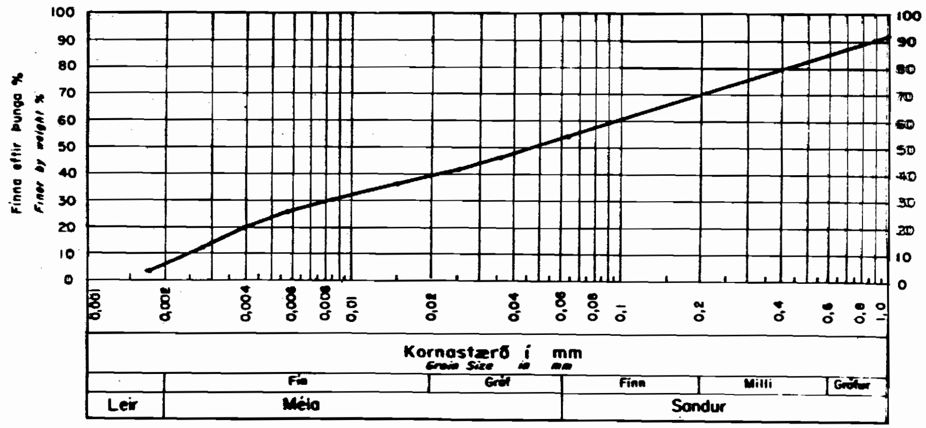
HAUST - *AUTUMN*



VOR - *SPRING*



VETUR - *WINTER*



SUMAR - *SUMMER*

Skýringar - *Legend*

Einkennandi kornakúrfur fyrir aurburð hverrar árstíðar

Representative grain size curves for the sediment load, each season

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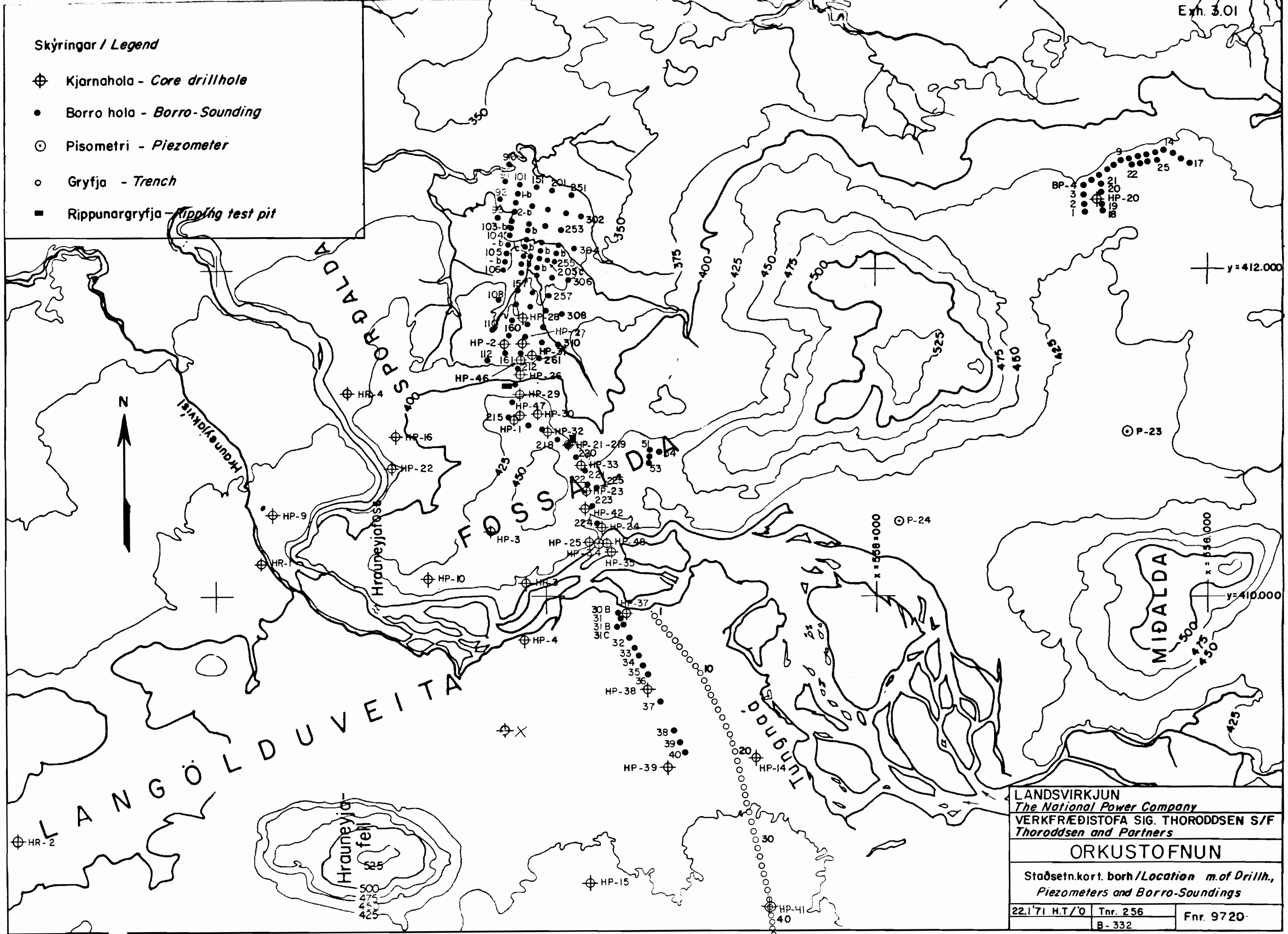
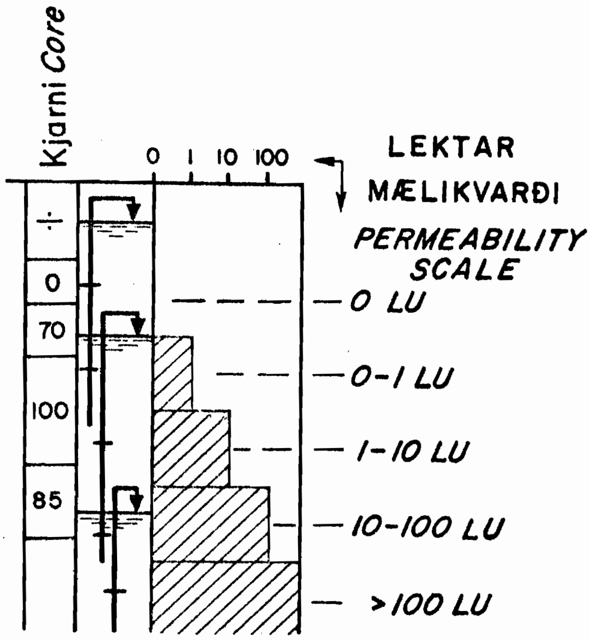
ORKUSTOFNUN
HRAUNEYJAFOSS,
EINKENNANDI KORNAKÚRFUR

20.1'70 H.T/O | Tnr. 255 | B-332 | Fnr. 9719


Exh. 3.01
Skýringar / Legend
Kjarnahola - Core drillhole
Borro hola - Borro-Sounding
Pisometri - Piezometer
Gryfja - Trench
Rippunargryfja - Ripping test pit
N
SPORÐALDA
FOSSALDA
LANGÖLDUVEITA
MIÐALDA
Hrauneyjafoss
Hraunaeyjakvísl
Tungnaá
Hrauneyjafell
y=412.000
y=410.000
x=558.000
x=556.000
LANDSVIRKJUN
The National Power Company
VERKFRÆÐISTOFA SIG. THORODDSEN S/F
Thoroddsen and Partners
ORKUSTOFNUN
Staðsetn.kort. borh/Location m.of Drillh.,
Piezometers and Borro-Soundings
22.1'71 H.T/'0
Tnr. 256
B-332
Fnr. 9720

MYND *Exh.*	0.00	ORKUSTOFNUN Raforkudeild KJARNA-, LEKTAR OG JARÐVATNSÚTSKÝRING *NOTE ON CORE PERMEABILITY AND GROUND WATER*	18/9'70 HT/EK Tnr. 204 B – Ým. Fnr. 9586



LEKTAR-OG JARÐVATNSÚTSKÝRING
NOTE ON PERMEABILITY AND GROUND WATER

Jarðvatnsborð er sýnt með örvum. Neðri endi örvarinnar og þverstrikin sýna holudýpið, þegar jarðvatnsborðið var mælt. Ef jarðvatn breytist ekkert í borun, nær örin í botn.
Ground water levels are shown by arrows. Base of the arrows and the horizontal bars indicate the hole depth when the water level was measured. If no change in level was observed during drilling, the arrow reaches the bottom of the hole.

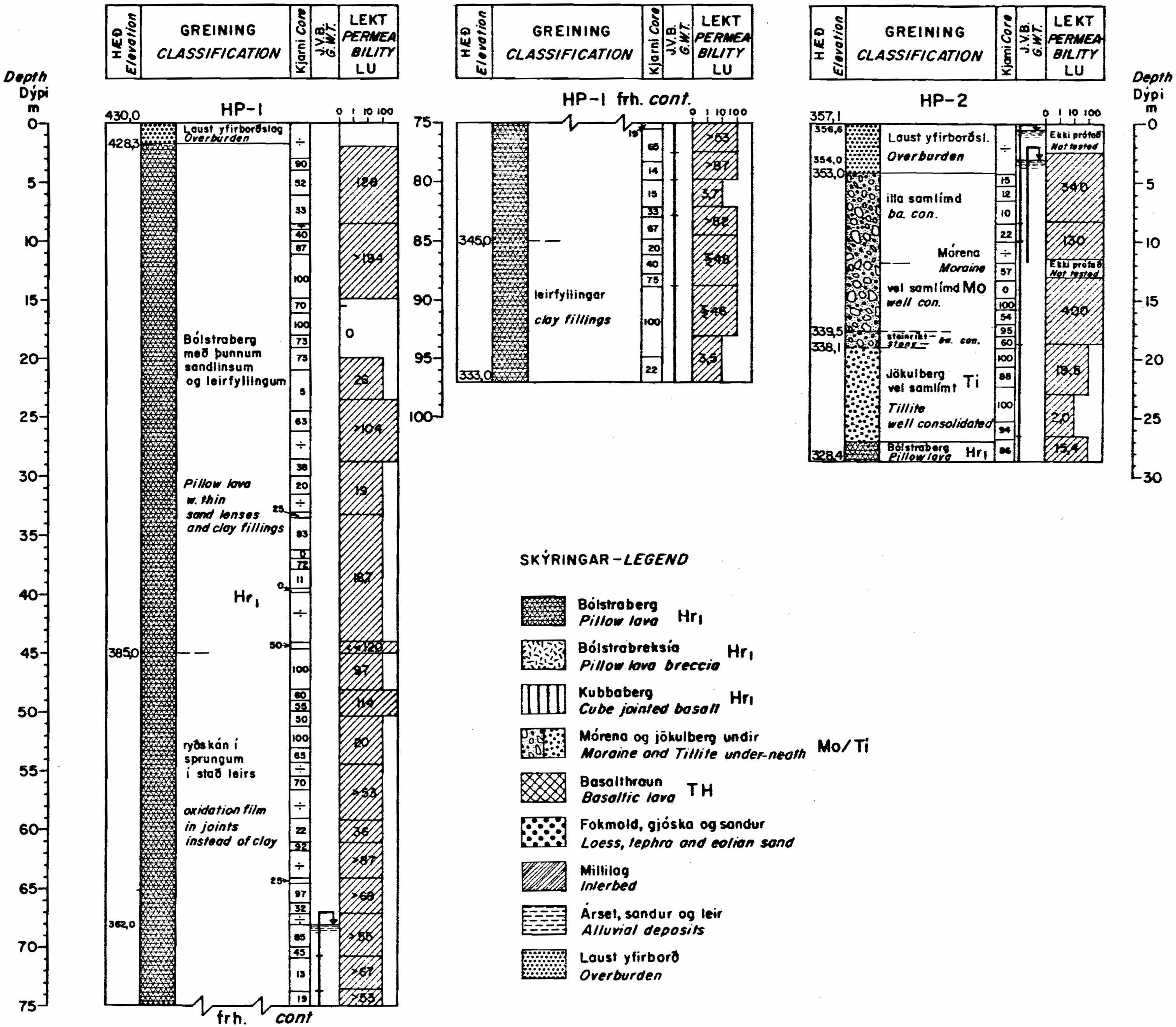
1 LU = Lugeon Unit = 1 l/mín/m í 76 mm Ø holu við þrýsting 10 kg/cm^2
1 LU = Lugeon Unit = 1 l/min/m in 76 mm Ø hole at pressure 10 kg/cm^2

Hæðartölur jarðvatns eru ritaðar smærra letri en hæðartölur bergs, á borholusniðum.
Figures for ground water levels are shown with smaller lettering on graphic core logs.

Kjarni: Tölur sýna kjarnaheimtur í %
÷ kjarnataka ekki reynd.

Core: Numbers indicate % core recovery
÷ core sampling not attempted.

Exh. 302



Skammstafanir
Abbreviations

all. = alluvial
ba. con. = badly consolidated
bret. = brecciated
co. = coarse
cu. j. = cube jointing
de. = dense
dol. = doleritic
eo = eolian
fragm. = fragments
ox. = oxidation
scor. = scorasious
ves. = vesicular
w. = with
bas. = basalt
br. = breccia
cl. = clay
cl. f. = clay fillings
int. = interbed
la. = lava
lo. = loess
mo. = moraine
pi. la. = pillow lava
pi. la. br. = pillow lava breccia
sa. = sand
sa. l. = sand lenses
te. = tephra
te. l. = tephra layers
ti. = tillite

Staðsetning sjá
Location see Exh. 3.01

Kjarna-lektar-og jarðvatnsútsk. sjá
Note on core, permeab. and ground water see Exh. 0.00

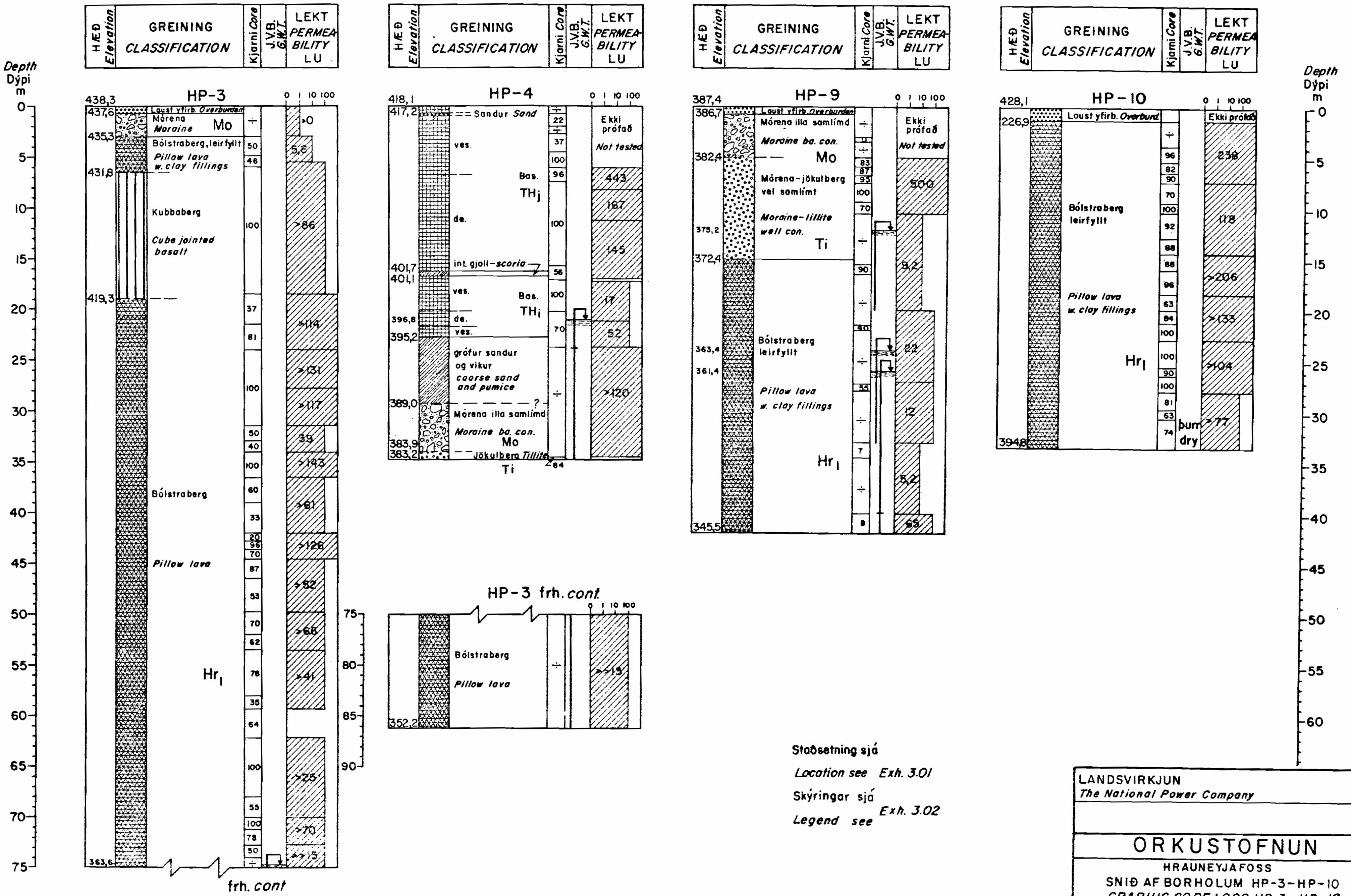
LANDSVIRKJUN
The National Power Company

ORKUSTOFNUN

HRAUNEYJAFOSS
SNIÐ AF BORHOLUM HP-1 OG HP-2
GRAPHIC CORE LOGS HP-1 AND HP-2

18.9.'70 BJ/IK/IS | B-332 | Fnr. 9563
Blað 1 af 6 | Tnr. 208

Exh. 3.03



Staðsetning sjá
Location see Exh. 3.01
Skýringar sjá
Legend see Exh. 3.02

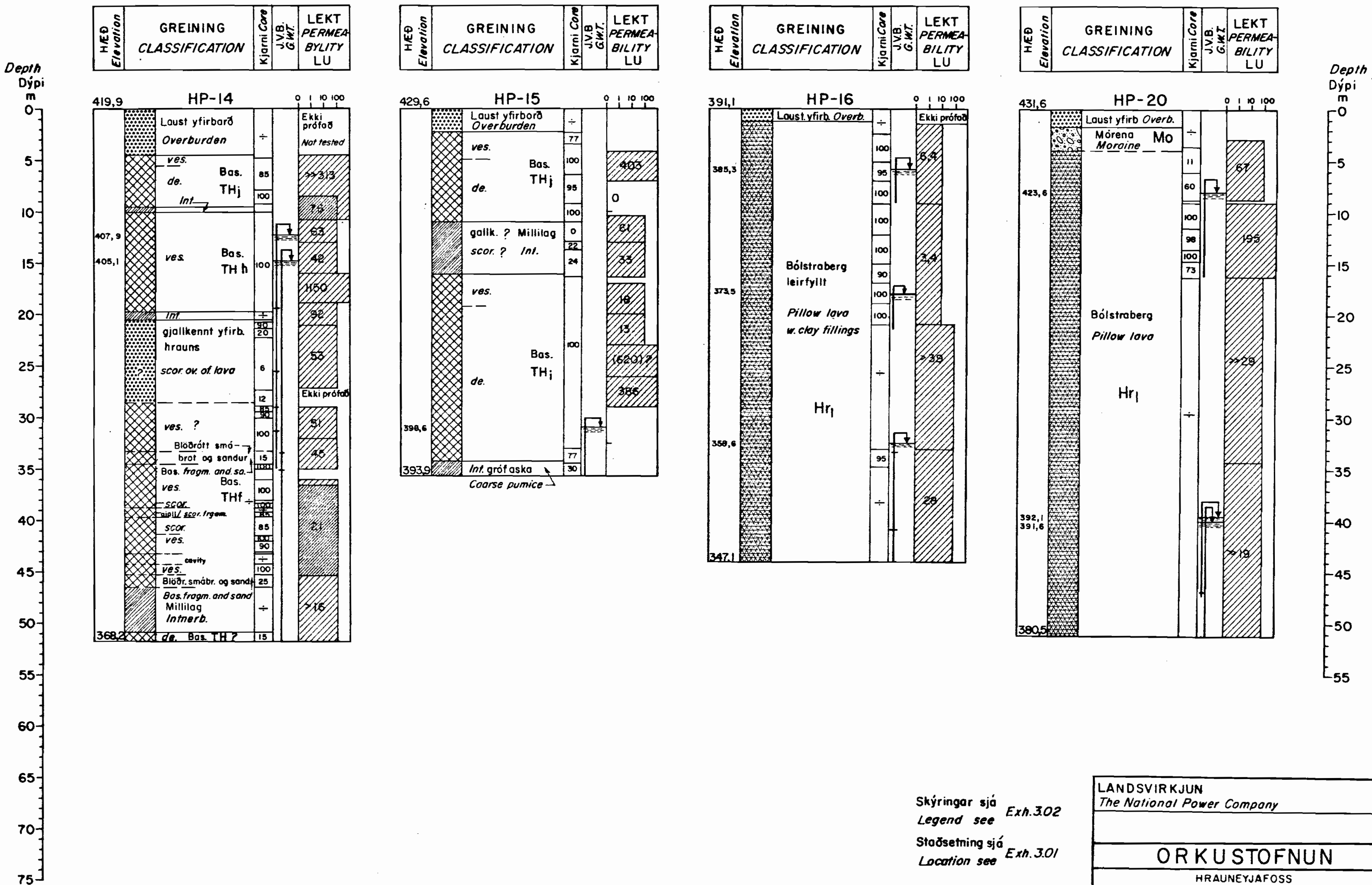
LANDSVIRKJUN
The National Power Company

ORKUSTOFNUN

HRAUNEYJAFOSS
SNIÐ AF BORHOLUM HP-3–HP-10
GRAPHIC CORE LOGS HP-3–HP-10

17.9.'70 BJ/LK/LS | B-332 | Fnr. 9576
Bl. 2 af 6 | Tnr. 214

Exh. 3.04



Skýringar sjá Exh. 3.02
Legend see

Staðsetning sjá Exh. 3.01
Location see

LANDSVIRKJUN
The National Power Company

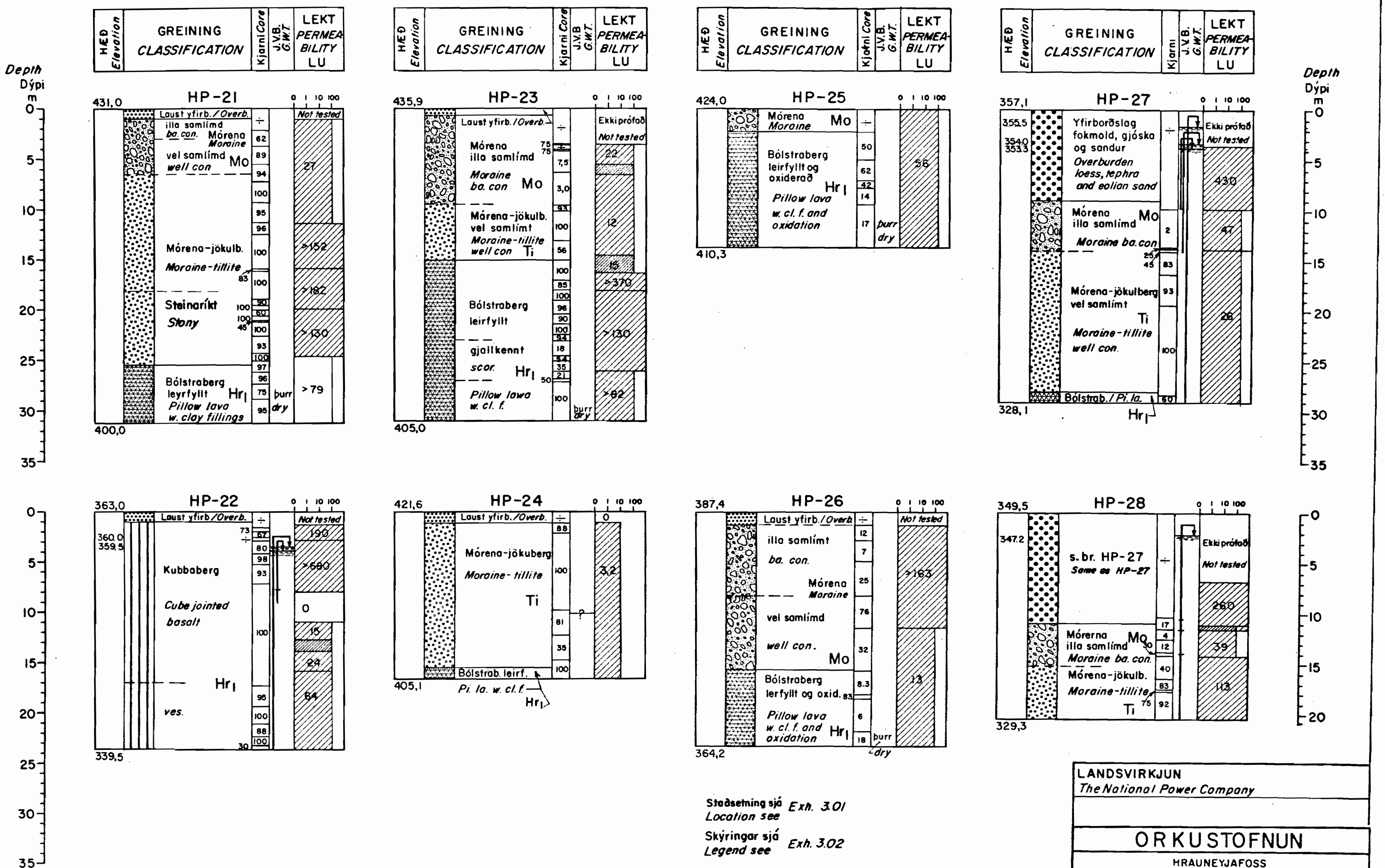
ORKUSTOFNUN

HRAUNEYJAFOSS

SNIÐ AF BORHOLUM HP-14—HP-20
GRAPHIC CORE LOGS HP-14—HP-20

4.1'71 P.I./I.S. B-332
Blað 3 af 6 Tnr. 275
Fnr. 9754

Exh. 3.05



Staðsetning sjá Exh. 3.01
Location see

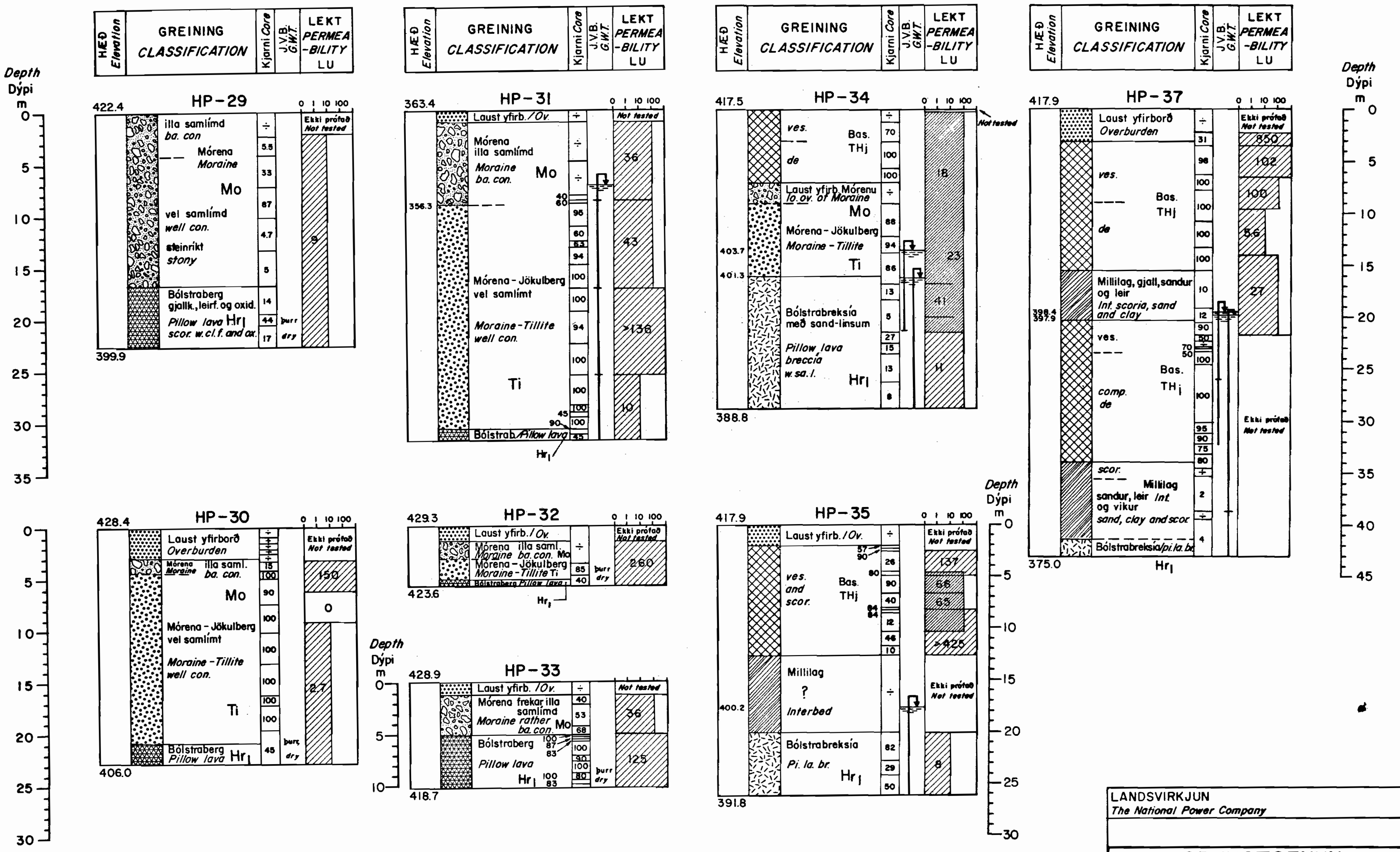
Skýringar sjá Exh. 3.02
Legend see

LANDSVIRKJUN
The National Power Company

ORKUSTOFNUN

HRAUNEYJAFOSS
SNIÐ AF BORHOLUM HP-21 – HP-28
GRAPHIC CORE LOGS HP-21 – HP-20

4.1.'71 P.I./I.S.	B-332 Tnr. 277	Fnr. 9755



Skýringar sjá Exh. 3.02
Legend see

Staðsetning sjá Exh. 3.01
Location see

LANDSVIRKJUN
The National Power Company

ORKUSTOFNUN

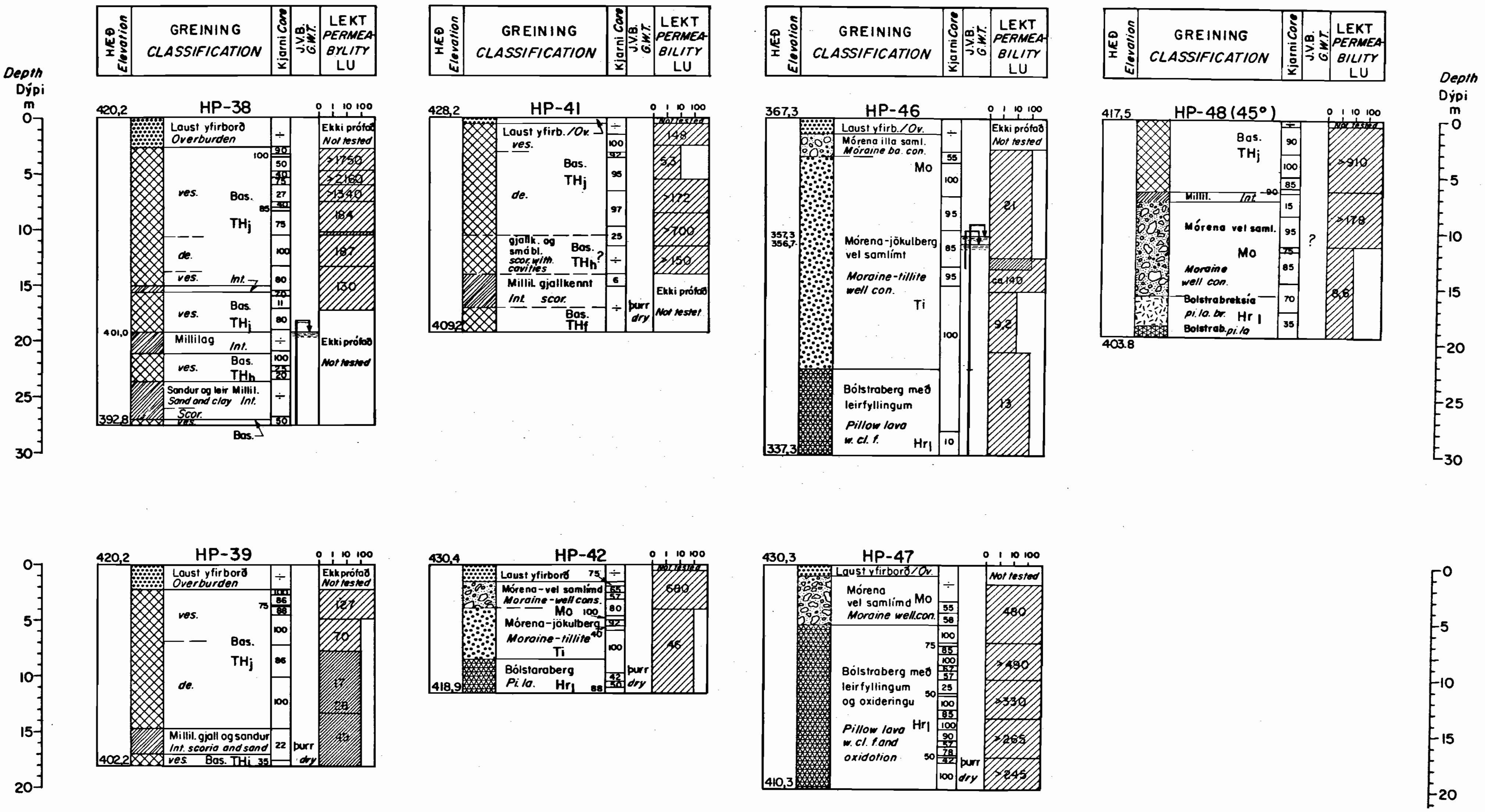
HRAUNEYJAFOSS

SNIÐ AF BORHOLUM HP-29 – HP-37

GRAPHIC CORE LOGS HP-29 – HP-37

Febr. 1971 HT/Gyða | Tnr. 277 | B-332 | Fnr. 9756

Exh. 3.07



Skýringar sjá Exh. 3.02
Legend see

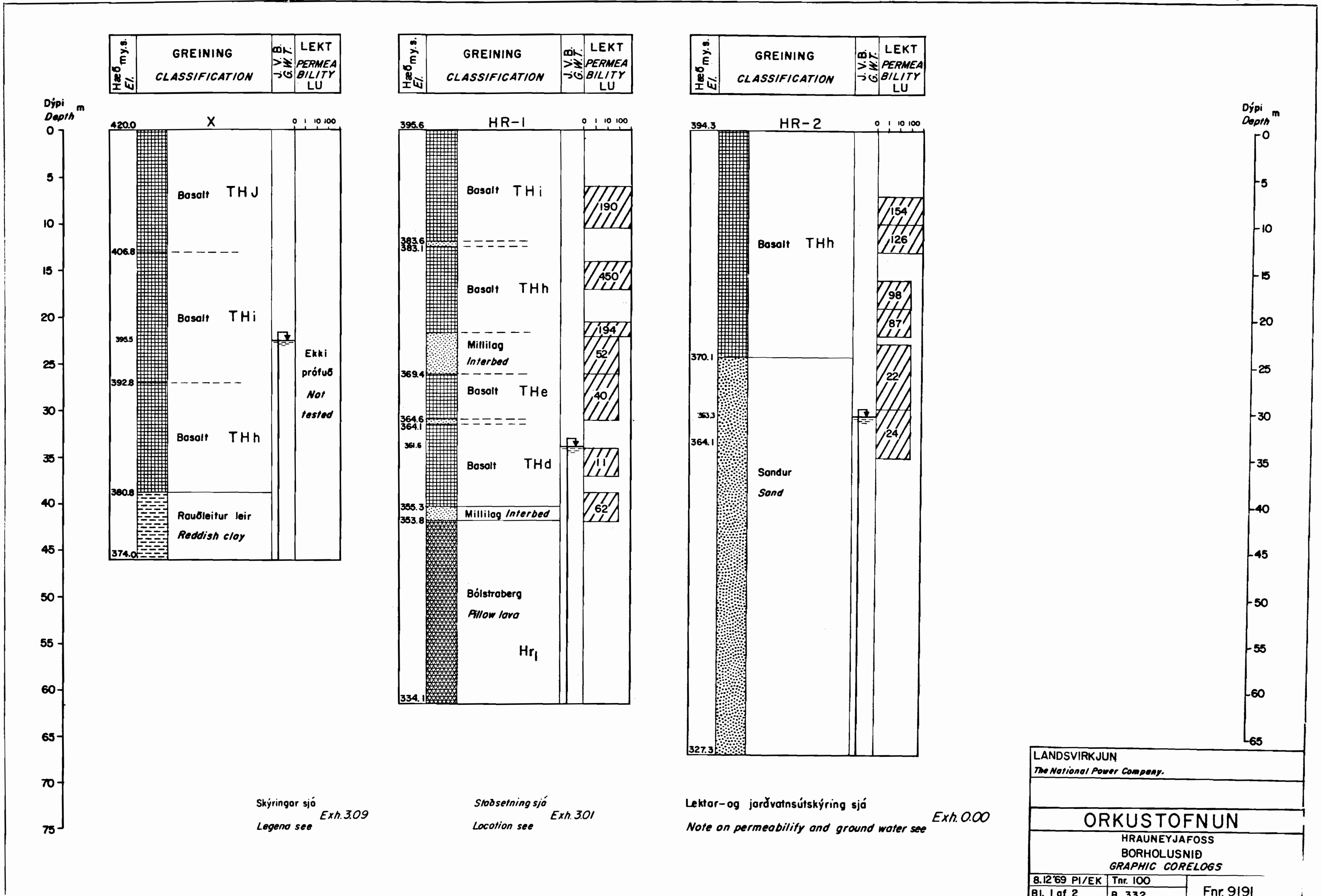
Staðsetning sjá Exh. 3.01
Location see

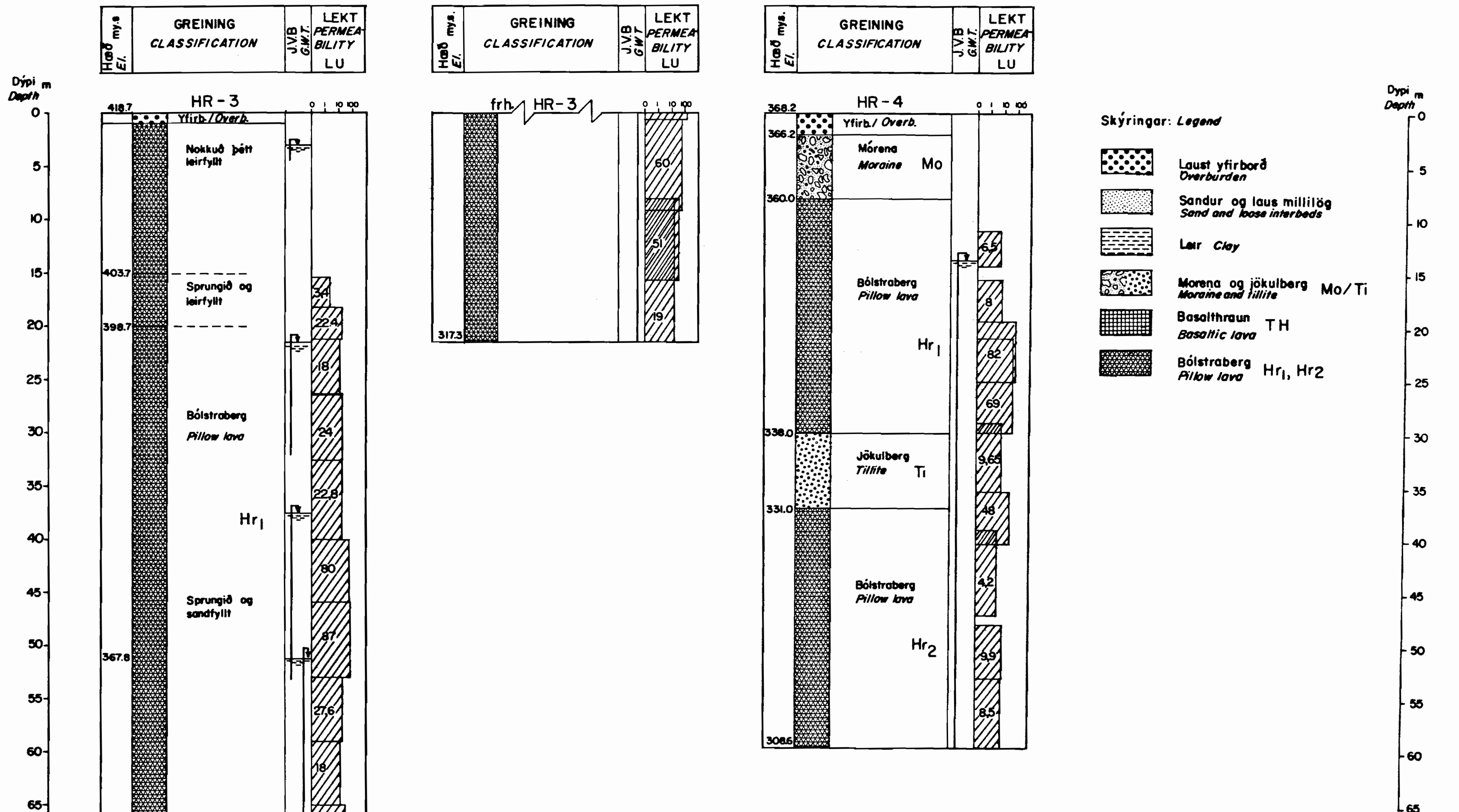
LANDSVIRKJUN
The National Power Company

ORKUSTOFNUN

HRAUNEYJAFOSS
SNIÐ AF BORHOLUM HP-38–HP-48
GRAPHIC CORE LOGS HP-38–HP-48

8.1'71 P.I./I.S.	B-332	Fnr. 9757
Blað 6 af 6	Tnr. 278	


Hæð m.y.s. El.
GREINING CLASSIFICATION
J.V.B. G.W.T.
LEKT PERMEABILITY LU
Dýpi Depth m
X
420.0
406.8
395.5
392.8
380.8
374.0
Basalt THJ
Basalt THi
Basalt THh
Rauðleitur leir Reddish clay
Ekki prófuð Not tested
HR-1
395.6
383.6
383.1
369.4
364.6
364.1
361.6
355.3
353.8
334.1
Basalt THi
Basalt THh
Millilag Interbed
Basalt THe
Basalt THd
Millilag Interbed
Bólstraberg Pillow lava
Hr1
190
450
194
52
40
11
62
HR-2
394.3
370.1
363.3
364.1
327.3
Basalt THh
Sandur Sand
154
126
98
87
22
24
Skýringar sjá Legend see Exh. 3.09
Staðsetning sjá Location see Exh. 3.01
Lektar-og jarðvatnsútskýring sjá Note on permeability and ground water see Exh. 0.00
LANDSVIRKJUN
The National Power Company.
ORKUSTOFNUN
HRAUNEYJAFOSS
BORHOLUSNIÐ
GRAPHIC CORELOGS
8.12'69 PI/EK
Tnr. 100
Bl. 1 af 2
B 332
Fnr. 9191



Lektar—og jarðvatnsútskýring sjá Exh. 0.00
Note on permeability and ground water see

Staðsetning sjá Exh.301
Location see

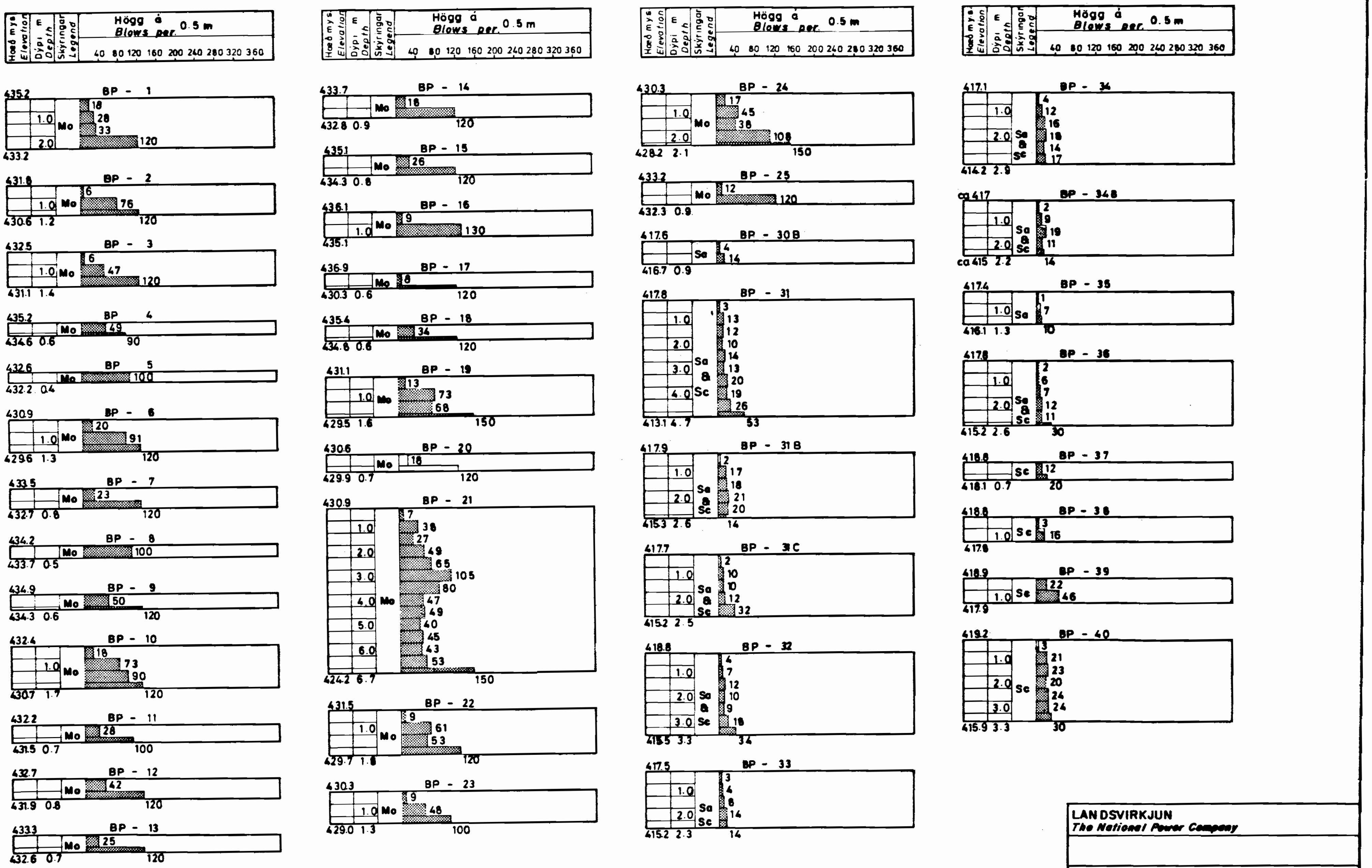
LANDSVIRKJUN
The National Power Company

ORKUSTOFNUN

HRAUNEYJAFOSS
BORHOLUSNIÐ
GRAPHIC CORELOGS

10.12.'69 Pl/S.	Tnr. 101	Fnr. 9192
Bl. 2 af 2	B-332	

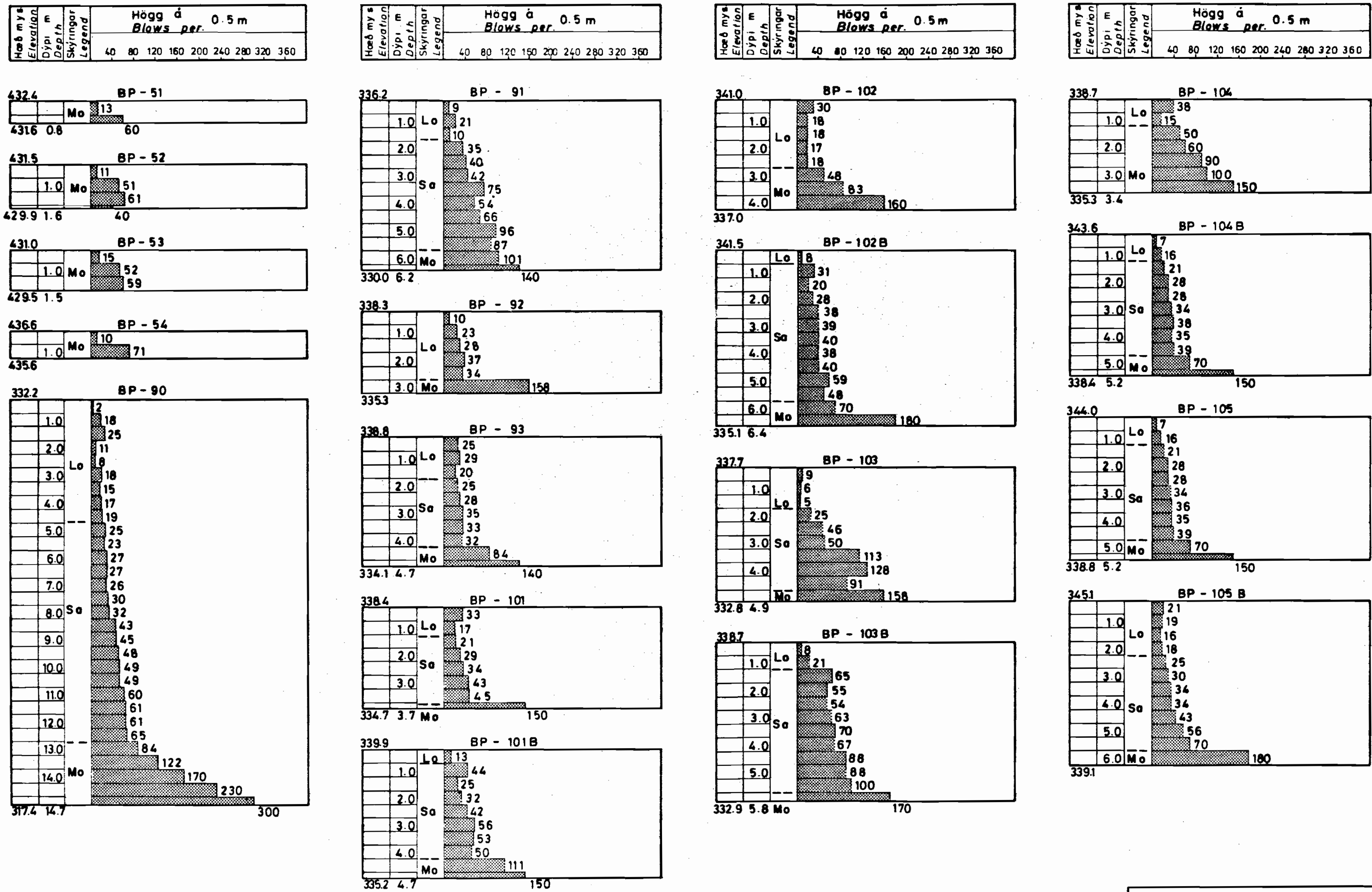
Exh. 3.10



Skýringar sjá *Legend see* Exh. 3.13

Staðsetning sjá *Location see* Exh. 3.01

LANDSVIRKJUN *The National Power Company*		
ORKUSTOFNUN		
HRAUNEYJAFOSS Borro-borholur *Borro-Soundings* BP-1-40		
14.1.'71	B-332	Fnr. 9741
Bl. 1 af 6	Tnr. 267	

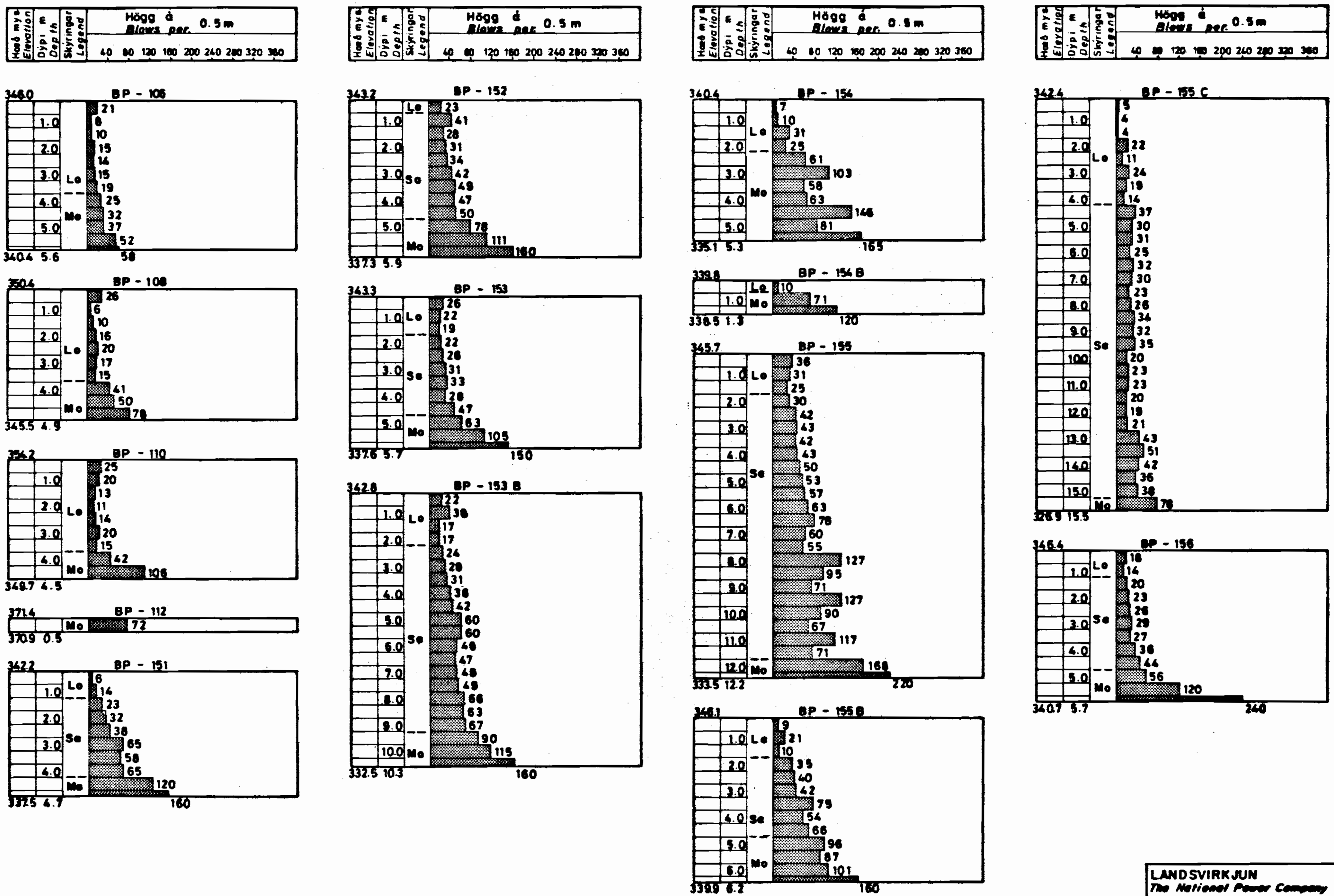


Skýringar sjá *Legend see* Exh. 3.13

Staðsetning sjá *Location see* Exh. 3.01

LANDSVIRKJUN ***The National Power Company***		
ORKUSTOFNUN		
HRAUNEYJAFOSS Borro-borholur *Borro-Soundings* BP 51-105B		
14.1'71	B-332	F.nr. 9742

Exh. 3.12



Skýringar sjá *Legend see* Exh. 3.13

Staðsetning sjá *Location see* Exh. 3.01

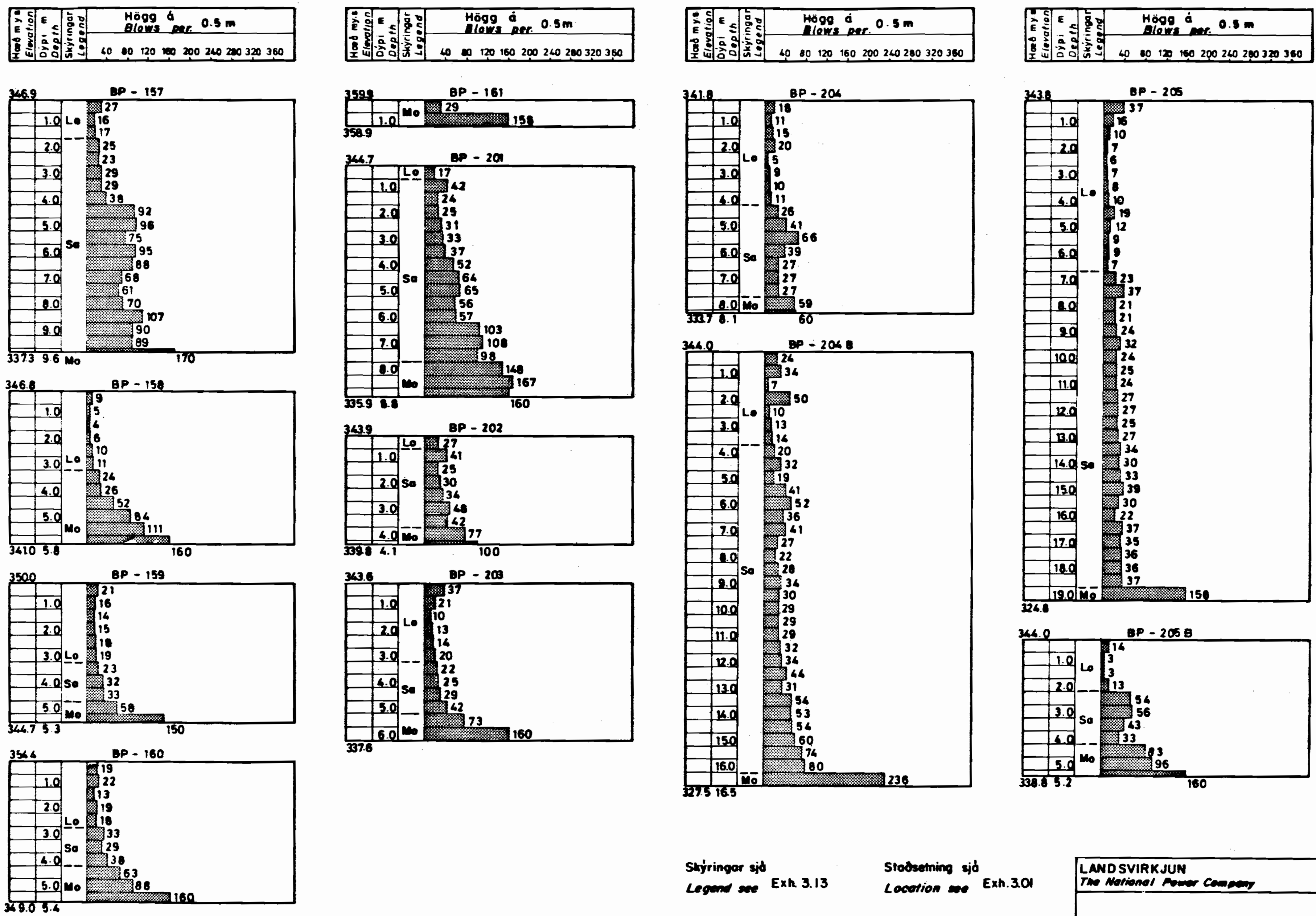
LANDSVIRKJUN
The National Power Company

ORKUSTOFNUN

HRAUNEYJAFOSS
Borro-borholur BP 106-156
Borro-Soundings

18.1'71	B-332	Fnr. 9743
Bl. 3 af 6	Tnr. 271	

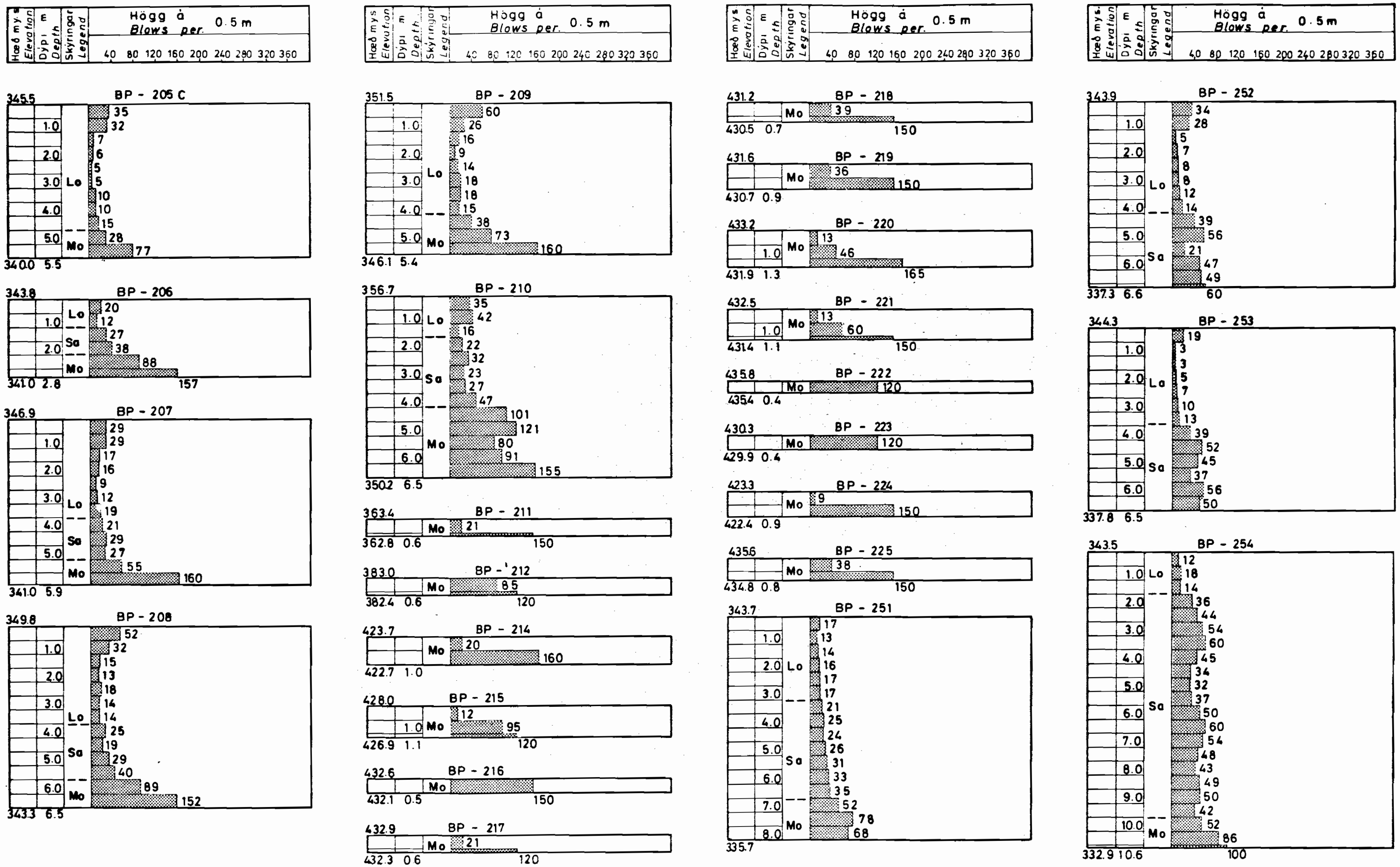
Exh. 3.13



Skýringar sjá
Legend see Exh. 3.13

Staðsetning sjá
Location see Exh. 3.01

LANDSVIRKJUN *The National Power Company*		
ORKUSTOFNUN		
HRAUNEYJAFOSS Borro-borholur *Borro - Soundings* BP 157-205 B		
18.1.'71	B-332	Fnr. 9744
Bl. 4 af 6	Tnr. 27.2	



Skýringar sjá *Legend see* Exh. 3.13

Staðsetning sjá *Location see* Exh. 3.01

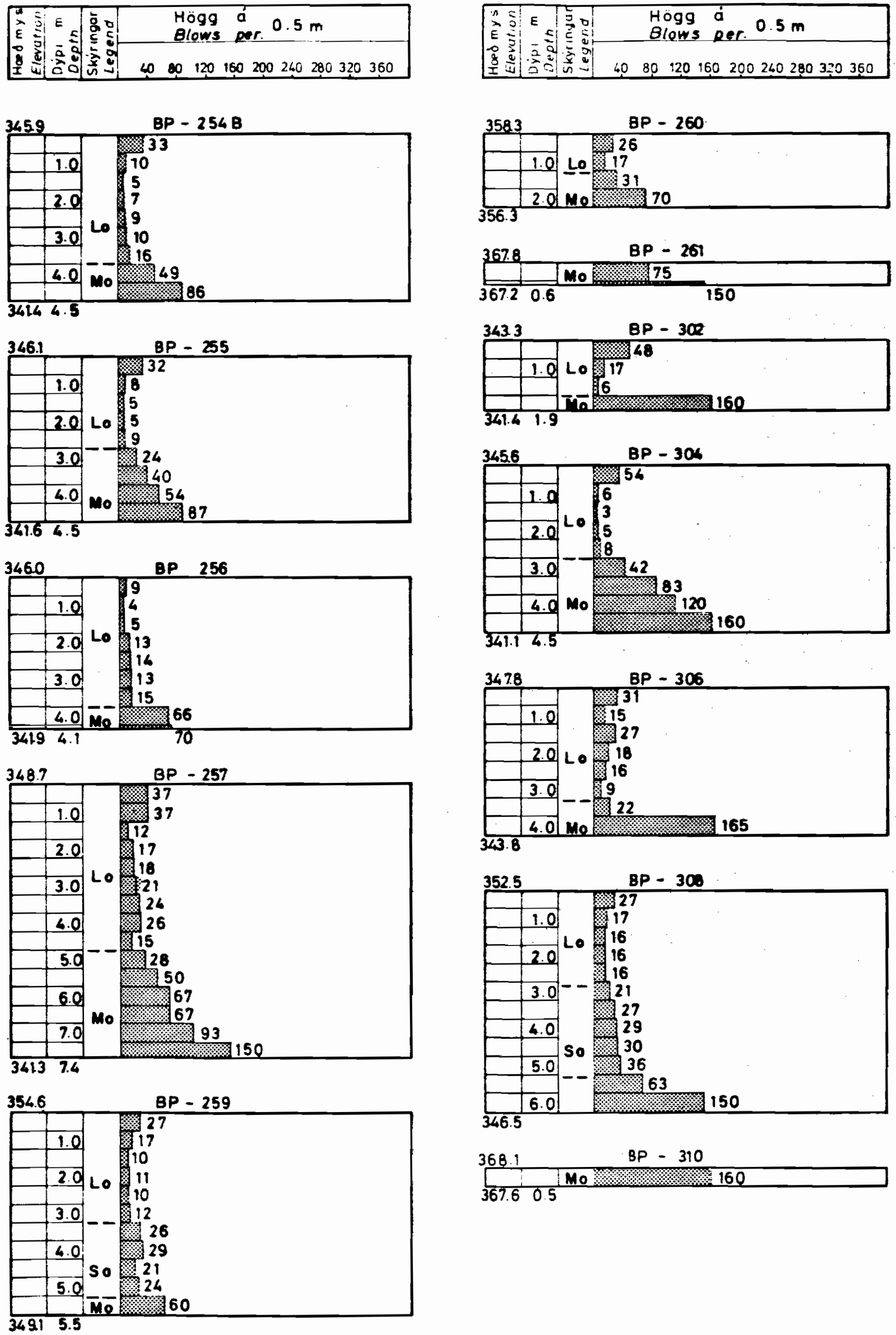
LANDSVIRKJUN
The National Power Company

ORKUSTOFNUN

HRAUNEYJAFOSS
Borro-borholur BP 205-254
Borro - Soundings

14.1'71	B-332	Fnr. 9745
Bl. 5 af 6	Tnr. 273	

Exh. 3.15



Skýringar / *Legend*

Mo	Mórena og jökulberg	*Moraine and tillite*
Sa	Sandur	*Sand*
Sc	Gjall	*Scoria*
Lo	Fokmold og mór	*Loess and peat*

Þvermál stanga *Rod diameter*	32 mm
Þyngd lóðs *Hammer weight*	65 kg
Fall lóðs *Hammer drop*	1 m

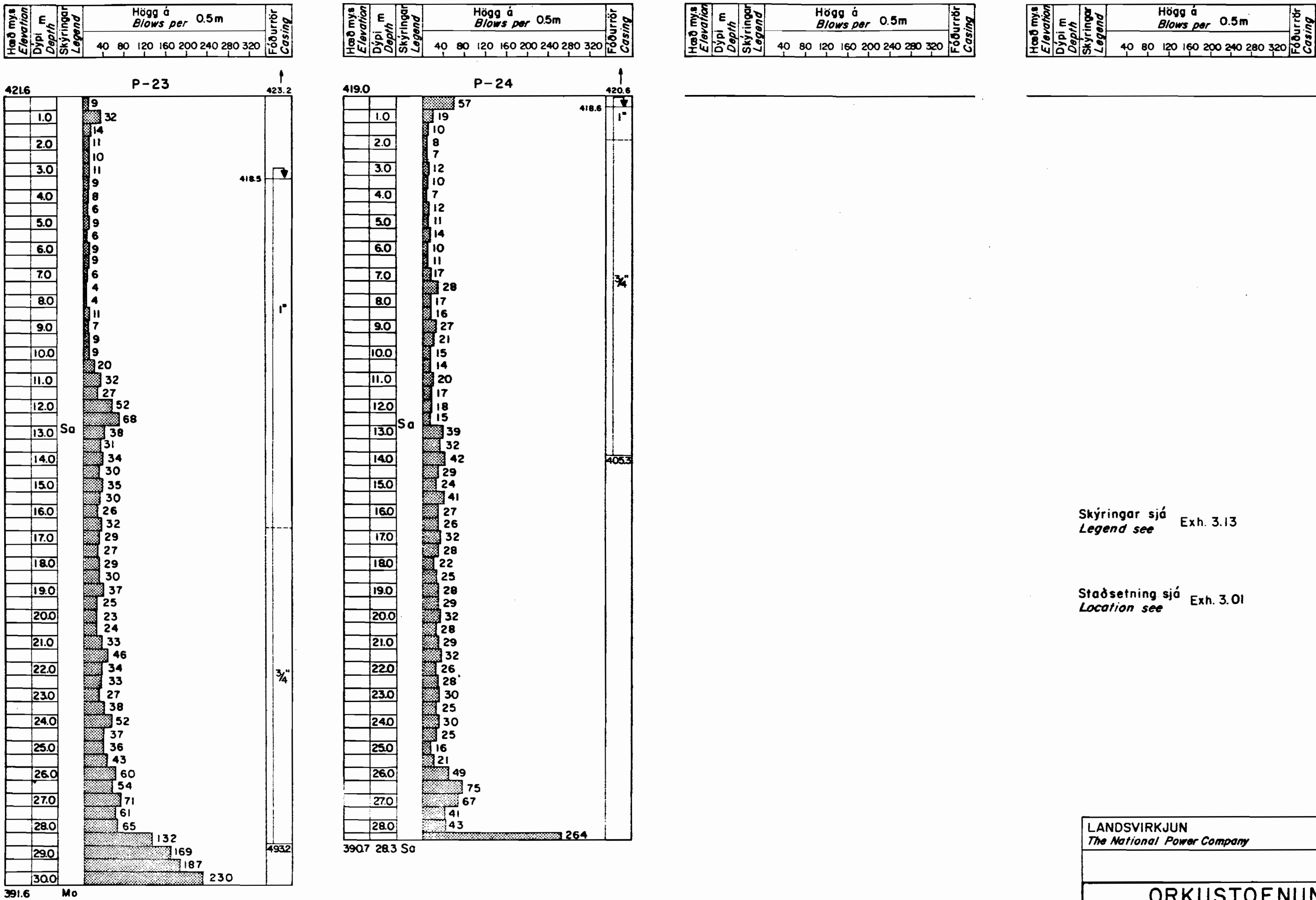
Staðsetning sjá *Location see* Exh. 3.01

LANDSVIRKJUN
The National Power Company

ORKUSTOFNUN

HRAUNEYJAFOSS
Borro-borholur *Borro - Soundings* BP 254 C - 310

14.1'71 | B - 332 | Fnr. 9746



Skýringar sjá *Legend see* Exh. 3.13

Staðsetning sjá *Location see* Exh. 3.01

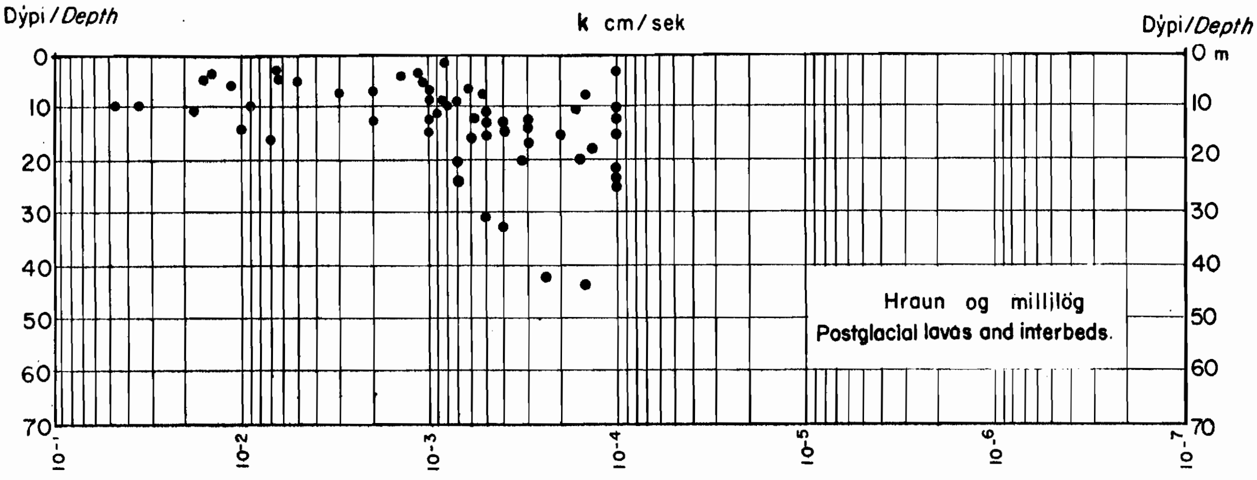
LANDSVIRKJUN
The National Power Company

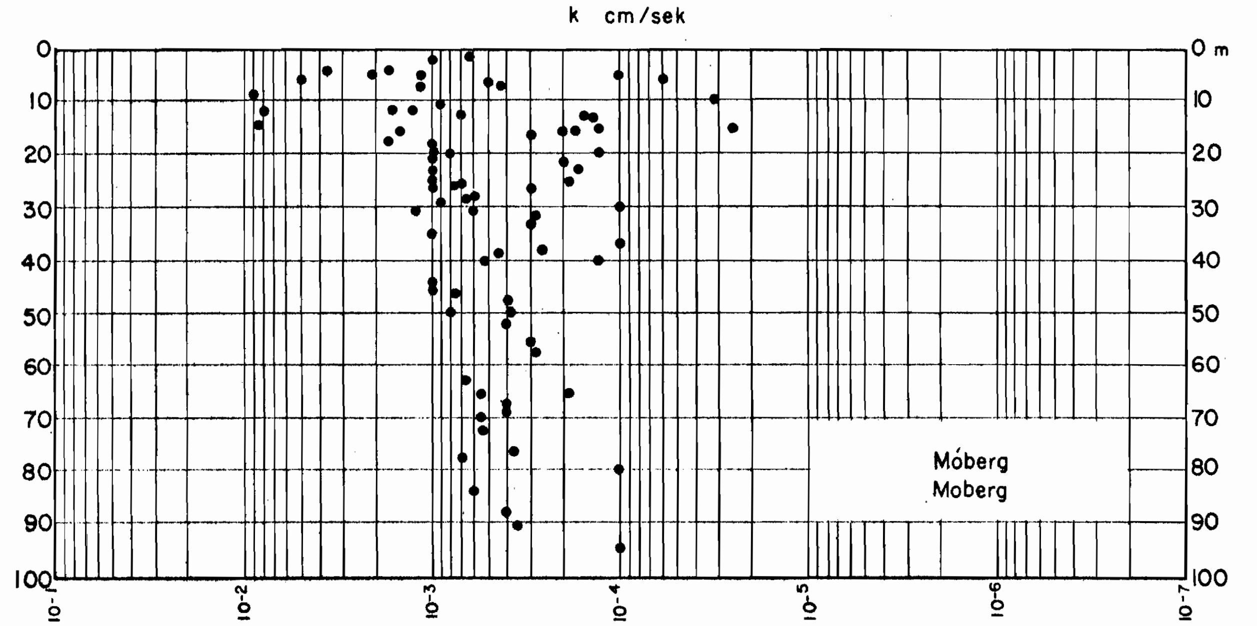
ORKUSTOFNUN

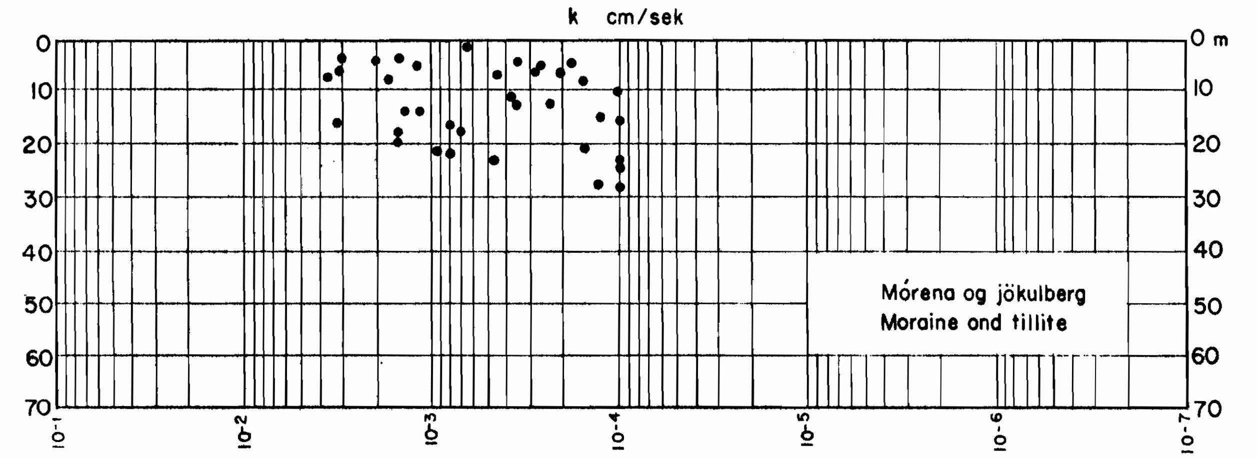
HRAUNEYJAFOSS 1970
Písómetrar P-23 og P-24
Piezometers P-23 and P-24

3.9.70 BJ/IK/Gyða | Tnr. 208 | B-332 | Fnr. 9555

Exh. 3.17







Skýringar / *Legend*

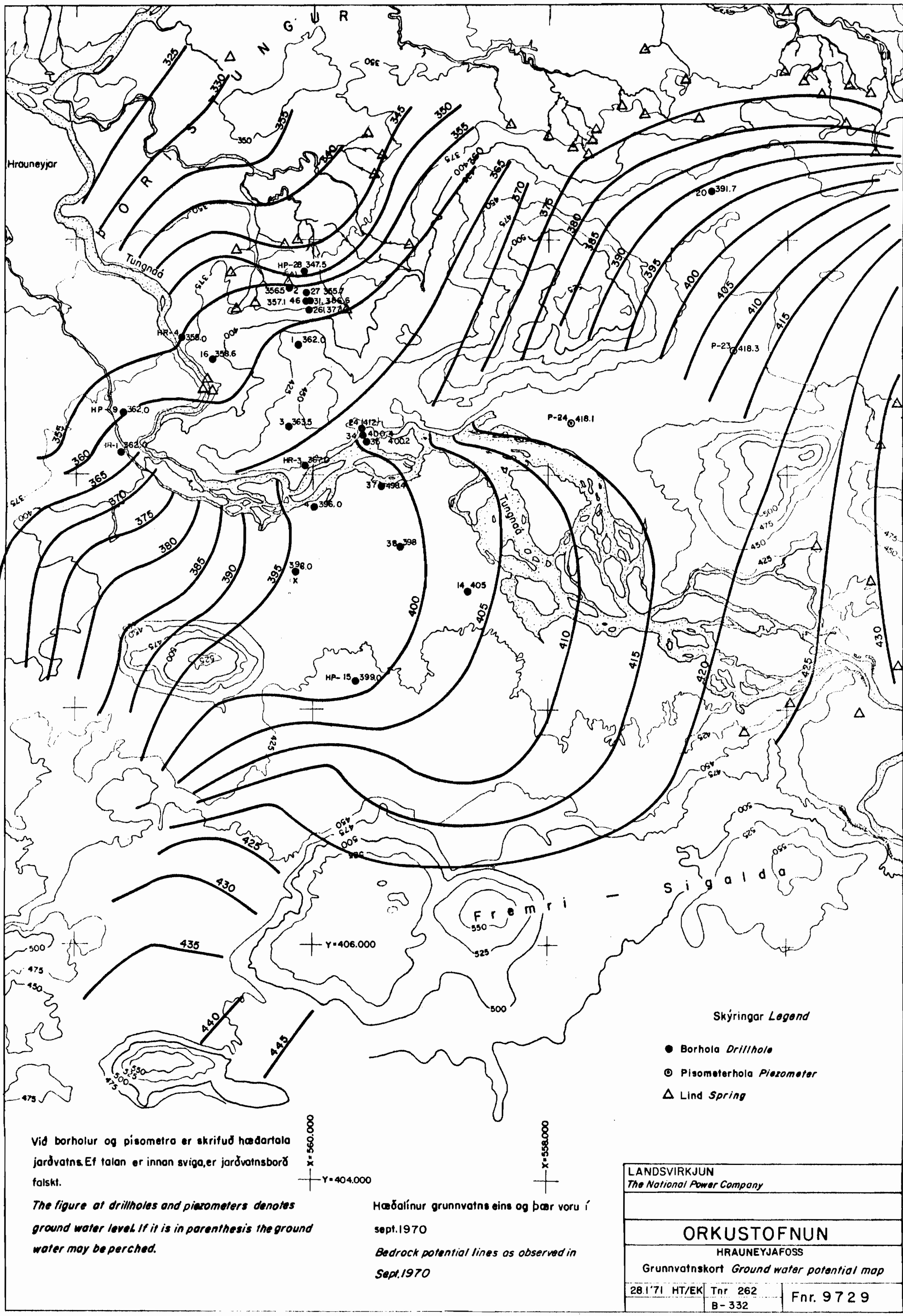
Lektarstuðlar eftir dýpi skv. lektarprófunum

Coeficients of permeability with depth according to permeability tests.

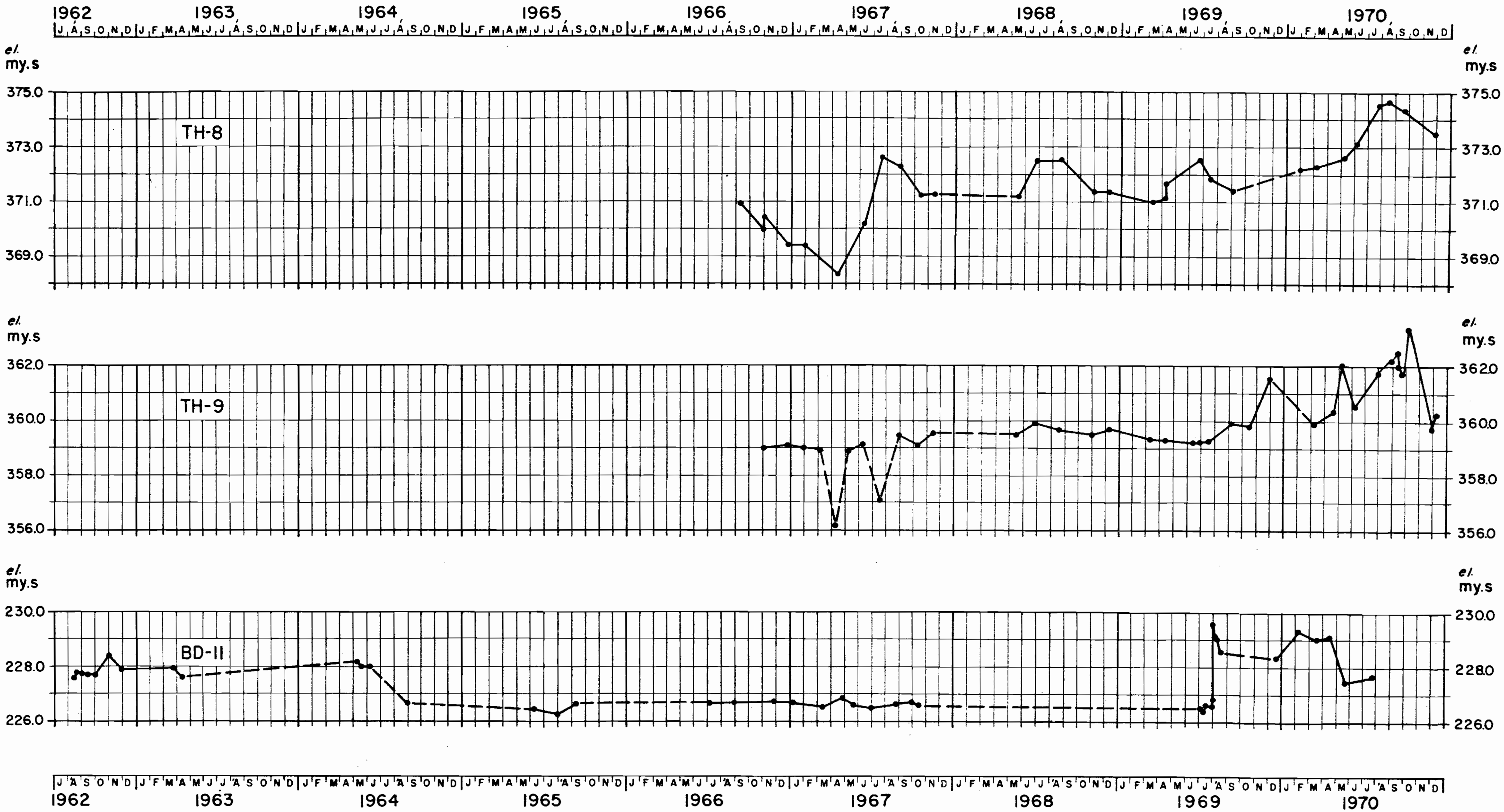
Hver punktur táknar eina lektarprófun

• *Each dot represents one permeability test.*

LANDSVIRKJUN *The National Power Company*	
ORKUSTOFNUN	
HRAUNEYJAFOSS LEKTARSTUÐLAR. *COEFICIENTS OF PERMEABILITY*	
28 I '71 H.T/O Tnr. 261 B-332	Fnr. 9728


Þ O R I S T U N G U R
Hrauneyjar
Tungnaá
Fremri – Sigalda
Y=406.000
Skýringar Legend
Borhola Drillhole
Pisometerhola Piezometer
Lind Spring
Við borholur og písometra er skrifuð hæðartala jarðvatns. Ef talan er innan sviga, er jarðvatnsborð falskt.
The figure at drillholes and piezometers denotes ground water level. If it is in parenthesis the ground water may be perched.
X=560.000
Y=404.000
X=558.000
Hæðalínur grunnvatns eins og þær voru í sept. 1970
Bedrock potential lines as observed in Sept. 1970
LANDSVIRKJUN
The National Power Company
ORKUSTOFNUN
HRAUNEYJAFOSS
Grunnvatnskort Ground water potential map
28.1.'71 HT/EK
Tnr 262
B-332
Fnr. 9729

Exh. 3.19



Staðseting hnit / *Location coordinates*

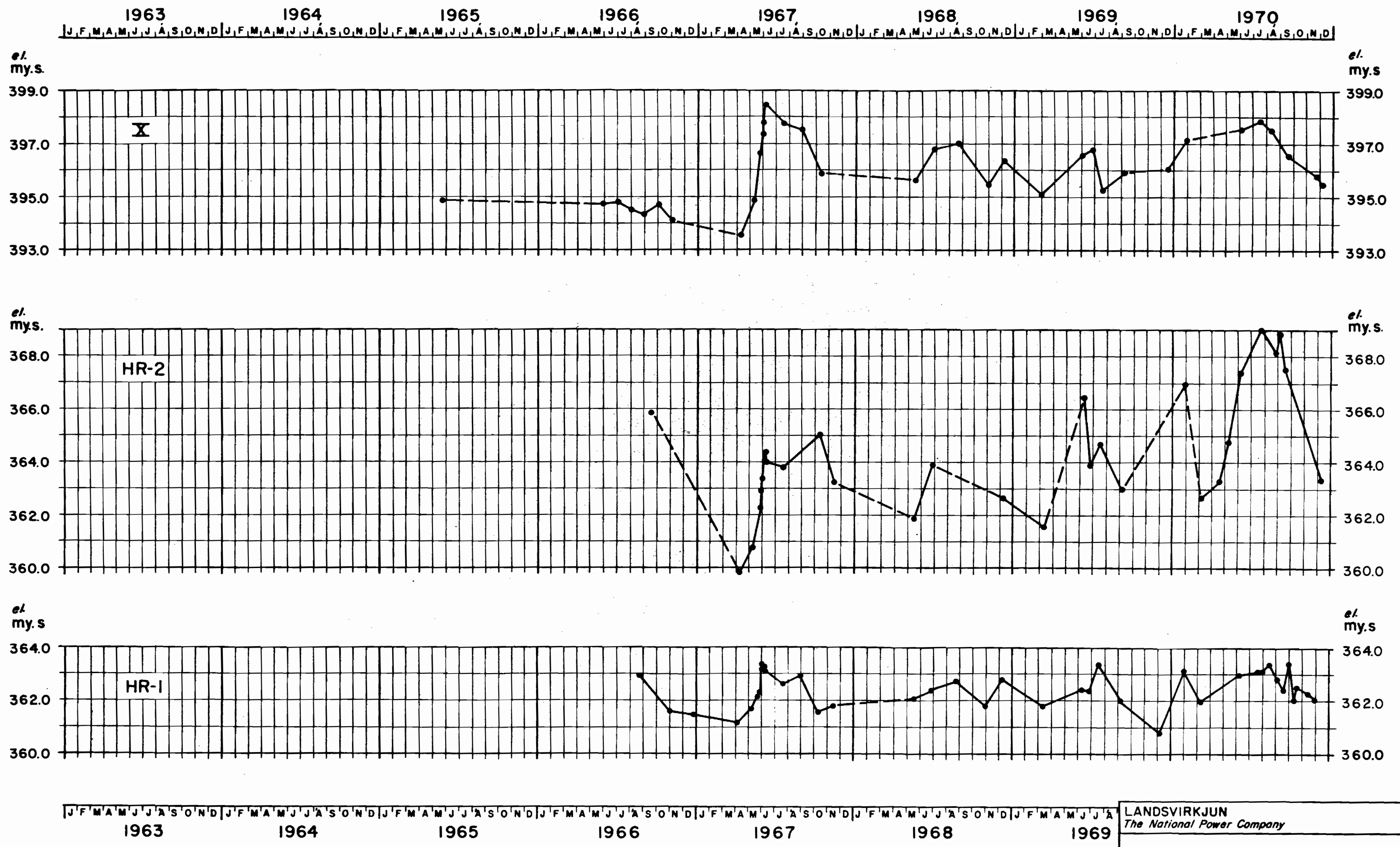
	X	Y
TH-8	568.152	405.615
TH-9	564.307	406.988
BD-11	(585.175)	(402.428)

LANDSVIRKJUN
The National Power Company

ORKUSTOFNUN
HRAUNEYJAFOSS
Jarðvatnsmælingar í borholum
Groundwater measurments in drillholes

19.1.1971 PI/Gyða | Tnr. 3 | B-Grunnvatn | Fnr. 9643

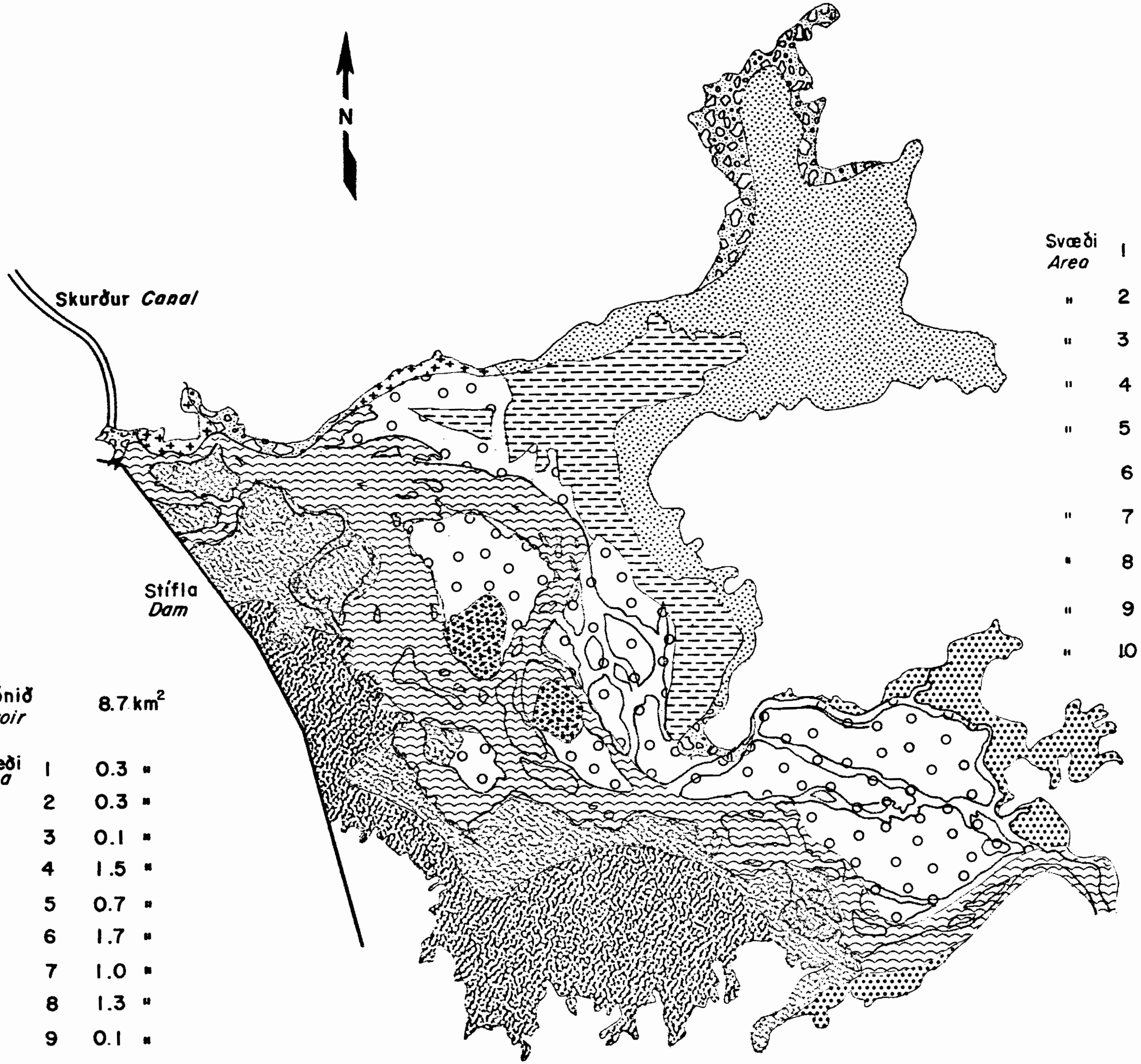
Exh. 3.20



Staðsetning borhola sjá
Location of drillholes see Exh. 3.01

LANDSVIRKJUN *The National Power Company*	
ORKUSTOFNUN	
HRAUNEYJAFOSS Jarðvatnsmælingar í borholum *Groundwater measurments in drillholes*	
19.I.'71 PI/Gyða	Tnr. 3 B-Grunnvatn	Fnr. 9643

Exh. 3.21



Skýringar *Legend*

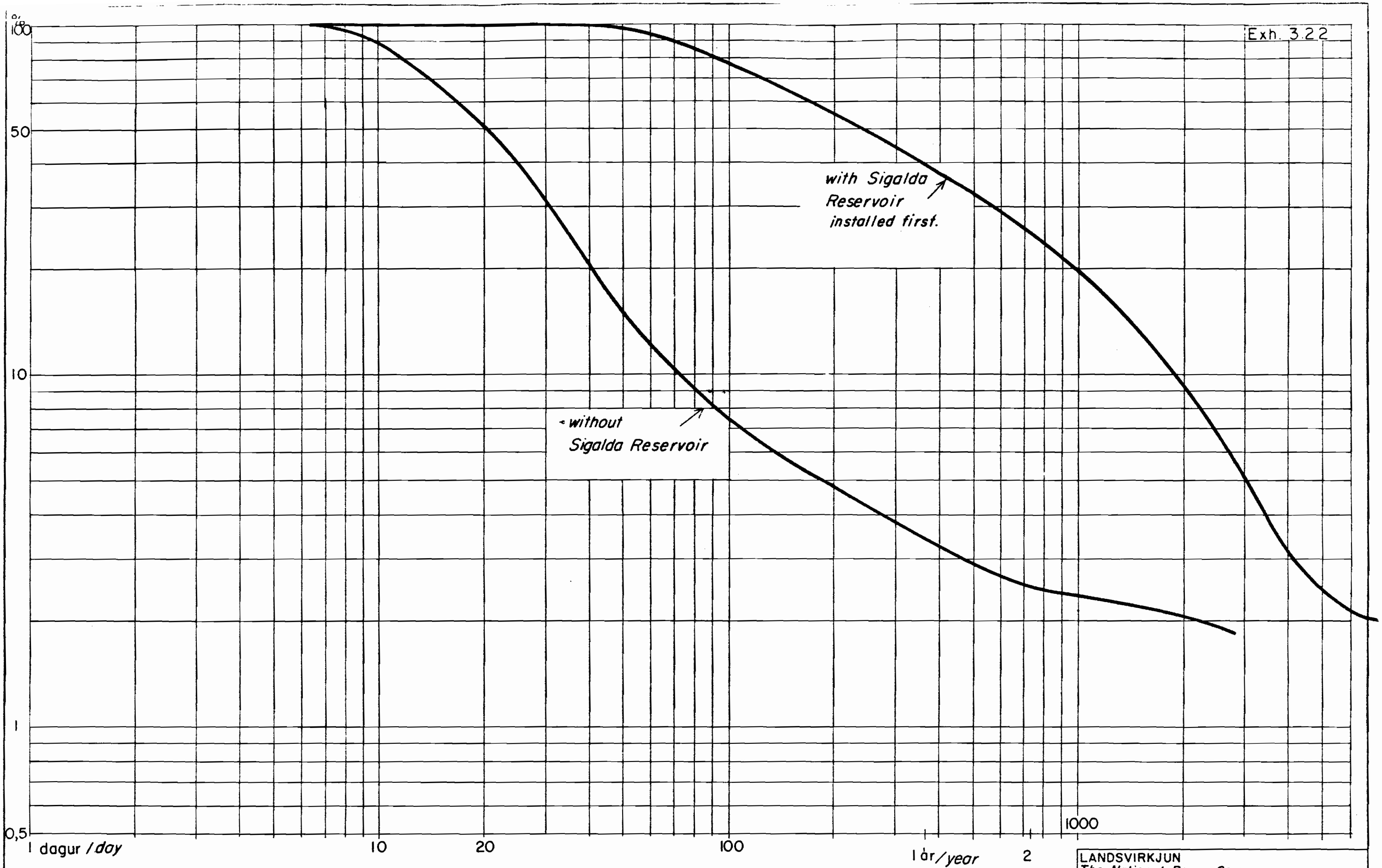
Svæði *Area*		
Svæði *Area*	1	Sandur og set, jarðvatn í yfirborði *Sand and silt G.W.T. at surface*
"	2	Morena *Moraine*
"	3	Móberg *Moberg*
"	4	Sandfylling í lægðum *Sandfilled depressions*
"	5	Vatnaset *Lake deposits*
	6	Áraurar *Alluvial deposits*
"	7	Hraun sem áin hefur runnið yfir *Lava which has been flooded by the river*
"	8	Hraun sem áin hefur aldrei flætt yfir *Lava which has never been flooded by the riv.*
"	9	Gerfigígar *Pseudocraters*
"	10	Tungná *Tungna*

Allt lónið *Reservoir*		8.7 km^2
Svæði *Area*	1	0.3 "
"	2	0.3 "
"	3	0.1 "
"	4	1.5 "
"	5	0.7 "
"	6	1.7 "
"	7	1.0 "
"	8	1.3 "
"	9	0.1 "
"	10	1.8 "

LANDSVIRKJUN
The National Power Company

ORKUSTOFNUN
HRAUNEYJAFOSS
LEKASVÆDI *LEAKAGE AREAS*

1.2.'71 HT/EK Tnr. 263 B-332 Fnr. 9730



Áætluð minnkun á leka úr Hrauneyjalóni, sem fall af tíma í % af upphaflegum leka.

Estimated decrease in leakage from Lake Hrauneyjalón as a function of time in % of initial leakage.

LANDSVIRKJUN
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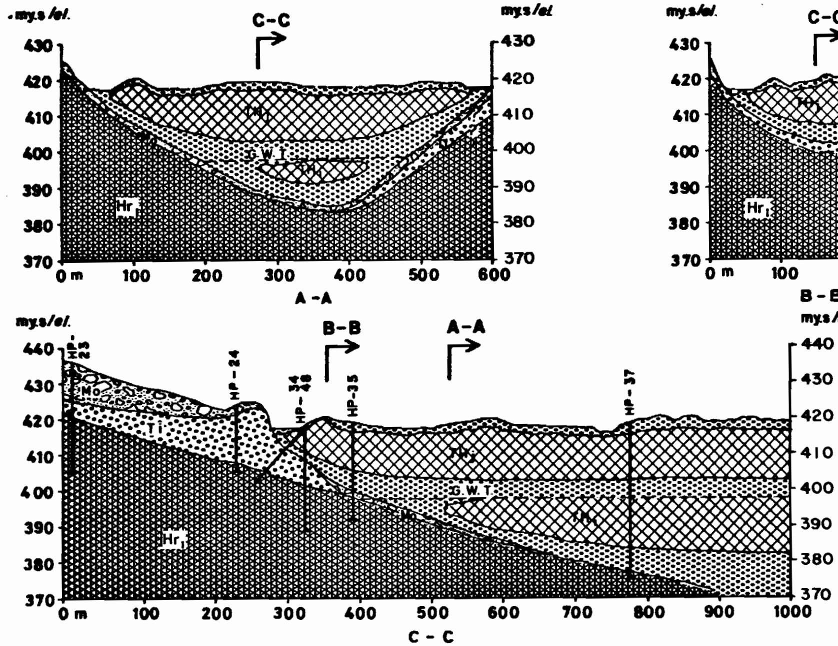
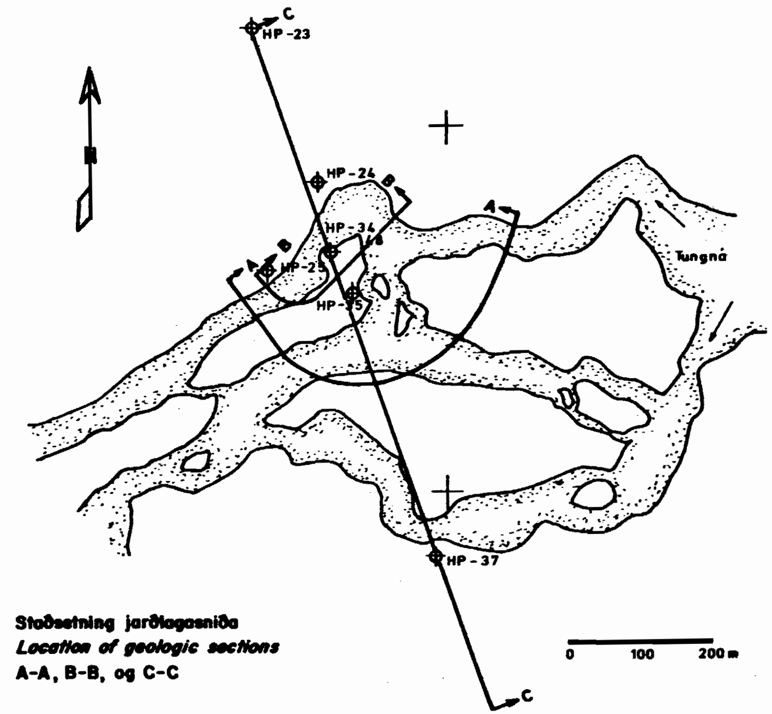
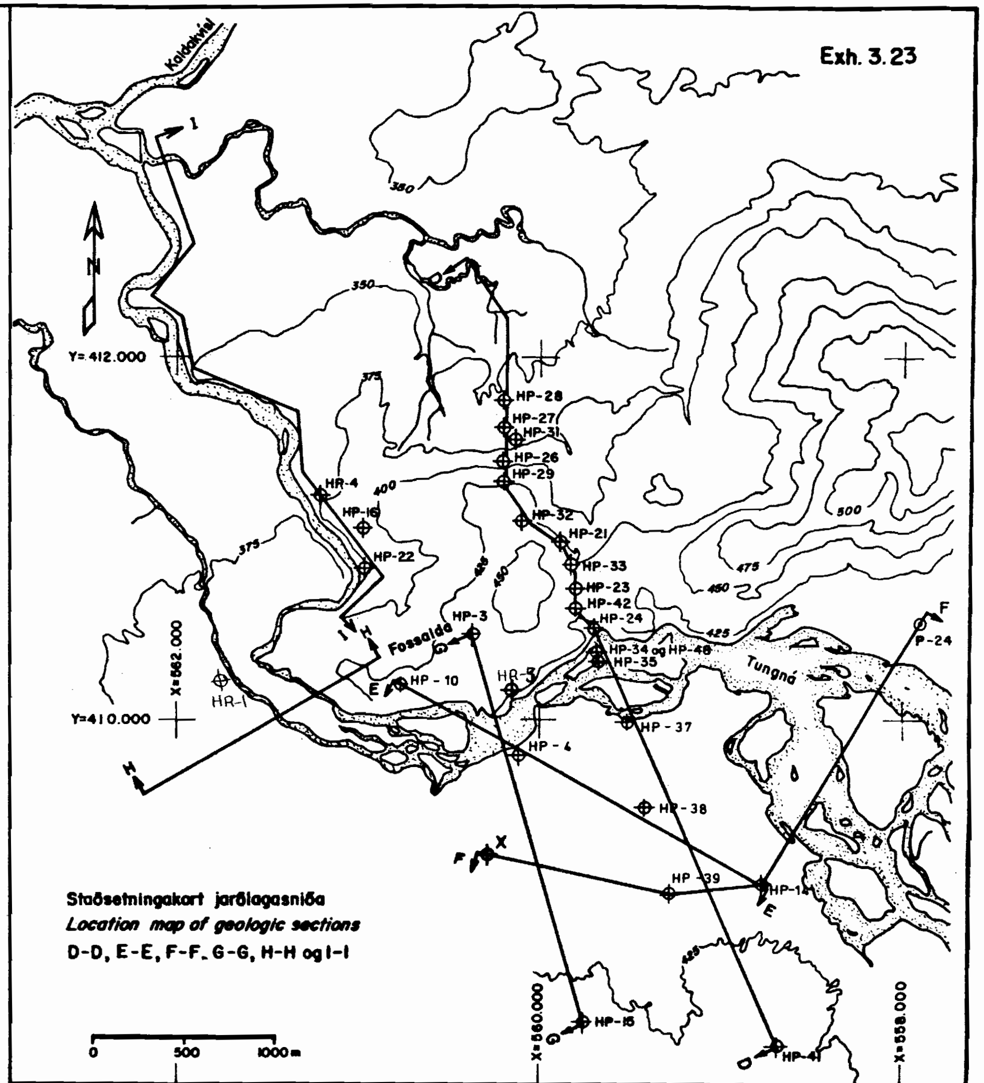
ORKUSTOFNUN
HRAUNEYJAFOSS
Leki úr uppistöðulóni / *Leakage from reservoir.*

2.2.'71 HT/ÓM	Tnr. 259 B-332	Fnr. 9727





Staðsetning jarðlagasniða
Location of geologic sections
A-A, B-B, og C-C



Staðsetningakort jarðlagasniða
Location map of geologic sections
D-D, E-E, F-F, G-G, H-H og I-I

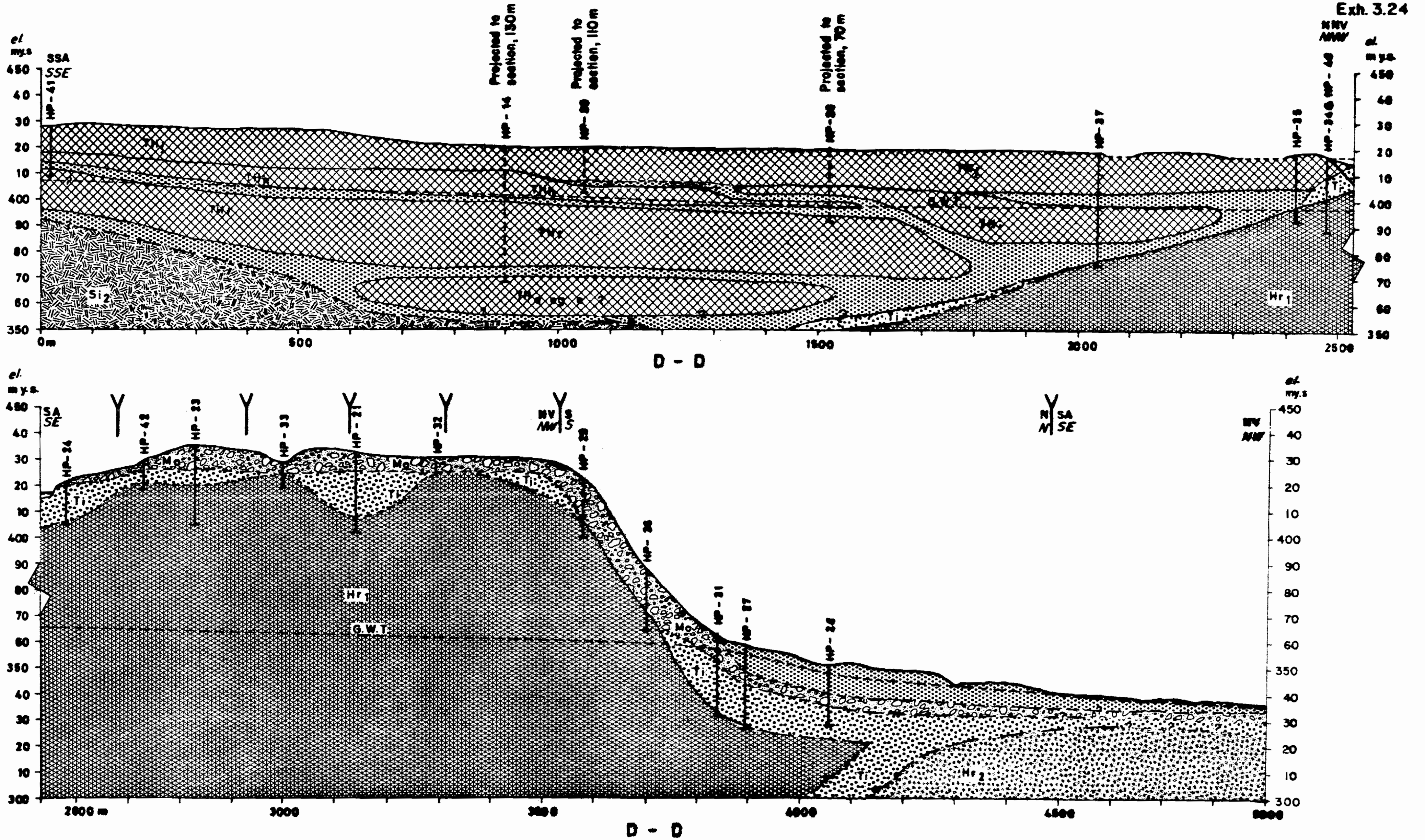
Skýringar við jarðlagasnið sjá Exh. 1.08
Legend for geologic sections see

Skýringar við staðsetningakort sniða
Legend for location map of sections

- Jarðlagasnið — *Geologic section*
- Borhola — *Drillhole*
- Písometri — *Piezometer*

LANDSVIRKJUN *The National Power Company*	
ORKUSTOFNUN	
HRAUNEYJAFOSS Jarðlagasnið AA-BB-CC og staðsetningakort *Geological Sections AA-BB-CC and Location Map*	
Jan. 1971 HT / Blað 1 af 5	Tnr. 265 / B-332
Fnr. 9732	

Exh. 3.24



Skýringar sjá Exh. 1.08
Legend see

Staðsetning sjá Exh. 3.21
Location see

LANDSVIRKJUN
The National Power Company

ORKUSTOFNUN

HRAUNEYJAFOSS
Jarðlagasnið DD
Geological section DD

Jan. 1971 HT/	Tnr. 286	Fnr. 9733
Blað 2 af 5	B-333	

ORKUSTOFNUN
Raforkudeild

JARÐVATNSMÆLINGAR Í BORHOLUM
Groundwater measurements in drillholes

Mælt: K.B.
Unnið af: P.J.

Svæði : Hrauneyjafoss

Ár: 1970

Dags. mæl-ingar	Heiti holu/jarðvatnsborð m y.s.												
	HP-1	HP-2	HP-3	HP-4	HP-9	HP-14	HP-15	HP-16	HP-20	HP-22	HP-24	HP-26	HP-27
16/6					361.50		399.05						
1/7		356.67		396.79				391.90					
8/7		356.66		397.09	361.83		399.61		391.76				
15/7		356.66			361.88	407.34	399.46		391.73				
22/7									391.61				
23/7		356.67		396.89	362.23	407.30	399.40						
24/7			363.60										
26/7	361.96												
27/7	361.94												
29/7	362.02		363.60	396.84	362.32	407.30	399.39		391.68				
5/8								358.57					
6/8	362.03			396.93	362.54	407.26	399.40		391.65				
7/8		356.68	363.60					358.61					
13/8	362.09	356.70	363.63					358.67	391.62	359.38			
14/8				396.89	362.96	407.27							
21/8		356.66	363.58					358.55	391.60	359.27			
22/8	361.96				362.70	407.11	399.11						
27/8	361.98	356.67	363.55		361.96	407.07	398.94	358.59	391.56	359.33			
4/9	361.91	356.66	263.48	396.29	362.26	406.97	398.83	358.44	391.57	359.17	(412.18)		355.70
17/9	361.70	356.49	363.25	395.69	360.84	406.74	398.37	358.23	391.53	358.99			
23/9	361.65	356.46	363.22	395.61	360.94	406.56	398.18	358.40	391.52	359.00			
30/9	361.98	356.46	363.22	395.61	360.94	406.56	398.19	358.68	391.48	359.45	(414.09)	(377.99)	355.79
6/10	361.91	356.83	363.49	396.40	362.65	407.17	398.87	358.40	391.57	359.13	(412.43)	(377.37)	355.69
14/10	361.97	356.83	363.52	(392.48)	362.10	407.10	398.86	358.48	391.70	359.22	(413.11)	(377.57)	355.74
16/10													
20/10	361.96	356.80	363.45	396.49	362.82	407.10	398.95	358.48	391.70	359.08	(412.63)	(377.35)	355.71
29/10	361.84	frosin	363.44	396.35	360.88	407.09	398.90	358.29	391.77	w59.10	(412.53)	(376.25)	355.63
9/11	361.67	"	363.27	395.72	358.62	406.12	398.12	358.17	391.73	359.01	(411.66)	(375.57)	354.90
28/11	361.44	"	363.36	394.84	357.72	405.80	397.30	358.00	391.62	358.74	(410.53)	(373.20)	354.68
11/12	361.39	"	362.92	(391.63)	358.20	(402.30)	397.87	357.51	391.48	356.35	(413.40)	(378.33)	355.44
7/1	362.20	"	363.11	(393.80)		406.32	397.81	358.08	391.68	358.94	(411.30)	(375.53)	356.04
20/1	361.40	"	362.91	395.18	358.07	405.48	397.91	357.94	391.51	358.76	(411.52)	(373.63)	355.35

107020x35FDH

APPENDIX 1

blað sheet 2

ORKUSTOFNUN
Raforkudeild

JARÐVATNSMÆLINGAR Í BORHOLUM

Groundwater measurements in drillholes.

Svæði : Hrauneyjafoss

Ár: 1970

Mælt: K.B.

Unnið af: P.I.

Dags. mæl-ingar	Heiti holu/jarðvatnsborð m y.s.												
	HP-28	HP-31	HP-34	HP-35	HP-37	HP-38	HP-46	HR-1	HR-3	HR-4	X	P-23	P-24
25/6												418.44	418.54
1/7									368.31			418.59	418.60
8/7									368.40				418.59
15/7								363.04	368.39				418.49
22/7									368.36				418.60
23/7								363.03		354.81			
29/7								363.09	368.36	354.84			418.62
6/8								363.19	368.40				418.69
7/8										354.94			
13/8									368.42	355.02			418.78
14/8								363.35					
21/8									368.35	354.74			418.59
22/8								363.02					
27/8								363.18	368.26	354.90		418.30	
4/9	347.46							362.80	368.17	354.71		418.30	418.53
17/9								362.43		354.42			
23/9								362.78		354.66			
30/9	347.50	356.60					357.21	363.36		355.23			
6/10	347.50	356.60			398.20		357.10	362.83		354.74			
7/10			401.14	400.20									
14/10	347.52	356.57	400.55	(404.72)				362.11		354.83			
15/10						(400.95)							
16/10			400.47	(404.84)				362.57					
20/10	347.50	356.56	400.28	(404.55)		398.53	357.14			354.58			
29/10	347.47	356.48	400.28	(403.81)		398.25	358.25						
9/11	347.43	356.38	399.70	(403.90)	397.59	397.59	357.55	362.34		354.20		418.16	418.25
28/11	347.34	355.74	397.73	(403.12)	397.40	397.57	356.78	362.08	367.58	353.33	395.76	418.06	418.70
8/12													418.56
11/12	347.44	356.21	397.18	(402.88)	397.23	396.69	356.79	(359.90)	367.61	354.09	395.44		
7/1	347.44	357.38	397.72	(403.41)	396.85		356.92		367.32	354.13	397.72		
9/1												418.06	418.30
20/1	347.36	356.20			396.87	398.14	356.72	361.95	367.43	354.03	396.31	417.81	418.28

A P P E N D I X 2

Skrá yfir dýpi og lýsing á efni í prufugryjum á stíflustæði á Hrauneyjum

List of the depth and description of material in the test pits on the damstie in Hrauneyjar

Gryfja Nr. Trench No	Dýpi Depth m	Lýsing efnis og aðrar athugasemdir Description of material and other remarks
1	0	Á hraunklöpp/On solid lava
2	1.5	Í lægð; fokmold, leir og aska/Loess, clay and ash
3	0.8	Sama og 2/Same as 2
4	0.5	Foksandur og vikur/Eolian sand and pumice
5	0	Á hraunhól, klöpp/On solid lava
6	2.0	Foksandur, vikur og aska/Eolian sand, pumice and ash
7	0	Á klöpp/On solid lava
8	0	Sama og 7/Same as 7
9	4.0	Sand, ösku og moldarlög austan í gryfju, en gjall og hraungrýti vestan meginn, leirfyllt Loess, sand, scoria and lava blocks, clayish
10	4.5	Gjallríkt og hraungrýti fyllt foksandi, leirkennt/ Lava blocks, scoria and eolian sand, clayish
11	3,5	Sama og 10/Same as 10
12	3.0	Sama og 10 nema óleirfyllt/Same as 10, but without clay
13	3.0	Sama og 12/Same as 12
14	1.5	Gróft, aðallega hraungrýti og gjall/Mainly scoria and lava blocks
15	0.5	Groft, aðallega hraungrýti/Mainly lava blocks
16	<1.0	Foksandur, gjall og hraungrýti, vikur/ Colian sand scoria lava block and pumice
17	1.0	Sama og 16/Same as 16
18	2.0	Sama og 16/Same as 16
19	2.0	Sama og 16 nema grófara/Same, but coarser
20	2.0	Sama og 16/Same as 16
21	2.0	Sama og 16/Same as 16
22	2.5	Sama og 16 nema fínna/Same as 16, but finer
23	2.0	Sama og 16/Same as 16
24	2.0	Sama og 16, grófara/Same as 16, but coarser
25	1.5	Foksandur, gjall og vikur/Eolian sand, scoria and pumice
26	0.5	Sama og 25/Same as 25
27	2.0	Hraungrýti, bl. foksandi og vikri, gjallkennt Lava blocks, eolian sand, pumice and scoria
28	1.5	Sama og 27, grófara/Same as 27 but coarser
29	1.0	Sama og 27, gróft/Same as 27
30	1.5	Sama og 28/Same as 28
31	1.5	Sama og 27/Same as 27
32	0.7	Sama og 28/Same as 28
33	1.0	Sama og 28/Same as 28
34	1.0	Sama og 28/Same as 28
35	1.5	Foksandur, gjall, vikur og hraungrýti/Eolian sand, scoria, pumice and lava blocks
36	1.0	Sama og 35/Same as 35
37	1.5	Sama og 35 nema í litlum mæli hraungrýti og vikur/Same as 35, mostly eolian sand and scora
38	1.0	Sama og 37/Same as 37
39	2.0	Sama og 37/Same as 37
40	3.0	Sama og 37/Same as 37
41	2.0	Foksandur, gjall og hraungrýti/Eolian sand, scoria and lava blocks
42	2.0	Sama og 41/Same as 41
43	2.0	Sama og 41/Same as 41
44	3.0	Sama og 41/Same as 41
45	2.0	Sama og 41/Same as 41
46	2.0	Sama og 41/Same as 41

Staðsetning gryfja sjá

Location of trenches see

Exh. 3.01