A Request from the Government of Iceland to the United Nations Special Fund for Assistance in a Survey of the Hydro-electric Power Potential of Hvítá and Thjórsá River Basins, Southern Iceland

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Summary

The present request from the Icelandic Government to the United Nations Special Fund is for an assistance, both financial and expert, in some aspects of an hydro-electric power survey of the Hvitá and Thjórsá River Basins in Southern Iceland, in which a substantial part of the country´s hydro-electric resources are concentrated.

The reason for the request is that the first hydro-electric power plant to be constructed on any of the major rivers inside the two basins will have to be ready for operation some time near the end of the present decade. It is important that a comprehensive plan - a Master Plan - for the overall development of the two basins to prepared in conjunction with the initiation of the first project, in order to ensure from the very beginning a coordinated development of the hydro potential of the two basins, a mode of development that will secure the most efficient utilization of the resources and maximum benefit from their exploitation. To achieve this end it is necessary to undertake, in connection with preparations for the initial project, comprehensive basin-wide planning studies involving a number of coordinated system power operation studies. Personnel with experence in river basin planning and system operation studied involved in it are presently not available in this country; hence the Special Fund is requested to provide expert assistance in this field.

Another highly urgent aspect of the preparations for the initial power developments mentioned above is the solution of problems presented by the ice in the rivers. Ice conditions in rivers in this country are in several respects peculiar to Iceland which entails that results from studies of river ice in other countries are applicable in Iceland to a small extent only. The ice presents serious problems to the design and operation of potential power stations in the area, and their solution is therefore of great importance. It is felt imperative to start research into these problems, both field surveys of the ice conditions in the rivers and more basic studies of the mechanism of ice formation and transport under the conditions prevailing in the two basins.
In this request, the Special Fund is asked to finance the purchase of the necessary instruments and equipment for the ice studies, as well as for expert assistance in their initation.

Testing of soil and rock will form an important item in preparatory investigations for power projects in the Thjórsá and Hvítá basins. Presently, facilities are lacking in Iceland for such tests. The Special Fund is here requested to finance the necessary testing equipment and to provide expert assistance in the set-up of a laboratory for this purpose.

The work for which Special Fund support is requested and outlined above, is rendered special importance by the presently good prospects for the establishment of large-scale power consuming industries in Iceland, based on the water power resources of the two basins. Negotiations are now in progress with Swiss and French aluminium manufacturers on a smelter in Iceland, and detailed planning studies are being carried out of the most promising project on Thjórsá River, the Búrfell Project, with development industrial purposes in mind. The establishment of power-consuming industries in Iceland is considered the most realistic way to sustain an econonomic growth in Iceland comparable with that in other European countries.

More specifically, the main items of this request to the United Nations Special Fund are as follows:

1. Load growths studies in Southwestern Iceland.
2. Schedule of emergy developments for Hvítá and Thjórsá River basins.
3. Ice research centre.
4. Soil and rock testing laboratory.
5. Fellowships (in the fields of activity listed under 1-4 above).
6. Equipment, incl. hydrologic equipment and special vehicles (for the activities listed under 1-4 above).

The estimated amount of expert services is 92 man-months and of fellowships 71 man-months. The over-all duration of the main part of the Project is estimated at two years, with the fellowships extending somewhat into the third year. The starting date has tentatively been set by mid - 1963, which means that the expert services would be completed by mid - 1965 and the fellowships in 1966.

The total cost of the Project is estimated at $ 702.000, of which the Special Fund contribution amounts to $ 342.000 and that of the Icelandic Government to $ 360.000. In Appendix 9, at the end of the Request, a detailed break-down of the cost-estimate is given, as well as a list of personnel, both foreign and Icelandic, the time of service for each of the experts and for each fellowship.

1. Background

1.1 General information

Iceland is an island in the North Atlantic Ocean, between latitudes 63°24´ and 66° 32´ North and longitudes 13°20´ and 24° 32´ West. From north to south the greatest span is 300 km approx. and 500 km approx. from east to west. The distance from Greenland is 350, from Scotland 850 and from Norway 1050 kilometres, approximately (See Annex 1 & 2). The area is about 103.000 sq km.

For the most part, Iceland is a mountaneous country. Most of the lowland is in the southwest. The interior consists entirely of mountains and high plateaus, and is almost completely uninhabitated. Glaciers cover some 11.500 sq km of the highlands; biggest of them is Vatnajökull, 8400 sq km (Annex 2). Numerous volcanoes are there too, some of them active.

The population of Iceland is 180 000 approximately and is concentrated in the coastal districts, especially in Southwestern Iceland, where approximately 70,8 per cent of the total population is living. The capital, Reykjavík, pop. 73 400 is in this area.

The population is growing rapidly. The average annual increase has been approximately 2 per cent for a decade or more.

The climate of Iceland is a wet oceanic climate, with relatively mild winters and cool summers. The island lies at the intersection of warm air-streams moving from the east coast of America north-east across the Atlantic and streams of dry polar air from Greenland and the Polar Sea. The result is a very unstable, constantly changing weather.

The annual mean temperature is 3 to 5°C at the southern and western coast, and 2 to 3°C at the northern and eastern coast.

The mean annual precipitation is between 1000 and 2000 millimetres along the south and west coast, but 500 to 600 mm at the north and east cost.

Meterological data from the uninhabitated interior are scarce, but it is known that the temperature shows greater annual variations there than in the coastal districts, and also that precipitation in some mountaneous regions and on the glaciers, especially in the southern and south-eastern part of the country, is appreciably higher than on the coastal lowlands.

The high precipitation gives rise to rivers of a considerable magnitude, in spite of their relatively small drainage area, i.e. to a high run off per unit of drainage area. Thus, the specific runoff in Iceland varies between 20 and 180 litres per second per sq km of drainage area. This compares with approx. 2 l/sec., km^2 for the Colorado at Lees Ferry and approx. 30 l/sec, km^2 for the Tennessee at Fortana Dam, just to mention two examples. This high run-off, in conjunction with mountaineous topography, gives rise to the very considerable hydro-power potentialities of Iceland.

The principal occupations in Iceland are (1) fishing and fish processing, (2) agriculture and (3) industry, mainly consumer goods manufacturing for the domestic market. Fish and fishproducts account for over 90 per cent of the export. Agriculture is restricted to animal husbandry, for climatic seasons. All cereals have to be imported, but the country is largely self-sufficient with meat; milk and dairy products and potatoes. (For further information about the Icelandic economy, references 1 to 3 enclosed herewith may be consulted).

1.2 Natural resources of Iceland

The chief natural resources of Iceland are the fishing grounds around the coast and energy potentials in the form of water power and geothermal heat. The fishing banks rank amongst the richest in the world, but due to very intensive fishing during the last few decades both by Icelandic and foreign vessels, they were rapidly becoming overfished a few years ago, when the fishery limit, inside which not only all foreign but also some of the Icelandic fisheries, like trawling, are prohibited, was extended from 4 miles off the coast to 12 miles. It is hoped that these and other protective measures will prevent deterioration of the banks, but if is nevertheless obvious that they will soon be exploited to the limit of their capacities. By contrast, the energy potentialities have as yet been harnessed to a few percent only. These energy resources are of quite considerable magnitudes (cf. Section 1.5), especially when viewed in relation to the size of the population.

Other natural assets are very limited in Iceland. No fuels have been found except some scattered peat deposits of doubtful economic value; no ores and practically no other mining resources with the exception of diatomaeous earth that has been found in various places and in large quantities at one location where it may be processed with the aid of geothermal steam.

1.3 Power-consuming industries as a basis of continued economic growth in Iceland

In recent studies, undertaken in connection with drafting of a Development Programme for Iceland, one of the main conclusions arrived at was that it was necessary to develop a new export industry in Iceland. It could not be expected that the exports of fish products could increase by more than about 4% a year in view of the already heavy exploitation of the available fish stock. However, in order to sustain an increase in the natural product of about 5% a year, it would be necessary for exports to rise by at least 7% a year. This increase in exports can only be realized by the development of new export industries. It was concluded that the most realistic way to solve this problem would be through the development of some of the unused power resources of the country for the production of aluminium or other products requiring a large amount of electric power.

Several decades have elapsed since the idea of utilizing the country's water power resources for industrial purposes was first conceived. For a long time, however, the resources remained largely unexplored, but considerable progress has been made during the last few years in their investigation. (The work done to date to explore the potentialities of the Thjórsá and Hvítá basins will be described in greater detail in a subsequent section).

Appraisal studies of some of the most promising potential projects indicated that power could be produced in Iceland at approximately the same price as in Norway and considerably cheaper than in any other European country. In order to achieve such prices it is necessary to construct large power plants that could produce energy far beyond the needs of the Icelandic domestic market. The studies of power plants for industrial purposes have mainly been concentrated on two projects:

1. The Búrfell Project on Thjórsá River, Southern Iceland. An initial run-of-river, power plant might be constructed there with an installed capacity of 150 000 kW at an estimated capital cost of $ 31 million, transmission included. Búrfell is situated 100 km approx. from Reykjavík, the main load centre of Iceland. In view of the demand in this area now and in near future (to be described later), about two thirds of the initial capacity of Búrfell or about 100 000 kW could be made available to power consuming industries.

2. Dettifoss Project on the Jökulsá á Fjöllum River, Northern Iceland. Here, an initial, run-of-river plant of 105 000 kW capacity could be constructed at an estimated cost of $ 25 million approx. including transmission. There is only a limited domestic market for power in the North so that this plant would have to be based almost completely on electricity sales to power-consuming industries.

It is therefore, clear that a large-scale utilization of the hydro-electric resources of Iceland cannot be realized in the near future except through the building up of power-consuming industries. Negotiations have already started some time ago with two foreign aluminium concerns. Aluminium - Industrie, Aktien - Gesellschaft (AIAG) in Zürich, Switzerland, and Pechiney in France, about the possibility of building in Iceland an aluminium smelter of 30 000 - 40 000 tons capacity.

These negotiations have been based on the assumption that the power plants would be wholly owned by Iceland whereas the smelter would be predominantly foreign-owned. Sales of power to the smelter would be on the basis of a long-term contract. Such a contract would greatly facilitate the financing of the power project on the private market. Nevertheless, it is clear that the larger part of the financing would have to be found through borrowing from international investment credit institutions. It would also be very important to be able to raise a considerable part of the finance at better than normal market rates in order to strengthen the financial position of the power plants and make it possible to generate income to finance further expension.

The discussions have so far been promising and seem to indicate that Iceland should be in a good position to attract this type of industry. It was decided that detailed planning studies were needed of the two projects mentioned above, the Búrfell and Dettifoss Projects, and also that studies shall be undertaken in connection with the siting and operation of the smelter, such as of harbour facilities; water supply; access to labour and so on.

The planning studies of the two projects, whose primary aim it is to establish within close limits the cost of energy from them, have been going on for a little over a year, and have been accompanied by fairly extensive site investigations at the two projects, especially at Búrfell. From time to time, as these studies proceeded, the aluminium cencerns have been informed about the results. When the final results of the planning become available, expectedly some time during the first months of 1963, the negotiations will be continued and will then expectedly enter a decisive stage. Of course, nothing definite can be said at the moment about the outcome of the negotiations, but judging from the results of the planning studies obtained to date, the prospects should be promising.

1.4 Water-power resources of Iceland, with special reference to the Thjórsá and Hvítá River basins.

The aggregate technically harnessable water power of Iceland is at present estimated at 31000GWh a year under adverse hydrological conditions, and at 35 000 GWh a year under average conditions. The estimate, while admittedly of a quality that leaves much to be desired, due to insufficient data, is believed to be conservative.

For comparison, Annex 3 shows similar figures for the water-power potential of several other countries, based on the statistics of the United Nations. Annexes 4 & 5 show the geographical distribution of the water power within Iceland. From the table in Annex 5 it may be seen that the areas with the greatest technical potentials are the Thjórsá Basin, Eastern North, East and the Hvítá Basin.

The estimate refers to technically harnessable power, without regard to economic considerations, since the data available do not yet permit economic evaluation of many of the potential projects. However it seems safe to say that from an economic standpoint, the most important areas of those enumerated in Annex 5 are the Thjórsá and Hvítá Basins and Eastern North, the first two due both to their high potentials and to their closeness to the main population centres in Southwestern Iceland (transmission distances are of the order of 100-150 km in most cases), and the third one because of favourable conditions at the Dettifoss site on the Jökulsá-á-Fjöllum River which lies in that area. The potential of that river basin accounts for ab. 73% of the total of the Eastern North area. Accordingly, the site investigations carried out to date have mainly be concentrated on these three basins, the Thjórsá, the Hvítá and the Jökulsá-á-Fjöllum Basins.

Altogether, 12 power sites have been conceived in the Thjórsá basin, none of which has yet been developed, and 17 sites in the Hvítá basin, of which three have been developed. The sites, with their energy figures, are listed in Annex 5.

1.5 Load growth in South-west Iceland 1952-1961 and expected growth within the present consumption pattern 1962-71.

As stated above, about 70,8 percent of the whole population of Iceland is living in the South-western part of the country. Accordingly the overwhelming part, or about 82,3 percent of the total power consumed in Iceland is used in this area, and the largest power plants and the most extensive power system is also found there. Annex 6 shows the geographical distribution of power plants in this area and the power system, and Annex 7 the gross power generation 1952-61. As apparent from the figures, by far the greatest portion of the power used in the area is generated by the three plants Steingrímsstöð; Ljósafoss and Írafoss which are all located on the Sog River, a tributary to the Hvítá River (cf. Annex 2). Also apparent is that the rate of increase has been very varying during the same period. The large increase 1953/54 is due mainly to two reasons: (1) Owing to shortage of power considerable load shedding had been necessary in 1952 and 1953, until the Írafoss plant was completed in October that year, when it was discontinued. (2) A fertilizer plant using large amounts of electric power for electrolysis began operation in 1954. This plant has used a considerable part of the total energy as evident from the figures, mostly secondary power generated during off-peak hours from water that would otherwise have been wasted.

Somewhat smaller quantities of power have been sold wholesale to a Cement Plant that began operation in 1958, and to a NATO air base at Keflavík International Airport, some 50 km southwest from the capital, Reykjavík. Power sales to the Airport began in 1961 after commissioning of the last of the Sog plants, the Steingrímsstöð, in 1960 and the construction of a new transmission line from Reykjavík to Keflavík plus erection of a 50/60 cycles converter station at the Airport, which was completed in 1961. The present contractual amount of power sales to the Airport is approx. 40 GWh a year.

Annex 8 shows the estimated load growth in the area 1962-71, within the pattern of present consumption, i.e. in absence of new power-consuming industries. The estimate is based on an assumed average annual increase in the general purpose load of 6.5 percent, and the assumption that power delivery to the Fertilizer Plant and the Airport will remain at the present level throughout the period. However, although no decisions have as yet been taken, there have been plans of an increase in the capacity of the Fertilizer Plant that would raise its energy requirements by about 50 percent. There are also propects of power sales to the Airport beyond the amount stipulated in the present contract. The above estimate, therefore, is in these respects pessimistic.

Based on this estimate, the energy production capacity of the present power plants in the area would be fully utilized by the middle of the period or around 1966, when a new plant must be ready for operation.

1.6 Work done to date to explore the power potentialities of the Thjórsá - Hvítá basins and origin of the present request for aid from the Special Fund.

As just stated, the energy production capacities of the Sog plants is expected to be fully utilized in a few years. Since with the three existing power plants, the Sog River is fully developped, a new hydro plant would have to be erected on some of the other tributaries to the Hvítá or Thjórsá Rivers, or on the main stem of these rivers.

At this point it is worth noticing that the Sog River is in several repects unique among Icelandic rivers as regards ease of development for power purposes. The developed head of the river, totalling some 77 m, is in two sections separated by a short lake, Lake Úlfljótsvatn (cf. the map, Annex 2). The upper section, lying between the 82 sq. km Lake Thingvallavatn, the largest in Iceland, in which the river originates, and Lake Úlfljótsvatn, is developed in a single power plant, Steingrímsstöð, with a gross head of 21 m and water conductors of only ab. 400 m length, i.e. a headrace tunnel through a narrow hill that separates the two lakes. The intake is placed directly in Lake Thingvallavatn and only a small dam was required across the outlet to divert the water into the tunnel. The lower section, below the outlet of Lake Úlfljótsvatn, is developed in two stages, the Ljósafoss and the Írafoss plants, in that order when looking downstream. Lake Úlfljótsvatn serves as a pond for these two plants. The water conductors of the Ljósafoss plant are only about 100 meters in length; the gross head 17 meters. A few hundreds of metres downstream is the intake dam of the underground Írafoss plant, which has a gross head of 38 m and water conductors of some 650 m length. The dams of both plants are small. Owing to the size of Lake Thingvallavatn and the fact that most of its inflow is in the form of groundwater flowing through a heavily fractured postglacial lava field at the northern end of the Lake, the flow of Sog River is extremely uniform and floods are practically non-existent. Only very moderate spillways were therefore required at the Sog plants. For similar reasons, ice problems are practically, and sedimentation problems entirely, non-existent. Furthermore, geological conditions were favourable, at least when compared to many other sites in the Hvítá or Thjórsá basins. After completion of the uppermost plant, Lake Thingvallavatn provides an ideal seasonal storage reservoir for all three plants.

All these circumstances have contributed to render the power from the Sog plants exceptionally cheap for plants of their sizes. Development conditions were straightforward with relatively few alternatives to be considered. This, together with rather favourable geological conditions; small dams; absence of long water conductors and generally simple design, made it possible to avoid extensive and costly site investigations before erecting the plants.

The cheapness and - for a long time - abundance of the power from Sog are possibly the main reasons why investigations of the power potential of the Thjórsá and Hvítá basins (outside the Sog) and of the conditions for its development received rather little attention until some 10 years ago when it was becoming apparent that the Sog would be fully utilized in a relatively near future and that some other sites suitable for development had to be found in time to meet the growing demand for power. At the same time, the idea of establishing power-consuming industries in the country was gaining momentum. Therefore, the need arouse to study the conditions for development at the sites on the Thjórsá and Hvítá Rivers and their tributaries in some detail.

It was clear at the outset and has been substantiated by investigations carried out since that the development of these river systems would in many respects be far more complicated than that of the Sog River described above. The Hvítá and Thjórsá are both glacial rivers and as such subjected to much greater fluctuations in flow than the Sog, with a correspondingly greater storage requirements. On the other hand natural storage opportunities comparable to Lake Thingvallavatn were found at a few places only elsewhere in the Thjórsá and Hvítá basins, in all cases near the headwaters of the rivers. Both rivers are subjected to floods of considerable magnitudes. Ice conditions on both were known to be unstable, with alternative building-ups and breaking-ups of the ice cover throughout the winter, accompanied by considerable amounts of sludge and frazil ice in the water. Ice jams were known to occur at some of the important sites. The amount of silt carried by the rivers is considerable and might cause problems in many cases. Moreover, geological reconnaissance showed that the geology at some of the sites would be fairly complicated: moraines with sand lenses at some of the damsites, fractured postglacial lava or weak palagonite rocks at others. Sound rocks, suitable for easy tunnelling are scarce.

For these reasons it soon became apparent that fairly extensive site investigations would be required at most - if not all - the power sites in the Hvítá-Thjórsá River basins.

Since favourable conditions for the creation of storage reservoirs are mainly confined to the headwater parts of both basins, as already mentioned, such reservoirs would have to serve a number of downstream plants, whose modes of operation would therefore be very much interrelated and whose designs would therefore also be dependent of one another and of the size of the upstream reservoirs that could be constructed. Moreover, the power plants would operate interconnected. These circumstances led naturally to the conclusion that before construction of any major power plant on each river was started at least a preliminary plan for coordinated ultimate development of that river would have to be prepared in order to ensure that an initial development would fit harmoneously into a scheme that would secure maximum benefit from the overall utilization of the river. In other words a Master Plan for the overall development of each river should be prepared before any major development on each of them was undertaken, in order not to forego the benefits from coordinated development of the river system as a whole.

The Master Plan concept led naturally thereto that in some parts of the investigations, above all the ones that were aimed at fixing the principal features of an overall development, each river basin had to be treated more or less as a single unit or a whole. These so-called Master Plan investigations had to proceed or be performed parallel to more detailed planning studies of individual sites. These circumstances necessarily increased the scope of the investigations and placed heavier burden on the limited resources, both financial and manpower that could be devoted to this work than would have been the case if it were possible to study each project without any regard to other projects in the same river basin.

The work done to date in investigating the hydropower resources of the Thjórsá-Hvítá River basins may be briefly descrived as follows:

1. Most - if not all - potential sites in both basins for power and storage projects have been recognized. A preliminary design has been prepared for many of them, for the purpose of a rough appraisal and to serve as a guide to site investigations.

2. Topographical mapping of most of the area involved in these developments is nearing completion. More mapping of the immediate vicinity of individual structures will however be required as detailed planning studies proceed.

3. A network of hydrological stations has been established throughout both basins. Stream-flow records are still available for a few years only at most of the stations. Some items of hydrological investigations, such as sedimentation studies; ice and snow surveys, have hardly started. These studies, especially the ice studies, are extremely important for developments in the two basins, since ice problems and - in the case of some of them sediment problems also - may be expected to be very serious and complicated.

4. Geological reconnaissance and mapping has been carried out at a number of sites, and a fairly large amount of exploratory drilling has been done at some of them, particularily at Búrfell on the Thjórsá, a project that is thought to be the most favourable one as the source of power for industrial purposes. However, very much work remains to be done in this field, since, as already stated, reconnaissance shows the geology at many of the sites in the

Thjórsá and Hvítá basins to be complicated.

5. Preliminary engineering studies and appraisals have been carried out both in connection with appraisals of individual projects and as a part of the development of Master Plans for the two river basins (cf. Reference 4). Somewhat more detailed planning studies have been performed for a few projects, in particular the aforementioned Búrfell Project on the Thjórsá but also the Hestvatn Project and several other projects on the Hvítá. (References 5 & 6). The Búrfell Project has been studied in greatest detail, owing to its promising prospects as the source of industrial power. The others have been studied more with the aim of finding a suitable development to meet the general load requirements of Southwest Iceland. Along with the Búrfell planning, the possibilities of creating a storage for that Project at Lake Thorisvatn, the second largest lake in Iceland (70 sq km) have also been investigated. After the creation of such a storage, some other projects in the Thjórsá basin, like the Hrauneyjafoss and Urriðafoss Projects presents themselves as a natural continuation of the Búrfell Project and have therefore to be studied to some extent in connection with the Búrfell studies.

Although considerable work in investigating the power potentialities of the Thjórsá-Hvítá Basins has been carried out to date, very much still remains to be done. The most pressing are some aspects of the master planning and several general studies such as those of the ice conditions. The time is approaching when decision will be taken on the next site to be developped, after which a final design for that project will be prepared. It is highly important that the position of the Búrfell Project - or for that matter any other project that might be selected - shall fit well into a scheme leading to full and ultimate development. To secure this it is necessary to undertake, on the basis of estimates of future load growths, numerous power co-ordination studies under varying combinations of sequencial project developments, varying storage developments and varying size of installations of each of the projects under consideration. The results of these studies would indicate the preferred scheme of energy developments in the two river basins and clarify the position of each project in their ultimate development. The results would therefore have important bearing on the position ultimately occupied by the project selected for initial development such as Búrfell, and therefore on its design.

The first two items of the present request from the Icelandic Government for aid from the Special Fund refer to these studies that are urgently required before the next power project in the area can be initiated. River basin planning of the scope and comprehensiveness required here has not hither to been undertaken in this country, and we do not therefore have people experienced in it. Besides, with the rapid development of the data processing and computing techniques that has taken place in recent years, methods for such planning studies have evolved that are based on these techniques and greatly facilitate the job of carrying out these studies. The purpose of the requested Special Fund aid under these two items is firstly to have carried through studies that are urgently needed as a part of a pre-investment survey for the next power development in the Thjórsá-Hvítá River basins and for which experienced personnel is not now available in this country, and secondly at the same time to have Icelandic engineers trained in performing such studies with the aid of modern methods, so that they may continue the work after termination of Special Fund aid.

The third item of the request refers to the ice problems. As previously mentioned, the problems caused by the ice in connection with water power developments in this country are due primarily to the unstability or absence of an ice cover on many Icelandic streams in the winter. That, in turn, is due mainly to two causes: (1) the very pronounced changebility of the Icelandic weather combined with (2) the interaction between the cooling process of open rivers and the inflow to them of relatively warm (several degrees Centigrade above zero) water as springs from lava fields and other permeable formations that cover large parts of these two rivers basins. The frequent break-ups of an ice cover, together with large amount of frazil ice and sludge that is formed in the long open reaches or blown into them as snow, give rise to the formation of ice jams at several of the proposed sites of up to 18 m height. Such jams, which in some cases cause flooding of the river banks, would raise the tailwater of some of the power stations appreciably. The large amount of floating ice, a mixture of broken ice floes and sludge, would in some cases fill the intake basins of some plants completely and render their operation impossible, while in other, less serious cases, the plants would operate at reduced output. These troubles may in some cases, partly, at least, be avoided by taking special measures in the design of the power plant, such as by the provision of a large, deep intake basin or large ice-outlets; heating of the thrash-racks, and so on. Some of these measures, such as the provision of a large intake basin may prove very costly. In any case, in order to effectively and at the same time, economically, counteract ice troubles by design measures, a fairly large amount of data is needed on the ice in the river and its behaviour near the structures; the amount and duration of transport of floating ice; the conditions for ice formation along the river; height and duration of possible ice jams near the tailwater, and so on.

The behaviour of ice experienced in many Icelandic rivers is in many respects peculiar to Iceland. While the formation of ice in rivers is of course a common occurence in all northern countries, conditions such as described above are rarely found outside Iceland, at least not to the same extent. In countries with a continental or a semi-continental climate, like Canada; Siberia and most of the Scandinavian Peninsula the general rule is for an ice cover to be formed on the rivers early in the winter which, when formed, largely remains stable until some time in early spring, when it is broken up again. Some troubles may occur at power plants during the formation or disappearing of the ice cover, but they are usually small and of a short duration. The conditions on the west coast of Norway are more similar to those in Iceland with some important exceptions, however, among them the absence in Norway of lava fields from which large amounts of relatively warm water comes to deteriorate an ice cover on the rivers.

In view of the obvious importance of the ice in design and operation of power plants in the Thjórsá and Hvítá basins on the one hand, and on the other hand of the peculiarities of the ice conditions in Icelandic streams which entail that results from ice studies and investigations in other countries are applicable in Iceland to a limited extent only, it is felt imperative to start research and investigations into the ice conditions in the Hvítá-Thjórsá basins. The purpose would be (1) to provide data, both qualitative and quantitiative, of importance in the design of power plants, and (2) to throw light on some aspects of the mechanism of ice formation and transport in rivers under

Icelandic conditions in order to make it possible to predict the effect of various countermeasures and to appraise their efficiency in reducing or elliminating troubles. These tasks are by no means straightforward. They would involve among other things, quantitative measurements of the flow of ice in rivers, for which no satisfactory methods are presently available and would therefore have to be developed. They would also involve collection of meterological data in the upper, uninhabitated parts of the two basins, from where no meteorological records are now available, and correlation of these data with observed ice data. Model studies of the effect of ice on power plants structures of various design might also be required.

In order to carry out this reasearch and investigations, it would be necessary to create an Ice Research Centre, equipped with the necessary facilities and instruments. The requested Special Fund aid under this item is to finance the purchase of the necessary equipment the cost of a foreign specialist and a fellowship in ice studies.

The aim of the third item of the request is to create facilities in Iceland for engineering testing of soil and rock in connection with hydro-power developments in the two basins. The fund is requested to finance the purchase of necessary equipment for this purpose; the cost of an expert to guide in the set-up of a testing laboratory, and of two fellowships.

To date, no major earth dams have been built in Iceland, and no dams have been founded on other materials than rock. Tunnelling has been limited to a few, short tunnels under favourable geological conditions. The needs for soil and rock testing have hitherto, in general, been very small, when tests of concrete aggregates are exempted, for which facilities are available. With the advent of power plant construction in the Hvítá-Thjórsá basins, the need for such testing will increase greatly. In fact, the lack of adequate facilities have already been felt in some of the field investigations carried out to date.

2. The Project

2.1 Description of Project

The Special Fund Project contemplated in the present request comprises the following main items:

1. Load growth studies in Southwestern Iceland.

2. Schedule of energy developments for Hvítá and Thjórsá River basins.

3. Ice research centre.

4. Soil 2 rock testing laboratory.

5. Fellowships (in the fields of activity listed under 1-4 above).

6. Equipment, incl. hydrologic equipment and special vehicles (for the activities listed under 1-4 above).

The activities cemtemplated under each item will now be further described.

Item 1

This item, which is a necessary presequisite for Item 2, ~~should~~ consist of a study of the load growth in South-western Iceland in the past and of making forecasts of the future growth. Expecially however, the problems of power marketing and the effect of marketing efforts on the future energy requirements should be studied in detail. Power marketing as a seperate topic has received little attention to date in this country, but with the possible advent of power consuming industrial projects and construction of large power plants, the problem of power marketing aquires much greater actuality. Amongst the problems to be studied under this item would be (1) long-term power sales to industrial firms; (2) marketing of surplus energy from power plants, firm and secondary; (3) the general methodics of energy forecasting, both short-term and long-term.

Item 2

The work contemplated under this item would consist in establishing, on basis of the results of Item 1, a general scheme of energy developments in the Thjorsá - Hvítá basins. The main porpose of such a scheme would be to serve as a reference against which the position of individual projects in the ultimate basin development may be appraised and to show the increments in capacity and energy each project would furnish the power system at various levels of basin development.

More specifically, the work would consist of numerous power cordination studies made under varying combinations of sequencial project developments, varying size of installation of each of the projects under investigation, and, finally, under varying estimates of future load growths.

The necessary computations will presumably have to be performed with the aid of an electronic computer, and the programming required would also fall under this item.

Prior to the studies and computations just mentioned, a thorough check would have to be made of the stream flow computations that have been carried out to date for the two river basins, since the flows will have a direct and important bearing on the results obtained.
Furthermore, since streamflow records at some of the sites are available for a few years only, while at others records for 12-15 years are at hand, the shorter records would have to be extended by correlation with the longer ones.

Item 3

Primarily requested under this item is financing of the purchase of the necessary equipment and instruments to study the behaviour of river ice in the two basins and its effect on power plant design and operation. Also requested is financing of the cost of a foreign expert in ice studies and of fellowships.

The work of the expert would involve guidance in the preparation of a program for a field survey of ice conditions in the basins including measurements of meteorological data that may be expecred to influence the ice conditions and their correlation with observed ice data; further in the development - to the extent found practicable - of methods for quantitative determination of the flow of ice in rivers; in the study of the mechanism of ice formation and transport in rivers under the conditions prevailing in the Thjorsá - Hvítá basins, and, finally, in the set-up of laboratory facitities that may be required.

Item 4

This item would consist in financing the purchase of the necessary equipment for making standard engineering tests of soil and rocks materials, both in situ and laboratory tests. An expert to guide in the set-up of the facilities is also requested, and finally, two fellowships, one in standard procedures for soil testing, the other in rock mechanics and its engineering applications; rock testing ~~involved~~. [illegible]

Items 5 & 6

These items are mostly included in what is described above. Item 6 would comprise the purchase of certain special vehicles, such as jeeps, trucks and snow-tractors that would be used primarily in connection with field studies of ice and the associated collection of meteorological data, and to a less extent, in connection with check-up of computed winter flows, under Item 2.

2.2 Duration of Project

It is expected that the Special Fund Project in question here could be completed in about 24 months; c.f. Annex 9, page 5 where it has been tentatively assumed that the Project started by mid-1963. Some fellowships have been placed after this two-year period, with the view that the fellowship personnel could work on the Project with the experts during the latters' stay in Iceland, before going abroad on fellowship trips.

The overall duration may to some degree be affected by the time of the year when the Program is started, since much of the work under Item 3, ice research will necessarily have to be confined to the winter.

2.3 Foreign experts.

The following foreign experts have been contemplated:

1. Project Manager (Duration of service: 24 months)

The Project Manager will be an engineer possessing a wide experience in all fields of activity pertaining to river basin planning and development. In his capacity he is expected to be in charge of the administrative as well as the engineering work of the proposed project, and will thus be reponsible for successful execution of all work on the project. The Project Manager would also serve in the capacity of liaison between the technical experts, the Icelandic Government and the Special Fund. Further, the Project Manager is expected to act as a planning engineer in connection with Item 2.

2. Power Marketing Specialist (Duration of service: 6 months)

The Power Marketing Specialist will be responsible for the collection of data on current and future power load requirements, including magnitude and characteristics of the load. He will, together with counterpart personnel, visit residential and industrial areas for purposes of ascertaining the existing power situation and the future demands. The Power Marketing Specialist will be an electrical engineer or economist who is experienced in power market surveys, energy forecasting procedures, and preferably also in the design of powersales contracts.

3. System Power Specialist (Duration of service: 18 months)

The System Power Specialist will perform the necessary coordinated system power operation studies. This will involve a preparation of numerous reservoir regulations for long periods of records with varying conditions of streamflow and storage and at various levels of development.

In each instance it will be his reponsibility to develop river control plans which will best meet the power demands consistent with the best utilization of the water resources.

The System Power Specialist will work in a close cooperation with the Hydrologist and the Project Manager in his capacity as Planning Engineer in advancing orderly schemes of development in consistence with comprehensive river basin development. He will utilize the checked streamflow data furnished by the Hydrologist and load forecasts furnished by the Power Marketing Specialist. Further he will be responsible for the electronic computer programming required in connection with his studies. He will also train and direct counterpart personnel in the performance of the studies and computations involved in Item 2.
The System Power Specialist is required to have extensive experience in the fields of activity described above.

4. Hydrologist (Duration of service: 18 months)

The hydrologist will be responsible for the checking of available streamflow data. Special attention will have to be paid to winter flows, above all at points were the water stage is affected by ice. The Hydrologist will also undertake the necessary correlation studies to extend short-term records by comparison with longer ones. Further he would train counterpart personnel in the procedures for streamflows correlations and in the interpretation of hydrological data.

The Hydrologist should have experience in appraisal and interpretation of hydrological data as well as in the use of statistical methods in hydrology.

5. Ice Specialist (Duration of Service: 24 months)

The Ice Specialist will study the ice conditions in the two basins and their relation to meteorological conditions. He will guide in the preparation of an ice research program for the basins, both field surveys and laboratory work. He will supervise the development of necessary measuring techniques. He is required to have experience in operation and planning of hydro-electric plants under difficult ice problems.

6. Soil and Rock Testing Specialist (Duration of service: 2 months)

His responsibility would be to recommend the equipment to be purchased and to assist in placing this equipment into operation.

Total amount of expert services 92 man-months.

2.4 Fellowships.

The following fellowships are included in the request:

1. Power marketing: The various apects of the marketing of electric power and energy forecasting would be studied. Expected duration: 6 months.
2. Computer programming: Field of study would be the programming of an electronic computer with special reference to the use of computers in operation studies of a system of water power plants. Expected duration: 3 months.
3. Power system studies including computer ~~programming~~ application: The integrated operation of interconnected hydro-electric power plants would be studied with emphasis on the development of operating plans for such system; load dispatching and the use of electronic computers for system operation studies. Expected duration: 12 months.
4. Hydrological studies: Subjects for study would be general hydrology, interpretation of hydrological data; statistical methods in hydrology; corrletion methods. Expected duration: 6 months.
5. Water control plans; river forecasting (Same person as in 4 would go on this fellowship after completion of No. 4): Studied would be the procedures for river forecasting and the development of water control operating plans for storage reservoirs. Expexted duration: 8 months.
6. Soil testing: Subject of study would be the standard procedures for soil testing; both in the laboratory and in situ. Expected duration: 6 months.
7. Rock mechanics and testing: The study subject would be rock mechanics with engineering applications, as well as the procedures for testing the engineering properties of rock; both in situ and in a laboratory. Expected duration: 9 months.
8. Sedimentation; measuring techniques: The methods of sampling river water and analysis of the sediment content will be studied. Expected duration: 6 months.
9. Sedimentation; erosion studies: The study subject will be soil erosion by wind and water and its effect on the sediment transport of rivers; methods of measuring the erosion and the prospects of reducing the sediment load of rivers by checking the erosion; possible methods to that end. Expected duration: 6 months.

10. Model construction and instrument maintenance: The study subject will be the construction of hydraulic models (which may be required in connection with the ice studies) as well as maintenance of laboratory instruments. Expected duration: 6 months.

The total duration of fellowships is estimated at 71 months.

2.5 Equipment.

Annex 9, pages 15 & 16 shows a list of contemplated equipment. The list is only preliminary; the final list would be prepared in close cooperation with the various experts.

2.6 Government participation.

The Icelandic Government would pariticipate in the Project by providing the following at its own cost:

1. Conterpart personnel to the foreign experts. Total number of such personnel, excluding clerical persons, and assistants, is estimated at 6 persons.

2. Assistants to the experts and their Icelandic counterparts. Total number 7.

3. Clerical personnel, 4 persons.
   (A list of personnel is found in Annex 9, page 9.)

4. Office space and supplies. Telephone services.

5. Travel cost, both international and within Iceland of all personnel associated with the Project;

6. Quarters allowance for foreign experts.

7. Buildings, including installations other than equipment, plus the part of equipment that may be obtained in Iceland.

8. Materials and supplies for the operation of research facilities, including operation of field equipment; and operation of transport equipment.

2.7 Timing of Project.

As mentioned earlier, the starting date for the Project has tentatively been fixed beginning of July 1963. A diagram showing the estimated timing of the Project is found in Annex 9, pages 5-7.

3. Financing.

A cost estimate for the Project is shown in Annex 9. The Annex gives a summary of costs by categories and years, both for the Special Fund contribution and that of the Icelandic Government, and also detailed break-downs of costs by categories, years and contributors (Special Fund and Government).

Total estimated cost of the Project is $ 702 000, of which amount Special Fund is expected to contribute $ 342 000 and the Icelandic Government $ 360 000. A break-down of the total cost by main items is as follows. (Annex 9, page 4.)

Item No.	Costs borne by Special Fund $	Costs borne by Iceland $	Total costs $
1.	16 600	11 200	27 800
2.	144 900	102 100	247 000
3.	144 700	191 700	336 400
4.	35 800	55 000	90 800
Total	342 000	360 000	702 000

The cost of the other Items 5 and 6 have been subdivided among the four main items since Items 5 and 6 pertain directly to the activities of the other four.

4. Follow-up

It was mentioned above that, based on an estimate of the load growth in Southwestern Iceland 1962-71 within the present pattern of consumption, i.e. in absence of power-consuming industries, the energy producing capacity of the existing plants would be exhausted by around 1966, when a new plant must be ready for operation. The planning studies of the Búrfell Project and the negotiations on an aluminium smelter in Iceland have also been described. The Búrfell Project will require four years or more to place into full operation, so that, even if a final descision to construct it were reached early in 1963, it would not be completed before 1967.

In view of this, the present outlook in the power field in Southwestern Iceland may be described briefly as follows:

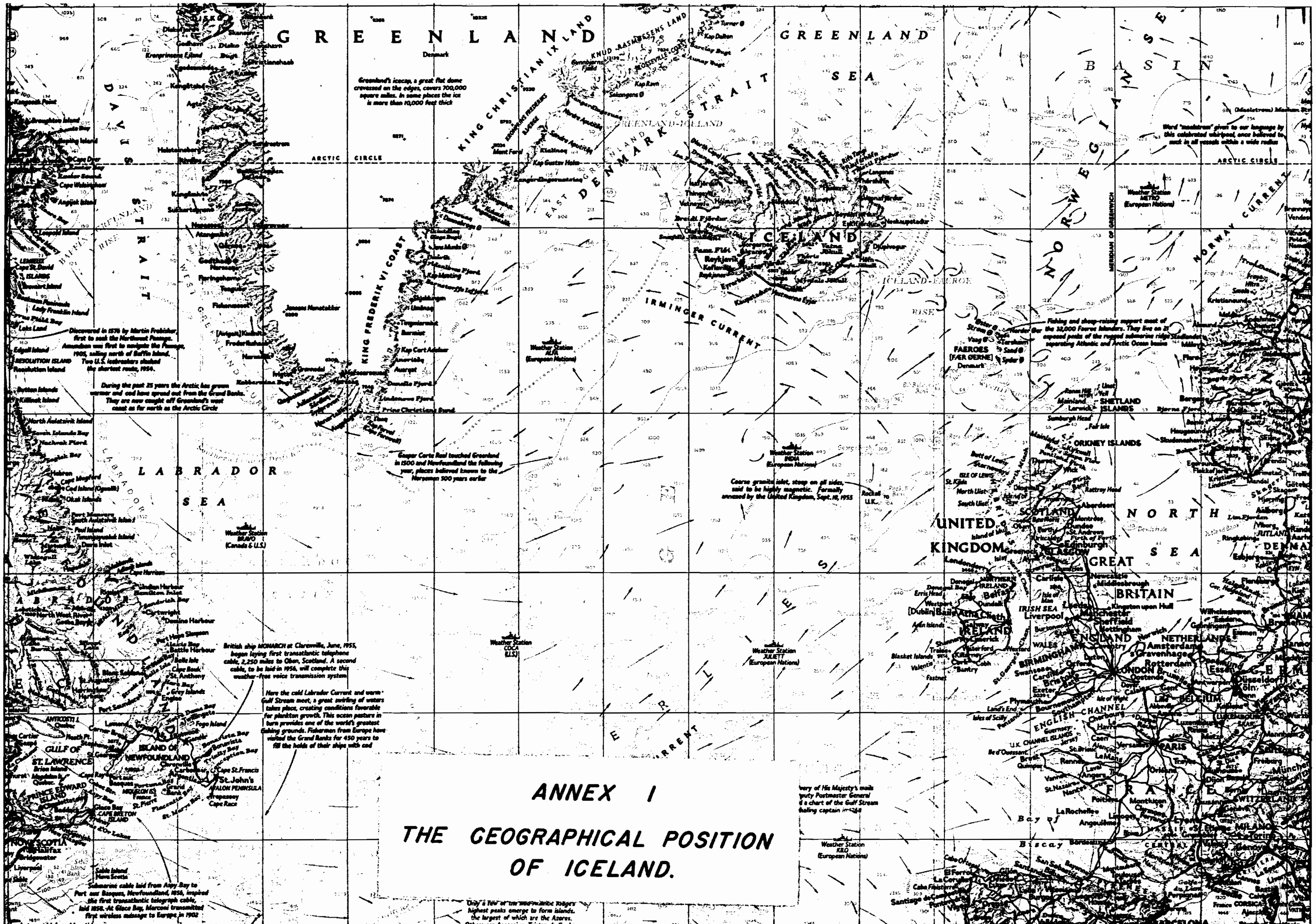
If a final decision to build an aluminium smelter in Iceland is reached early in 1963 or thereabout, power developments for the needs of the present consumption in the area and for the smelter will be combined in a single project, in all probability Búrfell. If, on the other hand, it becomes obvious by early 1963 that such a decision will not be reached for a considerable time, it will presumably be found necessary to construct a relatively small power plant to meet the requirements of the present power consumers. This plant will be either a geothermal plant or a hydro-plant, with an installation in the range 15-25 megawatts. This plant may be expected to be fully utilized 2-3 years after completion i.e. by 1968-´69, when another plant will have to be ready for operation. If a decision on an aluminium smelter is reached in sufficient time for Búrfell to be completed by that time, that plant will absorb the general power needs, in addition to those of the smelter; if not, the new power station will be designed for the general load alone. Its installation will probably not be less than 40-50 megawatts, and it will be constructed at some site on the Thjórsá or Hvítá or some of their tributaries.

The application of the results of the proposed Special Fund Project will be only a minor degree be affected by the alternatives described. If a final descision to build the smelter and the Búrfell plant is reached in early 1963, its construction must expectedly get under way ahead of completion of a Master Plan for the two river basins. However, the initial Búrfell project, while limited to a run-of-river development will permit the future provision of an upstream storage. Storage releases would justify an increase of generation at Búrfell and would alter its mode of operation. If the Special Fund Project is successfully completed within the time scheduled here, its results which will be an important contribution to the urgently needed Master Plan for the basins and, expectedly, also to a solution of the serious ice problems will become available sufficiently in advance of the required upstream storage development to be of direct use in the design of that development. Should a final decision on the smelter be delayed, the results can be used directly in the design of the first power plant, Búrfell or some other, to be constructed in the Thjórsá or Hvítá basins, outside the Sog.

In either case therefore, it may safely be concluded that the results of the proposed Special Fund Project will be utilized in actual construction work a few years after they become available.

ANNEX I

THE GEOGRAPHICAL POSITION OF ICELAND.



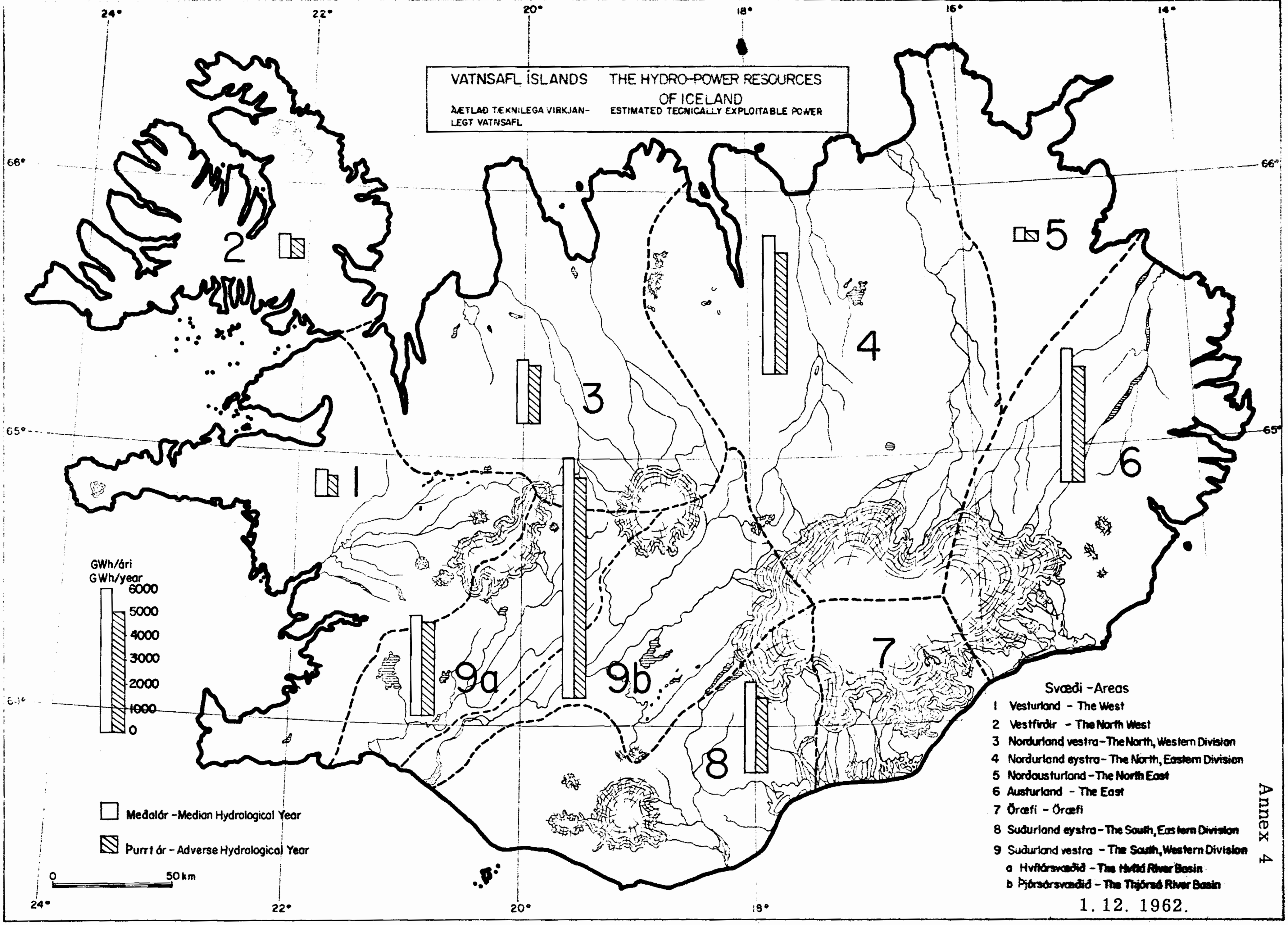
ESTIMATED TECHNICALLY
EXPLOITABLE ENERGY
IN EUROPE
RH/sg

Nr.	Country	GWh/year	kWh/inhabitant
1.	Iceland	31.000[1)]	174.850
2.	Norway	104.500	29.130
3.	Sweden	85.000	11.360
4.	Switzerland	33.000	6.230
5.	Austria	43.000	6.070
6.	Finland	17.000	3.820
7.	Yugoslavia	66.500	3.560
8.	Albania	5.000	3.110
9.	France	76.270	1.670
10.	Spain	48.000	1.590
11.	Romania	27.000	1.470
12.	Portugal	13.200	1.450
13.	Bulgaria	11.100	1.410
14.	Italy	60.000	1.220
15.	Czechoslovakia	12.000	880
16.	Greece	6.500	780
17.	W. Germany	25.165	470
18.	Poland	13.300	450
19.	Ireland	1.050	370
20.	Hungary	3.350	330
21.	Luxemburg	100	310
22.	United Kingdom	11.470	220
23.	E. Germany	2.000	120
24.	Belgium	545	60
25.	Denmark	50	10

[1)] In an adverse hydrological year.

Ref.: Economic Commission for Europe

Annex 4



1. 12. 1962.

B-O TNR242 FNR 6010

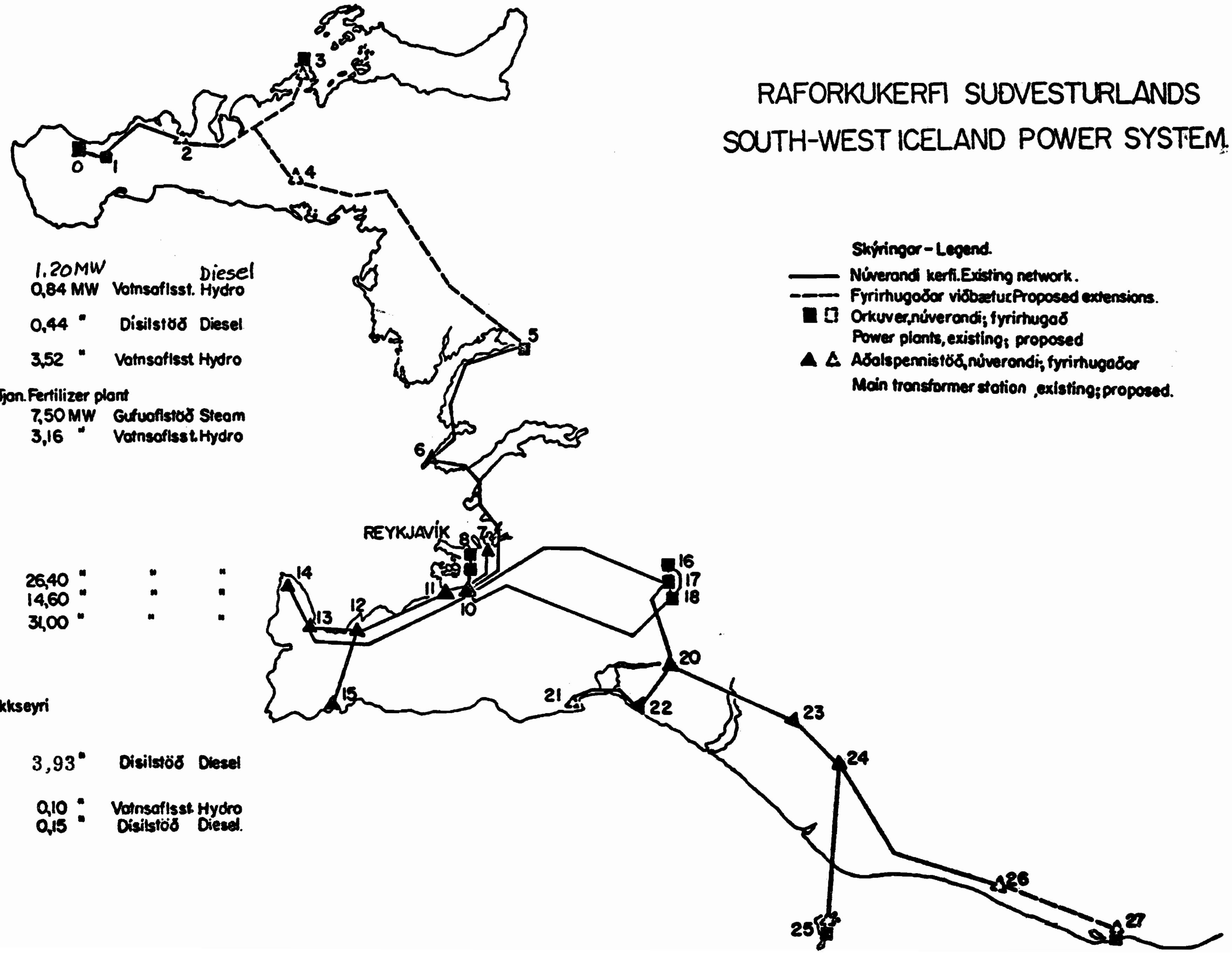
The Hydro-Power Resources of Iceland

Estimated technically Exploitable Energy

Hydrologic Districts			Median Year GWh			Adverse Year GWh
The South-West			1.205			984
The North-West			1.107			924
The North, Western Division			2,630			2.461
The North, Eastern Division:						
The Jökulsá River Basin:						
Dettifoss	2.060			1.870		
Vígabergsfoss	2.040	4.100		1.845	3.715	
Others		1.716	5.816		1.365	5.080
The North-East			614			467
The East			5.627			4.837
The South, Eastern Division			3.801			3.147
The South, Western Division:						
The Thjórsá River Basin:						
Bjallar	280			260		
Tungnaárkrókur	710			710		
Hrauneyjafoss	1.110			1.090		
Hald	278			270		
Hvanngiljafoss	175			140		
Dynkur	1.400			1.110		
Sultartangi or Búrfell[1)]	2.780			2.610		
Hjálp	650			600		
Skarð	850			815		
Búðafoss	333			325		
Urriðafoss	905			875		
Háifoss	246			220		
Other	283	10.000		175	9.200	
The Hvítá River Basin:						
Åbóti	173			160		
Sandárver	675			630		
Fremstaver	123			110		
Tungufell	985			960		
Haukholt	470			455		
Hestvatn	292			265		
Óri	223			200		
Selfoss	178			170		
Einholt	39			35		
Faxi	28			25		
Kálfá	27			24		
Efstidalur	161			146		
Reykir	22			20		
Dynjandi	45			40		
Steingrímsstöð	165			140		
Ljósafoss	130			110		
Írafoss	295			250		
Other	169	4.200	14.200	160	3.900	13.100
Grand Total			35.000			31.000

1) Alternative developments

RAFORKUKERFI SUDVESTURLANDS
SOUTH-WEST ICELAND POWER SYSTEM



0. 'Olafsvik	1,20 MW		Diesel
1. Rjúkandi,	0,84 MW	Vatnsaflsst.	Hydro
2. Grafarnes			
3. Stykkishólmur,	0,44 "	Dísilstöð	Diesel
4. Vegamót			
5. Andakíll	3,52 "	Vatnsaflsst	Hydro
6. Akranes			
7. Áburðarverksmiðjan. Fertilizer plant			
8. Varastöð	7,50 MW	Gufuaflstöð	Steam
9. Elliðaár	3,16 "	Vatnsaflsst.	Hydro
10. Elliðaár			
11. Hafnarfjörður			
12. Vogar			
13. Keflavík			
14. Gerðar			
15. Grindavík			
16. Steingrímsstöð	26,40 "	"	"
17. Ljósafoss	14,60 "	"	"
18. Írafoss	31,00 "	"	"
20. Selfoss			
21. Þorlákshöfn			
22. Eyrarbakki-Stokkseyri			
23. Hella			
24. Hvolsvöllur			
25. Vestmannaeyjar	3,93 "	Dísilstöð	Diesel
26. Skógar			
27. Vík í Mýrdal	0,10 "	Vatnsaflsst.	Hydro
	0,15 "	Dísilstöð	Diesel

Annex 7

GROSS POWER GENERATION IN
SOUTH-WESTERN ICELAND 1952-61
GWh

Power Plants	Type	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961
Ljósafoss	Hydro	110,1	110,5	85,9	90,9	102,3	104,5	105,0	110,7	96,1	103,5
Írafoss	"	-	15,2	166,5	207,2	211,9	213,6	221,5	234,5	209,7	215,5
Steingrímsstöð	"	-	-	-	-	-	-	-	0,2	94,3	123,9
Elliðaár	"	6,7	9,7	5,4	5,0	9,2	9,9	5,9	11,7	6,8	5,4
Elliðaár	Steam	29,5	21,5	0,6	0,3	0,2	0,4	1,0	2,8	1,6	0,1
Andakíll	Hydro	14,0	15,0	19,7	18,5	19,1	19,2	22,7	25,9	23,8	24,6
Total existing Sog System		160,3	171,9	278,1	321,9	342,7	347,6	356,1	385,8	432,3	473,0
Annual increase %		.	7,2	61,9	15,8	6,5	1,4	2,5	8,3	12,1	9,4
Rjúkandi	Hydro	-	-	* 1,0	1,2	1,9	2,4	3,3	3,3	3,6	3,7
Stykkishólmur	Diesel	* 0,5	* 0,5	* 0,5	* 0,5	* 0,5	* 0,5	* 0,5	0,8	1,1	1,3
Vestmannaeyjar	"	3,2	3,5	3,7	4,0	4,2	4,3	4,7	5,2	5,6	5,6
Vík í Mýrdal	Hydro	* 0,4	* 0,4	* 0,4	* 0,4	* 0,4	* 0,4	* 0,4	* 0,3	* 0,3	0,4
Total, S.W. Iceland		164,4	176,3	283,7	328,0	349,7	355,2	365,0	395,4	442,9	484,0
Annual increase %		.	7,2	60,9	15,6	6,6	1,6	2,8	8,3	12,0	9,3
Subdivision of load:											
General load		164,4	175,2	191,2	204,7	217,7	228,9	247,4	268,6	272,1	283,0
Annual increase %		.	6,6	9,1	7,1	6,3	5,2	8,1	8,6	1,3	4,1
Fertilizer Plant		-	1,1	92,5	123,3	132,0	126,3	111,3	113,3	142,7	151,7
Cement Plant		-	-	-	-	-	-	6,3	13,5	13,2	11,2
Keflavík Airport		-	-	-	-	-	-	-	-	14,9	38,1

Estimated Load Growth in Southwestern Iceland 1962-71

(Excluding possible power-consuming industries established during the period)

Year	General purpose load + Cement Plant GWh	Fertilizer Plant load GWh	Keflavik Airport Load GWh	Total load GWh
1962	290	120	40	450
63	312	120	40	472
64	333	120	40	493
65	356	120	40	516
66	381	120	40	541
67	406	120	40	566
68	435	120	40	595
69	464	120	40	624
70	495	120	40	655
71	529	120	40	689

Iceland Special Fund Project

Cost Estimate – Summary I

Item	Division of cost between Iceland and Special Fund										Total
	1963 - 1st year		1964 - 2nd year		1965 - 3rd year		1966 - 4th year		Total 1963 - 1966		
	Sp. Fund $	Iceland $	Sp. Fund $	Iceland $	Sp. Fund $	Iceland $	Sp. Fund $	Iceland $	Sp. Fund $	Iceland $	$
1. Personnel cost of foreign experts	40'000	–	83'300	–	30'000	–	–	–	153'300	–	153'300
2. Fellowships	4'580	3'600	12'080	8'570	10'000	5'125	2'920	2'575	29'580	19'870	49'450
3. Icelandic personnel cost	–	12'360	–	41'200	–	20'220	–	–	–	73'780	73'780
4. International travel cost. (excluding fellowship travel)	–	2'950	–	5'550	–	2'600	–	–	–	11'100	11'100
5. Travel cost in Iceland	–	990	–	1'540	–	770	–	–	–	3'300	3'300
6. Supplies and operation of research facilities	–	13'000	–	30'600	–	15'600	–	–	–	59'200	59'200
Transported	44'580	32'900	95'380	87'460	40'000	44'315	2'920	2'575	182'880	167'250	350'130

Iceland Special Fund Project

Cost Estimate - Summary; Cont'd

Item	Division of cost between Iceland and Special Fund										Total
	1963 - 1st year		1964 - 2nd year		1965 - 3rd year		1966 - 4th year		Total 1963-1966		
	Sp. Fund $	Iceland $	Sp. Fund $	Iceland $	Sp. Fund $	Iceland $	Sp. Fund $	Iceland $	Sp. Fund $	Iceland $	$
Transported	44'580	32'900	95'380	87'460	40'000	44'315	2'920	2'575	182'880	167'250	350'130
7. Quarters allowance	-	2'880	-	6'000	-	2'160	-	-	-	11'040	11'040
8. Office rental + operation; utilities	-	8'040	-	5'200	-	4'900	-	-	-	18'140	18'140
9. International per diem	-	150	-	500	-	350	-	-	-	1'000	1'000
10. Electronic Computer Service	500	-	15'675	-	1'500	-	-	-	17'675	-	17'675
11. Equipment + Construction	63'645	68'400	44'305	59'150	2'300	2'200	-	-	110'250	129'750	240'000
Subtotal	108'725	112'370	155'360	158'310	43'800	53'925	2'920	2'575	310'805	327'180	637'985
Contingencies 10% ±	11'275	11'630	15'640	15'690	4'200	5'075	80	425	31'195	32'820	64'015
Total	120'000	124'000	171'000	174'000	48'000	59'000	3'000	3'000	342'000	360'000	702'000

Iceland Special Fund Project

Cost Estimate - Summary II

Item	Division of cost between Iceland and Special Fund										Total $
	1963 - 1st year		1964 - 2nd year		1965 - 3rd year		1966 - 4th year		Total 1963-1966		
	Sp. Fund $	Iceland $	Sp. Fund $	Iceland $	Sp. Fund $	Iceland $	Sp. Fund $	Iceland $	Sp. Fund $	Iceland $	
1. Load Growth Studies in South-Western Iceland	4'120	2'590	10400	5'880	450	1'770	-	-	14'970	10'240	25'210
2. Schedule of Energy Developments for Hvita and Thjorsa River Basins	42'895	33'740	64'285	40'520	22'640	16'750	2'090	1'825	131'910	92'835	224'745
3. Ice Research center	61'710	59'040	51'705	84'220	17'090	30'130	830	750	131'335	174'140	305'475
4. Soil + Rock Testing Laboratory	-	17'000	28'970	27'690	3'620	5'275	-	-	32'590	49'965	82'555
Subtotal	108'725	112'370	155'360	158'310	43'800	53'925	2'920	2'575	310'805	327'180	637'985
Contingencies 10%±	11'275	11'630	15'640	15'690	4'200	5'075	80	425	31'195	32'820	64'015
Total	120'000	124'000	171'000	174'000	48'000	59'000	3'000	3'000	342'000	360'000	702'000

Iceland Special Fund Project

Cost Estimate - Summary III

Category	Cost borne by Special Fund $	Cost borne by Icelandic Government $	Total Cost $
1. Load Growth Studies in Southwestern Iceland	16'600	11'200	27'800
2. Schedule of Energy Developments for Hvítá and Thjorsá River Basins	144'900	102'100	247'000
3. Ice Research Center	144'700	191'700	336'400
4. Soil and Rock Testing Laboratory	35'800	55'000	90'800
Total	342'000	360'000	702'000

Iceland Special Fund Project

Proposed Schedule for the Work of Foreign Experts

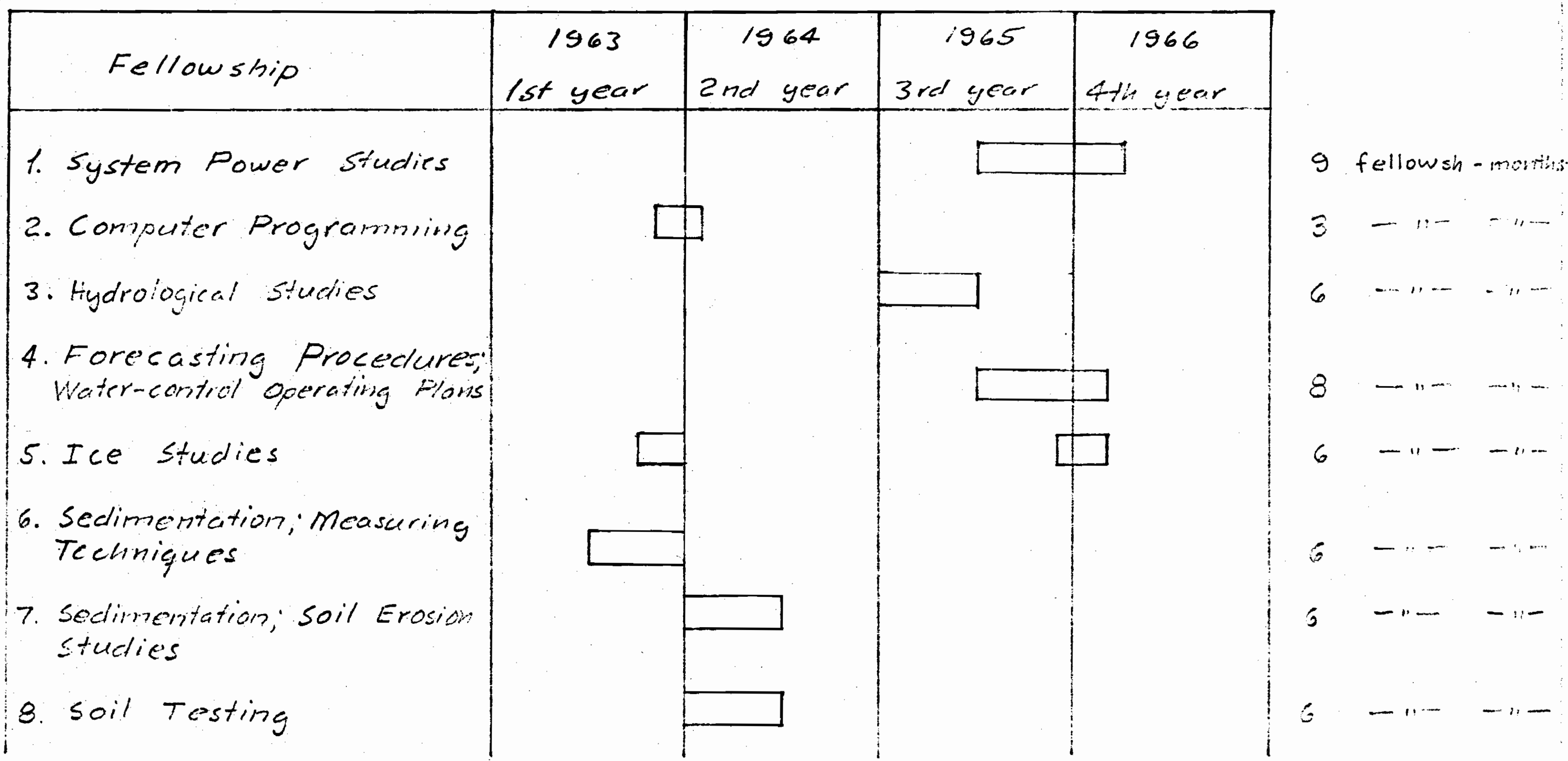
Experts	1963 1st. year	1964 2nd year	1965 3rd year	
1. Project Manager				24 man-months
2. System Power Specialist				18 -"- -"-
3. Hydrologist				18 -"- -"-
4. Ice Specialist				24 -"- -"-
5. Power Marketing Specialist				6 -"- -"-
6. Soil + Rock Testing Specialist				2 -"- -"-

Total: 92 man-months

Cost:
92 man-months = 7.67 man-years @ $ 20'000 = $ 153.300

Iceland Special Fund Project

Proposed Fellowship Schedule



cont.

Iceland Special Fund Project

Proposed Fellowship Schedule

Fellowship	1963 1st year	1964 2nd year	1965 3rd year	1966 4 th year	
9. Rock Mechanics + Testing					9 fellowsh.-months
10. Power Marketing					6 — " — — " —
11. Model Construction and Instrument Maintenance					6 — " — — " —

Total: 71 fellowsh.-month

Cost:
71 fellowship-month = 5.92 fellowship-years @ $ 5'000 = $ 29'580

Iceland Special Fund Project

Icelandic Fellowship Cost

Position	Fellowship	Duration, months	Cost of Allowance per month $	Cost of Allowance Total $	Travel cost @ $300/R.T. ticket No. of R.T. tickets	Travel cost Cost $	Total Cost $	Total cost per year $ 1963	1964	1965	1966
Engineer	Computer progr. (single)	3	300	900	1	300	1200	750	450	–	–
	System power (family)	9	125	1125	4	1200	2325	–	–	1350	975
Engineer	Hydrological studies (f)	6	125	750	} 4	1200	1350	–	–	1350	–
	Forecasting procedures (f)	8	125	1000			1600	–	–	750	850
Engineer	Ice Studies (s)	3	300	900	1	300	1200	1200	–	–	–
	—"— —"— (s)	3	300	900	1	300	1200	–	–	450	750
Field Hydrologist	Sedim. Meas. Techniques (f)	6	125	750	3	900	1650	1650	–	–	–
Engineer	Sedim. Soil erosion (f)	6	125	750	4	1200	1950	–	1950	–	–
Lab. Technician	Soil testing (f)	6	85	510	3	900	1410	–	1410	–	–
Eng. or Geol.	Rock Mech. + Testing (f)	9	125	1125	4	1200	2325	–	1100	1225	–
Economist	Power Marketing (f)	6	125	750	4	1200	1950	–	1950	–	–
Mechanic	Model const. etc. (f)	6	85	510	4	1200	1710	–	1710	–	–
	Totals	71		9'970		9'900	19'870	3600	8570	5125	2575

Iceland Special Fund Project

List of Personnel

Foreign Experts		Counterpart Personnel (Icelandic)			
Position	Duration; months	Position	Duration - months: In Iceland	Fellowship	Total
Project Manager	24	Typist - stenographer	24	–	24
		Supply clerk	24	–	24
		Accountant	8[1]	–	8
		Typist	24	–	24
System Power Specialist	18	Engineer	21	12	33
		Assistant	21	–	21
Hydrologist	18	Engineer	18	14	32
		Assistant	18	–	18
Ice Specialist	24	Engineer (office + lab)	21	6	27
		Assistant (-"- -"-)	24	–	24
		Mechanic	12	6	18
		Field Hydrologist	18	6	24
		Field Assistant	18	–	18
Power Marketing Specialist	6	Economist	10[2]	6	16
Soil + Rock Testing Specialist	2	Engineer or Geologist	1	9	10
		Laboratory Technician	12	6	18
		Engineer (soil erosion studies)	6[3]	6	12

Notes:

1) Part-time job (1/3)
2) Full-time job while foreign expert is here but part-time job (1/2) after returning from fellowship
3) Part-time job (1/2) after returning from fellowship.

Iceland Special Fund Project

Icelandic Personnel Cost

Position	Working in Iceland months	Salary $/month	Cost per year - $ 1963	1964	1965	Total Cost $
Typist-stenographer	24	200	1'200	2'400	1'200	4'800
Supply clerk	24	200	1'200	2'400	1'200	4'800
Accountant	8	250	500	1'000	500	2'000
Typist	24	150	900	1'800	900	3'600
Engineer (System Power)	21	400	1600	4'400	2'400	8'400
Assistant (-"- -"-)	21	160	640	1'760	960	3'360
Engineer (Hydrology)	18	400	2'400	4'800	–	7'200
Assistant (-"-)	18	160	960	1'920	–	2'880
Engineer (Ice Studies)	21	400	1'200	4'800	2'400	8'400
Assistant (-"- -"-)	24	160	960	1'920	960	3'840
Mechanic	12	250	–	1'500	1'500	3'000
Field Hydralogist	18	400	–	4'800	2'400	7'200
Field Assistant	18	250	–	3'000	1'500	4'500
Economist (Power Marketing).	10	400	800	2'000	1 200	4'000
Engineer or Geologist (Rock Mech. + Testing)	1	400	–	–	400	400
Lab. Technician (soil lab.)	12	250	–	1'500	1'500	3'000
Engineer (soil erosion studies)	6	400	–	1'200	1'200	2'400
Total:			12'360	41'200	20'220	73'780

Iceland Special Fund Project

International Travel

Traveller	No. of R.T. tickets	Total Cost @ $ 300 per R.T. ticket $	Total cost per year $		
			1963	1964	1965
Project Manager (family)	9	2700	600	1500	600
System Power Sp. (family)	5	1500	300	600	600
Hydrologist (family)	4	1200	600	600	–
Ice Specialist (family)	7	2100	600	900	600
Power Marketing Sp. (fam)	3	900	450	450	–
Soil + Rock Test. Sp. (single)	1	300	–	300	–
Conference Trips	8	2400	400	1200	800
	37	11'100	2'950	5'550	2'600

Travel Cost Within Iceland

Item	Total Cost $	Cost per year $		
		1963	1964	1965
Subsistence cost of personnel while travelling in Iceland – (Lump Sum)	3000	900	1400	700
Air travel within Iceland (L.S.)	300	90	140	70
	3'300	990	1540	770

Iceland Special Fund Project

Supplies and Operating Cost of Research Facilities

Ice Research Center:

Utilities @ $50 per month for 12 months =	600
Supplies (Lump Sum)	3000
Misc. expenses (L.S.)	1000
Total	4600

Soil + Rock Testing Laboratory

Utilities @ $ 50 per month for 12 months =	600
Supplies (L.S.)	1000
Misc expenses (L.S.)	1000
Total	2600

Field Surveys:

Aerial ice surveys (L.S.)	15 000
2 years operation of 4 jeeps @ $1500 per jeep per year	12 000
2 years operation of 2 snow tractors @ $ 2000 per tractor per year	8 000
2 years operation of 2 trucks @ $ 3000 per truck per year	12 000
Operation and maintenance of field recording stations (L.S.)	5 000
Total	52 000

Item	Cost per year $			Total cost
	1963	1964	1965	
Utilities	–	600	600	1200
Supplies + misc. expenses	–	4000	2000	6000
Aerial ice survey	4000	7000	4000	15000
Operation vehicles + field sta	9000	19000	9000	37000
Total	13 000	30 600	15 600	59 200

Iceland Special Fund Project

Quarters Allowance of Foreign Experts

92 man-months @ $120 per man-month = $11'040

Office Rental and Operation. - Utilities

Office rental - 200 m² for $ 240 per month for 24 months	5'760
Office furniture and equipment (L.S.)	5'500
Telephones @ $ 60 per month - 24 months	1'440
Office supplies $ 60 " —"— —" —	1'440
Publications; reproductions etc. (L.S.)	4'000
Total	18'140

International per Diem

L.S. 1'000

Iceland Special Fund Project

Electronic Computer Service

1. Electronic computer time 160 hrs @ $ 75 per hr	=	12·000
2. Data card punching time 650 hrs @ $. 7.50 per hr	=	4·875
3. Other misc. services 160 hrs @ $ 5.00 per hr	=	800
	Total	17·675

Iceland Special Fund Project

Cost Estimate – Equipment and Construction

Item	Quantity	Unit Cost $	Portion of Cost Assumed by		Total Cost $
			Spec. Fund $	Iceland $	
A. For Ice Surveys:					
1. Aerial Camera	1	1000	1000		1000
2. Cameras 35 mm stereo	2	300	600	–	600
3. Snow shoes, skiis, winter clothing tents, stoves etc.		Lump Sum	500	300	800
4. Hand Operated Core Drill for Ice	1	1500	1400	100	1500
5. Snow Sampling Sets	2	250	500		500
6. Balances, Thermometers and Misc. Labware		Lump Sum	800	200	1000
7. Misc. stream gaging accessories		Lump Sum	300	200	500
8. Gage house and well	2	4 500	3000	6000	9000
9. Water stage recorders	2	475	950		950
10. Cableways	3	2000	1500	4500	6000
11. Precipitation recorders	12				
12. Anemometers and recorders	7				
13. Wind direction meters & recorders	7				
14. Thermometers and recorders	7				
15. Barometers and recorders	7				
16. Sunshine meters and recorders	7				
Meterologic instrum.; total	47	350	14 000	2500	16500
17. Totalizers (rain gages)	20	25		500	500
18. Movie Cameras	10	800	7000	1000	8000
19. Thermometers for existing stage recorders	10	300	3000		3000
20. Projector	1	200	200		200
21. Amplifiers + recorders	2	2500	5000		5000
22. Transducers	5	300	1000	500	1500
23. Geiger-counter	1	3000	3000		3000
24. Pumps and motors		L.S.	1500		1500
25. Refrigeration system	1		800		800
26. Hook Gages	10	70	700		700
27. Midget Current meter	1	165	165		165
28. Pitot tubes	2	70	140		140
29. Manometers	5	50	250		250
30. Misc. instruments		L.S.	500	300	800
31. Flumes and Piping system		L.S.	1500	4500	6000
32. Pump bay, sumps etc.				1500	1500
33. Calorimetric instrumentation		L.S.	2000		2000
Subtotal; Ice Research			51'305	22 100	73'405

Iceland Special Fund Project

Cost Estimate - Equipment and Construction; Cont'd.

Item	Quantity	Unit Cost $	Portion of Cost Assumed by Sp. Fund $	Portion of Cost Assumed by Iceland $	Total Cost
B. Machine Shop		L.S.	5000	1500	6500
C. Soil and Rock Testing Lab.					
1. Soiltest type X-100 complete lab		L.S.	15000	-	15000
2. High Pressure Triaxial Chamber	1	4000	4000	-	4000
3. Testing Machine for Rock Cores	1	2000	2000	-	2000
Subtotal Soil & Rock lab			21000	-	21000
D. Soil Erosion Studies		L.S.	1000	2000	3000
E. Stream Gaging Equipment:					
1. Gage house and well	3	4500	4500	9000	13500
2. Cableways	3	2000	1500	4500	6000
3. Water Stage recorders	3	475	1425	-	1425
4. Current meters	3	250	750	-	750
5. Sediment samplers	2	250	500	-	500
6. Hand reels	2	35	70	-	70
7. Type B. reel	2	275	550	-	550
8. Snow shoes, skiis, tents etc.		L.S.	500	300	800
9. Misc. stream gaging equipm.		L.S.	1500	500	2000
10. Aluminum boats (16 ft)	2	300	600	-	600
11. Outboard motors (10 h.p.)	2	250	500	-	500
12. Misc. boat supplies		L.S.	250	-	250
Subtotal, stream gaging equipm.			12645	14300	26945
F. Special Vehicles					
Jeeps	4	2000	8000	-	8000
Snow tractors	2	2600	4700	500	5.200
Trucks (3 tonns)	2	5000	6600	3400	10.000
Subtotal Vehicles:			19300	3900	23200
G. Construction					
Ice Research Lab	1000 m³	30	-	30000	30000
Machine shop	180 m³	40	-	7200	7200
Soil and Rock Testing Lab.	600 m³	40	-	24000	24000
Storage for rock cores	300 m³	30	-	9000	9000
Offices - rest rooms etc	150 m³	45	-	6750	6750
Subtotal construction			-	76950	76950
H Shipment cost (8% of $ 110.250)			-	9000	9000
Grand total, equipm. + const.			110250	129750	240000

Iceland Special Fund Project

Cost Estimate - Equipment + Construction

Item	Division of cost between Iceland and Special Fund								Total
	1963 - 1st year		1964 - 2nd year		1965 - 3rd year		Total 1963-1965		
	Sp. Fund $	Iceland $	Sp. Fund $	Iceland $	Sp. Fund $	Iceland $	Sp. Fund $	Iceland $	$
1. Ice research equipment	34'000	14'500	16'305	6'600	1 000	1'000	51'305	22'100	73'405
2. Machine shop equipment	500	300	4'200	900	300	300	5'000	1'500	6'500
3. Soil and rock testing equipm	-	-	20'500	-	500	-	21'000	-	21'000
4. Equipm. for soil erosion studies	-	-	800	1 600	200	400	1'000	2'000	3'000
5. Stream gaging equipment	9'845	9'500	2'500	4'500	300	300	12'645	14'300	26'945
6. Vehicles	19'300	3'900	-	-	-	-	19'300	3'900	23'200
7. Construction	-	35'000	-	41'950	-	-	-	76'950	76'950
8. Shipment cost (8% of S.F. cost)	-	5 200	-	3'600	-	200	-	9'000	9'000
Total	63.645	68'400	44'305	59'150	2'300	2'200	110'250	129'750	240'000

Iceland Special Fund Project

Division of Costs by Categories and Years

			Personal cost of foreign exp.	Fellowships	Icelandic personnel cost	International travel cost	Travel cost in Iceland	Supplies and operation of research fac.	Quarters allowance	Office rental	International per diem	Electronic computer service	Equipment and construction	Subtotal	Distribution of general exp.	Subtotal	Contingencies 10% ±	Total
			$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
General Expenses	1963	S.F	10.000	–	–	–	–	–	–	–	–	–	–	10.000	-10.000	0		
		Ice	–	–	3.800	700	–	–	720	8.040	160	–	–	13.410	-13.410	0		
	1964	S.F	20.000	–	–	–	–	–	–	–	–	–	–	20.000	-20.000	0		
		Ice.	–	–	7.600	1.800	–	–	1.400	5.200	500	–	–	16.540	-16.540	0		
	1965	S.F	10.000	–	–	–	–	–	–	–	–	–	–	10.000	-10.000	0		
		Ice.	–	–	3.800	800	–	–	720	4.900	350	–	–	10.570	-10.570	0		
	Total	S.F	40.000	–	–	–	–	–	–	–	–	–	–	40.000	-40.000	0		
		Ice.	–	–	15.200	3.300	–	–	2.880	18.140	1.000	–	–	40.520	-40.520	0		
Leaf Growth Studies	1963	S.F.	3.300	–	–	–	–	–	–	–	–	–	–	3.300	820	4.120	480	4.600
		Ice.	–	–	800	450	–	–	240	–	–	–	–	1.490	1.100	2.590	310	2.900
	1964	S.F	6.700	2.500	–	–	–	–	–	–	–	–	–	9.200	1.200	10.400	1.100	11.500
		Ice.	–	1.950	2.000	450	–	–	480	–	–	–	–	4.880	1.000	5.880	520	6.400
	1965	S.F	–	–	–	–	–	–	–	–	–	–	–	–	450	450	50	500
		Ice	–	–	1.200	100	–	–	–	–	–	–	–	1.300	470	1.770	130	1.900
	Total	S.F	10.000	2.500	–	–	–	–	–	–	–	–	–	12.500	2.470	14.970	1.630	16.600
		Ice	–	1.950	4.000	1.000	–	–	720	–	–	–	–	7.670	2.570	10.240	960	11.200
Schedule of Energy Developm.	1963	S.F	16.700	3.300	–	–	–	–	–	–	–	500	16.245	36.775	6.120	42.895	4.405	47.300
		Ice.	–	2.400	5.600	900	330	3.000	1.200	–	–	–	12.100	25.530	8.210	33.740	3.460	37.200
	1964	S.F.	33.300	2.910	–	–	–	–	–	–	–	15.675	3.300	55.185	9.100	64.285	6.415	70.700
		Ice	–	2.400	14.080	1.500	340	6.000	2.400	–	–	–	6.300	33.020	7.500	40.520	4.080	44.600
	1965	S.F.	10.000	7.500	–	–	–	–	–	–	–	1.500	500	19.500	3.140	22.640	2.160	24.800
		Ice.	–	3.450	4.560	800	170	3.000	720	–	–	–	750	13.450	3.300	16.750	1.550	18.300
	1966	S.F	–	2.090	–	–	–	–	–	–	–	–	–	2.090	–	2.090	10	2.100
		Ice.	–	1.825	–	–	–	–	–	–	–	–	–	1.825	–	1.825	175	2.000
	Total	S.F	60.000	15.830	–	–	–	–	–	–	–	17.675	20.045	113.550	18.360	131.910	12.990	144.900
		Ice.	–	10.075	24.240	3.200	840	12.000	4.320	–	–	–	19.150	73.825	19.010	92.835	9.265	102.100
Ice Research Center	1963	S.F.	10.000	1.250	–	–	–	–	–	–	–	–	47.400	58.650	3.060	61.710	6.390	68.100
		Ice	–	1.200	2.160	900	660	10.000	720	–	–	–	39.300	54.940	4.100	59.040	6.060	65.100
	1964	S.F	20.000	2.500	–	–	–	–	–	–	–	–	20.505	43.005	8.700	51.705	5.295	57.000
		Ice	–	1.710	16.020	1.600	1.200	23.000	1.440	–	–	–	32.150	77.020	7.200	84.220	8.380	92.600
	1965	S.F	10.000	420	–	–	–	–	–	–	–	–	1.300	11.720	5.370	17.090	1.610	18.700
		Ice	–	450	8.760	900	600	11.600	720	–	–	–	1.400	24.430	5.700	30.130	2.870	33.000
	1966	S.F	–	830	–	–	–	–	–	–	–	–	–	830	–	830	70	900
		Ice	–	750	–	–	–	–	–	–	–	–	–	750	–	750	250	1.000
	Total	S.F.	40.000	5.000	–	–	–	–	–	–	–	–	69.205	114.205	17.130	131.335	13.365	144.700
		Ice.	–	4.110	26.940	3.300	2.460	44.600	2.880	–	–	–	72.850	157.140	17.000	174.140	17.560	191.700
Soil and Rock Testing	1963	S.F.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
		Ice	–	–	–	–	–	–	–	–	–	–	17.000	17.000	–	17.000	1.800	18.800
	1964	S.F	3.300	4.170	–	–	–	–	–	–	–	–	20.500	27.970	1.000	28.970	2.830	31.800
		Ice	–	2.510	1.800	300	–	1.600	240	–	–	–	20.700	26.850	840	27.690	2.710	30.400
	1965	S.F	–	2.080	–	–	–	–	–	–	–	–	500	2.580	1.040	3.620	380	4.000
		Ice	–	1.225	1.900	–	–	1.000	–	–	–	–	50	4.175	1.100	5.275	525	5.800
	Total	S.F	3.300	6.250	–	–	–	–	–	–	–	–	21.000	30.550	2.040	32.590	3.210	35.800
		Ice	–	3.735	3.400	300	–	2.600	240	–	–	–	37.750	48.025	1.940	49.965	5.035	55.000
Total Costs	1963	S.F	40.000	4.580	–	–	–	–	–	–	–	500	63.645	108.725	–	108.725	11.275	120.000
		Ice	–	3.600	12.360	2.950	990	13.000	2.880	8.040	160	–	68.400	112.370	–	112.370	11.630	124.000
	1964	S.F.	53.300	12.080	–	–	–	–	–	–	–	15.675	44.305	155.360	–	155.360	15.640	171.000
		Ice	–	8.570	41.200	5.550	1.540	30.600	6.000	5.200	500	–	59.150	158.310	–	158.310	15.690	174.000
	1965	S.F	30.000	10.000	–	–	–	–	–	–	–	1.500	2.300	43.800	–	43.800	4.200	48.000
		Ice	–	5.125	20.220	2.600	770	15.600	2.160	4.900	350	–	2.200	53.925	–	53.925	5.075	59.000
	1966	S.F	–	2.920	–	–	–	–	–	–	–	–	–	2.920	–	2.920	80	3.000
		Ice	–	2.575	–	–	–	–	–	–	–	–	–	2.575	–	2.575	425	3.000
	Total	S.F	153.300	29.580	–	–	–	–	–	–	–	17.675	110.250	310.805	–	310.805	31.195	342.000
		Ice	–	19.870	73.780	11.100	3.300	59.200	11.040	18.140	1.000	–	129.750	327.180	–	327.180	32.820	360.000
	Comb. Total		153.300	49.450	73.780	11.100	3.300	59.200	11.040	18.140	1.000	17.675	240.000	637.985	–	637.985	64.015	702.000