PROJECT PLANNING REPORT VOLUME I

BURFELL PROJECT

BY THE

HARZA ENGINEERING COMPANY INTERNATIONAL

PREPARED FOR

THE STATE ELECTRICITY AUTHORITY
GOVERNMENT OF ICELAND

JANUARY 1963

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HARZA ENGINEERING COMPANY INTERNATIONAL
CONSULTING ENGINEERS
RIVER PROJECTS

OFFICES
TEHRAN, IRAN
BAGHDAD, IRAQ
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TEGUCIGALPA, HONDURAS
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LAHORE, WEST PAKISTAN
AMMAN, JORDAN
TAIPEI, TAIWAN

REPRESENTED IN THE UNITED STATES BY
HARZA ENGINEERING COMPANY
CHICAGO, ILLINOIS

January 24, 1963

CABLE ADDRESS "HARZINT"

ADDRESS REPLY TO
HARZA ENGINEERING COMPANY
FOR THE ACCOUNT OF
HARZA ENGINEERING COMPANY INTERNATIONAL
400 WEST MADISON STREET
CHICAGO 6, ILLINOIS

TELEX NUMBER CG 1-4385

BURFELL HYDROELECTRIC PROJECT

SUMMARY OF REPORT

The State Electricity Authority
P. O. Box 40
Reykjavik, Iceland

Gentlemen:

Introduction

We are pleased to present our Project Planning Report on the Burfell Hydroelectric Project. The Report is presented in two Volumes, Volume I represents the main body of the Report and summarizes our engineering investigations and studies on the Project to date. Volume II contains supplementary information of a detailed nature, primarily of interest to technical specialists. That Volume contains Appendices on hydraulics and hydrology, geology, natural construction materials, and Thorisvatn initial storage.

Volume I consists of seven Chapters. Chapter I is an "Engineering Summary" which briefs, for the general interest reader, the more detailed engineering data presented in the subsequent six Chapters. Economic data is presented in Chapter II.

Our engineering interest in the Burfell Project began in 1959 with general studies of the hydroelectric potential of the Thjorsa and Hvita Basins which were presented in our Advisory Report of March 1960. These general studies indicated that Burfell, with its great flow and high head concentration, might be the most attractive large hydroelectric potential as a single development in Southwest Iceland. Somewhat more detailed investigations and studies in 1961 and early 1962 led to the decision by the State Electricity Authority (SEA) to proceed with the investigations and studies which are summarized in this Report.

Concurrently, the need to industrialize in Iceland became apparent to the extent that the Government opened preliminary negotiations to attract an aluminium smeltering load as a first large step in developing Iceland's huge hydroelectric resources. Further, it was apparent that additional resources were required to meet the normal load growth of the Southwest Iceland System.

Selection of Size of Installation

During the late months of 1962, we appraised a development of 60,000 kilowatts at Burfell which was designed only to meet the normal load growth, but which could be expanded readily to supply a large industrial load. Even this relatively small initial development appeared to us to be attractive economically in comparison to other and smaller developments which we have studied in similar detail in Iceland.

The preliminary negotiations with aluminium interests indicated that an initial smelter in Iceland might have from one to two potlines in half-potline increments, with the smallest possibly enlarged within a few years after initial operation. The demand for each half-potline might vary between about 25,000 and 30,000 kilowatts depending on plant design. Studies by SEA of normal system load growth pointed to the need for 30,000 to 60,000 kilowatts of additional capacity within a few years. Using the higher of these estimates we selected an installed rated capacity of 180,000 kilowatts in six units as the basic design for the initial hydroelectric development at Burfell. The Burfell Project thus is planned to serve two maximum size potlines plus a large increment of normal load.

Because the first smelter installation might be smaller than the above maximum and because the normal load would grow progressively, we made cost estimates of initial installation of four units and of five units in the basic six-unit plant. These last units would be added in the vacant bays as required. Pertinent data with respect to these installations is as follows:

Number of Units	Installed Rated Capacity (kw)	Delivered Annual Primary Energy Production (millions of kwh)*	Required Flow (cubic meters per second)	Percent of Time Required Flow is Available
4	120,000	940	116	99.8
5	150,000	1160	145	98
6	180,000	1375	174	91

* With one transmission line.

The power and energy estimates are presented in Chapter VI.

Description of Project

The Burfell Project will be located approximately 86 kilometers upstream of the mouth of the Thjorsa where the river falls about 120 meters in 13 kilometers as it circles the south end of the mountain, Burfell. The Project will be a run-of-river development with daily pondage only, and the initial stage as presented in this Report will develop the minimum dependable flow of the River. Physical factors of the Thjorsa are presented in Chapter III, and of the site in Chapter IV.

The plan of development is based on the results of extensive field investigations, discussed in Chapter IV, conducted at the selected site beginning early in 1962. These investigations are continuing. The office studies covered a number of alternatives for each Project structure prior to adoption of the selected design. The arrangement of the Project features is discussed in detail in Chapter V.

The Project, as planned, consists of two main components, the power production facilities and the transmission facilities. The former are shown in plan and section on the attached Exhibit A. They consist of three main features: (1) diversion works to divert the river into, (2) the Bjarnalaekur Pond, and (3) the power features. The power features include the intake and penstocks, the powerstation, and the tailrace. The recommended transmission system includes a single circuit 230-kv line from Burfell to the Reykjavik area, sending and receiving substations, and a tie to the existing system in Reykjavik. Alternatives are presented for the terminal substation at Eidi and at Straumsvik. Further, costs are also presented for two circuits by separate routes extending to each of these terminals. A major industrial customer may desire the somewhat greater dependability of two circuits.

River ice represents the only major operation problem which might develop. We are confident that the final designs can solve this problem satisfactorily. A possible cost contingency exists if it develops ultimately that a supplemental supply of ice sluicing water, such as from an initial development at Thorisvatn, becomes necessary. This could increase costs on the order of up to about five percent.

Operating experience with the existing transmission line from the Sog to Reykjavik indicates that no serious operation problems, such as wind or ice, will exist with a line from Burfell. Therefore, we consider that provision of a single 230-kv transmission line is adequate for the planned Burfell Project.

Construction Time

The Burfell Project as planned can be completed within three years after initiation of construction. The planning has been based on unusually thorough and extensive field investigations. No major design or construction problem which would seriously affect costs adversely is apparent or considered probable. The construction of the Project is discussed in Chapter VII.

Cost Estimates

Cost estimates were prepared for the basic six-unit power production plant with four, five, or six units installed initially. Cost estimates were also prepared for the transmission plant with the alternatives of one or two circuits to each of the two terminals, Eidi and Straumsvik--a total of four estimates. The cost estimates are discussed in detail in Chapter II.

Each of the cost estimates is presented to show the total investment. Each total investment was determined by adding allowances for contingencies, engineering and overhead, and construction interest to the estimated direct cost. No allowances were included for one year of interest reserve, which might be desired by some financing agencies, or for working capital. None of the estimates include any allowance for import duties and taxes. All estimates are presented in United States Dollars. An exchange rate of 43 Icelandic Kronur to one U. S. Dollar was used where appropriate in the detail of each estimate.

The total investment required for the various installations with the terminal substation at Eidi was estimated as follows:

	Four Units	Five Units	Six Units
Production Plant	$25, 400, 000	$26, 700, 000	$27, 700, 000
Transmission Plant	3, 800, 000	4, 100, 000	4, 100, 000
Total	$29, 200, 000	$30, 800, 000	$31, 800, 000

These estimates are based on a single circuit transmission line. The addition of the second line, by the Southern route, would increase each of the three totals about $2, 600, 000. The increase of each with the terminal at Straumsvik would be $300, 000 for one transmission line and $3, 000, 000 for two lines.

Estimates were prepared for items of annual cost not controlled by financing terms. These items include operation and maintenance costs, compensation for water rights, and reserves to provide for extraordinary replacement costs not included in normal maintenance or covered by insurance. These annual costs, based on a single transmission line to either terminal, are estimated as follows:

Number of Units	Annual Costs Other Than Debt Service
4	$745, 000
5	840, 000
6	910, 000

The provision of the second transmission line would add about $50,000 to these annual costs.

The appropriate debt service would be added to each of these above annual costs in order to estimate total annual charges. Inasmuch as financing terms have not been established, it is not possible at this time to estimate debt service exactly. However, we have calculated the annual debt service for the range between the lowest and highest expected terms; i.e., 5 percent and 9 percent of the total estimated project investment.

Using the estimated annual costs other than debt service and the range of debt service shown above, we have computed the estimated unit costs of primary energy for the Project. These energy cost estimates are shown graphically on the attached Exhibit B in the range between 5 and 9 percent. Alternative projects include 4, 5, and 6 units installed initially, and one or two transmission lines for each installation. The estimates of Exhibit B are for the terminal substation located at Eidi. Comparable unit energy costs for Straumsvik delivery would be only about one percent higher, which is negligible for an estimate of this type.

The unit energy costs as estimated on Exhibit B represent to the owner, the Government of Iceland, average costs only. The selling price of the energy should include a further allowance to the owner for reserves needed during the first few years of load development, for bad business years, and possibly to provide cash funds for expansion studies and other system betterments. These further allowances may amount to as much as ten percent of the costs.

Conclusion

We conclude on the basis of our studies that the Burfell Project is feasible technically and attractive economically. This conclusion applies whether the initial development is a relatively small one intended primarily to meet the demands of normal system load growth, or a fairly large one intended to serve, in addition, a large industrial load or loads. Neither size develops the full potential available at the site, and the largest proposed (180,000 kilowatts) can be expanded readily. Our studies, which have extended over the past three and one-half years, of the hydroelectric resources of Southwest Iceland lead us to believe that developments at other potential sites may be somewhat more costly for either relatively small or large installations. A development at Burfell thus appears to be the next logical development of these resources.

Very truly yours,

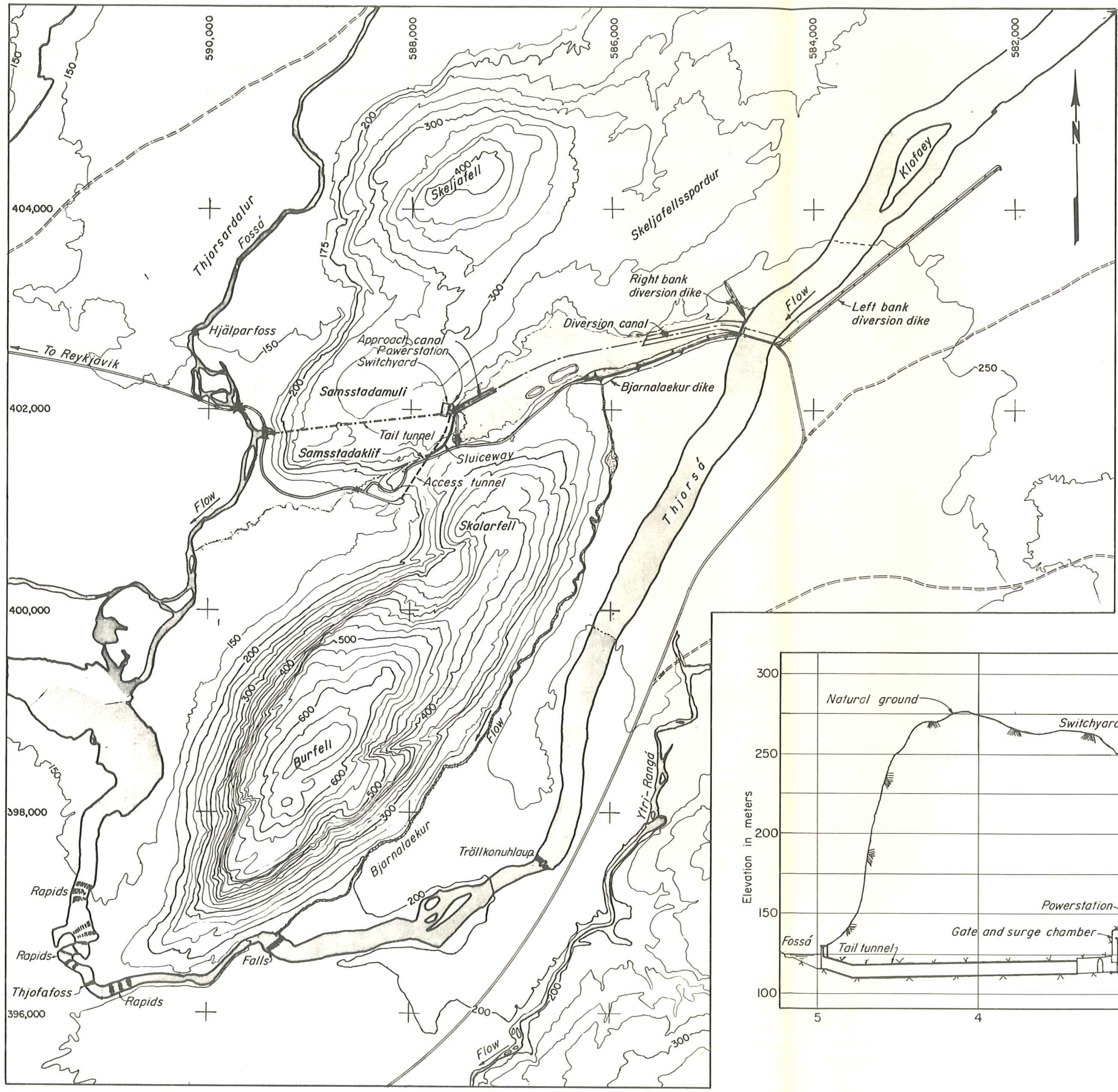
HARZA ENGINEERING COMPANY INTERNATIONAL

E. Montford Fucik

E. Montford Fucik
President

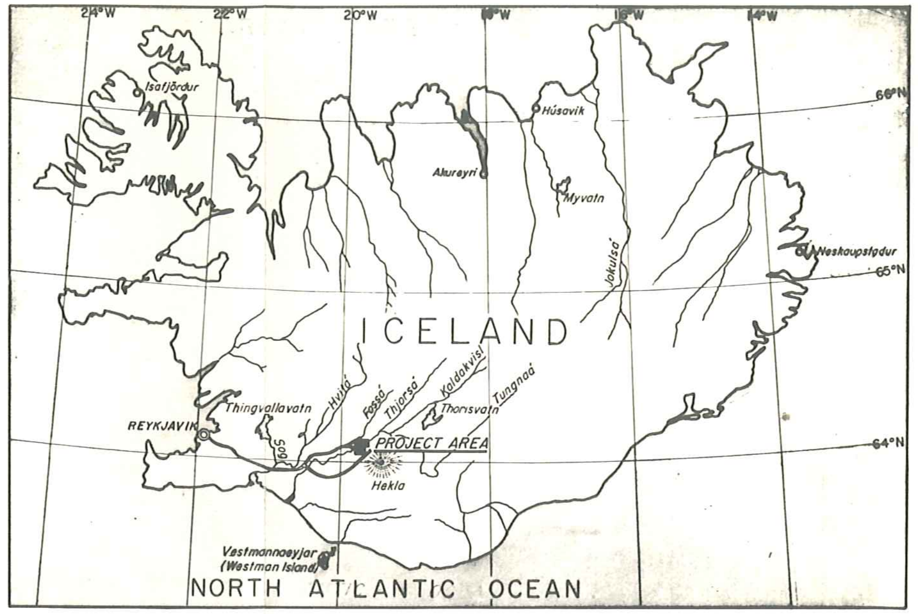
Enc. Exhibits A and B

EXHIBIT A



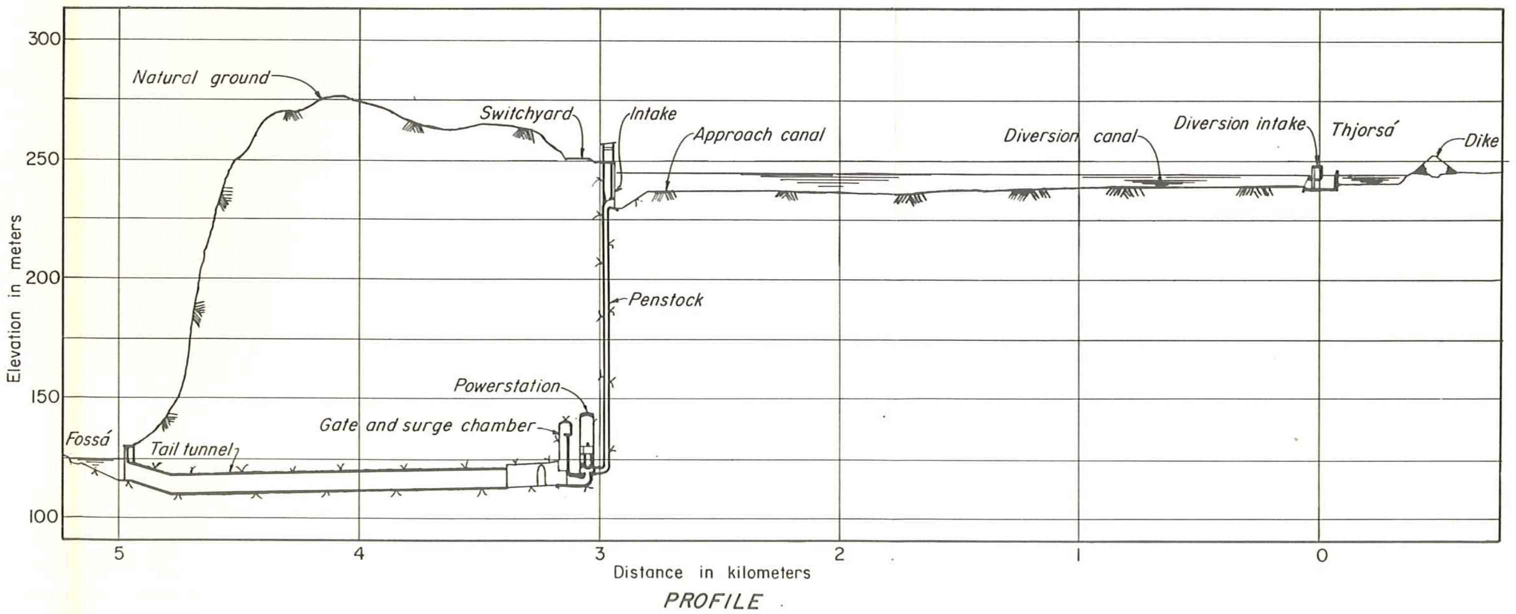
PROJECT PLAN

Scale 0 1 Kilometer



KEY PLAN

Scale 0 100 Kilometers



PROFILE

Scale distorted

REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.

THE STATE ELECTRICITY AUTHORITY
ICELAND

BURFELL PROJECT

LOCATION MAP AND PROJECT PLAN

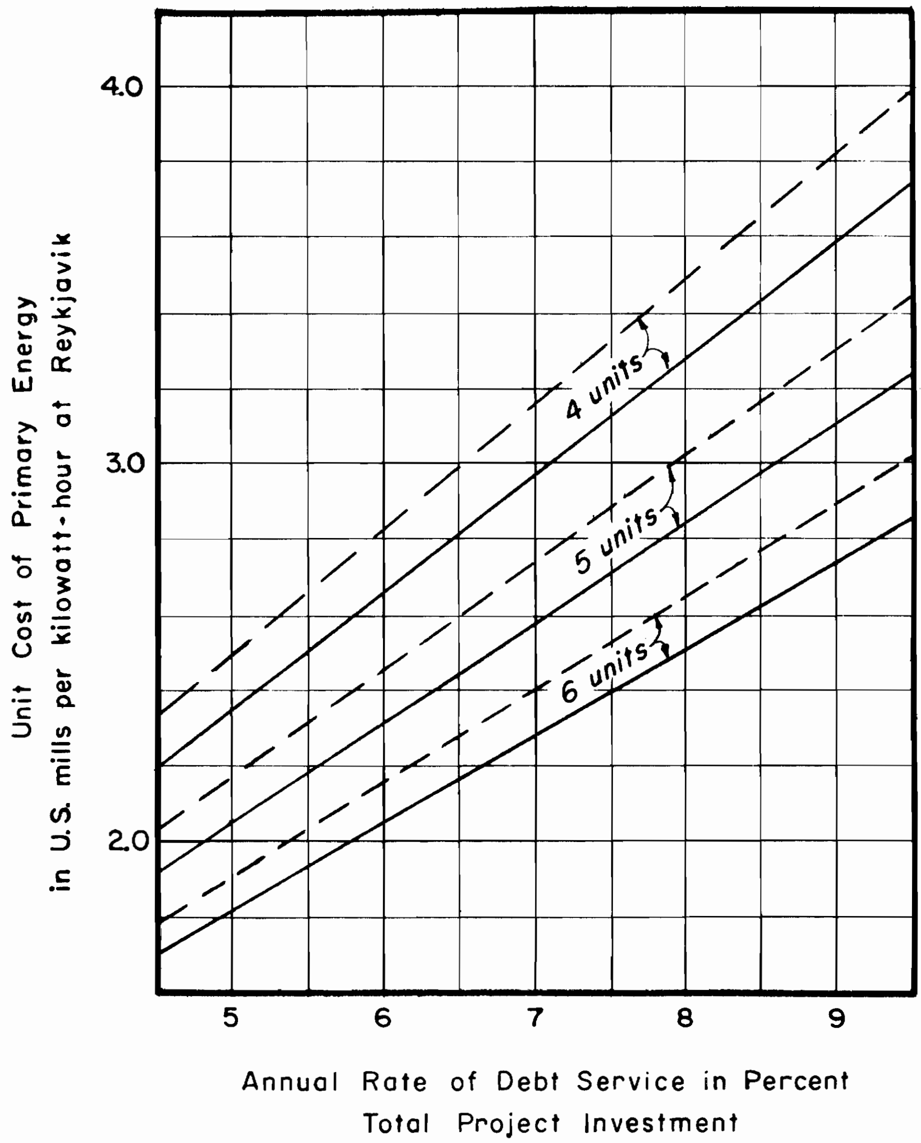
HARZA ENGINEERING COMPANY INTERNATIONAL

PREPARED BY
HARZA ENGINEERING COMPANY

APPROVED A.P. Geuss

CHICAGO, ILLINOIS | DATE JAN. 1963 | DWG. No. 290 P 8

EXHIBIT B



LEGEND

——— *One transmission line*

– – – – *Two transmission lines*

NOTES:

No allowance made for income from sales of secondary energy.

Import duties and taxes not included.

STATE ELECTRICITY AUTHORITY ICELAND	
BURFELL PROJECT	
UNIT COST OF ENERGY	
HARZA ENGINEERING CO. INTERNATIONAL	
PREPARED BY HARZA ENGINEERING CO., CHICAGO APPROVED A P Gauss	
DATE JAN. 1963	DWG. NO. 290 P 32

TABULATION OF SIGNIFICANT DATA

Drainage area - square kilometers	6380
Discharge - cubic meters per second	
Maximum design flood	7750
Maximum historical	2000
Average	338
Minimum historical	72
Headwater elevation - meters above sea level	
Maximum (at maximum design flood)	248
Normal	244.5
Minimum	243.5
Tailwater elevation - meters above sea level	
Maximum with ice jam in Thjorsa	130 ±
Normal maximum (flood in Fossa)	126.5
Normal	125.5
Minimum	125 ±
Minimum after assumed degradation in Fossa	123 ±
Diversion dam	
Crest elevation of overflow section - meters above sea level	244.5
Height of overflow section from foundations - meters	7
Dikes	
Total length - meters	5300
Maximum height from foundations - meters	30
Total volume of fill - cubic meters	1,300,000
Canals	
Total length - meters	2,100
Total volume of excavation - cubic meters	750,000
Penstocks	
Type	steel lined vertical shafts
Diameters - meters	3.8
Length - meters	135

TABULATION OF SIGNIFICANT DATA (continued)

Powerstation	
Type	underground
Length - meters	115
Width - meters	16
Height - meters	33
Tailrace tunnel	
Type	horseshoe, concrete lined
Diameter - meters	7.5
Length - meters	1560
Turbines	
Number	six
Type	Francis
Rating at 115 meters net head - metric horsepower	44,300
Discharge at rated head, full gate - cubic meters per second	32.5
Speed - revolutions per minute	333.3
Generators	
Number	six
Type	vertical shaft, hydraulic turbine driven
Rating - kilovolt-amperes	33,333
Power factor	0.9
Voltage - kilovolts	13.8
Phases	three
Cycles per second	50
Speed - revolutions per minute	333.3
Transformers	
Number	three
Type	outdoor, three-phase, OA/FA/FOA
Rating - megavolt-amperes	36-36-72
Voltage - kilovolts	13.8-230
Main transmission line	
Length	
Eidi Alternative - one line - kilometers	107
Eidi Alternative - second line - kilometers	112

TABULATION OF SIGNIFICANT DATA (continued)

Main transmission line (continued)	
Straumsvik Alternative - one line - kilometers	118
Straumsvik Alternative - second line - kilometers	118
Voltage - kilovolts	230
Construction	wood poles

TABLE OF EQUIVALENTS AND ABBREVIATIONS

Monetary Equivalents

1 dollar	equals	43 Kronur

Metric Equivalents

1 meter	equals	3.281 feet
1 kilometer	"	0.6214 miles
1 square kilometer	"	0.3861 square miles
1 cubic meter	"	35.32 cubic feet
1 million cubic meters	"	811 acre-feet
1 cubic meter per second	"	35.32 cubic feet per second
1 kiloliter per second	"	35.32 cubic feet per second
1 kilogram	"	2.205 pounds
1 metric ton	"	1.102 short tons

Abbreviations

Million cubic meters	MCM
Cubic meters per second	cms, m^3/sec
Kilowatt	kw
Kilovolt	kv
Kilovolt-ampere	kva
Megavolt-ampere	mva
Kilowatt-hour	kwh
Million kilowatt-hours	Mkwh
Revolutions per minute	rpm
Degrees centigrade	^{o}C
U.S. Dollars	$
Kronur	Kr.

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DETAILED TABLE OF CONTENTS

DETAILED TABLE OF CONTENTS (continued)

DETAILED TABLE OF CONTENTS (continued)

DETAILED TABLE OF CONTENTS (continued)

THE EXHIBITS (continued)

THE REPORT

CHAPTER I

ENGINEERING SUMMARY

Purpose of Burfell Project

The Burfell Project as presented in this Report is designed to serve a large block of new industrial load in the vicinity of Reykjavik, as well as a somewhat smaller increment of normal load growth in Southwest Iceland. The cost of power and energy produced is considered sufficiently low to attract a large power consuming industry, such as aluminium smelting.

Power Requirements

Industrial Load

The size and the characteristics of the industrial load are not established fully at this time. An aluminium smelter has been under consideration for some time. It appears to be the most likely type of industrial load that would be served by a large hydroelectric project at Burfell.

A modern aluminium smelter is normally designed for an annual capacity of 25,000 to 30,000 metric tons per potline, which would require 50,000 to 60,000 kilowatts of high load factor power on a continuous basis. The smallest increment of power to such a load would be that of one-half of one potline, or 25,000 to 30,000 kilowatts. It is understood that an initial aluminium plant should have a capacity of not less than 1 1/2 potlines, and that it might have two potlines. Therefore, the total industrial requirement would be 75,000 to 120,000 kilowatts, depending on the number of potlines and the actual requirement per potline. Also, it is understood that the aluminium industry should have reasonable assurance that additional low cost power can be provided for purposes of future expansion, either at the site of the initial power project or at another site within reasonable transmission distance.

The generating capacity would need to be five to ten percent greater than each of the above smelter requirements, depending upon the losses incurred in transmission.

An aluminium smelter can operate with less than full power requirement but at the expense of reduced efficiency. At least fifty percent of the full power is understood to be needed to prevent the potlines from "freezing", and represents, therefore, the minimum requirement for reserve power. Operation at fifty percent power should, however, be considered as an emergency condition to be avoided to the extent feasible. Operation at eighty percent of full load is acceptable for periods of several days, the only adverse effects being somewhat reduced production.

General Load

The present population of Southwest Iceland is about 125,000 of which about 115,000 are served by an interconnected power system called the "Sog System." The major load center is Reykjavik and its immediate surroundings, which has a total population of about 75,000. The Westman

Islands located about ten kilometers off the south coast are connected by a submarine cable. The NATO Base at Keflavik is connected through a 7000 kilowatt frequency converter.

The historic growth of this system from 1952 through 1962 is shown on Exhibit 1. The growth has been somewhat uneven, primarily because of occasional shortages of generating capacity and varying demands by the fertilizer plant. The average growth is estimated at about nine percent for peak load and ten percent for energy consumption. The peak load in 1962 was 81,500 kilowatts. The energy demand was 488 million kilowatt-hours. About 64 percent of the energy delivered in 1962 was to small industry and to domestic and commercial users. About nine percent was supplied to the NATO Base and about 27 percent to a fertilizer plant near Reykjavik. The fertilizer plant operates primarily on off peak power, which is one reason for the relatively high system annual load factor of 68 percent.

The present generating capacity of the system is shown in Table I-1.

Also shown on Exhibit 1 is a projection of the load growth until the year 1971 as estimated by the State Electricity Authority. Two alternatives have been shown after 1966 for the load to the fertilizer plant. The higher curve shows an increase in demand at the time of system peak from the present 4000 kilowatts to 28,000 kilowatts and an increase in energy demand of about 50 percent. The lower curve indicates only a small increase in peak demand, from 4000 to 6000 kilowatts, and slightly less than 50 percent increase in energy demand. The lower curve is based on the assumption that the present practice of using off-peak power will continue.

TABLE I-1

Existing Generating Facilities in Southern Iceland

Development	Installed Capacity in Kilowatts	
Hydro:		
Sog Development		
Steingrimsstod	26,400	
Ljosafoss	14,600	
Irafoss	31,000	
Subtotal Sog		72,000
Ellidaar	3,200	
Andakill	3,500	
Total Hydro		78,700
Thermal		
Ellidaar	7,500	
Westman Island	3,900	
NATO Base	7,500*	
Total Thermal		18,900
Total Hydro and Thermal		97,600

* The 7500 kilowatts at the NATO Base are Diesel capacity for emergency reserves.

The general load was assumed to increase at a rate of about seven percent per year over the nine year period, 1963-1971. The NATO Base requirements were assumed to increase at an annual rate of eight percent.

Additional power and energy resources to meet the normal load growth in Southwest Iceland represent a critical matter. The present capacity is sufficient only to 1964, assuming that the past rate of load growth will continue. Completion of the third 15,500 kilowatt unit at Irafoss, scheduled for the end of 1963, will end the planned installation on the Sog. This unit adds capacity only. 11,500 kilowatts of additional steam capacity at Ellidaar are on order. These additions should provide sufficient capacity for the estimated load growth, including necessary reserves, to 1966 or 1968, depending on the increase of the fertilizer plant. The Diesel capacity at the NATO Base will probably be increased in accordance with the load of that Base in order to have 100 percent reserve capacity available at all times. This increase in capacity is not shown.

No definite commitments have been made for further power developments, although preliminary investigations have been made of several hydro sites and of the use of geothermal energy.

Hydroelectric Potential

The hydroelectric resources of Southwest Iceland are concentrated primarily on the two principal river basins, the Thjorsa and the Hvita. A preliminary plan of development of these resources is shown on Exhibits 2 and 3, originally presented in the Advisory Report, dated March 1960. On the basis of this plan the potential of the Hvita was estimated to be 3150 million kilowatt-hours of gross annual energy. Similarly, the potential of the Thjorsa was estimated to be 9650 million kilowatt-hours of gross annual energy. The resources of the Sog, which joins the Hvita to form the Olfusa, are in addition thereto, and now considered fully developed.

The undeveloped resources of the Thjorsa and Hvita are adequate to meet the general load growth in Southwest Iceland in the foreseeable future and also to provide abundant power and energy for industrial development. Preliminary studies indicated that Burfell would be one of the most favorable sites for early development. Low cost power and energy may be produced for almost any size of plant, ranging from the minimum necessary to meet normal load growth to a size that would develop the full potential of the site. It is also within reasonable transmission distance of the Reykjavik load center. Thus, the Burfell Project is suited admirably to meet normal load growth, to supply an initial major industrial load, and, in some degree, to meet the needs for future expansion.

The capacity of the Burfell Project selected for this Report was based on consideration of power requirements, the physical features of the site, and the availability of water. After consideration of all factors involved, an initial installation of about 180, 000 kilowatts was selected as the most suitable. A plant of this size will be able to support an aluminium smelter of 1 1/2 to 2 potline capacity and, in addition, provide 30, 000 to 60, 000 kilowatts for the general market.

The Burfell Project

History of Development

The development of the hydroelectric potential of the Burfell site has been under study for a number of years. Surveys and planning studies were accomplished by a Norwegian engineer over thirty years ago for a development intended to serve a large industrial load which, apparently, did not materialize. That development was located in approximately the same position as the one proposed in this Report.

A development at Burfell was proposed by the Harza Engineering Company International (HARZINT) as an alternative to the Sultartangi Project planned by Thoroddsen in 1959. This proposal was presented in their "Advisory Report" dated March 1960. The recommendation in that report led to field investigations, including subsurface explorations, by the State Electricity Authority (SEA) in the summer of 1961. This was followed by engineering studies of an appraisal nature by HARZINT which were presented in their "Summary Report" dated November 4, 1961.

The HARZINT proposal in their Advisory Report envisioned a storage reservoir to elevation 260 created by a fill dam to the east of the mountain, Burfell. The subsequent foundation investigations revealed a relatively great depth to suitable foundations on the Thjorsa lavas for the required structures. They also revealed underseepage problems through pervious interbeds between the Thjorsa lava flows. A preliminary economic analysis revealed that a storage reservoir was not feasible economically as a feature of initial development, and was, accordingly, rejected in favor of a plan for run-of-river power development only. That development made provision for future construction of the storage dam.

The initial power features proposed in the Summary Report included a long headrace tunnel through the mountain, Burfell, connecting with an underground power station under the south slope. This three kilometer long tunnel deep within the mountain was not feasible of exploration in advance of construction. The subsurface investigations revealed unsuitable rock at powerstation level for a tailrace type of development. Also, the regulating pond created in the Bjarnalaekur after diversion from the Thjorsa was inadequate in volume. The obvious defects of this site, designated the "Lower Site," led to the initiation of investigations and studies at the "Upper Site," where these defects appeared to exist to a much lesser degree.

The initial field investigations conducted at the Upper Site in November 1961 were limited to three core borings. One of these revealed encouraging rock conditions at power station level for a tailrace type of development. Accordingly, a preliminary engineering appraisal of the Upper Site was made by HARZINT and presented in their "Appraisal Report" dated March 1962.

That appraisal resulted in the selection, on both engineering and economic bases, of the Upper Site for the development of the Burfell Project. Extensive field investigations were initiated immediately and have continued to the present. These investigations included large scale topographic mapping; overburden soundings; diamond core borings; permeability testing; groundwater measurements; locating, sampling, and testing sources of natural construction materials; geologic mapping; hydrographic surveys; hydraulic measurements; route reconnaissance for roads and transmission lines; driving an exploration tunnel; ice investigations; and meteorological observations. The project planning studies, summarized in this Report, were begun in the early fall of 1962 when the results of the field program became available in adequate detail.

The Burfell Project, evolved by these planning studies and based on the results of the extensive field investigations, consists of a generating plant located at Burfell, and a transmission plant to deliver power to the Reykjavik area. A general description of these features is presented in this Chapter. A detailed description is given in Chapter V.

Generating Plant

The Thjorsa, together with its principal tributary, the Tungnaa, originates at the glaciers Hofsjokull and Vatnajokull, and flows southwesterly to the North Atlantic Ocean. The Burfell generating plant will be located on the middle section of the Thjorsa, as shown on Exhibit 2. The drainage area upstream of the site is about 6380 square kilometers.

The Thjorsa has an annual cycle of flow that is governed primarily by precipitation and temperature occurrences. Peak flows ordinarily occur in the months of February through June and are usually caused by a combination of high precipitation, warm winds, and melting snow. The supply of water from the glaciers maintains a high sustained flow through the summer. Minimum flows occur generally in the winter during extreme frost periods.

The average flow of the Thjorsa at Burfell is estimated to be 338 cubic meters per second. The lowest flow in 15 years of record is estimated to be 72 cubic meters per second; however, flows less than 145 cubic meters per second have been experienced only two percent of the time. The highest flow experienced at Burfell is estimated to be 1980 cubic meters per second.

The Burfell Project will develop about 120 meters of gross head by a diversion north of the mountain Burfell into the Fossa about two kilometers upstream of its confluence with the Thjorsa. The location of the Project in relation to other proposed storage and power projects in the Thjorsa and Hvita Basins is shown on Exhibits 2 and 3.

The Burfell Project will be a run-of-river development utilizing the unregulated flow of the river. A small pondage will be available for daily peaking. The station flow capacity was chosen at 175 cubic meters per second, which is estimated to be available approximately 91 percent of the time.

The general plan of development is shown on Exhibit 4. The plan will have three principal elements: (1) a diversion dam and associated structures on the Thjorsa; (2) a large forebay pond formed by a dike across the Bjarnalaekur; and (3) the power features including the intake, penstocks, underground powerstation, and tailrace.

The diversion dam will be located northeast of the mountain Burfell, about six kilometers upstream of the waterfall, Trollkonuhlaup. It will consist of a concrete overflow weir about four meters high adjoining a gated spillway and sluice section, which incorporates a silt excluder. The combined capacity of the overflow and gated section will be sufficient to pass the spillway design flood. The primary function of the gated section is to sluice ice and sediment. The silt excluder extends upstream from the gated section and in front of the diversion inlet structure. Its purpose will be to exclude bedload sediment from entering the forebay pond by collecting and sluicing it downstream of the spillway.

A diversion inlet structure will be provided on the right bank of the river, contiguous and at a right angle to the gated spillway section. The water will be diverted through low level ports in the intake structure into a canal leading to the forebay pond.

Rockfill dikes to contain the river upstream of the dam will extend to high ground on either side of the river.

The forebay pond will be provided in a depression west of the diversion dam by the construction of a dike across the Bjarnalaekur. This pond will be about three kilometers long in the east-west direction, and will have a surface area of about one square kilometer.

The intake to the powerstation will be located at the west end of the Bjarnalaekur Pond near the divide between the Thjorsa and Fossa Basins. It will form the entrance to three vertical pressure shafts leading to the powerstation, which will be located approximately 120 meters below ground surface. Each pressure shaft will serve two units. A channel will be excavated from the west end of the intake to the west slopes of the divide in order to permit sluicing of sediment and ice from in front of the intake. A control structure will be provided in the channel near the intake.

The underground powerstation will be excavated to house six Francis type units, with each generator having a rated capacity of 30,000 kilowatts at 115 meters net head. Access to the powerstation will be by a 900 meter long tunnel and by a vertical shaft served by an elevator.

The six draft tubes will discharge into a tailrace surge chamber excavated downstream of the powerstation, and then into a tailtunnel about 1750 meters long. A short canal will connect the tunnel outlet with the Fossa.

The initial development at Burfell may consist of only four or five units, with provisions for early additions up to six units. Planning has recognized the possibility of and permits the further expansion of the Project beyond the six units proposed herein.

The construction of the generating plant is expected to require about three years. No unusual or serious construction problems are expected. River diversion will be relatively easy because of the wide and shallow channel, the high degree of impermeability of the bed, and the absence of great changes in stage. There are many precedents of underground construction similar to that proposed for Burfell. The extensive subsurface investigations have identified the geologic weaknesses to be expected and none pose a serious problem. In general, most of the required underground excavation will be in rock of high quality. The field investigations and tests revealed the availability of natural construction materials in adequate quantity and quality. All are within reasonable haul distances.

A bar graph construction schedule is shown on Exhibit 22. This schedule assumes award of contract in early January. It is recognized that construction commencement in other months would change this schedule somewhat because of the seasonal nature of some of the work. However, this change should not result in construction exceeding 36 months.

Transmission Plant

The transmission plant includes the step-up substation at Burfell, the transmission line between Burfell and the Reykjavik area, the terminal substation near Reykjavik, and a tie to the existing system at Reykjavik.

Two locations, Eidi and Straumsvik, in the Reykjavik area are under consideration for industrial development. Two alternative transmission schemes, one with a single line and one with two lines, were prepared for each industrial plant location. The line routes for the resulting four alternatives are shown on Exhibit 5. Only one line is recommended with the initial project since the capacity is entirely adequate to transmit the load. This line will be along the Northern route as shown in solid line on the Exhibit. The line voltage was selected as 230 kilovolts. The transmission towers will be of wood pole construction.

The Burfell substation will be located on the surface directly above the powerstation. Three main step-up transformers will be provided, each rated 36-36-72 megavolt-amperes. The substation also includes provisions to supply a 69-kilovolt transmission line which will connect with the existing local system. This line is not part of the proposed Project.

The terminal substation will be identical at either Eidi or Straumsvik. A connection will be provided with the Sog System by a 138-kilovolt line to the Ellidaar substation. A 70 megavolt-ampere, 230-138 kilovolt autotransformer will be installed in this line at the main terminal substation. A 70 megavolt-ampere, 138-11-34.5 kilovolt transformer will be added at Ellidaar. The length of the line to Ellidaar will be about 5.5 kilometers with the Eidi alternative, and 13 kilometers with the Straumsvik alternative. The power for the industrial load will be taken from the 230-kilovolt main bus.

Future Development of Power Resources

The Burfell Project is the logical first step in the development of the hydroelectric potential of the Thjorsa Basin.. The basic concept of the plan presented in this Report fits within the scope of comprehensive resources development of the Thjorsa Basin as presented in the Advisory Report of March 1960. Further, the basic plan will accommodate readily the future enlargement at Burfell as upstream storage is provided to regulate the flow.

Future large increments of industrial load, discussed above, will require the development of additional large blocks of power. The next development on the Thjorsa can take one of several paths, all of which appear attractive economically. The addition of upstream storage at Thorisvatn and diversion into the Tungnaa will allow development of the Hrauneyjafoss site. Diversion of the Kaldakvisl into Thorisvatn will allow for a greater installed capacity at any downstream plant such as

Hrauneyjafoss, Burfell, or Urridafoss. The Urridafoss site near the mouth of the Thjorsa offers good potential for development. The Burfell Project is complimentary to these potential developments.

Power and Energy Production

Peaking Capability

The peaking power, in kilowatts, which the Burfell Project can deliver at the load center with a single 230 kv transmission line is as follows:

	4 Units	5 Units	6 Units
Peaking Capability at Site	123,000	155,000	186,000
Transmission Losses (6 Percent)	7,000	9,000	11,000
Delivered Peaking Capability	116,000	146,000	175,000

These capabilities may be reduced slightly during periods of floods on the Fossa, and, to a lesser degree, on the Thjorsa. The low flows that occur occasionally on the Thjorsa will not affect this capability because of the reregulation possible in the Bjarnalaekur Pond.

Energy

The primary energy of the Burfell Project has been considered as that produced by a station flow of 116, 145, and 174 cubic meters per second for installations of four, five, and six units, respectively. The flow of 116 cubic meters per second is estimated to be available 99.8 percent of the time, 145 cubic meters per second about 98 percent of the time, and 174 cubic meters per second about 91 percent of the time. The energy was estimated from the duration curve shown on Exhibit 6, which is based on the streamflows at Burfell shown on Exhibit 7.

The overall efficiency, (not including hydraulic losses in the water conductors which are reflected in the net head, but including transmission losses and station service), was estimated at 85 percent with two transmission lines and at 83 percent with one transmission line. Water use will be nearly 100 percent, but for purposes of conservatism, a utilization factor of 98 percent was assumed in the estimate. On these bases, assuming transmission losses to be four percent, the annual primary energy delivered at the high tension side of the transformers in Reykjavik is estimated to be as follows:

Annual Primary Energy Delivered at Reykjavik
in Millions of Kilowatt-Hours

	4 Units	5 Units	6 Units
One 230 kv Line	940	1160	1375
Two 230 kv Lines	955	1180	1400

Some secondary energy will be available for extensive periods when available river flows exceed that required to deliver primary energy, up to the turbine capacity at full gate. The usable surplus flow amounts to 3.5 cubic meters per second per unit. The annual secondary energy production has not been evaluated.

As discussed in Chapter III, it would be feasible to firm the flow to at least the normal capacity of a six unit plant, 174 cubic meters per second, by initial development of storage at Thorisvatn. This would increase the amount of primary energy by about 1.5 percent. However, the development of this storage is not considered justified for the initial development at Burfell, at least for flow regulation purposes. Some storage for assisting in the sluicing of ice at the diversion structures may prove desirable. However, such a requirement is, at present, uncertain and has not been included in the cost estimates.

CHAPTER II

PROJECT COSTS

Capital Costs

Cost estimates for the Burfell Project were prepared for a basic six-unit generating plant with separate estimates for four, five, and six units installed initially. The incomplete plants involved all construction, except the equipment for the vacant bays and some associated accessory equipment and construction. The estimates for four alternative transmission schemes are also presented. The cost estimates are presented in Exhibit 8, which includes summary and detailed tabulations. All costs, local as well as foreign, are expressed in U. S. Dollars. The rate of exchange used for converting Icelandic Kronur to U. S. Dollars was 43 Kronur to one Dollar.

The construction costs were prepared from detailed quantity surveys based on the project drawings and on estimated unit prices for construction work. Lump sums were included for costs of equipment and other items which could not be estimated conveniently by the unit cost procedure. The unit prices and lump sums were estimated on the basis of labor rates and cost of material and equipment as of January, 1963.

The construction of the Burfell Project probably will require the services of a foreign contractor, although some participation of local contractors is expected. Construction equipment and such material as steel, timber, and fuel will need to be imported. The estimates are based on use of imported cement, although it is understood that cement is produced locally in sufficient quantities and may be used with only a slight increase in cost. Labor, both skilled and unskilled, was assumed to be available from local resources.

The unit prices in the cost estimates include the contractor's plant, equipment, overhead, profit, performance bond, taxes, and insurance. Customs duties and taxes on imported equipment and materials are not included.

The estimated costs for the permanent electrical and mechanical equipment were based on recent quotations from well-known Western European manufacturers. All costs are for the equipment fully installed.

The cost of land was not included in the estimate. The cost of water rights has been included as an annual charge, as discussed hereinafter.

Contingency allowances were added to the subtotal of direct costs obtained from the quantities and unit prices. These allowances are intended to cover possible unforeseen difficulties of construction, omissions from the estimates, and price escalations. Effects of any changes in rate of exchange are not included. A contingency allowance of fifteen percent on all civil works was considered to be adequate in view of the field information available and the generally conservative approach adopted in establishing the costs of the structures. A five percent contingency was allowed on all electrical and mechanical equipment, except for the transmission plant, where fifteen percent was used.

The addition of the contingency allowance established the total direct cost. An allowance of eight percent was then applied to provide for such indirect costs as design engineering, supervision of construction, and owner's overhead.

A further allowance was made to cover the estimated cost for preliminary planning basic to design and for field investigations. This allowance includes the total cost of the site explorations and engineering already carried out.

Financing terms are, at present, not established. Therefore, the cost of net interest during construction cannot be determined accurately. However, the cost normally amounts to about three or four percent of the construction cost for each year of construction. An allowance of ten percent of total construction cost was made to cover net interest during the estimated three-year construction period.

The cost of establishing working capital and interest reserves was not included, and may not be necessary. Some financing agencies, however, desire the capitalization of one year's interest as a reserve. Some working capital is considered to be provided in the form of reimbursement of the cost of preliminary investigations already accomplished.

The costs for five units installed includes the entire project with the exception of one turbine and one generator with their concrete foundations and accessory equipment. The cost for four units installed includes the entire project except for two units and their foundations and accessory equipment. One main transformer and the steel lining of the third pressure shaft was also excluded in the case of four units.

The estimated construction costs and project investments are shown in the tables below. The costs for the production plant are taken from

Sheet 1 of Exhibit 8 and the costs for the transmission plant from Sheets 2, 3, and 4.

Installation	Production Plant Construction Cost $ U. S.	Production Plant Project Investment $ U. S.
4 Units	23, 100, 000	25, 400, 000
5 Units	24, 300, 000	26, 700, 000
6 Units	25, 200, 000	27, 700, 000

Alternative	Transmission Plant Construction Cost $ U. S.	Transmission Plant Project Investment $ U. S.
(I) Burfell to Eidi - one 230 kv line	3, 800, 000	4, 100, 000
(II) Burfell to Eidi - two 230 kv lines	6, 200, 000	6, 700, 000
(III) Burfell to Straumsvik - one 230 kv line	4, 100, 000	4, 400, 000
(IV) Burfell to Straumsvik - two 230 kv lines	6, 600, 000	7, 100, 000

The difference in cost between the Eidi and the Straumsvik transmission plant alternatives is relatively small. In the following tabulation of total project investment, the Eidi alternative only has been considered:

Installation	Total Project Investment in $ U. S. One 230 kv Line	Total Project Investment in $ U. S. Two 230 kv Lines
4 Units (120, 000 kw)	29, 200, 000	31, 800, 000
5 Units (150, 000 kw)	30, 800, 000	33, 400, 000
6 Units (180, 000 kw)	31, 800, 000	34, 400, 000

The foreign currency requirements have been estimated at approximately 67 percent of the above construction costs for the production plant and approximately 80 percent for the transmission plant. Import duties and taxes would, if included, average approximately 20 percent of the construction costs for the production plant and approximately 30 percent for the transmission plant.

A cost estimate was also prepared for the provisions of initial storage at Thorisvatn, although it is not part of the initial project at Burfell as presented herein. The estimate is for a live storage of 300 million cubic meters, which can be released at a rate of 70 cubic meters per second at low reservoir levels. The total construction cost was estimated at $1,400,000, and the project investment at $1,500,000. Details of the estimate are given in Appendix D, Volume II.

Annual Costs

The annual charges against a power system include interest on invested capital, depreciation of the installation or amortization of investment, operation and maintenance expenses, administration and general expenses, and taxes.

The estimated annual operation and maintenance expenses, including administration and general expenses, of the Burfell Project, including the transmission plant, are presented in the table which follows. Insurance premiums and taxes are not included.

Interest and amortization charges (debt service) will represent the major portion of annual costs. This cost, however, will not be known until such time as the financing terms are established.

Compensation for the use of the water rights was included as an annual cost. This annual cost is considered to be the fair return on the value of such rights, which are not now known definitely. Reserve funds have also been included as an annual charge to cover expenses of an extraordinary nature not otherwise covered by insurance or normal maintenance. The total of these two annual costs were taken at one and one-third percent of the estimated total construction cost.

The estimated annual costs other than debt service are estimated to be as follows:

Annual Costs Other Than Debt Service in Thousands of U. S. Dollars

	4 Units 120, 000 kw		5 Units 150, 000 kw		6 Units 180, 000 kw	
	One 230 kv Line	Two 230 kv Lines	One 230 kv Line	Two 230 kv Lines	One 230 kv Line	Two 230 kv Lines
Operation and Maintenance	390	410	465	485	525	545
Reserves and Water Rights	355	385	375	405	385	415
Total	745	795	840	890	910	960

Primary Energy Costs

The unit cost of energy is estimated by dividing the total annual charges, including debt service, by the amount of energy delivered annually. In the evaluation of energy costs for the Burfell Project as presented herein, no consideration was given to the sale of any secondary energy, but all delivered primary energy was considered as sold.

Since financing terms have not been established it has been necessary to estimate the unit cost of energy for a range of annual debt service, expressed as a percentage of the total investment. The estimates are presented in the tabulation below for annual debt services of five, seven, and nine percent. The table shows the estimates for one transmission line only.

Estimated Unit Cost of Energy
One Transmission Line

	5% Debt Service	7% Debt Service	9% Debt Service
4 Units			
O&M Charges - $1000	745	745	745
Debt Service - $1000	1460	2045	2630
Total - $1000	2205	2790	3375
Annual Energy-Million kwh	940	940	940
Cost of Energy - U.S. mills/kwh	2.35	2.97	3.59
5 Units			
O&M Charges - $1000	840	840	840
Debt Service - $1000	1540	2155	2770
Total - $1000	2380	2995	3610
Annual Energy-Million kwh	1160	1160	1160
Cost of Energy - U.S. mills/kwh	2.05	2.58	3.11
6 Units			
O&M Charges - $1000	910	910	910
Debt Service - $1000	1590	2225	2860
Total - $1000	2500	3135	3770
Annual Energy-Million kwh	1375	1375	1375
Cost of Energy - U.S. mills/kwh	1.82	2.28	2.74

The results of the above unit energy cost estimates are shown graphically on Exhibit 9. This graph also shows the estimated cost of energy with two transmission lines. No allowance has been made for profit in these evaluations. Import duties and taxes have not been included in the estimated capital requirements.

CHAPTER III

THE THJORSA

Basin Description

The drainage basin of the Thjorsa, comprising 7530 square kilometers, is shown on Exhibit 2. The Thjorsa originates in the Hofsjokull and Vatnajokull Glaciers. From the high plateau of the glaciers the river flows through Southern Iceland for a distance of 230 kilometers, entering the North Atlantic Ocean. The total difference in elevation from the headwaters to the ocean is about 600 meters. Much of the fall is concentrated at waterfalls or rapids, offering excellent sites for hydroelectric development.

The topography of the Upper Thjorsa Basin is relatively rough, resulting from interaction of volcanic activity, glaciation, and stream erosion. The highest elevation in the Basin is about 2000 meters. Below the junction of the Tungnaa and the Thjorsa the relief becomes progressively more moderate, until it emerges into a broad flat plain about 50 kilometers above the mouth of the river. In the plains south of Hestvatn the Thjorsa approaches close to the Hvita. At one point the two rivers are only about four kilometers apart, with the flood plain between the two being so flat that during extreme floods the waters of the two rivers converge.

The upper portion of the Thjorsa Basin is undeveloped and uninhabited. In the lower plains area, scattered farms and villages are connected by a network of gravel roads. There is only one bridge over the Thjorsa, near Urridafoss, about 20 kilometers from the ocean. The drainage basin is generally barren, without trees, but good grasslands exist in the plains areas.

Near the mountain Burfell, the Thjorsa drops about 120 meters in 13 kilometers, as the river curves partially around the mountain. This fall, which occurs in a series of falls and rapids, offers the most feasible opportunity for initial hydroelectric development on the river.

Thorisvatn, located at about elevation 570 meters between the Kaldakvisl and the Upper Tungnaa, is a natural lake which offers potential for streamflow regulation. It has a surface area of 70 square kilometers, and drains an additional 260 square kilometers of land area. Moreover, there is appreciable underground flow into the lake. The lake drains into the Kaldakvisl through the six-kilometer long Thorisos.

Of significant hydrologic importance in the Burfell area are the streams, Ytri-Ranga and Bjarnalaekur, which parallel the Thjorsa at the site of the proposed diversion dam and downstream therefrom. Both of these streams are lower in elevation than the Thjorsa, and are separated from it by low, easily erodible overburden. The existance of a flood of sufficient magnitude to cause overflow into either stream would probably cause a permanent change in the course of the Thjorsa. Since such a change in course has not occurred, it indicates that the maximum historical flood in the Burfell area must have been less than that required to cause overflow to either of the two side streams. The Rauda Gap to the Fossa is lower than the divide separating the Thjorsa and the

Ytri-Ranga. Some flow from larger floods is known to have flowed through the Rauda Gap to the Fossa. This overflow will be permitted to continue as a natural safety feature against overflow to the Ytri-Ranga.

Climate

The climate in the Thjorsa Basin is similar to that of most of Iceland, being rainy with cool summers and warmer winters than are normally associated with a location near the Arctic Circle. The weather is dominated by air masses of maritime origin. Cyclonic systems tend to follow the Gulf Stream, bringing great volumes of humid, relatively warm air to the island. Major storms originate from this source.

Precipitation in the Basin varies somewhat throughout the year, as well as with elevation. Precipitation is heaviest during the period September through March, although substantial precipitation occurs in other months as well. The mean annual precipitation in the Basin is estimated to vary from 800 millimeters at the lower elevations to 3600 millimeters at the top of the glaciers, with the average for the area above Burfell being 1770 millimeters.

The mean annual temperature at Haell, in the Basin, is 3.7° C. The mean monthly temperatures at that location vary from minus 1.8° C in January to 11.4° C in July. The observed extremes in thirteen years of most recent record have been minus 17.6° C and 24.0° C.

Streamflow

The only streamflow record of long duration is at Urridafoss where records have been collected for fifteen years. The drainage area at this point is 7200 square kilometers, or 95 percent of the total Thjorsa Basin. These records provided the primary basis for streamflow estimates used in this Report.

Records have been collected since 1958 at seven additional locations on the Thjorsa and its key tributaries. These records were also useful in analyses of the available streamflow for the Burfell Project.

Nearly all the streamflow estimates that have been made previously for the various stations in the Thjorsa Basin were reviewed carefully. Where necessary, revisions to gage height-discharge relationships were developed and streamflows recomputed. For the Urridafoss station, it was necessary to recompute all periods of record, with the major changes being in the low water periods of ice effect. For several of the tributary stations estimates were made on a monthly basis for the fifteen-year record available at Urridafoss, using correlation procedures. In general, it was found that low-water estimates by SEA of winter flows were too conservative; in other words, the flow estimates could be safely increased during such periods, on the basis of very extensive analyses. The revisions to estimates for periods of ice effect at other stations were less extensive. A complete description of the review of the streamflow estimates is given in Appendix A of Volume II.

The drainage area at Burfell is approximately 89 percent of that at Urridafoss. Previous studies of Burfell have been based on the assumption that the flow at Burfell is 89 percent of that at Urridafoss. Analysis of the short period of concurrent record at Burfell and Urridafoss indicates that this assumption is reasonable. Accordingly, the estimates of flow available at the Burfell site were made on the same basis. The computed hydrographs for Burfell for the period 1947-1962 are shown on Exhibit 7.

The average annual runoff of the Thjorsa at Burfell for the fifteen-year period on this basis is 338 cubic meters per second. The maximum and minimum daily flows were estimated to be 1980 and 72 cubic meters per second, respectively. The most critical period of extended low flow occurred from November 16 to April 17 in the winter of 1950-51 when the estimated flow averaged 184 cubic meters per second.

The frequency of daily flows at Burfell for the fifteen-year period is as follows:

Percent of Time when Discharge was equal to or greater than that shown	Daily Discharge in cubic meters per second
100	72
98	157
95	159
90	178
75	221
50	309

Regulated Flow

The natural flow available at Burfell may be regulated by the construction and operation of storage reservoirs located upstream. Such regulation would be aimed principally to firm the low flows and increase the primary energy level. This increase would be primarily to justify future enlargements to Burfell for continued high plant factor operation. It is not considered justified to firm the energy level of the initial Burfell Project as presented in this Report. Within reasonable limits, say an additional 100, 000 kilowatts, the increase would not be needed for capacity additions only.

Possible major storage potentials were presented in the 1960 Advisory Report. They include Thorisvatn, Nordlingaalda, Langisjor, Bjallar, and Tungnaarkrokur; of these Thorisvatn appears to be the most attractive economically, either as a relatively small or large storage. Development of a small storage at Thorisvatn is discussed in Chapter VI, and in greater detail in Appendix D of Volume II. Recent studies have indicated that the Haifoss Project with its small amount of storage should be developed by diversion to the Thjorsa near the head of the Rauda. This diversion would add, from an outside watershed, additional flow to Burfell.

The critical winter period of 1950-51 was analyzed to determine the storage required to maintain various rates of flow at Burfell. The following amounts were determined:

Minimum Flow to be Maintained (cubic meters per second)	Stoage Required (millions of cubic meters)
145	6
174	54
203	337
232	747
290	1740

Probable Maximum Flood

Floods in Iceland originate from two sources, (a) glacial bursts and (b) heavy rainfall, either with or without melting snow.

Glacial bursts are caused either by a breaking of an ice barrier where a glacier has blocked a river or lake outlet, or by the breaking out of a large volume of water formed under a glacier by melting of ice from volcanic action. An SEA study found no reference to such floods in the Thjorsa Basin in 1000 years of history and sagas, and concluded that any such bursts that have occurred were minor in nature and did not exceed normal floods from other sources. Accordingly, it was concluded that the probable maximum flood in the Thjorsa will originate from other sources.

The flood potential has been investigated in some detail, as explained in Appendix A of Volume II. It was concluded that the most critical combination of rainfall, heavy snow cover, warm winds and low infiltration capacity of the soil will be in March or October.

The conclusion with respect to March is consistent with the limited flood history of the Basin. During the fifteen years of record at Urridafoss, February was the month of highest flow in two years, March was highest in two years, April in one year, May in seven years, June in two years, and December in one year. However, the two March occurrences were the highest of any of the annual peaks. The absence of occurrences in October is not considered conclusive. October is a month of near maximum precipitation, and minor increases in discharge have occurred in that month. The absence of major floods in October probably results from the absence of available snow, warm winds and frozen ground during the short historical period, all of which are considered possible under maximum flood conditions.

Maximum precipitation observed along the Pacific Coast in the Northwestern United States was considered to be representative of the maximum moisture supply, with appropriate adjustments downward (reduction factors of 0.54 to 0.61) to account for differences in dewpoint potential. Adjustments were also made for differences in mean annual precipitation.

Runoff from the probable maximum storm was determined by the unit hydrograph method using a synthetic unit hydrograph based on watershed characteristics. A low rate of basin retention was used on the assumption that the ground surface would be frozen at the time of the probable maximum flood. Snowmelt was computed on the assumption of a snow cover over the entire basin sufficient to provide full melting rates throughout an assumed eight-day temperature sequence.

The probable maximum floods at Burfell for October and March, respectively, were computed to be 7750 and 7550 cubic meters per second, respectively. Accordingly, the October flood peak was adopted as the design flood. This corresponds to a Creager "C" of 48, which appears reasonable for the area. The maximum flood experienced during the fifteen-year period of flood estimates at Burfell was about 2000 cubic meters per second, in March 1953.

An attempt to evaluate the maximum flood occurrence at Burfell during recent geologic time based on flood erosion of the lapilli overburden was inconclusive because of the absence of reliable flood marks. It was apparent from a study of this erosion, however, that small portions of past floods were diverted through the Rauda Gap to the Fossa. This diversion is believed to begin at about 2000 cubic meters per second.

CHAPTER IV

THE PROJECT SITE

Location and Access

The Burfell Project will be located on the Thjorsa about 85 kilometers from the mouth. This location is about midway between the south coast of Iceland and the glaciers and mountains of the central part of the country, as shown on Exhibit 2. It is approximately 100 kilometers due east of the capital city of Reykjavik, is 65 kilometers from the nearest town, Selfoss, and is about seven kilometers east of the nearest farm.

The routes of the main access roads to the Project are shown on Exhibit 5. The highway from Reykjavik approximately parallels the south coast and passes the Project area about 45 kilometers to the south. The highway is of reasonably good standards and crosses the Hvita at Selfoss and the Thjorsa at Urridafoss with bridges adequate for project construction requirements. Gravel roads and trails extend northeasterly from the highway on both sides of the Thjorsa to the vicinity of the Project site. These roads are of fairly good standard in the populated areas near the main highway, but decrease progressively in quality as they approach the Project area, becoming only jeep trails. Their improvement will be necessary.

Topographic Description of Site

The topography of the Project area is shown on Exhibit 11. The Project area is located at a natural bend in the Thjorsa, where the river drops approximately 120 meters over a distance of thirteen kilometers.

The Burfell area is characterized by a great variety of land forms varying considerably in configuration and elevation. Flat, almost featureless plains lie adjacent to mountains of high and varied relief. Vegetation is sparse, with no trees and practically no grass. Therefore, the land has little value for farming or grazing.

The highest feature in the area is Burfell, a mountain with a top elevation of 669 meters and a relief above the adjacent plain exceeding 400 meters. The northern end of Burfell, called Skalarfell, has an elevation of 425 meters. Directly north of Burfell is a group of lower mountains, Skalarfell, Samsstadamuli, Skeljafell, and Skeljafellsspordur, ranging in elevation from 300 to approximately 425 meters. These features are shown on Exhibit 11.

East of Burfell and extending along the Thjorsa for many kilometers upstream, beyond the limits of the Project, is a wide lava plain of low relief. Directly east of Burfell the elevation of the plain is 225 meters. It rises gradually to an elevation of over 250 meters at the upstream limits of the Project, a distance of approximately six kilometers. The plain forms the floor of a valley exceeding three kilometers in width at Skeljafellsspordur, narrowing to about two kilometers east of Burfell, and opening to many kilometers in width again as it passes to the south of Burfell. The plain is covered by a thick sheet of layered, highly permeable ash and pumice lapilli. Outside of the immediate Project area, about ten kilometers to the southeast, is located the volcanic mountain, Hekla, rising to an elevation of nearly 1500 meters. Much of the volcanic ash and lapilli deposited in the Burfell area in recent geologic time originated from this volcano.

Between Skalarfell and Skeljafellsspordur is a narrow valley less than a kilometer wide. It crosses Bjarnalaekurbotnar and narrows to the west until at Samsstadaklif it forms a steep-sided "V"-shaped slot before opening to the low sand plain south of Samsstadamuli. A lapilli layer forms a smooth floor over most of the valley.

A two-kilometer wide valley, called the Thjorsardalur, extends south from Stangarfjall along the western slopes of Skeljafell and Samsstadamuli to the Thjorsa. From Hjalparfoss to the Thjorsa the valley slopes approximately six meters over its length of approximately four kilometers.

The drainage from the Burfell area is through the Thjorsa and its tributaries, the Bjarnalaekur, the Fossa, and the Ytri-Ranga.

The Thjorsa flows through the valley east of Burfell where it has cut a 400-meter wide channel through the ash and lapilli and approximately a meter into the scoriaceous, blocky surface of the lava flow forming the plain. Upstream of Burfell the Thjorsa has a low gradient of about three meters per kilometer. As it passes along the east and south sides of Burfell, it forms a series of waterfalls and rapids, beginning with Trollkonuhlaup and dropping 80 meters before resuming a low gradient again about one kilometer upstream from its confluence with the Fossa. The river in this reach of about eight kilometers nearly reverses its direction as it flows around Burfell. It flows westward after being joined by the Fossa.

The Ytri-Ranga has developed along the eastern margin of the Thjorsa valley. The channel is about ten meters lower than that of the Thjorsa. The Ytri-Ranga is fed primarily by springs issuing from interbeds in the underlying lavas, which dip gently to the south. The Ytri-Ranga does not join the Thjorsa but continues in a southward direction to the sea.

The Bjarnalaekur has developed along the western edge of the lava plain. Its channel is about five meters lower than the plain. It joins the Thjorsa about three kilometers below Trollkonuhlaup. Like the Ytri-Ranga, it is fed almost entirely by springs issuing from the lavas. Much of the discharge appears to be supplied by a subsurface flow channeled along the buried front of one or more of the lava flows.

The Fossa, the second largest stream in the Project area, flows along the Thjorsardalur and has its confluence with the Thjorsa directly west of Burfell. The Fossa has one large tributary, the Rauda, which originates in the mountains east of Stangarfjall, and flows through the Rauda Gap before joining the Fossa west of Skeljafell.

Field Investigations

General

Extensive field investigations have been made in connection with planning of the Burfell Project, and to obtain information important to the future detailed design, construction, and operation thereof. While these investigations of both a general and specific nature have, in some degree, been underway for a number of years, specific investigations aimed toward the development of the selected site were initiated in the spring of 1962 and have continued on a broad and thorough basis. The investigations overall have included engineering and geologic reconnaissance; subsurface explorations; topographic, geologic and hydrographic surveys and mapping; groundwater and subsurface permeaility measurements; hydraulic measurements; investigation of natural construction materials; ice studies and measurements; and meteorological observations. These investigations are discussed in detail in the Appendices of Volume II, and are discussed briefly below.

Previous Investigations

Field investigations important to hydroelectric power development at Burfell have extended over a period of many years. Small scale maps of Iceland cover the area. These have been made by the Danish Geodetic Institute since 1906, and by the United States Army during World War II. Small scale maps of the Project area and some discharge measurements on the river were made by or for the Norwegian engineer who studied the site a number of years ago. The maps were of little value beyond the early reconnaissance phase of the present studies.

The Government of Iceland began investigations about 1947. In that year the State Electricity Authority began the very important maintenance of stream flow records of the Thjorsa, which have continued. The Department of Natural History has, for several years, been conducting regional geologic studies and mapping. In 1959, the State Electricity Authority (SEA) began an extensive field program aimed towards the development of a Master Plan for the development of the water resources of the Hvita and Thjorsa Basins and retained the Harza Engineering Company International (HARZINT) for consulting services. This basin type program included topographic mapping, geologic reconnaissance and mapping, and expansion of stream flow measurements which included also studies of ice and silt.

The State Electricity Authority began more specific field investigations at Burfell in 1961. These investigations were concentrated mainly at the Lower Site and included topographic and geologic mapping, hydraulic measurements, foundation explorations, and construction materials investigations. The foundations explorations included 13 coreborings totaling 785 meters in depth, and a number of overburden probings. Three bore holes were drilled at the selected Upper Site. The borings and geologic mapping contributed importantly to the understanding of the geology of the Burfell area. These 1961 investigations are set forth in detail in several reports of the SEA. The information presented therein, together with the earlier, more general investigations expedited greatly the detailed investigations of 1962, particularly in the initial phases. The information thus available was of inestimatable value to the planning of the Burfell Project as presented in this Report. The investigations which began in 1962 are discussed below. All were under the technical direction of engineers and geologists of HARZINT.

Foundation Explorations

The foundation explorations included Borro soundings, bulldozer trenching, diamond core borings, and driving an exploratory tunnel. All except the tunnel driving were accomplished by force account.

The Borro soundings were aimed to determine the thickness and, to some extent, the character of the overburden. The thickness was determined by direct measurement, while relative densities were determined approximately by analyses of the driving forces. A few samples were obtained. The soundings represented a principal source of information with respect to bedrock surfaces and permitted contour mapping of those surfaces. This facilitated the selection of the optimum locations for the dikes and diversion canals.

The Borro soundings were concentrated in the area of the diversion structures, Bjarnalaekur Pond, and in the general reach along the Fossa between the proposed tailtunnel outlet and the Thjorsa. 232 soundings, averaging nearly six meters in depth, were made in the first two areas, which are contiguous. Forty soundings were made in the Fossa area to assist in the location of the tailrace channel and to appraise the possible lowering of the Fossa grade to attain more head.

Numerous bulldozer trenches were used to supplement the Borro soundings, and for the same purpose. Inspection of the sides of the trenches gave detailed information on the nature of the overburden. The trenches were especially useful where a continuous rock profile was desired and could be obtained easily, such as at the west abutment of the Bjarnalaekur dike where the overburden was thin. Many of the trenches were located on the east side of the river to assist in locating the best alignment for the left bank dike.

Bedrock subsurface information was obtained by diamond core borings, collecting NX size core primarily. The core was preserved carefully and studied for engineering-geologic purposes. Seventy-two borings were made for a total length of 3626 meters. Their location is shown on Exhibit 12. The drilling was supervised carefully, which resulted in the remarkably high core recovery of approximately 93 percent in the area of the power features and somewhat less in the area of the diversion structures. The drilling was accomplished in two general areas--the location of the diversion structures and the vicinity of power features. The general program differed between the two areas.

The geologic reconnaissance showed that the diversion structures would be founded primarily on the uppermost of the Thjorsa lava flows. The relationship of the Thjorsa lavas and their interbeds together with the general characteristics of the uppermost flow was well known from the 1961 drilling at the Lower Site. With this knowledge and the consideration that only low structures were involved, it was feasible to lay out a program of near maximum economy and efficiency. Forty-seven borings were made for a total length of 792 meters in the area of the diversion structures, and were situated to explore the foundation of each structure. Most of the holes were relatively shallow and were carried into the rock only far enough to determine suitable foundation levels for each structure.

Fifteen holes, distributed to give the widest coverage penetrated through the first interbed and into the second Thjorsa lava flow. Of these, three were carried through the second flow. This deeper drilling permitted gathering important stratigraphic information. All holes in the Thjorsa lava near the western end were carried through the first interbed because of the known critical relationship of that bed with respect to short-path leakage. Five shallow holes were drilled from the surface of older rocks beyond the western limits of the Thjorsa lavas.

The initial geologic mapping indicated that the geology in the vicinity of the power features would be complex. The subsequent drilling and geologic mapping revealed that it was indeed very complex, as is discussed hereinafter. A principal aim was to discover the most favorable rock formation for the cavern of the underground powerstation. The progress of the drilling led to the selection of a tailrace type of development, hence, the deep holes tend to be concentrated towards the east end of Samsstadamuli near where the initial hole (BH-14) was drilled in late 1961. The other two 1961 holes near Trjavidarlaekur never penetrated through the overburden. The selection of the tailrace type of development meant also that drilling to tailtunnel level would be deep.

Altogether, 25 holes, totaling 2834 meters, were drilled for the foundations of the power features. In addition BH-14 was deepened 30 meters. Two of the 25 borings were relatively shallow holes located on the west slope of Samsstadamuli to investigate the foundations of the tailrace tunnel portal. Five shallow holes were drilled at the head of Samsstadaklif to explore the foundations for the western retaining dike of the Bjarnalaekur Pond and for the sluiceway channel. Sixteen holes were each more than 100 meters deep, and the remaining two were almost that depth. All of the drill holes obtained important information to assist in interpreting the complex geology.

Exploration tunnels, drifts, and shafts are considered to be by far the best exploratory procedure to follow for underground powerstations after the preliminary location has been established by geologic studies and coreborings. They permit visual examination of the rock in place and permit enlarging this information by relatively short coreborings from within the tunnels. Detailed information thus obtained assists greatly in final design by the engineer and bid preparations by the contractor.

An exploration tunnel was started at the Burfell Project in mid-1962 on the assumption that a tailrace type of development would be most favorable. It was positioned to serve as a pilot bore for the access tunnel. Driving was suspended 259 meters from the portal when it became evident that the probable location of the powerstation would not be reached in time to provide information for the planning studies incorporated in this Report. Budget considerations also had a bearing on the temporary suspension. It is expected that the exploration tunnel will be completed prior to final design, and be supplemented by drifts and coreborings therefrom in the powerstation zone. The tunnel would continue as a pilot for the access tunnel.

The completed portion of the exploratory tunnel penetrated 148 meters of moraine before entering somewhat altered andesite for the remainder of the distance, as shown in profile on Exhibit 13, Sheet 1.

The tunnel revealed the presence of the moraine as an adequate and suitable source of impervious core material for the dikes. Important data was also supplied with respect to tunneling characteristics and groundwater conditions in that portion of the future access tunnel.

Groundwater and Subsurface Permeability Measurements

Groundwater levels and movement and the permeability of the bedrock represent important engineering data to be obtained from boreholes. These data permit evaluation of leakage from reservoirs and waterways as well as into excavations. This evaluation serves as a guide to remedial treatment. Groundwater levels were measured in all boreholes during and immediately after drilling. Many of the holes were preserved for continued long-term measurement of the groundwater level. These measurements are continuing on a periodic basis.

The presence of the permeable interbed under the uppermost Thjorsa lava flow was known from reconnaissance and the 1961 explorations. It is the source of large springs in the Bjarnalaekur. This interbed lays beneath nearly the entire area of the diversion structures and, therefore, could represent a potential path of leakage unless treated. Accordingly, boreholes to penetrate that interbed were positioned to facilitate groundwater movement measurements using flourescein sodium dye. The dye was injected into selected holes and followed by observations in nearby holes and the Bjarnalaekur springs to determine the time of movement. Detection at the observation points was accomplished by the use of ultra-violet light on water samples. The general direction of movement was known from the slope of the groundwater table as observed by the measurements referred to above. The groundwater movement measurements indicated that groundwater in the interbed moves to the front of the second Thjorsa lava flow, thence swiftly in a southwesterly direction along that front to the springs. Average velocities as high as 12 meters per minute were measured, indicating a high degree of permeability.

All bore holes were water pressure tested in sections ranging from 1.5 to 3.0 meters using single and double rubber packers. Where bore holes penetrated unconsolidated interbeds between lava flows percolation tests were performed. The results of the permeability tests were converted to Lugeon units and are shown along the graphic core logs in Appendix B of Volume II of this Report.

Topographic and Geologic Mapping

Adequate and detailed topographic maps represent a first essential to the study of a hydroelectric site. The SEA as a part of their Thjorsa-Hvita Master Plan studies are in the process of mapping the basins of both rivers by aerial methods. Preliminary maps at a scale of 1:20,000 with five meter contours of the entire Burfell Project area became available in early 1962. These maps were very useful in the initial engineering and geologic reconnaissance and in the study and presentation of the overall Project.

These medium scale maps were inadequate for the required detailed study of specific engineering structures located on the surface.

Accordingly, the sites of all structures were remapped at a scale of 1:2000 with a one meter contour interval utilizing terrestrial methods. In general, this detailed mapping covered the general area outside the structures themselves, but useful for construction plant purposes. The mapping also included the area of the Bjarnalaekur Pond and of the tailrace, including its extension down the Fossa.

Some large scale topographic mapping and cross-sectioning was also accomplished at the location of some of the selected natural construction materials deposits.

Geologic information is of utmost importance in the design of a hydroelectric project, especially where underground structures are proposed, as at Burfell. The mapping of surface exposures in relation to topography coordinated with the results of subsurface explorations permits the making of geologic sections useful in placing properly designed engineering structures at optimum locations and evaluating their costs. Geologic studies are also useful in locating and evaluating sources of natural construction materials.

Extensive geologic mapping and investigations were accomplished in connection with the Burfell Project. The geology is discussed in greater detail elsewhere in this Report, and especially in Volume II. The mapping of the geology in the general area of Burfell, started in 1961, was continued throughout 1962. The map of the regional geology is shown on Exhibit 11. The immediate area of the Burfell Project was mapped in detail in 1962, using the new large scale topography as a base. This detailed mapping included the systematic examination and identification of outcrops. This mapping is shown on Exhibit 12, Sheets 1 and 2. Numerous geologic sections were prepared as the mapping and core drilling proceeded in order to serve as a guide to the drilling program. A few of these sections, taken along the alignment of proposed structures, are shown on Exhibit 13, Sheets 1 and 2.

Hydrographic Surveys and Hydraulic Measurements

The design of surface hydraulic structures in rivers requires hydrographic data. These data are essential to backwater studies and hydraulic model tests. River sections were measured across both the Thjorsa and Fossa. Seventeen sections were taken across the Thjorsa over a ten kilometer reach beginning about 1.5 kilometers below the diversion site and extending upstream to a point beyond the Rauda Gap. Ten sections were taken across the Fossa in the reach from its confluence with the Thjorsa to about 300 meters upstream of the proposed tailtunnel outlet.

Bench marks were established at each section as an aid to water surface profiling of the two rivers. Natural water surface profiles were made in each of these two river reaches for various known flows within the discharge range which has occurred in each river since the sections were established.

Staff gages were installed on the Fossa near the proposed tailwater outlet and on the Thjorsa near its confluence with the Thjorsa. Readings were made for the range of flows that have occurred since midsummer of 1962, and are continuing. The readings will permit a discharge record for the Fossa, and are necessary for confirming the estimated tailtunnel outlet rating curve.

The hydraulic measurements included also discharge measurements on the Fossa and Thjorsa in addition to those made routinely by the hydrology department of SEA.

Natural Construction Materials Investigations

The construction of the Burfell Project requires such natural construction materials as coarse and fine aggregates for concrete, sand and gravel for filters, rock shell material, riprap, fine grained impervious core material, and road metal. The availability and quality of these construction materials has an important bearing on Project costs. An extensive reconnaissance was conducted to locate potential sources of each of these materials. This included the location of bedrock exposures suitable for quarry sites, alluvial and glacial sand and gravel deposits, and deposits of soil and glacial moraine. The topographic mapping and regional geologic mapping assisted this reconnaissance greatly. Nearness to the site of estimated use was an important consideration. The investigations for the tests of natural construction materials are presented in detail in Appendix C of Volume II.

Deposits located by the reconnaissance were then appraised as to type, quantity and quality. Numerous auger holes and test pits were made in promising deposits of unconsolidated materials to permit sampling and determination of depth. When appropriate, each deposit was mapped or cross-sectioned. Selected samples were subjected to standard laboratory tests. Two potential quarry sites out of three investigated were drilled and test blasted. Samples were selected for laboratory tests. The drill core was studied to evaluate the use of required excavation for other appropriate constructions. A few cores were tested.

Concrete aggregates may be obtained by processing sand and gravel from alluvial deposits or by crushing excavated bedrock, either from quarries or required excavations. Four alluvial deposits were investigated. Three were west of Burfell and near the Fossa, while the fourth was along the west side of the Thjorsa approximately six kilometers upstream of the diversion structures. The latter deposit appears to be the most desirable. The three deposits near the Fossa and in the Thjorsa downstream therefrom contain more undesirable volcanic ash and scoriaceous constituents than the Thjorsa deposit. Chemical tests indicate the possible presence of alkali reactive minerals. Mortar bar tests will, therefore, be made. It is understood that the Iceland cement plant (Sementsverksmidjan) can produce low alkali pozzolanic cement which may possibly permit the use of aggregates containing alkali reactive minerals.

The cost estimates have been based on the use of aggregates manufactured from quarried rock. Rock from the basalt on top of the west end of Samsstadamuli appears, as a result of tests on samples from the test blast, to be acceptable. Similar physical tests on the blasted material from the basalt outcropping on the extreme north end of Skalarfell showed comparable results, but this basalt contains minerals showing potential alkali reactivity.

The basalt in which the underground powerstation is to be located is being tested for possible use as crushed aggregate, if desired by the contractor. This rock is dense and hard and petrographic analysis indicates that there may be no deleterious reaction with cement alkalis. It is expected to prove suitable.

The two kinds of acceptable impervious core materials investigated are morainal materials deposited by glaciers and loess-like materials deposited by the wind. Ten potential sources were investigated. The impervious material for the right bank dikes is planned to be supplied from a small (20,000 m^3) deposit of loessic soil located on the west bank of the Thjorsa approximately five kilometers upstream, and from the moraine discovered by the driving of the exploration tunnel. A high volcanic ash content eliminated a number of other loessic deposits located west of the Thjorsa. Impervious material required for the left bank dike may come from a deposit of loessic soil on the east side of the Thjorsa approximately opposite the one referred to above, and from a morainal deposit located on the slopes southeast of Rangarbotnar. Compaction and permeability tests indicated that material forming these four deposits was suitable for use in the impervious cores of the rock-fill dikes.

The alluvial deposits investigated for concrete aggregates contain suitable material for use as filters in the dikes. The area along the Thjorsa located upstream from the diversion structures can supply most of the requirements in addition to furnishing concrete aggregates. Fine filter material is available in copious quantities from the sand deposit located south of Samsstadamuli and east of the Fossa. Coarse material may also be obtained from the islands in the Fossa west of Samsstadamuli and from the bed of the Thjorsa downstream of the mouth of the Fossa. No deposits suitable for filter material are available nearby on the east side of the Thjorsa for use in the left bank dike. The cost estimate for this structure is based on manufacturing filter material from the Thjorsa lava flow which underlies the plain. Alternatively, the contractor may select to transport from the alluvial deposits on the west side. The rock fill for this dike may also be quarried from the Thjorsa lavas, or, alternatively, from the nearby Hekla flows.

The shells for the dikes located west of the Thjorsa will be constructed of suitable rock from the excavation required for the concrete diversion structures, outlet canal, intake canal, and sluiceway. The quantity is believed sufficient. Any deficiencies would be offset by a northward enlargement of the diversion canal or from quarries in the older basalt to the west. A test blast showed excellent breakage characteristics. Any required riprap, such as for the river cofferdams, could be select rock from the excavations.

Road metal of suitable quality is abundant almost everywhere in the Burfell area. The alluvial deposits referred to above can be used by proper blending. The scoriaceous surface of lava flows, almost everywhere abundant, can be easily worked into a suitable road surface.

Ice investigations must, of course, be limited to winter months. The earlier investigations of ice on the Thjorsa have been of a general nature and mostly concerned with such general matters as observations of ice jams and open water conditions. These observations were qualitative only. More detailed studies are underway this winter in the vicinity of Burfell aimed towards the collection of quantitative data in addition to continuous qualitative observations.

Meteorological observations made during the periods when personnel were resident at Burfell included air and water temperature readings, wind direction and velocity, relative humidity, and precipitation measurements.

Geology

The rocks encountered in the general area of Burfell consist mainly of several groups of thick accumulations of volcanic rocks (flows and intercalated sediments) separated by major erosional unconformities with appreciable relief. The lava flows exhibit considerable variations in their physical characteristics. They are often separated by clastic interbeds and overlap with accumulations of clastic deposits at their margins. Their stratigraphic sequence and notation are shown in the columnar section on Exhibit 10 and their distribution and occurrence are shown in plan and section on Exhibit 11.

The geology of the Burfell Project area is shown in plan on Exhibit 12. Selected sections are shown on Exhibit 13.

The oldest rocks encountered in the Burfell area are a thick series of basaltic, andesitic, and rhyolitic lava flows with clastic interbeds, referred to as the Older Burfell Group (OB). Near the end of the

Pliocene epoch, a broad northeast-southwest trending valley was eroded into these rocks in the area between the present location of Burfell and of Stangarfjall, six kilometers to the north. This valley was then partially filled with a complex sequence of materials consisting of tuffaceous sandstones interfingering at the margins with coarse talus breccias which were derived probably from higher topography to the south. A complex sequence of basalt flows and intercalated sediments then accumulated progressively on top of these materials. This sequence is known as the Samsstadamuli Group (SM).

The basalts of the Samsstadamuli Group consist essentially of seven flows separated by clastic, more or less tuffaceous, interbeds. Near the margins of the ancient valley these materials interfinger with talus and fanglomerate deposits. The basalt flows are dark colored, dense, and not notably porphyritic. Most of them show columnar jointing and an irregular bottom breccia. The underground powerhouse chamber will be excavated in the lowermost and thickest of the seven basalt flows in the group. The flow is dense, relatively watertight and is probably columnar jointed.

The Burfell pillow lavas (BP), although nearly 300 meters thick, are restricted to Burfell Mountain and were probably extruded from fissures cutting through the mountain, possibly when the region was covered by a glacier. Sporadic deposits of glacial till at the base of the Burfell pillow lavas mark the onset of Pleistocene glaciation.

In early to mid-Pleistocene time a deep canyon was eroded into the strata of the Older Burfell and the Samsstadamuli Groups. The development of the canyon probably followed the margins of the Samsstadamuli basalt flows where they interfingered with the talus. This canyon was filled with basalt flows and basaltic breccias which are known as the Samsstadaklif basalt (SB). These flows extended down to an elevation of at least 185 meters on the south slopes of Samsstadamuli.

The Skeljafells dolerite (SD) was deposited over the Samsstadaklif basalt without any noticeable signs of an unconformity. It forms the mountain Skeljafell and the ridge three kilometers to the east.

The mountains east of the Ytri-Ranga (the Hekla Massif) are built mainly of palagonite pillow lavas and volcanic breccias (PG) that were probably extruded beneath a glacier. These materials consist of very loose and porous pillow lavas and volcanic breccias.

The Burfell region was overrun by glaciers during the last glacial stage and sporadic deposits of dense, impervious tillite (GT) were laid down. The portal and a short segment of the access tunnel to the underground powerstation will be in a hard and dense morainal deposit.

The thick deposits of sand in the Fossa and Thjorsa valleys south and west of Burfell, referred to as Finiglacial deposits (FG), were probably laid down as deltas at the end of the Glacial epoch when sea level was over 100 meters higher than the present level.

In early Holocene a sequence of seven lava flows erupted from fissures in the Vatnaoldur district located 50 kilometers to the northeast. These flows, called the Thjorsa lavas (TH), filled the valley of the Thjorsa, changing the elevation and grade of the river and resulting in the formation of waterfalls and rapids as they passed around Burfell. The older lava flows filled the valley to the height of the Rauda Gap, diverting part of the youngest flow down the Thjorsardalur where it continued along the Fossa as far south as the Thjorsa.

The volcanic ridge, Hekla, lying eleven kilometers southeast of Trollkonuhlaup has contributed large amounts of ejectementa in the form of ash and pumice lapilli to the area. It underlies the Thjorsa lavas and together with sand and loessial soil forms the pervious interbeds between the lava flows. Thick deposits of lapilli, ash and wind blown loess form a thick overburden cover over the lava plains on either side of the Thjorsa.

Recent accumulations of silt, sand and gravel carried by ice and the river form deposits along the Thjorsa and the Fossa.

The lava flows and associated clastic interbeds lie generally nearly flat. Those of the Older Burfell Group dip about four to five degrees to the north. The strata of the Samsstadamuli Group dip little more than one degree to the east; while the Thjorsa lavas have an average dip of about two degrees to the south.

The soil cover is generally limited to dune-like deposits of loess-like materials. In large areas, particularly to the north of Burfell, soil cover is practically non-existent, unless the deposits of Hekla ash and lapilli which cover much of the Thjorsa valley are to be considered as soil. Rock weathering is confined to superficial breaking of the rock by frost action mainly. Chemical weathering is practically non-existent.

The most prominent geologic structural features of Iceland are two sets of faults which strike in a northeast-southwest direction. Movement along these faults began far back in the geologic past and seems to have practically died out in more recent time. Although several large northeast-southwest trending fissures can be traced across the Burfell region, the amount of displacement appears to be very slight in rocks younger than the Older Burfell Group. No appreciable brecciation was observed along any of the fissures. However, some hydrothermal alteration of the rocks in the Older Burfell Group occurs along some of these fissures. In the Plateau basalts, underlying the site at considerable depth, the displacement along the same fissures may be considerable. The valley, Samsstadaklif, is developed along one of these fissures. The Burfell region is visited by fairly frequent earthquakes of moderate intensity. There is no reason to believe that they represent a danger to properly designed and carefully constructed engineering works.

Because of the nearly flat-lying character of the lava flows and associated clastic interbeds, there is a marked tendency for the ground water to be perched on top of relatively impermeable layers. The Thjorsa itself is perched, having sealed the open joints in the underlying flow with silt and clay. A second perched water table lies about 15 meters below the bed of the river. There are probably still other perched water tables at greater depths.

The engineering aspects of the geology are discussed in Chapter V.

CHAPTER V

PROJECT ARRANGEMENT

General Description

The Burfell Project is a run-of-river power development with pondage. It will develop for hydroelectric power approximately 120 meters of gross head by a diversion of the waters of the Thjorsa from a point a short distance northeast of Skalarfell to the Fossa west of Samsstadamuli. The diverted waters will be re-regulated in the Bjarnalaekur Pond before utilization for power in the powerstation. Transmission lines will carry the power to load centers.

The Project consists of two main components, the production plant and the transmission plant. The general arrangement of the production plant is shown on Exhibit 4. The transmission routes from Burfell to the Reyjkavik area are shown on Exhibit 5.

The production facilities in the Burfell area consist of three essential features: (a) the diversion structure and associated features; (b) the Bjarnalaekur forebay pond, including the retaining dikes; and (c) the powerstation, including the sluices, intakes, penstock shafts, and tailrace.

The various facilities proposed for the Burfell Project are described in detail in this Chapter. The designs described formed the basis for the cost estimates discussed in Chapter II.

Diversion Structures

General

The diversion of the Thjorsa into the Bjarnalaekur Pond will be accomplished by relatively low structures as shown in plan on Exhibit 14. Their general location was established by the location of the natural depression to be utilized by the Pond, which provides a substantial length of the Project's water conductors at remarkably low cost. The specific location of the diversion structures was established as a result of economic analyses aimed to establish the most economic position and elevation with respect to costs and benefits. These costs included the costs associated with creating the Bjarnalaekur Pond.

The creation of a storage reservoir at Burfell was abandoned for economic reasons insofar as initial development is concerned as a result of the 1961 studies, discussed briefly in Chapter I. The cost and benefits of the required dam appear no more attractive at the selected Upper Site than at the Lower Site. However, the layout for the proposed initial development does not preclude the future creation of a storage reservoir by a fill dam located somewhat downstream from the diversion structures.

A diversion dam of moderate height to assist with ice control during the winter months would probably have been desirable. The pond thus created would assure a cover of surface ice which would eliminate most of the ice problems inherent with projects located in areas with cold winters. However, the Thjorsa in the general area under consideration flows with its bed incised only a meter or so into the surface of a broad, nearly flat lava flow. A dam of moderate height and of the great length required was considered prohibitively expensive. Other solutions to the ice problems were sought during the planning phase of the Project and had an important bearing on the designs.

The function of the diversion structures is to assure to the powerstation a reliable supply of water in adequate quantities with minimum losses. The principal factors affecting reliability are silting and icing. The former requires means for passing as much of the bedload of the river as feasible past the structures, excluding as much as feasible from filling into the forebay pond, and eliminating clogging in the passages between the river and the pond. Icing problems are much more unpredictable and their solution more difficult and unreliable. The requirement for adequate diversion quantities with low losses requires very little head, hence, in this regard, these structures are relatively low.

The diversion structures consist of (1) a free overflow weir and a gated spillway section across the river with a silt excluder located upstream from the gated section, (2) a contiguous inlet structure on the right bank, (3) rockfill dikes extending upstream on each side of the river, and (4) a diversion canal leading from the inlet into the Bjarnalaekur Pond. Details of the dikes are shown on Exhibit 14, while the weir and inlet structures are shown on Exhibit 15.

All of the structures will be founded on good basalt of the uppermost of the Thjorsa lava flows, as shown on Exhibit 12, Sheet 2. The relatively thin lapilli overburden and the upper scoriaceous zone of the lava will be removed where necessary. The foundations for these structures are shown in geologic section on Exhibit 13, Sheet 2.

The rock in the river channel has been sealed by silt and clay deposited in the fractures. Head differentials are small. Therefore, curtain grouting under the structures to control underseepage is not considered as required, except perhaps locally.

Diversion Dam

The diversion dam consists of an overflow weir on the left and a gated section on the right. The upstream portion of the gated section includes a silt excluder. The dam will serve to create the head required for diversion and also provide the spillway. The combined discharge capacity of the overflow weir and gated section is adequate to pass the probable maximum flood, which was selected as the design flood, without overtopping the left dike. The gated section will also serve to pass sediment and ice. Details of the structure are shown on Exhibit 15.

The gated spillway section will have an estimated discharge capacity of about 800 cubic meters per second with the water level at the crest of the overflow weir, elevation 244. 5. It is estimated that the water level immediately upstream of the weir will be at elevation 248. 0 in the case of the design flood of 7750 cubic meters per second. Of this, about 2300 cubic meters per second will be discharged through the gated section and the remainder over the weir.

The overflow weir will be of the mass concrete type. The crest will be about four meters above the riverbed. This height of weir was chosen on the basis of the minimum depth of water that will provide satisfactory inlet conditions under normal operating conditions with the water level at the crest or slightly below. The overflow weir will be 275 meters long extending from the dike terminal structure on the left bank across to the gated spillway and sluice section near the right bank.

The gated section thus will be located immediately to the right of the overflow weir. It will consist of four bays, each twelve meters wide. The total length of the structure will be 56 meters, including the piers. The two bays adjacent to the overflow weir will be provided with tainter gates, 12 meters wide and 4.5 meters high, operated by individual hoists positioned on the piers. The gate sill will be at elevation 240.5, the approximate present riverbed. The two bays adjacent to the inlet will have vertical lift gates, 12 meters wide and 5 meters high with additional two-meter high flaps that can be lowered to pass surface water and ice over the gate. The sill of the gates will be at elevation 237.5. These gates also will be operated by individual hoists positioned on the piers. Operation of all gates will be by remote control from the powerstation. Facilities for heating of the gates and the gate guides will be provided.

The silt excluder has been included at this stage of the design. Its purpose is to provide a means to sluice some of the bedload to downstream of the dam and prevent that portion from clogging the intake entrances or producing silting in the Bjarnalaekur Pond. It is expected that the bedload will accumulate upstream from the weir and establish eventually a new grade of the Thjorsa upstream which will tend to parallel the present grade. It is essential to maintain under this condition, insofar as feasible, a deep channel in front of the diversion inlet. The design shown is intended to serve this function, at least in part.

The basic design has been used with some success in connection with irrigation water diversion, particularly in southern Asia. The principle involved is to remove bedload from the face of an accumulating deposit utilizing medium velocities within culverts positioned across the front of the inlet. The discharge and the velocity of the sluicing water is controlled by sluice gates located at the downstream end of the culverts which, in this case, are represented by the vertical lift gates in the spillway. The details of the design will need to be developed by hydraulic model tests in the detailed design stage of the Project. It is not expected that the silt excluder will remove all the bedload and pass it downstream. Some portion will enter the diversion canal and the Bjarnalaekur Pond from where it may need to be removed by maintenance dredging. The cost of this dredging has been included in some degree in the annual operation and maintenance charges. Additional silt will tend to accumulate on top of the culverts, in front of the diversion inlet. The two vertical lift gates in the dam are designed to permit sluicing of these accumulations downstream, especially during flood seasons when excess water is available and bedload is greatest. Some dredging may occasionally be required to supplement the silt removal features incorporated in the present design. In any event, the proposed features for reducing siltation will need to be determined finally utilizing the results of hydraulic model tests as one important basis.

The details of the present design of the silt excluder are shown on Exhibit 15. Six concrete culverts, each 3.5 meters wide by 1.5 meters high, extend upstream from the vertical lift gate portion of the spillway to positions in front of the diversion inlet. The culverts will be of varying length, with the shorter lengths located at the greatest distance from the inlet. The outlet of the culverts will be immediately in front of the sluice gates where the sill elevation is 237.5. The available gross head of about four meters will provide medium to high velocities in the culverts by lifting the sluice gates about 1.5 meters. Relatively little water is required for the sluicing operation, nor should continuous discharge be required. It is expected that controlled operation will occur principally with river flows slightly above generating station capacity. When additional water is being sluiced to clear deposits on top of the culverts the system will operate uncontrolled at near maximum efficiency.

A training wall with crest at elevation 245 will extend for 90 meters upstream from the spillway and parallel to the diversion inlet. This wall is designed to exclude bedload from the river side and to reduce the amount of ice drawn towards the inlet. The wall provides a channel for the sluice gates separately from the remainder of the spillway. The flap element of the vertical lift gates permits sluicing ice through this channel and over the two gates. Some utilization of the silt excluders may be made with the flap gates down, thus helping to sluice the ice downstream after it passes over the gates.

The details of the training wall will also need to be established by hydraulic model tests. These may show the desirability of extending the training wall as an ice shear wall diagonally to or beyond the upstream end of the diversion inlet structure. This would require a different gating arrangement in the dam to the left of the training wall.

It is possible that the model studies may show that the silt excluder, a fairly expensive structure, cannot be justified for incorporation in the actual construction. Its annual cost might, in part, be more economically expended in increased dredging of silt accumulations from the Bjarnalaekur Pond. Some portion of the capital cost savings could be used for additional or more costly ice passing facilities than now incorporated in the designs, if required.

Inlet Structure

The inlet structure is located on the west bank of the river and at right angles to the dam. A reinforced concrete retaining wall will connect the inlet to the dam and serve as the east terminus of the Bjarnalaekur dike. The inlet serves principally to exclude ice from the Bjarnalaekur Pond and to provide a means for unwatering the Pond should that ever prove necessary. The upstream end terminates in a concrete connecting wall to the right bank dike. Details of the structures are shown on Exhibit 15.

The inlet will contain ten low level ports for entry of water into the diversion canal. Each port will be 10 meters wide by 1.5 meters high. A continuous wall above the ports will serve as a "shear" wall to guide floating ice towards the spillway and prevent its entry into the canal. The top of the wall will be on a grade from elevation 247 at the dam to elevation 247.5 at the upstream end. These elevations correspond approximately to the water surface during a flood of 5000 cubic meters per second, which is about two and one-half times the maximum flood in fifteen years of record. It was not considered necessary to protect against the design flood entering the Bjarnalaekur Pond. The sill of the ports will be one half of a meter above the top of the slab formed by the silt excluder in front of the inlet, and will be graded to correspond with the estimated normal water surface level.

The inlet structure will be of reinforced concrete construction except for the base slab which will be of mass concrete. Slots for stoplongs will be provided in the piers, but the stoplogs will not be provided initially. The necessity for unwatering the Pond appears unlikely. Future extensions of the inlet will be immediately to the upstream.

Dikes

The concrete diversion structures are connected by rock fill dikes to high ground on both sides of the Thjorsa. The left bank dike will extend from the left abutment of the spillway for about three kilometers upstream and nearly parallel to the Thjorsa. Only a short length at the downstream end will retain the normal reservoir upstream of the spillway.. The principal purpose of the dike is to retain flood waters and, in particular, to prevent their diversion to the Ytri-Ranga.

The top of the left bank dike will be graded in conformity with the estimated water surface for the design flood, as shown on Exhibit 6..

A minimum of two meters of freeboard will be provided under this condition. Backwater studies showed that the weir will have negligible influence on the water levels beyond the upstream end of the dike. Overflow into the Ytri-Ranga during floods, therefore, appears no more likely than for natural conditions. The construction of the diversion dam and dikes is believed to in no way affect this relationship.

The profile on Exhibit 14 shows the expected foundation levels as determined from the foundation investigations. The design section is also shown on that Exhibit. The dike will have a central impervious core protected by graded filters. The only foundation treatment required is assurance against piping of the core. Where necessary, this will consist of either slush grout or fine filters in the core trench.

The right bank rockfill dike will be tied to the inlet structure by a short curved concrete gravity wall extending upstream from the inlet. The dike will be about 400 meters long. The purpose of this dike is to prevent floating ice and all but the greatest floods from entering the Bjarnalaekur Pond. An impervious core will be provided up to the elevation of the water surface of normal floods, as shown on the section on Exhibit 14. The hydraulic gradient through this dike will be low since the water level on each side will be nearly the same. The impervious core is required only to permit unwatering of the Pond. No foundation treatment will be required except, perhaps, locally. The profile of the right bank dike is also shown on Exhibit 14. This profile shows the expected foundation levels, which were based on the foundation investigations.

Diversion Canal

The diversion canal will conduct diverted water from the inlet structure to the Bjarnalaekur Pond. It will extend from the diversion inlet westward for about one kilometer. A 300-meter long transition section will be excavated downstream of the inlet structure, gradually reducing from a width of 110 meters to a constant width of 70 meters. The bottom of the canal will be at elevation 240 at the inlet and will be graded with a slight slope towards the Pond. Under normal operating conditions, the average velocities will be about 0.5 meters per second for the design flow of 174 cubic meters per second with the six-unit plant. The excavation will be partly in the lapilli overburden, and partly in the Thjorsa and older lavas. The canal will cut through the Thjorsa lava into the underlying permeable interbed, a potential source of reservoir leakage. Remedies for control of this leakage are discussed below.

The alignment of the canal is curved slightly to the northward. This location was, in part, directed by placing the Bjarnalaekur Dike on the most favorable foundations.

The outlines of the canal are not necessarily fixed. Requirements for shell material for the dikes may make it desirable to widen the canal as a logical quarry source during construction.

Bjarnalaekur Dike and Pond

A forebay pond will be provided in the natural depression west of the diversion structures by construction of a rockfill dike extending from the diversion dam to high ground a short distance west of the

Bjarnalaekur. The Pond will have several functions. It will provide a low cost water conductor leading from the Thjorsa westward for about three kilometers to the intake for the powerstation. The surface area of about one square kilometer will permit the formation of an ice sheet early each winter and thus minimize ice problems at the powerstation intake.

The area and volume relationship with respect to elevation for the Bjarnalaekur Pond are shown on Exhibit 6. A large volume is available for detention of silt. The values shown on the graph are based on the present ground surface. However, much of the depression is covered by a thick mantle of light-weight lapilli, as shown on Exhibit 12. It may develop that much of this lapilli can be floated readily and removed from the reservoir hydraulically at low cost. Hydraulic dredging after the Pond is filled may also be cheap. It appears very probable that the silt detention capacity can be increased greatly at relatively low cost if and when required. Some capability may be attained as a result of sluicing out the lapilli floated by the initial filling of the Pond.

The volume of pondage available in the upper one or two meters of the reservoir will permit a considerable degree of peaking whenever capacity from the Burfell Project becomes important and valuable.

The Bjarnalaekur dike will be about 1700 meters long and located in plan as shown on Exhibit 14. The profile and a typical section are also shown on that Exhibit. The crest will be level at elevation 251, which is about two meters above the estimated water surface in the Pond under design flood conditions. The rockfill dike will have a central impervious core protected by graded filters.

The bedrock underlying the dike is shown in plan on Exhibit 12, Sheet 2, and in geologic section on Exhibit 13, Sheet 2. Slightly less than one-half of the length will be founded on the uppermost Thjorsa lava. The remainder of the foundation consists of grey basalts with some conglomerate, both of excellent quality. The lapilli overburden, up to ten meters thick, will be removed to the bedrock foundation. Additional excavation of the weaker surface zones will be required under the core. Piping of the core from underneath will be prevented by slush grout.

The significant feature of the dike foundations is the presence of the interbed at shallow depths beneath the uppermost Thjorsa lava flow. It daylights in the Bjarnalaekur downstream of the dike and is the source of large springs. It will be open to water in the Pond under the lapilli overburden and will also be cut by the diversion canal. There is thus the possibility of short-path leakage between these points accompanied by velocities adequate to result in piping of the interbed materials. Fluorescein dye injected into drill holes in the area showed moderately high groundwater velocities even under the existing lower flow producing heads. Permeability tests in the drill holes showed this interbed to be rather highly permeable.

For these reasons, the interbed will be pressure grouted under that portion of the dike which rests on the most westerly tongue of Thjorsa lava. Limited grouting may also be required where the dike core rests on the older basalts. A clay blanket tying to the impervious core of the dike will be provided where the interbed is cut by the diversion canal. These measures will prevent any appreciable leakage from the Pond through the interbed. Grouting of the interbed under the Thjorsa lava at the eastern portion of the dike will not be necessary.

Elsewhere than described above, the Bjarnalaekur Pond is contained by older rocks of lower permeability and no leakage of consequence may be expected.

The saddle between Skalarfell and Samsstadamuli at the western end of the Bjarnalaekur Pond is lower than the control elevation of 251. A rockfill dike, shown in plan on Exhibit 17, will close this gap. The design of the two dikes is similar. Both dikes will support Project access roads.

The Ice Problem

That ice may be a problem in connection with the operation of the Burfell Project has, to some extent, been discussed above. It has not and cannot be taken lightly, representing, as it does, probably the only serious problem associated with operation of the Project. It is not sufficient to assume that designs to reduce or eliminate ice problems which have proven successful elsewhere can, in principle, be applied, as appropriate, to the Burfell Project with assurance of complete success. The Burfell Project has its own unique ice problems which can and will be solved successfully. The designs presented in this Report represent considered opinions to provide the greatest assurance of safety within the present knowledge of ice conditions on the river and the problems they will present when the structures are placed in operation. More refined details will be evolved and model tested during the detailed design phase of the Project. Further information on ice conditions in the Thjorsa will become available as a result of field investigations being conducted during the current winter. It is understood that the SEA is embarking on special research and studies associated with ice on Icelandic rivers. Data thus accumulated will be helpful to advance the designs pertinent to the solution of ice problems.

Much of the channel of the Thjorsa in the vicinity of the diversion structures remains open and free of sheet ice even in the coldest winters. Quantities of cake and sludge ice are carried in this open channel to a greater or less degree throughout most of every winter. Some of this ice is gathered into large ice jams at downstream points, notably below the mouth of the Fossa and downstream of Urridafoss. Data on these factors is being accumulated this winter and will be used for evaluating the present designs--or modifying them.

Much of the sludge ice is caused by snow blowing into the open waters of the river, especially during extreme frost periods. Snow fences have proven highly successful in the protection of highways under similar conditions. They are used extensively for that purpose in the windy and barren high plains of the western United States. The typical construction is a woven wire fencing slatted with wood lath and supported by posts.

This type of snow fence construction is proposed on both sides of the Thjorsa upstream from the diversion structures for about 10 kilometers, where the Thjorsa is known to be open, at least in part. These fences will be placed parallel to the river in the area to be protected. They are expected to trap much of the blowing snow into drifts on the lee side of each fence.

The principal problem associated with ice at the diversion structures is to present a jam which will block off, in whole or in part, the supply of water to the Bjarnalaekur Pond. The designs provided in this Report envision sluicing the ice past the structures and downstream with a minimum of water sacrificed from power generation. Usually, there is a surplus of water to powerstation requirements. If this basic procedure proves somewhat less than completely successful, it may be necessary to provide supplemental flow for sluicing by an initial storage at Thorisvatn, not now considered justified for power flows alone.

The floating cake and sludge ice might, for the most part, be prevented from reaching the diversion structures by creating artifically an ice jam at an appropriate upstream point. A solution of this type has been proposed in Norway and is understood to have been used in the Soviet Union. No detailed information is available on the latter. A procedure of this type would require a partial barrier to initiate the formation of a jam. It should be open enough as to not permit the accumulation of silt. It should be stable under the condition of large floods, yet not cause damaging flood stages either during floods or by the jam itself. The structure might be formed of constructions similar to tetrapods. They would, for stability, need to be placed on bedrock in the river bottom.

The development of about 55 meters of head for power immediately upstream from Burfell does not appear attractive. The construction of a protecting ice jam in this general reach would thus not interfere with any planned future project. The reach of the Thjorsa east of Stangarfjall appears favorable for such a barrier and jam. This possible solution to the ice problem will be studied during the design stage for Burfell.

An ice jam may form in the vicinity of the diversion structures and upstream without interference to the water supply for generation. It is believed that the height of the structures is adequate to prevent any damages thereto.

In any event, hydroelectric power developments have been constructured in great numbers in cold climates where ice presents the possibility of winter operational problems. There is thus a great accumulation of ice problem experience available which will be drawn on to the fullest in evolving final designs.

Power Features

General

The arrangement of the power features, beyond the Bjarnalaekur Pond, is controlled by topographic and geologic relationships. The Pond brings the head concentration for the diverted Thjorsa waters to within two kilometers of the Fossa. Within this length the remaining water conductors must be primarily in tunnel through Samsstadamuli. A dominantly open channel route via the topographic divide or somewhat farther south requires a prohibitive amount of excavation.

The tunnel route thus established permits a surface powerhouse near the Fossa or an underground powerstation involving either a headrace or tailrace tunnel. Cost-wise there appears little difference between a surface or underground location for the main generating plant. Underground construction was selected for the initial development principally because of more favorable construction conditions during the winter period of disagreeable construction weather. Surface construction should still be considered for enlargements of generating facilities beyond the completed initial plant.

The geologic relationships of the rock formations within Samsstadamuli are complex, as is discussed in Chapter IV, and in greater detail, in Appendix B, Volume II. These relationships were investigated by extensive core drilling, geologic mapping, and by a partially completed exploration tunnel. The controlling geologic factor is the placement of the large powerstation excavation in the best available rock, with due consideration to the location of the associated excavations of smaller size. The thick basalt flow, designed SMa of the Samsstadamuli Group, was considered to be the most favorable formation for powerstation construction, and was accordingly selected. This selection for the powerstation resulted in the requirement of placing the other underground excavations in rock of lesser quality than this basalt, but this other rock is adequate.

The selection of this basalt formation for the powerstation excavation dictated a tailrace type of development, because of the lateral limits of that formation. A powerstation served by a headrace tunnel would need to be positioned in tuffaceous sandstone of the Samsstadamuli Group. This sandstone is not considered favorable for large underground chambers. A headrace tunnel, on the other hand, would be located in upper flows of the

Samsstadamuli (SM) and the Samsstadaklif (SB) Groups. The same would be true for a pressure headrace tunnel serving a surface powerhouse at the western foot of Samsstadamuli.

The selected locations for the power features of the Burfell Project are shown on the geologic sections of Exhibit 13, Sheet 1. These sections show the important geologic relationships discussed above. Also shown are the borings from which these relationships were interpreted. The associated areal geology and the location in plans of the drill holes and exploration adit are shown on Exhibit 12, Sheet 1.

The specific location of the powerstation within the SMa basalt was controlled by two factors. The first factor was a location far enough from the edge of the flow to assure an adequate thickness of sound basalt. This controlled the location in a northerly direction. The second factor involved keeping the penstocks as short as feasible. This, together with surface topographic and geologic relationships associated with the power intake, controlled the powerstation location in the easterly direction. The selected location of the powerstation and associated features is shown in plan on Exhibit 17. The location of the power features with respect to the diversion structures and the Bjarnalaekur Pond is shown in plan and sections on Exhibit 4.

Power Intake and Sluice Facilities

The interrelation in the location of the powerstation, penstocks, and power intake was discussed above. In consideration thereof, the power intake was located as close to the Bjarnalaekur Pond as feasible, at the same time providing sound rock foundations with minimum excavation. The plans and sections of the power intake, including the approach channel and sluiceway, are shown in Exhibit 16.

The selected location of the power intake requires a short excavated approach channel to connect the power intake with the Bjarnalaekur Pond. The canal will be about 300 meters long and 40 meters wide. The bottom will be at about elevation 238, with a slight grade downward toward the intake. The canal will be widened and deepened in front of the intake to provide low approach velocities under all operating conditions. The excavation will be mostly in soil in the shallow portion toward the Pond, but will be almost entirely in basalt near the intake.

The intake will consist of three individual bays, each serving one pressure shaft. The bays will be in a straight line and oriented at an angle of about 60 degrees to the direction of the approach canal. They will be connected by short retaining walls placed in line with the front of the intakes, and by a continuous deck at elevation 249.0.

The intake will form the entrance to the vertical pressure shafts (penstocks) and will be provided with removable trashracks and with gate slots for a vertical lift gate. Concrete construction will be used. The sill will be at elevation 231.5, or about 2.5 meters above the bottom of the approach canal. The trashracks will be submerged about two meters below minimum water level and will be made removable. Stoplogs may be inserted in the trashrack slots if required. Heating of the trashracks will be provided. A guide wall for surface ice will be provided in line with the front of each opening, extending from the deck into the water about two meters below the minimum operating level.

The trashracks will be operated by a bridge crane located in a house constructed on the intake deck at elevation 249.0. This crane will also operate a wheeled gate, 5.5 meters wide by 6.5 meters high, which can be lowered into any of the three intake openings as required. The transition from the trashrack openings to the pressure shafts is designed to minimize hydraulic losses.

Provisions are required beyond the intake for sluicing silt, ice, and such debris as floating lapilli. An excavated open channel with a control structure will be provided. The channel is carried only to the point where the sluicing waters may be released down the west slope of Skalarfell to the Fossa. Much of this route is in easily erodable material, and considerable erosion will take place until a reasonably stable channel is achieved. It is expected that the powerstation discharge will carry the eroded material out of the Fossa and into the Thjorsa downstream. However, some initial artificial removal during the initial operating period may be required from the Fossa channel between the tailrace outlet and the newly eroded channel. The construction of the permanent access road bridge across the eroded discharge channel will probably need to be deferred until the channel approaches stability.

The excavated channel beyond the intake will be eight meters wide at the bottom and constructed with a grade towards the outlet. The channel excavation will be almost entirely in basalt, as indicated on Exhibit 12, Sheet 1. Most of the rock excavated from this channel as well as the headrace canal will be used in the construction of the dikes.

The sluiceway control structure will be located in the channel at the downstream end of the power intake. The structure is designed to permit passing debris and ice over a weir at elevation 242.5. Sediment and other materials can be bypassed through an undersluice with the sill at elevation 229.5, two meters lower than the intake sill. Both openings in the sluice structure will be six meters wide. A hoist with movable trolley will operate both gates. The hydraulic capacity of the two openings will total about 150 cubic meters per second.

Pressure Shafts

The three vertical pressure shafts will connect the intake with the six turbines in the underground powerstation, each shaft serving two units. A profile of the shafts, which will all be of the same design, is shown on Exhibit 20. The number of shafts was selected on the basis of economic studies which included evaluation of head losses and associated costs and benefits. The shafts will be steel lined throughout with a constant diameter of 3.8 meters from the intake to the bifurcation at the powerstation level. A 90-degree bend at the bottom of each shaft connects with a short, horizontal section, which bifurcates into two smaller pipes leading to the turbines. Each of the pipes will be provided with a butterfly valve located inside the powerstation and accessible from the machine hall crane.

The total length of the penstock including the bifurcation and horizontal portion will be about 135 meters. The annular space between the steel lining and the rock excavation will be filled with concrete. The rock surrounding the penstocks will be pressure grouted.

The geologic section through the penstocks is shown on Exhibit 13, Sheet 1. This section shows that about 80 meters in the middle portion of the vertical leg will be in talus-fanglomerate materials. The remainder will be in basalt of good quality. The talus-fanglomerate materials are erratic in composition with a more or less clayey matrix that tends to slake when exposed to air. Some portions have a rather high permeability and moderate flows of groundwater may be encountered at various depths. The cost estimates include steel supports for the entire excavation that will be in this formation.

Powerstation

The bases for the selection of the location of the underground powerstation were discussed above. The excavation will be under about 100 meters of rock cover and will be entirely in the SMa basalt except for the roof arch which may extend into the overlying talus-fanglomerate. The contact between these two formations is not known in detail. Therefore, the present designs for cost purposes assume placing the roof arch in this weaker material.

Details of the powerstation are shown in plan and sections on Exhibits 18 and 19. As presently planned, the machine hall will house six units of a vertical setting. It will be 16 meters wide and 115 meters long, including the erection bay at the south end and the control bay at the north end.

The roof in the machine hall will be concrete lined throughout. An allowance has been made in the cost estimate for the provision of a suspended drip ceiling. The crown voids behind the concrete lining are to be thoroughly grouted. Temporary support during construction of the roof probably will be required over most of the length. An allowance was included in the cost estimate to cover the cost of such support. The actual type that will be used will depend somewhat on the excavation methods adopted by the contractor.

The substructure concrete of the powerstation will be placed against rock throughout. The generator foundations are of concrete construction and founded on the concrete embedded around the spiral casings. Space is provided for all electrical and mechanical equipment in accordance with conventional practice for this type of underground arrangement. An overhead bridge crane will be supported by concrete columns and beams along the entire length of the machinehall. Concrete block walls will be installed between the columns under the beams, with an air space between them and the excavated rock faces.

The reinforced concrete control building will be a free standing structure within the powerstation excavation and will contain the main control room, station service equipment, compressor room, battery room, and offices.

The turbines will be set at elevation 120, or three meters below the estimated minimum tailwater, in order to permit high speed units. This setting includes an allowance for probable future degradation in the streambed of the Fossa. The draft tubes will discharge into a surge chamber excavated downstream of the machinehall. A draft tube gate structure will be provided within the surge chamber. The gates will be handled by a monorail hoist suspended from the concrete roof. Access to the deck will be by a short level tunnel connection with the access and cable shaft. Venting of the surge chamber will also be through this tunnel. The two draft tube gates will be brought in through the tailtunnel.

A gallery will be provided above the powerstation to permit drainage of the rock mass above the powerstation roof. Drain holes will be drilled from the tunnel into the surrounding rock. The gallery will drain into the surge chamber.

Access to the powerstation will be provided by a shaft at the north end and a tunnel at the south end. Both will serve for ventilating purposes. The shaft will provide a vertical route from the switchyard and connect at the bottom through a short tunnel to the control bay at generator floor level. The tunnel will represent access for vehicles principally, during both the construction and operation periods.

The shaft will contain a stairway and an elevator. It also will contain the low tension cables connecting the generators to the transformers. Fresh air will be drawn in through the main access tunnel by fans located in the erection bay below the main floor and from there distributed through the powerstation. The air will be exhausted through the shaft.

The location of the access tunnel is shown in plan on Exhibit 17. It is shown in profile in the geologic section of Exhibit 13, Sheet 1. The location was selected to provide a low grade with the portal at a safe location with respect to erosion of or flooding by discharges from the sluiceway at the intake. The alignment incorporates the completed portion of the exploratory tunnel. It is expected that this exploratory tunnel will be completed prior to final design.

The tunnel will be 900 meters long and slope towards the power-station at about 3.5 percent grade. It will enter the erectionbay at the 130 floor elevation. A section is shown on Exhibit 20. As shown on the geologic section, the portal and the first 120 meters will be in compact glacial moraine. The central part will be in andesitic lava flows of the Older Burfell Group, the next 200 meters in fanglomerate materials, and the remainder in the basalt of the power station area. The floor of the 5.5 meter wide tunnel will be concrete paved throughout, but the walls and roof will be lined only where steel supports are required, estimated at 50 percent of the length. The concrete floor will contain a water collecting system and a drainage line which will discharge into the surge chamber with flap valve protection.

Extensive use of rockbolts for temporary support was assumed for all excavations required for the power features.

Tailrace

The tailrace will extend from the surge chamber to the Fossa west of Samsstadamuli as shown in plan on Exhibit 17. It will be in tunnel from the surge chamber to the portal, a distance of about 1750 meters. The tunnel portion is shown in profile on Exhibit 20. The upstream portion of the tailtunnel will consist of short tunnels, one for each draft tube, leading from the surge chamber to a collecting upstream extension of the tail-tunnel which is oriented at an angle of about 20 degrees to the powerstation, as shown on Exhibit 18. These tunnels and their connections are designed to minimize turbulence and hydraulic losses. The tailtunnel will be of horseshoe shape with a nominal diameter of 7.5 meters. It will be flowing full under low pressures and is planned to be concrete lined except for the upstream 150 meters which will be unlined and slightly enlarged to serve as a surge gallery under load rejection operations. The short collecting tunnels immediately downstream of the surge chamber will, however, be concrete lined for hydraulic efficiency.

As shown by the geologic section of Exhibit 13, Sheet 1, nearly all of the tailtunnel except the upstream 300 meters will be in the talus-fanglomerate and tuffaceous sandstone of the Samsstadamuli Group. An undetermined, but probably short, length at the downstream end will be in pillow lava. The upstream portion will be in good SMa basalt of the powerstation. Other than this basalt, the rock through which the tunnel will pass is relatively weak, requiring some support and full concrete lining. The cost estimates are based on the expectation that 25 percent of the length of the lined portion of the tunnel will require steel supports during construction. The crown voids and the rock behind the concrete lining will be grouted under moderate pressures. Tunnel sections are shown on Exhibit 20.

The tailtunnel will discharge into a 150-meter long open canal which will be excavated between the portal and the Fossa. The bottom of the canal will be on an upgrade from elevation 115 at the portal to elevation 123 at the Fossa. The excavation will be in overburden of sand and gravel except near the portal, where it will be partially in rock.

The Fossa drops about four meters between the tailrace outlet and the Thjorsa, a distance of about two kilometers. It may be feasible to gain a portion of this head by a deepening of the Fossa channel, which is mostly in alluvial sand and silt. However, excavation for this purpose is not proposed at this time because the discharge from the powerstation may cause a natural degradation of the Fossa. The discharge from the powerstation will be much greater than the average flow of the Fossa which is estimated at about 15 cubic meters per second. The rating curve for the tailwater under initial conditions at the tailrace outlet is shown on Exhibit 6. The curve shows that the tailwater will be at about elevation 125.5 for normal discharges between 100 and 195 cubic meters per second. This is an estimated value based on backwater studies and the present conditions of the Fossa channel. The estimates show that the water level of the Thjorsa has little effect on the tailwater levels except during extreme floods and possibly during ice jams. There are indications that ice jams in the Thjorsa may raise the tailwater as high as to elevation 130. This was taken into account in the design of the tailrace surge chamber.

Powerstation Electrical and Mechanical Equipment

The powerstation electrical and mechanical equipment will include turbines and governors, generators, such miscellaneous powerstation equipment as valves, cranes, pumps, compressed air system, heating and ventilation, fire protection systems, and drainge and unwatering systems; such accessory electrical equipment as low tension power cables, low tension switchgear, station service equipment, d.c. power supply, emergency diesel-generator sets, control and protection equipment; and all other equipment normally associated with a powerstation of this magnitude. Greater detail is presented below with respect to the turbines and generators.

Turbines and Governors

The six hydraulic turbines will be of the Francis type, vertical shaft, single runner, with steel spiral casing and steel elbow type draft tubes. Each turbine will be rated, 44,300 metric horsepower at 115 meters net head. The full-gate turbine discharge will be about 32.5 cubic meters per second. The speed was selected at 333 rpm.

Generators

Each generator will be rated 33,333 kva, 0.9 power factor, 13.8 kv, three phase, 50 cycles. Each generator will be protected by a 13.8 kv draw-out type air circuit breaker located in the powerstation.

Access Roads and Bridges

The road system that will serve the Burfell Project is indicated on Exhibit 5. All imported materials and equipment will be unloaded in Reykjavik and transported by trucks or trailers to the Project site, a road distance of about 120 kilometers. The route will be by main roads to a point about three kilometers west of the Urridafoss Bridge across the Thjorsa, and then along an existing secondary road that extends northeasterly on the west side of the Thjorsa and the Fossa. This secondary road and portions of the main road will need widening and resurfacing to serve as the main access to the Project. A bridge will be constructed across the Fossa about 300 meters upstream of the tailrace outlet.

The road system within the Project area is shown on Exhibits 4 and 17. The road to the access tunnel portal will require bridges across the tailrace channel and across the channel which will be eroded by sluiceway discharge in the valley between Skalarfell and Samsstadamuli. The latter bridge will be a pile bent structure. The road to the intake and switchyard area will be up the west slopes of Skalarfell and across the dike at the west end of Bjarnalaekur Pond. Access to the dikes and the diversion structures on the right bank of the Thjorsa will be by a road along the north slopes of Skalarfell and across the Bjarnalaekur Dike.

Access to the diversion structures from the left bank of the Thjorsa will be by a road on the east side of the Thjorsa, connecting with the main road to Reykjavik at a point about 10 kilometers east of Urridafoss Bridge. This road will follow existing secondary roads and trails which will need some improvement in order to be suitable as construction access.

Operators' Village

The establishment of an operators' village will be necessary, in view of the lack of a settled community in this area. The location of this village is not finally decided, but a lump sum item has been included in the estimate to cover the cost of construction.

Transmission Plant

General

The transmission plant includes the Burfell step-up transformers and high-voltage switchyard, transmission lines between Burfell and the Reykjavik area and terminal substation equipment at Reykjavik. Included in the Burfell switchyard is a transformer designed to feed a 69-kv transmission circuit which would connect to the existing system at Hvolsvollur. The existing system is fed from a substation at Irafoss, which delivers power principally to the Reykjavik area over a 138-kv line. A short length of 138-kv transmission line will connect the main terminal substation to the existing major substation at Ellidaar.

Two locations in the Reykjavik area are under consideration for industrial development, namely, Eidi and Straumsvik. Two alternative transmission schemes, one with a single line, and one with two lines, were prepared for each of the two locations, as shown on Exhibit 5. One-line diagrams are shown on Exhibit 21 for the single line and two line transmission schemes with the terminal station at Eidi. The electrical arrangement with the Straumsvik terminal station would be identical; only the line lengths will vary. Estimates of cost were made for the four alternative transmission plants.

In each scheme the main terminal substation is located at the proposed location of the industrial development. This substation includes provisions for a single feeder to the industrial plant and breaker positions for the incoming transmission line(s) from Burfell and the connection to the Ellidaar substation. Therefore, power could be fed from Burfell to both the industrial plant and the existing Reykjavik system. It would also be possible for power to flow from the Reykjavik system to the industrial plant or back to Burfell, in case all Burfell generation should be stopped.

A transmission voltage of 230 kv was selected after giving due consideration to the possible use of lower voltages for the initial development.

It was found that the saving in cost which would result from use of a lower voltage would be significant only in the earlier stages of the development and that a 230-kv system would prove most economical when the Burfell capacity was increased and other potential hydroelectric sites were developed.

Substations

The Burfell switchyard will be 120 meters long and 60 meters wide and will be located at elevation 253 directly above the powerstation and adjacent to the power intake. Some shallow excavation and fill will be required.

As shown on exhibit 21 there will be three step-up transformers at Burfell. Each transformer will have two low-voltage windings, connected to two generators through circuit breakers, and one high-voltage winding connected to a high-voltage bus through a circuit breaker. A main-and-transfer-bus switching scheme is proposed. The step-up transformers will be three-phase, forced-oil-forced-air cooled, and will have a triple output rating as follows:

Mode of Cooling	%	kva
Self (OA)	60	43,200
Forced-Air (FA)	80	57,500
Forced-Oil-Forced-Air (FOA)	100	72,000

The low-voltage windings will each have an FOA capacity rating of 36,000 kva and a voltage rating of 13.2 kv. The high voltage winding will have a FOA capacity rating of 72,000 kva and a voltage rating of

230 kv. Basic impulse levels will be 900 kv for the high-voltage winding and 110 kv for the low-voltage windings.

The 69-kv circuit will be fed through a three-phase 12,000/15,000 kva, OA/FA, 230-11 - 69 kv, two-winding transformer.

The 230-kv terminal substation would be of the same construction as Burfell, whether located at Eidi or Straumsvik. A main-and-transfer bus switching scheme is proposed, as shown on Exhibit 21. For those alternatives involving only one 230-kv circuit the switching scheme would not be fully developed, but the equipment would be laid out to permit full development in the future.

Cost estimates for all alternatives include a three-phase, 70,000 kva, 230-138 kv autotransformer at the main terminal substation and a three-phase, 70,000-kva, 138-11 - 34.5 kv transformer at the Ellidaar substation. The transformers will be type OA/FA/FOA, similar in design to the main step-up transformers at Burfell. Basic impulse level for 138-kv windings will be 550 kv.

Transmission Lines

Two separate 230-kv transmission line routes have been selected as shown on Exhibit 5. One, designated the Northern route, would pass the Sog Development just south of Thingvallavatn. The other, designated the Southern route, would go by way of Urridafoss and Selfoss. Approximate distances for the alternative schemes are:

Route	km
Northern, Burfell to Eidi	107
Northern, Burfell to Straumsvik	118
Southern, Burfell to Eidi	112
Southern, Burfell to Straumsvik	118

For the schemes involving only one transmission line the Northern route was selected.

The routes chosen traverse relatively flat ground throughout most of their length and access for construction will be easy in most places.

The 230-kv lines will be of single-circuit wood pole construction with 795 mcm-a.c.s.r. conductors.

The 138-kv line to the Ellidaar substation will be approximately 13 km long if the main terminal is at Straumsvik and 5.5 km long if the main terminal is at Eidi. It will be of single-circuit wood pole construction with 477 mcm-a.c.s.r. conductors.

Provisions for Future Expansions

The designs presented in this Report include no specific provisions intended solely for a future expansion of generating capacity beyond the proposed 6-unit plant. However, the layouts were made with such future expansion in view but without adding to the initial investment for the Project.

Increased capacity in any major amount will require expansion of the diversion facilities. Space is provided at the north end of the diversion inlet structure for extension of that structure in that direction. This will require the removal of at least a portion of the concrete tie structure. The right bank dike would need to be replaced with one of shorter length, which will require a new concrete tie structure. The diversion canal would need some enlargement to the north.

Future extensions to the power intake would be beyond the initial structure and to the north. The approach channel would be widened in that direction also. The remainder of the power features involved in an expansion would be separate, substantially, from the initial plant. A similar underground powerstation of the tailrace type would probably be located in the same SMa basalt as the initial one, and in a separate chamber to the north. The access tunnel could be extended past the initial works on the upstream side to serve such a chamber. Alternatively, the new intake could connect with a headrace tunnel serving a surface powerhouse at the foot of Samsstadamuli on the west side, as discussed above.

Additional transmission line capacity might be required, but presents no problem. The transmission facilities should take into consideration, as appropriate, the status of the development of the Master Plan for the Thjorsa-Hvita Power System as of that time.

CHAPTER VI

HYDROELECTRIC GENERATION

The Potential of the Site

The energy potential of a hydroelectric development is a product of head and water availabe, up to the limit of the hydraulic capacity of the installation. Each of these two factors will be discussed below.

Head

The Burfell Project is designed as a run-of-river development which will operate under a nearly constant gross head of 120 meters, from elevation 244.5 on the Thjorsa to elevation 124.5 on the Fossa. Minor changes in this gross head may be caused by floods or by ice jams downstream, but these changes will have little effect on the energy produced or the capability of the plant.

The net head on the turbines will depend on the losses in the water conductors and variations in headwater and tailwater. The losses have been estimated and are presented in graphical form on Exhibit 6. The graph shows the total losses between the diversion inlet and the tailrace outlet. Total losses will amount to about four meters for a station flow of 150 cubic meters per second and about six meters for the maximum station flow of 195 cubic meters per second. The headwater will remain relatively constant. Tailwater will, however, vary somewhat with discharge. The estimated tailwater rating curve is shown on Exhibit 6.

Flows

The estimated natural flows of the Thjorsa at the site of the diversion dam for the period September 1, 1947, through August 31, 1962, are shown on Exhibit 7. The flows are shown in duration form on Exhibit 6. The development of these data is discussed in Chapter III, and, in greater detail, in Appendix A of Volume II.

The average flow of the river on this basis is estimated at 338 cubic meters per second. The median flow is slightly lower at about 309 cubic meters per second. The minimum daily flow was estimated at 72 cubic meters per second. A flow of 178 cubic meters per second is estimated to be available 90 percent of the time.

The Burfell Project as presently planned is a run-of-river development with no provisions for at site or upstream storage. The water available for power and energy production is, therefore, the natural river flow as outlined above. However, in the ultimate development of the river, upstream storage will be provided, probably at several locations. A small amount of storage may be developed at Thorisvatn at relatively low cost as is discussed in greater detail in Appendix D of Volume II. Only the natural inflow into the lake will be regulated. This flow would provide about 274 million cubic meters of regulation. That amount would regulate the flow at Burfell to the six-unit full gate capacity of 195 cubic meters per second. Further enlargement of the Burfell station for high plant factor operation will require more complete regulation at Thorisvatn. This would also involve diversion of the Kaldakvisl into the lake.

Pondage

Some pondage will be available for the Burfell Project by the utilization of the Bjarnalaekur Pond, which will have a surface area at elevation 244.0 of somewhat more than one square kilometer, as shown on Exhibit 6. One meter of drawdown will thus provide over one million cubic meters of pondage which may be used for daily peaking. By drawing on this pondage, the station flow could be increased by about 50 cubic meters per second for a period of six hours. This is equivalent to about 50,000 kilowatts. A two-meter drawdown would double these amounts.

Power Installations

Initial Project

The power installation that should be provided at the initial Burfell Project at Burfell is determined by two factors: (1) the expected load that the Project will serve, and (2) the availability of water.

The load requirements are presented in Chapter I. They indicate that the Project should be designed to provide nearly continuous power of 90,000 to 120,000 kilowatts for an industrial load in Reykjavik and, in addition, provide 50,000 to 60,000 kilowatts of firm power at a medium load factor to the general power system. The higher of these two values requires a plant of 180,000 kilowatts capacity, operating at the fairly high plant factor of about 85 percent.

The installed power level was, on the basis of the flow duration curve, taken to be that which would be produced from flows available about 90 percent of the time. Some energy deficiencies would be acceptable the remaining ten percent of the time. This power level and its resulting energy production was compared to the load requirements and found to be satisfactory. The station flow capacity was selected at 174 cubic meters per second with the turbines operating at best gate. This flow will be available about 91 percent of the time. The corresponding generator output will be about 172, 000 kilowatts based on a net head of 115 meters, 90 percent turbine efficiency and 97 percent generator efficiency.

Selection of Equipment

The selection of the number and size of the units was determined on the basis of a comparative study of four, five, and six-unit plants, each totaling 180, 000 kilowatts, in relation to the existing power system and the expected future loads discussed in Chapter I. It was apparent from these studies that a four-unit plant would result in a unit size that would be too large in relation to the system and the expected increments of load. A five-unit plant would not be suitable with respect to initial loads because three units would not be adequate for the loads expected, and four units would provide power somewhat in excess of what would probably be needed. A six-unit plant appeared, on the other hand, to be suitable with respect to initial installation as well as system reserve, and was, therefore, selected for the Project as presently planned. The resulting unit size of 30, 000 kilowatts also is about equal to the power requirements for one half of an aluminium potline.

The turbines were sized on the basis of a normal discharge of 29 cubic meters per second from each unit. Peaking capability was not considered of special importance, in view of the characteristics of the loads expected. The full gate capacity was selected at 32. 5 cubic meters per second at the rated head of 115 meters. The turbine will then operate near best efficiency with the normal discharge of 29 cubic meters per second. The full gate output at rated head is estimated at 44,300 metric horsepower. The full gate output at the maximum head of 122 meters is estimated at 48, 500 metric horsepower.

The generator was rated at 33, 333 kilovolt-amperes at 0. 9 power factor. This rating was determined on the basis of no overload at 0. 95 power factor for full gate output of the turbines at rated head. The overload at maximum head and 0. 95 power factor is estimated at nine percent. Consideration may be given in the detailed design stage to lowering this generator rating to take better advantage of the cold cooling water and inherent overload capabilities.

CHAPTER VII

CONSTRUCTION

General

In order to provide a reliable basis for estimating the cost of the Burfell Project, it was necessary to make assumptions with respect to the construction. These assumptions are logical, taking into account the designs, physical factors, location, common practices which have been developed by experience within the construction industry for similar projects, and many others. Some of the more important assumptions which were made are presented in general terms only.

The Project will be accomplished by contract(s). The general construction will be done by a large foreign contractor highly experienced in hydroelectric construction. Some of his work will be subcontracted. Some items of the Project may be done by smaller contractors. These may include, in whole or in part, such items as permanent roads and bridges, transmission lines, terminal substations, and minor construction not part of the principal features. Some of the subcontractors and small contractors may be qualified Icelandic firms. Icelandic labor, both skilled and unskilled, will be used to the maximum extent available. The same applies to engineers, accountants, clerks and supervisory personnel. The foreign contractors and the supervising engineer will provide key supervisory personnel and some special employees from abroad having skills not available in Iceland. It may still be necessary to import some labor. The dominance of underground construction on the Project, permitting sustained winter operations in reasonable comfort, will provide substantial employment during this usually slack season. A high percentage of the Project cost will represent Icelandic payrolls, both on the actual work and in such support matters as transport, services to both domestic and foreign personnel, off-job equipment maintenance, etc. In brief, the construction expenditures will represent a stimulus to Icelandic internal economy.

Nearly all of the required plant, material and equipment will need to be imported. Imported construction materials will include such items as fuels, steel products, timber and lumber, processed plastic, rubber and non-ferrous metal items, etc. Cement is produced locally in sufficient quantities and may be used. The cost estimates, however, are based on imported cement at slightly lower cost (without duties and taxes). Modern heavy construction equipment and machinery will be used. The cost estimates are based on importation of all requirements with the delivered cost written off on the Project. Salvage values were not considered. Further, the local contractors may have on hand a relatively small amount of used equipment serviceable for that aspect of the work. All of the permanent equipment was considered to be imported and fully shop fabricated. However, some of the smaller items, such as steel gates, might be fabricated locally using imported materials. This would not apply to highly specialized complex equipment.

The extensive field investigations and tests, discussed in Chapter IV, developed the availability of suitable natural construction materials in adequate quantity within reasonable haul distances. These include coarse and fine concrete aggregates, impervious core material, filter and rock shell material, riprap, road metal, etc.

On the basis of the designs and the appropriate above construction assumptions, a bar graph construction schedule was prepared and is shown on Exhibit 22. Details of the construction procedures assumed are discussed in greater detail below. Actual procedures, including sequences used by the successful contractor(s) may, of course, differ from the assumptions, but should not tend to increase costs or construction time. The schedule shows that the key item of construction is the powerstation, including installation of equipment, resulting in a construction period extending for three years. This period represents the basis for estimating the amount of interest during construction. The construction procedures assumed are one of the important bases for establishing the unit costs in the detailed estimates presented in Exhibit 8.

Construction Procedures

The construction procedures assumed are considered logical for the purpose of evolving the detailed cost estimates. The basic designs, however, tend to control general procedures and sequences. Therefore, major departures during actual construction from the procedures discussed in detail below are not considered probable.

The tailtunnel will be driven from downstream using the full face method. Steel sets with timber and steel lagging will be required for supports in zones of weak rock, primarily in portions of the sandstone. Rock bolting will be used liberally, especially in the basalt and pillow lava. The spoil from the surge chamber and draft tube excavations, and also the lower part of the powerstation and pressure shafts will be brought out through the tailtunnel. Rubbertired dumptors will be used for hauling the spoil to the disposal areas. The disposal areas will be downstream of the outlet and will be arranged to confine to some extent the erosion by waters from the sluiceway.

The tunneling procedure for the access tunnel may be similar to that for the tailtunnel, except for that portion which will represent simply enlargement of the exploratory tunnel. It is expected that the exploratory tunnel will be completed prior to the general construction. The access tunnel, an important key time factor for the powerstation construction, could, in this case, be constructed quickly. This expedient was not, however, considered in the cost estimates or the construction schedule.

The excavation of the powerstation machine hall will be by drifts from the main access tunnel. The first stage will be the excavation of the roof to below the springing line level. The roof arch will be pumpcreted immediately following the excavation to provide protection. The next excavation stage will be for the walls and the central core, followed by that portion of the substructure not removed through the tailtunnel. Rockbolting will be used extensively both in the roof and the wall of the powerstation. Additional heavy supports may be required for portions of the roof.

The vertical portion of the pressure shafts and of the access and cable shaft will be excavated by the pilot shaft method. These pilot shafts will be of minimum dimensions and will be used for downward mucking of the spoil obtained from enlargements of the shafts to design dimensions. The spoil will be removed from access provided by horizontal tunnels at the bottom of each shaft.

An aggregate plant for processing concrete aggregates will be located on the south slopes of Samsstadamuli. If found suitable, rock may be obtained from the powerstation and portions of other underground excavations. The estimates, however, are based on rock from a quarry located on Samsstadamuli. A dry batch plant serving the entire main project area will be provided in the vicinity of the aggregate plant. The location of these and other portions of the construction plant must consider that sluiceway waters may produce erosion in that general area for as long as a year before construction completion.

Mixing and transport of concrete for the structures will be by transit mixers, with minor amounts mixed by portable mixers. Placement will be mostly by pumpcrete methods for concrete located underground. For the surface structures the concrete will be placed by bottom dump buckets handled by cranes. Steel liner forms will be used for the various tunnel walls and roofs, and also for the machinehall roof arch. Elsewhere, the estimates are based generally on the use of wooden forms.

The steel liner for the pressure shafts will be welded into individual sections (cans) in a field assembly yard before hauling into position. The vertical portions will be installed by a hoist located at the surface. Backfill concrete will be placed after each can is installed and girth welded to the one below, but leaving working room for the next higher weld.

The rock excavation of the sluice channel, the approach canal, and the diversion canal will be by power shovels and heavy trucks. The suitable spoil from these excavations will be placed in the nearby dike shells by direct haul. Excavation of the overburden for these canals and for the dike foundations will be mostly by dragline casting and by bulldozers.

The impervious core material for the dikes will come from the moraine in the vicinity of the access tunnel portal and from loessic soil deposits on both banks of the Thjorsa about five kilometers upstream of the diversion dam site. The shell materials for the left bank dike will be quarried within a short haul distance.

Construction of the intake and sluice structures will be by conventional methods. The construction of the diversion dam and inlet structure on the Thjorsa will be similar, but provisions will be required to handle the river. The first phase of construction will include the gated spillway section, the diversion inlet structure, and a short portion of the overflow weir near the gated section. A fill cofferdam will be constructed around the work area, tying into the right bank of the river. The fill will need to be about four meters high and will be protected from scour on the outside by large rocks. The cofferdam will be removed after completion of the work, scheduled for the end of the first year. The second phase, to be completed during the second year, will include construction of the remaining portion of the overflow weir and the terminal structure for the left bank dike. This work will be protected by a similar cofferdam in the left river channel, with the river diverted over the completed portion of the diversion dam. Temporary construction access will be provided for the transport of concrete to the structures from the right bank of the river.

Some water control problems will exist elsewhere. Construction of the Bjarnalaekur dike will require water control provisions at the stream crossing. However, the flows involved are small. The estimates are based on diversion by pumping. Thjorsa water will be kept out of the Bjarnalaekur Pond during the second stage diversion for the dam by a temporary dike across the diversion channel downstream of the inlet structure. Alternatively, the Contractor may select the use of stoplogs placed in the inlet. This closure will be maintained until water may be permitted to flood the Pond.

The machinehall will be served by an 85-ton overhead traveling crane which will unload electrical and mechanical equipment onto the erection bay floor and later lift it into final position. The heaviest lift, which will be the generator rotor, is estimated at 80 tons.

The substation and transmission line construction will be by conventional methods and is not expected to involve any unusual construction problems. The same is true of the permanent access roads and bridges.

Construction Program

The construction program is scheduled as shown on Exhibit 22. This schedule assumes award of contract at the beginning of a calendar year, which is the best and most economical time for award. Because of the dominance of underground construction which has few seasonal limitations, award in any other month is not expected to require a construction time in excess of 36 months. Later award, however, does not take best advantage of construction seasons. Access roads construction was assumed to be contracted early and completed substantially by shortly after the award of the general construction contract. The first two to three months will be consumed with such preliminary work as general organization, equipment acquisition, establishment of camps and workshops, and assembly of the general construction plant.

The work will be spread over a relatively large area and can, therefore, be carried out simultaneously at several locations. A number of major work items can proceed more or less independently. Some curtailment of activity will occur during the winter months, confined mostly to the surface work, particularly the concreting of structures.

The key nature, timewise, of the construction of the powerstation, referred to above, requires the excavation of the access and tailtunnels to get under way in as short a time as feasible after contract award. The access tunnel will be completed before the end of the first year and will permit excavation of the machinehall beginning with the second winter. The excavation of the tailtunnel is estimated to require 13 months. This schedule will permit the excavation of the lower portion of the powerstation to be carried out through the tailrace. Should the tailtunnel excavation require more time it will be necessary to excavate the lower portion of the powerstation through the access tunnel in order not to delay Project completion. Concreting in the powerstation will be completed to permit starting installation of the first unit by November of the second year. The installation of all six units will be completed by the end of the third year. Concrete lining of the tailtunnel will be accomplished during the last three months of the second year and the first six months of the third year. The access tunnel will be lined where required in the last three months of the third year.

The excavation of the vertical access and penstock shafts will commence with pilot shaft excavation early in the first year and will be completed essentially at the same time as the powerstation excavation, midway through the second year. Installation of the steel lining and placing of the concrete will take place during the summer of the third year. The concreting of the intake and the installation of the gates and hoists will be accomplished during the summer of the third year, but may be accomplished much earlier.

The activities at the location of the diversion structures will start early in the first year by the construction of the cofferdam around the inlet structure and the right bank portion of the spillway, including the gated section. Concreting of these structures will be accomplished in the summer months of the first year, which also will see the completion of a major portion of the Bjarnalaekur dike. Excavation of the diversion canal and the sluiceway channel will proceed more or less simultaneously with the construction of dikes on the right side of the river.

The spoil together with suitable rock excavation from the diversion structures will be used as shell material. The dikes will be completed in the second summer.

The left portion of the spillway will be completed during the summer of the second year behind the protection of a cofferdam placed early in the spring. Construction will also start on the downstream portion of the left bank dike.

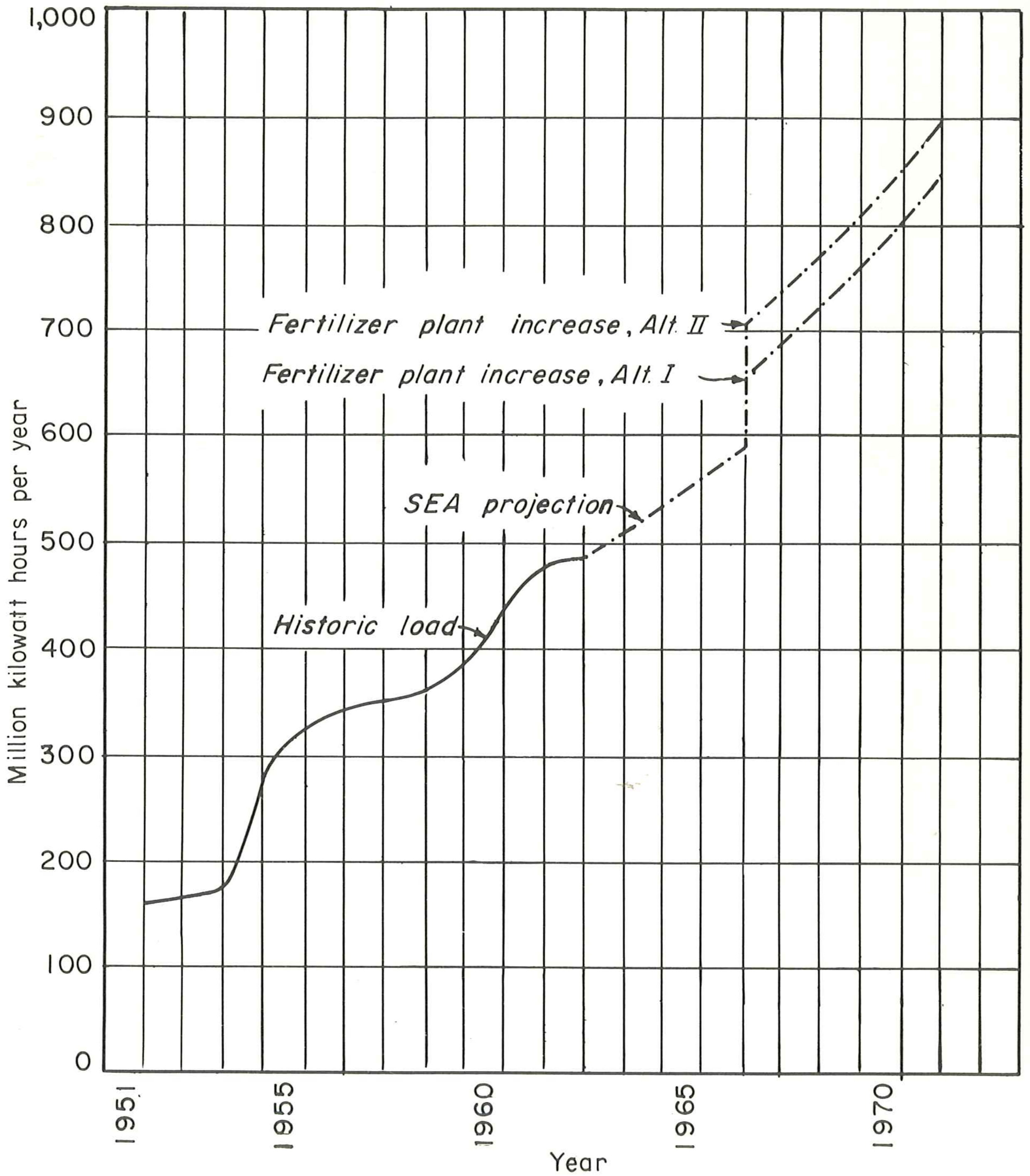
The construction of all of the diversion structures is thus scheduled to be completed by the end of the second year, with the exception of the upstream portion of the left bank dike which will be completed during the third summer.

The construction of the left dike, which could be subcontracted conveniently, can, however, be completed easily during the first two summers. It may be very desirable to require the contractor to complete all construction associated with the diversion structures, Bjarnalaekur Pond, and the power intakes and sluiceway by the end of the second summer. This will permit at least a one winter prototype test of the ice problem, leaving a year to solve any problems of that nature which may become evident. This test will require full flow through the Pond and out the sluiceway. The resulting flow and erosion towards the Fossa will complicate construction access somewhat but at no great cost if provided for properly in the construction plant layout. This interim flow operation could also assist with clearing lapilli from the Bjarnalaekur Pond, and provide a test of the underseepage control, all in advance of power operation.

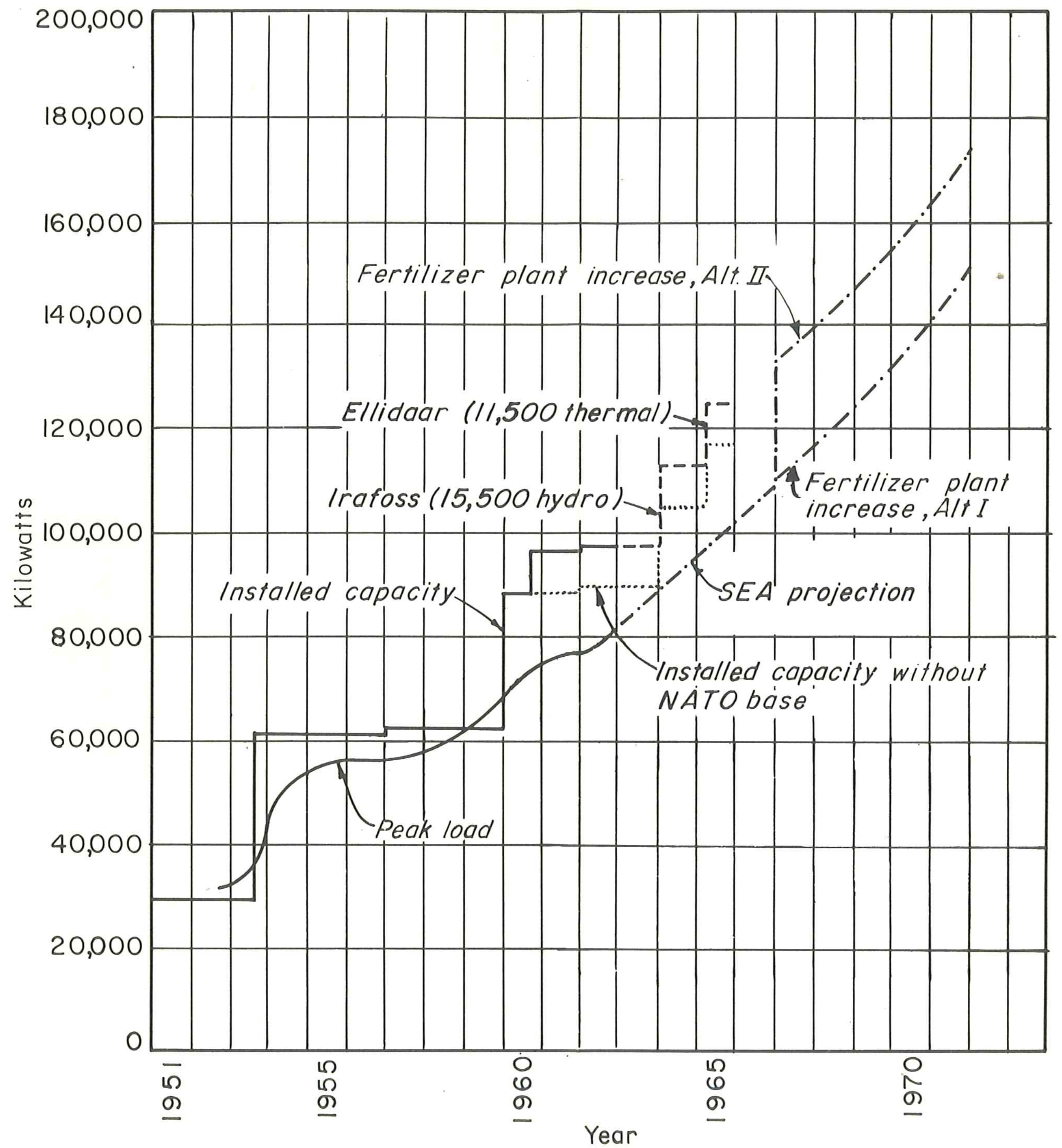
The transmission line will be constructed during the summer months of the second and third year. Installation of the substation equipment will be carried out during the spring and early summer of the third year to be ready for the first power which may be available by early fall.

THE EXHIBITS

EXHIBIT I



ENERGY



PEAK LOAD AND INSTALLED CAPACITY

NOTES:
1. Energy and peak loads include losses and powerstation consumption
2. Loads and installations include:
   a.) General domestic and commercial
   b.) Fertilizer plant
   c.) NATO base

THE STATE ELECTRICITY AUTHORITY ICELAND
BURFELL PROJECT
SYSTEM LOAD GROWTH
HARZA ENGINEERING COMPANY INTERNATIONAL PREPARED BY HARZA ENGINEERING COMPANY APPROVED A.P. Gauss
CHICAGO, ILLINOIS — DATE JAN 1963 — DWG NO 290 P 33

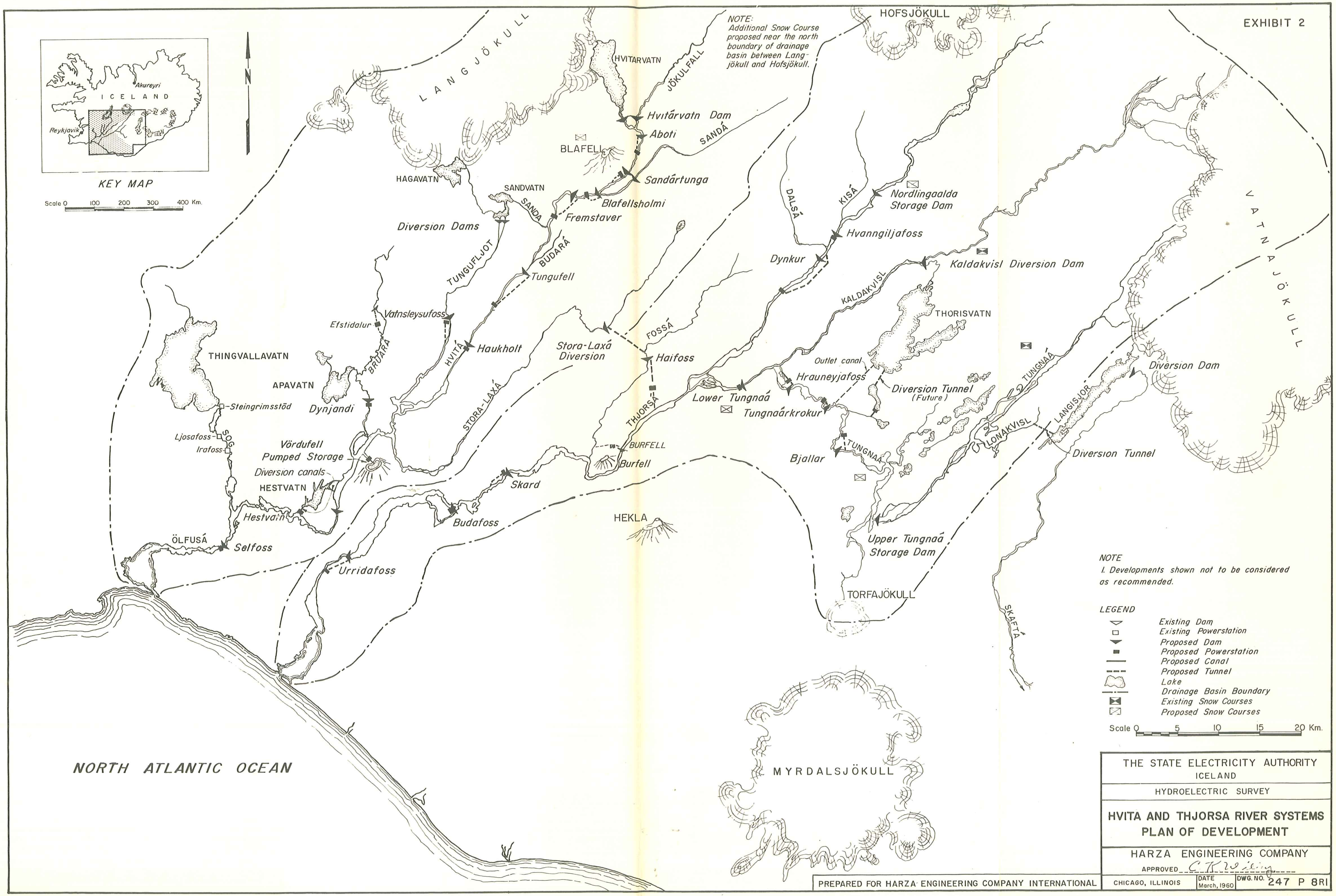


EXHIBIT 2
NOTE: Additional Snow Course proposed near the north boundary of drainage basin between Langjökull and Hofsjökull.
KEY MAP
Akureyri
ICELAND
Reykjavik
Scale 0 100 200 300 400 Km.
N
LANGJÖKULL
HOFSJÖKULL
VATNAJÖKULL
HVITARVATN
JÖKULFALL
Hvitárvatn Dam
Aboti
SANDÁ
BLAFELL
Sandártunga
Blafellsholmi
Fremstaver
HAGAVATN
SANDVATN
SANDÁ
Diversion Dams
TUNGUFLJOT
BUDARÁ
Tungufell
Vatnsleysufoss
Efstidalur
BRÚARÁ
HVITÁ
Haukholt
THINGVALLAVATN
APAVATN
Dynjandi
Steingrimsstöd
Ljosafoss
Irafoss
SOG
Vördufell Pumped Storage
Diversion canals
HESTVATN
Hestvatn
ÖLFUSÁ
Selfoss
Urridafoss
Budafoss
Skard
STORA-LAXÁ
Stora-Laxá Diversion
FOSSÁ
Haifoss
THJORSÁ
BURFELL
Burfell
HEKLA
DALSÁ
KISÁ
Nordlingaalda Storage Dam
Hvanngiljafoss
Dynkur
KALDAKVISL
Kaldakvisl Diversion Dam
THORISVATN
Outlet canal
Hrauneyjafoss
Diversion Tunnel (Future)
Lower Tungnaá
Tungnaárkrokur
TUNGNAÁ
Bjallar
Upper Tungnaá Storage Dam
TORFAJÖKULL
LONAKVISL
LANGISJOR
Diversion Tunnel
Diversion Dam
SKAFTÁ
MYRDALSJÖKULL
NORTH ATLANTIC OCEAN
NOTE
1. Developments shown not to be considered as recommended.
LEGEND
Existing Dam
Existing Powerstation
Proposed Dam
Proposed Powerstation
Proposed Canal
Proposed Tunnel
Lake
Drainage Basin Boundary
Existing Snow Courses
Proposed Snow Courses
Scale 0 5 10 15 20 Km.
THE STATE ELECTRICITY AUTHORITY ICELAND
HYDROELECTRIC SURVEY
HVITA AND THJORSA RIVER SYSTEMS PLAN OF DEVELOPMENT
HARZA ENGINEERING COMPANY
APPROVED
CHICAGO, ILLINOIS
DATE March, 1960
DWG. NO. 247 P 8R1
PREPARED FOR HARZA ENGINEERING COMPANY INTERNATIONAL

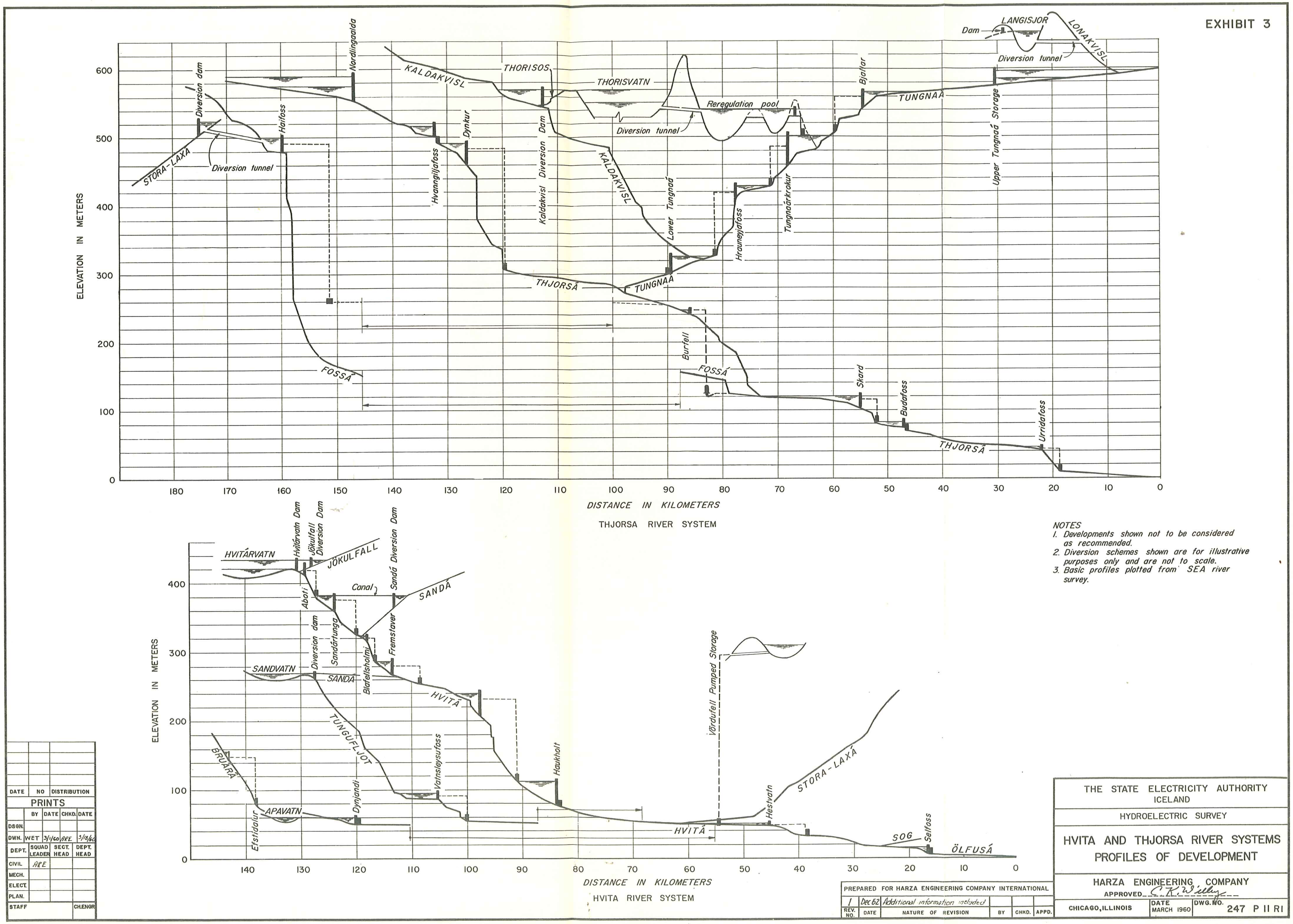
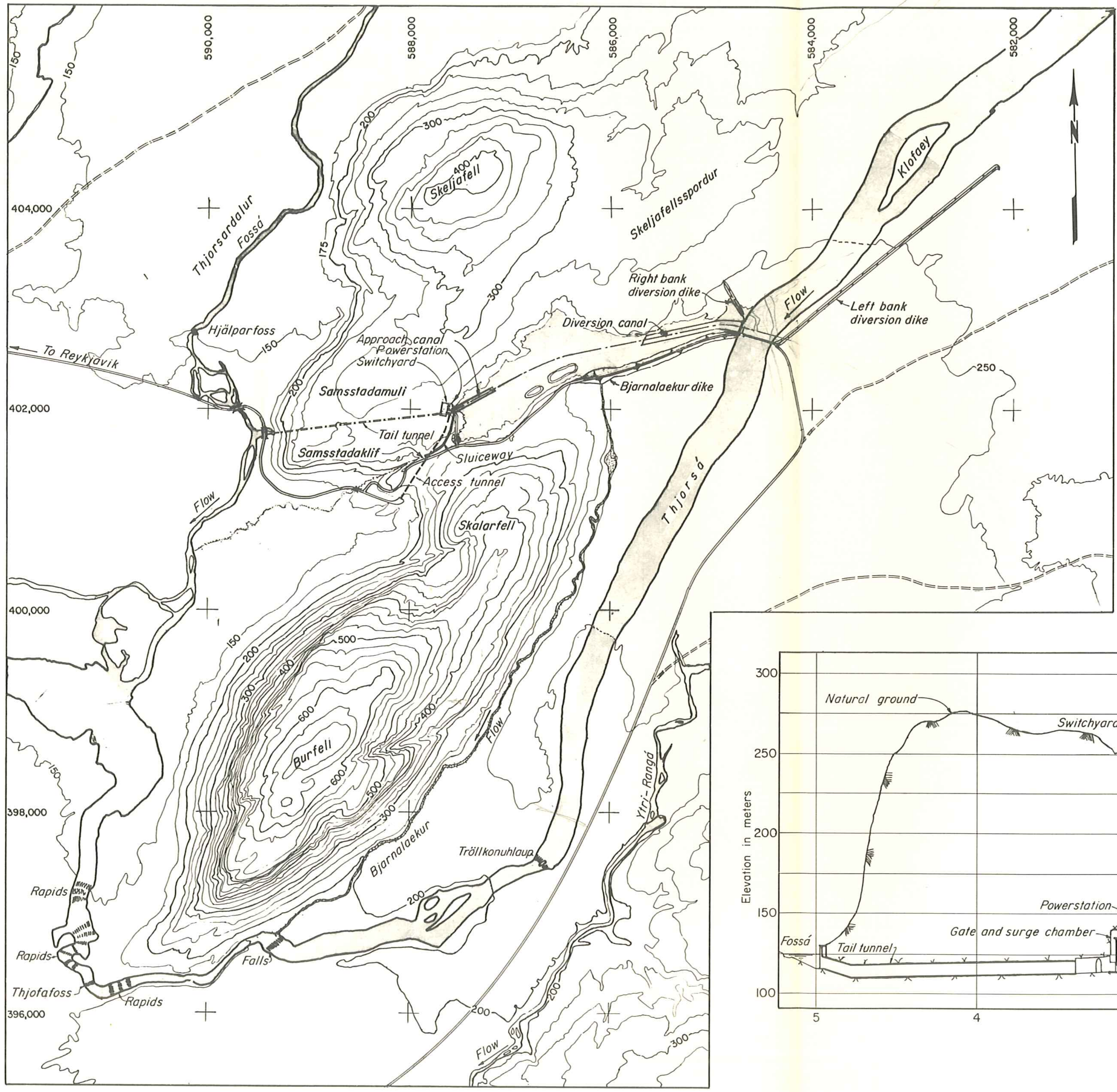


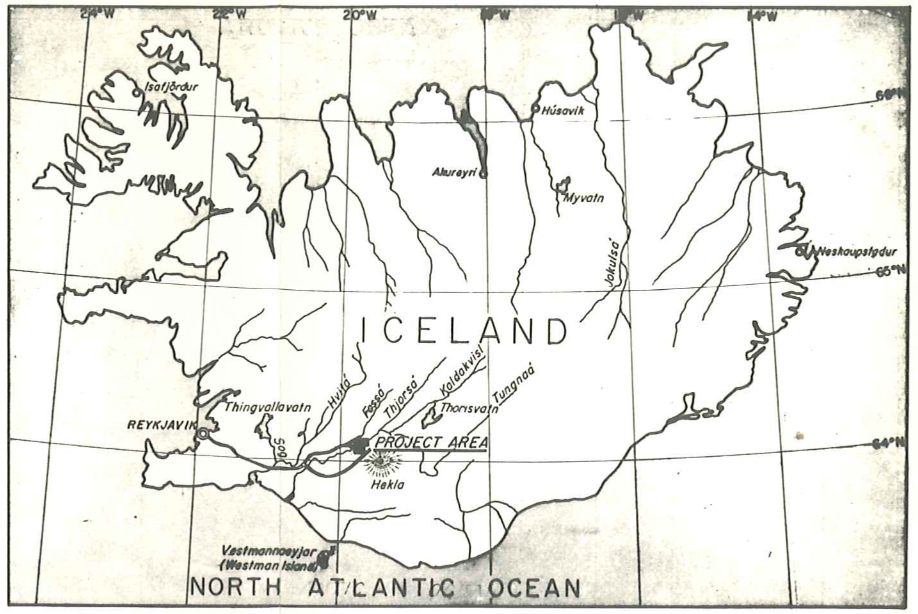
EXHIBIT 3
ELEVATION IN METERS
DISTANCE IN KILOMETERS
THJORSA RIVER SYSTEM
STORA-LAXA
Diversion dam
Diversion tunnel
Haifoss
Nordlingaalda
KALDAKVISL
Hvanngiljafoss
Dynkur
THORISOS
THORISVATN
Kaldakvisl Diversion Dam
Diversion tunnel
Reregulation pool
Lower Tungnaá
Hrauneyjafoss
Tungnaárkrokur
Bjallar
TUNGNAA
Upper Tungnaá Storage
Dam
LANGISJOR
LONAKVISL
THJORSÁ
FOSSÁ
Burfell
Skard
Budafoss
Urridafoss
HVITA RIVER SYSTEM
HVITÁRVATN
Hvitárvatn Dam
Jökulfall Diversion Dam
JÖKULFALL
Aboti
Canal
Sandá Diversion Dam
SANDÁ
Diversion dam
Sandártunga
Fremstaver
Blafellsholmi
SANDVATN
HVITÁ
TUNGUFLJOT
BRUARÁ
Efstidalur
APAVATN
Dynjandi
Vatnsleysufoss
Haukholt
Vördufell Pumped Storage
Hestvatn
STORA-LAXÁ
SOG
Selfoss
ÖLFUSÁ
NOTES
1. Developments shown not to be considered as recommended.
2. Diversion schemes shown are for illustrative purposes only and are not to scale.
3. Basic profiles plotted from SEA river survey.
THE STATE ELECTRICITY AUTHORITY
ICELAND
HYDROELECTRIC SURVEY
HVITA AND THJORSA RIVER SYSTEMS
PROFILES OF DEVELOPMENT
HARZA ENGINEERING COMPANY
APPROVED C.K. Willey
CHICAGO, ILLINOIS
DATE MARCH 1960
DWG. NO. 247 P II R1
PREPARED FOR HARZA ENGINEERING COMPANY INTERNATIONAL
1 Dec 62 Additional information included
REV. NO. DATE NATURE OF REVISION BY CHKD. APPD.
DATE NO DISTRIBUTION
PRINTS
BY DATE CHKD. DATE
DSGN.
DWN. WET 3/1/60 ARE 3/18/60
DEPT. SQUAD LEADER SECT. HEAD DEPT. HEAD
CIVIL ARE
MECH.
ELECT.
PLAN.
STAFF CH.ENGR.

EXHIBIT 4



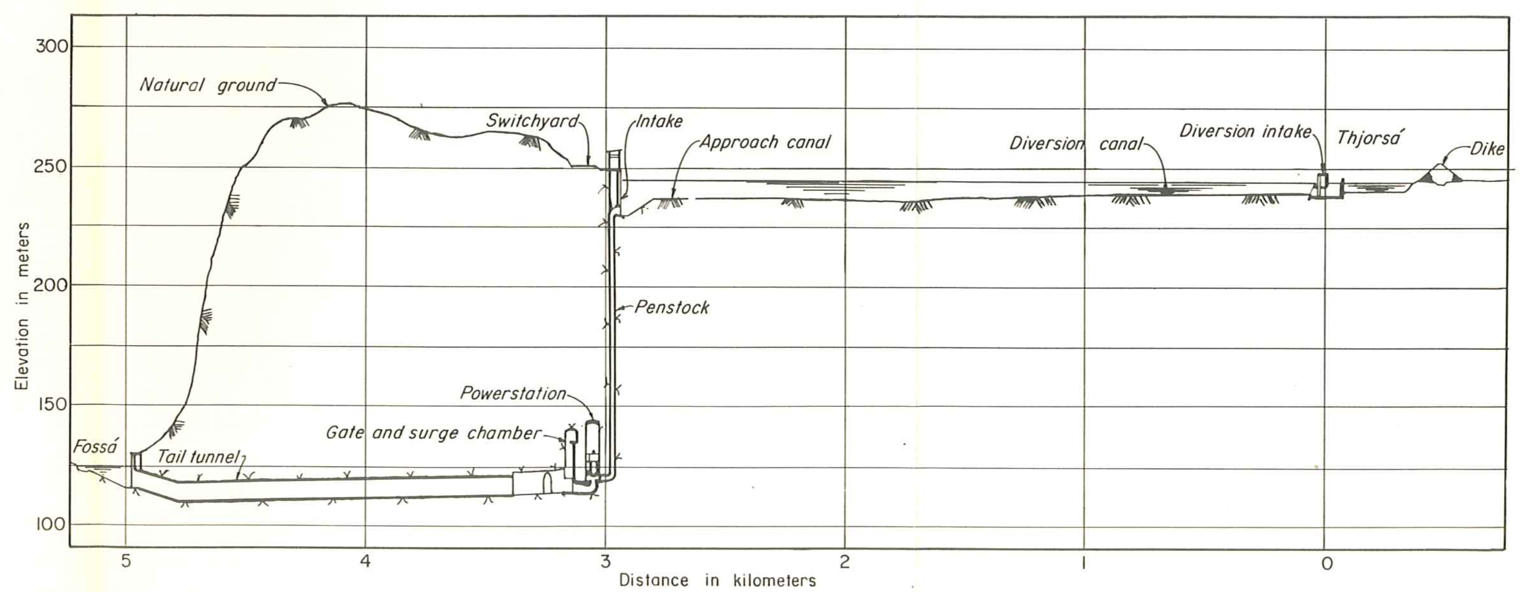
PROJECT PLAN

Scale 0 1 Kilometer



KEY PLAN

Scale 0 100 Kilometers



PROFILE

Scale distorted

THE STATE ELECTRICITY AUTHORITY
ICELAND

BURFELL PROJECT

LOCATION MAP
AND
PROJECT PLAN

HARZA ENGINEERING COMPANY INTERNATIONAL

PREPARED BY
HARZA ENGINEERING COMPANY

APPROVED A.P. Geuss

REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.

CHICAGO, ILLINOIS	DATE JAN. 1963	DWG. NO. 290 P 8

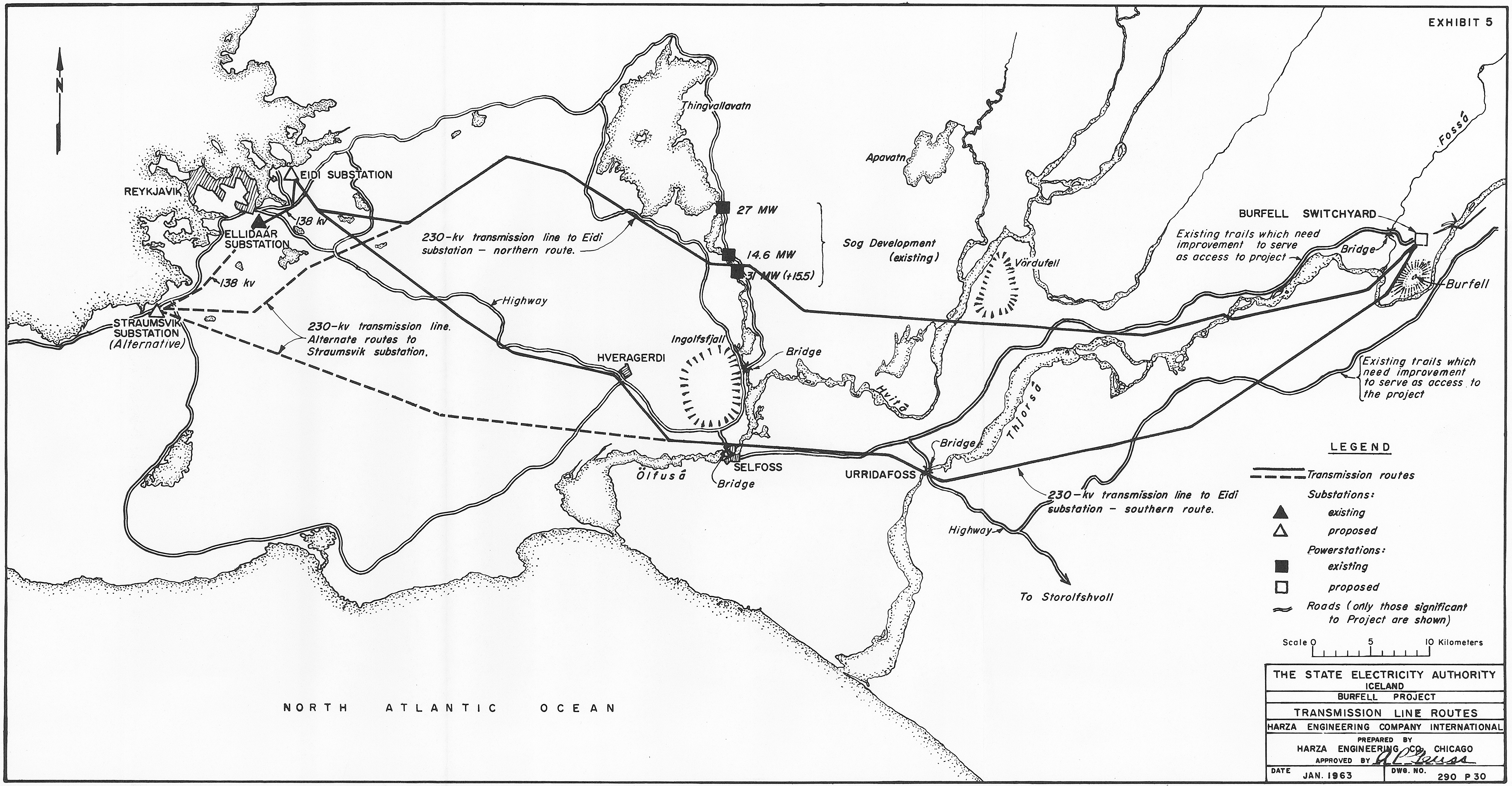
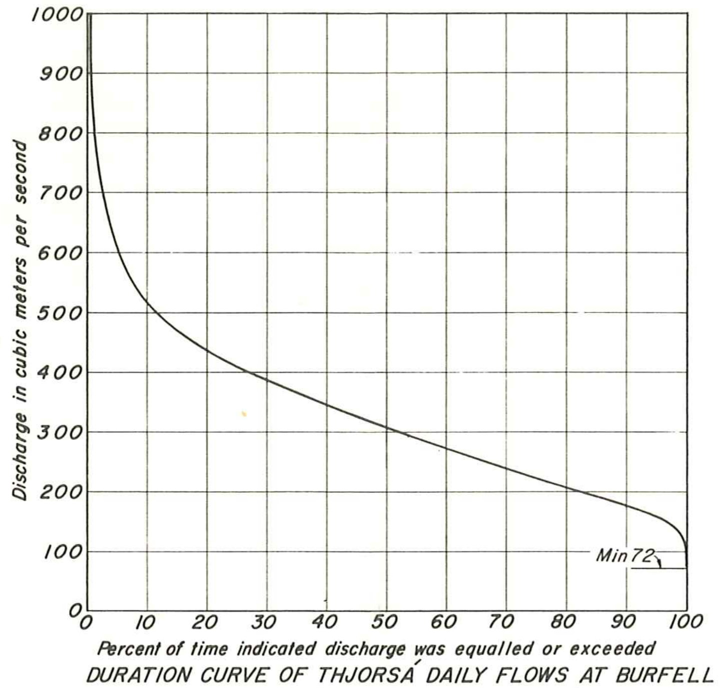
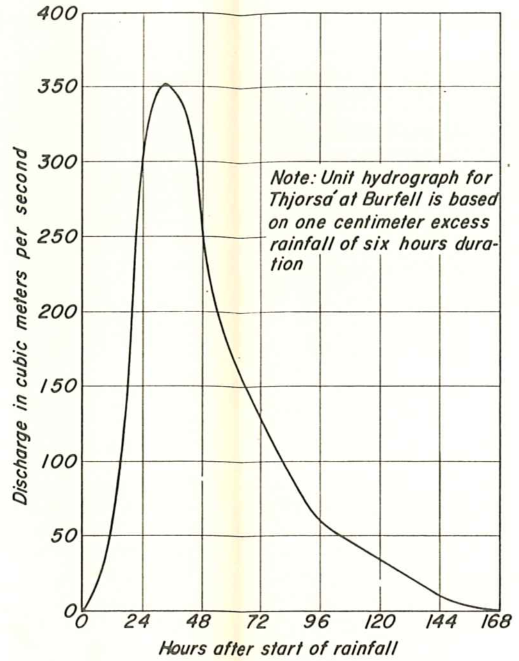


EXHIBIT 5
N
REYKJAVIK
EIDI SUBSTATION
ELLIDAAR SUBSTATION
138 kv
138 kv
STRAUMSVIK SUBSTATION (Alternative)
230-kv transmission line. Alternate routes to Straumsvik substation.
230-kv transmission line to Eidi substation - northern route.
Highway
Thingvallavatn
27 MW
14.6 MW
31 MW (+15.5)
Sog Development (existing)
Apavatn
Vördufell
Fossá
BURFELL SWITCHYARD
Existing trails which need improvement to serve as access to project
Bridge
Burfell
Ingolfsfjall
Bridge
HVERAGERDI
Hvitá
Thjorsá
Existing trails which need improvement to serve as access to the project
Ölfusá
SELFOSS
Bridge
URRIDAFOSS
Bridge
230-kv transmission line to Eidi substation - southern route.
Highway
To Storolfshvoll
NORTH ATLANTIC OCEAN
LEGEND
Transmission routes
Substations:
existing
proposed
Powerstations:
existing
proposed
Roads (only those significant to Project are shown)
Scale 0 5 10 Kilometers
THE STATE ELECTRICITY AUTHORITY
ICELAND
BURFELL PROJECT
TRANSMISSION LINE ROUTES
HARZA ENGINEERING COMPANY INTERNATIONAL
PREPARED BY
HARZA ENGINEERING CO. CHICAGO
APPROVED BY
DATE JAN. 1963
DWG. NO. 290 P 30

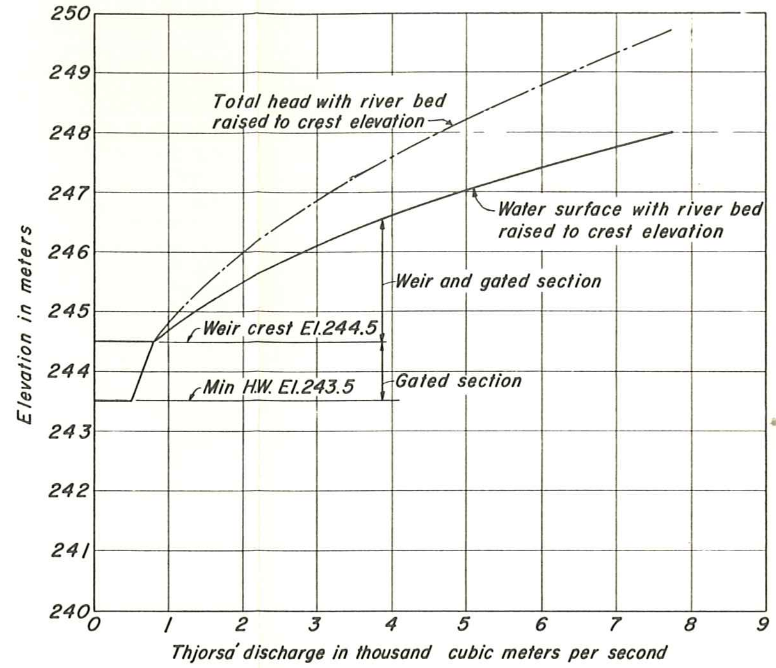
EXHIBIT 6



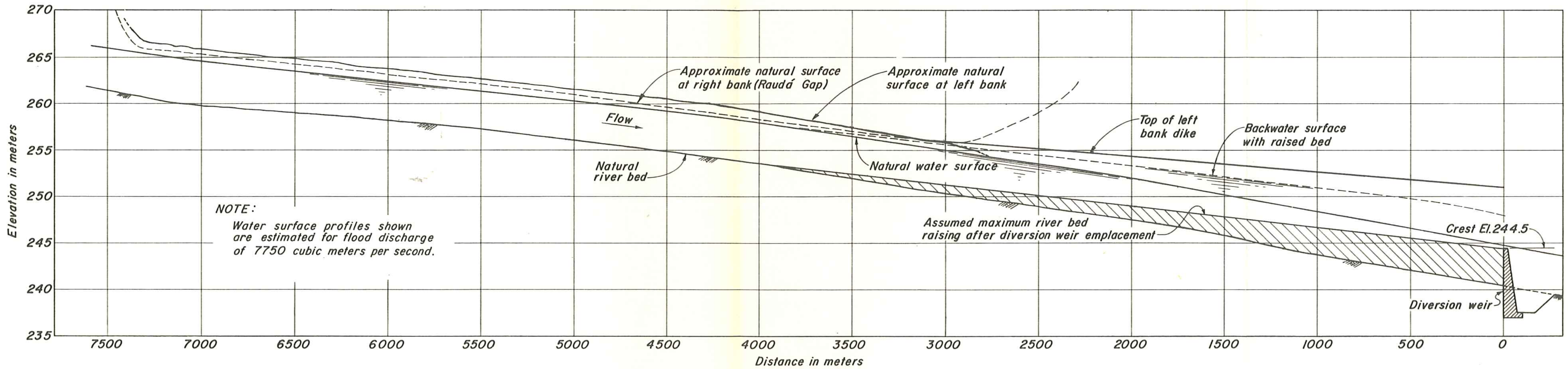
DURATION CURVE OF THJORSÁ DAILY FLOWS AT BURFELL



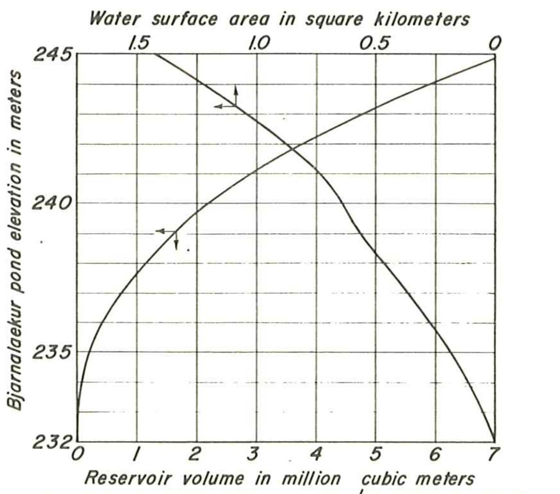
UNIT HYDROGRAPH



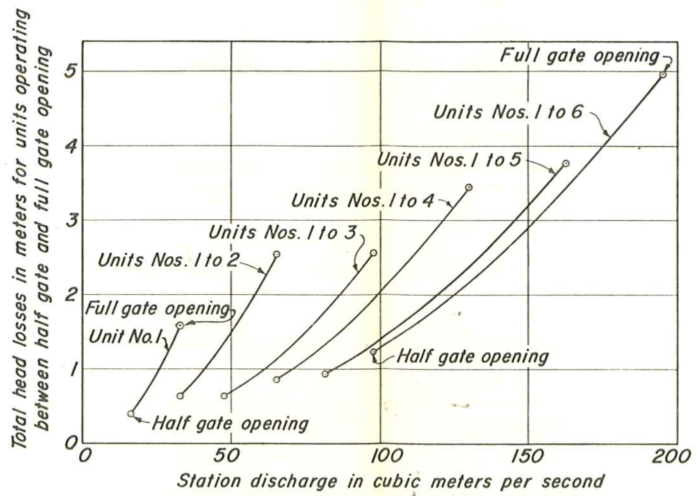
DIVERSION WEIR RATING CURVE



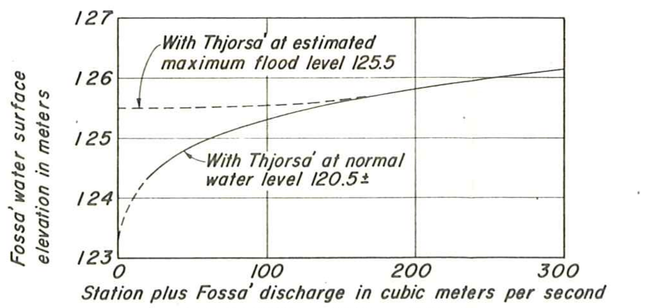
PROFILE OF THJORSÁ UPSTREAM OF DIVERSION WEIR



BJARNALAEKUR POND AREA/VOLUME CURVES



HEAD LOSS–DISCHARGE RELATIONSHIP



TAILWATER RATING CURVE

NOTES: 1. Normal flow in Fossá 10 to 20 cubic meters per second.
2. Estimated maximum flood in Fossá 200 cubic meters per second.
3. Ice jam in the Thjorsá may cause a rise in tailwater to El. 130±.

DATE	NO	DISTRIBUTION

PRINTS	BY	DATE	CHKD.	DATE
DSGN.				
DWN.	SA	1/7/63	JNF	Jan 63

DEPT.	GROUP LEADER	SECT. HEAD	DEPT. HEAD
CIVIL			
MECH.			
ELECT.			
PLAN.	JNF	ARE	VAK
STAFF			CH.ENGR.

REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.

THE STATE ELECTRICITY AUTHORITY
ICELAND

BURFELL PROJECT

HYDRAULIC DATA

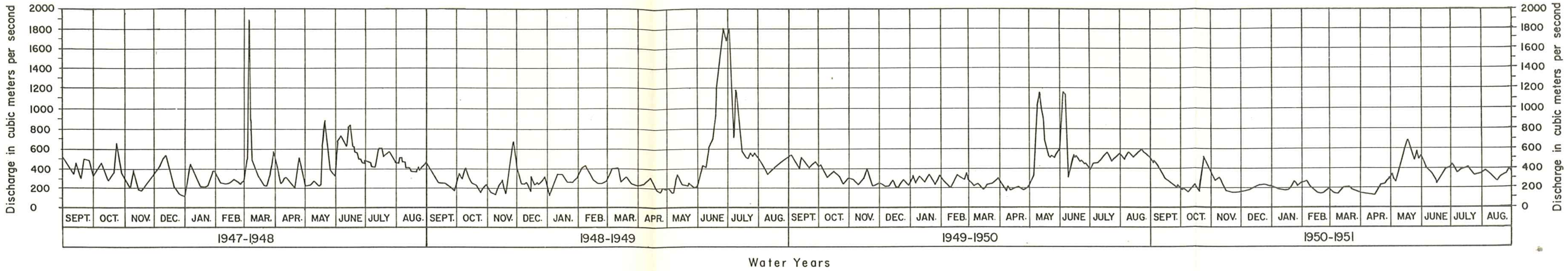
HARZA ENGINEERING COMPANY INTERNATIONAL

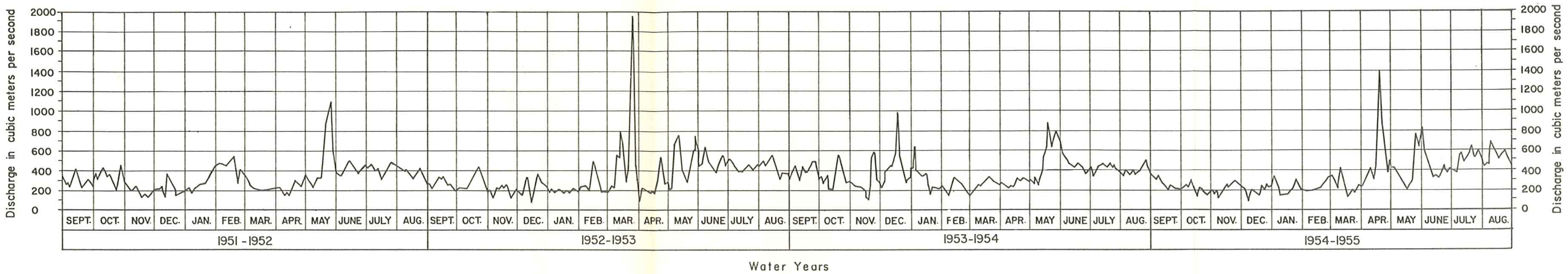
PREPARED BY
HARZA ENGINEERING COMPANY

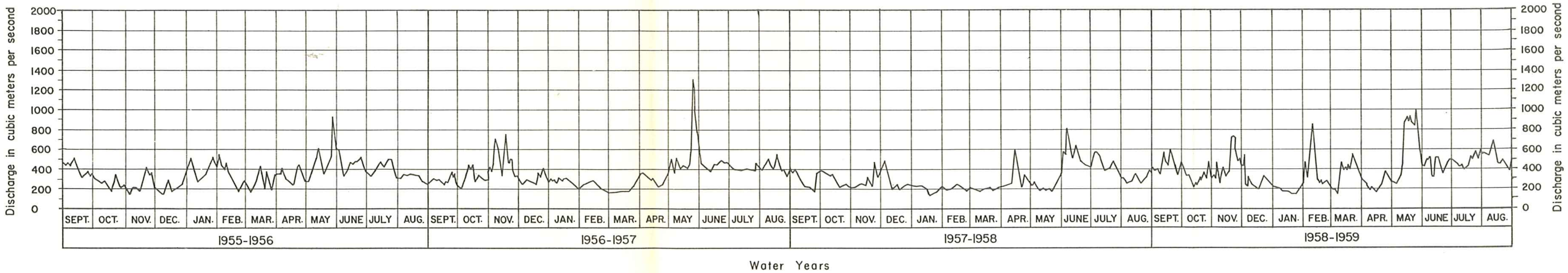
APPROVED A.P. Geuss

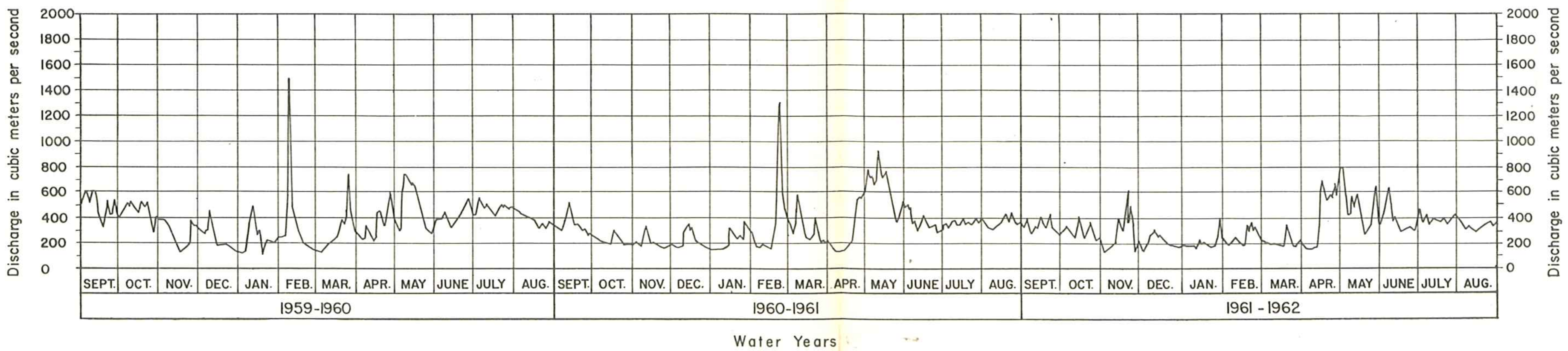
CHICAGO, ILLINOIS | DATE JAN. 1963 | DWG. NO. 290 P 28

EXHIBIT 7









NOTE:

Daily discharge at Burfell computed on the basis of daily discharge records for Thjorsa at Urridafoss by applying a factor of 0.89, which is the ratio of drainage areas at Burfell (6,380 km²) and at Urridafoss (7,200 km²).

DATE	NO	DISTRIBUTION	
PRINTS			
	BY	DATE	CHKD. DATE
DSGN.			
DWN.	V.E.T.		M.N.Ó.
DEPT.	GROUP LEADER	SECT. HEAD	DEPT. HEAD
CIVIL			
MECH.			
ELECT.			
PLAN.		MSS	VÁK
STAFF			CH.ENGR.

REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.

THE STATE ELECTRICITY AUTHORITY
ICELAND

BURFELL PROJECT

DAILY DISCHARGE HYDROGRAPH THJORSA AT BURFELL 1947 - 1962

HARZA ENGINEERING COMPANY INTERNATIONAL

PREPARED BY
HARZA ENGINEERING COMPANY

APPROVED A.P. Gruss

CHICAGO, ILLINOIS | DATE JANUARY, 1963 | DWG. No. 290 P 31

BURFELL PROJECT

COST ESTIMATES - SUMMARY

PRODUCTION PLANT

Item	4 Units Installed $ U.S.	5 Units Installed $ U.S.	6 Units Installed $ U.S.
Power Plant Structures	3,447,500	3,489,900	3,529,300
Reservoirs, Dams, and Waterways	10,783,780	10,972,680	10,972,680
Turbines and Generators	2,306,000	2,882,500	3,459,000
Accessory Electrical Equipment	577,500	697,500	817,500
Miscellaneous Power Plant Equipment	525,700	601,300	674,200
Access Roads and Bridges	550,000	550,000	550,000
Operators Village and General Plant	300,000	300,000	300,000
SUBTOTAL DIRECT COST	18,490,480	19,493,880	20,302,680
Contingencies, Civil Works 15% ±	2,259,280	2,297,041	2,300,077
Contingencies, Electrical and Mechanical Equipment, 5% ±	170,240	209,079	247,243
TOTAL DIRECT COST	20,920,000	22,000,000	22,850,000
Engineering and Supervision, 8% ±	1,670,000	1,790,000	1,840,000
Preliminary Investigation Costs	510,000	510,000	510,000
CONSTRUCTION COST	23,100,000	24,300,000	25,200,000
Interest During Construction, 10% ±	2,300,000	2,400,000	2,500,000
PROJECT INVESTMENT	25,400,000	26,700,000	27,700,000

BURFELL PROJECT

COST ESTIMATES - SUMMARY

TRANSMISSION PLANT

Eidi Alternative - One 230 kv Transmission Line

Item	4 Units Installed $ U.S.	5 Units Installed $ U.S.	6 Units Installed $ U.S.
Burfell Step-Up Substation	768,000	971,000	971,000
Transmission Line Burfell - Eidi	1,498,000	1,498,000	1,498,000
Eidi Substation	348,000	348,000	348,000
Transmission Line Eidi - Ellidaar	52,250	52,250	52,250
Ellidaar Substation Additions	172,000	172,000	172,000
SUBTOTAL DIRECT COST	2,838,250	3,041,250	3,041,250
Contingencies, 15% ±	421,750	458,750	458,750
TOTAL DIRECT COST	3,260,000	3,500,000	3,500,000
Engineering and Supervision, 8% ±	220,000	280,000	280,000
Preliminary Investigation Costs	20,000	20,000	20,000
CONSTRUCTION COST	3,500,000	3,800,000	3,800,000
Interest During Construction, 8% ±	300,000	300,000	300,000
PROJECT INVESTMENT	3,800,000	4,100,000	4,100,000

BURFELL PROJECT

COST ESTIMATES - SUMMARY

TRANSMISSION PLANT

Eidi Alternative - Two 230 kv Transmission Lines

Item	4 Units Installed $ U.S.	5 Units Installed $ U.S.	6 Units Installed $ U.S.
Burfell Step-Up Substation	851,000	1,054,000	1,054,000
Transmission Line Burfell - Eidi	3,066,000	3,066,000	3,066,000
Eidi Substation	596,000	596,000	596,000
Transmission Line Eidi - Ellidaar	52,250	52,250	52,250
Ellidaar Substation Additions	172,000	172,000	172,000
SUBTOTAL DIRECT COST	4,737,250	4,940,250	4,940,250
Contingencies, 15% ±	712,750	739,750	739,750
TOTAL DIRECT COST	5,450,000	5,680,000	5,680,000
Engineering and Supervision, 8% ±	430,000	500,000	500,000
Preliminary Investigation Costs	20,000	20,000	20,000
CONSTRUCTION COST	5,900,000	6,200,000	6,200,000
Interest during Construction, 8% ±	500,000	500,000	500,000
PROJECT INVESTMENT	6,400,000	6,700,000	6,700,000

BURFELL PROJECT

COST ESTIMATES - SUMMARY

TRANSMISSION PLANT

Straumsvik Alternatives

Item	One 230 kv Transmission Line 5 or 6 Units Installed $ U.S.	Two 230 kv Transmission Lines 5 or 6 Units Installed $ U.S.
Burfell Step-Up Substation	971,000	1,054,000
Transmission Line Burfell - Straumsvik	1,652,000	3,304,000
Straumsvik Substation	348,000	596,000
Transmission Line Straumsvik - Ellidaar	123,500	123,500
Ellidaar Substation Additions	172,000	172,000
SUBTOTAL DIRECT COST	3,266,500	5,249,500
Contingencies, 15% ±	493,500	790,500
TOTAL DIRECT COST	3,760,000	6,040,000
Engineering and Supervision, 8% ±	320,000	540,000
Preliminary Investigation Costs	20,000	20,000
CONSTRUCTION COST	4,100,000	6,600,000
Interest During Construction, 8% ±	300,000	500,000
PROJECT INVESTMENT	4,400,000	7,100,000

BURFELL PROJECT

COST ESTIMATES

PRODUCTION PLANT

6 Units Installed

Item	Quantity	Unit Price $ U.S.	Amount $ U.S.
POWER PLANT STRUCTURES			
POWERSTATION			
Excavation			
Main hall	50,000 m^3	6.00	300,000
Draft tubes	2,700 m^3	10.00	27,000
Cable and access shaft	9,200 m^3	12.00	110,400
Drainage gallery	900 m^3	25.00	22,500
Miscellaneous tunnels and shafts	1,250 m^3	20.00	25,000
Temporary support of roof		L.S.	150,000
Steel supports in tunnels and shafts	240,000 kg	0.50	120,000
Timber	450 m^3	80.00	36,000
Rockbolting	11,000 lin.m	8.00	88,000
Grouting and drainholes		L.S.	55,000
Pumping		L.S.	50,000
Concrete			
Substructure	7,200 m^3	22.00	158,400
Superstructure	4,600 m^3	30.00	138,000
Roof arch	3,200 m^3	35.00	112,000
Draft tubes	1,200 m^3	35.00	42,000
Cable and access shaft	3,100 m^3	30.00	93,000
Miscellaneous tunnels and shafts	540 m^3	35.00	18,900
Concrete block walls	500 m^3	40.00	20,000
Formwork, straight	20,600 m^2	10.00	206,000
Formwork, curved	3,600 m^2	20.00	72,000

BURFELL PROJECT

COST ESTIMATES

PRODUCTION PLANT
(Continued)

6 Units Installed

Item	Quantity	Unit Price $ U.S.	Amount $ U.S.
Reinforcing steel	1,000,000 kg	0.28	280,000
Structural steel	10,000 kg	0.48	4,800
Miscellaneous metals	50,000 kg	1.10	55,000
Architectural treatment		L.S.	150,000
Plumbing		L.S.	14,000
Heating and ventilating		L.S.	135,000
Lighting		L.S.	30,000
Elevator building		L.S.	15,000
Station yard, landscaping, grading, etc.		L.S.	20,000
SUBTOTAL POWERSTATION			2,548,000
ACCESS TUNNEL			
Excavation, open cut, common	600 m^3	1.50	900
Excavation, open cut, rock	2,700 m^3	5.00	13,500
Excavation, tunnel	37,600 m^3	8.50	319,600
Steel supports	215,000 kg	0.50	107,500
Timber	680 m^3	80.00	54,400
Rockbolting	2,800 lin.m	8.00	22,400
Grouting		L.S.	75,000
Pumping		L.S.	20,000
Concrete, tunnel lining, including formwork	6,000 m^3	43.00	258,000
Concrete, floor slab	1,300 m^3	20.00	26,000
Reinforcing steel	300,000 kg	0.28	84,000
SUBTOTAL ACCESS TUNNEL			981,300
SUBTOTAL POWER PLANT STRUCTURES			3,529,300

BURFELL PROJECT

COST ESTIMATES

PRODUCTION PLANT
(Continued)

6 Units Installed

Item	Quantity	Unit Price $ U.S.	Amount $ U.S.
RESERVOIRS, DAMS, AND WATERWAYS			
BURFELL RESERVOIR			
Snow fences		L.S.	70,000
Water level recorder stations		L.S.	5,000
SUBTOTAL BURFELL RESERVOIR			75,000
THJORSA DIVERSION DIKE, LEFT BANK			
Excavation, common	350,000 m^3	0.50	175,000
Excavation, rock	12,000 m^3	5.00	60,000
Foundation preparation and treatment		L.S.	20,000
Impervious core	115,000 m^3	1.80	207,000
Filters	98,000 m^3	3.50	343,000
Rockfill	305,000 m^3	2.00	610,000
SUBTOTAL THJORSA DIVERSION DIKE, LEFT BANK			1,415,000
THJORSA DIVERSION DIKE, RIGHT BANK			
Excavation, common	100,000 m^2	0.50	50,000
Excavation, rock	2,000 m^2	5.00	10,000
Foundation preparation and treatment		L.S.	1,500
Impervious core	15,500 m^3	2.10	32,550
Filters	7,400 m^3	2.50	18,500
Rockfill (from canal excavation)	84,000 m^3	0.25	21,000
SUBTOTAL THJORSA DIVERSION DIKE, RIGHT BANK			133,550

BURFELL PROJECT

COST ESTIMATES

PRODUCTION PLANT
(Continued)

6 Units Installed

Item	Quantity	Unit Price $ U.S.	Amount $ U.S.
THJORSA DIVERSION WEIR AND INLET			
Diversion and care of water		L.S.	275,000
Excavation, rock	45,000 m^3	3.00	135,000
Foundation preparation and treatment		L.S.	10,000
Concrete, spillway, mass	15,000 m^3	25.00	375,000
Concrete, spillway, structural	4,250 m^3	35.00	148,750
Concrete, diversion inlet, mass	4,300 m^3	27.00	116,100
Concrete, diversion inlet, structural	7,100 m^3	30.00	213,000
Formwork, straight	17,500 m^2	10.00	175,000
Formwork, curved	2,150 m^2	20.00	43,000
Reinforcing steel	617,000 kg	0.28	172,760
Vertical gates (2), guides, and frames	50,000 kg	1.00	50,000
Tainter gates (2), guides, and anchorage	30,000 kg	1.00	30,000
Tainter gate hoists, 10 ton capacity	2	L.S.	13,000
Vertical lift gate hoists, 50 ton capacity	2	L.S.	45,000
Gate heating		L.S.	15,000
SUBTOTAL THJORSA DIVERSION WEIR AND INLET			1,816,610
DIVERSION CANAL			
Excavation, common	210,000 m^3	1.00	210,000
Excavation, rock	90,000 m^3	2.50	225,000
SUBTOTAL DIVERSION CANAL			435,000

BURFELL PROJECT

COST ESTIMATES

PRODUCTION PLANT
(Continued)

6 Units Installed

Item	Quantity	Unit Price $ U.S.	Amount $ U.S.
BJARNALAEKUR DIKE			
Diversion and care of water		L.S.	50,000
Excavation, common	290,000 m^3	0.50	145,000
Excavation, rock	12,000 m^3	5.00	60,000
Foundation preparation and treatment		L.S.	10,000
Cut-off grouting along dike		L.S.	40,000
Reservoir treatment		L.S.	125,000
Impervious core	120,000 m^3	1.80	216,000
Filters	75,000 m^3	2.40	180,000
Rockfill	400,000 m^3	0.80	320,000
SUBTOTAL BJARNALAEKUR DIKE			1,146,000
APPROACH CANAL			
Excavation, common	32,000 m^3	1.00	32,000
Excavation, rock	19,000 m^3	3.00	57,000
SUBTOTAL APPROACH CANAL			89,000
SLUICEWAY			
Excavation, common	5,300 m^3	1.25	6,625
Excavation, rock	157,000 m^3	2.50	392,500
Foundation preparation and grouting		L.S.	10,000
Concrete, mass	950 m^3	27.00	25,650
Concrete, structural	2,400 m^3	37.00	88,800
Formwork	2,400 m^2	10.00	24,000
Reinforcing steel	127,000 kg	0.28	35,560
Sluice gate, frame, and guides	17,300 kg	1.00	17,300
Ice gate, frame, and guides	10,400 kg	1.00	10,400

BURFELL PROJECT

COST ESTIMATES

PRODUCTION PLANT
(Continued)

6 Units Installed

Item	Quantity	Unit Price $ U.S.	Amount $ U.S.
Gate hoist, movable, capacity 75 tons		L.S.	65,000
Gate heating		L.S.	10,000
Gatehouse		L.S.	10,000
SUBTOTAL SLUICEWAY			695,835
DIKE AT SLUICEWAY			
Excavation, common	23,000 m^3	1.00	23,000
Excavation, rock	1,200 m^3	5.00	6,000
Foundation preparation and grouting		L.S.	25,000
Impervious core	8,000 m^3	2.00	16,000
Filters	5,000 m^3	2.50	12,500
Rockfill	28,000 m^3	0.25	7,000
SUBTOTAL DIKE AT SLUICEWAY			89,500
INTAKE			
Excavation, common	4,500 m^3	1.25	5,625
Excavation, rock	8,000 m^3	5.00	40,000
Foundation preparation and treatment		L.S.	2,000
Concrete, mass	2,100 m^3	27.00	56,700
Concrete, structural	4,000 m^3	30.00	120,000
Formwork	4,400 m^2	10.00	44,000
Reinforcing steel	115,000 kg	0.28	32,200
Emergency gate, frames, and guides	29,000 kg	1.00	29,000
Bulkhead gates (2), frames, and guides	43,000 kg	1.00	43,000
Trashracks and guides	58,500 kg	0.80	46,800
Bridge crane, capacity 35 tons		L.S.	50,000

BURFELL PROJECT

COST ESTIMATES

PRODUCTION PLANT
(Continued)

6 Units Installed

Item	Quantity	Unit Price $ U.S.	Amount $ U.S.
Backfill	6,000 m^3	1.50	9,000
Gatehouse		L.S.	60,000
Gate heating		L.S.	20,000
SUBTOTAL INTAKE			558,325
PENSTOCKS			
Excavation, shaft and tunnels	9,000 m^3	12.00	108,000
Steel supports	171,000 kg	0.50	85,500
Timber	240 m^3	80.00	19,200
Rockbolting	1,200 lin.m.	8.00	9,600
Grouting		L.S.	90,000
Pumping		L.S.	15,000
Concrete	4,500 m^3	30.00	135,000
Steel plate	480,000 kg	0.65	312,000
Reinforcing steel	52,500 kg	0.28	14,700
SUBTOTAL PENSTOCKS			789,000
TAILRACE SURGE CHAMBER			
Excavation, surge chamber	19,000 m^3	8.00	152,000
Excavation, draft tube extensions	9,200 m^3	10.00	92,000
Temporary support of roof		L.S.	25,000
Rockbolting	7,000 lin. m	8.00	56,000
Grouting		L.S.	70,000
Concrete, surge chamber and tunnels	2,900 m^3	30.00	87,000
Concrete, roof in surge chamber	700 m^3	40.00	28,000
Formwork	5,000 m^2	15.00	75,000
Reinforcing steel	132,000 kg	0.28	36,960

BURFELL PROJECT

COST ESTIMATES

PRODUCTION PLANT
(Continued)

6 Units Installed

Item	Quantity	Unit Price $ U.S.	Amount $ U.S.
Draft tube gates (2) and guides	31,000 kg	1.00	31,000
Miscellaneous		L.S.	10,000
SUBTOTAL TAILRACE SURGE CHAMBER			662,960
TAILRACE TUNNEL			
Excavation	120,000 m^3	6.50	780,000
Steel supports	460,000 kg	0.50	230,000
Timber	650 m^3	80.00	52,000
Rockbolting	4,500 lin.m	8.00	36,000
Grouting		L.S.	235,000
Pumping		L.S.	10,000
Concrete, tunnel lining incl. formwork	33,300 m^3	35.00	1,165,500
Concrete, tunnel portal incl. formwork	360 m^3	50.00	18,000
Reinforcing steel	1,180,000 kg	0.28	330,400
Stoplogs and guides		L.S.	20,000
SUBTOTAL TAILRACE TUNNEL			2,876,900
TAILRACE CANAL			
Excavation, common	200,000 m^3	0.50	100,000
Excavation, rock	30,000 m^3	3.00	90,000
SUBTOTAL TAILRACE CANAL			190,000
SUBTOTAL RESERVOIRS, DAMS, AND WATERWAYS			10,972,680

BURFELL PROJECT

COST ESTIMATES

PRODUCTION PLANT
(Continued)

6 Units Installed

Item	Quantity	Unit Price $ U.S.	Amount $ U.S.
TURBINES AND GENERATORS			
Turbines and governors	6	201,500	1,209,000
Generators and exciters	6	375,000	2,250,000
SUBTOTAL TURBINES AND GENERATORS			3,459,000
ACCESSORY ELECTRICAL EQUIPMENT			
Conductors and insulators		L.S.	430,000
Conduits		L.S.	70,000
Switchgear and control equipment		L.S.	310,000
Transmission to Thjorsa diversion weir and inlet		L.S.	7,500
SUBTOTAL ACCESSORY ELECTRICAL EQUIPMENT			817,500
MISCELLANEOUS POWER PLANT EQUIPMENT			
Butterfly valves	6	48,000	288,000
Unwatering and low level drainage system		L.S.	58,000
Raw water system		L.S.	35,000
Head and tailwater gauges		L.S.	9,200
Compressed air system		L.S.	15,000
Fire protection equipment		L.S.	60,000
Generator room crane, capacity 85 tons		L.S.	95,000
Draft tube gate hoist, capacity 8 tons		L.S.	10,000
Elevator		L.S.	28,000
Machine shop		L.S.	10,000
General station equipment		L.S.	53,000
Diesel generator		L.S.	13,000
SUBTOTAL MISCELLANEOUS POWER PLANT EQUIPMENT			674,200

BURFELL PROJECT

COST ESTIMATES

PRODUCTION PLANT
(Continued)

6 Units Installed

Item	Quantity	Unit Price $ U.S.	Amount $ U.S.
ACCESS ROADS AND BRIDGES		L.S.	550,000
OPERATORS VILLAGE AND GENERAL PLANT			
Operators village		L.S.	200,000
Office furniture and equipment		L.S.	25,000
Tools, shop, and garage equipment		L.S.	25,000
Communication equipment		L.S.	50,000
SUBTOTAL OPERATORS VILLAGE AND GENERAL PLANT			300,000
SUBTOTAL PRODUCTION PLANT			20,302,680

BURFELL PROJECT

COST ESTIMATES

TRANSMISSION PLANT

6 Units Installed

Item	Quantity	Unit Price $ U.S.	Amount $ U.S.
EIDI ALTERNATIVE			
ONE 230 KV TRANSMISSION LINE			
BURFELL STEP-UP SUBSTATION			
Transformer, 13.2-13.2-230 kv, 36-36-72 mva, OA/FA/FOA, 900 kv B.I.L.	3	138,000	414,000
Disconnecting switches, 230 kv	11	5,000	55,000
Circuit breakers, 230 kv	6	45,000	270,000
Structures, foundations, and buses	6 bays	5,000	30,000
Grounding, conduits, and wiring	6 bays	10,000	60,000
Carrier current equipment		L.S.	12,000
Grading, surfacing, and fencing		L.S.	50,000
Transformer, 230-11-69 kv, 12/15 mva, OA/FA	1	60,000	60,000
Miscellaneous		L.S.	20,000
SUBTOTAL BURFELL STEP-UP SUBSTATION			971,000
TRANSMISSION LINE BURFELL-EIDI			
795 mcm-a.c.s.r., 230-kv single circuit on wood poles	107 km	14,000	1,498,000
EIDI SUBSTATION			
Autotransformer, 230-138 kv, 70 mva, OA/FA/FOA, 900 kv & 550 kv B.I.L.	1	126,000	126,000
Disconnecting switches, 230 kv	6	5,000	30,000
Circuit breakers, 230 kv	2	45,000	90,000
Structures, foundations, and buses	2 bays	5,000	10,000
Grounding, conduits, and wiring	2 bays	10,000	20,000
Carrier current equipment		L.S.	12,000
Control building and switchboard		L.S.	30,000
Grading, surfacing, and fencing		L.S.	30,000
SUBTOTAL EIDI SUBSTATION			348,000

BURFELL PROJECT

COST ESTIMATES

TRANSMISSION PLANT
(Continued)

6 Units Installed

Item	Quantity	Unit Price $ U.S.	Amount $ U.S.
TRANSMISSION LINE EIDI - ELLIDAAR			
477 mcm-a.c.s.r., 138-kv single circuit on wood poles	5.5 km	9,500	52,250
ELLIDAAR SUBSTATION ADDITIONS			
Transformer, 138-11-34.5 kv, 70 mva, OA/FA/FOA, 550 kv B.I.L.	1	93,000	93,000
Circuit breaker positions, 138 kv	2	27,000	54,000
Additions to structures and buses, 138 kv	1 bay	4,000	4,000
Grounding, conduits, and wiring		L.S.	5,000
Carrier current equipment, indoors		L.S.	3,000
Carrier current equipment, outdoors		L.S.	3,000
Line and transformer control switchboard		L.S.	10,000
SUBTOTAL ELLIDAAR SUBSTATION ADDITIONS			172,000
SUBTOTAL TRANSMISSION PLANT, EIDI ALTERNATIVE, ONE 230 KV TRANSMISSION LINE			3,041,250

BURFELL PROJECT

COST ESTIMATES

TRANSMISSION PLANT
(Continued)

6 Units Installed

Item	Quantity	Unit Price $ U.S.	Amount $ U.S.
EIDI ALTERNATIVE			
TWO 230 KV TRANSMISSION LINES			
BURFELL STEP-UP SUBSTATION			
Transformers, 13.2-13.2-230 kv, 36-36-72 mva, OA/FA/FOA, 900 kv B.I.L.	3	138,000	414,000
Disconnecting switches, 230 kv	14	5,000	70,000
Circuit breakers, 230 kv	7	45,000	315,000
Structures, foundations, and buses	7 bays	5,000	35,000
Grounding, conduits, and wiring	7 bays	10,000	70,000
Carrier current equipment		L.S.	20,000
Grading, surfacing, and fencing		L.S.	50,000
Transformer, 230-11-69 kv, 12/15 mva, OA/FA	1	60,000	60,000
Miscellaneous		L.S.	20,000
SUBTOTAL BURFELL STEP-UP SUBSTATION			1,054,000
TRANSMISSION LINE BURFELL - EIDI			
795 mcm - a.c.s.r., 230-kv single circuit on wood poles	219 km	14,000	3,066,000
EIDI SUBSTATION			
Autotransformer, 230-138 kv, 70 mva, OA/FA/FOA, 900 kv & 550 kv B.I.L.	1	126,000	126,000
Disconnecting switches, 230 kv	14	5,000	70,000

BURFELL PROJECT

COST ESTIMATES

TRANSMISSION PLANT
(Continued)

6 Units Installed

Item	Quantity	Unit Price $ U.S.	Amount $ U.S.
Circuit breakers, 230 kv	5	45,000	225,000
Structures, foundations, and buses	5 bays	5,000	25,000
Grounding, conduits, and wiring	5 bays	10,000	50,000
Carrier current equipment		L.S.	20,000
Control building and switchboard		L.S.	50,000
Grading, surfacing, and fencing		L.S.	30,000
SUBTOTAL EIDI SUBSTATION			596,000
TRANSMISSION LINE EIDI - ELLIDAAR 477 mcm - a.c.s.r., 138-kv single circuit on wood poles	5.5 km	9,500	52,250
ELLIDAAR SUBSTATION ADDITIONS			
Transformer, 138-11-34.5 kv, 70 mva, OA/FA/FOA, 550 kv B.I.L.	1	93,000	93,000
Circuit breaker positions, 138 kv	2	27,000	54,000
Additions to structures and buses, 138 kv	1 bay	4,000	4,000
Grounding, conduits, and wiring		L.S.	5,000
Carrier current equipment, indoors		L.S.	3,000
Carrier current equipment, outdoors		L.S.	3,000
Line and transformer control switchboard		L.S.	10,000
SUBTOTAL ELLIDAAR SUBSTATION ADDITIONS			172,000
SUBTOTAL TRANSMISSION PLANT, EIDI ALTERNATIVE, TWO 230 KV TRANSMISSION LINES			4,940,250

BURFELL PROJECT

COST ESTIMATES

TRANSMISSION PLANT
(Continued)

6 Units Installed

Item	Quantity	Unit Price $ U.S.	Amount $ U.S.
STRAUMSVIK ALTERNATIVE			
ONE 230 KV TRANSMISSION LINE			
BURFELL STEP-UP SUBSTATION Same as Eidi Alternative (sheet 15)		L.S.	971,000
TRANSMISSION LINE BURFELL-STRAUMSVIK 795 mcm-a.c.s.r., 230-kv single circuit on wood poles	118 km	14,000	1,652,000
STRAUMSVIK SUBSTATION Same as Eidi Substation (sheet 15)		L.S.	348,000
TRANSMISSION LINE STRAUMSVIK-ELLIDAAR 477 mcm-a.c.s.r., 138-kv single circuit on wood poles	13 km	9,500	123,500
ELLIDAAR SUBSTATION ADDITIONS Same as Eidi Alternative (sheet 16)		L.S.	172,000
SUBTOTAL TRANSMISSION PLANT, STRAUMSVIK ALTERNATIVE, ONE 230 KV TRANSMISSION LINE			3,266,500

BURFELL PROJECT

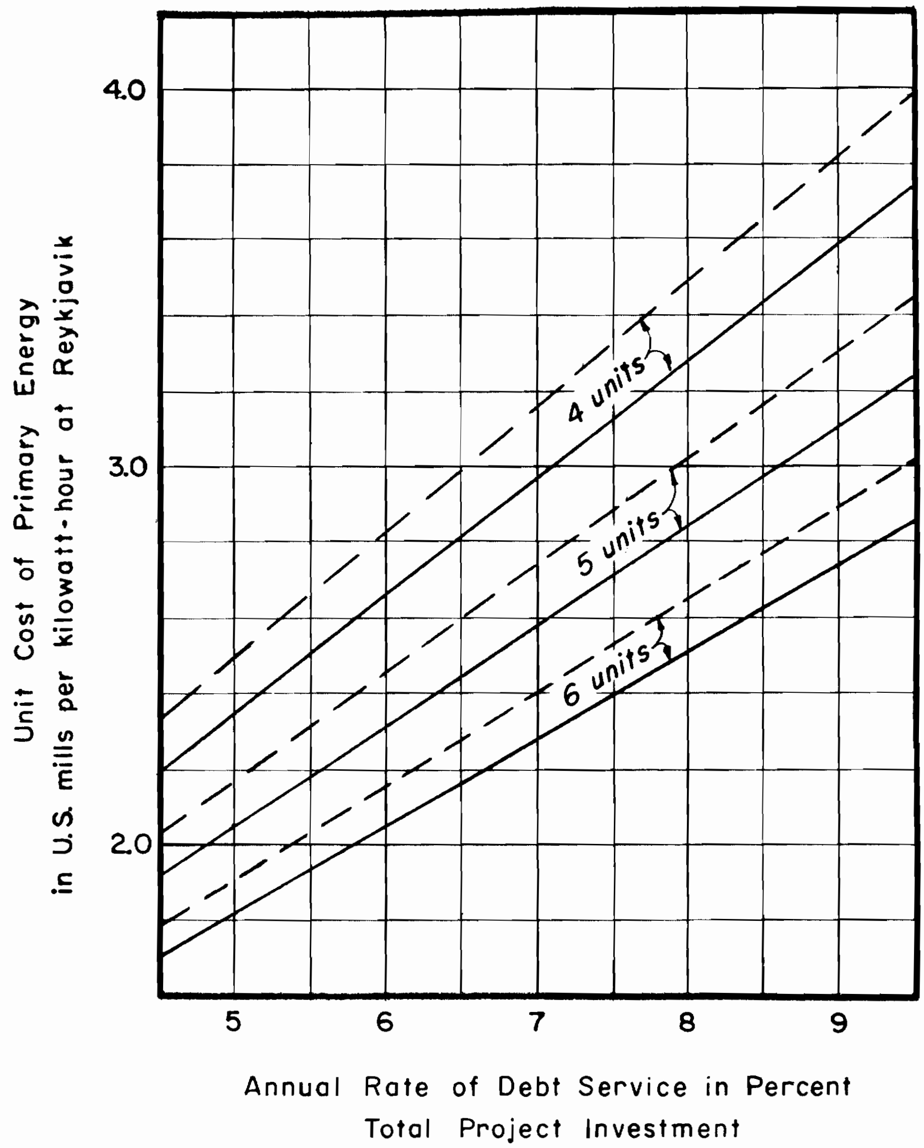
COST ESTIMATES

TRANSMISSION PLANT
(Continued)

6 Units Installed

Item	Quantity	Unit Price $ U.S.	Amount $ U.S.
STRAUMSVIK ALTERNATIVE			
TWO 230 KV TRANSMISSION LINES			
BURFELL STEP-UP SUBSTATION Same as Eidi Alternative (sheet 17)		L.S.	1,054,000
TRANSMISSION LINE BURFELL-STRAUMSVIK 795 mcm-a.c.s.r., 230-kv single circuit on wood poles	236 km	14,000	3,304,000
STRAUMSVIK SUBSTATION Same as Eidi Substation (sheet 18)		L.S.	596,000
TRANSMISSION LINE STRAUMSVIK-ELLIDAAR 477 mcm-a.c.s.r., 138-kv single circuit on wood poles	13 km	9,500	123,500
ELLIDAAR SUBSTATION ADDITIONS Same as Eidi Alternative (sheet 18)		L.S.	172,000
SUBTOTAL TRANSMISSION PLANT, STRAUMSVIK ALTERNATIVE, TWO 230 KV TRANSMISSION LINES			5,249,500

EXHIBIT 9



LEGEND

——— *One transmission line*

- - - - *Two transmission lines*

NOTES:

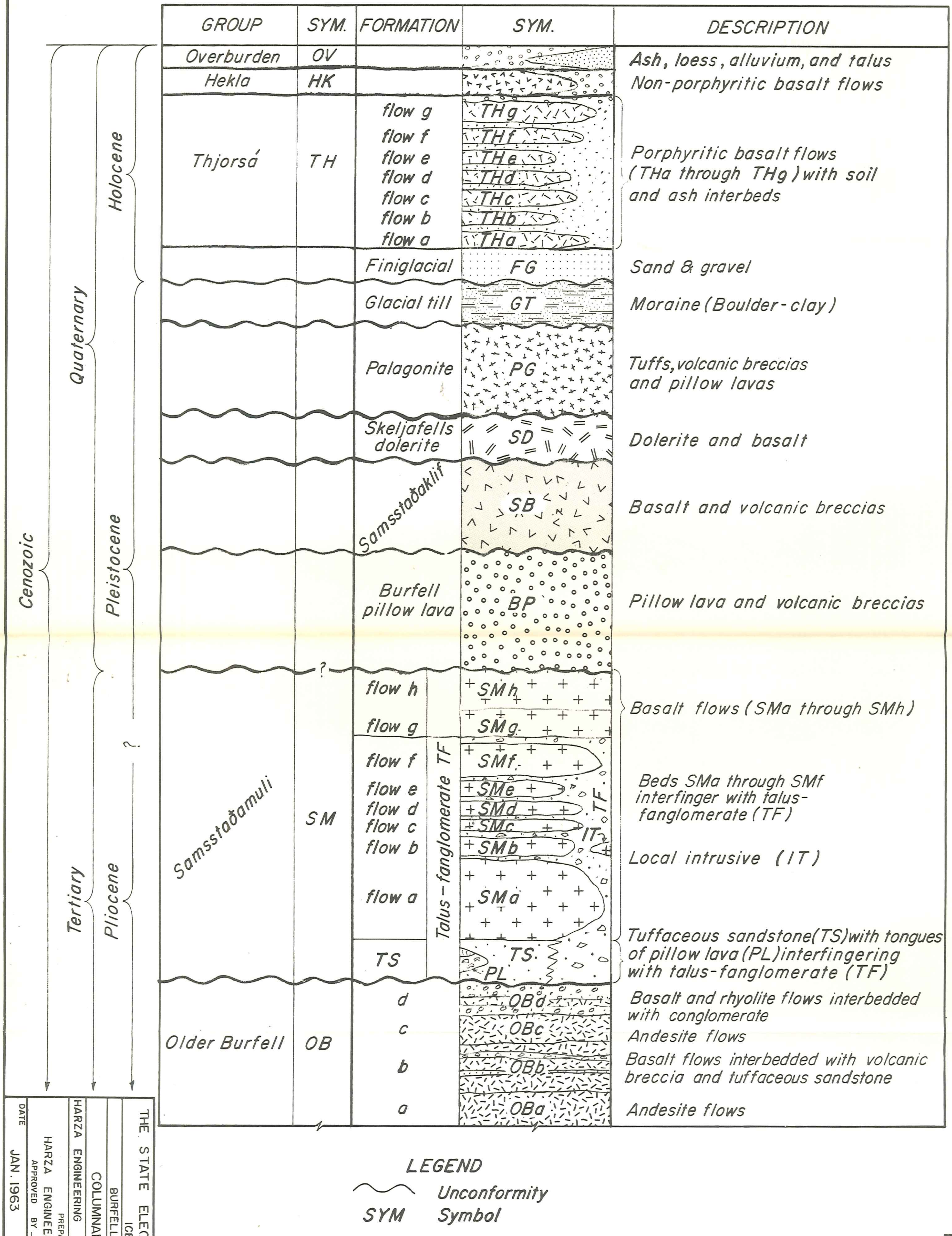
No allowance made for income from sales of secondary energy.

Import duties and taxes not included.

STATE ELECTRICITY AUTHORITY ICELAND	
BURFELL PROJECT	
UNIT COST OF ENERGY	
HARZA ENGINEERING CO. INTERNATIONAL	
PREPARED BY HARZA ENGINEERING CO., CHICAGO APPROVED A P Gauss	
DATE JAN. 1963	DWG. NO. 290 P 32

EXHIBIT 10

COLUMNAR SECTION



THE STATE ELECTRICITY AUTHORITY
ICELAND
BURFELL PROJECT
COLUMNAR SECTION
HARZA ENGINEERING COMPANY INTERNATIONAL
PREPARED BY
HARZA ENGINEERING CO. CHICAGO
APPROVED BY

DATE	DWG. NO.
JAN. 1963	290 P 24

EXHIBIT II

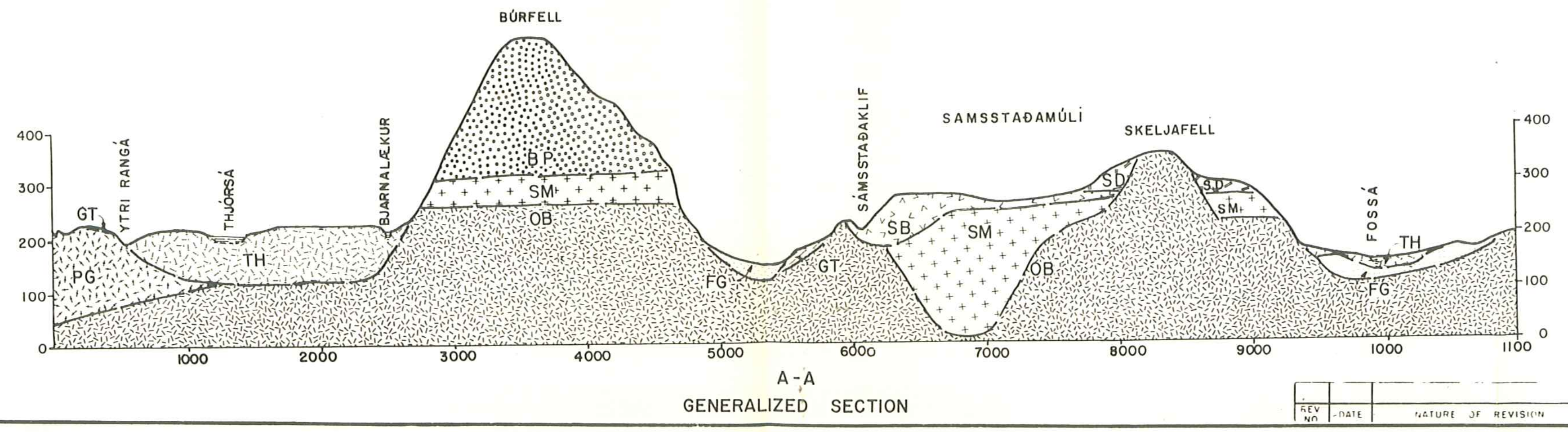
LEGEND:

- Overburden (OV) — River alluvium; Ash and lapilli
- Hekla (HK) — Non-porphyritic basalt flows
- Thjorsá group (TH) — Porphyritic basalt flows, THa through THg, with soil and ash interbeds
- Finiglacial (FG) — Sand and gravel, unconsolidated
- Glacial till (GT) — Moraine (boulder, clay)
- Palagonite (PG) — Tuffs, volcanic breccia and pillow lava
- Skeljafell dolerite (SD) — Dolerite and basalt
- Samsstaðaklif basalt (SB) — Basalt and volcanic breccia
- Burfell pillow lava (BP) — Pillow lava and volcanic breccia
- Samsstaðamuli group (SM) — Basalt flows (SM) interfingering with talus-fanglomerate (TF). Tuffaceous sandstone (TS) with tongues of pillow lava (PL)
- Older Burfell (OB) — Basalt, andesite and rhyolite flows with clastic interbeds
- Approximate geologic contact
- Fault

NOTES:

Topography based on topographic mapping performed under the direction of Harza Engineering Co, International and on aerial surveying performed by Wideroe Aerial Survey Co, Norway.

Geologic sections shown on drawings 290 P19 and 290 P20



A-A
GENERALIZED SECTION

DATE	NO	DISTRIBUTION
PRINTS		

	BY	DATE	CHKD.	DATE
DSGN.				
DWN.				

DEPT.	GROUP LEADER	SECT. HEAD	DEPT. HEAD
CIVIL			
MECH.			
ELECT			
PLAN			
STAFF			CH. ENGR.

REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.

THE STATE ELECTRICITY AUTHORITY
ICELAND

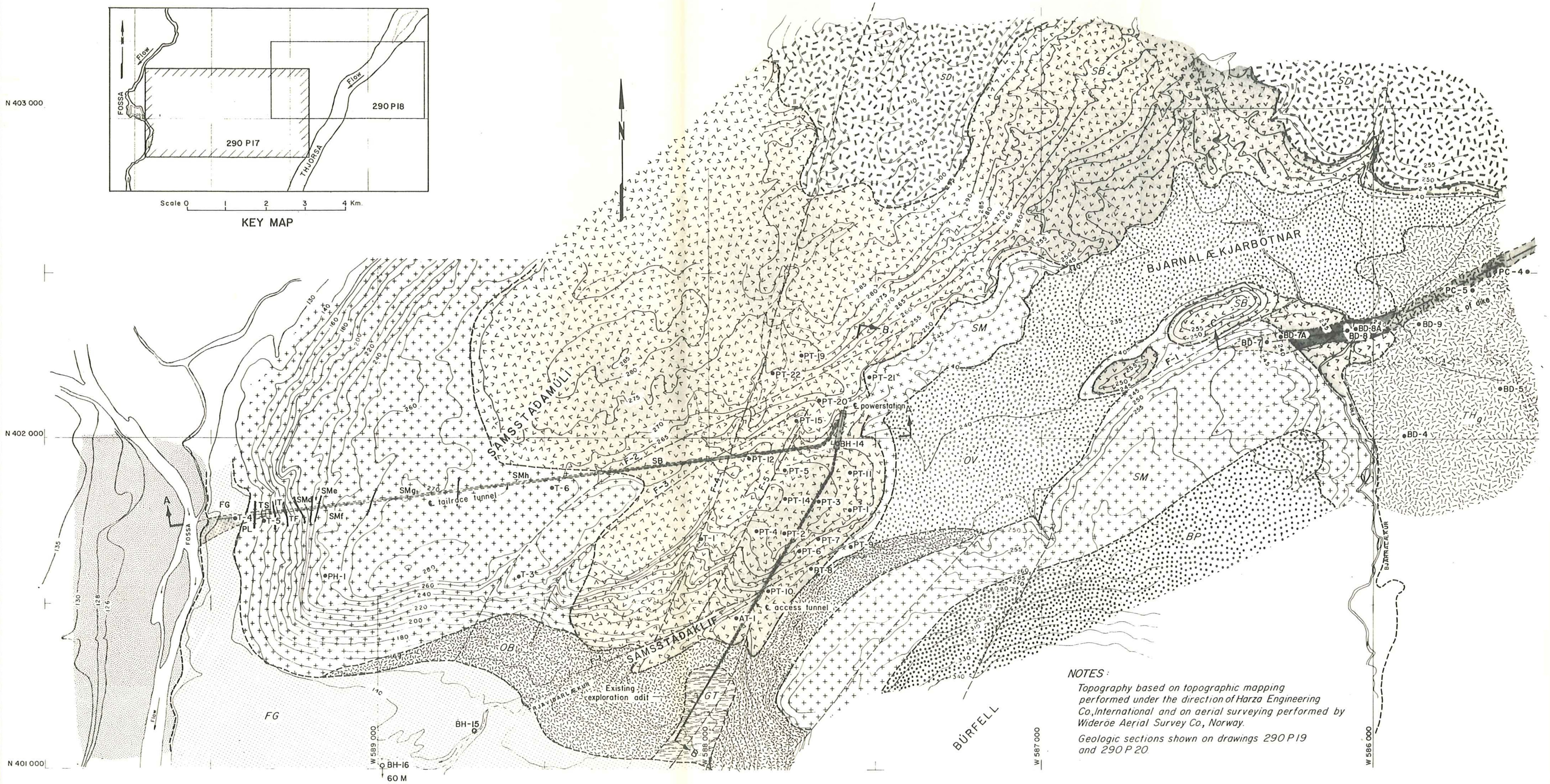
BURFELL PROJECT

GEOLOGIC MAP
BURFELL AREA

HARZA ENGINEERING COMPANY INTERNATIONAL
PREPARED BY
HARZA ENGINEERING COMPANY
APPROVED

CHICAGO, ILLINOIS | DATE JAN. 1963 | DWG. No. 290 P 16

EXHIBIT 12



NOTES:

Topography based on topographic mapping performed under the direction of Harza Engineering Co, International and on aerial surveying performed by Wideröe Aerial Survey Co, Norway.

Geologic sections shown on drawings 290 P 19 and 290 P 20.

Scale 0 100 200 300 Meters

LEGEND:

- Overburden (OV) — River alluvium; Ash and lapilli
- Thjorsá flow (THg) — Upper flow of Thjorsá group, consisting of porphyritic basalt flows with soil and ash interbeds
- Finiglacial (FG) — Sand and gravel, unconsolidated
- Glacial till (GT) — Moraine (boulder, clay)
- Skeljafell dolerite (SD) — Dolerite and basalt
- Samsstaðaklif basalt (SB) — Basalt and volcanic breccia
- Burfell pillow lava (BP) — Pillow lava and volcanic breccia
- Samsstaðamuli group (SM) — Basalt flows (SM) interfingering with talus-fanglomerate (TF). Tuffaceous sandstone (TS) with tongues of pillow lava (PL)
- Older Burfell (OB) — Basalt, andesite and rhyolite flows with clastic interbeds
- Approximate geologic contact between groups
- Approximate geologic contact between formations
- Fault
- ○ Exploration hole drilled under supervision of Harza Engineering Co, International 1961 during exploration for the "Lower Site"
- ● Exploration hole drilled under supervision of Harza Engineering Co., International 1962 during exploration for the "Upper Site"

DATE	NO	DISTRIBUTION
PRINTS		

	BY	DATE	CHKD	DATE
DSGN	P.H.O.	12/21/62	GWO	1-11-63
DWN.	HES	1/4/63		
DEPT.	GROUP LEADER	SECT. HEAD	DEPT. HEAD	
CIVIL		RJF	[illegible]	
MECH.				
ELECT.				
PLAN				
STAFF	CLW		CH.ENGR.	

REV NO	DATE	NATURE OF REVISION	BY	CHKD	APPD

THE STATE ELECTRICITY AUTHORITY
ICELAND

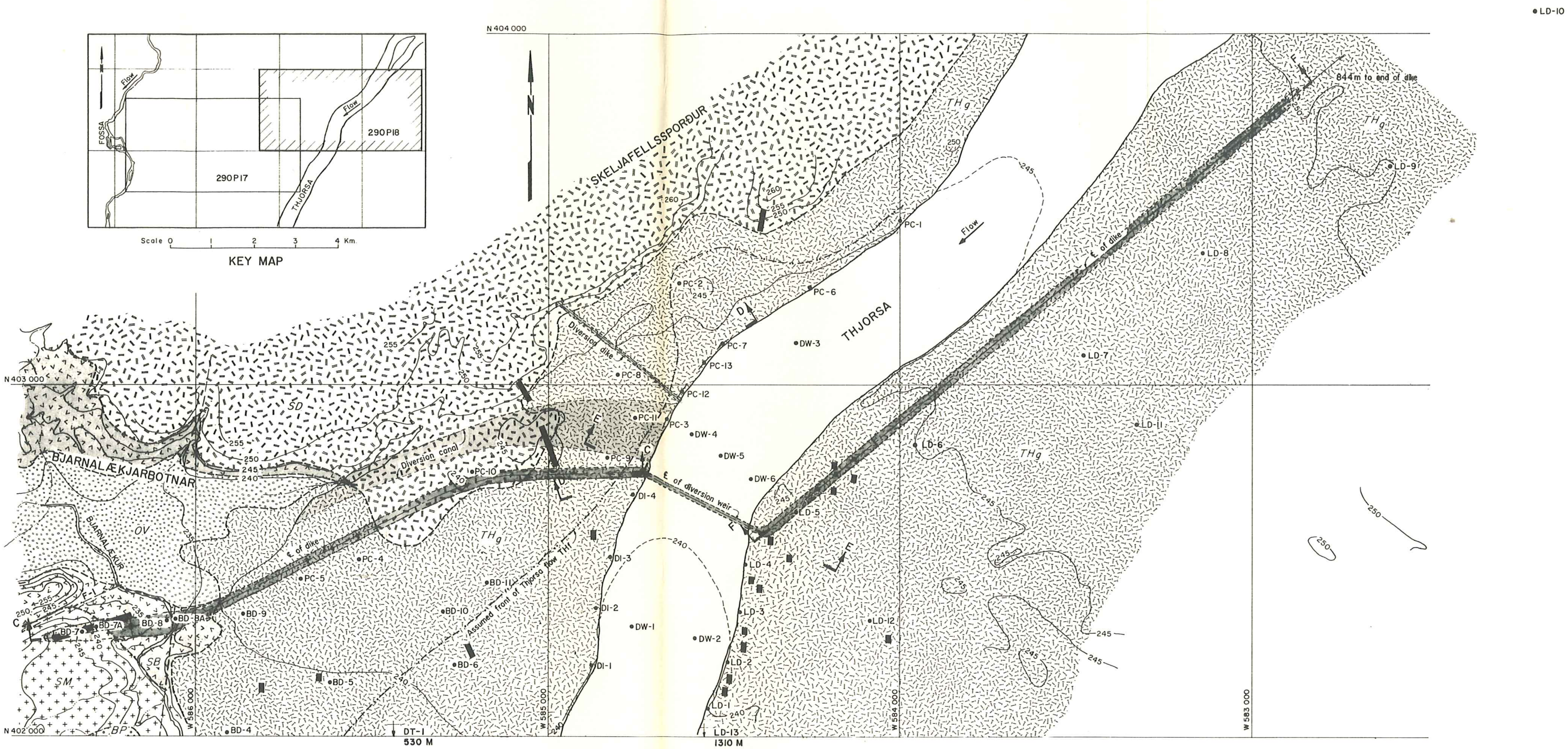
BURFELL PROJECT

GEOLOGIC MAP-PROJECT AREA
SHEET 1 OF 2

HARZA ENGINEERING COMPANY INTERNATIONAL
PREPARED BY
HARZA ENGINEERING COMPANY
APPROVED [signature]

CHICAGO, ILLINOIS | DATE JAN. 1963 | DWG. No. 290 P 17

EXHIBIT 12



LEGEND:

Overburden (OV)
Ash and lapilli

Thjorsá flow (THg)
Upper flow of Thjorsá group, consisting of porphyritic basalt flows with soil and ash interbeds

Skeljafell dolerite (SD)
Dolerite and basalt

Samsstaðaklif basalt (SB)
Basalt and volcanic breccia

Samsstaðamuli group (SM)
Basalt flows

Approximate geologic contact between groups

Fault

Exploration hole drilled under the supervision of Harza Engineering Co. International 1961 – 1962

Trench

Outline of structure

NOTES:

Topography based on topographic mapping performed under the direction of Harza Engineering Co. International and on aerial surveying performed by Wideroe Aerial Survey Co, Norway.

Geologic sections shown on dwg. 290 P 20

Scale 0 100 200 300 Meters

THE STATE ELECTRICITY AUTHORITY
ICELAND

BURFELL PROJECT

GEOLOGIC MAP-PROJECT AREA
SHEET 2 OF 2

HARZA ENGINEERING COMPANY INTERNATIONAL
PREPARED BY
HARZA ENGINEERING COMPANY

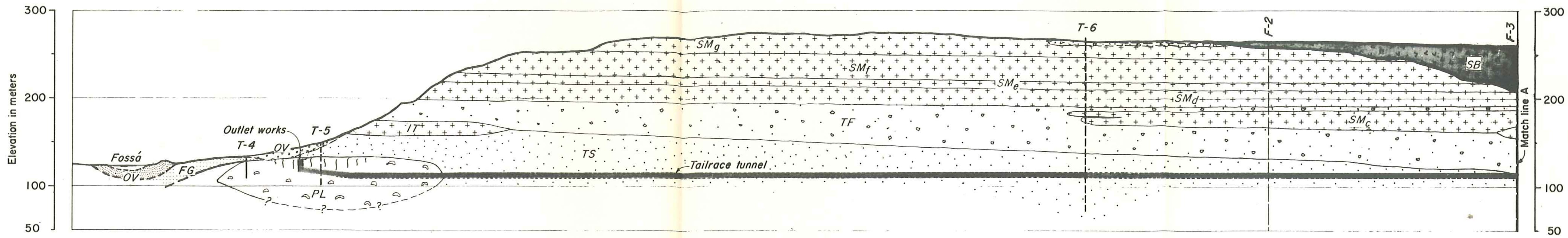
APPROVED [signature]

CHICAGO, ILLINOIS | DATE Jan., 1963 | DWG. No. 290 P 18

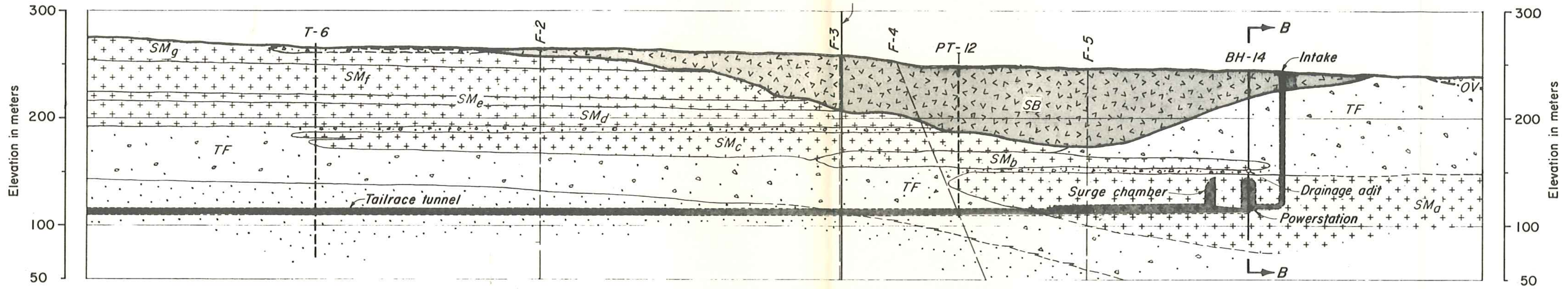
REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.

DATE	NO	DISTRIBUTION	
PRINTS			
	BY	DATE	CHKD.	DATE
DSGN.				
DWN.	W.H.			
DEPT.	GROUP LEADER	SECT. HEAD	DEPT. HEAD
CIVIL			
MECH.			
ELECT.			
PLAN.			
STAFF			CH.ENGR.

EXHIBIT 13

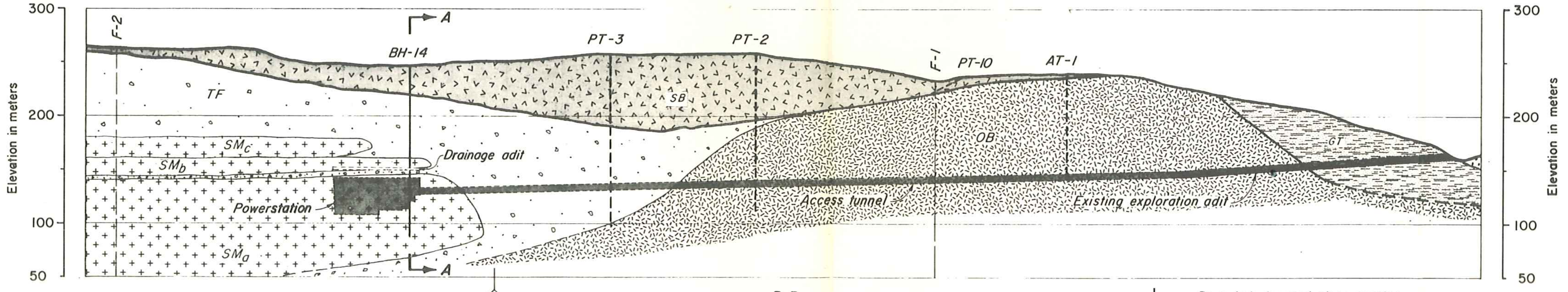


A-A
SECTION ALONG ℄ OF TAILRACE TUNNEL



A-A (continued)
SECTION ALONG ℄ OF TAILRACE TUNNEL

NOTES:
For location of geologic sections see dwg. 290 P 17



B-B
SECTION ALONG ℄ OF ACCESS TUNNEL

Scale 0 50 100 Meters
1cm = 20m

LEGEND

Overburden (OV) — River alluvium; Ash, lapilli and talus
Finiglacial (FG) — Sand and gravel, unconsolidated
Glacial till (GT) — Moraine (boulder, clay)
Samsstaðaklif basalt (SB) — Basalt and volcanic breccia

Samsstaðamuli group (SM) — Basalt flows (SMa through SMh) and intrusive (IT); Talus-fanglomerate (TF); Tuffaceous sandstone (TS); Pillow lava (PL)
Older Burfell (OB) — Basalt, andesite and rhyolite flows with clastic interbeds

Bore hole located along section
Bore hole projected to section. See dwg. 290 P 17 for exact distance.
Geologic contact between groups
Geologic contact between formations
Inferred geologic contact between groups
Inferred geologic contact between formations
Section turns
Outline of structures
Fault

DATE	NO	DISTRIBUTION
PRINTS		

	BY	DATE	CHKD.	DATE
DSGN.				
DWN.	N.H.			1-9-63
DEPT.	GROUP LEADER	SECT. HEAD	DEPT. HEAD	
CIVIL		RJF		
MECH.				
ELECT.				
PLAN.				
STAFF			CH.ENGR.	

REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.

THE STATE ELECTRICITY AUTHORITY
ICELAND

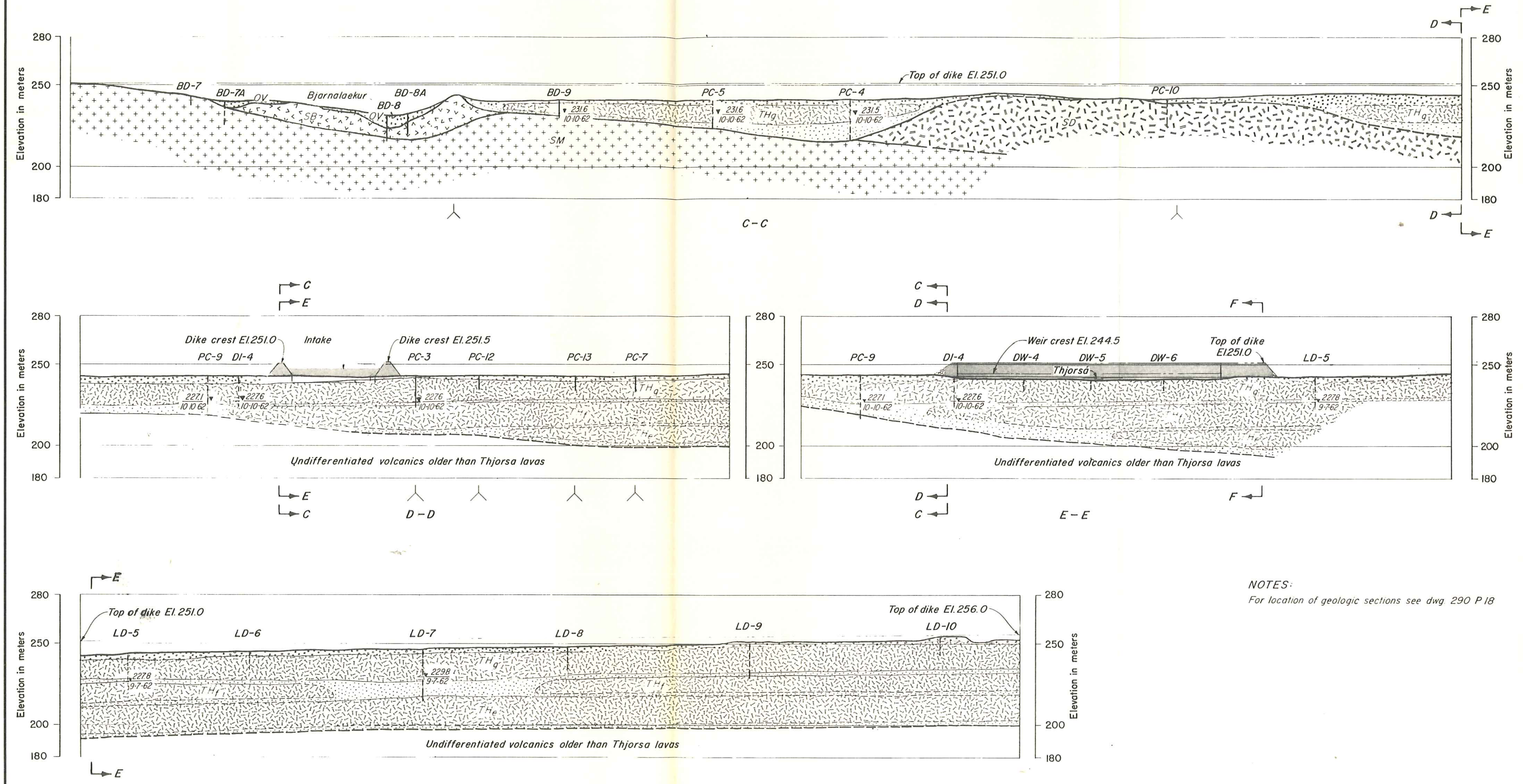
BURFELL PROJECT

GEOLOGIC SECTIONS
SHEET 1 OF 2

HARZA ENGINEERING COMPANY INTERNATIONAL
PREPARED BY
HARZA ENGINEERING COMPANY
APPROVED A.P. Geuss

CHICAGO, ILLINOIS | DATE JAN. 1963 | DWG. No. 290 P 19

EXHIBIT 13



NOTES:
For location of geologic sections see dwg 290 P 18

Horiz. scale 0 50 100 Meters
Vert. scale 0 50 Meters
Except as noted

LEGEND

Overburden (OV) — Ash, lapilli and talus

Thjorsá group (TH) — Basalt flows (THa through THg); Soil and ash interbed

Skeljafell dolerite (SD) — Dolerite and basalt

Samsstaðcklif basalt (SB) — Basalt and volcanic breccia

Samsstaðamuli group (SM) — Basalt flows

Outline of structures

227.1 / 10-10-62 — Ground water elevation / Date of recording

Bore hole located along section

Bore hole projected to section. See dwg. 290 P 18 for exact distance.

Geologic contact between groups

Geologic contact between formations

Inferred geologic contact between groups

Inferred geologic contact between formations

Section turns

DATE	NO	DISTRIBUTION	
PRINTS			
	BY	DATE	CHKD. DATE
DSGN.	W.G.D.	12-21-62	
DWN.	HLS	1/4/63	
DEPT.	GROUP LEADER	SECT. HEAD	DEPT. HEAD
CIVIL			
MECH.			
ELECT.			
PLAN.			
STAFF			CH. ENGR.

REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.

THE STATE ELECTRICITY AUTHORITY
ICELAND

BURFELL PROJECT

GEOLOGIC SECTIONS
SHEET 2 OF 2

HARZA ENGINEERING COMPANY INTERNATIONAL
PREPARED BY
HARZA ENGINEERING COMPANY
APPROVED

CHICAGO, ILLINOIS — DATE JAN. 1963 — DWG. NO. 290 P 20

EXHIBIT 14

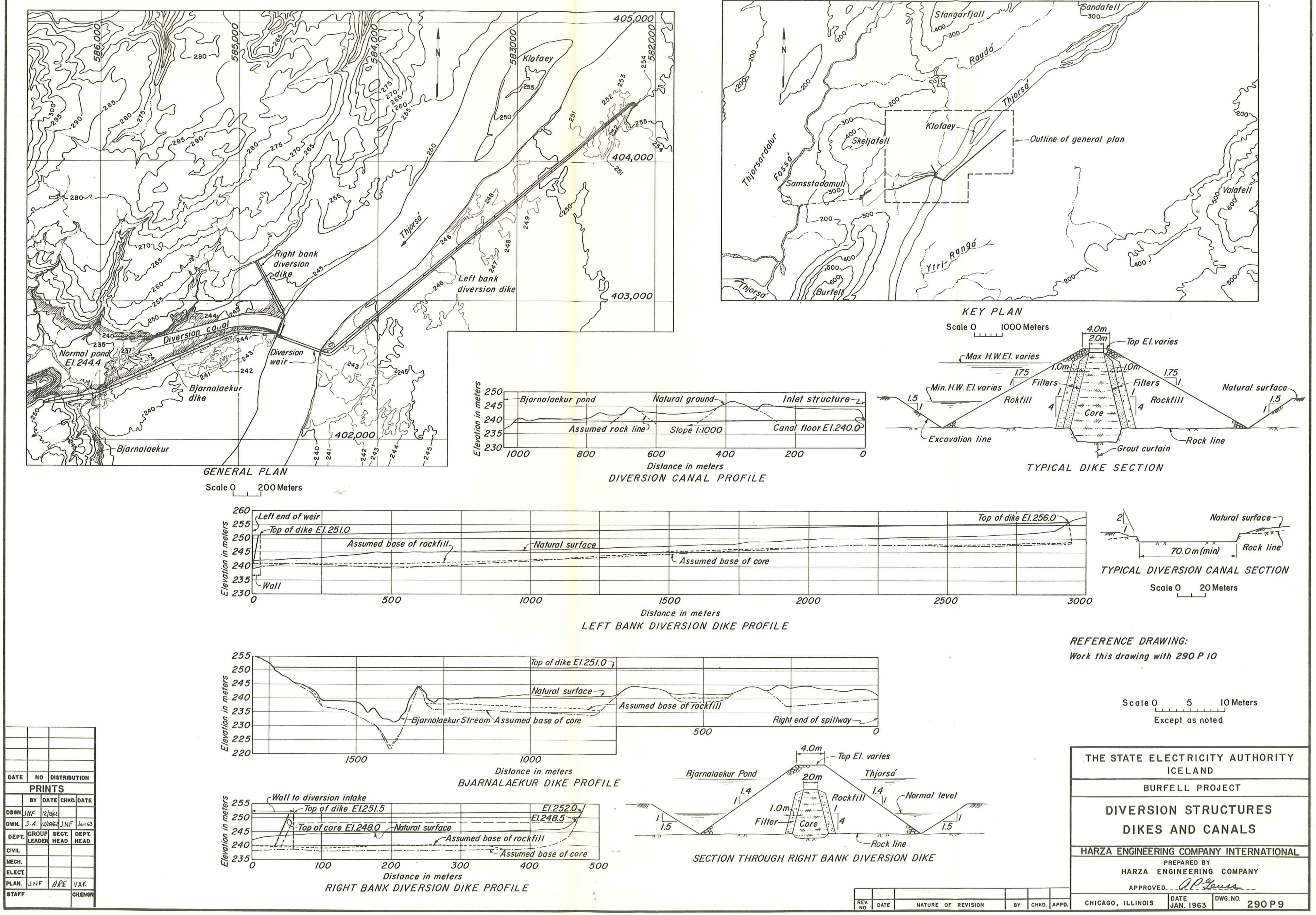
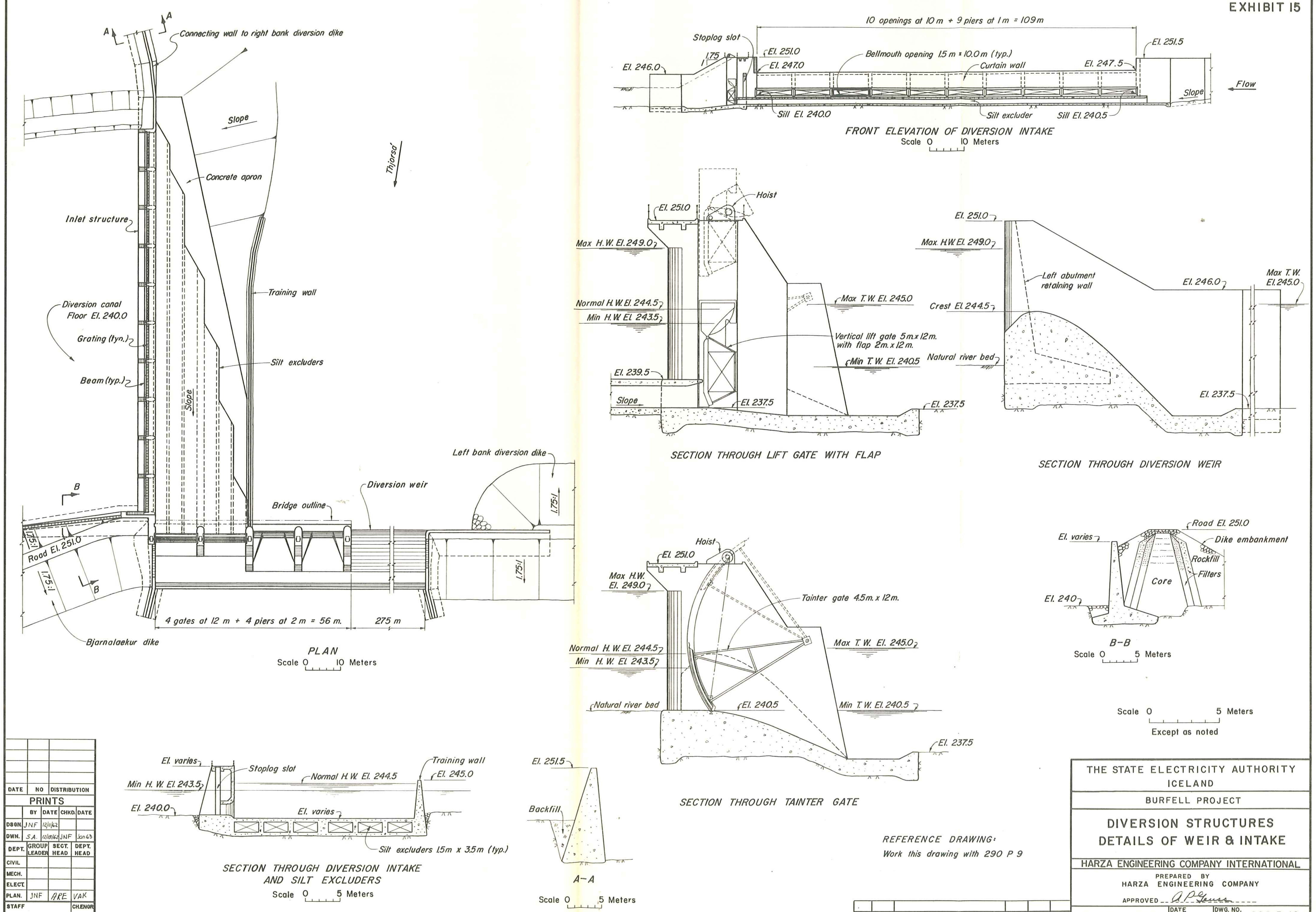

GENERAL PLAN
Scale 0 200 Meters
Klofaey
Thjorsá
Right bank diversion dike
Left bank diversion dike
Diversion canal
Diversion weir
Normal pond El. 244.4
Bjarnalaekur dike
Bjarnalaekur
405,000
404,000
403,000
402,000
586,000
585,000
584,000
583000
582,000
KEY PLAN
Scale 0 1000 Meters
Stangarfjall
Sandafell
Rauda
Thjorsá
Klofaey
Outline of general plan
Skeljafell
Thjorsardalur
Fossá
Samsstadamuli
Valafell
Ytri-Ranga
Burfell
DIVERSION CANAL PROFILE
Bjarnalaekur pond
Natural ground
Inlet structure
Assumed rock line
Slope 1:1000
Canal floor El. 240.0
Elevation in meters
Distance in meters
TYPICAL DIKE SECTION
Top El. varies
Max H.W. El. varies
Min. H.W. El. varies
Filters
Rokfill
Rockfill
Core
Natural surface
Excavation line
Rock line
Grout curtain
LEFT BANK DIVERSION DIKE PROFILE
Left end of weir
Top of dike El. 251.0
Top of dike El. 256.0
Assumed base of rockfill
Natural surface
Assumed base of core
Wall
TYPICAL DIVERSION CANAL SECTION
Natural surface
70.0 m (min)
Rock line
Scale 0 20 Meters
REFERENCE DRAWING:
Work this drawing with 290 P 10
BJARNALAEKUR DIKE PROFILE
Top of dike El. 251.0
Natural surface
Assumed base of rockfill
Bjarnalaekur Stream
Assumed base of core
Right end of spillway
Scale 0 5 10 Meters
Except as noted
RIGHT BANK DIVERSION DIKE PROFILE
Wall to diversion intake
Top of dike El. 251.5
El. 252.0
El. 248.5
Top of core El. 248.0
Natural surface
Assumed base of rockfill
Assumed base of core
SECTION THROUGH RIGHT BANK DIVERSION DIKE
Bjarnalaekur Pond
Thjorsá
Top El. varies
Rockfill
Filter
Core
Normal level
Rock line
THE STATE ELECTRICITY AUTHORITY
ICELAND
BURFELL PROJECT
DIVERSION STRUCTURES
DIKES AND CANALS
HARZA ENGINEERING COMPANY INTERNATIONAL
PREPARED BY
HARZA ENGINEERING COMPANY
APPROVED
CHICAGO, ILLINOIS
DATE JAN. 1963
DWG. NO. 290 P 9
REV. NO.
DATE
NATURE OF REVISION
BY
CHKD.
APPD.
DATE
NO
DISTRIBUTION
PRINTS
BY
DATE
CHKD.
DSGN.
DWN.
DEPT.
GROUP LEADER
SECT. HEAD
DEPT. HEAD
CIVIL
MECH.
ELECT.
PLAN.
STAFF
CH.ENGR.

EXHIBIT 15



REFERENCE DRAWING:
Work this drawing with 290 P 9

DATE	NO	DISTRIBUTION	
PRINTS			
	BY	DATE	CHKD. DATE
DSGN.	JNF	12/11/62	
DWN.	S.A.	12/18/62	JNF Jan 63
DEPT.	GROUP LEADER	SECT. HEAD	DEPT. HEAD
CIVIL			
MECH.			
ELECT.			
PLAN.	JNF	ARE	VAK
STAFF			CH. ENGR.

THE STATE ELECTRICITY AUTHORITY
ICELAND

BURFELL PROJECT

DIVERSION STRUCTURES
DETAILS OF WEIR & INTAKE

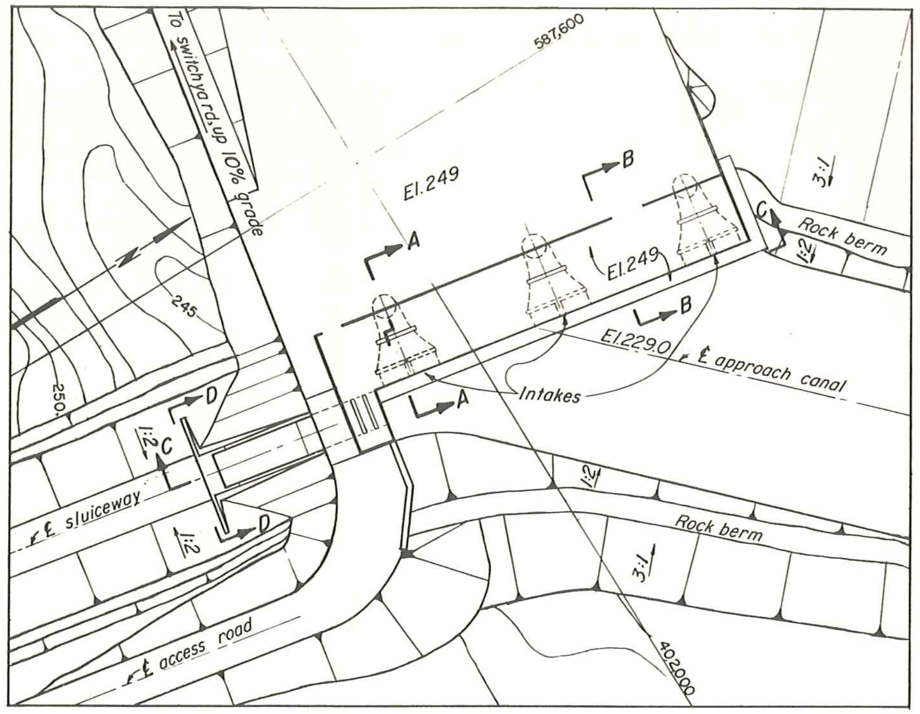
HARZA ENGINEERING COMPANY INTERNATIONAL
PREPARED BY
HARZA ENGINEERING COMPANY

APPROVED A.P. Geuss

REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.

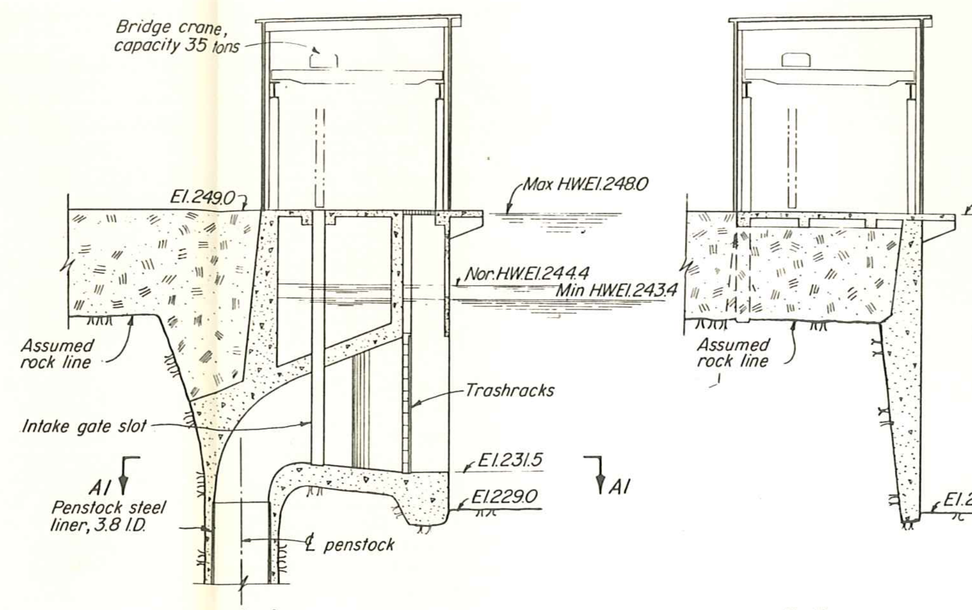
CHICAGO, ILLINOIS | DATE JAN. 1963 | DWG. NO. 290 P 10

EXHIBIT 16



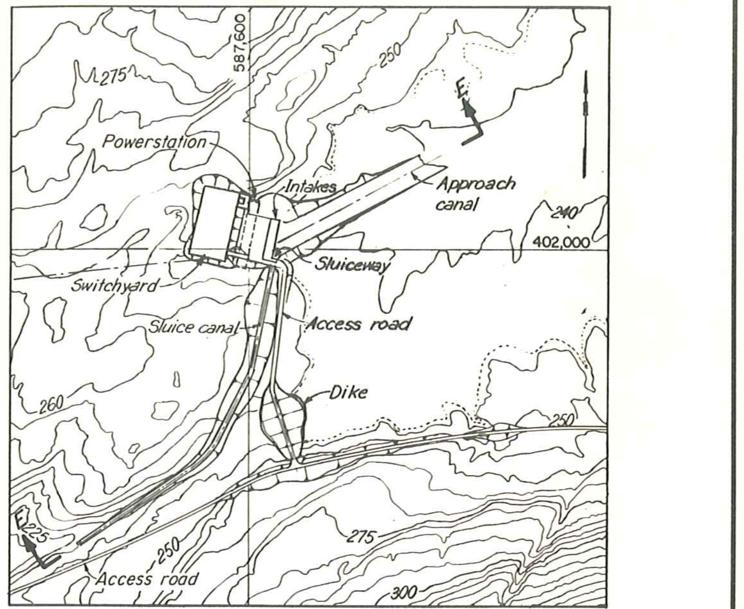
PLAN - INTAKES AND SLUICEWAY

Scale 0 10 Meters



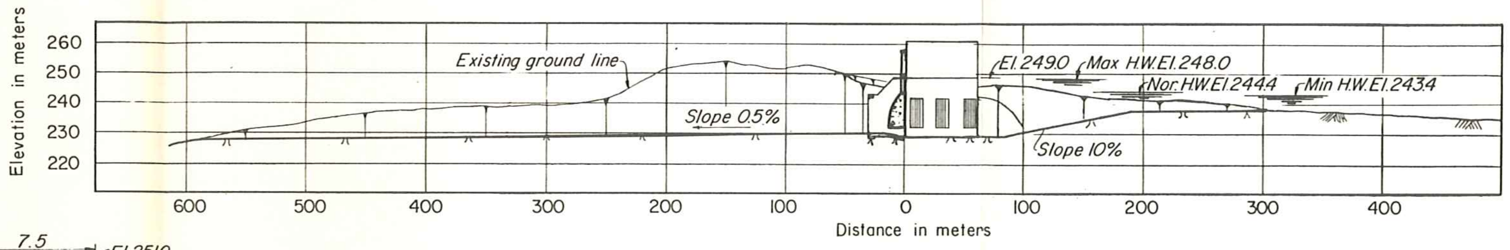
A - A

B - B

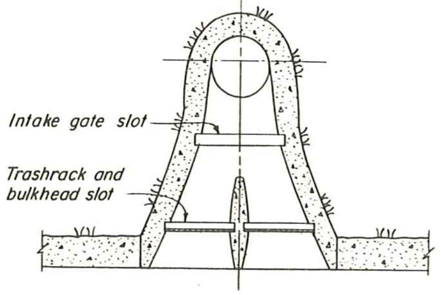


KEY PLAN

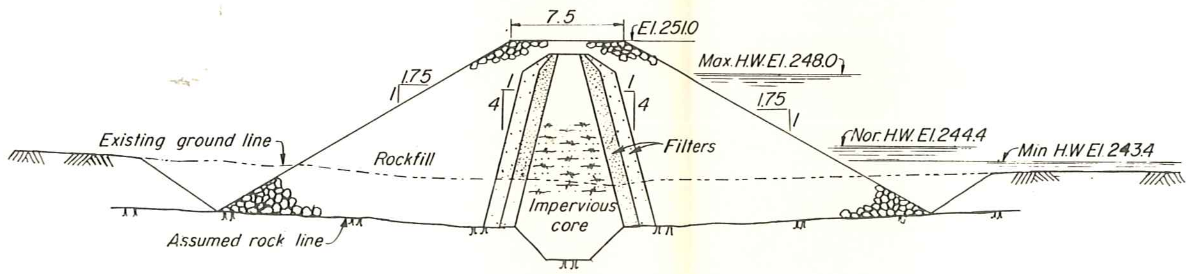
Scale 0 100 Meters



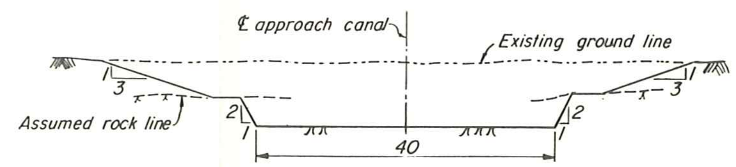
E - E



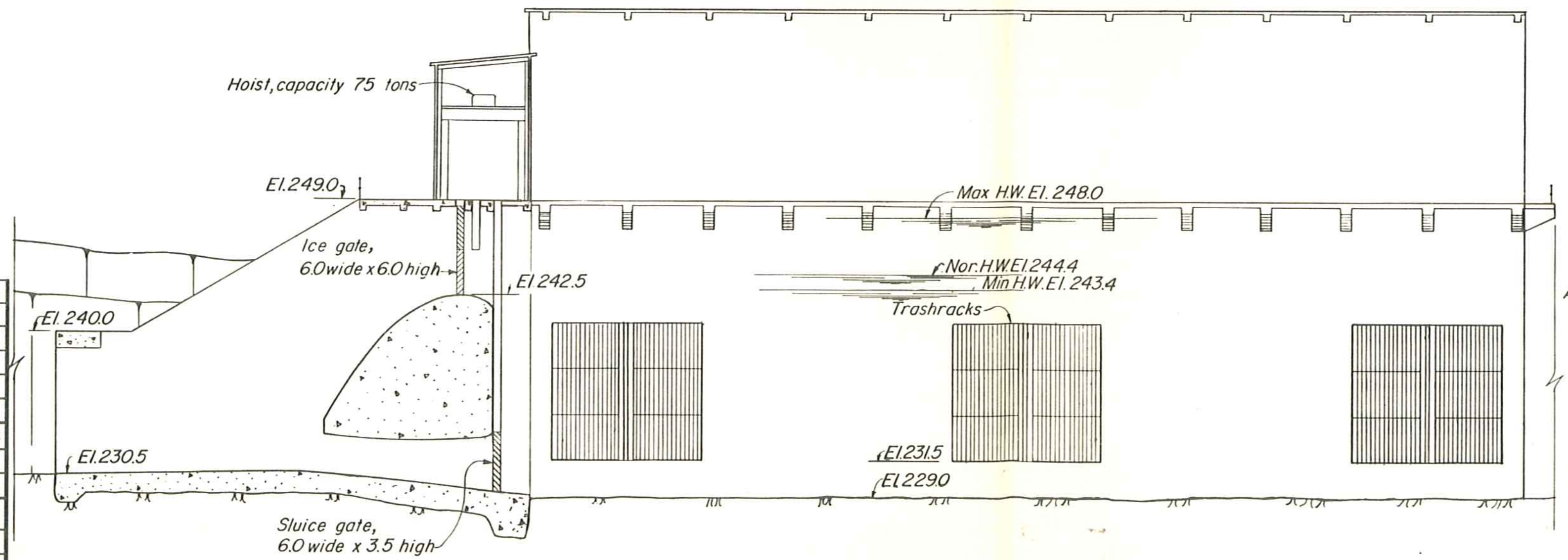
A1 - A1



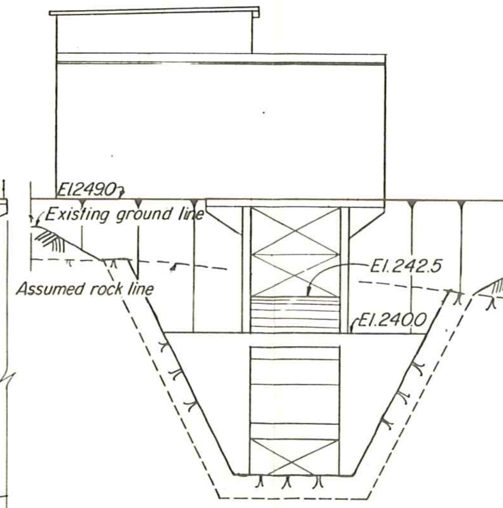
DIKE - TYPICAL SECTION



APPROACH CANAL - TYPICAL SECTION



C - C



D - D

Scale 0 5 10 Meters
Except as noted

DATE	NO	DISTRIBUTION

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	BY	DATE	CHKD.	DATE
DSGN.				
DWN.	RLR	11/1/62	VT	JAN. 1963
DEPT.	GROUP LEADER	SECT. HEAD	DEPT. HEAD	
CIVIL				
MECH.				
ELECT.				
PLAN.	VT	HRE	VAK	
STAFF			CH. ENGR.	

REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.

THE STATE ELECTRICITY AUTHORITY
ICELAND

BURFELL PROJECT

APPROACH CANAL, INTAKE AND SLUICEWAY

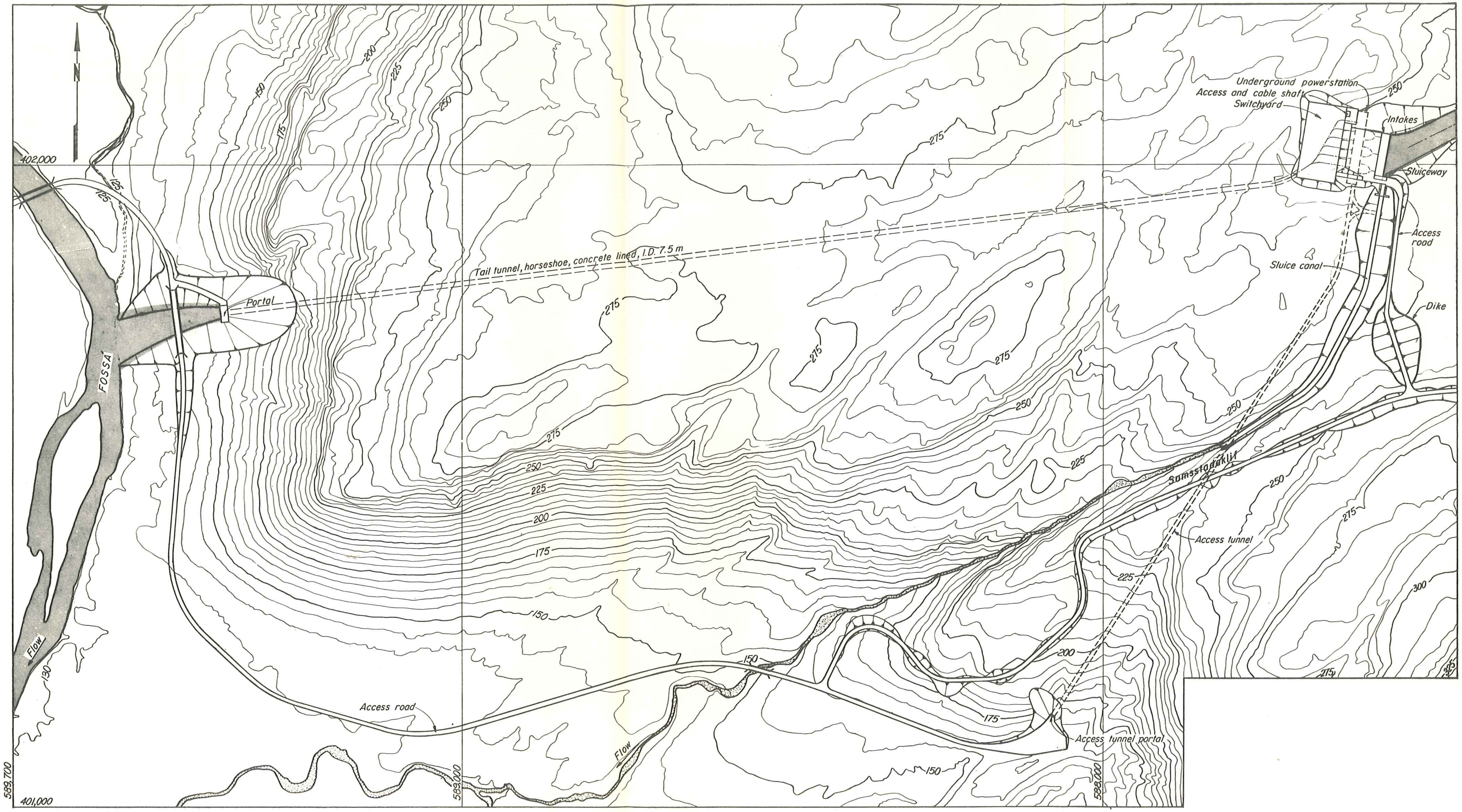
HARZA ENGINEERING COMPANY INTERNATIONAL

PREPARED BY
HARZA ENGINEERING COMPANY

APPROVED A.P. Geuss

CHICAGO, ILLINOIS | DATE JAN. 1963 | DWG. NO 290 P 11

EXHIBIT 17



Scale 0 — 100 Meters

DATE	NO	DISTRIBUTION	
PRINTS			
	BY	DATE	CHKD.	DATE
DSGN.				
DWN.	PP/ADC	JAN. 1963	VT	JAN 1963
DEPT.	GROUP LEADER	SECT. HEAD	DEPT. HEAD	
CIVIL				
MECH.				
ELECT.				
PLAN.	VT	AKE	VAK	
STAFF			CH.ENGR.	

REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.

THE STATE ELECTRICITY AUTHORITY
ICELAND

BURFELL PROJECT

POWERSTATION AND TAILRACE GENERAL PLAN

HARZA ENGINEERING COMPANY INTERNATIONAL
PREPARED BY
HARZA ENGINEERING COMPANY

APPROVED A.P. Gross

CHICAGO, ILLINOIS | DATE JAN. 1963 | DWG. NO. 290 P 12

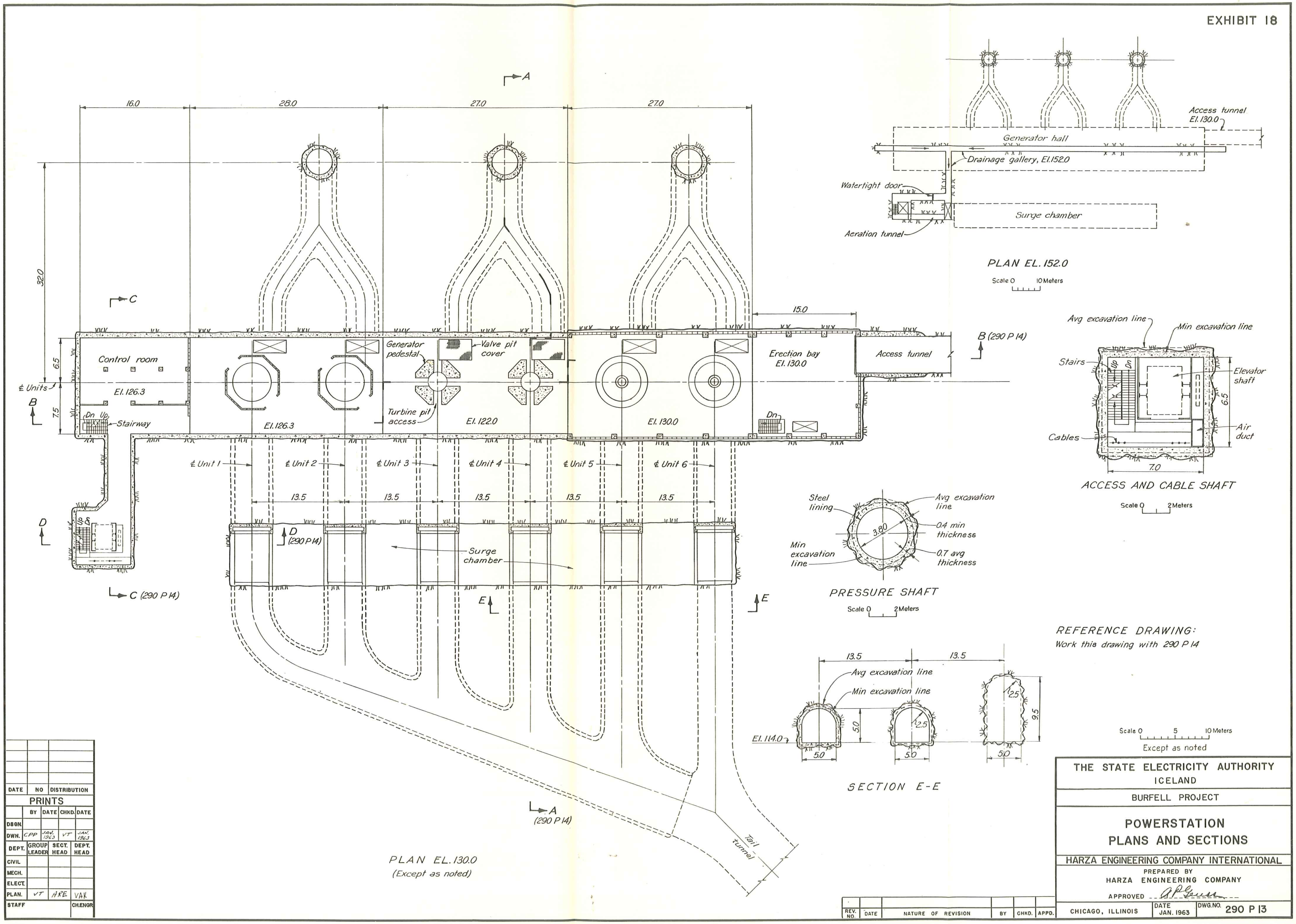
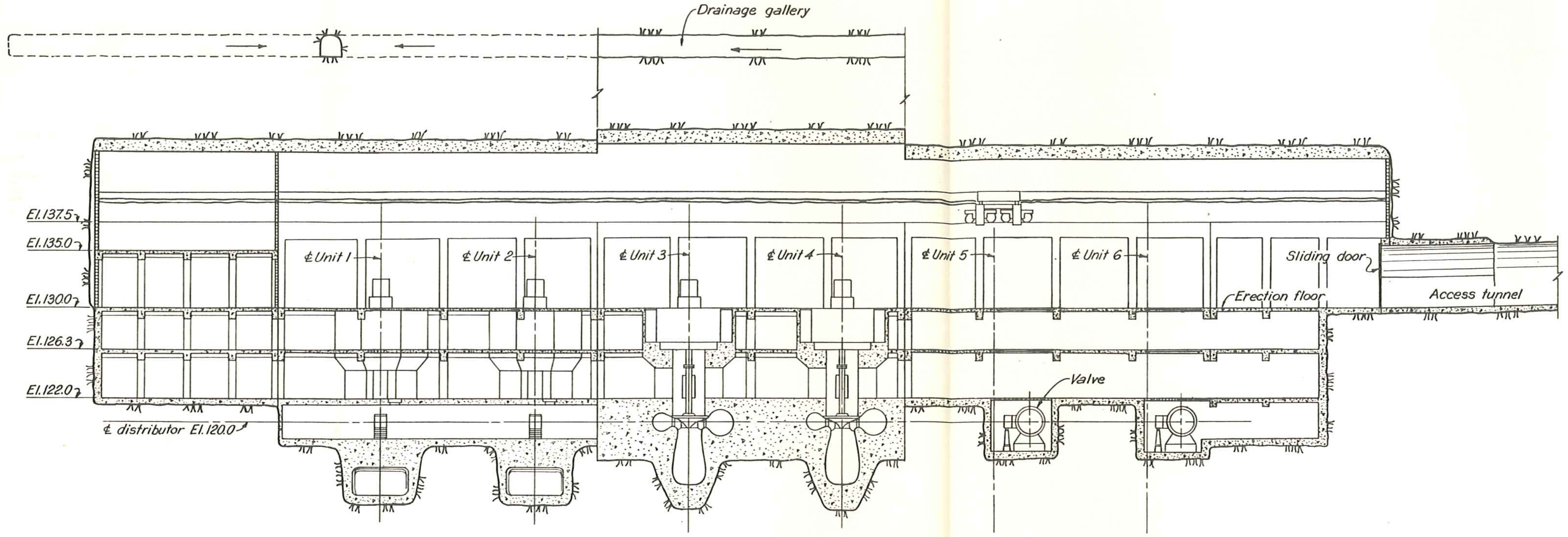
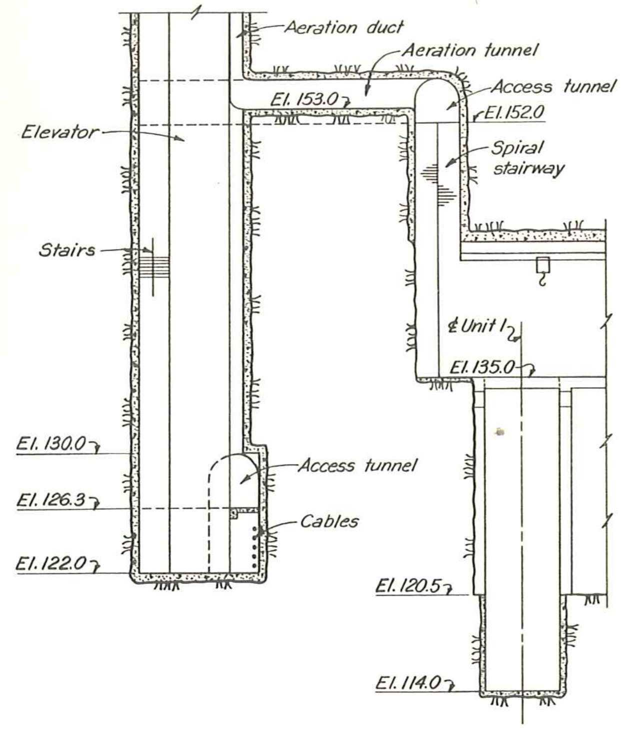


EXHIBIT 18
PLAN EL. 130.0
(Except as noted)
16.0
28.0
27.0
27.0
32.0
15.0
Control room
El. 126.3
Generator pedestal
Valve pit cover
Turbine pit access
El. 126.3
El. 122.0
El. 130.0
Erection bay
El. 130.0
Access tunnel
B (290 P 14)
℄ Units
6.5
7.5
Dn Up
Stairway
℄ Unit 1
℄ Unit 2
℄ Unit 3
℄ Unit 4
℄ Unit 5
℄ Unit 6
13.5
13.5
13.5
13.5
13.5
Surge chamber
D (290 P 14)
C (290 P 14)
A (290 P 14)
Tail tunnel
Access tunnel El. 130.0
Generator hall
Drainage gallery, El. 152.0
Watertight door
Surge chamber
Aeration tunnel
PLAN EL. 152.0
Scale 0 10 Meters
Avg excavation line
Min excavation line
Stairs
Up
Dn
Elevator shaft
6.5
Cables
Air duct
7.0
ACCESS AND CABLE SHAFT
Scale 0 2 Meters
Steel lining
Avg excavation line
3.80
0.4 min thickness
Min excavation line
0.7 avg thickness
PRESSURE SHAFT
Scale 0 2 Meters
REFERENCE DRAWING:
Work this drawing with 290 P 14
13.5
13.5
Avg excavation line
Min excavation line
El. 114.0
5.0
5.0
2.5
5.0
2.5
9.5
5.0
SECTION E-E
Scale 0 5 10 Meters
Except as noted
THE STATE ELECTRICITY AUTHORITY
ICELAND
BURFELL PROJECT
POWERSTATION
PLANS AND SECTIONS
HARZA ENGINEERING COMPANY INTERNATIONAL
PREPARED BY
HARZA ENGINEERING COMPANY
APPROVED
CHICAGO, ILLINOIS
DATE JAN. 1963
DWG. NO. 290 P 13
REV. NO.
DATE
NATURE OF REVISION
BY
CHKD.
APPD.
DATE
NO
DISTRIBUTION
PRINTS
BY
DATE
CHKD.
DATE
DSGN.
DWN. CPP JAN. 1963 VT JAN. 1963
DEPT.
GROUP LEADER
SECT. HEAD
DEPT. HEAD
CIVIL
MECH.
ELECT.
PLAN. VT ARE VAK
STAFF
CH. ENGR.

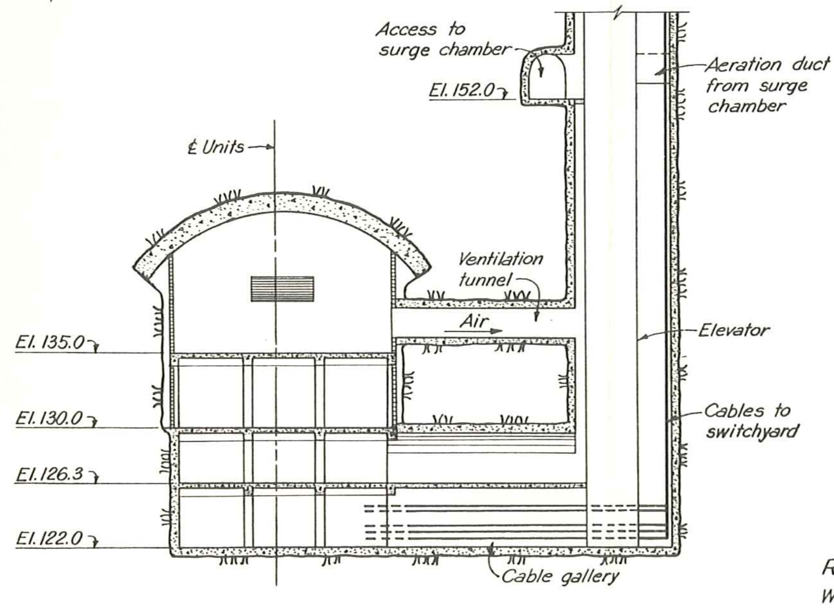
EXHIBIT 19



LONGITUDINAL SECTION B-B

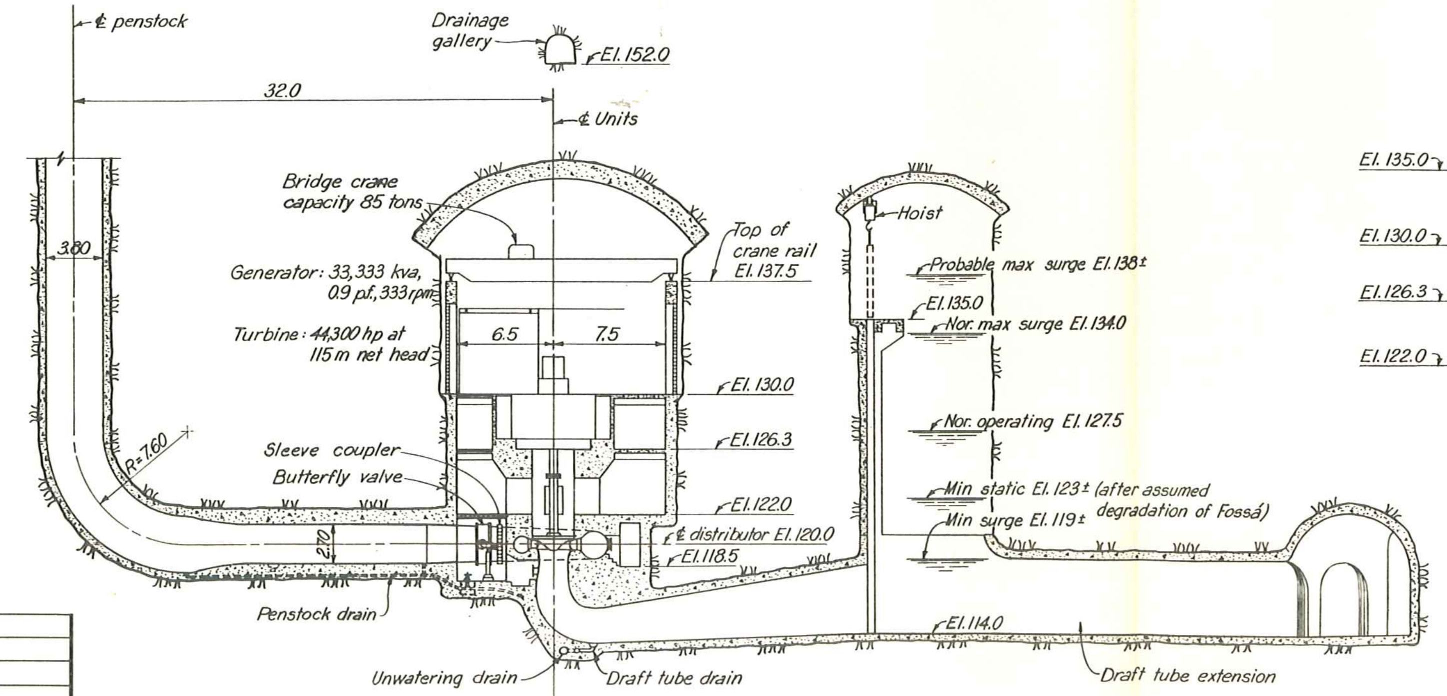


SECTION D-D



TRANSVERSE SECTION C-C

REFERENCE DRAWING:
Work this drawing with 290 P13



TRANSVERSE SECTION A-A

Scale 0 5 10 Meters

DATE	NO	DISTRIBUTION

PRINTS

	BY	DATE	CHKD.	DATE
DSGN.				
DWN.	CPP	JAN. 1963	VT	JAN. 1963
DEPT.	GROUP LEADER	SECT. HEAD	DEPT. HEAD	
CIVIL				
MECH.				
ELECT.				
PLAN.	VT	ARE	VAK	
STAFF			CH.ENGR	

REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.

THE STATE ELECTRICITY AUTHORITY
ICELAND

BURFELL PROJECT

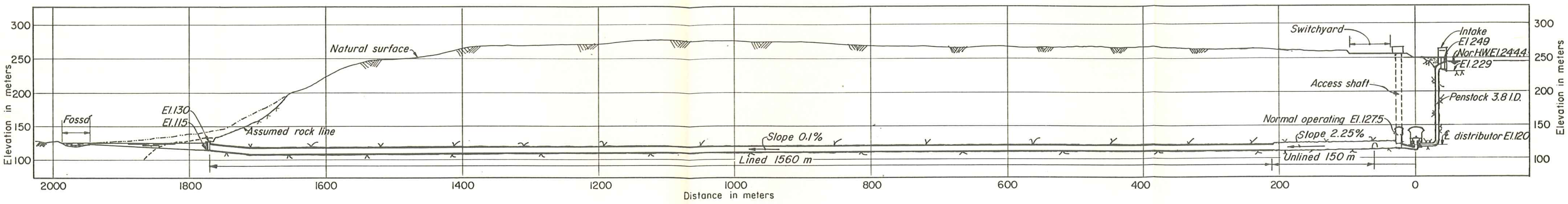
POWERSTATION
SECTIONS

HARZA ENGINEERING COMPANY INTERNATIONAL
PREPARED BY
HARZA ENGINEERING COMPANY

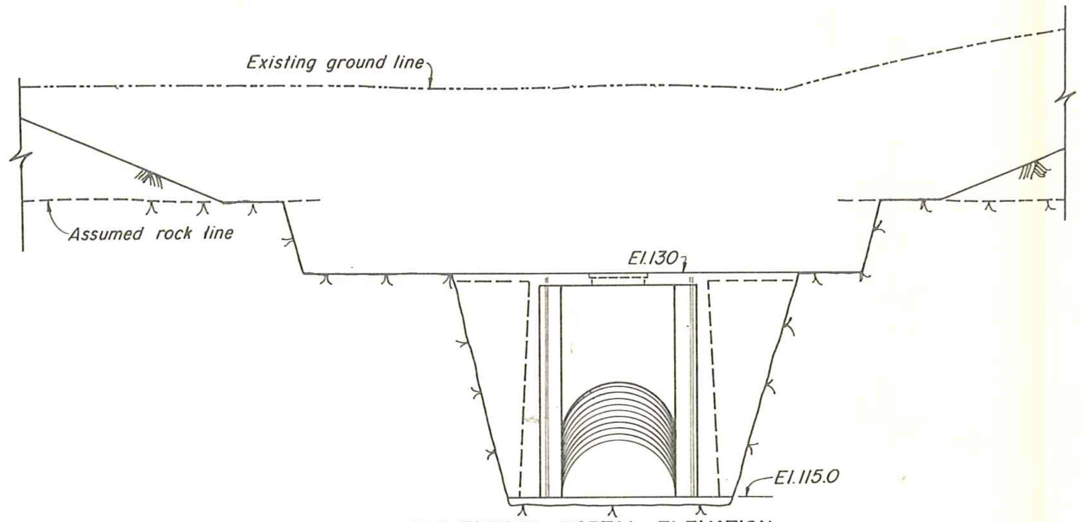
APPROVED A.P. Geuss

CHICAGO, ILLINOIS | DATE JAN. 1963 | DWG. NO. 290 P 14

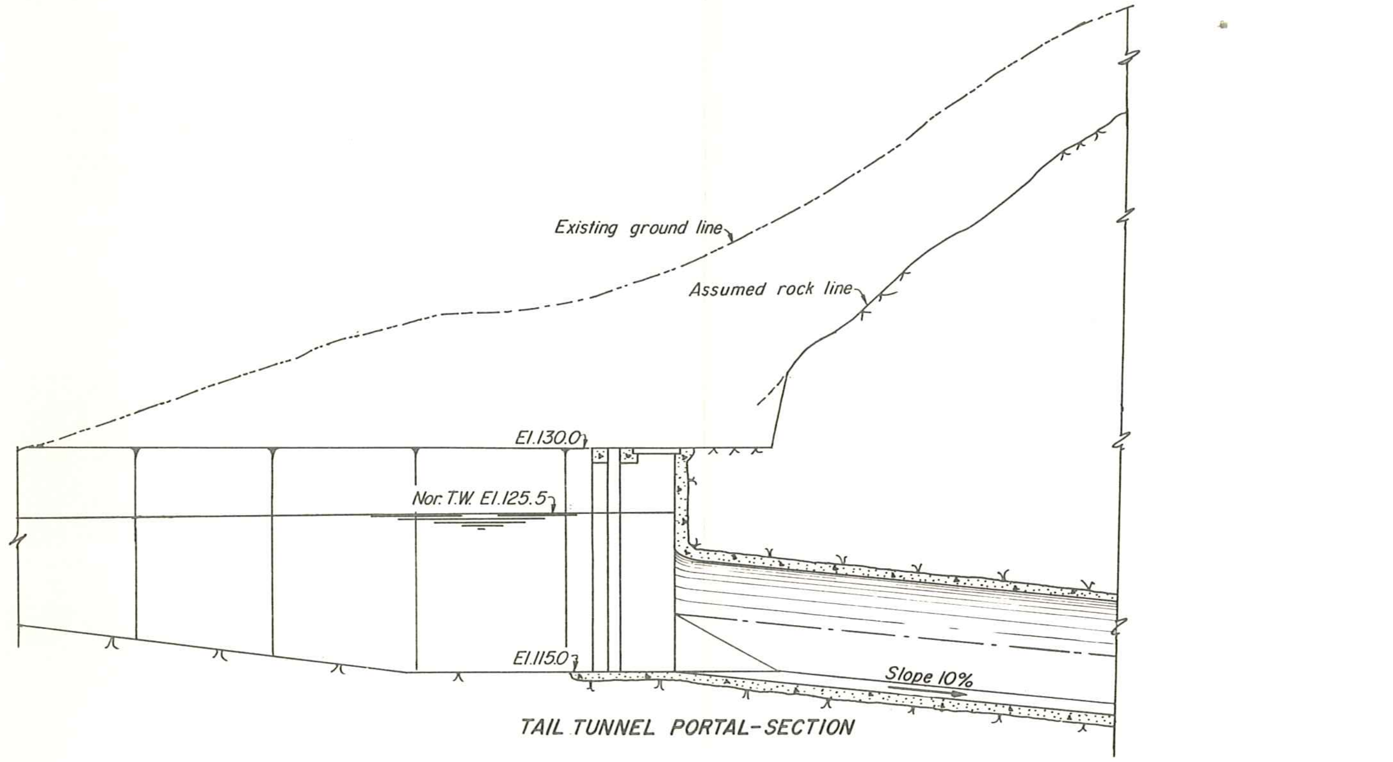
EXHIBIT 20



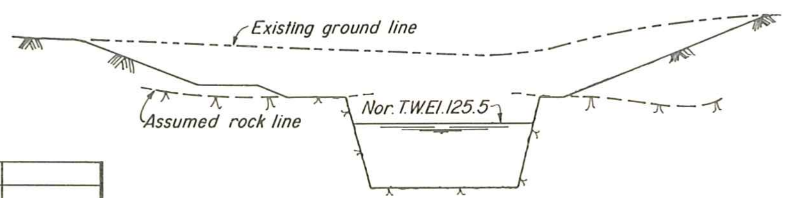
PROFILE



TAIL TUNNEL PORTAL-ELEVATION

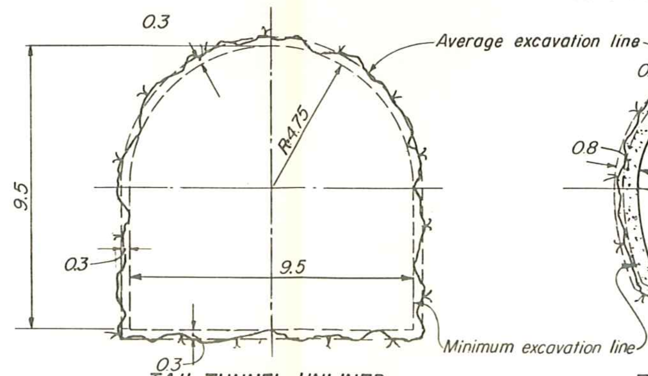


TAIL TUNNEL PORTAL-SECTION



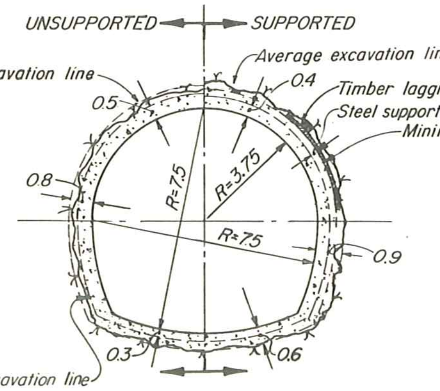
TAILRACE CANAL-TYPICAL SECTION

Scale 0 10 Meters



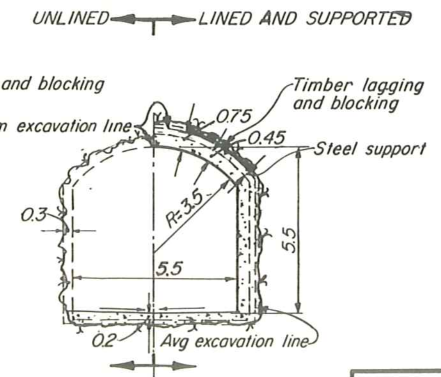
TAIL TUNNEL-UNLINED

Scale 0 2 Meters



TAIL TUNNEL-LINED

Scale 0 2 Meters



ACCESS TUNNEL

Scale 0 2 Meters

Scale 0 5 10 Meters

Except as noted

THE STATE ELECTRICITY AUTHORITY
ICELAND

BURFELL PROJECT

TAILRACE
PROFILE AND SECTIONS

HARZA ENGINEERING COMPANY INTERNATIONAL

PREPARED BY
HARZA ENGINEERING COMPANY

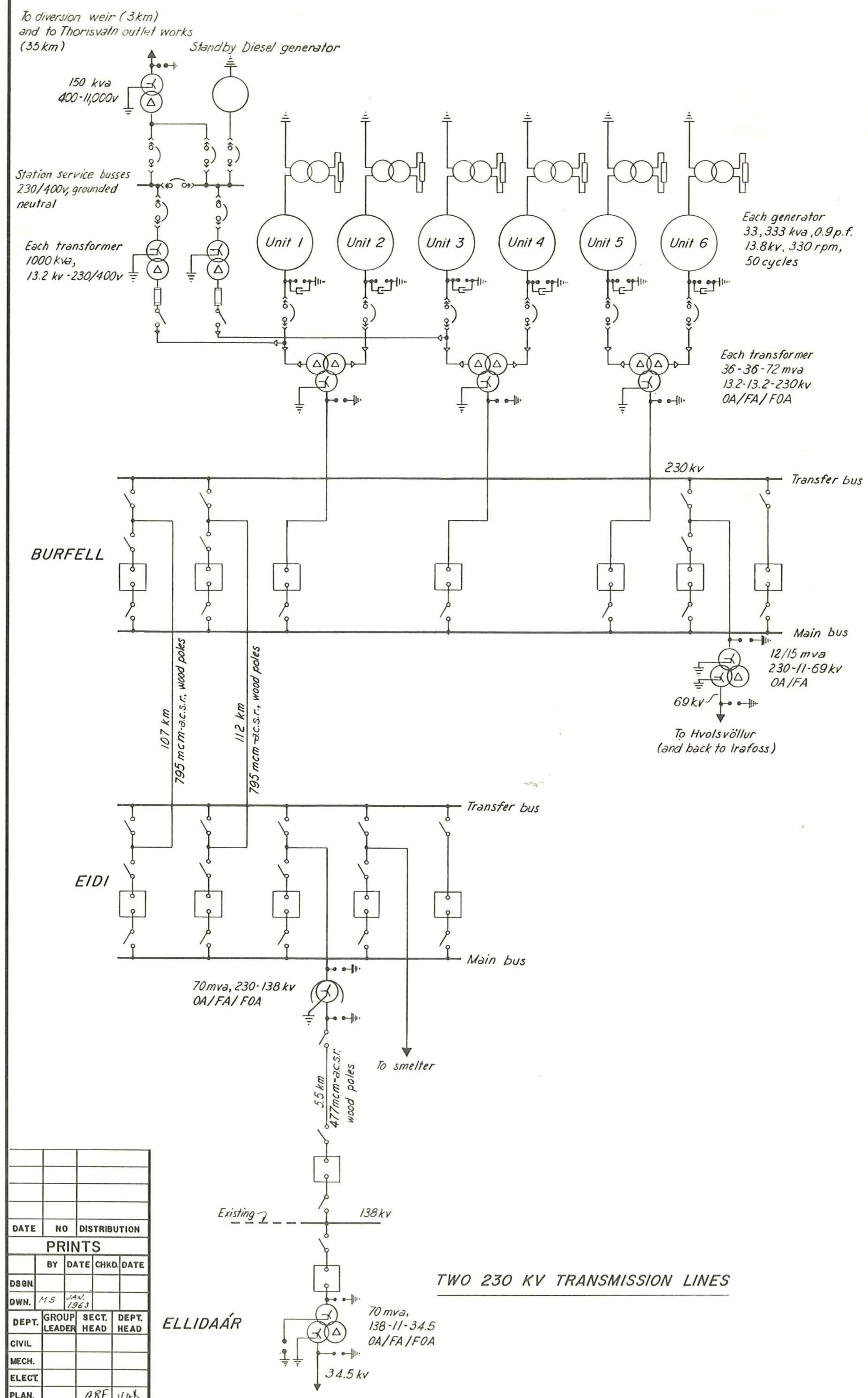
APPROVED [signature]

CHICAGO, ILLINOIS | DATE JAN. 1963 | DWG.No. 290 P 15

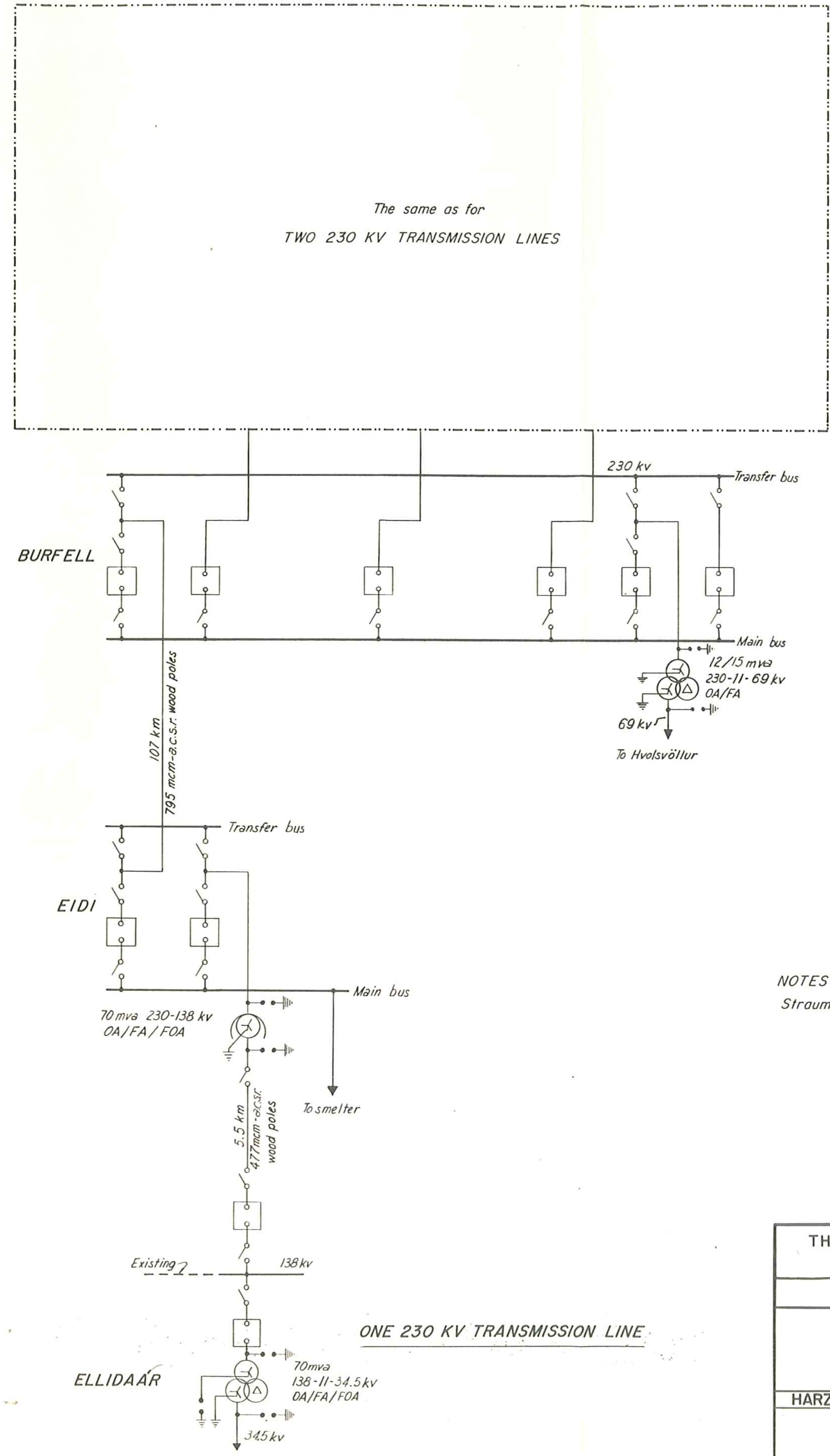
REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.

DATE	NO	DISTRIBUTION	
PRINTS			
	BY	DATE	CHKD.	DATE
DSGN.				
DWN.	RLP/ADC	JAN. 1963	VT/RLR	JAN 1963
DEPT.	GROUP LEADER	SECT. HEAD	DEPT. HEAD	
CIVIL				
MECH.				
ELECT.				
PLAN.	VT	AKE	VAK	
STAFF			CH.ENGR	

EXHIBIT 21

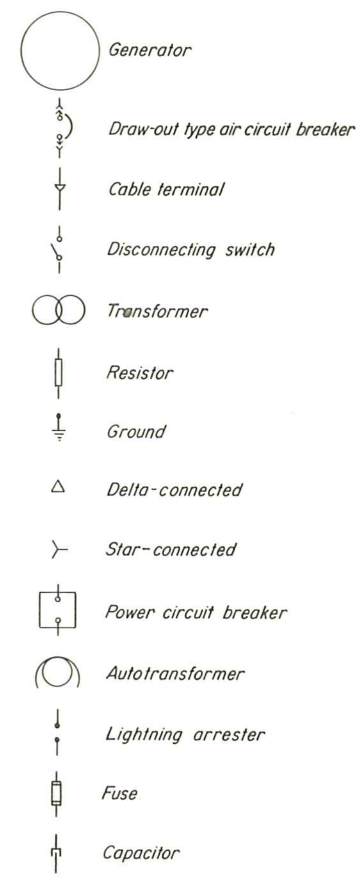


TWO 230 KV TRANSMISSION LINES



ONE 230 KV TRANSMISSION LINE

LEGEND



NOTES

Straumsvik alternative will be similar.

DATE	NO	DISTRIBUTION

PRINTS

	BY	DATE	CHKD.	DATE
DSGN.				
DWN.	MS	JAN. 1963		
DEPT.	GROUP LEADER	SECT. HEAD	DEPT. HEAD	
CIVIL				
MECH.				
ELECT.				
PLAN.		ARE	VAK	
STAFF	E.G.C.		CH.ENGR.	

REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.

THE STATE ELECTRICITY AUTHORITY
ICELAND

BURFELL PROJECT

ONE-LINE DIAGRAMS

EIDI ALTERNATIVES

HARZA ENGINEERING COMPANY INTERNATIONAL

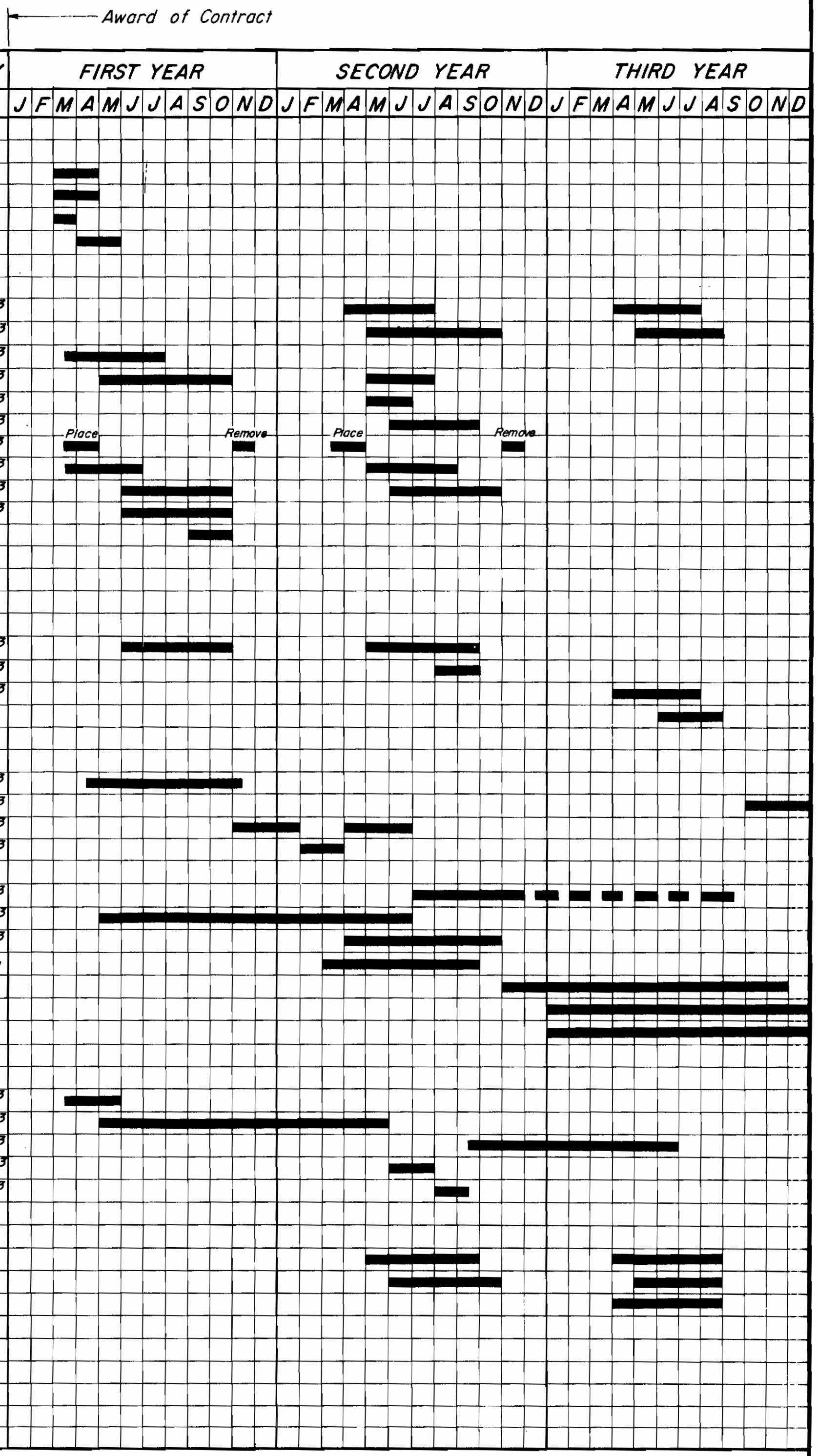
PREPARED BY
HARZA ENGINEERING COMPANY

APPROVED A.P. Geuss

CHICAGO, ILLINOIS	DATE JAN. 1963	DWG. NO. 290 P 26

EXHIBIT 22

DESCRIPTION	QUANTITY
PREPARATORY WORK	
1. Camp	
2. Access roads and bridges	
3. Move-in	
4. Concrete plant	
DIVERSION STRUCTURES	
5. Left bank dike, excavation	360,000 m^3
6. Left bank dike, fill	520,000 m^3
7. Bjarnalaekur dike, excavation	300,000 m^3
8. Bjarnalaekur dike, fill	600,000 m^3
9. Right bank dike, excavation	100,000 m^3
10. Right bank dike, fill	110,000 m^3
11. Place cofferdams-Remove cofferdams	65,000 m^3
12. Excavation, structures & diversion canal	350,000 m^3
13. Spillway, concrete	20,000 m^3
14. Inlet structures, concrete	12,000 m^3
15. Gates and hoists	
APPROACH CANAL, SLUICEWAY, DIKE AND INTAKE	
16. Excavation	250,000 m^3
17. Dike, fill	40,000 m^3
18. Concrete, intake and sluiceway	10,000 m^3
19. Gates, trashracks, hoist and crane	
POWERSTATION	
20. Access tunnel, excavation	38,000 m^3
21. Access tunnel, concrete	7,000 m^3
22. Generator hall, excavation	55,000 m^3
23. Generator hall, roof arch, concrete	3,200 m^3
24. Generator hall, sub-structure and superstructure, concrete	14,000 m^3
25. Access shaft and penstocks, excavation	18,000 m^3
26. Access shaft and penstocks, concrete	7,600 m^3
27. Penstock steel	480,000 kg
28. Turbine erection	
29. Generator erection	
30. Powerstation and switchyard equipment	
TAILRACE	
31. Excavation, open cut	230,000 m^3
32. Tunnel excavation	120,000 m^3
33. Tunnel lining	33,000 m^3
34. Surge chamber, excavation	28,000 m^3
35. Surge chamber, concrete	3,600 m^3
TRANSMISSION	
36. Wood poles	
37. Overhead lines	
38. Substations	



THE STATE ELECTRICITY AUTHORITY
ICELAND

BURFELL PROJECT

CONSTRUCTION SCHEDULE

HARZA ENGINEERING COMPANY INTERNATIONAL

PREPARED BY
HARZA ENGINEERING COMPANY

APPROVED A.P. Geuss

CHICAGO, ILLINOIS | DATE JAN. 1963 | DWG.No. 290 P 29

REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.