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Sigurður Thoroddssen:

MAJOR POWER PLANTS IN ICELAND

Survey of the hydroelectric development of some streams.

okt. 1954.

Nowadays it is considered important to know something about the power husbandry of each nation. Most nations areaware of this fact, and have long since endeavoured to account for their different sources of power, and how long they will last.

Water power is Iceland's chief source of power. The first attempt to obtain a general view of the water power was made by Mr. Jon Thorlaksson, Civil Engineer, about the year 1920, in connection with the passing of the Water Power Act. He arrived at the conclusion that the power capable of being developed here in Iceland would be approximately 4 milion horsepowers.

This attempt he based upon such precipitation measurements, discharge measurements and maps as were available at the time. He allowed for a certain percentage of the head of each river being capable of favourable development, arriving thus at the horsepower figure, without considering where or how the rivers should be developed; this was hardly possible, for to do so the information at his command was too inaccurate.

Possibly the same is true to-day, even though strides for improvements have been made, particularly during the last decade and after the passing of the Electric Power Act in 1946, when discharge measurements to any appreciable extent commenced.

Nevertheless, I have decided to make proposals for the development of our great rivers, without having before me but scant premises, which will be referred to later, and without having in my hands special surveys of dam sites, and without geological information other than surveys of a general nature.

It must therefore be pointed out and emphasized that these proposals merely constitute an attempt to account for concievable possibilities of development, and there can be no question of accuracy or affirmation that the developments should be carried out thus, for such is not the case at all. This is merely a question of first investigation of possibilities. On the other hand, it is assumed that these observations may be of value as an initial preparation for later surveys.

Reykjavík, October 1954

Sigurdur Thoroddsen.

MAJOR POWER PLANTS IN ICELAND

Survey of the hydroelectric development of some streams.

This survey deals with the possible hydroelectric developments of some streams in Iceland, in so far as they can be visualized in the light of the information at hand.

This information consists of the following:

1) General Staff maps of Iceland.

2) Information about the nature of the flow of streams made available by the Projects and Surveying Department of the State Electricity Authority in Iceland.

3) Various geological reports of a general nature and other information written and verbal, which however will not be enumerated here.

The following is based partly on previous observations and partly on new information.

S U M M A R Y

Development	With storage MW	$Q_{average}$ MW	Q_{9m} MW	Q_{6m} MW	Q_{min} MW	Probable size of Development MW	Total MW
Skaftá I	20		18	36	10	20	
Skaftá II	140		130	260	70	140	
Skaftá total:	160		148	296	80	160	160
Thjorsá at:							
Lambafell	85	85	50	70	19	85	
Fossheidi	73	73	43	60	16	73	
Fossalda	627	627	370	515	140	627	
Vatnaalda	109	109	65	90	24	109	
Tungnárkrókur	70	70	40	57	16	70	
Hrauneyjarfoss	123	123	73	100	28	123	
Thoristungur	57	57	34	47	13	57	
Sultartangi	288	288	170	235	65	288	
Hjálp	84	84	50	70	19	84	
Skard	57	57	34	47	13	57	
Thjórsárholt	80	80	47	65	18	80	
Hestfoss	80	80	47	65	18	80	
Urridafoss	130	130	77	110	30	130	
Thjórsá total:	1863	1863	1100	1531	419	1863	1863
Hvítá at:							
Bláfell	38	38	22	31	11	38	
Tungufell	120	120	70	100	35	120	
Drumboddsstadir	38	38	22	31	11	38	

Development	With storage MW	$Q_{average}$ MW	Q_{9m} MW	Q_{6m} MW	Q_{min} MW	Probable size of Development MW	Tota: MW
Urridafoss	83	83	60	74	36	38	
Hvítá total	279	279	174	236	93	279	279
Nordlingafljót	110	110	77	88	55	110	
Nordlingafljót total:	110	110	77	88	55	110	110
Blanda and Vatnsdalsá	160	160	110	133	53	160	
Blanda total:	160	160	110	133	53	160	160
Skjálfandafljót:							
Íshólsvatn	50	50	28	36	24	50	
Godafoss	16		9	11	8	16	
Ullarfoss	17		10	12	8	17	
Skjálfandafljót total:	83	50	47	59	40	83	83
Laxá at:							
Hólakotsgil	37						
Brúar II	8						
Brúar III	32						
Brúar IIa	5						
Laxá total:	82						8?

Development	With storage MW	$Q_{average}$ MW	Q_{9m} MW	Q_{6m} MW	Q_{min} MW	Probable size of development MW	Total MW
Jökulsá á Fjöllum at:							
Dettifoss	260	260				260	
Réttarfoss	290	290				290	
Mödrudalur	60	60				60	
Jökulsá á Fjöllum total	610	610				610	610
Jökulsá á Brú at Brú	220	220	48	180	40	220	
Jökulsá á Brú total:	220	220	48	180	40	220	220
Lagarfljót at:							
Múli	85	85			18	85	
Lagarfoss[x]	20	20			5	20	105
						Total:	3672

[x]Jökulsá included.

Description of development arrangements.

River Skaftá

I. It is proposed to dam the river Skaftá at Rótarhólmi near Sæmundarsker (heigh 340 m) and conduct the water from there through a tunnel to a reservoir in Hellisá at Leidólfsfell (height 332 m), thence through a tunnel to a reservior in Lambshagaá (height 325 m), and finally through a tunnel under Skálarheidi to a power station at Skál. Here a head of about 240 m is obtainable, and the length of the tunnel is about 21 km. The volume of water in the river Skaftá and the river Hellisá which it is proposed to utilize is understood to be about 110 m^3/secs average flow. Minimum flow about 40 m^3/secs. Nine months' flow (Q_{9m}) about 70 m^3/secs and six months' flow about 140 m^3/secs. From this it will be observed that the flow is very even, the catchment area consisting mostly of lava. The glacier is about 210 km^2. There will not be much storage regulation except at lake Langisjór, which is 27 km^2. Its position in the catchment area of the river is such that the average flow cannot be utilized, as much water is bound to be lost during flood stages. By raising the water level of lake Langisjór by 10 m it is however possible to store about $270x10^6 m^3$, and it may be considered safe that its catchment is sufficient for that purpose. This storage should suffice for the development of not less than Q9m, or about 75 m^3/secs. It may therefore be assumed that the basic power of this development will be about 140 MW.

II. Dammed at a height if 390 m. Head obtainable 40 m. Catchment area 731 km^2, which corresponds to Qaverage = 73 m^3secs. Q9m = 45 m^3/secs. Q6m = 90 m^3secs and Qmin = 27 m^3/secs. Sane storage as before. The head is obtainable on a strech of 1 km. Proposed development Q = 48 m^3secs, or about 20 MW.

The Development of the rivers Thjorsá and Tungná.

Continuous discharge measurements of Thjórsá extending over long periods of time are not available, although this river has chiefly attracted attention when major developments in this country have been discussed, even to the extent that surveys have been carried out for development, and estimates have been made. As will be known, these estimates were made by the Norwegian engineer Sætersmoen. The discharge measurements upon which he based his estimates were very imperfect and their interpretation doubtful. However, the position has improved, as continuous water level measurements have been carried out in Thjórsá during the past three[x] years, as well as so many discharge measurements that a fairly reliable key has been found to the river.

At the instigation of the State Electricity Authority a flow duration curve has been compiled, covering these three years, in addition to some other observations having been made. The chief characteristics of the river, which was recorded at Krókur, are as follows:

The catchment area at the recording station is 7200 km^2. The average flow of the river is about 430 m^3/secs, which corresponds to about 60 l/s/km^2 from the catchment area. From the curves available it may furthermore be deduced that

[x] now seven

during the year 1947 - 48 it would have been necessary to store 11,5 °/o of the annual average flow in order to develop the average flow. In the year 1948 - 49 it would have been necessary to store 31 °/o of the annual average flow, and the year 1949 - 50 about 21,5 °/o. These are very different figures, and no experience has been gained as to which of them should be applied. It may be pointed out that the recording station is on lowland, and it is therefore evident that there is, or may be, less need for storage there than if the place of development were situated in the highland, for thaws which are quite frequent on the lowland in January - February are by no means equally effective in the highland, and their influence is very favourable and reduce the need for storage. In conformity with the foregoing, allowance has been made for greater storage needs for the following development estimates, namely that 40 °/o of the annual average discharge must be stored in order to develop an annual average flow, but this is of course an estimate only.

Furthermore, it is presumed to develop about the annual average flow at each place of development, or 60 l/secs per each km^2, and thereupon allow for the aforementioned storage need, 40 °/o, and finally allow for dam heights according to the sizes of reservoirs required by that storage.

It is not hereby implied that this is the most economical size of development, as the estimates are so sketchy and the premises uncertain that it is useless at this stage to engage in such comparisons. However, these premises, in addition to the aforementioned measurements, are based on General

Staff maps, showing 20 m contours, and possibly it is doubtful that these contours are entirely reliable, although it is considered likely that they indicate possibilities, especially as regards major projects as in this case.

But it is a different matter that it is quite uncertain that what is practical is necessarily economical at the same time, - that it will be a paying proposition - and in order to ascertain this finally, estimates are necessary, based on much more accurate surveys than those available, in addition to geological research and other preparation of various kinds, which will not be enumerated here.

It has been considered right to make estimates of the cost of the development in Thjórsá mentioned hereafter, and this has therefore been done, however not for developments situated below the valley Thjórsárdalur. It may be said about these estimates that they possibly give an idea of the scale of development costs. Before going further, it is therefore proposed to give an account of the unit prices used for compiling the estimate of cost, as well as other matters in this connection.

Generally speaking, earth dams up to 40 m high have been planned, however in one instance on a strech up to 50 m. The earth dams are planned 0,25xh broad on top, where h is the height of the dam, side slopes 1:5 on both sides of dams up to a height of 23 m, and 1:4 on both sides of higher dams.

The plan allows for the average cost of 30/- kr. per m^3 in the earth dams.

Concrete dams have been planned where the height is over 40 to 50 m, and also where overflow is considered necessary. Concrete gravity dams have been planned, their material contents has been estimated according to information respecting dams from the New York Board of Water Supply Dams, the most copious ones having been selected. Unit prices have been calculated at 300/- kr./m^3.

The cost price of tunnels has been estimated at 100/- kr./m^3. The cost price of power houses 200/- kr. per installed horsepower, and the cost price of machinery 500/- kr. for each horsepower installed. Over and above the cost thus arrived at, 60 °/o have been added for unforeseen expenses.

Development arrangements.

Several development arrangements may be considered, whereas only two will be accounted for here.

Arrangement I.

A. The Development of the river Thjórsá

The river Kaldakvísl to be dammed above Thveralda, and the water conducted through a 4,5 km long, 25 m^2, tunnel to Thjórsárbotnar, which is a name given to the plain through which the river Thjórsá runs, south of Hofsjökull.

The river Thjórsá to be dammed between Nordlinga-alda and Thveralda. The water is thereupon conducted through a 4 km long and 90 m^2 wide tunnel under Nordlingaalda, thereupon a dam built west across Miklubæjarbotnar over the hills east of Lambafellskvísl, which carries the water to Dalsá, which is dammed at Öræfahnúkur. A dam is built between the hills east of Lambafellskvísl where necessary. The altitude of these dam constructions is planned at 60 m above sea level. In order to obtain sufficient storage at Thjórsárbotnar, it will be necessary for the dam at Nordlingaalda - Thveralda to reach a height of 608 m above sea level, and storage must be utilized down to 600 m above sea level.

The water is thereupon conducted through an 11,5 km long tunnel, 90 m^2, to Fossárdrög, below which the first or uppermost place of development has been planned, and which is called

The Lambafell Development

The catchment area of this development is 3000 km^2. The harnessed water will therefore be about 180 m^3/secs.

By damming at an altitude of 590 m a good reservoir for 12 hour period storage is obtainable. The head of this development is from 590 - 520 - 70 m, and the basic power 126.000 hp. The discharge tunnel of this development will be 2.2 km in length.

At the next development, the Fossheidar Development, a large reservoir is likewise obtainable, and a 40 m head at a stretch of 1 km. An average of 182 m^3/secs may be developed here, and the basic power will be 73.000 hp.

At the lowermost development, the Fossalda Development, damming between Fossalda and Fossheidi is planned at a height of 480 m, and a 480 - 160 - 320 m head down to Thjórsárdalur utilized. A 7 km long tunnel is necessary.

The damming of the river Stóra-Laxá at the lower side of Geldingafell is planned with a dam at an altitude of 500 m above sea level, the water to be conducted to the reservoir of the development. For this a 6 km long tunnel is necessary.

With the added catchment area obtained here, an average of about 196 m^3/secs may be developed, which means a basic power of 627.000 hp.

Estimate of costs.

Kaldakvísl conducted to Thjórsá	Kr.	23.000.000,-
Thjórsá dammed at Nordlingaalda-Thveralda ...	-	260.000.000,-
Tunnel under Nordlingaalda	-	36.000.000,-
Dams between Nordlingaalda and Öræfahnúkur ..	-	159.000.000,-
Tunnel from Öræfahnúkur to Fossárdrög	-	103.000.000,-
Lambafell Development	-	193.000.000,-
Fossheidar Development	-	90.000.000,-
Fossalda Development	-	741.000.000,-
Unforeseen expenses	-	965.000.000,-
Total	Kr.	2.570.000.000,-

This estimate is based on installed machine power of 1.150.000 hp. or 2240 kr. each horsepower.

It is estimated that the 826.000 hp basic power under reference is 10 °/o dearer per horsepower, or about 2460 kr.

B. The Development of river Tungná

The lowermost development is visualized with a dam right across Sultartangi, and a tunnel from there to Thjórsárdalur. Here the catchment area is 3700 km^2, and as previously, this corresponds to 222 m^3/secs. According to what has been said previously, the storage need is $2800x10^6$.

If storage in lake Thórisvatn is planned from an altitude of 580 - 575 m, about $385x10^6 m^3$ may be obtained. It is therefore necessary to store $2415x10^6 m^3$ at Veidivötn, and this storage is obtainable by utilizing the difference in water level from a height of 596 - 576 m if a dam is built at Vatnaöldur, where the uppermost development of Tungná is visualized.

The Vatnaöldur Development

The catchment area about 1725 km^2 . Q = 103 m^3/secs. Head $\frac{596 + 576}{2}$ - 480 = 106 m average head. Basic power 106x103x10 = 109.000 hp. Discharge tunnel 6,5 km long.

The Development at Tungnárkrókur.

The catchment area 1950 km^2. Q = 117 m^3/secs. Head 480 - 420 = 60 m. Basic power 60x117x10 = 70.000 hp. Tunnel 1.2 km.

The Development at Hrauneyjarfoss.

The catchment area 2060 km^2 . Q = 123 m^3/secs. Head 420 - 320 = 100 m. Basic power: 100x123x10 = 123.000 hp. Tunnel 3,5 km.

The Development at Thoristungur.

The catchment area 3160 km^2 . Q = 190 m^3/secs. Head 320 - 290 = 30 m. Basic power: 57.000 hp. Tunnel 6,5 km. long.

The Sultartangi Development

The catchment area 3706 km^2 . Q = 222 m^3/secs. Head 290 - 160 = 130 m. Basic power 288.000 hp. Tunnel 10 km long.

Estimate of cost.

Storage in Thórisvatn	5.000.000
Storage in Veidivötn	220.000.000
Storage in Langisjór	20.000.000
Vatnaalda Development	155.000.000
Tungnárkrókur Development	90.000.000
Hrauneyjarfoss Development	179.000.000
Thoristungur Development	155.000.000
Sultartangi Development	491.000.000
Unforeseen expenses, 60%	795.000.000
Total:	2.110.000.000

This estimate of cost is based on installed machine power 915.000 hp. or 2310 kr/hp.

The cost of basic power may be estimated at about 2600 kr/hp.

Taking A and B together, or the development of Thjorsá and Tungná above Thjórsárdalur, this looks as follows:

Basic power: $(825 + 647) \cdot 10^3 = 1.472.000$ hp at 3.662.000.000,oo kr.

C. The Development of Thjórsá further down.

The Hjálp Development.

The catchment area 7057 km^2 . Q = 423 m^3/secs. Head about 20 m. Basic power 84.000 hp.

The Skard Development

The catchment area 7382 km^2 . Q = 442 m^3/secs. Head 13 m. Basic power 57.000 hp.

The Thjórsárholt Development.

The catchment area 7404 km^2 . Q = 444 m^3/secs. Head 18 m. Basic power 80.000 hp.

The Hestfoss Development

The catchment area 7482 km^2 . Q = 448 m^3/secs. Head 18 m. Basic power 80.000 hp.

The Urridafoss Development.

It is presumed that Hvítá, Tungufljót and Brúará will be conducted into Thjórsá east of Vördufell. The catchment area will then be 11891 km^2 . Q - 713 m^3/secs. Head 30 m. Basic power 213.000 hp.

Survey of the Development of Thjórsá and Tungná

Places of Development	Catchment area km^2	m^{3}Q/secs.	Head m	Basic Power hp	Basic Power total hp
Lambafell	3000	180	70	126.000	126.000
Fossheidi	3040	182	40	73.000	199.000
Fossalda	3260	196	320	627.000	826.000
Vatnaalda	1725	103	108	109.000	935.000
Tungnárkrókur	1950	117	60	70.000	1005.000
Hrauneyjarfoss	2060	123	100	123.000	1128.000
Thóristungur	3160	190	30	57.000	1185.000
Sultartangi	3760	222	130	288.000	1473.000
Hjálp	7057	423	20	84.000	1557.000
Skard	7382	442	13	57.000	1614.000
Thjórsárholt	7404	444	18	80.000	1694.000
Hestfoss	7482	448	18	80.000	1774.000
Urridafoss	11891	713	30	213.000	1987.000

It is anticipated that proportionately equal power may be developed based on drainage areas in the lowland as compared with upper regions without increasing the storage, and this is not considered an incautious calculation as these places are both more favourable as regards storage, and good inlet reservoirs are also obtainable at all the places of development. As to Urridafoss, it should be mentioned that the estimated power is based on discharge regulations of Hvítá.

It has been decided to cipile approximate estimates of the cost of the developments, based on the premies available, as these speculations eould only be of some value if it were possible to show that the constructions are practicable on a financially sound basis, and it may be said that this is the first step towards adducing reasons towards this fact, even though the reasons may be open to doubt.

But many other factors are more uncertain. As an example, a 50 m high dam is planned far up in Thjórsá, and in Tungná at Vatnaöldur a dam about 40 m high. There is no reason to suppose that the ground is unable to stand up to such dams, but it is perhaps more questionable whether the surrounding ground and hills are able to withstand such elevations of the water level.

This matter has been discussed with men versed in geology, but they have been unable to agree. These dams are on the tuff area. One geologist considers that there will be so much percolation in this area that such storages will never fill, whereas others have had no fears in this respect.

All the developments are based on tunnels. What about their tightness, for if it were necessary to line them, the cost would increase a great deal . However, the pressure on the tunnels will not be very great, although in some it will be up to 20 - 30 m. What about material for the dams; is it conveniently available . And many other questionable matters migh be added.

At Sultartangi and other developments further down Thjórsá it will be necessary to build dams on or near lava fields, for the Thjórsá lava field runs alongside the river all the way down. This is an unattractive ground for a dam, and worse still, soft clay is understood to lie under the lava field.

What has been said here about the development of Thjórsá is an extract from a lecture given by the author at a meeting of the Association of Chartered Engineers in Iceland in 1949.

Since then a geological survey has been made of the Thjórsá and Tungná areas.

As a result of this survey it is considered very doubtful that so large a reservoir can be made by damming at Vatnaöldur, as the surrounding hills will drain all the water. Judgment on this theory will not be passed here, but on the other hand it may be pointed out that in such an event a perfect storage would have been obtained at Tungná, for it may be expected that the water would return to the open Tungná at the next place of development at Tungnárkrókur. The Vatnaöldur development would in that case have to be dropped, or reduced very considerably, as it is also considered doubtful that suitable rock is to be found for tunnelling.

This matter will not be discussed further here.

The Development of Hvítá.

In April 1949 a survey was made of the development of Hvítá, based on General Staff maps. Since then, considerable land suveys of its development area have been carried out, and at the same time better information about the nature of the rivers flow has been obtained.

Both have resulted in confirmation of the aforementioned survey in that it may be relied upon in its main Points as to sizes of development.

There is not considered to be reason for explaning the development arrangements in this report, since surveys are available and it should therefore be possible to make estimates of the developments planned in the report, or other arrangements which may be considered more suitable.

The Development of rivers Nordlingafljót, Lambá and Kjarrá. Water flow and arrangement of development.

It is proposed to dam Nordlingafljót between Kleppir and Strútur. The catchment area above the dam is 993 km^2, divided as follows: Glacier 28.4%, lava 25,6%, lakes 1,5% and other kinds of ground 44,5%.

From this division of the catchment area it may be assumed that the flow of the river is comparatively even, and that the minimum flow will hardly be less than 20 m^3/secs, the average flow being understood to be about 50 m^3/secs. It is proposed to utilize storage in lake Stóra-Arnarvatn and lake Gunnarssonarvötn. The catchment area of these lakes is 52 km^2, and of this, lakes constitute 12%. The drainage from Lake Arnarvatn may presumably be conducted without too much cost through Lake Mjóavatn and Lake Thórhallalón and Presumably to Lake Úlfsvatn in the drainage area of river Lambá or to Lake Arnarvatn litla in the catchment area of Nordlingafljót.

It is proposed to dam Kjarrá about 1600 m above the confluence of this river and Lambá, and conduct the water through a tunnel to Lambá. The tunnel will probably be about 1 km long. The rivers Lambá and Skammá flowing from Lake Hólmavatn to be dammed, so that all their discharge will flow into Bæjargil.

The drainage area of Bæjargil will then be about 195 km^2. Lakes in this area constitute about 10% of the catchment area, and in addition it contains extensive grass-land and march.

It is belived that hardly more than 20% of the discharge needs to be stored in order to make the development of the average flow possible, and this is understood to be about 62 m^3/secs.

The discharge will be $1953 \times 10^6 m^3$, and the necessary storage according to this $40 \times 10^6 m^3$. Lakes in the area cover about 40 km^2, and in addition it appears that considerable storage may be obtained by damming Nordlingafljót at Álftatjörn.

The development arrangement will be as follows: Storage constructions will be erected at Arnarvatn, in Nordlingafljót and Álftatjörn, and elsewhere if need be. Kjarrá, Lambá and Skammá dammed and conducted to Hólavatn, and Bæjargil will be the outlet. Nordlingafljót to be dammed between Kleppir and Strútur. The water to be conducted through a tunnel from the dam under Bæjargil to an inlet to be constructed at Bjarnastadaflói at Kinnargil, and at the same time an inlet to be constructed in Bæjargil leading to the tunnel.

This intake tunnel will be about 17 km long, in addition to a discharge tunnel 1,5 km long.

A head of about 240 m will be obtainable here, and the size of the development could be in the neighbourhood of 110 MW.

Cost.

An attempt at estimating the cost of this development will not be made here. Probably the cost will be rather high.

The Development of the rivers Blanda and Vatnsdalsá

Development arrangement.

It is proposed to dam river Blanda below Sandárhöfdi, about 100 m below the confluence of this river and Sandá. This dam will form the main reservoir for the development, strecthing up along Blanda and Sandá and to the Kolkuflói bay. Another dam is necessary between Kolkuhóll and Áfangafellshali, and another low dam in a glen extending north from Kolkuflói bay. At Kolkuhóll the water will be conducted to Fellakvísl, which is the easternmost of the three branch rivers forming Vatnsdalsá. Vatnsdalsá to be dammed at an altitude of 443 m at Bótarfell. This river will then flow north across Melbrigduflá, east of Eyjavatnsbunga and into Lake Eyjavatn. A channel will however be constructed in Melbrigduflá in a northerly direction, and storage will then be better utilized. Tungnalækur, which flows from Lake Eyjavatn to river Fridmundará, to be dammed at an altitude of 443m, and Eyjavatn conducted to the western Fridmundarvatn, which will be dammed at an altitude of 441 m, presumably with an 800 m long tunnel or channel with gates. From the western Fridmundarvatn the water will be conducted through a tunnel about 9.000 m long, into Dalsbunga. Here a surge tower will be erected.n The power plant will be constructed underground, under Dalsbunga. The discharge tunnel, which will be about 1,5 to 2 km long, will come out below Forsæludalur farm at a height of about 70 m. Here a head of about 370 m is obtainable on a strech of about 11,5 to 12 km. The average discharge will be about 54 m^3/secs (see later), and the power therefore about 160 MW basic power.

Flow.

The catchment area of Blanda above Sandárhöfdi is 1412 km^2, and of this 16% is glacier and 3,2% lava. It is believed that the average flow of the river in this area is about 42 m^3/secs. The catchment area of Vatnsdalsá above Eyjavatnsbunga is 364 km^2, and the average flow is about 9,1 m^3/secs according to discharge measurements.

The catchment area of Fridmundarvatn to Eyjavatn including Melbrigduflá is about 50 km^2, and the average flow about 1,3 m^3/secs.

A flow duration curve for the river Fremri-Laxá in Húnavatnssýsla covering four years is available. Fremri-Laxá flows in the neighbourhood of Blanda and Vatnsdalsá. In the three years 1948 - 1949, 1949 - 1950 and 1951 - 1952 a storage of 22 - 30% is sufficient for developing the average flow, whereas for the foruth year, 1950 - 1951, 38% is needed, this year being one of the driest during the past three decades. It is however considered right to base calculations upon this year, and a storage of $1650x10^6 0.40\ m^3 = 660x10^6 m^3$ is therefore necessary for developing the average flow of 54,4 m^3/secs.

This storage may be obtained by damming Blanda at a suitable height. Thus a storage of about $600x10^6 m^3$ is obtainable by damming at an altitude of 480 m, and in the reservoirs formed in Fridmundarvötn and the strip of grassland above Eyjavatn over a hundred million m^3 are obtainable.

Cost.

It is difficult to make estimates of cost for the storage constructions at Blanda, as surveys of the area are not available. On the other hand, fairly accurate estimates of cost may be made for the other developments, as surveys are available for these. However, a detailed account will not be given here, although the opinion may be expressed that this will probably be an economical development.

All the dam and tunnel sites have been inspected, and they are considered suitable from a geological viewpoint.

Finally, it should be added that comparatively little additional surveys would have to be carried out to make it possible to ascertain the total cost of this development.

Other developments.

A head of 20 to 30 m is obtainable between Kolkuflói and Fellakvís, capable of being developed up to about 7 MW basic power.

The Development of river Skjálfandafljót.

I. It is proposed to dam the river at Skafhólar. By damming at an altitude of 400 m, a fairly large reservoir will be obtained. The water to be conducted through a tunnel into Lake Íshólsvatn. The level of the water to be raised by a common dam for the rivers Fiská and Mjóadalsá. Developed thence by tunnel down to Bárdardalur with a head of 140 m, and about 50 MW should be obtainable here.

II. At Godafoss a head of 40 m can be obtained. There is probably no question of any additional storage here. It should be possible to develop 16 MW.

III. A head of 40 m could probably be obtained at Ullarfoss. Some additional storage is obtainable at Ljósavatn. This ahould produce about 17 MW.

These developments are probably reasonably favourable.

River Laxá in Thingeyjarsýsla.

The possibility of conducting the rivers Sudurá and Svartá into river Kráká has been thought of. River Kráká flows into Lake Mývatn. The average flow of these rivers is understood to be just under 20 m^3/secs.

I. Hólkot Development.

About 35 m^3/secs may be developed from Lake Myvatn with a level change of about 1/2 m of the lake. With the addition of the discharge from Svartá and Sudurá, this will be 55 m^3secs. The head is about 100 m, and the power will therefore be about 37 MW.

II. Laxá II, the development of which was finished last autumn, yields 8,5 MW, may be increased by about 5 MW.

III. It is presumed that a dam will be built at Brúar so high up that full storage of the mean discharge of Laxá is obtained. This may presumably be achieved by damming at a height of 145 m, and utilize down to 124 m. The upper water level at the present Laxá II development is 69 m in the reservoir. An average head of about 65 m is thus obtained. The average discharge will be about 64 m^3/secs, and the power therefore about 32 MW.

The Development of river Jökulsá á Fjöllum.

It is sufficient here to refer to the survey of 31st March 1954.

The Development of river Jökulsá á Brú

No discharge measurements are available for this river.

It is proposed to dam the river about 1,5 km below the farm Brú with a fairly high dam, so that sufficient storage is obtained here, thereupon to conduct the water through a tunnel right under Fljótsdalsheidi below the farm Hóll in Fljótsdalur. During this flow the tunnel will receive water from Lake Gilsárvötn and the rivers Eyvindará and Hölkná, so that the whole discharge of these rivers will be utilized.

The catchment area and discharge are estimated as follows:

Jökulsá down to Brú	1319 km^2	at 60	1/secs/km^2	79 m^3/secs
Gilsárvötn	78 km^2			2 -/-
Eyvindará and Hölkná	234 km^2	at 30	1/secs/km^2	7 -/-
Thverá	121 km^2	at 20	1/secs/km^2	2.2 -/-
	1752 km^2	at 51,5	1/secs/km^2	90.2 m^3/secs.

It is planned to develop the average flow, and the storage need is considered to be 40% of this, which corresponds to 1140 . $10^6 m^3$.

This storage is obtained by damming at Brú at an altitude of 426 m above sea level, and the dam will then be about 60 m. It is visualized that the inlet will be utilized at an altitude of 380 m. It is conceivable to reduce the height of the dam by constructing reservoirs in the rivers Thverá and Fiskidalsá, but their discharge is however insufficient except for a small part of the storage.

Average head should be $\frac{426 + 380}{2} - 40 = 363$ m.

The basic power obtainable should be 328.000 hp. or about 220 MW.

Estimate of cost.

Dam	418.000.000.oo kr.
Tunnel 25 km^2,, 60 m^2 wide	150.000.000.oo "
Machinery and power houses 460.000 at 700/- ..	322.000.000.oo "
Unforeseen, 60%	530.000.000.oo "
Total	1.420.000.000.oo kr.

or 4330 kr. per hp of basic power.

The Development of river Lagarfljót.

I. Jökulsá í Fljótsdal to be dammed about 2 km above Eyjabakkafoss, and the water conducted into Lake Folavatn, which has an outflow into river Kelduá. River Kelduá to be dammed where this river meets Grjóta, the water to be conducted through a tunnel about 15 km long into Lake Fossárvatn, which is on the edge of Múli. Developed from there down to Fljótsdalur with a head of about 540 m.

It may be presumed that about 85 MW may be developed here. It is not possible to say whether this will be an economical development.

II. The Development of Lagarfoss

A head of 20 m may probably be developed here, and about 150 m^3/secs, thereof 90 m^3/secs from Jökulsá á Brú.

This will be an economical development.