THE POSSIBILITIES OF DEVELOPMENT OF THE INLAND WATERWAYS IN EAST-CENTRAL EUROPE AS A PART OF THE GENERAL NETWORK OF TRANS-EUROPEAN NAVIGABLE WATERWAYS

"What is to happen to the large number of small nations, whose rights and interests must be safeguarded"......
....
"It would, therefore, seem to be at any rate worthy of patient study that, side by side with the great Powers, there should be a number of groupings of states, or confederations, which would express themselves through their own chosen representatives, the whole making a Council of great States and groups of States"

/-/W.Churchill
/-/ 22 th March 1943.

Introduction

Among the fundamental problems with which the countries of Europe will be concerned at the end of the present war, the two following are the most important:-

(a) it will be necessary to create a high degree of interdependence between certain groups of countries,

(b) it will be necessary to change the agricultural structure and develop industry in these countries where over-population in rural districts leads to malnutrition.

The countries of East-Central Europe particularly need the development, which would be possible through increased international economic co-operation.

The possibility of a confederation on an economic basis in the area between the Baltic, the Black Sea and the Adriatic is already being visualized.

The solution of this problem, among others, necessitates the integration of markets, and in this, transport must play a decisive part.

In a prosperous area or country the various means of transport co-operate in harmony, and the different kinds of communication lines cross and recross like a spider's web.

Each method of transport should be used in the way best fitted to the kind of work it can do.

Inland navigation was in the past one of the main factors in the industrial development and commercial expansion of the majority of countries, and is to day an essential and irreplaceable part of transport in some countries. It will, in the future, play a still more important part, if it is adjusted to modern requirements.

The advantages of the use of inland waterways which have been proved in the West, must not be over-looked in connection with the development of East-Central Europe.

The geographic and economic conditions of East-Central Europe allow a very large stream of traffic to be carried on the great rivers, that flow between neighbouring states, and tap the resources of that vast area. After improvement, the waterways would facilitate and increase the exploitation of goods by adding to the number of markets, whereas without the possibility of cheap water transport several of the available commodities would find no market.

The following conditions must be considered when drawing up a scheme for the modern development of an effective inland waterway network:-

1.If the navigable waterways of a country are dependent entirely on the natural conditions the resulting network can only be built with very wide meshes.

If the conditions of inland water-borne traffic are such that the distances covered are short and that the transport of goods in bulk does not play a large part, the transport costs are relatively high and navigation has to meet sharp competition from other means of communication. For example, in sea-bound countries, where the geographic conditions do not lend themselves to the development of an ample and organic network of navigable waterways, the importance of the inland navigable waterways is slight as compared with that of railways and roads and also in comparison with the coasting trade that goes on all around the shores.

On the other hand, in water transport of goods in bulk over long distances, such as exists in continental inland countries, especially in Central Europe, the freight rates are low and the other means of transport cannot compete with it.

In addition, it should be pointed out that the principal inland waterways should ensure traffic with the seaports. This is one of the predominating factors in the development of inland waterways. It has been proved that the policy of inland navigation is a seaport policy and that the role of inland navigation is much more important when the waterways connect the most extensive hinterland with the seaports.

For this purpose the inland waterways in East-Central Europe have favourable geographic conditions,but at present, the improvement of rivers and the uniting of all systems has not yet been completed. Therefore, the railways are supreme in the realm of transport in this area, in spite of the very long distances over which goods are carried.

The rivers which will form the framework of the future net-work are still disconnected, but by the construction of junction canals they can without great difficulty be developed into a great network covering a very extensive area.

As regards the technical aspect of such a scheme there are particularly favourable conditions.

The watersheds of the rivers: Vistula and Dnieper,Oder and Danube, Vistula and Oder and Vistula and Dniester, are the lowest in Europe. Indeed, from the technical point of view,the shortest and most convenient routes for inland waterways between the Baltic and the Black Sea lie through East-Central Europe. They are also parallel with the flow of commerce, i.e. the arteries correspond with the main directions of the exchange of commodities. Under such conditions the system would fully satisfy the demands of production and commerce. Around navigable waterways there would arise zones of influence to which cheap transport rates would attract on ever increasingly large flow of traffic.

2.In order to keep pace with the inevitable competition between the various means of transport we must make provision for a future increase of traffic, and also for the development and perfecting of other means of communication.

Any improvement made to inland waterways should tend to reduce the cost of transport by <u>shortening the time</u> of transport, and by the use of large craft with a tonnage appropriate to modern requirements. That is why in modern / planning we can see a remarkable increase in the size of canals and the carrying capacity of vessels. There is also an increasing tendency to discontinue ordinary regulation methods in favour of canalisation, which is the most effective and quickest way of obtaining the proper navigable depth.

There are many examples of existing canals of small dimensions suited to past requirements, which can no longer compete with other improved means of communications, because their dimensions are unadequate for present conditions.

3. The preliminary survey of any particular area should show the possibilities of rivers with regard not only to navigation but also to hydro-electric power, flood control, irrigation, drainage and other functions.

The whole problem is very complex and, while the development of inland navigable waterways is particularly important for the economic life of all continental countries, it must be remembered that this is only a part and that the other factors must be considered in order to obtain the <u>maximum utilisation</u> ~~XX XXX XXXXX XXXXX~~ of the river water.

Engineers must endeavour to let the natural flow develop so that the efficacy of the water in all respects will be increased to a maximum extent, and its harmful effects reduced to a minimum.

The maximum use of a river basin should be based on the canalisation and storage of water or on a combination of several methods, the object of which is to reduce gradually, to a minimum, the harmful effects of low and high water on navigation and the working conditions of hydro-electric stations.

Whatever the future judgement may be of the various kinds of transport, the share of inland navigable waterways, owing to their special diverse characteristics will always be an important one, if they are developed to the fullest extent.

A scheme for the development of inland waterways in East--Central Europe, which also should ensure the maximum utilization of the vast available water power resources must be preceded by a description of the geographic situation and an analysis of existing needs and methods in individual countries. Therefore in presentating my thesis, in which I have endeavoured to produce a comprehensive scheme for improving the existing natural waterways and uniting the river basins by connecting canals (Vol. 2), I first examine the present utilization and development of water resources in the countries of East-Central Europe (Vol. 1).

This thesis is based upon a translation of the essential parts of my full report, written in Polish.

I have been asked by the Polish Authorities to make this report for the following reasons:-

(a) as a consequence of the great destruction of Polish libraries is it desirable to collect information for the use of Polish engineers regarding recent development and methods of construction in civil engineering;

(b) to investigate the existing conditions of the navigable waterways in East-Central European Countries and to suggest methods by which they might be improved and interconnected to form an international network;

(c) to examine the problem of navigation with a view to making the maximum use of the water-power available for the construction of hydro-electric stations in this area.

This report will be used as a basis for discussion between the Allied countries that are concerned. Some initial progress has already been made in this direction and during the past year I have been invited to take part in discussions on the subject with various Allied associations and committees and with British Firms interested in future developments.

Volume 1. " Development of water resources in the countries of EAST-CENTRAL EUROPE "

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D E V E L O P M E N T

OF WATER RESOURCES IN THE COUNTRIES

OF

EAST-CENTRAL EUROPE

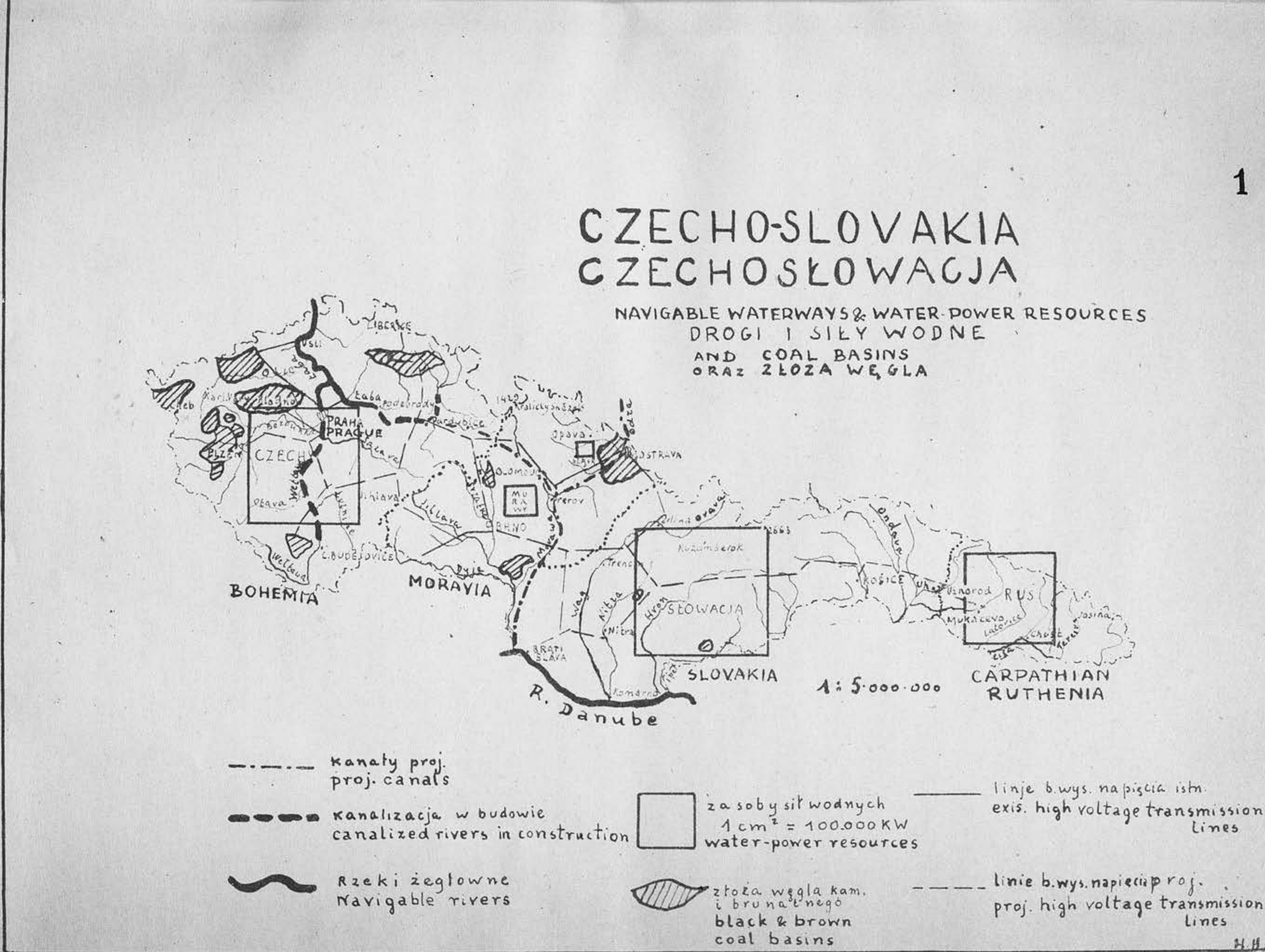
CHAPTER II

DEVELOPMENT

OF WATERWAYS

IN

CZECHO-SLOVAKIA



1
CZECHO-SLOVAKIA
CZECHOSŁOWACJA
NAVIGABLE WATERWAYS & WATER-POWER RESOURCES
DROGI I SIŁY WODNE
AND COAL BASINS
ORAZ ZŁOZA WĘGLA
BOHEMIA
MORAVIA
SLOVAKIA
CARPATHIAN RUTHENIA
R. Danube
PRAHA
PRAGUE
CZECHY
SŁOWACJA
RUS
MU RA WY
PLZEŇ
USTI
Łaba
LIBERCE
Pardubice
Olomouc
Brno
Opava
OSTRAVA
Odra
Morava
Váh
Nitra
Hron
Bratislava
Komárno
Košice
Ondava
Užhorod
Mukačevo
Jihlava
Dyje
Vltava
Otava
Sázava
Ruzomberok
Trenčín
C. Budějovice
1: 5.000.000
kanały proj.
proj. canals
kanalizacja w budowie
canalized rivers in construction
Rzeki żeglowne
Navigable rivers
za soby sił wodnych
1 cm² = 100.000 KW
water-power resources
złoża węgla kam. i brunatnego
black & brown coal basins
linje b.wys. napięcia istn.
exis. high voltage transmission lines
linie b.wys. napięcia proj.
proj. high voltage transmission lines
H.H.

Development of waterways in Czecho-Slovakia.

Czecho-Slovakia is entirely an inland state. Its territory, measuring 140,000 km^2, is situated for the greater part, at an altitude of 200-400 metres above sea level.

The territory of Czecho-Slovakia is divided hydrographically by the great water sheds between the North and Baltic seas on the one hand, and the Black Sea on the other.

Approximately 35% of the surface of the country belongs to the North Sea basin, and 8% - to the Baltic, whereas 57% belongs to the Black Sea.

Running towards the North Sea there is the river Elbe, with its confluent the Vltava; towards the Baltic - the river Oder; and towards the Black Sea the river Danube with its confluents: the Morava, the Vah, the Nitra and the Ipel.

Recognizing the advantages of good navigable waterways, for the prosperity of the country, the Czecho-Slovakian authorities undertook canalisation and regulation works for the development of waterways, capable of taking 1000 ton craft.

After the world war, by the Treaty of Versailles (Article 331), the internationalisation of the following river waterways was instituted:

the Elbe from the confluence of the Vltava, and the Vltava from Prague; the Oder from the confluence of the Opavice(never ratified by Germany); the Danube from the town of Ulm.

The other rivers used for navigation, are placed under the

National control.

The network of waterways is much more extensive in the West then in the East of the country.

The Czecho-Slovakian navigable waterways represent, on the whole, as in other continental countries, the cheapest means of transport, especially for raw materials and low priced goods, that do not require to be carried quickly.

The average quantity of goods traffic on the inland navigable waterways is 4.1 million tons (max. about 5.0) and the average transport output 2.1 milliard t-km . Thus the share of naviagble waterways in the transport is 5.3% of the total quantity or 15.3% of the total output of transport in the country.

Table No. 1 . The statistics of Czecho-Slovakian transport are summarised in the following table

	Railways	Roads	Inland navigable waterways
length in km	13,500	70,000	550
output in mio t-km	10,900	780	2,100
Percentage	79%	5.7%	15.3%

It has been proved that several branches of Czecho - - Slovakian industry owe their development to the possibility of receiving their raw materials by water, at low rates.

The creation of junction canals between the three main rivers Elbe, Oder and Danube will have a far-reaching influence on the economic life, not only of Czecho-Slovakia, but also of the whole of East-Central Europe. The political changes that will take place after the war should facilitate the development of inland navigation in this large area.

Let us now examine the existing conditions and the possibilities of improving the inland waterways in Czecho-Slovakia for modern navigation.

DANUBE.

The river Danube passes over a distance of 173 km along the South-East frontier of the country (Czecho-Slovakia - Austria; Czecho-Slovakia - Hungary).

The Danube, fed by Alpine glaciers, has far more water in summer, than in winter, with a maximum average flow in May.

The average annual flow near Bratislava amounts to 2056 cubic meter per second, whereas the monthly average maximum in May is 2846 m^3/s and the monthly average minimum in November is 1442 m^3/s .

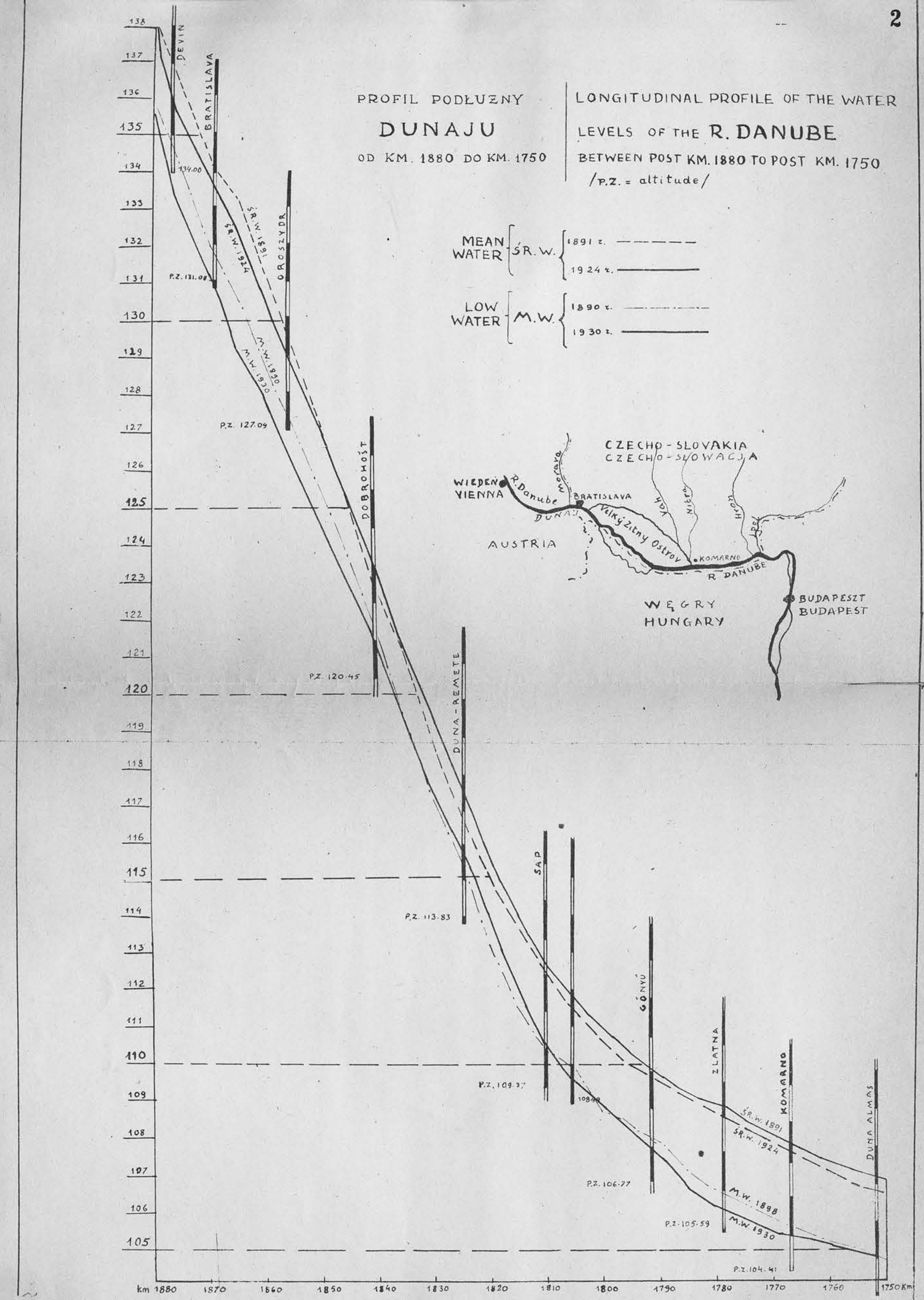
The following table No. 2 shows us the range of flow obtained from the stage-discharge curve for the Bratislava gauging station.

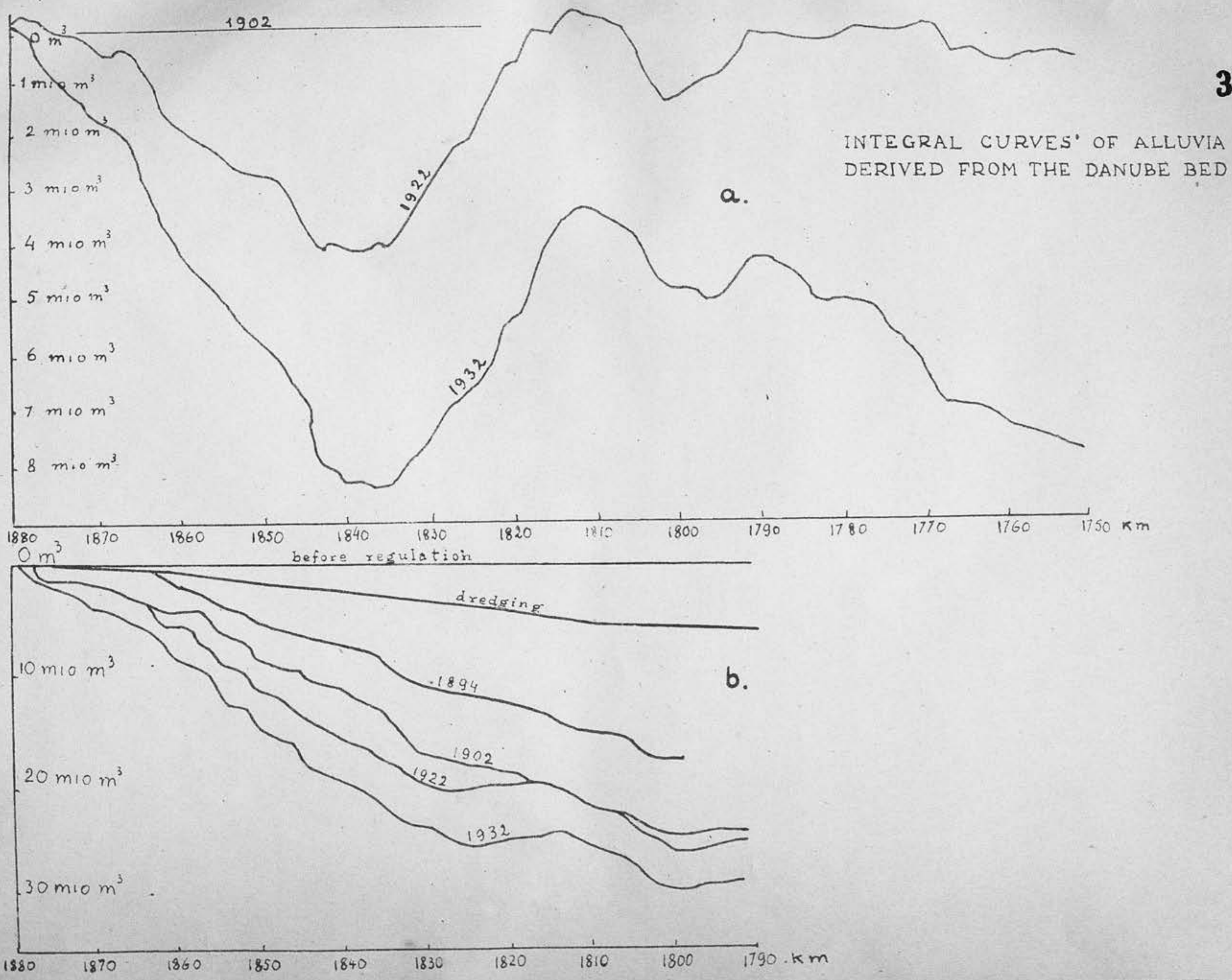
Table Nº 2 . D a n u b e at Bratislava

No	Gauge height cm	Discharge cubic meter per second	Average velocity meter per second
1.	- 45	740	1.36
2.	- 5	920	1.45
3.	75	1,370	1.67
4.	155	1,871	1.85
5.	235	2,479	2.16
6.	275	2,843	2.18
7.	325	3,240	2.30
8.	355	3,645	2.43
9.	770	10,872	4.00

The Upper course of the Danube between Devin at km 1877 , and Sap at km 1810 is notable for its fairly steep average slope of 36 cm per km ; the maximum slope on this portion of the Danube amounts to 45 cm per km .

The middle course of the Danube, between Sap at km 1810 and Kliska Nema at km 1792 , has an average slope of 14 cm per km ; whilst the part downstream from Kliska Nema has only a very slight slope of 8 cm per km on the average ; the minimum slope on this portion of the Danube is 4 cm per km . See sketch.2..


PROFIL PODŁUZNY
DUNAJU
OD KM. 1880 DO KM. 1750
LONGITUDINAL PROFILE OF THE WATER
LEVELS OF THE R. DANUBE
BETWEEN POST KM. 1880 TO POST KM. 1750
/P.Z. = altitude/
MEAN WATER
ŚR. W.
1891 r.
1924 r.
LOW WATER
M.W.
1890 r.
1930 r.
CZECHO-SLOVAKIA
CZECHO-SŁOWACJA
WIEDEŃ
VIENNA
R. Danube
BRATISLAVA
DUNAJ
Morava
Vah
Nitra
Hron
Ipol
Velky Zitny Ostrov
KOMARNO
R. DANUBE
AUSTRIA
WĘGRY
HUNGARY
BUDAPESZT
BUDAPEST
DEVIN
BRATISLAVA
OROSZYDR
DOBROHOŠT
DUNA-REMETE
SAP
GÖNYU
ZLATNA
KOMARNO
DUNA ALMAS
134.00
P.Z. 131.08
P.Z. 127.09
P.Z. 120.45
P.Z. 113.83
P.Z. 109.37
108.40
P.Z. 106.77
P.Z. 105.59
P.Z. 104.41
ŚR.W. 1891
ŚR.W. 1924
M.W. 1890
M.W. 1930
ŚR.W. 1891
ŚR.W. 1924
M.W. 1898
M.W. 1930
138
137
136
135
134
133
132
131
130
129
128
127
126
125
124
123
122
121
120
119
118
117
116
115
114
113
112
111
110
109
108
107
106
105
km 1880
1870
1860
1850
1840
1830
1820
1810
1800
1790
1780
1770
1760
1750 Km


3
INTEGRAL CURVES' OF ALLUVIA
DERIVED FROM THE DANUBE BED
a.
1902
1922
1932
0 m3
1 mio m3
2 mio m3
3 mio m3
4 mio m3
5 mio m3
6 mio m3
7 mio m3
8 mio m3
1880
1870
1860
1850
1840
1830
1820
1810
1800
1790
1780
1770
1760
1750 km
b.
0 m3
before regulation
dredging
1894
1902
1922
1932
10 mio m3
20 mio m3
30 mio m3
1790 km

We can deduce from figure "a" that the 1922 curve and the 1932 curve show in principle the same tendency. From the foregoing deductions made from table No 3 it can be confirmed that in the district of junction of different slopes (km 1830 - 1810) there is a progressive rising of the bed and on the remaining sectors a slow and almost regular deepening of the bottom.

These two actions: the deepening and rising of the bottom, both have an important influence **on** the navigation and **on** the adjacent land.

The sector between km 1880 and km 1840 (see sketch No. 3fig.a), from which about 8 million cubic meter of silt were removed by the current since 1902 up to 1932 , which corresponds to an average deepening of 0.8 m - provides satisfactory conditions for navigation.

On the other hand, the deepening of the bottom and consequently the lowering of the Danube levels has caused a lowering of the ground water in adjacent land. This has been observed in the drained upper part of the Velky Zytni Ostrov.

If this lowering of the water levels were to continue and increase, it would be necessary to counter-act and stop this unsatisfactory influence by a new scheme of irrigation.

The deposits of the silt,however, in the next sector between km 1835 and km 1810 have a much more unfavourable influence on the adjacent land protected by dykes, especially during ~~the periods of high water, when the lowel~~

the periods of high water, when the level rises, with the result that the adjacent lands are flooded and great damage is done to crops. For example, this phenomena happened in 1926 on a large scale when the highest mean water was maintained for three months without a break, and almost the entire crops on the adjacent land were destroyed.

Moreover, the silting action deteriorates conditions for navigation. It has been observed that, as a result of the back-water caused by change of slopes, there has been a considerable decrease in volume of the water passing along the main channel and an increase in the side arms.

According to direct gauging taken in 1927, the loss of water from this cause at km 1821 amounted to about 50% for a flow of 2,116 m^3/s, which is approximately the mean water flow. But the volume of silt corresponding to these losses through back-water is not carried through these arms and branches, which are sometimes deeper then the main bed of the Danube, but partly remain in the latter. They cause a deposit on the bottom, which alters the river bed and reduces the height of the longitudinal dykes.

As a result of this a series of sills are formed, making the course of navigation narrow, winding and difficult.

In addition the necessity arises of raising the level of longitudinal dykes, It is most difficult to keep stability in this part (km 1835-1810) of the Czecho-Slovakian section of the river Danube and consequently to get the required conditions for modern navigation.

This problem requires thorough investigations before chosing the method best fitted for further improvements. It would possibly be necessary to build a new lateral canal over a distance of 25-30 km , in the section of the junction of different slopes instead of applying the ordinary river training process.

ELBE AND VLTAVA

Elbe and Vltava in Czecho-Slovakia. The beginning of navigation on the Elbe and Vltava dates back to the VIth century, when commerce developed,consisting of an exchange of agricultural products for arms and clothing.

The first custom houses were installed on the Elbe in Bohemia at Usti and Litomerice round about the year 1000.

In the XIth. and XIIth. centuries they used the Elbe and Vltava for transporting iron ware,beer,wine and tin. In the XIVth. century King Charles IV had ordered the construction of sluiceways, to improve the conditions for navigation, and he had abolished the heaviest navigation tolls.

After the period of stagnation that followed the Thirty Years War, the revival of navigation took place in the middle of the XVIIIth. century,when improvement works had been carried out on these rivers.

Towards 1770 a navigation Commission was founded for the Elbe and Vltava, and after the Congress of Vienna in 1821 freedom of navigation on these rivers was proclaimed by the Elbe Act.

The first satisfactory tests with a steamboat were made by the Czecho-Slovakian engineer Josef Božek on the river Vltava in 1817.

Recognizing the advantages of an efficient system of navigable waterways for the prosperity of the country, the authorities undertook canalisation works on the rivers Vltava and Elbe, over the stretch from Prague to Usti, towards the end of XIXth. century.

The river Elbe in Czecho-Slovakian territory has a length of 379 km, but after the canalisation works, which have been carried out the length was shortened to 336 km.

The Elbe receives its waters from the slopes of the Giant Mountains. Its upper and middle courses, as far as the town of Melnik, run through a flat and very fertile country, very thickly populated and called the "golden strip", which produces sugar, beet, wheat, barley and vegetables. Its lower course from Melnik, where the river Vltava joins the Elbe, runs through hilly country, known as Saxon Switzerland and rich in industries. Crossing the Czecho-Slovakian-German frontier, and running for a distance of 621 km, the Elbe reaches the port of Hamburg and flows 105 km further on into the North Sea near Cuxhaven.

The lower course of the Czecho-Slovakian Elbe comprises the canalised sector situated between Melnik and Usti, 73,2 km in

length, and the remaining sector of 36 km between Usti and the frontier; thus the whole length is 109.2 km .
The canalisation works provided with locks and capable of taking vessels of 1000 tons, have been completed.
The last and most recent dam on this sector of the Elbe was built in 1936 at Strekov, and is called the Masaryk Dam. This dam comprizes 4 openings of 24 m with double rolling gates and is provided with a lock 24 m in width in order to accomodate craft of 2,000 tons in the future.
A power station, with 3 Kaplan turbines of a capacity 13,500 kW is installed near this dam.

The following table No 4 shows the date of existing dams on the canalised Elbe below the town of Melnik at the mouth of the river Vltava.

In Commission since	Retaining water level m	Normal head at the weir m	at the locks m	Distance between the weirs km	Storage capacity per thousand m^3	Surface of the reach (pondage) ha
1. Borkovice VI. km 6.70						
1908	155.30	2.33	2.70	18.03	1,074	97.7
2. Stetti VII. km 18.10						
1909	152.60	2.30	2.80	11.40	2,098	192.1
3. Roudnice VIII. km 27.30						
1912	149.80	1.94	2.90	9.20	1,369	125.3
4. Litomerice IX. km 41.20						
1914	146.90	2.70	3.20	13.90	3,029	193.8
5. Lovosice X. km 49.27						
1919	143.70	2.15	2.70	8.07	1,372	118.5
6. Strekov XI. km 68.89						
1936	141.00	7.05	7.10	19.62	9,064	313.8

The remaining sector of the lower course of the Elbe, below Usti, is improved for navigation, over a distance of 36 km, by regulation works and by deepening of the river, which ensures a depth of 1.50 m during mean flows.

The type of boat adopted here is of 700 to 800 tons carrying capacity. These boats have the following dimensions: length - 72.5 m ; width - 10.1 m ; draught when fully loaded - 1.8 m .

The table No 5 gives the data regarding the conditions of navigation below the canalized stretch of Elbe from Strekov through Usti to the frontier (see the next page).

In addition to the table No 5 the times during which the regular navigation of cargo boats stopped, due to drought, were as follows:

1904	from 19 July	till	19 September;	
1911	24 "		21	"
1918	10 June		22	"
1921	26 July		8 November;	
1923	9 "		18 July;	
1928	1 "		18 October.	

As can be seen in the table No 5 on this stretch of the Elbe a depth of water beneath the bottom of boats of 44 to 53 cm is required and consequently a great part of the draught is

The following table No 5 gives the data regarding the conditions of navigation below the canalized stretch of Elbe from Strekov through Usti to the frontier.

Water level at the gauge at Usti cm	Corresponding rate of discharge m^3/s	Depth of the navigable channel cm	Authorized draught of the boats cm	Security depth beneath the boat cm	Number of days of navigation: In the rainy year	In the average year	In the dry year	In the dryest year 1921
Highest navigable water level								
300	1020	480						
Fully loaded the barge of 900 t capacity								
44	262	224	180	44	213	161	107	104
Loaded up to 2/3 the barge of 900 t capacity								
0	175	180	136	44	294	235	189	142
Loaded up to 1/2 the barge of 900 t capacity								
-25	131	155	111	44	343	287	202	176
Loaded up to 1/3 the barge of 900 t capacity								
-50	91	130	87	53	357	335	250	227
Standing still of navigation for passengers								
-69	64	111	65	46				
Lowest navigable water level								
-72	60	108	60	48				

lost. The reasons for this precaution are as follows:

1. The valley of the Elbe below Litomerice shows on both banks,

high, and steep rocky slopes,consisting chiefly of basalt. The basalt forms not only compact rocks,but also rocky masses, which are steep, and are created by the action of the atmosphere. Heavy rainfalls cause the breaking away of the rock and carry down large quantities of boulders into the river. The large blocks of basalt which lie in the river bed are a permanent danger to navigation. This is partly due ~~due~~ to the fact that navigation is carried on by towing by means of chains and the action of the chain causes the displacement of large blocks of basalt from banks into the navigable channel, and constitutes an additional danger to navigation.

2. As a consequence of the effect of the wash of the boat the draught caused by a boat in movement is greater than when it is at rest. When two trains of barges pass each other, even at a low speed and with ~~xxxx~~ every care, there is a loss of 10-15 cm in the useful draught.

Until further improvements can be made over this section of the Elbe and a constant discharge obtained from storage reservoirs in the upper basin the present limitation of the draught of boats must be maintained.

The middle and upper courses of the Czecho-Slovakian Elbe above Melnik and through Pardubice towards Jaromer are 227km in length. The transformation of the river Elbe,over this distance into a modern navigable waterway, available for craft of 1000 tons, will be most effectively obtained by canalisation of the river. It is impossible to achieve this object by the ordinary river regulation works on account of the steepness of the slopes and the low volume of water. The characteristic flows for the river middle Elbe are as follows:

	Low water flow m^3/s	Mean water flow m^3/s	Flood flow m^3/s
At Melnik above the mouth of the river Vltava	13	53	1,200
At Pardubice	9	36	700

On this stretch 148 km have already been canalized, and work is still being carried out on the remaining length. Twenty seven weirs and lock installations are required for a total head of 94.2 m and of these 15 weirs and locks have been completed; plans have been prepared for the remainder. In the following table No 6 some data of these installations are summarized.

(see the next page)

Table No 6

No	Weir, lock and power station		Head m	Power capacity kW	Yearly output capacity in million kWh
1	Melnik	(built)	1.8	1,000	4.0
2	Obristvi	"	2.2	1,300	5.2
3	Lobkovice	"	2.7	1,600	6.4
4	Kostelec	"	3.5	2,100	8.4
5	Brandys	"	3.8	1,700	6.8
6	Celakovice	(planned)	2.7	1,450	5.8
7	Lysa	(built)	3.1	1,650	6.6
8	Hradistko	(planned)	2.9	1,550	6.2
9	Kostomlaty	(built)	3.7	1,950	7.8
10	Nymbark	"	2.7	1,700	6.8
11	Podebrady	"	2.2	1,000	4.0
12	Osecky	(planned)	2.4	1,200	4.8
13	Klavary	(planned)	3.5	1,600	6.4
14	Kolin	(built)	2.1	1,700	6.8
15	Veletov	(planned)	4.3	1,850	8.3
16	Tynec	"	2.4	1,050	4.2
17	Kladruby	"	5.3	2,300	10.5
18	Prelouc	(built)	3.0	1,700	6.8
19	Sznojedy	"	3.8	1,500	6.0
20	Pardubice	(planned)	3.6	1,300	5.2
21	Kunetice	"	4.1	1,200	5.4
22	Opatovice	"	4.7	1,400	6.3
23	Hradec-Kralove	(built)	3.4	600	2.4
24	Predmerice	(built)	8.2	1,600	8.0
25	Smirice	"	9.0	1,800	9.0
26	Josefov	(planned)	2.7	450	1.8
27	Jaromer	"	2.2	350	1.4
		total	94.2	54,810	161.3

The river Vltava, the main tributary of the Elbe, rises in the Sumava mountains in Southern Bohemia, a well wooded district, which for ages past, has been a rich source of timber. For a large part of its course, the river runs through a deep, rocky and tortuous valley.

On the middle course of the Vltava the slope of its bed is very steep, 1 metre per kilometre and even more; it runs there through a vast wooded district in which granite,porphyry,as well as basalt are found. It is only as it approaches the town of Prague that the Vltava valley opens out. Further downstream, between Prague and Melnik the Vltava first runs through hilly country consisting of phyllite,porphyry and greenstone rock, and then continues on its course through a wide and very fertile valley as far as Melnik,where it runs into the river Elbe.

The river Vltava which is used for navigation from Ceske Budejowice downstream,according to its degree of navigation can be divided into two ~~xxxxxxx~~ distinct sectors:

1. the upper course, 180 km in length, between the town of Ceske Budejowice and the mouth of the river Berounka, 9km upstream from Prague;
2. the lower course, 65 km in length,between the mouth of Berounka and Melnik.

The upper course is improved,by partial regulation works for smaller craft of 100 to 120 tons, and at present we may consider this sector as being seminavigable.

Canalisation works are being carried out in order to suit 800 to 1,000 tons craft. Thirteen weirs and locks have been planned,of which five have already been built on the upper course of the river Vltava. Simultaneously plans were made for the utilization of water for the development of power. In the following table the data comprising the installations planned on the upper sector of Vltava are summarized.

Table No 7

No	Weir,lock and power station		Head m	Power capacity HP	Yearly output capacity million kWh
6.	Prague-Stramice VI	built	4.0	1,480	7.0
7.	Prague-Sitkovsky VII	built	1.2	-	-
8.	Vrane VIII	"	12.9	19,350	68.7
9.	Stechovice IX	planned	19.1	28,650	79.0
10.	Slapy X	"	36.4	83,720	150.0
11.	Zvirotice XI	"	13.6	14,000	53.4
12.	Kamyk XII	"	13.4	13,000	52.4
13.	Orlik XIII	"	52.0	130,000	203.5
14.	Podolsko XIV	"	16.0	16,000	48.6
15.	Hnevkovice XV	"	18.2	18,200	27.1
16.	Hluboka XVI,	built	4.7	---	--
17.	Ces.Vrbne XVII	planned	9.0	---	--
18.	Ces Budejowice XVIII	built	3.5	1,000	4.5
		total	204.0	325,400	693.2

The lower course of the river Vltava was canalized during the period 1897-1921 by the construction of 5 weirs, and locks for the passage of craft of 800-1,000 tons and sluiceways for rafting. After the completion of the work at the Vrane dam, above the mouth of Berounka,bigger vessels were able to navigate 20 km further upstream, and therefore the total length for modern navigation,taking barges of 800-1,000 tons,is 65 and 20 = 85 km .

It must be added,that the lowest part of the river Vltava is not canalized, but there is a lateral canal from Vranany to Horin, 10 km in length, which is situated on the left bank of the river. The lock installations at Horin, for a head of 8.9 m , consists of an ordinary lock and a lock for trains of barges. The ordinary lock has an effective length of 78 m and width of 11 m . The lock for barge trains has a length of 137.5 m and is 20 m wide. A tug with a train of four barges of 700 tons each can negociate this lock in one operation in eighteen minutes.

All the reaches of the canalized Elbe and Vltava are supplied solely by the natural flow of the rivers. When the volume of discharge of the Vltava exceeds 380 m^3/s and that of the Elbe 580 m^3/s the weirs have to be opened. In the winter all the movable parts and the frames of the old weirs on both of these rivers are removed and lowered, in view of the fact that the weir and frame needles, as well as the shutters would be exposed,during long periods of frost, to the risk of formation of icicles and to the impact of ice blocks. Only the modern weirs which are provided with Stoney sluices remain closed during the winter.

In the following table No 8 are summariezed some data of the weirs on the lower course of the river Vltava.

Table No 8

No	In commission since	Retaining water level m	Normal head at the weir m	Normal head at the locks m	Distance between the weirs km	Storage capacity thousands m^3	Surface of the reach (pondage) ha
1.		Troja I below Prague km 200.18					
	1902	180.50	2.70	5.40	6.00	1,254	80.7
2.		Klecany II km 208.96					
	1889	175.10	2.70	3.10	8.78	481	59.6
3.		Libsice III km 218.58					
	1901	172.00	3.56	3.90	9.62	1,503	98.7
4.		Mirejowice IV km 227.80					
	1903	168.10	3.80	3.90	9.22	1,198	80.2
5.		Vranany-Horin V km 234.37 - 245.7					
	1905	164.20	2.80	8.90	6.47	1,267	80.8

The river VAH(WAG)

In Slovakia, the largest river is the Vah. It flows over a distance of about 400 km from its sources in the Tatra Mountains to the river Danube at Komarno.

For the river Vah a general scheme has been worked out for navigation with simultaneous utilization of water power in each of the canalization steps.

Canalization works over the whole stretch of the river are being planned to comprise the construction of 15 dams, locks and hydro-electric stations, under a total head of 214.8 m .

It would be possible to have installations amountaing to 219,200 kW capacity with the yearly output capacity of 1,200 million kWh .

The only step that has so far been taken is the building at Ladce of a water power station of 14,000 kW capacity and a yearly output capacity of 90 million kWh , serving the purposes of systematic electrification.

The projected canalisation works and the possibilities of the utilization of water power on the river Vah are summarized in the following table.

Table No 9

No	Canalisation step and hydro-electric station	Head m	Capacity kW	Yearly output capacity kWh
1.	Sala n. V.	12.9	14,600	75.9
2.	Sered Nove Mesto	12.4	14,000	73.0
3.	Leopoldov	12.0	13,600	70.6
4.	Drahovce	12.3	13,900	72.4
5.	Pistany	15.0	14,500	88.3
6.	Nove Mesto n.V.	15.8	15,300	93.0
7.	Bodovka	16.0	15,500	94.2
8.	Trencin	14.0	13,600	82.4
9.	Dubnice	12.1	11,700	71.2
10.	Ilava	11.3	11,000	66.5
11.	Ladce(built)	13.7	14,000	90.0
12.	Puchov	14.1	13,700	83.0
13.	Okrut	15.1	14,600	88.9
14.	Plevnik	19.0	19,400	111.8
15.	Zilina-D.Hricov	19.1	18,500	112.4
	total	214.8	219,200	1,203.6

To complete the description of the Czecho-Slovakian navigable waterways I should mention the rivers: Tissa, Oder and Morava.

The TISSA

The Tissa is the largest tributary of the Danube, on its navigable sector and touches Czecho-Slovakian territory for a distance of 22 km , forming the frontier between Hungary and Czecho-Slovakia. The river has a channel 100 to 150 m wide, with a slight slope. Leaving Czecho-Slovakian territory, the river enters the great Hungarian plain through which it flows for a distance of 500 km , to join the Danube.

The ODER

The Oder has its source in moderately high/ mountains, of 634 m above sea level, in Czecho-Slovakia it pursues its course first through hilly country,enters the Ostrava-Karvin coal basin,passes through Vitkovice,Ostrava and Karvina which are important centres of the metal industry. After 123 km it leaves Czecho-Slovakia near the town Bohumin at the mouth of the Olza and enters Poland and later Germany in the district of Silesia. After a further distance of 727 km it flows into the Baltic.

On the Czecho-Slovakian sector,the Oder is so far only a navigable waterway of local and small importance. It will be able to take larger craft after the canalisation works that I propose;in using this sector of the Oder for the Oder-Danube canal. The new scheme for this canal will be discribed in the Chapter No.I/a,Vol.2 .

The Morava

The Morava, a tributary of the Danube rises at Jesenik,near the German frontier, and runs in a southerly direction,through a very fertile plain,having a highly developed agricultural industry. The possibility of improving this river for navigational purposes by means of canalisation works will be described in the Chapter No.I/a Vol.2/ as its middle and lower courses would be used as the southern part of the proposed Oder--Danube canal.

Commercial Development of Inland Navigable Waterways in Czecho-Slovakia

The water borne transport either in the interior of the country or to and from foreign countries, can be divided in two distinct groups, that on the Elbe and Vltava and that on the Danube.

Transport on the Elbe and Vltava, may be classified into three kinds, as follows:

	Average quantity	Maximum quantity (in 1928)
1. In the interior of the country	680,000 tons	870,000 tons
2. For export	980,000 "	1,496,000 "
3. For import	780,000 "	845,000 "
total	2,440,000 "	

The political changes that took place after the war 1914-1918. influenced and altered transport.

The export figures for many kinds of goods were higher, for instance in the year 1913 exports amounted to 2,359,000 tons. The ratio between exports and imports was 3 : 1 in 1913 and has changed in recent years to $1^1/4$: 1 . Chiefly the export of lignite has fallen to $^1/5$th.

First place in exports is taken by the agricultural and food stuffs industry: sugar, malt and flour, barley and fruit; then industrial products such as: glassware, iron, pulp, paper, textiles and timber; finally minerals: potter's earth, graphite, sand and gravel. About 80% of the merchandise transported via the Elbe

and Vltava for export goes through the port of Hamburg and is consequently either despatched to or comes from overseas, The part played by Czecho-Slovakian transport in the total traffic of the port of Hamburg amounted to about 20% of the total exports and 14% of the total imports of that port.
The average navigation rates between Usti and Hamburg over a distance of 650 km were: 65 crowns per ton or 10 hellers per ton-km; and between Prague and Hamburg, over a distance of 772 km - 100 crowns per ton or 13 hellers per ton-km (100 hellers= 1 crown ≙ 0.8 d).

As regards imports, they are non-agricultural products such as: industrial salt, artificial fertilizers, crude iron, metals, oil e t.c.

Transport by boat carried out in the interior of the country on the Elbe and Vltava represents, in general, low-priced goods, such as river sand and gravel, which accounts for about 53 to 73% of the transport; sand and gravel from quarries(5-14%), stone for building and paving(6-12%), sugar beet(2-5%), manure-(3-11%).

The traffic at the Elbe and Vltava ports according to loading and unloading figures are as follows -

(see the next page)

Table No 10

No	Port	Annual average loading tons	unloading tons
1.	Smichiv-Holesovice (Prague)	83,788	33,374
2.	Kralupy	4,080	7,216
3.	Melnik	119,466	24,738
4.	Lovosice	13,210	28,587
5.	Usti	411,542	114,262
6.	Krasne Brezno	113,469	24,012
7.	Nestemice	46,369	90,831
8.	Rozbelesy	33,117	25,085
9.	Decin	1,812	67,481
10.	Loubi	79,115	260,257

Finally, I must add, that the predominating method of transporting timber is by rafts. The rafts 6 metres wide and running up to 190 m in length are steered by three men.

The average quantity of timber brought to Prague in rafts amounts to about 420,000 cubic meter per annum. Transport by rafts for foreign countries exceeds about 150,000 tons i e. 13% of the total export ~~xxxxxx~~ through the Elbe and Vltava.

Transport on the Danube, carried out within Czecho-Slovakia forms a relatively small part of the whole. This is because of the different geographical natures of the two Czecho-Slovakian waterway systems; the Elbe and Vltava on the one hand, and the Danube on the other, which are not connected. This explains the fact that certain kinds of merchandise are only encountered on one or the other system.

Transport on the Czecho-Slovakian Danube can be classified into four kinds as follows:

	Average quantity	Maximum quantity
1. In the Interior of the country	52,000 tons	------
2. For export	835,000 "	1,154,000 tons
3. For Import	541,000 "	920,000 "
4. For transit	1,154,000 "	
total	2,382,000 tons	

Transport carried in the interior of the country consists mostly of stone, which comes principally from Devin near the mouth of the Morava and which is sent to numerous points on the river for regulation works; to a secondary degree there are sugar, beet, timber as well as industrial products.

The exports consist principally of coal and coke transported downstream to Danubian states. Industrial products come next: crude and wrought iron, paper, textilles, glass, chemical products etc. The average participation by the Danubian states in Czecho-Slovakian water-borne traffic was as follows:

Hungary - 34%, Yugoslavia - 31%, Rumania - 21%, Bulgaria-6%, Germany - 4% and Austria - 2% .

Imports coming via the Danube comprise chiefly, raw materials and agricultural products: wheat, maize, tobacco and fruit. These accounted for 2/3 of the imports, whilst the remainder consists of crude oil, benzine and soda.

Approximately two thirds of the goods transported are carried downstream whilst the remaining one-third proceeds upstream.

The average navigation rates betwen the town of Bratislava ana the port of Braila over a distance of 1677 km were: 250 crowns per ton or 15 hellers per ton-km; the rates between the town of Komarno and the Braila were - 175 crowns per ton or 11 hellers per ton-km , over a distance of 1577 km .

The total amount of traffic on the Czecho-Slovakian sector of the Danube estimated from the number of tugs and motor carriers in use during the period 1922-1933 was as follows:

Year	
1922 -	5,518
1923	8,152
1924	15,522
1925	15,771
1926	19,805
1927	22,502
1928	23,928
1929	19,996
1930	21,299
1931	22,742
1932	19,997
1933	17,952

The falling off in the number of units counted in 1932 and 1933 is the result, chiefly of the introduction of larger units.

The number of round trips possible per year between Bratislava and Braila is stated to vary from six to eight.

By the Treaty of Versailles Czecho-Slovakia acquired a commercial fleet consisting of 900 units of 288,396 tons capacity;160 of which were passenger boats with 37,434 HP power capacity,and the remainder consisted of 55 tugs and many barges.

A small part of this fleet was used for navigation on the Danube the remainder being used on the Elbe and Vltava.

In the spring of 1940 the Czecho-Slovakian commercial fleet on the

Danube was as follows:

passenger boats	- 3;	
tugs	13;	
barges	136;	with 99,593 tons capacity;
tankers	12	with 10,354 tons capacity.

Water-Power As A Part Of The Energy Resources In Czecho-Slovakia

The chief source of energy in Czecho-Slovakia is bituminous coal, the reserves of which are estimated, to be approximately 6,144 million tons (according to other calculations it amounts to 8,787 million tons).

The other resources of energy are: brown-coal, the reserves of which are estimated to be 12,416 million tons, and water power, the vast potential capacity of which is estimated to be 1,722,000 HP.

The remaining resources of energy,, crude oil(petroleum) and natural gas are very scarce and only suffice for 5% of the consumption in the country.

The main field of bituminous coal in Czecho-Slovakia is situated near Ostrava-Karvina, the others are smaller as can be seen from the following table No 11 of bituminous coal production in 1935 in 80 coal mines.

Table No 11 Fields of bituminous coal in Czecho-Slovakia

Ostrava - - Karvina	Kladno	Plzeň	Žaclez	Rosice Oslavany	Other	Total
Yearly production in thaousands of tons						
7,768.0	1,343.7	941.7	467.7	367.2	76.8	10,965.1

In recent years the production of bituminous coal increased, but did not attain the maximum output of 1929.

The following table No 12 shows the comparative statistics of production of bituminous coal, coke and byproducts in 1929 and in 1934.

Table No 12

	1929	1934	
Bituminous coal	12,580,000	7,504,000	in tons
Coke	3,113,000	1,291,000	in tons
Crude benzol	28,607	14,548	" "
Crude tar and resin	111,190	56,172	" "
Ammonium sulphate $(NH_4)SO_4$	38,547	19,687	" "
Export of coal	1,591,524	1,064,614	in tons
" of coke	882,472	344,267	" "

The centre of the brown-coal production in Czecho-Slovakia, from which comes about 95% of all Czecho-Slovakian brown coal, lies in the north of Bohemia and west of the river Elbe(Labe). The second largest brown-coal field is the basin of Falknov, lying in the north-west corner of Bohemia. Besides the basins in Bohemia, brown coal is mined in Slovakia on the upper part of the river Nitra; and in Southern Moravia on a smaller scale. The brown coal production of 173 mines in 1935 is shown in the following table No. 13

Table N°13 The brown coal production of 173 mines in 1935.

in thousands of tons

Northern-Bohemia Duchcov-Most-Chomutov	Falkov between Cheb and Karlovy Vary	Slovakia	Southern Moravia	Other	Total
11,463.7	2,787.4	575.8	306.5	93.5	15,226.9

The maximum production of brown coal in Czecho-Slovakia reached 22.56 million tons in 1929. , about 5 million tons of which was exported.

On the basis of the present consumption of coal, the reserves of bituminous coal should last 400 years and brown coal 600 years.

The recent average consumption of coal in percentages is divided as follows:

Table No 14 Consumers of coal

Kind of coal	Industry	Communication	Domestic premises	Coke works	Total
bituminous coal	50%	17.5%	9.3%	23.4%	100%
brown coal	49.4	18.1%	28.2	4.3	100%

Water-power resources- The present records of water-power resources in Czecho-Slovakia indicate an ultimate capacity of 1,722,000 HP. , which are summarised in the following table.

Table No 15

County	Capacity HP	%%
Slovakia	775,000	45
Bohemia	600,000	34.8
Ruthenia	227,000	13.3
Moravia	89,000	4,6
Silesia	40,000	2.3
Total in Czecho-Slovakia	1,722,000	100%

The development of water turbines is shown by these data:

1923	--	212,646	Horsepower
1928	--	263,000	"
1930	--	308,949	"
1934	--	326,000	"
1936	--	410,000	"

Besides the canalization schemes on the rivers Elbe,Vltava and Vah (described above), there has been carried out in Czecho-Slovakia a planned development of dams, which served for storage and regulation purposes and later for the utilization of water power. The dams are built and planned chiefly on the upper sections of the rivers.

The total capacity of the hydro-electric stations,for which the schemes have been already carried out - amounts to

650,000 kW capacity with the yearly output capacity of 2,300 million kWh .

To facilitate the planning of important hydro-electric stations, a law has been passed (No.50 of March 27,1931) to institute a state foundation for navigation,construction of dams and utilization of water power at the Ministry of Public Works.

This law permits financing on a loan basis, the interest and amortization being carried by the state. Thus a continuous development of these plants is assured.

Among a number of dams and storage reservoirs which for various purposes, have been planned or are in course of construction or already built, the most important are described in the following brief summary:

1. On the Dyje river near Vranov there has been built the largest modern dam of 165 million m^3 storage capacity. The useful capacity of 132.6 million m^3 holds all flood water of Dyje river, thus obviating the necessity for costly regulation of the basin of this river. The reservoir will yield water for the irrigation of lands extending to 8,000ha. Below the reservoir, over the stretch of 71 km , four hydro--electric power stations to be situated at Vranor,Hradek, Podmoly and Znojmo, have been proposed.Of these the hydro--electric station Vranov only has been built. It has a capacity of 14,000 kW.

2. In Sumava, on the rivers Vydra and Kremelna, two dams are planned to gather flood waters and regulate the flow. The reservoir at Vydra would have a capacity of 5.2 million m^3 and that at Kremelna - 16.4 million m^3. Water from both reservoirs would be taken through ducts and pipes to a common hydro-electric station at Cenkova-Pila, located at the junction of both rivers.

The water turbines would work under a head of 318 m from Vydra reservoir, and under a head of 176 m from Kremelna reservoir. The total hydro-electric power capacity is estimated as 25,150 kW (15,700 and 9,450) with yearly output capacity of 50 million kWh (30 and 20 million kWh). Below the common hydro-electric station would be the daily equalizing reservoir, provided with a power station of 400 kW capacity and a yearly production of 3 million kWh.

For retention and regulation purposes in the basin of the river Elbe there were built or planned the following storage reservoirs.

3. On the upper Elbe two dams have been built at Kransovy and in the forest of Kralovstvi, with a power station of 2,000 HP capacity, and a yearly output capacity of 5,7 million kWh.

4. To reduce floods on the river Jizera, three dams are being planned at Karlov, Vilemov and Benesov, with a possibility of production of 49 million kWh per annum.

5. On the Rozkossky river at Ceska Skalice plans are being made for a reservoir of 80 million m^3 capacity, to regulate the flows

of the river Upa and river Metuje. It would reduce not only the floods on the Upa river but over the whole Polabi river and would form a base for the artificial humidification of the soil in the Middle Polabi valley extending to 18,000 ha .

6. On the Divoka Orlice river there is a dam at Pastviny, containing 11 million m^3 storage capacity,which should prevent floods. The power station under a head of 22 m has a 2,400 kW capacity and yearly production of 7 million kWh .

7. On the Chrudimka at Sec, a dam has been built of 22 million m^3 storage capacity,protecting lands in the valley of Chrudimka from floods and reducing floods in the valley of Polabi.

8. Below the dam of Sec, three hydro-electric stations are planned at Padrat,Svidnice and Skrovady, totaling 14,800 kW with a yearly output of 21 million kWh .

From the reservoir at Sec would be taken the water for a large aqueduct,supplying the towns of Chrudim,Pardubice and a number of others.

All reservoirs mentioned in 3 to 8 will, in dry seasons, improve the water flow on the Elbe and also navigation conditions on this river.

Similar retention action is carried out in the basin of the river Vltava, where the following storage reservoirs schemes are planned.

9. A dam at Zelnava with 26 million m^3 storage capacity is being planned, to smooth out the flow of the upper Vltava. This dam would protect the basin of the upper Vltava, especially near Ceske Budejovice, from floods and should improve the working of all hydro-electric stations there, as far as Milejovice. On this dam, water power of 1700 kW capacity would be utilized with 9 million kWh output capacity per annum.

10. Karlovy Vary (Karlsbad) suffers to a large extent from floods from a small river Tepla. To prevent such damages, a dam of 5 million m^3 storage capacity has been built, by means of which water power of 500 kW capacity, yielding yearly 1,4 million kWh , is obtained.

11. On the Berounka river near Krivoklat, a dam with a large storage reservoir of 530 million m^3 capacity is being planned. This dam would protect the basin of the river Vltava from floods and improve the navigation conditions there. A hydro-power/-electric station of an average capacity of 7,000 kW , producing about 50 million kWh yearly is being planned.

12. On the Svratka river at Kninicky - there is a scheme for a dam of 21 million m^3 storage capacity. This reservoir would reduce floods and supply water for industrial as well as domestic use for Velke Brno, and in addition, improve the flow conditions of the Svratka river during the dry season. Below the dam a water power of 1,700 kW capacity will be utilized, yielding yearly 7 million kWh .

In Silesia a number of storage reservoirs have been built or are being planned. Their total capacity is 138 million m^3 and they are designed to protect lands and property from floods in that basin, and in addition, they would supply the district of Ostrava-Karvina with water for industrial purposes.. There is a scheme for an aqueduct for groups of 40 communities, as well as for power stations.

13. The largest one in this scheme is a storage reservoir on the river Moravice near Kruśperk and Zimrovice with capacity of 20 million m^3. The power station on this dam would have capacity of 31,000 HP with a yearly output capacity of 65 million kWh .

In Slovakia a number of small hydro-electric stations have been developed.

14. A large storage reservoir has been planned on the river Orava at Turdosin with capacity of 800 million m^3 . This reservoir would improve the water flow on the river Vah, and would facilitate the canalisation works which are being carried out on this river for navigation purposes.

In Ruthenia water power stations have been constructed but on a small scale.

15. In addition, there is a larger scheme for the utilization of the power of the small rivers Tereblja and Rika at North Bystra, which have a head of 200 m , yielding 30,000 kW capacity.

The share of water power in the electrification of of Czecho-Slovakia - Czecho-Slovakia is a country with considerable coal reserves , and the systematic development of central stations was based primarily on steam generation of electricity. Recently, however, when systematic electrification could guarantee rational utilization of water power, larger hydro-electric stations are being planned and built, and the development of water power stations is growing.

Up to the present less than 10 percent of the total production of electricity is produced by hydro-electric stations.

The production of electricity in Czecho-Slovakia was 3,042 million kWh in 1930; 2,853 million kWh in 1934 and about 4,000 million kWh in 1937.

The production of electricity, according to the type of power is distributed as follows:

1. steam stations	85.4%	
2. hydro-electric stations	9.32%	
3. oil and gas stations	5.28%	100%

According to generator capacity of power stations they divided as follows:

1. steam motors	80.3%	
2. water turbines	11.7%	
3. remainder	8.0%	100%

The production of electricity, according to kind of stations is distributed as follows:-

Table No 16.

	steam, oil and gas stations	hydro-electric stations
Public utilities	25.7%	31.6%
Non public "	12.7%	20.8%
Industrial plants	61.6%	47.6%

The water power stations can be subdivided into three groups:-

1. Water plants with a capacity up to 20 HP numbering about 11,628 or 88% of the total of 13,088 plants. Seventy four percent of these are driven mechanically and they are of local importance only from the point of view of industry but cannot be used to supply general distribution networks.
2. Water plants from 20 to 100 HP, numbering 1,170 or 9% of all plants. About 80% are purely mechanically driven. These have a greater economic value since they form the motive power for mills, for textile, paper, wood and similar industries. Also in many places they originated electrification.
3. Water plants above 100 HP, numbering about 370 or 3% of the total, are mostly electrified. They are built on larger

rivers and cooperate with general networks, thus augmenting their own income.

The share of water power in the electrification of Czecho-Slovakia will increase considerably, when the planned hydro-electric schemes, described above, have been completed.

C H A P T E R III

D E V E L O P M E N T

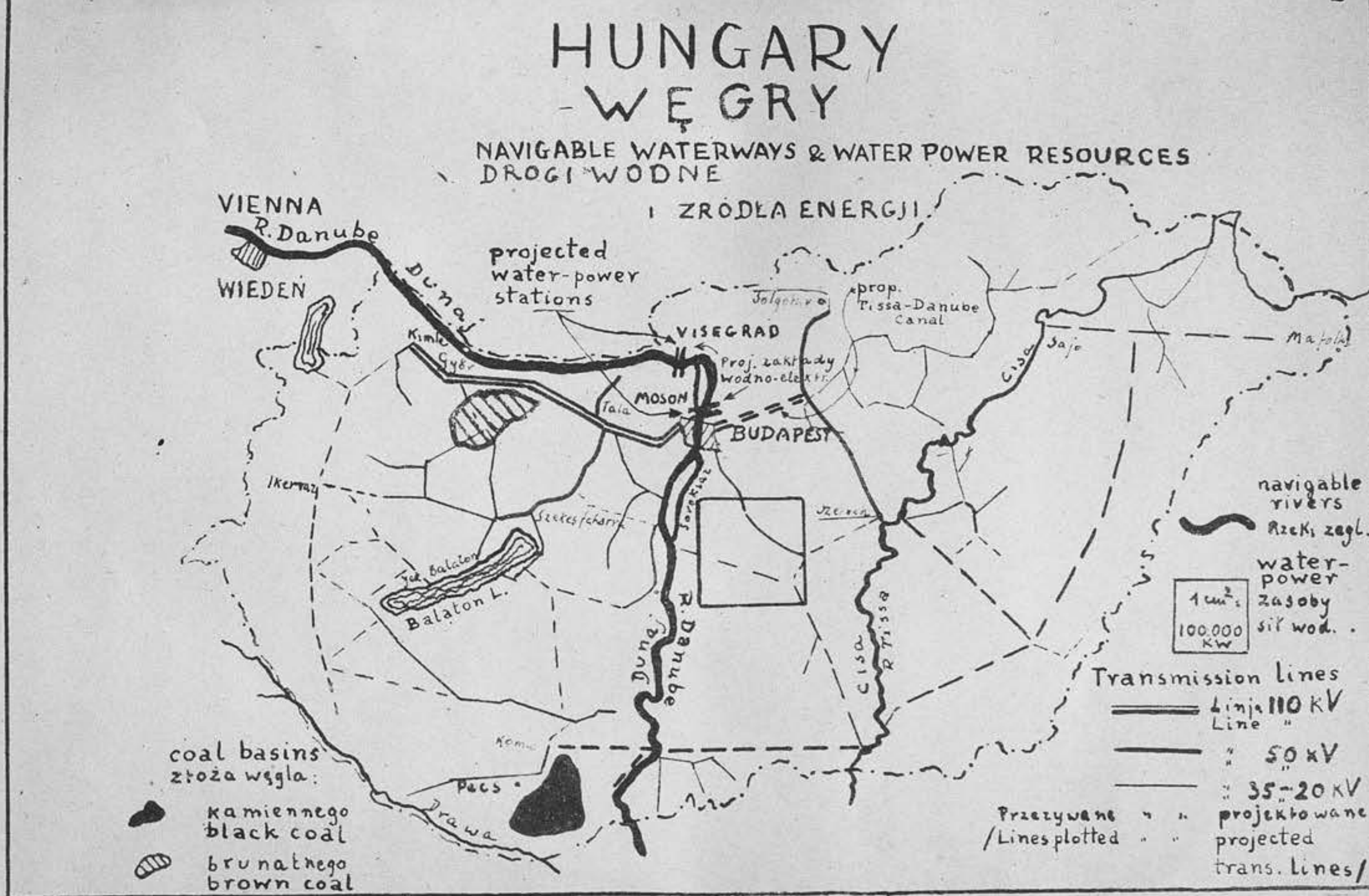
O F W A T E R W A Y S

I N

H U N G A R Y

C H A P T E R III

D E V E L O P M E N T
OF W A T E R W A Y S
IN
H U N G A R Y


HUNGARY
WĘGRY
NAVIGABLE WATERWAYS & WATER POWER RESOURCES
DROGI WODNE
I ŹRÓDŁA ENERGJI
VIENNA
R. Danube
WIEDEŃ
Dunaj
projected
water-power
stations
VISEGRAD
Proj. zakłady
wodno-elektr.
MOSON
BUDAPEST
prop.
Tissa-Danube
Canal
Cisa
Sajo
Balaton L.
R. Danube
Duna
Cisa
R. Tissa
Pecs
Drawa
coal basins
złoża węgla:
kamiennego
black coal
brunatnego
brown coal
navigable
rivers
Rzeki żegl.
water-
power
zasoby
sił wod.
1 cm² = 100.000 KW
Transmission lines
Linja 110 KV
Line "
" 50 KV
" 35-20 KV
Przezywane " " projektowane
/Lines plotted " " projected
trans. Lines/
H.H.

Development Of Waterways In Hungary.

Hungary is purely an inland state. Its territory, after the war 1914/1918 with an area of 92,963 km^2, was situated on the Great Hungarian Plain. This lowland was divided by the sluggish rivers Danube and Tissa and their tributaries, with very small slopes ranging from

$0,02\ ^0/_{00}$ to 0.1 % .

The relative differences in altitude are also very slight, and mountains are to be found only in the western and northern parts of the country. The topographical distribution of the country is as follows:

29.4%	of the area is at an altitude between	75-100 m	above the sea level
53.7	" " "	100-200 m	" " lev.
16.2	" " "	200-500 m	" " "
0.7	" " "	500-1000 m	" " "

Hungary is by nature an agricultural country, made so by the excellent alluvial soil covering the river valleys (40 to 50 km) broad and by a temperate climate giving a long growing period. However, extreme variations in temperature occur. The yearly mean temperature is 10.5^0C ; average in January - 2.5^0C ; in July 21.5^0C ; minimum - 34^0C and maximum 39^0C . The mean annual rainfall is 500 - 600 mm .

After the world war of 1914-1918 the area of Hungary was reduced to about one-third of its orginal size and the density of population has increased from 64.6 to 94 inhabitants per square kilometer. This circumstance calls for a reorganization of Hungarian agricultural production involving first the improvement of land irrigation, and second the development of inland waterways. The first of these would raise the agricultural production and make crop production safe ~~the~~ and would also stabilize the quantity of the crops. The second would provide a cheap means of transport over a dense and coordinated network of waterways.

The possibility of the utilisation of water power is small, due to the loss of the surrounding highlands where the rivers were suitable for their purpose.

The policy of utilisation of the Hungarian water resources is greatly influenced by the above circumstances. A plan was worked out in 1930 for future developments; but this presents difficulties which may be summarised as follows:

1. The flat slopes (0.05 - 0.15 $^{0}/00$) of the plains render the construction of channels difficult, because large dimensions are necessary; excavation work and expropriation costs are expensive; water must frequently be raised by pumping.
2. Water storage on plains is very difficult and expensive.
3. The construction of foundations is rendered difficult as the alluvial sub-soil is several hundred meters in depth.
4. The highlands from which the water comes are outside the country and the flow of rivers ~~x~~ cannot be controlled either by storage or in any other way.
5. Landed property has not as yet entirly amortized the investment costs for flood - control services which impose a constant

a constant charge upon agriculture.

6. The agricultural class is conservative and the spirit of enterprise is lacking.

7. The whole country, both public and private corporations, is in need of capital.

The present utilization and development of the water resources of Hungary can be classified as follows:

1. The first trend of waterworks are of a passive nature i.e. to establish good flood-control on the slightly sloping areas of the country and to provide adequate channels for carrying the back-waters from the areas liable to be inundated beyond the levees.

   Levees to a length of 7,421 km and channels to the extent of 20,425 km , for draining the marshes and carrying off harmful rainwater, have been built; two hundred and forty pumping stations with a total capacity of 22,775 HP were constructed to lift the water collected in the channels, during flood periods; 122 cut-offs were made on the Tissa, which shortened the length of the river by 37% and increased the slopes to hasten the flood run-off. Cut-offs of similar extent were made on the tributaries of the Tissa and also on the Danube.

   All these works resulted in flood protection of an area of 3.93 million hectares, one of the largest works of this kind in Europe, as is shown in the following table No 17 .

Table No 17

Country	Lenght of levees km	Protected area million ha
Hungary(The Danube and Tissa)	7,421	3.93
Italy (The river Po)	2,387	0.7
Holland	1,504	1.44
France(The river Loire)	483	0.1

2. The second step towards the utilisation of waterways was the improvement of the rivers for navigation.

Previous to 1918 there were in Hungary 6,011 km of navigable waterways, 1,114 of which remained after the post-war subdivision. The regulation works which have been carried out on the rivers Danube and Tissa, increase the length of the navigable waterways from 1,114 km to 2,486 km and will be described later. The navigable waterways serve to carry mainly the agricultural products and also bauxite which is the chief raw material in Hungary. The output of bauxite is 550,000 tons per year.

3. The third step in water utilisation is that of irrigation and this is of the greatest importance in Hungary.

To provide for the growing population and effect the necessary counter-balancing of the considerable imports of industrial raw materials, Hungary must develope, ~~as this is~~

in quality and quantity her agriculture as this is the chief source of export. As I have mentioned above no considerable progress has been made in land irrigation and it is still in the state of being planned. The Government plans in this connection were worked out for a first period which dealt with an area off 120,000 ha .

Among the other problems connected with the utilization of water the following may be mentioned:-

4)Fishing in navigable waterways has suffered much from flood control and river regulation works. This circumstance has given rise to the development of another branch of agricultural water utilization in the form of fish ponds,initiated by the National Fisheries Committee. One hundred and sixty six fish ponds and forty - one fishing companies exist in Hungary and the annual production amounts to 7,500 tons, an average of 1,400 tons of which is exported.

5)The supply of drinking water is provided on the plains chiefly from deep artesian wells; sometimes it is obtained from spring -water and sometimes from ground-water sources. The disadvantages of the low - lands are evident in this case as the supply of water and its distribution are very expensive as water must be pumped to considerable heights.

6)An important factor from the point of view of national economy is the utilization of water resources for public hygiene,bathing and water-sport purposes. In this connection may be mentioned Lake Balaton,the largest lake in Central

Europe having a surface area of 670 sq.km and particularly the medicinal and thermal springs numbering about two hundred and eighty in all. The thermal springs in Budapest having a daily discharge of 22 million litres and including the second warmest spring in Europe, are visited by 3.3 million people annually, mostly from foreign countries, and offer a valuable source of income for the country.

7. The water-power development in Hungary is restricted by natural conditions. Of the water power resources 94.5% was lost after the war of 1914-1918.

Some suggestions for solving this problem by means of the canalisation works proposed on the part of the river Danube, above Budapest, will be described later, in the Chapter on the Oder-Danube Canal.

<u>The river Danube.</u>

The river Danube flows in its upper sector as a frontier-river between Czecho-Slovakia and Hungary. Further on, at the mouth of the river Ipel it enters Hungary and later leaves it above the mouth of the river Drava.

The upper sector was described in the chapter on the Czecho-Slovakian Danube.

The improvement on the lower sector has been under consideration since 1877 and much regulation work has been carried out.

The Hydrographic data of the Hungarian section of the river Danube are as follows:

The fluctuation in the levels is very considerable; the difference between the level of the low-water and that of the maximum highwater varies from 7 to 9 metres.
The width of the river changes from 400 m to 900 m.
The average flow discharge at the town of Szob is 1,380 m^3/s.
The regulation works carried out on the Hungarian section of the Danube were based on Girardon's rules, which were derived from close observation of natural phenomena and the course of the river has had to be very little changed from its natural channel.
A coordinated series of curves with varying curvature has been formed, and the concave sides of the bends, attacked by the water, have been mostly stabilized by applying bank protection works, or training walls, if the regulation line is not close to the bank.
For the protection works of the Danube brushwood (fascine) and stone-rubble are the chief constructional materials. The use of concrete blocks has recently been increasing chiefly in sections of the river in which gravel is available. They have proved useful, too, in withstanding the destructive forces of wave action resulting from the backwash of the trains of barges towed at high speed.
The chief object of these regulation works to ensure a minimum depth of 2 metres during low water and over the whole distance of the Hungarian Danube, has not yet been achieved.

I must add that just below Budapest there exists a navigable lateral arm of the Danube, called Soroksar branch, where a free port on Csepel Island is situated. The arm branching off from the main river was closed by a dam as early as 1876, as a consequence of flood-control works. This dam, is now removed and the 58 km of waterway form in fact a canalized river, connected with the Danube, with locks at both ends; and in addition water power is now developed there. In the lower section of this canal there is a navigable depth of water but in the upper section the bed was dredged for a distance of 17 km and a width of 25 metres for navigation.

The deeper channel occupies only one third of the water-surface, which is 120-150 m wide, in the upper section, and 200-240 m in the lower section of the canal. The rest of the cross-section of the canal is covered with reed and sedge, thus providing full protection against wave action, except at certain open spaces, where various methods have been adopted for the protection of the banks.

Another two sections of the Danube, at the town of Visegrad and on the Moson arm of the Danube are suitable for future canalisation works. These proposed works, which I will describe in the Chapter "Oder-Danube Canal" will help condiderably in improving the navigation conditions and will also provide for the utilization of water power.

Transport on the Hungarian Danube amounted to 2.2 million tons in 1941, 50% of which was traffic for Germany.

The commercial fleets on the Hungarian Danube in 1940 consisted of 46 passenger boats 35 tugs, 240 barges of 140,123 tons carying capacity, 16 tankers of 11,058 tons capacity.

The river Tissa.

The river Tissa had a natural length of 1,127 km, but as a result of the regulation works, which have been completed so far this length has been shortened to 669 km, and this has increased the slopes as follows:

a) on the section between Ujlak and Tokay from 0.08^0/00 to 0.12^0/00

b) " " " Tokay and Csongrad from 0.025^0/00 to 0.045^0/00

c) " " " Csongrad to the mouth from 0.020^0/00 to 0.027^0/00

Regulation also speeded up the flood run-off and shortened the duration of floods to 60% of the previous time.

Levees, to a length of 3,555 km, have been built to protect an area of 2.58 million ha.

The distance between levees, calculated for a flood discharge of 3,800 m^3/s, is at least 750 m and increases to 1000 m in the middle and lower sections of the Tissa, according to the regulation scheme.

The difference between the level of the lower water and that of the maximum high-water amounted on the Tissa from 9 to 11 m before the regulation cut-offs were made.

Now, after shortening the length of the river, these differces are as follows:

at Tokay - 7.8 m ; at Szeged - 9.0 m and at Titel-6.0m.

The levee crests exceed the highest flood water level by 1.5 m and the breadth at the crest is about 6.0 m , but in spite of this precaution a wave action in windy weather still necessitates considerable protection works of nearly one thousand km in length at the time of protracted floods.

The provision of flood protection in the exceedingly broad x valley of the Tissa is a most important task,since an area of 10,000-100,000 ha might be inundated in consequence of a single break in a levee. For this reason the problem has been very thoroughly investigated. Because of the extraordinary length of the line of defence levees,protection must be obtained by the simplest and cheapest means,but,as the defence material must be stored in large quantities,security has proved extremely costly.

Stone is very scarce and expensive along the Tissa and in general brick is the natural alternative for use as revetment material. In less important plans straw,corn-stalks,brushwood, pegs and earth etc. are used.

A prominent Hungarian product is wheat, from the valley of the Tissa,which owing to its excellent quality compares favourably with the best kinds of wheat from all parts of the world and forms a considerable part of Hungarian export.

It is proposed to build the Tissa-Danube Canal to obtain more favourable freight charges. This canal would serve also to import stone from upper Danube in order to facilitate the protection works in this rich valley.

A detailed description of the proposed canal will be given in the Chapter on the Oder-Danube-Black Sea Canal.

Water Power As A Part Of The Energy Resources in Hungary.

Hungary is not rich in sources of energy. After the war of 1914-1918 her sources in water power were reduced to 6% and in forestry resources to 11.4% of their orginal quantity. The remaining area of forest in 1939 was 10,550 km^2, and consequently the yearly production fell from 9.5 to 1.3 million m^3. Instead of her previous exports she must import at least 150,000 tons of firewood supplied mostly by Rumania.

Hungary has no productive mineral-oil resources. The research borings carried out by the Hungarian treasury, and the European Gas and Electric Co. have had good results in producing oil, and an asphalt deposit which promises to be productive.

Hungary's petroleum (crude oil) requirements were mostly covered by imports from Rumania amounting roughly to 180,000 tons per year until 1938. Later Hungary has developed an annual output which now exceeds 200,000 tons per year, and may soon have an export surplus.

The coal mines of Hungary are generally classed in three mains groups: 1) lias coal mines, 2) brown coal mines and 3) lignite mines.

The total reserves of coal are estimated to be 1,818 million tons, only 38.4% of which possesses relatively high caloric value i.e. more than 3,500 calories per kilogram. The reserves of peat are estimated to be 98 million tons, so far not developed.

Of the total output of all collieries in Hungary brown coal mines represent 83 percent, lias mines 11 percent and lignite - 6 percent. In the years 1925-1938 the production of these coals varied from 6.33 to 8.1 million tons per year, which reduced to the equivalent of black coal correspond to 2.8-3.8 millions tons. These quantities were not enough for the normal consumption per head before 1914-1918, and 40% had to be imported, but due to the necessary counter-balancing of import and export; the import of coal varied from 20.2 to 4.9% of the total comsumption.

The figures, regarding the comsumption in percentages are as follows:

Industry - 26.6%; Railways - 25.4%; Collieries -11.0%
Electrification - 9.1%; Heating - 8.8%;
Agriculture - 4.2%; Navigation - 0.8%.

Water Power.

Because of the present state (before 1939) of the country a considerable utilization of water power is impossible. Owing to unfavourable topographic conditions Hungary's rivers that carry large volumes of water cannot be dammed up, and the utilizable heads are about 5 to 6 meters on the average. In spite of such conditions the available water power of the two rivers, the Danube and the Tissa, and their tributaries can be estimated at:

120,000 kW for low water , and

220,000 kW for mean water.

The present development of water power in Hungary is very small. According to statistics there are 2,300 small plants, with total capacity of 12,000 kW .

Sixty percent of these plants are mostly serving the purposes of the milling industry,so that only about 40% of 12,000 kW i.e. 4,900 kW capacity is used exclusively for the production of electrical energy with a yearly output of 11.2 million kWh. Among these water power stations only five have capacity of over 100 kW .

Electrification of Hungary.

Data regarding electricity production and distribution,which are collected by the Royal Hungarian Ministry of Industry, shows that systematic development of central stations is in progress chiefly to save the consumption of coal. The scheme of electrification,which has been carried out since 1927 tends to reduce the consumption of coal in railways to 60% in collieries - to 50% and in agriculture - to 70% of the present values.

The proposed power stations are based primarily on steam generation and only two water power stations were projected:

1. The water power station on the Moson arm of the Danube,with a flow of 300 m^3/s; 14 m head ; a capacity of 35,000 kW ;
2. The water power station on the river Hernad at Tissaluc, with a flow of 40 m^3/s,and a head of 13 m , with a capacity

of 4,300 kW .

The production of electricity in Hungary was in 1935 - - 810 million kWh ; in 1938 - 1,080 million kWh ; in 1940 - - 1,200 million kWh with a power capacity of 770,000 kW .

The consumption of electricity was distributed as follows:

1. Industry - 65% (chiefly in steel works, the output of which amounts to about 1 million tons of steel);
2. Domestic use - 16.4%;
3. Communication - 14.3% (chiefly electric railway Budapest--Vienna);
4. Towns - 38% (electric light);
5. Agriculture - 0.5% .

Hungary has great reserves of bauxits, these being estimated at 250 million tons or nearly a quarter of the world's total. As the power resources are small it has not been possible to produce electrical energy in large quantity and to develop the aluminium industry with the result that almost all the bauxite is exported.

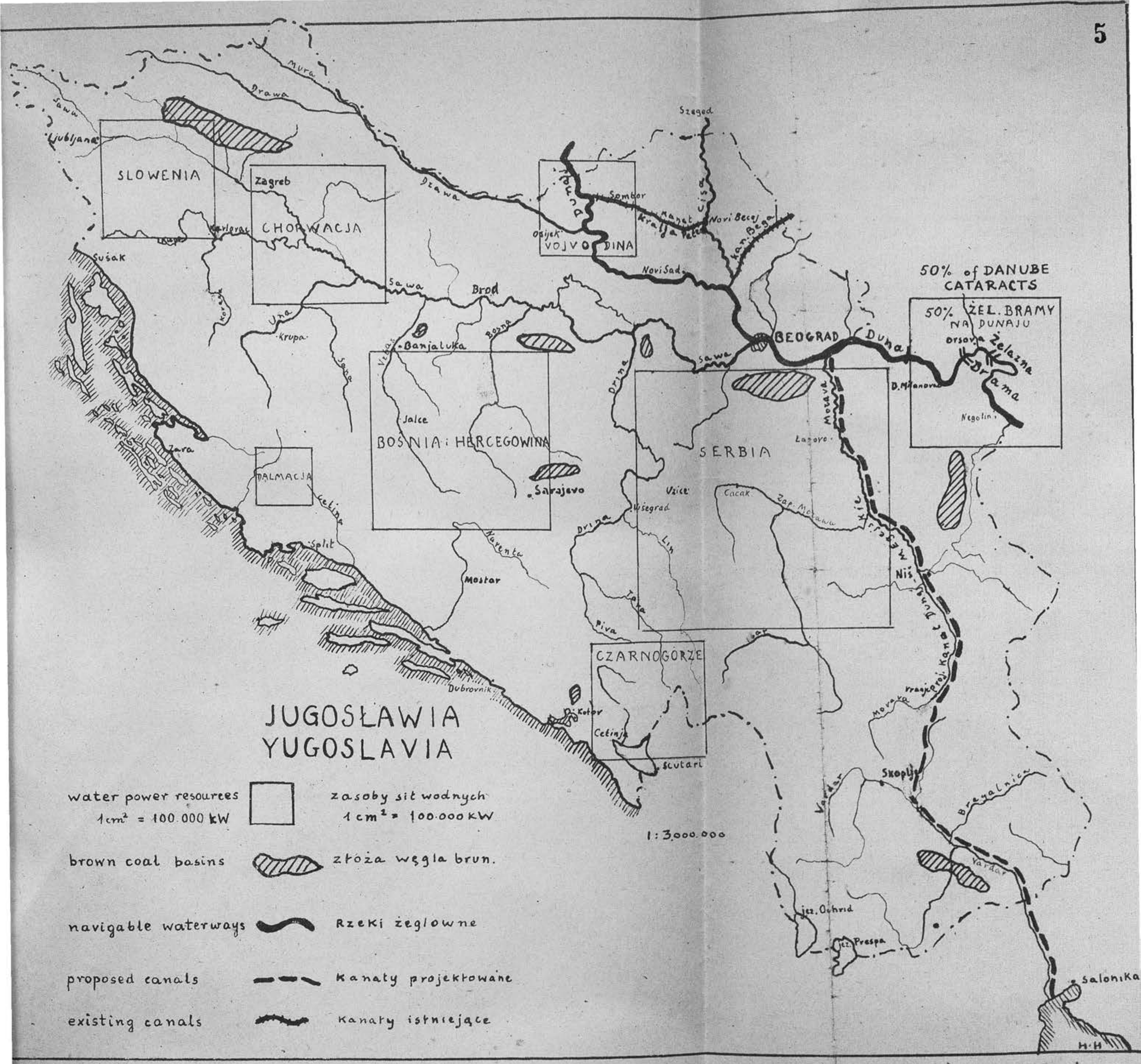
C H A P T E R IV

D E V E L O P M E N T

OF W A T E R W A Y S

IN

Y U G O S L A V I A


JUGOSŁAWIA
YUGOSLAVIA
water power resources 1cm² = 100.000 kW
zasoby sił wodnych 1cm² = 100.000 kW
brown coal basins
złoża węgla brun.
navigable waterways
Rzeki żeglowne
proposed canals
Kanały projektowane
existing canals
Kanały istniejące
1:3.000.000
50% of DANUBE CATARACTS
50% ŻEL. BRAMY NA DUNAJU
SLOWENIA
CHORWACJA
VOJVODINA
BOSNIA i HERCEGOWINA
DALMACJA
SERBIA
CZARNOGÓRZE
Ljubljana
Zagreb
Karlovac
Sušak
Zara
Split
Dubrovnik
Kotor
Cetinje
Scutari
Mostar
Sarajevo
Jalce
Banjaluka
Krupa
Brod
Osijek
Sombor
Novi Sad
Novi Becej
Szeged
BEOGRAD
Orsova
D. Milanovac
Negolin
Užice
Višegrad
Cacak
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Bosna
Drina
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Cisa
Kanał Kralja Petra
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Morava
Zap. Morawa
Lim
Tara
Piva
Ibar
Neretva
Cetina
Vardar
Bregalnica
Żelazna Brama
H.H

Development Of Waterways In Yugoslavia.

Yugoslavia has territory measuring 284,000 km^2, situated for the greater part in mountains the highest peak of which is called Triglav at an altitude of 2,864 m above sea level.

Before the present war its population amounted to 15 million inhabitants.

The orginal official name of the country, the Kingdom of the Serbs, Croats and Slovenes was abandoned in favour of the name Yugoslavia in 1929, which indicated the definite adoption of a unitary as against a federated basis for the new state.

The territory of Yugoslavia is divided hydrographically by the great watersheds between the Black Sea, Adriatic and Aegean Sea.

Approximately 74% of the surface of the country belongs to the Black Sea basin, and 12% to the Adriatic Sea, in spite of the very long coast line of 965 km.

Yugoslavia has been abundantly endowed by nature with water power resources.

In general the country consists of rugged highland valleys with the rivers descending steeply to the sea level or the Danube, and many natural falls are to be found.

On the other hand the natural precipitation, 460-500 mm per year and its distribution are normally not sufficient to meet the requirements for the economic development of hydro-electric stations without storage reservoirs.

For this reason the development of water power in Jugoslavia is, in general, accompanied by the construction of reservoirs, to store the flood water and utilize it in the dry season of the year. The higher parts of the country offer many facilities for the construction of storage reservoirs and on the steep descents there are many sites suitable for power stations of moderate capacity.

The present utilization and development of the water resources of Yugoslavia can be classified as follows:

1. The first trend of the development of water power for electrification is to create and maintain the aluminium and steel industries, for which there are great reserves of suitable ores in the country.
2. The second step towards the utilization of the water resources is the improvement of the large rivers for navigation i.e. the Danube, the Tissa and the Sava.
3. The third step in water utilization is that of serving agriculture, especially in the north of the country, where the importance of melioration works is evident.

Water Power As A Part Of The Energy Resources In Yugoslavia.

In spite of the abundance of raw materials Yugoslavia did not greatly develop her industries because of the lack of fuel and it follows that the generation of electricity from the water power resources is of the utmost importance.

Mining has undergone considerable development in Yugoslavia and the exports of ores are of considerable importance in the mineral econpmy of Europe.

Bauxite

The reserves are estimated to be 100 million tons,or nearly 10% of the world's total. In recent years the production contimued to increase and in 1939 reached the amount of 500,000 tons or nearly 14% of the world's total. The following table No18 shows the development of production of bauxite in Yugoslavia.

Table No 18

Year	1931	1932	1933	1934	1935	1936	1937	1938	1939
Production of bauxite in thousand tons	64.8	67.1	80.9	84.8	216.2	292.2	353.2	406.4	500

Yugoslavia's output of bauxite,almost as great as the Hungarian level, is nearly all exported to Germany.

Copper ore

The Yugoslavian copper supply similarly assumes an importance, out of proportion to its magnitude,in comparison with the total world output. The average output of copper ore(content) is 40,000 tons or nearly 28% of total European output.The copper deposits are mostly controlled by the French Mines de Bor Company,which also extracts most of the gold,produced in the country from the same ore in quantity of about 2,500 kg per year.

Chrome ore.
The chrome ore output of Yugoslavia also forms a fairly important part of world production though not so important as that of Turkey. In the European production of chrome ore (Cr_2O_3 content), Yugoslavia plays the greatest part, because ~~theyproo~~ she produces 28,000 tons or nearly 56% of the total European output.

Lead ore.
The ouput of lead ore increased in Yugoslavia and in 1938 reached the amount of 83,000 tons, or nearly 5% of the world's total or 25% of the European total.

Zinc ore. (content).
The production of zinc ore in Yugoslavia forms also a fairly important part of European production. The output in 1938 was 48,800 tons or nearly 10% of European ~~total~~ total. The maximum output of 59,300 tons was in 1933 .

Iron ore.
The reserves of iron ores are estimated to be 350 million tons, 230 million tons of which are situated in Ljubija basin, and the remaining 120 million tons in Vares basin.

The production of iron ore in 1938 amounted to 1.1 million tons, which includes 300,000 tons of metal, mostly destined for export.

Among the fuel sources we may specify the following:

Brown coal.
~~Brown coal~~ The main fields of brown coal in Jugoslavia are situated in the West, Central and East regions.

In the West, between the rivers Sava and Drava from the town of Zagorje to the town of Pitomac, the reserves are estimated to be 1,629 million tons.

In the Central region there are four (districts distinct):

a) in the valleys of the river Spreca and the river Jala, the reserves are estimated to be 3,500 million tons;

b) at the mouth of the river Drina - 100 million tons;

c) near Serajevo - 650 million tons;

d) and near Banjaluki - 300 million tons.

In the East region, in Macedonia, the reserves of brown coal are estimated to be 2,000 million tons, so far, not exploited. Thus the total reserves of brown coal in Yugoslavia amounts to 8,677 million tons; the caloric value of which varies from 3,000 to 3,700 calories per kilogram, excluding a small quantity of reserves which possesses higher value.

The total output of all collieries in Yugoslavia in 1938 was 5.3 million tons, which reduced to black coal equivalent represents 2.2 million tons. These figures show a double increase as compared with those of 1922.

Forestry.

Jugoslavia is rich in forest resources. The total forest area in 1939 amounted to 7,780,000 ha , or 31% of total area.

According to the type of timber, in percentages of the total area, they are as follows:

5,810,000 ha deciduous trees; 850,000 ha pine and fir trees; 1,120,000 ha - mixed trees.

The importance of the forest areas in the different countries of Yugoslavia is brought out by the following table No19 , showing the percentages of forest areas to the total area :

Table No 19

Bosnia	50%	other countries
Croatia	34%	possess forest areas
Slovenia	43%	below the average 31%
Serbia	31%	

The average yearly production of timber amounts to 16 million m^3, which reduced to black coal equivalent (6,000 cal/kg) gives 3.2 million tons, or nearly 1.5 times more than that of brown coal.

Firewood is used mostly for home consumption and is exported on a small scale.

Yugoslavia has had large surpluses of sawn wood for which markets have been found in Germany and Italy.

Crude oil(petroleum).
Yugoslavia has a very small output of petroleum but new drillings are now being made.

Water power.
The chief source of energy is estimated to be 10.2 million HP capacity at mean water. ~~discharge~~.

Discharge estimates as to the available water power resources in different counties of Jugoslavia are shown in the following table No 20 .

Table No 20

Country	Water Power resources at low water level HP	at mean water level HP	% at mean water level %
Serbia	1,265,568	3,796,974	37.0
Bosnia and Hercegovina	621,141	1,864,423	18.2
Croatia	356,836	1,010,563	9.9
Czrnagora (Monte Negro)	280,089	840,257	8.2
Slovenia	260,308	780,224	7.6
Vojvodina	159,280	477,840	4.7
Dalmatia	59,700	179,100	1.7
50% of the frontier Danube at Iron Gate and other rivers	800,000	1,300,000	12.7
total	3,802,922	10,249,381	100.0%

To facilitate the development of water power the Ministry of Agriculture has worked out several schemes, which are summariezed in the following table No 21 .

Table No 21

No	Name of hydro-electric station	Name of river	Head m	Capacity HP
1	Skoplje	Treska	250	250,000
2	Lake Ohride	Lin	207	200,000
3	" Prespa	Lin	219	200,000
4	Sw Juraj	Like Gorka	375	100,000
5	Dubrava Dol.	Drava	15	75,000
6	Varaždin	"	12	40,000
7	Maribor	"	14	46,000
8	Sw Orbolt	"	13	43,000
9	Brezno	"	13	43,000
10	Krsko	Sava	9	18,000
11	Kupino	Sava	1.6	4,000
12	Ostrozac	Una		22,000
13	Banialuka	Vrbas		20,000
14	Modric	Bosna		8,000
15	Brestovac	Bosna	10	10,000
16	Koviljaca	Driha		29,000
17	Jablanica	Neratva		40,000
18	Rama	Rama		25,000
19	Nova Sela	Cetina		29,000
20	Ombla	Trebisnica	260	42,000
21	Slano	Trebisnica	236	70,000
22	Sujlica	Miljac	200	2,000
23	Prisoje	Sujlica	148	9,500
24	Vinica	Ricina	83	7,000
25	Ricice	"	227	35,000
26	Lake Blata	"	112	15,000
27	Pec	Vrlika	120	27,000
28	Vitina	Tihaljena	33	8,000
29	Rastok	Tihaljena	30	1,800
30	--	Matica	17	2,400
31	Kravice	Trebirat	30	6,500
32	Zimanja	Ricica	530	15,800
33	Svica	Gacka	27	3,000
34	Kosinji Gornji	Lika	70	9,000
35	Svica	Lika	80	10,000
36	Ogulin	Dobra	107	5,000
		Total		1,300,900

Of these schemes two, those at Lake Ohrida and Lake Prespa were about to be started before the war. The difference in altitudes between these two lakes situated at 906 m and 687 m respectively above sea level, gives an effective head of 219 m . By taking the water from the latter by means of pipes to the river Urak a second fall of 207 m may be obtained.

The water flow varies from 20 to 40 m^3/s, but in order to conserve the surplus rain water for dry periods it is only necessary to raise the water level in the lakes by 1.0 m . In this way a great volume of flood water amounting to 800 millio m^3 can be stored and it is possible to regulate the discharges and thereby improve the efficiency of the hydro--electric stations.

The yearly output capacity estimated for these two stations is to be 1,500 million kWh .

The present development of water power in Yugoslavia amounts to 300,000 HP or nearly 3% of the vast potential of water power resources in the country.

Among medium sized hydro-electric stations in Yugoslavia the following are most important:

on the river Drava at Fala with 47,800 HP capacity and a head of 13.2 m , which supplies electricity for the town of Maribor;

on the river Cetina at Gubavica with 36,000 HP capacity and a head of 110 m ;

on the river Krka at Morojlovac with 24,000 HP capacity and a head of 100 m .

The second step towards the utilization of the water resources is the improvement of the rivers for navigation.

DANUBE.
The river Danube comes into the territory of Yugoslavia near the town of Sombor, runs through the north part of the country and finally passes along the frontier between Yugoslavia and Rumania from Bela Crkva to the town of Radujevac.
Regarding the recent improvement works, we find that on the upper section of the Yugoslavian Danube the main object, the stabilization of the medium and low water channel is nearly completed, whereas the lower frontier course of the Danube, which possesses cataracts, needs further improvement on a large scale, because the harmful influence on shipping of the rapids in this stretch, can only be eliminated by the erection of dams.
Generally speaking it is still necessary to carry out maintenance and constructional works on the upper section.
The first includes the protection of existing groins and training works, and the preservation of the shapes of the existing cross-sections, which secure a minimum navigable depth of 2.0 m , except in the very dry seasons.
The second includes the protection of the solid banks for their preservation against the wave action due to motor driven shipping and the increase of speed, and the raising of the level of longitudinal dykes in the neighbourhood of the town Novi Sad, where the flood control works are not yet completed.
Quarry stone is the only kind of material suitable for the protection of the banks and capable of resisting the strong

wash, and therefore this part of construction would be costly, as in the other courses of the Danube to which I have refered above.

The lower course of the Danube on the frontier between Yugoslavia and Rumania, called the rapids of the "Iron Gates" particularly needs further improvement.

The first part of the regulation works was established in the years 1834-35 and later they were continued between 1889 and 1898 at a cost of 10 million dollars. The method of regulation adopted was not sufficient for the alteration of this very difficult and rapid passage through the Iron Gate, into a good navigable waterway acessible to large craft and permitting the passage of towed trains of barges upstream without the expenditure of considerable power.

Throughout the thousand odd miles of the navigable Danube the general type of barge used is of 650 tons, which, when fully loaded, has a draft of from 1.6 to 1.7 metres. In certain sections of the river, especially in the lower Danube in Rumania, 1000 ton barges are used and it is necessary to tranship the cargoes at the Iron Gate and on the Czecho-Slovakia Danube at Komarno (Velki Zytni Ostrov).

The alteration of the river Danube at Iron Gate into a modern navigable waterway, is obtainable in the quickest and most effective way by canalisation works, which I shall discribe in Chapter "The Vistula-Oder-Danube-Black Sea Canal".

The Yugoslavian commercial fleet on the Danube in 1940 consisted of: 16 passenger vessels,75 tugs,375 barges with capacity of 316,137 tons and 41 tankers with capacity of 31,478 t. In Yugoslavia the traffic is blocked by ice for a period varying from one to four months.

The largest ports on the Yugoslavian Danube are at Belgrade and Novi Sad.

Tissa.

The lower course of the river Tissa reaches Yugoslavia below the town of Szeged. The river regulation works,which have been done for the purpose of flood control were also of importance to shipping.

Almost all these works were carried out simultaneously with that on the middle course of the river in Hungaria.

The construction and maintenance of works along the course of the lower Tissa are being continued by the Yugoslavian Government to preserve the existing conditions for the navigation of medium sized craft. This waterway has two other branches towards the West and East.

The first - is the Franz Joseph Canal,which links the Tissa at Novi Becej with the Danube at Somber. This canal built in the XVIII century has a length of 118 km , a width at bottom of 16 m and a navigable depth of 2.0 m .

The second - is the canalized river Bega on the lower course (the upper is on the Rumanian territory). This canal has a length of 120 km, a navigable depth of 2.2 m and a width at bottom - 30 m . The works were completed in 1914 .

The profit,obtained from this canal i.e. from the cheap water -transport,accruing to agriculture and industry and indirectly through these to trade between Yugoslavia and Rumania proves the economic value of inland waterways.

The third step in water utilization of the water resources in Yugoslavia is that of flood control and the serving of agriculture in the low lands.

The North countries of Yugoslavia situated in the valley of the Danube, have a dry climate,with some rain in summer. The good soil in the Yugoslavia plains xxxxx requires schemes for irrigation and drainage and the construction of dykes to protect the rich crops against summer floods in order to increase its production.

Among the important works of these kinds are the following:

1. Drainage works in the marshy region of Negotin(Banat of Morava) by means of the regulation of the small rivers:Jasenicka, Srbovska,Dupljanska and the construction of a network of ditches;
2. Flood control in the valley of the river Kocosar(Banat of Danube) by the construction of longitudinal dykes to protect an area of 961 ha ;
3. Drainage works in the marshy region of Pancevo,containing an

area of 34,429 ha , by constructing a network of canals, pumping stations and the dykes to protect against flood-water

4. Flood control and melioration works in the region of Godomin (Banat of Danube), south east of Belgrade, which cover an area of 5,812 ha. The works would comprise the regulation of the river Jezava, a network of canals, dykes and pumping stations;

5. Irrigation works in the region of Metohija (Banat of Zeta), containing an area of 42,065 ha , by the construction of several canals and sluices;

6. Flood control along the river Sava between the town of Brody to the town of Mitrovice, by the construction of longitudinal dykes, and pumping stations. These works would protect an area of 240,000 ha. In addition it would be necessary to carry out melioration works in the region of Posavina;

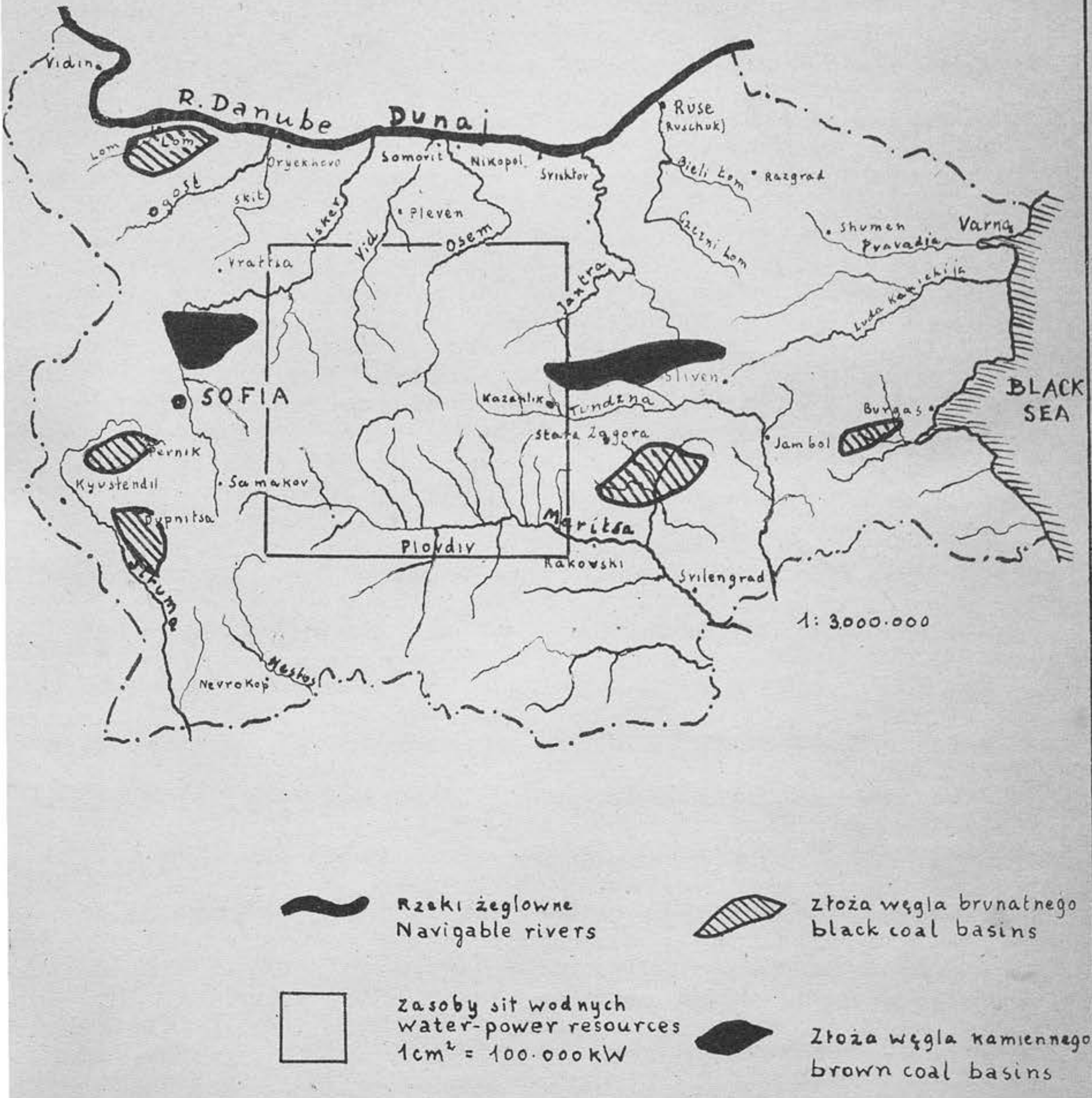
7. Some of these works have already been commenced, by the construction of the following melioration canals: Decansko-Lumbarski Canal, Lugbanarski Canal, Cerimski Canal, Jurno-Pecaki Canal, Preko-Luski Canal, Istinicaki Canal, Marnicki Canal and Grmljanski Canal, but a large part of this work still remains to be completed.

CHAPTER V

DEVELOPMENT OF WATERWAYS IN BULGARIA

BULGARIA
BUŁGARJA

NAVIGABLE WATERWAYS & WATER-POWER RESOURCES
DROGI WODNE I ŹRÓDŁA ENERGJI



H.H.

Development Of Waterways In Bulgaria.

Bulgaria, in 1939, had a surface of 103,196 km^2 and a population of 6,371,000 inhabitants, 82.4% of which was a farming community.

In Bulgaria there are few large farms, and the distribution of land is in small holdings; only 6% of the area is covered by farms of over 30 hectares, and the average over all the holdings is 5.4 ha .

In Bulgaria overpopulation of the rural communities is more serious than in other South-east coast European countries, due to the great natural increase of population. The average rate of the natural increase per 1000 of the population per year being 14.8 .

Because of the rather small natural resources of energy and minerals, the principal aim in Bulgaria is to raise the agricultural production of the country and to adjust to it market conditions; for this reason in the past six years, while the agricultural area has been doubled, that under cereals has been reduced and that under fruit and vegetables has been increased.

Bulgaria for the greater part is mountainous and the only plains are in the north, in the valley of the Danube and in the southeast, in the Maritza valley.

In northern Bulgaria, though natural conditions are much the same as in the Rumanian plains, a higher standard of farming prevails, due largely to the agricultural cooperative societies and the credit facilities available through the Agricultural Bank.

In Southern Bulgaria, as a result of an almost Mediterranean climate and good soil in the valleys, vines, fruit trees and tabacco are grown.

For her exports Bulgaria has an outlet to the Black Sea either directly or through the Danube.

After the Peace Treaty in 1919, Bulgaria lost the territory, between Kavalla and the River Maritza, leading to the Aegean Sea, which she had secured in 1913 by the defeat of Turkey.

Bulgaria also suffered seriously from the loss of the Dobrudja wheatlands, which had been her main source of wheat for export, from the loss of a port at Silistra on the Danube and the formation of a frontier in close proximity to her Black Sea port of Varna.

In Bulgaria there is great need for the development of the water resources in order to increase navigation on the Danube to deal with the problems of flood control, irrigation and drainage and to erect hydro-electric stations.

In the Chapter refering to Rumania a description was given of the section of the Danube which forms the northern boundary of Bulgaria and it was pointed out that the river is capable of taking 1000 ton craft.

The Bulgarian commercial fleet on the Danube is rather small consisting in 1940 of 11 barges with 10,790 tons capacity, 2 tugs,4 tankers with 1,760 tons capacity and 3 passenger vessels. In addition seven other vessels have been ordered from German ship-yards.

Over the whole length of the Bulgarian Danube between Radujevac and a point just beyond Ruse(Ruschuk) there are no bridges and only the ports of Vidim, Lom and Ruse.

In 1941 a ferry service was instituted between Ruse and the Rumanian port of Giurgiu. The size of the ferry is 65 m x 15m and having 770 HP,it is capable of carrying fifteen loaded railway wagons with a speed of 15 km per hour.

This ferry was constructed in Guterhoffnungs Hütte shipyard at Walsum in the Rhineland.

Water power as a part of the energy resources of Bulgaria.

Bulgaria is not rich in minerals and energy resources and although water power is relatively the largest,its amount has not yet been accurately estimated. Surveys of the more important sites are being carried out by the Ministry of Agriculture.

Coal.

The principal thermal power resource of Bulgaria is coal, of which 99.18% consists of brown coal and lignite and 0.19% of ordinary bituminous coal.

The probable reserves of bituminous coal are estimated to be 20 million tons only one million tons of which is proved.

The probable reserves of brown coal and lignite are estimated to be 1,005 million tons, 503 million tons of which are proved, they are found in the Pernik basin near Sofia,in the Burgas and Stara Zagora basins in the south-east and finally at Lom in the nothern part of the country.

The calorific value of the Bulgarian brown coal varies from 4,000 to 5,000 cal/kg .

The production of brown coal in 1938 was 1.8 million tons and of black coal only 0.14 million tons; these figures reduced to black coal equivalent give a quantity of 792,000 tons.

Wood.

The other thermal energy resource in Bulgaria is wood.The forest area in 1939 amounted to 2,901,000 ha , or 28% of the total surface of the country.

Eighty two percent of the forest lands are covered by deciduous trees. The production of wood varies on the average from 4.0 -5.0 million m^3 and is compatible with natural regeneration. Firewood is exported by Bulgaria only on a small scale.

Water power.

The development of water power in Bulgaria is administered and controlled by the Water Division of the Agricultural Ministry,according to the Law for Hydraulic Syndicates(Associations),of 11th September 1920. Since this date surveys of the more important sites heve been undertaken but are not complete.

Accurate information concerning the water power resources are lacking,but according to statistics so far furnished by the Agricultural Ministry,which made systematic observations and gaugings of the water flow in the rivers,it is estimated that the more important sources of water power amount to about 800,000 HP . This figure after the completion of the surveys of all the rivers would be increased to a probable total ree serve of about 2 million HP .

Because of the variation of water flow in Bulgarian rivers the rational utilisation of water power on a large scale is only possible if storage reservoirs are constructed.

The rivers which are taken into consideration for the utilization of water power are as follows:

1. The Ogost, the Isker, the Osem, the Jantra running on the northern slopes of the Balkan range of mountains, towards the Danube;
2. The Maritza with its tributaries, the Arda and Fundra, the Struma and Nestos, running on the southern slopes of this range of mountains, towards the Aegean Sea.

The present development of water power in Bulgaria comprises chiefly the utilization of the smaller sources, for the production of mechanical power. There are about 15,000 water power plants with a total capacity of about 210,000 kW , which furnish the power for many flour mills, sawmills, and other factories.

There are also 24 hydro-electric stations of about 1000 kW capacity each, and they provide experimental data for the erection of the larger stations planned for the electrification of the country. The total development of water power amounts to 257,000 kW .

In 1935, the electric-economy law was passed, which provides for the creation of an electrification council and electrification fund. To facilitate the development of water power the state worked out some hydro-electric schemes for a total capacity of about 300,000 kW.

In spite of the comparatively small development of water power, the share of hydro-electric stations in the total output of electricity is very high.

The existing hydro-electric stations, with a total capacity of 55,700 kW , produced 71% of energy, while the thermal stations with a total capacity of 65,620 kW, produced only 29% of the total output of energy i.e. about 150 million kWh .

The average yearly utilization factor in the thermo-electric stations is very low, about 700 hours per year, whereas in the hydro-electric stations it is relatively higher being 1,780 hours per year.

The latter value, however is still below a normal level and this is accounted for by the fact that there are no transmission lines ~~since the~~ since the process of electrification is only beginning.

C H A P T E R VI

D E V E L O P M E N T

OF W A T E R W A Y S

IN

R U M A N I A


RUMANIA
RUMUNIA
NAVIGABLE WATERWAYS & RESOURCES of ENERGY
DROGI WODNE I ZRODŁA ENERGJI
Cernauti
Prut
Dniestr
R. Dniester
Cisa
Satu Mare
Vişau
Balti
Orhei
Falticeni
Seret
Somesuri
Somesul Mare
Oradea
Bistrita
Chisinau
Roman
Dorzecza: Seret, Bistrita
Bucau
Cluj
Dorzecza: G. Cisa, Somesuri
Mures, Crisuri
Crisuri
Mures
Tarnava Mica
Tarnava Mare
Arad
Akkerman
Cogilnic
Proj. Kanał
Timisoara
Kan. Bega
Timis
Sibiu
Olt
Brasov
Galati
Ismail
Braila
Buzau
50% Żel. Bramy na Dunaju
Orsova
Turnu Severin
Żelazna Brama
Iron Gate
Radujevac
Jiu
Ploesti
Pitesti
Dorzecza: Timis, Jiu, Olt, Arges, Jalomita
Jalomita
Dunaj
BLACK SEA
BUCHAREST
BUCUREŞTI
Arges
Cerna Voda
Proj. Kanał
Constanța
Craiova
Silistra
1:3.000.000
Vidin
Giurgiu
Ruschuk
Corabia
Duna
R. Danube
Rzeki żeglowne
Navigable rivers
Zasoby siłwodnych
1 cm² = 100.000 KW
Water power resources.
Złoża gazu ziemnego (metanu)
natural gas
Proj. Kanały
Proj. canals
Złoża ropy naftowej
crude oil
/petroleum/
Złoża węgla brunatnego
brown coal
" " " " Kamiennego
black coal
H.H.

Development Of Waterways in Rumania.

Rumania is bordered on the northeast by the river Dniester; to the north the frontier crosses the chain of the Carpathian Mountains, follows the valley of the river Tissa to the West, and then runs southwards to the Danube, which forms the southern frontier. To the east Rumania is bounded by the Black Sea; into which flow the Danube and the Dniester. In the centre of the country the mountains, more than 2,500 meters high, run in a large semicircle, from the Danube to the north; these mountains form the eastern part of the Transylvanian high-lands.

All round this plateau are the regions of fertile plains; to the west the plain of the Tissa, to the south the Danubian plain, and to the northeast the plain of the rivers Prut and Seret. Other large rivers are the Somes, the Crisuri and the Mures flowing westward to the Tissa, and the Jiu, the Olt, the Arges and the Jalomita flowing southward to the Danube.

Rumania in 1939 had a surface of about 295,000 km^2 and a population of about 19.4 million inhabitans.

On account of its fertile plains Rumania is so far mostly an agricultural country, but natural resources, including gold, silver, petroleum, natural gas, water power, coal and wood are abundant and offer opportunities for the industrialization of the country, although this is somewhat handicapped by the lack of iron.

The inland trade communications are served mainly by railways, with a total length of 11,500 km , which carry about 20 million tons per year or 5,800 million t-km. While the total length of navigable waterways is 2,700 km , and thus carry 4-5 million tons or nearly 20-25% of the total traffic. The navigable waterways serve mainly to transportXXXXX wood or to carry foreign trade to the centre of Europe and the Black Sea, along the Danube route.

Of the navigable waterways only 60 km run along artificial canals on the Bega and Timis, and the remainder consists of natural rivers, the most important of which is the Danube.

THE DANUBE.

The total catchment area of the Danube is about 800,000 km^2, it is i.e. the next biggest river to the Volga. After receiving over 120 tributaries, 60 of which are of some importance, the Danube runs to the Black Sea, by three principal branches forming an immense delta.

From the standpoint of navigable conditions and international control the Danube can be divided into an upper section above Braila, and a lower section, the so called "Maritime Danube" below this port.

The upper section of the Danube proceeding down stream from the frontier, between Yugoslavia and Rumania is suitable for taking 1000 ton barges, excepting during very dry seasons.

Only the upper part of the Danube, comprising the difficult passage through the Iron Gate, which I have mentioned in the Chapter on Yugoslavia, needs important canalisation works.

At present if the biggest craft is used for long distance traffic there must be transhipment at the Iron Gate.

Below this bottle-neck at the Iron Gate, the water level varies from 0 to 8 m , in the upper reach, from 0 to 7 m in the middle reach, from 0 to 6 m and from 0 to 4 m in the lower reach.

The width of the river varies from 1,000 to 1,500 m , and the minimum navigable depth is generally, 2.0 m .

The Rumanian commercial fleet on the Danube in 1939 consisted of 553 barges with a total capacity of 469,546 tons, 66 tankers with a capacity of 41,603 tons, 127 tugs and 25 passenger vessels.

The lower section ~~between~~ of the Danube between Braila and the Black Sea, over a distance of about 200 km is considered as maritime with a navigable depth of 7.0 m below the lowest water level.

Traffic on the Danube itself is fed by road, rail and water communications, and by oil pipe lines.

Timber and grain for Danube river ports is brought down on the tributary waters; oil is brought by pipe line from the oil wells to Giurgiu. The main cargoes up-stream on the Danube are cereals, especially wheat and maize, and oil. The oil is shipped from Giurgiu to the refineries in Hungary, Czecho-Slovakia and Austria and to the distributing centre at Regensburg in Germany.

The main cargoes downstream are oil, timber and also cereals, to the ports of Braila and Galaţi on the Maritime Danube, to be transferred into sea-going ships.

The proportion of total imports and exports of Rumania carried on the Danube was as follows in 1938:

imports 13.5%, exports 17.2% .

Rumania has only some 101,000 tons of sea-going shipping, but a great deal of its trade is carried in foreign ships.

Owing to the importance of this remarkable river from the international standpoint it was natural that the originators of the recent peace treaties should have made a special study of the geographical, economical and international conditions of the Danube and should have established special regulations for it. One of these applies from the upper point where the river becomes navigable, down to the point where the maritime reach begins and the other is applicable to this maritime reach.

In accordance with the regulations laid down in Part XII of the Treaty of Peace 1919, Articles 346-353, the Danube Statute of July 23, 1921, which came into force one year later, placed the fluvial Danube, from Ulm to Braila under the International Danube Commission, generally known as C.I.D.

On this Commission Germany, Austria, Hungary, Czecho-Slovakia, Yugoslavia, Rumania, Bulgaria, Great-Britain, France and Italy were represented. The statute provided full freedom for navigation, each riparian country, having the duty of executing any works for the improvement of navigation, and of applying the navigation regulations drawn up by the International

Commission.

After the arrangement was denounced by Germany in November 1938, the Commission removed their headquartes from Vienna to Belgrade.

The change in the European situation, in the summer 1940, made it unlikely that riparian states would be able to carry the resolutions of the international statute into effect, and all navigation problems on the Danube are now controlled by Germany.

The regimen of the lower reach of the Danube, that is its maritime part, differed from the other regimen in that, on this lower reach the works and the maintenance of the channel were not executed by Rumania, the riparian country, but ~~only~~ by a European Commission, composed of representatives of Great Britain, France, Italy and Rumania (since 1919).

The role of this European Danube Commission was orginally fixed by the Treaty of Paris in 1856 and altered later on by various stipulations.

Before the war 1914-1918, a Commission on which Great Britain, France, Italy, Germany and Russia were represented, was appointed to guarantee freedom of navigation ~~of~~ to all ships, and to carry out necessary improvements in the channel through the flats of the Delta which were obstructed by reeds.

In 1919 Germany and Russia ~~and Rumania~~ lost and Rumania regained membership of the Commission. Rumania was entrusted with authority over the port of Sulina and responsibility for maintenance works at the mouth of the river and for the supervision of navigation and pilotage.

Water-Power as a part of the energy resources in Rumania.

Rumania possesses power resources of all kinds, which are sufficient to supply all home needs, and even to allow of exportation. There is at present, no rational coordinated policy for the development and utilization of the resources of energy and there is urgent need for a scheme in which water power would form the basis for the electrification of the country and the exploitation of petroleum would be to some extent restricted.

Crude oil (petroleum).

The petroleum fields form a long strip on the southeastern slopes of the Carpathian Mountains, reaching up to Bucovina (see sketch No) and smaller fields are found in the sub--Carpathian region in the south-west of the country.

The total area of the petroleum fields is estimated to be approximately 160,000 ha. The areas sounded by a sufficient number of exploration wells, and actually known as proved petroleum fields amount to only about 49,000 ha.

Of this total, the areas actually in exploitation in the recent years from 1922 varied from 3,000 to 4,759 ha, and the active wells number between 1,152 to 1,941.

The exploitation of these petroleum fields was started in 1857, and up to 1938 a total production of 124.1 million tons of ~~crude oil had been re-~~

registered. In recent years exploitation has increased with extraordinary rapidity, reaching the peak of 8.7 million tons in 1936, whereas the home consumption was 0,472 million tons in 1919 and increased to 1.9 million tons or nearly 22% the total output in 1935.

During the recent years export has grown in an extraordinary manner from 1.5 million tons in 1926 to 6.7 million tons in 1936. These figures placed Rumania in the fourth place in the list of the petroleum producing countries of the world, but Rumanian output, as will be seen from the following table, No 22, has been steadily decreasing since 1936, and the general consensus of geological opinion in Rumania seems to be that the life of the field will not be long.

Table No 22

Petroleum production in million tons	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939
	4.9	5.8	6.8	7.3	7.3	8.5	8.3	8.7	7.2	6.6	6.3

Professors Macovei, Mrazec and Patriciu show that in the year 1930 the remaining proved reserves were only 61 million tons, whereas the probable reserves would not be fixed at more than 95 million tons.

Compared to the probable reserves, the average production during past years is much too high, as at this rate exhaustion would be reached in a few years. This is a very pessimistic but undeniable statement, unless new investigations prove the reserves to be more extensive than the evaluation already stated. It is nevertheless evident that Rumanian economy demands urgent measures in order to restrain this very high production.

The Rumanian attitude to the foreign oil companies has not encouraged new drilling.

The petroleum industry was mostly in the hands of foreign capitalists:British and Dutch controling some 39.8 per cent, French - 16.6%, U.S.A. - 12.5% and Rumania - 9.7% of the out--put in 1939. Complete state control of the petroleum industry was enforced in the late summer of 1940 before the German occupation took place.

The petroleum sources have been exploited in the present years much more intensively than is normal for the following reasons:

1. The fall in price of petroleum all over the world has forced petroleum companies to intensify production,in order to maintain the rentability of the capital invested in the various installations;
2. The demand for external and internal consumption has been continually increased because of the low prices and owing to its high calorific value,petroleum has superseded the other resources of energy;
3. Rumania's revenues from export have recently been steadily falling,chiefly due to the accompanying fall in prices of exported cereals;at the some time the equivalent for one ton of goods imported has risen from 6.6 tons to 16 tons of the exported goods. An intensification of the export

of petroleum has, therefore been necessary in order to maintain the balance between external payments and revenues and for this reason the state could not impose restrictions.

Natural Gas.

Two distinct kinds of natural gas are available in Rumania, the first being petroleum gas found in the petroleum regions and the other, a gas which is almost pure methane, found in the Transylvanian plateau.

Petroleum gas contains about 66 to 77 % methane (CH_4), 5 to 21% carbon dioxide (CO_2), 3 to 6 % oxygen (O) and various other constituents. It is found in a proved area of about 50,000 ha, and a probable area of 160,000 ha. This gas flows generally under low pressure, but sometimes under very great pressure up to 60 atm, and the probable reserves have been estimated to be 20 - 40 milliard m^3. The calorific value of petroleum gas varies from 5,500 to 6,000 cal/m^3. The life of the resources of this gas depends on the duration of the petroleum exploitation.

Natural methane gas with calorific value of over 9,000 cal/m^3 contains 98 to 99% methane (CH_4), the remaining constituents being (CO_2), (N_2) and (O_2). It is found in a total area of about 50,000 ha and it flows from wells which are generally drilled to a depth of 100 to 200 m, with a pressure varying from 16 to 28 atm, but at the well of Copsa Mica it was found at 430 m with a pressure of 50 atm, and at 765 m with a pressure of 100 atm.

The utilization of this gas dates from 1913 and the maximum production reached 272 million m^3 in 1928. Since that date the production has decreased to about 200 million m^3.The probable reserves were estimated as being 72 milliard m^3 proved and 216 milliard m^3 probable,which, reckoning with an efficiency of 0.2 , would give an energy of 464.5 milliard kWh , or nearly double the energy available from petroleum. If production does not increase,the reserves of methane gas from the Transylvanian plateau would be sufficient for 300 years,but it is probable that the use ~~ex~~ of this gas will be highly intensified in the future so that this figure will be much reduced.

The natural methane gas is so far insufficiently used for the following reasons:

1. From a geographical standpoint,only petroleum gas is found in the industrial zone,whereas methane gas is found in the Transylvanian plateau far from the centres of consumption and in districts where the population is rather sparse,and where from lack of raw materials,industry cannot be developed;
2. Transport of methane gas to the distant centres of consumption was hindered by the lack of a network of pipes,and consequently the centres of consumption are largely served by other cheap resources of energy,among which are chiefly petroleum and wood;
2. A greatly increased utilization of methane gas is possible in electric power stations,but this would necessitate a large investment capital.

Forestry.

The total area of forests in Rumania is 7,134,000 ha or much nearly 24% of the total area of the country. Regarding the kind of timber there are 1,615,000 ha of pine and fir trees, the remaining areas having mixed trees.

The normal production compatible with natural regeneration could be 16 million m^3 per year, of which 7 million m^3 is constructional timber and 9 million m^3 is fire wood.

Meanwhile the present production of wood varies from 20 to 25 million m^3, 8-10 millions m^3 of which is construction timber and 12 - 15 million m^3 is firewood. Production at this excessive rate would lead to the destruction of all forests in about 200 years.

In home consumption 60% are used for domestic purposes as fuel, and 40% in industries, paper mills and in construction work.

Export of wood reached the maximum quantity of 2.55 million m^3 in 1924, the average is about 2.0 million m^3. which comprises fire wood and sawn wood.

The intensive exploitation of wood can be explained as follows:

1. The favourable geographical situation of the forests, which allows easy water transport (rafting) towards the internal centres of consumption as well as towards the Danube ports for export;
2. Wood is extensively used because the cheap labour allows the realization of good returns for any enterprise, even at low selling prices;

3. The lack of restrictive control so that the private enterprises in many cases, do not respect the limits of natural regeneration.

Black coal.

Black coal, in which category are included anthracite and bituminous coal, are found chiefly in the Province of Banat. Anthracite, with a high value of 8,000 to 9,000 cal/kg is found only in a single mine at Gorj, but the reserve is small being approximately 100,000 tons.

The probable reserves of other bituminous coals, with a caloric value varying between 4,800 and 8,000 cal/kg are also small; they amount to about 30 to 48 million tons, 26 million tons of which are proved, and are scattered in various mines in Banat. Another optimistic estimate shows that the probable reserves of black coal may be 1,620 million tons.

The present production of black coal in Rumania reaches a maximum output of only about 400,000 tons, with an average of about 200,000 tons per annum.

Brown coal and lignite.

Brown coal and lignite , on the contrary, are to be found in Rumania in rather large quantities. The probable reserves exceed 2,839 million tons , and the proved reserves are estimated to be 996 million tons.

The brown coal reserves are situated mostly in the north of Transylvania, and are scattered in various mines at Lapusi, Zalan, Baia de Cris, Moldava, Comanesti and Falticeni and in the valley of the river Jiu, at Petrosani, Lupeni, Vulcana and

Livezeni.

The lignite reserves are situated in the sub-Carpathic region from the valley of the river Olt to the valley of the Dambrovita, and smaller seams are found in Transylvania at Carpeni and Bara Olt and in Crisana at Derma and in Bassarabia at Imputia Bolgrad.

The calorific value of brown coal varies from 4,200 to 6,500 cal/kg and that of lignite is about 3,500 cal/kg.

The production of brown coal and lignite has grown from 1.35 million tons in 1919 to a maximum of 2.85 million tons in 1927, from that date the production fell again to a minimum of 1.3 million tons in 1933, and slowly increased to 1.9 million in 1937.

The total output of all kinds of coal in 1938 reduced to black coal equivalent was 992,000 tons.

Admitting an average yearly production of 2.0 million tons of brown coal and lignite, the exhaustion of the corresponding brown coal reserves would take place in 850 years and lignite in 3,700 years. Production could therefore, be considerably increased.

The present reduced utilization of coals is due to the fact of the relatively high cost of mining and the long distances from centres of consumption.

Peat.

Peat has not so far been exploited in Rumania; it is found in Transylvania and in the Danube delta. The probable reserves are estimated to be 67 - 130 million tons, respectively in Transylvania and the Danube delta. The calorific value of the peat is about 2,500 to 3,500 cal/kg .

Water power.

The development of water power has been neglected in Rumania in the past, because of the remarkable wealth of the country in thermal resources. After the first signs of over-production of petroleum and wood, and the indication of their exhaustion - systematic studies and inventories of all water power resources were made from 1923 onwards, due to the initiative of the Rumanian Institute for Development of the National Energy Resources.

The available water power resources in the whole country, at mean flow water are estimated to be about 6 million kW , and their output capacity, on the assumption that all flows could be used, which would necessitate important storage reservoirs, would reach 36 milliard kWh per year.

The water power resources with higher heads are situated along the Carpathian slopes, while on some larger rivers, such as the Olt and the Mures, favourable sites are found for the construction of hydro-electric stations with medium and low heads; among the latter, the Danube itself constitutes a very important reserve of energy in the rapids of the Iron Gate, 50% of which belongs to Rumania.

The water power resources are summarized in the following table No 23 .

Table No 23.

Basin	River	Capacity in KW at low water level	Capacity in KW at mean water level
Tissa	Upper Tissa	32,000	90,000
	Somesuri	90,000	266,000
	Crisuri	40,000	116,000
	Mures confluents	320,000	912,000
	Bega	3,000	10,000
	Total	485,000	1,394,000
Danube	Timis	50,000	150,000
	Confluents Timis	30,000	107,000
	Jiu	100,000	304,000
	Olt and confluents	380,000	1,130,000
	Arges	70,000	200,000
	Jalomita	80,000	231,000
	50% of Danube cataracts	520,000	720,000
	Total	1,230,000	2,842,000
Seret	Upper Seret	60,000	178,000
	Bistrita	130,000	356,000
	Lower Seret	140,000	332,000
	Total	330,000	866,000
	Remaining rivers	230,000	826,000
	Grand Total	2,275,000	5,928,000

The present development of water power is very small in comparison with these great resources.

The total water power utilization amounts to 135,000 kW capacity and 184 million kWh output capacity per year, or nearly 2.3% of the total sources.

Compared to the total consumption of energy in Rumania, which is estimated at 10 milliards kWh, the water power stations producex extremely little energy, representing only 1.8% of the total. Due to the very small amount of electrification in the country the share of water power in the production of electricity is greater, being about 20% .

Water power resources are not sufficiently utilized for the following reasons:

1. The water power resources have not been adequately studied in the past in comparison with other better known resources;
2. The geographical situation of water power sites in Rumania does not coincide with the centres of energy consumption;
3. The flows, in general, are not favourable, having the maximum flow in spring and summer, and a very pronounced minimum in winter, which necessitates the creation of storage reservoirs;
4. The planned construction of water power stations should be coordinated with the general electrification of the countrry, which so far is not in progress on a large scale.

The present development of water power can be divided into three classes: hydro-electric power stations, hydro-mechanical stations and water wheels, the production of which is shown in the following table No 24 .

Table No

	Capacity kW	Production per year kWh
Hydro-electric stations	53,000	124,000,000
Hydro-mechanical stations	32,000	40,000,000
Small mills and saw-mills	50,000	20,000,000
Total	135,000	184,000,000

Among the 24 hydro-electric power stations, the largest situated at Dobresti has 16,680 kW, supplies Bucarest; 5 stations have a capacity between 1,000 and 3,000 kW, another five between 500 and 1,000 kW, all the rest are smaller stations. Over 60% of all hydro-electric stations have thermal reserves installed. The average yearly utilization factor is very low, for instance in 1934 : 2,530 hours per year for the hydraulic part and 1,193 hours for the thermal part in hydro-electric stations with thermal reserves.

For industrial plants the corresponding figures were 2,092 and 1,515 hours.

Electrification of the country.

Power capacity and output of the electric power stations in Rumania are rather small, but have grown continuously. Classified by categories of power stations, this development can be seen from the following table No 25 .

Table No 25 .

Year	Capacity Electric stations	Capacity Industrial plants	Capacity Total	Production Electric stations	Production Industrial plants	Production Total
	thousand kW.	....		million kWh.	....	
1925	105.6	69.4	175.0	171.8	178.2	350.0
1935	217.0	218.0	435.0	415.0	452.0	867.0

The total electric production increased to 1,100 million kWh in 1937.

Resources of energy used for the generation of electricity in percentages of the whole output in the utility stations are as follows:

petroleum	45%
natural gas	20.6%
water power	19.5%
brown coal	8.2%
lignite	5.2%
wood	1.5%

The Rumanian Institute for the development of the National Energy Resources has formulated a rational coordinated policy in order to utilise these resources.

In order to make a comparison between the various forms of energy, it was decided to assume an arbitrary period of 100years as the period for complete exhaustion and to use, as a basis for calculation, the actual consumption for the year 1935, this being assumed to remain constant.

In order to compare the thermal and hydraulic resources readily the yearly utilization is expressed in kWh in all cases.

Table No 26.

Power resources	Rational utilization with exhaustion in 100 years		Present utilization (1935)		Probable time of exhaustion in years
	milliard kWh per year	%%	milliard kWh per year	%%	
Petroleum	2.21	2.77	19.50	63.42	11
Petroleum-gas	0.465	0.58	3.04	9.89	15
Black coals	0.75	0.94	0.46	1.49	163
Brown "	22.15	27.81	1.92	6.25	1160
Lignite	9.00	11.32	-	-	
Peat	13.95	1.75	-	-	
Methane	4.18	5.25	0.43	1.39	970
Total exhaustible sources	40.15	50.42	25.35	82.44	
Firewood	3.49	4.38	5.22	16.98	
Water power	36.00	45.20	0.18	0.58	
Grand total	79.64	100.00	30.75	100.00	

Comparing the figures of this table we may draw the following conclulusions:

a) Petroleum is the most gravely menaced resource and it is necessary to restrict its exploitation;

b) Firewood is at present exploited in a higher quantity then permitted by natural regeneration. The consumption of wood as fuel should be partially replaced by brown coal, gas and electricity.

c) Natural xxx petroleum-gas is not completely used and a great part of the gases that issue from petroleum wells are lost and not utilized.

d) Natural methane gas is even less utilized compared with its rationally possible utilization.

The creation of electric power stations, using gas as fuel, and situated in the gas districts would very well serve as auxiliary power stations for the demand of energy which cannot be provided by hydro-electric stations at certain periods, especially in the winter-months. Similar combined gas and hydro-electric stations are in use in Poland.

e) Water power is the least used of all the resources although it represents 36% of the total energy available. It could be used with advantage as the basis for the supply of electricity to the country.

To complete the description of Rumanian natural resources I would like mention the mineral resources.

Bauxite reserves have been estimated in recent years to be 10 - 12 milliard tons, but only 20 million tons are proved. The output of bauxite was 11,800 tons in 1938.

Gold deposits, are situated in Transylvania, and they are amongst the largest in Europe, the production being 5,465 kg in 1937.

Silver deposits, also situated in Transylvania gave a production of 25,600 kg in 1937.

Manganese ores,found in Bucovina and estimated at 9-10 million toms contain 14% to 40% of metal content. The average yearly output is about 50,000 tons,with about 18,000 tons content.
Iron ores are not found in large quantities in Rumania.The estimated reserves are 20 million tons in the Banat; the output of which in 1937 was 130,000 tons with 63,000 tons of metal content.
Moreover Rumania possesses deposits of molybdenum ores,the next largest in Europe to the Norvegian resources,; chrome ores, copper ores, pyrites, which Rumania has recently begun to produce; and finally large salt mines.

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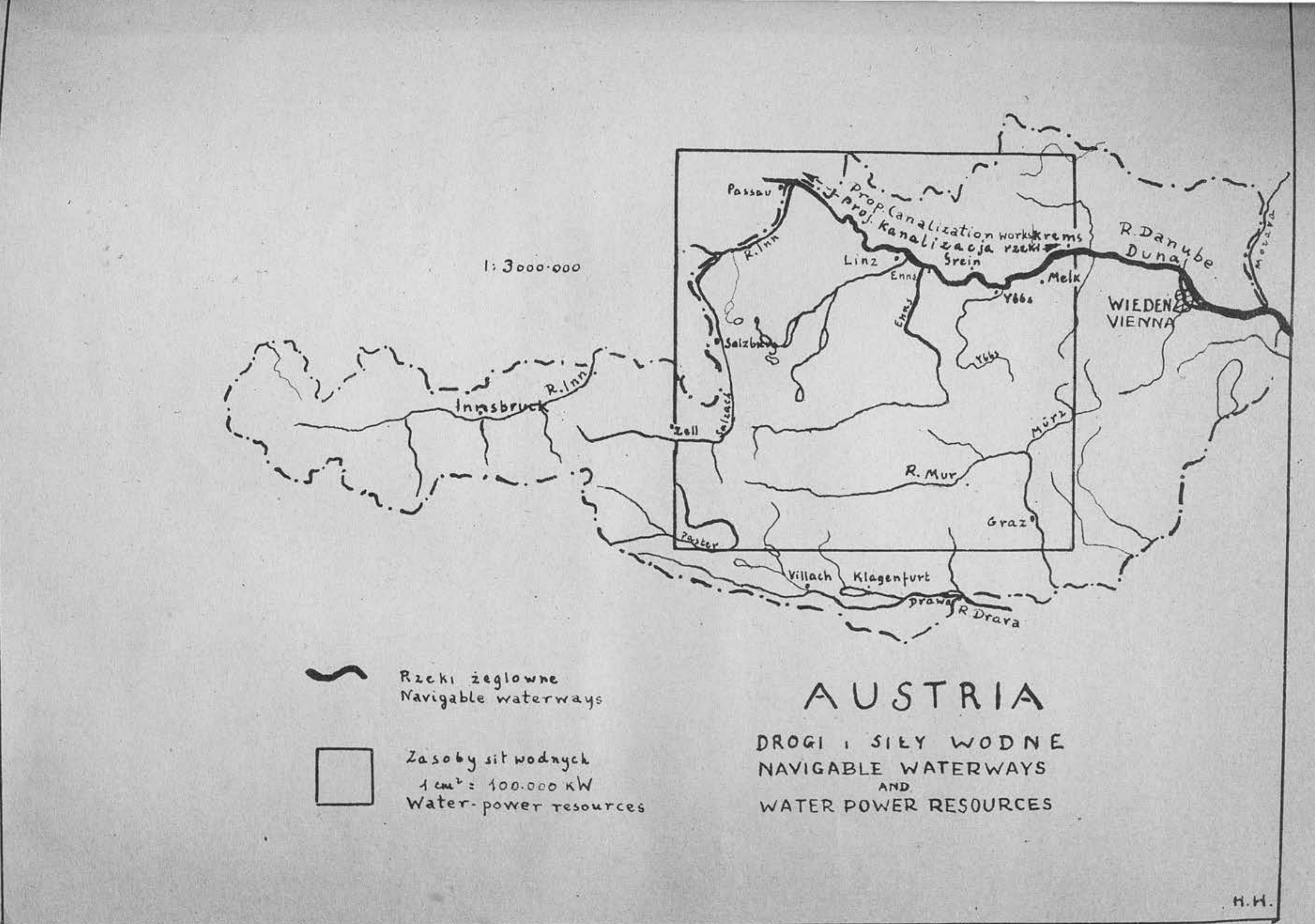
C H A P T E R VII

D E V E L O P M E N T

OF W A T E R W A Y S
IN
A U S T R I A


1: 3000·000
Passau
Prop. Canalization works
Proj. Kanalizacja rzeki
Krems
R. Danube
Dunaj
R. Inn
Linz
Enns
Grein
Melk
Ybbs
WIEDEN
VIENNA
Morava
Salzburg
Salzach
Innsbruck
R. Inn
Zell
Enns
Ybbs
Mürz
R. Mur
Graz
Villach
Klagenfurt
Drawa
R. Drava
Rzeki żeglowne
Navigable waterways
Zasoby sił wodnych
1 cm²: 100.000 KW
Water-power resources
AUSTRIA
DROGI I SIŁY WODNE
NAVIGABLE WATERWAYS
AND
WATER POWER RESOURCES
H.H.

Development Of Waterways in Austria

Austria is purely an inland state. Its territory before its incorporation with Germany was 83,857 km^2, with 6,8 million of inhabitants.

Austria with its mountains and valleys has very many possibilities for the construction of the large as well as small hydro-electric stations. In addition the abundance of water flow due to the high average annual rainfall of 1,200 mm helps the development of water power, from the economic point of view. The annual rainfall corresponds to a volume of 100 milliard m^3 for the total area, 57% of which runs to the rivers, and 37% is available for use in water power stations.

Danube

The largest river in Austria enters the country in the north at the foot of hills and possesses all the characteristics of a mountain river.

The Austrian Danube has a total length of 349 km , with a total head of 154 m , which on an average corresponds to 44 cm per km ; this in the lower course decreases to 30 cm per km , and in the upper course increases to 150 cm per km , in stretches, with rocky subsoil, liable to erosion.

The catchment area of the Austrian Danube varies from 76,472 km^2 at Passau, near the mouth of the river Inn (2,226 km), to 104,569 km^2 at Devin near the mouth of the river Morava (km 1,877).

The first figure corresponds to 9.5% of total area of the basin of the Danube, and the second figure to 13% .

Owing to the different slopes the typographical and hydrological features of the Austrian Danube has varying navigational conditions.

The following table No 27 shows the distribution of:

1. the erosion stretches with rocky subsoil, with cataracts and steep slopes,

2. the lowland stretches, on the Austrian Danube.

Table No 27

Erosion stretches From - to	length km	Lowland stretches From - to	length km
Passau, km 2,226 - Aschbach km 2,160	66	Aschbach, km 2160 - Grein, km 2,083	77
Grein, km 2,083 the mouth of the Ibbs, km 2,060	23	The mouth of the Ibbs, km 2060 - Melk, km 2034	34
Melk, km 2,034 - Stein, km 2,002	32	Stein, km 2,002 - the mouth of the Morava, km 1877	125
T o t a l	121	T o t a l	228

The improvement of the Austrian Danube in order to make it a waterway suitable for large vessels is not yet completed. The methods already adopted are divided into three regulation works:

1. the high water regulation, as passive waterworks, to establish

perfect flood-control;
2. the medium water regulation, to create a single river bed;
3. the low water regulation, to obtain a narrow channel of a minimum navigable depth of 2.0 m at lowest water level in the river.

The high water regulation works.

Of the total length of 349 km, only the 122 km running through lower Austria, from Krems to the mouth of the river Morava are provided with high water embankments. Of this section only the stretch extending over some 73 km, from Stockerau down-stream and including Vienna, can be described as completely embanked.

Above this stretch, the embankments are limited to one side of the river only, the other shore remaining unprotected. During the highest floods, inundations on that shore extended to a width of 4.5 km. The distance between the high water levels varies from 770 m to 850 m upstream from Vienna, and from 850 m to 2,500 m, downstream from Vienna to the mouth of the Morava.

A maximum discharge of 4,500 m^3/s was assumed for the high water cross-section of the river excluding the 20 km stretch on the Danube in the region of Vienna, where this figure ~~xxx~~ increases to the amount of 5,600 m^3/s.

Compared with the embankment works carried out on the other stretches, only this 20 km stretch is perfectly embanked, giving favourable results. These embankments were erected so as to enclose the so-called Vienna Cut, 15 km long, with a bed diverging entirely from the course of the old river, and during floods, 98% of the total water volume was discharged in the ordinary , old bed.

The medium water regulation works

The first works on the Austrian Danube date from 1830 , about the time when steam vessels were first put into use.
These works were much impeded by the political troubles of 1848 and by the war of 1866 . It was only from 1870 to 1900 that the creation of a single bed, for mean flow-water, was carried through in a coherent manner and with sufficient financial support.
About the year 1900 the Austrian Danube was capable of evacuating in one river bed the mean water and small high water discharges, excepting only in the parts where erosion stretches with rocky subsoil and slopes up to 1.50 m per km occur.
The worst stretches are the Strudengau near Grein and the Schlägener Schleife at some 35 km below Passau, or the Kachlet section, near Asbach and Brandstatt, some 25 km above Linz, where the bed of gravel and sand is strewn with large boulders of rock, and also has a steeper slope.
In the remaining ~~xxx~~ longer lowland stretches, where the slope varies between 30 and 50 cm per km , the results of the medium water regulation works are good. The width to be given to the medium water bed in the lowland regions was indicated by nature; it had to be similar to the width existing in those stabilized stretches which presented the same longitudinal slope.

Some sharp bends were eliminated by cuts, but fortunately there were only a few cases where the direction of the bed had to be changed.

In spite of good results obtained by the construction of a single bed for the medium water - further improvements are necessary to reinforce its banks with strong protection against the action of the current, and the wash caused by motor-driven craft. On a total length of 670 km of banks some 500 km had to be protected, which gives an idea of the extent of the work.

For the bank protection stone must generally be used. For navigational purposes the medium water regulation did not prove a success.

The reason for this is to be found in the fact, that the so-called medium water bed was too wide for the low discharges.

In this bed, the water volumes corresponding to the minimum navigable depth are only about 40% of the medium rate of discharge.

The evacuation of these water volumes did not secure a sufficient depth for navigation.

Lack of navigable depths was not the only noticeable result of the period of the low water but also an alteration in the position of the channel within the medium water bed.

Owing to these circumstances it was necessary to carry out the low water regulation works.

The low water regulation works.

The method which was applied to the Austrian Danube, was the same as that applied with much success by Gotthilf Hagen on the Rhine and by Girardon on the Rhone for the improvement of navigability at low water, by erecting groins and training works in order to contract the low water bed.

On a length of about 10 km, on the Vienna section, the left bank was provided with groins, leaving a navigable channel of about 160 m alongside the right bank on a total width of 286 m of the medium water bed.

As the success was immediately demonstrated and the improvement appeared to have become permanent, this method of regulation was applied as a rule to the other stretches, and the low regulation was subsequently extended further and further.

The situation to day below the mouth of the Enns viz. from km post 2,112 to the Austro-Czecho-Slovakian frontier at km post 1,873, is as follows: on a total river length of 239 km about 102 km are provided with groins and training works reducing the width of the river to 150-190 m.

In the remaining length, which requires further improvements, are the erosion stretches at Grein and Wachau totalling 52 km and a lowland stretches of 85 km. The first part possesses natural conditions for canalisation, the second for regulation, which should be done in future.

The low water regulation above the mouth of the Enns up to Passau was also carried out but on a smaller scale. The length of this stretch is 114 km , between the km post 2,112 and km post 2,226 , 66 km of which consists of cataracts. Owing to the smaller flow of the Danube above the mouth of the Enns, the river bed is mostly of smaller width with a fairly steep average slope.

It is desirable to secure a depth of 2,0 m over a width of 150 m for this whole stretch. With the regulation works consisting of groins and training walls dredging work must be carried out at the same time.

The aim of securing a minimum navigable depth of 2.0 m over the whole course of Austrian Danube by low water regulation has not so far been attained.

The completion of these works would allow for the passage, at all times, of vessels of 700-800 tons capacity with a draught of 1.80 m . It may be noted that at certain points the present lowest navigable water decreases to 1.0-1.3 m .

The present conditions however when compared with these in 1904 show fewer difficulties for navigation. There was originally a total of 56 shoal areas of less 2.0 m , of which 10 had less than 1.5 m navigable depth, whereas now the total number has been reduced to 14 .

These figures correspond to the level -55, at the gauge at Spitz, which was the basis for the low water regulation. It was found that during the period March 15th to December 25 - the water only dropped below this level on 10 days during which navigation was stopped.

The following table No28 shows the list of shoal areas which still exist on the Austrian Danube:

Table No28

No	Name	km post
1.	Schildorf	2,220 - 2,218
2.	Aschbacher-Kachlet	from km post 2,160
3.	Laumbauer	to km post 2,145
4.	Goddworth	almost without
5.	Hagenau	interruption
6.	Linz	2,133
7.	Steyeregger brücke	2,128 - 2,126
8.	Klosterwasser	2,102
9.	Sarling	2,057
10.	Marbach	2,050
11.	Pöchlarn	2,045
12.	Traismaner	1,990 - 1,989
13.	Altenberg	1,951
14.	Theben	1,876

The increased efficiency of the Austrian Danube as a navigable waterway is proved by the fact that over the period, during which the regulation of the low water channel was in course of construction, the average tug horse power rose from 570 to 700 HP and the towing capacity from 1,350 tons to 2,570 tons, while the carrying capacity of barges rose from 500 to 700 tons. Actually, to day, there are vessels of 900 to 1200 HP , with a carrying capacity of 1,000 tons.

The obtaining of a minimum navigable depth of 2.0 m , which was the aim of the low water regulation, and which is so far not reached, can only be considered as a partial achievement towards the complete development of the Danube as a waterway for large craft.

As already stated, individual vessels of 1000 tons carrying capacity use certain parts of the river with a draught, at full load, of 2.50 m . The maximum draught of the modern 1200 tons vessels which form the basis of the constructions linking the Rhine-Main-Danube Canal and the planned Vistula-Oder-Danube Canal is 2.3 m .

The danube should also be improved to accommodate vessels of this draught too.

It will be necessary therefore to carry out further improvements, and to find a solution to the problem of the erosion stretches.

Suggestions have been made to canalize three stretches: between Aschbach and Wallsee, Krems and Kornenberg, Bisamberg and the mouth of the Russbach.

These canals will utilize falls of 8 m , 25 m , and 24 m . The nine months water flows, on an average, are as follows: 850 m^3/s , 1000 m^3/s and 1050 m^3/s , while the main water flow varies from 1400 to 1600 m^3/s .

Thus it is possible to achieve a power of 700,000kW capacity with average yearly output capacity of 3,500 million kWh.

One of these schemes which provides 160,000 HP under a head of 7.6-13.4 m was planned at Wallsee before war.

Water Power as a part of Energy resources in Austria

The chief source of energy in Austria is water power, which will be described later. The others are as follows:

Brown coal, of which reserves are estimated to be 611 million tons, confirmed, or 2,337 million tons, probable.

Black coal, of which reserves are estimated to be only 13 million tons, confirmed, or 19 million tons, probable.

The coal production in Austria in 1934 was: 0.25 million tons of black coal and 3.5 million tons of brown coal. This is much below the national comsumption, which is approximately 16 million tons, namely:

4.7 million tons for communication,
6.5 " " " industry
1.0 " " " agriculture
4.8 " " " domestic purposes.

In fact a part of this requirement was covered by water power and actually the maximum comsumption of black and brown coal was 10.2 mio tons in 1929 , 6.5 million tons of which was imported. The latter figure of imported coal was the maximum and it has a permanent tendency to decrease due to the further development of water power.

For instance in 1935 the import of coal droped to 3.0 million tons as it is evident from the following table No 29 .

Table No 29

Year	Cosumption of black coal		Consumption of brown coal		T o t a l consumption of coal
	own production	import	own production	import	
	tons	tons	tons	tons	tons
1922	166,000	4,406,000	3,136,000	1,404,000	9,101,000
1929	208,000	6,066,000	3,525,000	591,000	10,192,000
1932	221,000	3,311,000	3,104,000	197,000	6,808,000
1935	261,000	2,849,000	2,971,000	170,000	6,250,000

Austria is rich in timber resources and its percentage of forest areas are only lower than those in Finland and Sweden. The total forest area amounts to 3,138,000 ha which corresponds to 37% of the total area of the country.
The type of timber in the forests is indicated by the following values expressed as percentages of the total wooded area: 85% coniferous trees and 15%-deciduous trees.
The maximum yearly production(utilisation) of timber amounted to 9.2 million m^3 in 1936 , 3.2 million m^3 of which was exported
Austria has developed the paper and cellulose industries.
In 1937 the production of paper amounted to 232,000 tons,50% of which was exported; the production of cellulose was 300,000 tons, 60% of which was exported.

The resources of crude oil (petroleum) and natural gas are very small and only suffice for about 2% of the consumption in the country. In recent years the production of crude oil amounted to 6,600 tons and the production of natural gas to 15.2 million m^3.

During the same period the import of crude oil increased to 350,000 tons.

~~xxx~~ Water power is one of the largest natural resources in Austria. The importance assumed by hydro-electric generation in the nation's economy, the distance of the utilized water resources from the chief centers of consumption and the necessity of rationally coordinating the water power stations belonging to the same hydrographic basin or serving the same area have led to the formation of powerful electrical systems. These ensure centralized service in the generation and distrubution of electric energy over wide areas, not only for natural consumption but also for export. It was the aim of Austria to export electrical energy to neighbouring countries in order to balance the considerable import of coal, raw materials and agricultural products.

The potential water power resources of Austria are estimated to be: 5,400,000 kW capacity with the yearly output capacity of 20,000 million kWh, including the possibilities of utilization of water power on the canalized Danube.

The development of water power is shown by the following data:

1923 in all water power stations	about	400,000 kW
1935 in 90 large hydro-electric stations(more than 1000 kW)	"	629,000 "
1936 in 92 large hydro-electric stations(more than 1000 kW)	"	641,000 "
1936 in all water power stations	"	762,000 "

The latter figure corresponds to about 14% of the vast potential water power resources in Austria.

After its incorporation with Germany the "Göring's" scheme was designed to increase the development of water power in Austria in the near future, to the amount of 10,000 million kWh output capacity per year i.e. to 50% of vast potential resources.

The present share of water power in the electrification of Austria is great, because 90% of the electricity produced in public and non public utilising stations(excluding industrial plants) was generated by water power.

The total production of the electricity was:

1935 - 2.44 milliard kWh

1937 - 3.00 " ",

which corresponds to 440 kWh per head of population.

CHAPTER VIII

DEVELOPMENT OF WATERWAYS IN GERMANY

Development Of Waterways In Germany.

Regarding the proposed Vistula-Oder-Danube-Black Sea Canal, we can see on the map that there will be three waterways branching out from the main route (way) to Germany via the rivers Main and Neckar, through the upper basin of the Danube to the river Rhine, and via the river Oder to the canals round about Berlin and the Baltic Sea.

I shall therefore give a brief summary of the development of the inland navigation system in Germany.

In Germany the conditions are, on the whole, comperatively favourable to the development of a system of inland navigable waterways.

At the present time the uniting of all the Germany fluvial systems has not yet been completed. There are still three distinct systems:

1. The Western system, which comprises the basins of the Rhine, Ems and Weser and also includes the west German canal;
2. The eastern system, which is formed by the basins of the Elbe and Oder, and the Markdistrict navigable waterways around Berlin and which, via the lower Vistula makes communication with the East Prussian waterways;
3. The Danube system in upper course comprising junction canals which are in course of constraction.

The German network of navigable waterways comprises some

13,000 km and is divided as follows:

natural navigable waterways -- 10,600 km = 82%

artificial canals -- 2,400 km = 12%

Of these waterways 7,500 km are capable of carrying the largest craft, and form a very important part of the system of communication.

This length is divided over the three systems, as follows:

Western syatem:	the Rhine basin	1,713 km
	the Ems-Weser basin with the West German canals	1,549 km
Eastern system:	the Elbe basin	1,537 km
	the Mark navigable water--ways (the Havel and Spree basin)	875 km
	The Oder basin	1,102 km
	East Prussian navigable waterways	524 km
The Danube basin		213 km
	Total	7513 km

All means of communication in Germany are subject to the unitary traffic policy of the Reich and at certain points, they work very closely together.

The density of the German network of communications is shown in the following table No 30 .

Table No 30 The density of the German network of communications

	Length km	Division per 100 km² km
Railway system including light railways and tramways........	about 75,000	about 15.5
Road system	" 220,000	" 47.0
Inland navigable waterways.......	" 13,000	" 2.8

The part which the inland waterways play in the traffic output is shown in the next table No. 31 , in comparison with the traffic carried by the railways.

Although road traffic which has recently been greatly developed m may be an important part of Germany's transport output, statistics about it are based on such uncertain facts that, having regard to the very exact figures for rail and water traffic, it is imposible to make a comparison.

Table No 31 Goods traffic on the railways and on the navigable waterways

Year	Railways: Quantity million of t	Railways: Quantity %	Railways: Output milliards of t-km	Railways: Output %	Inland navigable waterways: Quantity million of t	Inland navigable waterways: Quantity %	Inland navigable waterways: Output milliards of t-km	Inland navigable waterways: Output %
1924	466	80.8	67.6	74.4	110.7	19.2	23.2	25.6
1932	266.8	78.4	38.9	68.4	73.5	21.6	18.0	31.6
1933	294.5	79.0	45.6	70.7	78.0	21.0	18.9	29.3
1937	550	82.0	79.8	73.5	120.0	18.0	29.0	26.5

The navigable waterways in Germany therefore secured about a fith of the quantity of goods or more than a quarter of the traffic output.

Owing to the world-wide economic crisis,the transport figures in the years 1932-1933 were lower , but from the above table it will be seen that the navigable waterways were not so hard hit as the railways; in spite of the drop,inland shipping succeded in increasing its share to 31.6%,or about a third of the total traffic.

It is remarkable that the share of the inland navigable waterways is higher as regards output in t-km , than for the quantity of merchandise carried in tons. That arises from the fact that the distance the goods are carried is usually much longer by water than by rail. The average transport distance on railways is 145 km as opposed to 245 km on inland navigable waterways.

Coal is the main item of the quantity carried by inland navigable waterways. As for the other merchandise , the most striking fact is that the waterways carry more ores,stones, cereals and milled products, i.e. the goods the value of which is comparatively low and consequently the low cost of their transport has a great influence on the selling-capacity of the goods.

Inland navigable waterways also play an important role in the export and import traffic, 41% of total overseas cargoes being despatched to,or coming from, inland navigable ports. According to the different nature of the various German economic areas and the varying capacity of the waterways, the share of various navigable waterways in the traffic is as follows:

The Rhenish basin	58.5%	
The Elbe "	14.2%	
Ems-Weser basin with West German canals	12.6%	
The Oder basin	8.4%	
The Mark navigable waterways	5.3%	
East-Prussia navigable "	0.5%	
Danube	0.5%	100%

The navigable waterways have greatly helped towards the growth of the highly industrialised towns. Among the 47 large German cities of over 100,000 inhabitants there are at present 35, viz. about three quarters,that are directly connected to a waterway,which gives them such great advantages,that they can compete with other districts under particularly favourable conditions.

Craft. The differences in the capacity of the navigable waterways have had the result of developing a large number of varying types of craft. The size of the boats,depending both on the natural conditions of the waterways and on the economic conditions of traffic requirements,reaches its maximum in Western Germany on the Rhine,whereas eastwards the vessels are smaller. By far the largest share of goods transported on the inland navigable waterways is carried in towed trains of barges.

As regards these non-self-propelled boats, the German inland shipping trade in 1933 had, at its disposal 12,944 craft having a total carrying capacity of 5.99 million tons, and 2,236 tugs totalling 496,515 HP . These commercial fleets are summarized in the following tables No 32 No33 No34 , but during recent years a constant increase is noticed in the number and size of the boats, due to the progressive enlargement of the rivers and increasing traffic requirements.

There are no general statistics available of the total commercial fleets in Germany in recent years, but a comparison of the increase on the river Danube may give some idea of the total increase.

Comparing the years 1933 and 1940 the figures are:

	1933	1940
Barges	231	534
Capacity	229,837 tons	332,460 tons
Tugs	28	57
Tankers	7	85

==

Table No 32 Number of non-self propelled craft in Germany (1933)

	having a capacity of:						Total	
	21-50 tons	51-250 tons	251-600 tons	601-1000 tons	1000-1400 tons	1401 tons and over	number	capacity
The Rhine basin	88	437	504	662	495	380	2,566	2,066,864
West German canals	194	173	74	286	2	----	729	312,578
The Weser basin	47	165	262	232	---	---	706	296,995
The Elbe basin	183	506	1,016	937	87	---	2,729	1,326,801
The Mark navigable waterways	98	1,305	859	116	--	---	2,378	694,991
The Oder basin	67	647	1,612	166	--	1	2,493	917,222
East Prussian navigable waterways	59	314	261	12	--	---	646	147,673
The Danube	8	66	13	139	5	---	231	129,837
Various small navigable waterways	65	170	229	2	--	---	466	97,162
Total for the Germany	809	3,783	4,830	2,552	589	381	12,944	5,990,123

Table No 33 Number of tugs in Germany (1933) having a power capacity of:

	number	HP
The Rhine basin	447	181,518
The West German Canals	219	35,586
The Weser basin	131	27,926
The Elbe basin	562	116,970
The Mark navigable waterways	390	50,861
The Oder basin	343	60,978
East Prussian navigable waterways	66	7,019
The Danube	28	13,255
Various small navigable waterways	30	2,402
Total	2,236	496,515

In addition to the fleet of towed boats there have been developed on the German waterways a fleet of self-propelled boats, the numbers and kinds of which are as follows:

Table No 34) Boats carrying goods and tankers

Boats carrying goods			Tankers		
Number	tons	HP	Number	tons	HP
The Rhine basin					
149	51,262	18,766	8	3,599	1,447
West German Canals					
162	21,630	6,638	2	200	47
The Weser basin					
79	21,841	6,115	2	236	110
The Elbe basin					
657	123,315	52,674	30	5,396	2,483
The Mark navigable waterways					
206	42,605	9,452	6	1,059	269
The Oder basin					
55	11,166	5,918	-	-	-
East-Prussian navigable waterways					
52	6,883	3,098	-	-	-
The Danube					
25	7,528	4,540	7	4,617	3,820
Various small navigable waterways					
54	4,495	2,016	-	-	-
Total For Germany					
1,438	290,725	109,117	55	15,107	8,176

Table No34a Passenger boats and Passenger-cargo boats

Passenger boats			Passenger and cargo boats		
Number	tons	HP	Number	tons	HP
The Rhine basin					
120	8,299	27,849	20	2,298	6,607
West German Canals					
6	179	640	2	57	75
The Weser basin					
26	1,798	3,847	4	90	133
The Elbe basin					
200	10,067	26,046	293	7,717	11,360
The Mark navigable waterways					
232	7,336	14,521	9	335	954
The Oder basin					
30	973	2,174	12	606	1,562
East-Prussian navigable waterways					
38	1,579	3,585	6	358	660
The Danube					
15	681	3,171	1	28	100
Various small navigable waterways					
65	2,557	14,044	18	835	1,730
T o t a l for Germany					
732	33,469	95,517	365	12,316	23,181

Utilisation of water power resources in Germany .

The estimated water power resources in Germany are as follows:

Table No 35

	Kilowatt existing power resources	Average estimated annual energy million kWh
North Germany	2,500,000	12,500
Bavaria	2,700,000	13,500
Baden	970,000	4,850
Würtemberg	180,000	900
Total	6,350,000	31,750

The problem of the utilization of water power resources is very old in Germany, and has always been controlled by the Government. Modern utilisation of water power began with the advent of electricity. The older plants, small water power stations, still predominate in number, but they are decreasing. The number of high-pressure stations is low in comparison to that of low-pressure stations, because of the topography of the territory.

The development of water power is still in progress , as we can see from the following statistics:

in 1926 developed power of 1,100,000 HP
in 1930 " " 2,000,000 HP
in 1936 " " 3,100,000 HP

The corresponding yearly output capacity of the latter amounted to 11,000 million kWh.

The next table No36 shows the distribution according to size of the German water-power stations.

Table No. 36

Size group according to developed power horsepower	Number of stations	Total power in HP	% of power of all stations
0 to 10	29,000	160,000	5.16
11 to 100	12,500	390,000	12.00
101 to 500	1,600	320,000	10.30
501 to 1,000	200	140,000	4.52
1001 to 2000	110	148,000	4,78
2001 to 5,000	60	170,000	5.50
5001 to 20,000	40	350,000	11.28
20000 to 100,000	35	1,070,000	34,51
100,000 - over	3	352,000	11.35
Total	43,548	3,100,000	100,00

For many years it has been a definite policy, in Germany, to develop the water power resources and the use of brown coal for the production of electricity so that they will be less dependent on the reserves of black coal which are situated in the Ruhr and in Silesia and so are far from the centre of the country.

The production of electricity, in recent years amounted to 70,000 million kWh output capacity per annum.

The distribution and sources of this supply are given in the following table No 37 .

Table No 37

Year	Black coal %	Brown coal %	Water power %	Other %
1913	64.5	23.0	11.5	0.9
1922	48.5	41.2	9.7	0.6
1929	41.0	45.1	13.5	0.4
1933	33.5	47.7	18.0	0.8
1934	34.7	49.6	15.0	0.7

Extension of the German network of navigable waterways towards the Black Sea.

Among the principal canal schemes in Germany two great inland navigable waterways, the Rhine-Main-Danube canal and the Rhine-Neckar-Danube canal, are in course of constraction.

Germany has paid greater attention during the last few years to the constraction of these canals, which will have a great influence on future German goods traffic in a north-south direction. This tendency to go south has long been the policy of the German authorities whose aim it is to be the exporters of the industrial products required in the basin of the Danube.

Rhine-Main-Danube Canal, see sketch No 9 .

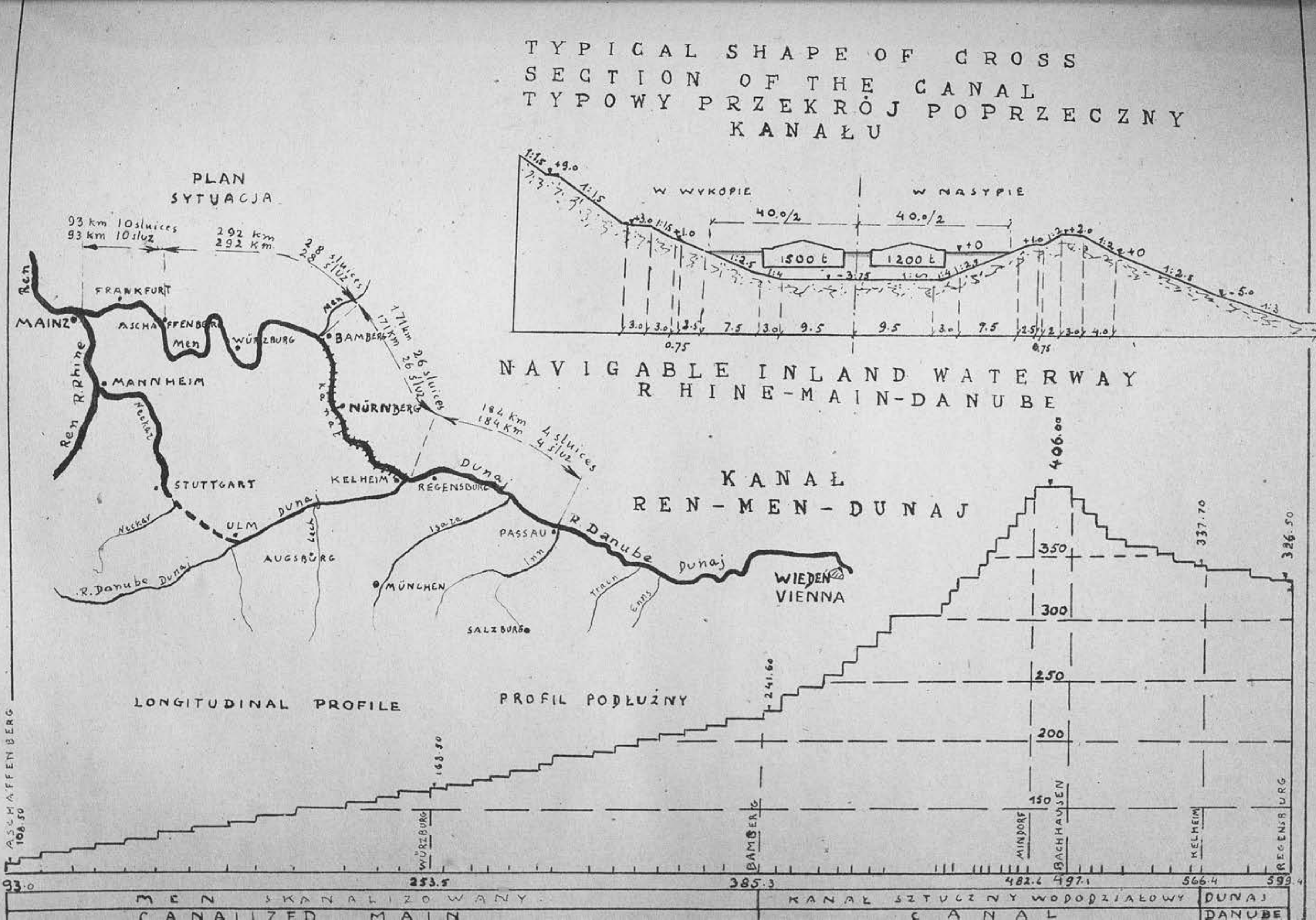
To join up the river Rhine accessible to craft of 1,200-1,500 tons with the Danube, along the river Main and an artificial canal, this new waterway would have to cross the principal

European watershed at an altitude of 406 m above sea level. The total distance between the Rhine at Mainz and the Danube at Passau is 740.4 . The craft would complete a rise of 321.7 m and a fall of 126.4 m giving a total available head of 448.1 m by means of 68 locks; fifty five of which are on the slope towards the Rhine and thirteen - towards the Danube, see sketch No. 9 .

The following table No 38gives the general data of the Rhine-Main-Danube Canal.

Table No. 38

	Length km	Total fall m	Number of locks
1. The canalized Main			
From Mainz to Aschaffenburg	93	27	10
From Aschaffenburg to Würzburg	160.5	57.2	13
From Würzburg to Bamberg	131.8	62.3	15
total	385.3	146.5	38
2. The canal linking the watershed			
From Bamberg to Nürnberg	68.7	72.2	7
From Nürnberg to Scheitelhaltung	35.7	103.0	10
From Scheitelhaltung to Beilngries	28.4	43.00	4
From Beilngries to Kelheim	38.3	25.3	5
total	171.1	243.5	26
3. The Danube, partly canalized			
From Kelheim to Regensburg	33.5	11.2	3
From Regensburg to Vilshofer	125.5	37.7	-
From Vilshofer to Passau	25.0	9.2	1
total	184.0	58.1	4
On the whole	740.4	448.1	68



TYPICAL SHAPE OF CROSS
SECTION OF THE CANAL
TYPOWY PRZEKRÓJ POPRZECZNY
KANAŁU
W WYKOPIE
W NASYPIE
40.0/2
40.0/2
1500 t
1200 t
PLAN
SYTUACJA
93 km 10 sluices
93 km 10 sluz
292 km
292 km
28 sluices
28 sluz
171 km 26 sluices
171 km 26 sluz
184 km 4 sluices
184 km 4 sluz
NAVIGABLE INLAND WATERWAY
RHINE-MAIN-DANUBE
KANAŁ
REN-MEN-DUNAJ
MAINZ
FRANKFURT
ASCHAFFENBURG
WÜRZBURG
BAMBERG
NÜRNBERG
MANNHEIM
STUTTGART
ULM
AUGSBURG
KELHEIM
REGENSBURG
PASSAU
MÜNCHEN
SALZBURG
WIEDEN
VIENNA
Ren
R. Rhine
Men
Neckar
R. Danube
Dunaj
Inn
Traun
Enns
LONGITUDINAL PROFILE
PROFIL PODŁUŻNY
406.00
337.70
326.50
241.60
168.50
108.50
ASCHAFFENBERG
WÜRZBURG
BAMBERG
MINDORF
BACHHAUSEN
KELHEIM
REGENSBURG
93.0
253.5
385.3
482.6
497.1
566.4
599.4
MEN SKANALIZOWANY
CANALIZED MAIN
KANAŁ SZTUCZNY WODODZIAŁOWY
CANAL
DUNAJ
DANUBE

The first part of this navigable waterway passes along the river Main, which has been progressively canalized. The water of the Main comes principally from the Central Mountains, the highest water levels occuring generally during the rainy autumn and winter months, whereas during the summer months a decided decrease in the flow takes place.

The whole catchment area extending to 27,395 km^2 shows the following discharges at its mouth:-

lowest	varies from 25	to 36	m^3/s;
main	99	165	"
highest	2000	2814	"

The relatively small discharges and too steep slope, on an average 38 cm per km, have made the achievement of a modern navigable waterway, accessible to craft 1,000 - 1,500 tons, impossible by a simple regulation works.

The oldest section of the canalized Main lies between the mouth of the river and Frankfurt o/Main, a distance of 33 km, and has 5 weirs with a total fall of 10.4 m. It was constructed between 1883 and 1886, and improved ten years later by reconstructing the chamber locks, which could only take single vessels, into locks for trains of barges. Further improvements in the construction of weirs, locks for 3,000 ton barges and of a power station were completed in 1935.

The second section of the Main between Frankfurt o/Main and

Aschaffenburg, over a distance of 60 km, was canalized in the years 1907-1914. Five weirs and locks with a total fall of 16.6 m have been built. The average length of the reaches is 7.3 km; the maximum draught allowed is 2.30 m, sufficient for craft of 1000 tons.

Four water power stations are installed to utilise a max. water volume of 130 m^3/s.

The third section between Aschaffenburg and Würzburg, over a distance of 160.5 km, has been canalized since 1922. Thirteen reaches have been provided representing a total fall of 57 m; the individual falls vary from 3.5 to 5.5 m. According to the plan, the depth for navigation, after providing for a minimum lock depth of 3.0 m, is to be 2.50 m for the time being, which is sufficient for craft of 1,500 tons capacity. The dimensions of the locks are 300 x 12 x 3.5 m, which allows a train of three 1200 ton barges: 81 x 10 x 2.3 m or a train of three 1500 ton barges: 85 x 10.25 x 2.5 m to enter the chamber locks.

The breadth of the weir openings for the 6 lower falls is 105 m, and for the remaining upstream falls 90 m. The utilization of water power is provided by the installation of Kaplan turbines with capacity of 130 m^3/s in lower falls and 100 m^3/s in upper falls.

Up till 1935 had 7 weirs been built, the remaning 6 weirs were completed in 1938, but at certain falls the water power stations are still in course of construction.

The following table No 39 gives some data about the general x arrangements of the canalized Main between Aschaffenburg and Würzburg.

Table No 39

No	Name of weir	Km	Altitude of water level at head water m	at tail water m
1.	Aschaffenburg(Obernau)	93	112.5	108.5
2.	Kleinwallstadt	102	116.5	112.5
3.	Klingenberg	113	120.5	116.5
4.	Kleinhenbach	123	124.5	120.5
5.	Freudenberg	134	129.0	124.5
6.	Faulbach	142.5	133.5	129.0
7.	Eichel	161	138.0	133.5
8.	Lengfurt	175	142.0	138.0
9.	Rothenfals	186.5	147.3	142.0
10.	Steinbach	201	152.4	147.3
11.	Harzbach	220	157.3	152.4
12.	Hammelstadt	233	161.5	157.3
13.	Erlbrunn	242	165.7	161.5
14.	Würzburg(backwater)	253.5	--	--

The fourth section of the canalised Main between Würzburg and Bamberg,over a distance of 131.8 km is now in course of construction.

The craft would complete the total rise of 62.3 m by means of 15 locks. The completion of these canalisation works is expected in 1945 .

The second part of the navigable waterway Rhine-Main-Danube Canal, between Bamberg o/Main and Kelheim o/Danube,has to cross the watershed at an altitude of 406 m above sea level. The scheme was passed by the by-law of 11 th May 1938 and was

intended to be completed and put into commission in 1945.
The length of this artificial canal would be 171.1 km and the craft would rise above the total head of 243.5 m by means of 26 locks.
Forty-one alternatives have been thought out for the most suitable route for this canal. Finally one was chosen which will run mostly along the old canal called Ludwigs-Donau--Main Canal, built in the years 1836-1845, with small dimensions, 14 m in depth and 4.5 m in width, which was enough for the previous small navigation craft. The new canal would be accessible to craft 1,200 tons and for a yearly transport quantity of 10 million tons.
Considerable difficulties have arisen with artificial water supply for filling the locks on the watershed reaches of the canal. The estimated movement of traffic passing through the very large locks calls for large volumes of water.
The soil of the region of the Jura mountains is very permeable and it was difficult to build a storage reservoir, near the watershed sections of the canal.
The Germans have ~~on the watershed reaches~~ chosen a very costly artificial supply of water on the watershed reaches, which comes from a long distance by means of pipes and aqueducts, from a storage reservoir 90 km away in the basin of the river Lech, situated on the other side of the Danube. An additional water supply for the canal would be derived from several small storage basins provided with pumping stations, situated near

the line of the canal.

The third part of the navigable waterway Rhine-Main-Danube Canal, between Kelheim and Passau, over a distance of 184 km, passes along the river Danube.

The upper course between Vilshofen and Passau would be canalized by means of 4 locks to rise above the total head of 20.4 m. The middle course between Regensburg and Vilshofen, over a distance of 125.5 m would be regulated by simple river training works.

So far only one dam at Kachlet on the Danube is built, with a head of 11.3 m, and provided with a lock 230 m in length and 12 m in width.

According to the statistics from 1939, on the whole stretch of the Rhine-Main-Danube Canal before the canal could be put into commission it was necessary to complete the construction of the following works:

22 weirs, 43 locks, 170 bridges and about 100 million m^3 of earth works.

This canal of 740.4 km in length would link up a widespread navigable waterway for the use of Germany transport over a distance of 3,351 km from Rotterdam to Braila.

<u>The Rhine-Neckar-Danube Canal.</u>

In addition to the above described scheme, that is being carried out, there is another scheme for the Rhine-Neckar-Danube Canal, which would from a parallel navigable waterway for the remaining 10 million tons of goods traffic to be carried per year from Germany to the Danube valley.

In spite of the fact that the watershed is situated at a very high altitude of 569 m above sea level - it was decided to build the canal , and a great part of it is in couse of construction , especially in the north section along the river Neckar.

The Neckar just like the Main, is a river rising in the Central Mountains, and has the same characteristics; low and continuous summer level, and remarkable increases in winter time.

The area of the basin to the mouth of the river amounts to 13,965 km^2. The flow varies from 20 m^3/s at lowest water level to 4,800 m^3/s at highest water level; and the main flow at middle water level is 100 m^3/s .

The canalisation works have been in course of construction since 1920 over a distance of 207 km between Mannheim and Plochingen, near Stuttgart.

Twenty six falls (weirs and locks) are provided with a total head of 159 m ; the falls vary between 2.6 and 11.0 m .

Of the 26 falls eleven were completed by 1935 on the lower course of the river Neckar, between Mannheim and Heilborn, over a distance of 113 km , and a total head of 67.5 m . The remaining upper course of the river,between Heilborn and Plochingen,over a distance of 94 km , is now in course of construction. There will be 15 weirs and locks with a total head of 91.5 m .

The minimum draught allowed for is 2.5 m for the 1,200 ton vessels,with a width at the canal bottom of 36 m . The size of the locks is as follows:

110 m in length, 12 m in width and 3.5 m in depth.

At 25 of the falls (except Heidelberg) the power will be used, on a water volume basis varying according to the situation and the discharge,between 14 and 100 m^3/s , and which is estimated to last 180 days per year.

The total cost of the canalisation work carried out on the river Neckar would be approximately 246 million Reichs Mark. The completion of these works was planned for 1944 .

The canalized Neckar forms a part of the future navigable waterway for large vessels from the Rhine to the Danube.

The remaining junction canal to cross the watershed and run to the Danube is still to be completed, but construction has been started on a small scale.

C H A P T E R IX

D E V E L O P M E N T

OF W A T E R W A Y S

IN

P O L A N D

POLSKA POLAND
DROGI WODNE I ŹRÓDŁA ENERGII
NAVIGABLE WATERWAYS AND RESOURCES OF ENERGY.

Development of waterways in Poland.

Poland in 1939 had a surface area of about 390,000 km^2 and a population amounting to 35.1 million inhabitants. The density of population was over 90 to the square kilometre, that is to say, more than in France.

Poland is situated in the very heart of Europe on the geographical latitude of Great Britain and Northern France. The most Northen point of Poland - the river Dźwina - lies on the latitude of Glasgow; the most Southern point - the Rumanian frontier - on the latitude of the city of Orleans in France.

In the past Poland was an agricultural country, but in recent years Poland has developed the ambition to become an agricultural-industrial country. Much has been done in this matter, in spite of many unfavourable conditions: war devastation, lack of capital and " heavy international competition."

From the point of view of industrial development and standard of living we can divide Poland into two different parts: Western Poland, reaching in general the economic life of Western Europe, and Eastern Poland, more sparcely populated with very little industry, a lower level of agriculture and a less well developed system of communications. In recent years a great step has been made towards raising the Eastern part of Poland to the level of the Western part, but the difference is still considerable.

The foreign trade of Poland amounted to about £.190 millions, in the best years, in which exports and imports were nearly balanced.

The territory of Poland is divided hydrographically by the great watersheds between the Baltic and the Black Sea, approximately 4/5 of the surface of the country is belonging to the Baltic Sea basin, in spite of the very short coast-line of about 70 km .

In Poland the conditions are,on the whole very favourable to the development of a system of inland navigable waterways. Except in the Southern part of Poland where the Carpathian Mountains are at the average height of 1,000 - 1,500 m above sea level,with a peak at Tatra of 2,660 m above sea level,the main part of Poland is low lying country,and there are great possibilities for the creation of a network of inland navigable waterways over long distances, connecting the large hinterland to the sea ports.

The present exceptionally small development of Poland's inland navigable waterways is caused not by lack of favourable geographical conditions,but because the improvement of rivers and the uniting of all the systems has not yet been completed. The existing improvements,obtained by regulation works carried out,are not sufficient for the constantly increasing demands, and for the use of larger and larger craft.

For these reasons,the railways at present carry the largest share of Poland's transport,about 99.1% of the total quantity in tons, in spite of very long distances over which the goods are transported, on an average over 305 km, as opposed to 145 km in Germany or 100 km in Great Britain.

The following tables show the lengths and navigable capacities of the larger rivers and give data regarding the traffic and the commercial fleets.

Table No 40 Length of Waterways

Grand total	Navigable total	Navigable – max. tonnage vessels of: to 50	51/100	101/200	201/400	401/600	over 600	Rafting rivers
in kilometres								km
The Vistula with tributaries								
5,338	2,515	794	148	1,070	77	394	32	2,823
of which the tributaries amount to:-								
4,398	1,575	794	148	556	77	---	--	2,823
The Warta								
582	426	192	--	--	100	134	--	156
The Niemen								
3,153	605	116	245	160	84	---	--	2,548
The Dźwina								
582	199	---	116	83	--	---	--	383
The Prypeć								
2,831	1,257	409	505	227	90	26	--	1,574
The Prut								
214	--	--	--	--	--	--	--	214
The Dniester								
1,016	361	99	262	--	--	--	--	655
Canalized rivers								
504	504	--	--	300	50	154	--	--
Canals								
268	268	--	33	182	28	25	--	--
Lakes								
115	115	18	--	30	67	--	--	--
Grand total:								
14,603	6,250	1,628	1,309	2,052	496	733	32	8,353

Table No 41 Transport of passengers and goods.

Description	1932	1934	1936	1938
No of passengers in thousands	600	597	805	991
Goods, total in thousands tons	479	671	725	742
Live animals in thous. tons	80	75	46	29
Rafting and transport of timber in thous, m^3	--	746	627	1,027

Table No 42 Commercial fleet on the Polish Inland Waterways

Description	1928	1935	1938
No of steam vessels	118	134	127
No of Motor "	24	39	46
No of barges	1,367	2,896	2,621
Total No of boats	1,509	3,069	2,794
Cargo capacity in thous. tons	104.9	138.2	157.1

Table No 43 Commercial fleet of the Free City of Gdańsk(Danzig).

Description	1936	1938
No of steam vessels	82	81
No of Motor "	17	19
No of barges	391	390
Total No of boats	490	490
Cargo capacity in thous. tons	59.9	59.7

The technical problems, connected with the improvement of the Polish system of navigable waterways and with joining them up to the various links of the East European waterways in order to form a wide network suited to modern requirements will be discussed in Vol.II Chapters I,II,III .

Water power as a part of the energy resources in Poland.

The chief source of energy in Poland is black coal. The major part of the so-called Silesian coal fields, with an area of approximately 3,800 km^2, is located within the boundaries of Poland in the south-western part of the country.

With regard to coal resources Poland ranks third in Europe, after Great Britain and Germany, with 62,000 million tons at a depth of up to 1,000 m , in layers of a thickness of not less than 0.5 m. The probable total of Polish reserves of coal is

estimated at 158,000 million tons.
The coal fields may be divided into two areas: the northern, where the deposits either protrude almost to the surface,or are covered by a superstructure of up to 100 - 150 m in thickness; and the southern,with much thicker layers under a super-structure of a thickness of several hundred meters. The calorific value of the black coal in Poland varies from 7,800 to below 5,000 calories,and it decreases from west to east,because the best grades of coal in Poland are available in the western part of Upper Silesia,and towards the east, the contents of carbon (C) and hydrogen (H) gradually decrease.

The Polish coal fields contain all grades of coal,except the best variety used for coke and anthracites. On the whole the coal is typical fuel coal,due to a high oxygen content and it ignites easily,but there are also varieties of the industrial type,suitable for gas works,and industrial furnaces, as it contains on the average about 33% of volatile matter. The production of black coal in Poland varied from 28.8 million tons in 1932 to 40.6 million tons in 1928, and 38.1 million tons in 1938. The average home consumption in years 1933-1937 was 20.8 million tons which increased to 26 million tons in 1937 or 736 kg per head. The remaining 10-11 million tons of coal was exported.

Brown coal.
The deposits of brown coal are scattered over small areas practically throughout the whole of Poland.The caloric value

of brown coal varies from 4,500 to 5,000 cal/kg. A considerable increase in the output of brown coal occurred in the course of 1920-1921. This was due to the destruction of collieries during the war 1914-1918. As the output of black coal increased, the output of brown coal again decreased, to the small quantity of 26,000 tons.

Brown coal, not being of a quality to compete with black coal is used locally as a fuel.

Crude oil. (petroleum)

The oil fields in Poland have not yet been fully geologically explored although systematic surveys of the areas are in progress. Owing to the fact that so far only approximately 7% of the known area of oil fields is under exploitation, the quantity of crude oil mined in Poland at the moment undoubtedly represents merely a small fraction of the available resources, located at the foot of the Carpathian Mountains and covering an area of about 2 million ha .

Oil mining is in progress in some seventy localities along the Carpathian highlands, from the line of the river Dunajec to Bukovina, those in the eastern part, particularly in the Borysław, Tustanowice and Mrażnica districts having the largest output.

Larger quantities of crude oil in the Polish oil fields are situated at a much greater depth than in other countries, namely, at a minimum of 1,000 m , but sometimes at 1,700 m . The cost of these deep drillings is the main reason why, in many localities, the drillings have not been carried out to the proper depth and as a result the largest sources of supply have not yet been reached.

The oil mined in the basins of Borysław, Tustanowice is known as "Standard Oil" its chemical composition is more or less uniform, containing approximately 12% petrol and above 30% paraffin.

The oil in other districts shows greater fluctuations in chemical ~~xx~~ composition; certain of these grades are among the lighter oils, containing up to 30% petrol; others are among the heavier oils and contain a larger percentage of viscous matter.

The calorific value of mineral oil amounts to 10,000 - 11,000 calories/kg .

The following table No 44 gives data concerning the petroleum resources and its production in Poland.

Table No 44

1. Petroleum resources:		
a) probable total reserves	2	million ha
b) proved reserves	0.1	" "
c) producing fields	0.007	" "
2. Wells:		
a) total drilled	5,817	
b) producing in 1934	3,101	
3. Production of crude oil:		
a) maximum annual in 1909	2.4	million tons
b) latest figure available - max.1938	0.507	" "
c) total from beginning	41,245	" "

Natural gas.

Natural gas is available in Poland practically throughout the Carpathian highlands. It usually precedes the exudation of mineral oil and is, to a certain extent, an indication of proximity to oil layers, but in certain places natural gas occurs in very considerable quantities and is entirly independent, of oil. The latter variety is the so-called "dry gas", consisting mainly of methane (CH_4), and has a calorific value of 9,000 calories, or more.

There is every likelihood that natural gas in Poland will prove to be an abundant source of energy and, if capital were available for the necessary investments, the natural gas industry would be likely to occupy a place next to the oil industry, in importance.

So far in two cities (Gdynia and Stryj) all buildings are heated by means of natural gas; and in two large power stations, Mościce and Nisko, with a total capacity of 60,000 kW, the fuel supplied is partly natural gas.

A fairly extensive system of trunk pipe lines was in operation to convey this gas, and other lines were in course of construction in 1939.

Natural gas resources and its production up to 1934 were as follows:

Producing fields in thousands of ha...............		7
Wells: a) total drilled	3,058	
b) producing in 1934	1,988	
Maximum annual output in 1925 in millions m^3.....		537
Annual output in 1934	"	469
Total output from beginning	"	15,000 about .

Water power.

While Poland, in general, is favoured with abundant water power resources these are not so great as those of Yugoslavia or Rumania. The present development is rather small, the requirements in electrical power being covered principally by thermal stations, while the hydro-electric stations play only a subsidiary role.

This present ratio must be changed and the Polish policy of utilization of the resources of energy leads to the development of water power, the potentialities of which have not been fully realised in the past.

The most favourable regions for the production of hydro-electric power are found in the south of Poland in the Carpathian Highlands, where the mountainous configuration, the heavy precipitation and steep slopes and many sites suitable for storage reservoirs are all factors favouring economical development. The necessity for the creation of storage reservoirs coincides with the problem of flood control, which in Poland is of the first importance, owing to the fact that the ratio between the low water flow and the flood flow is approximately 1 : 1000.

Other sites suitable for the development of water power will be available along the Vistula, after the canalisation works have been carried out on the Middle Section.

The investigation of this entirely new scheme, which will be described in the Chapter No. II and IV/ ~~Vol.II~~ . shows that it is easily possible not only to obtain the depth,necessary for modern navigation,but also to supply several power stations.

Suitable sites are also to be found in North-Western and North Eastern Poland where there are numerous natural lakes which can be converted into storage reservoirs without difficulty, and in some cases the combination of the reservoirs with canalisation works would effect a considerable improvement in navigation depths,as for example on the rivers Niemen and Wilia.

On behalf of the National Power Committee of Poland I made the first estimate of the water power resources,at mean water flow,and this was published in my paper to the World Power Conference in London in 1924.

The following extract is taken from that paper:

Poland	River basins of				
	Vistula	Dniester	Prut	Niemen	Dnieper
3,650,000 HP	2,180,000 HP	760,000 HP	286,000 HP	251,000 HP	173,000 HP

Under my direction,as Head of the Hydro-electric Research Centre further surveys of the more important sites were carried out and investigations made into the problems of flood control and peak stations with a view to the electrification of the country. In this report,published in the Proceedings of the Polish Congress of Civil Engineers,Lwów 1937, I estimated the power capacity at 1,915,000 kW with an average yearly output of 11,200 million kWh .

In this report I also gave a description of 131 proposed water power stations, of which 34 were intended to be built during the first period of electrification; the capacity and value of output for these power stations was estimated as about 500,000 kW and 2,000 million kWh.

Taking into account the schemes for the canalisation work of the Vistula and the Bug which are now proposed for the first time, the total available water power in Poland can be estimated as:- 2,800,000 kW with an average annual production of about 15,000 million kWh.

Among the schemes which have been already completed or were in course of construction during the years 1933-1939, under my supervision, are the following:

Table No 45

Name of station	River	Head m	Storage capacity mil.m^3	Power capacity kW	Yearly output mil.kWh	Cost £. thousend
Rożnów	Dunajec	31.5	229	50,000	142	1,750
Czchów	"	10.0	15	10,000	47	390
Porąbka	Soła	18.0	30	20,000	27	700
Turniszki	Wilia	13.0	40	14,000	86	540
Myczkowce	San	16.0	5	4,000	22	200
Solina	San	47.5	270	30,000	90	1,150
Pomiechówek	Wkra	13.0	40	15,000	15	460

Two of these power stations: Różnów and Porąbka where completed, others were in course of construction.

The past development of water power in Poland comprised chiefly the utilisation of the smaller sources, for the production of mechanical power, which is evident from the following table.

Table No 46.

Part of Poland	Water Power Stations with capacity: less than 100 HP		from 100 to 1000 HP		more than 1000 HP	
	No	HP	No	HP	No	HP
South	2,521	26,600	36	6,500	-	-----
East	1,217	17,000	12	2,000	1	2,000
West	478	9,000	28	7,400	3	20,100
Central	2,469	31,600	40	5,400	-	-----
Total	6,685	86,200	116	21,300	4	22,100

From this it is seen that the total number of small stations with a capacity of 129,600 HP is 6,805.

Taking into acount two larger power stations just completed the total power amounts to 234,600 HP or about 6% of the vast potential water power resources in Poland.

Electrification.

Electric power production is one of the most important problems in Poland, and the electrification of the country is planned and carried out systematically. The installed capacities and production of electricity have grown considerably as is shown in the following table No47.

Table No 47 The installed capacities and production of elec.

	1925	1928	1932	1934	1936	1938
Installed power thousand kW	831	1020	1285	1536	1580	1692
Output in million kWh	1800	2618	3048	2622	3082	4200

The present programme of electrification for post-war development includes the erection of high-voltage-lines, closer cooperation between the power stations, and greater development of water power stations, so that an interchange of energy between power stations may be made to a greater extent.

The six year plan of electrification comprises the following:

1) The construction of transmission lines of 5,290 km in length, with a voltage of 200 kV, 100 kV and 60 kV;

2) The construction of power stations with a total capacity of 2,200,000 kW.

The estimated output of energy after completion of these works would amount to 12,200 million kWh per annum, and consequently the consumptiom per head would increase to 350 kWh instead of being, as at present, 120 kWh which is much below the normal in West European countries.

Peat.

Peat has so far been developed in Poland on a very small scale and is used locally as a fuel. It is found in northern and eastern Poland in a area of about 18,400 km^2. The probable reserves exceed 5,500 million tons with 25% of moisture, and the proved reserves are estimated to be 2,200 million tons, which reduced to black coal equivalent, is about 1,000 million tons.

Forestry.

The total area of forests in Poland,in 1938 , was 8,624,000 ha, or 22.2% of the total area of the country. According to the type of timber,in percentages of the total forest area,there are 79% of coniferous trees and 21% of decidous trees.

The production of wood in 1938 was 16.4 million m^3, 62% of which was timber and 38% - firewood,and is compatible with natural regeneration. Export of wood varies from 2 to 3 million tons per annum.

To complete this description of Polish natural resources I would like to mention the mineral resources.

Zinc and lead ore.

Zinc and lead ore reserves found in South-east Poland,have been estimated to be 20 million tons. The production of zinc ore forms a fairly important part of the European production. The output in 1937 was 109,000 tons,about 50% of which was exported.

The production of lead ore in this same year was about 17,300 toms, 43% of which was also exported.

Iron ore.

Poland does not possess large deposits of iron ore, and must import about 2/3 of the raw material necessary for the production of iron and steel,which in 1938 was as follows:

Pig-iron - 879,000 tons, and steel-1,441,000 tons.

Rock salt.

Rock salt deposits are found at the foot of the Carpathian Mountains and in the North-West of Poland. The reserves are enormous being estimated at about 6,000 million tons. The output of salt in 1938 was 643,000 tons.

Potassium salt.

Potassium salt deposits are also abundant, they are found chiefly in the South-East of Poland. The output of potassium salt in 1938 was 872,000 tons with 84,500 tons of potassium ovide (K_2O).

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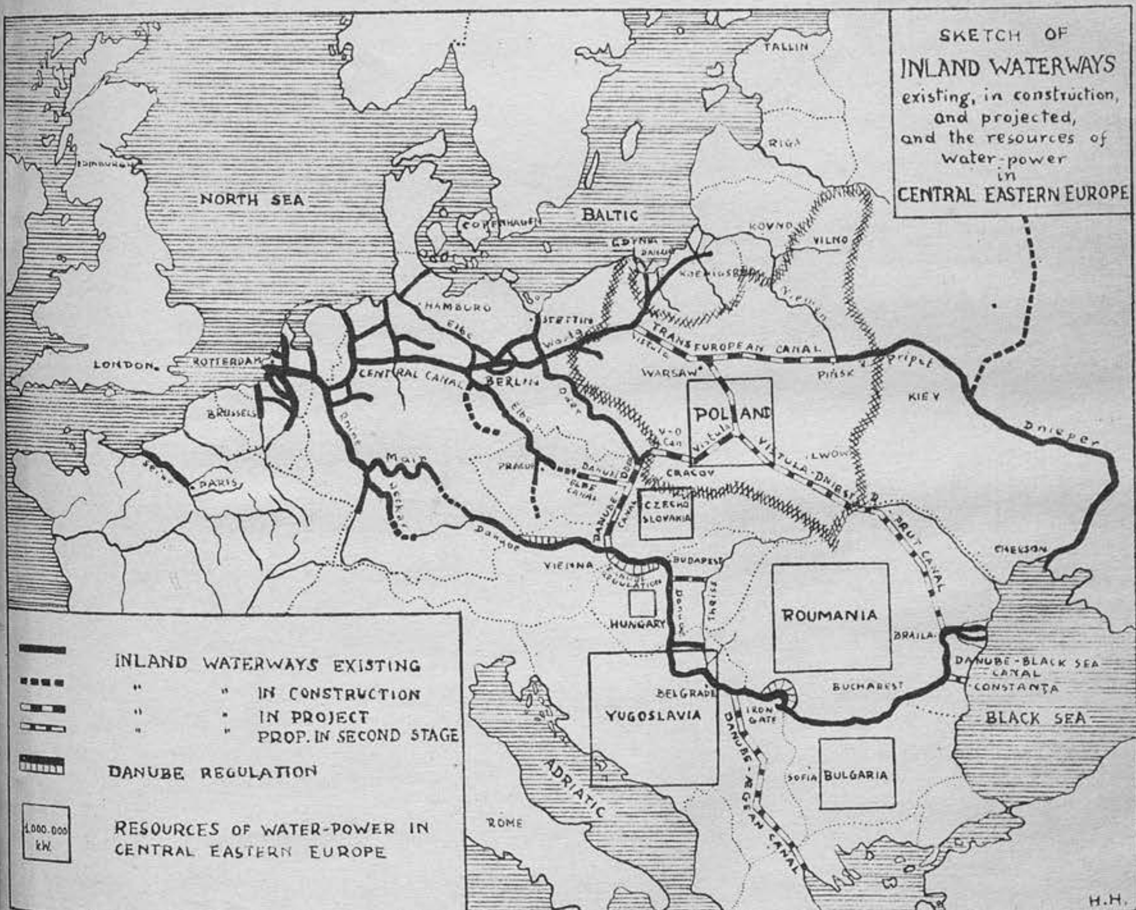
THE POSSIBILITIES OF DEVELOPMENT OF THE INLAND WATERWAYS IN EAST-CENTRAL EUROPE AS A PART OF THE GENERAL NETWORK OF TRANS-EUROPEAN NAVIGABLE WATERWAYS

Volume 2.

TABLE OF CONTENTS

In the Volume No. 1 , the state of waterway development in the countries adjacent to the proposed great Vistula - Oder - Danube - Black Sea Canal was explained and the navigational conditions in particular sections of this navigable waterway were discussed.

In the following Chapters (Volume No. 2) I propose to sum up the details of these schemes which in general lines form the programme of the development of an inland waterway of great importance in East-Central Europe for the post-war period.


SKETCH OF
INLAND WATERWAYS
existing, in construction, and projected,
and the resources of
water-power
in
CENTRAL EASTERN EUROPE
NORTH SEA
BALTIC
TALLIN
RIGA
KOVNO
VILNO
COPENHAGEN
GDYNIA
KOENIGSBERG
HAMBURG
STETTIN
LONDON
ROTTERDAM
BRUSSELS
PARIS
CENTRAL CANAL
BERLIN
TRANSEUROPEAN CANAL
WARSAW
PINSK
Pripet
KIEV
POLAND
Dnieper
LWOW
VISTULA-DNIESTR
CRACOV
PRAGUE
Main
CZECHO SLOVAKIA
Danube
VIENNA
BUDAPEST
CHERSON
PRUT CANAL
HUNGARY
ROUMANIA
BRAILA
DANUBE-BLACK SEA CANAL
CONSTANȚA
BUCHAREST
BELGRADE
YUGOSLAVIA
IRON GATE
BLACK SEA
DANUBE-ÆGEAN CANAL
SOFIA
BULGARIA
ADRIATIC
ROME
INLAND WATERWAYS EXISTING
" " IN CONSTRUCTION
" " IN PROJECT
" " PROP. IN SECOND STAGE
DANUBE REGULATION
1.000.000 kW.
RESOURCES OF WATER-POWER IN CENTRAL EASTERN EUROPE
H.H.

T H E

G R E A T   I N L A N D   N A V I G A B L E

W A T E R W A Y

O D E R - D A N U B E - B L A C K   S E A   C A N A L

The proposed new Oder - Danube - Canal (see sketch No 12).
First of all it is necessary to discuss the projected canal between the Oder and the Danube, which will constitute the link between the existing inland waterways on the Baltic - Black Sea route. This canal will form the first improvement necessary so that the navigable waterway from the North to the South-East, which is already suitable for navigation may be used for transport, as soon as possible.

The inadequate though comparatively considerable capacity possessed by some sectors of the Oder and the Danube will enable the development of inland navigation in East-Central Europe as soon as the Oder-Danube canal is available. Simultaneous or future improvement of the worst sectors of the Danube and Oder by alteration or the construction of several canalization stretches and by an intensification of regulation works, will increase the value of this route as a modern navigable water--way, capable of taking large craft of 1,200-1,500 tons.
The proposed navigable waterway and its connections, the Oder-Vistula canal, the canalized Vistula and the Great-Trans--european navigable waterway from West to East, will form a great system of inland European waterways, with practically the whole of Europe as its hinterland.

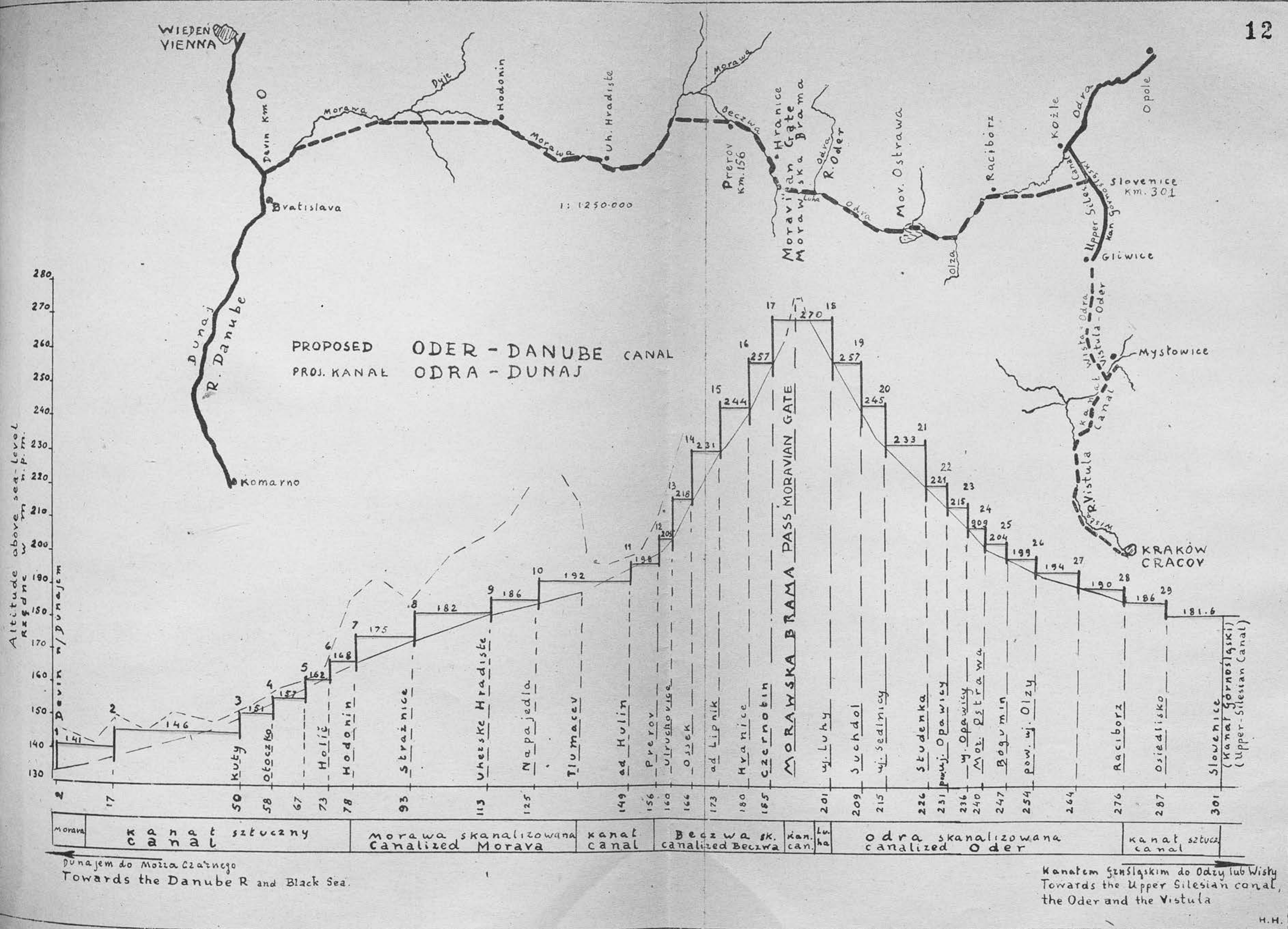
A detailed description of this scheme will be given in Chapters II, III/Vol.2.

The route on the proposed new Oder-Danube canal is as follows: From the North along the valley of the Oder, then to the South along the valley of the Morava. To join up the rivers Oder and Morava, this new waterway would have to cross the principal European watershed at an altitude of 270 m above sea level over the Pass called Moravian Gate.

The preliminary estimate of my project involves the carrying out of construction works, the ~~xxx~~ final result of which is represented by the following data:

1. Total length of the canal capable for 1,200 - 1,500 tons craft	301 km
a) Length of the canalized rivers	188 km
b) " of the artificial canals	113 km
2. Total available head	224.8 m
a) consisting of a rise in the Oder valley of	88.4 m
b) a fall in the Morava valley of	136.4 m
3. Number of falls and locks	29
4. " of weirs on the canalized rivers	11
5. The average fall about	7.8 m
a) the minimum fall	4.0 m
b) the maximum fall	13.0 m
6. Average length of reaches	10.4 m
7. Number of water power stations	16
a) the power capacity of which	55,000 kW
b) the output capacity of which per year	270 million kWh
8. Dimensions of locks:	
a) length	85 m
b) width	12 m
c) depth	3.5m

9. Total estimated cost of construction £. 22 million



WIEDEŃ
VIENNA
Devin Km O
Bratislava
Komarno
Dunaj
R. Danube
Morava
Dyje
Hodonin
Morava
Uh. Hradiste
Morava
Beczwa
Prerov
Km. 156
Hranice
Moravian Gate
Morawska Brama
Odra
R. Oder
Luha
Odra
Mor. Ostrawa
Olza
Raciborz
Koźle
Odra
Opole
Slovenice
Km. 301
Upper Silesian Canal
Kan. Gornoslaski
Gliwice
Wisła - Odra
Vistula - Oder
Kanał
Canal
Mysłowice
Vistula
Wisła
KRAKÓW
CRACOV
1: 1250.000
PROPOSED ODER - DANUBE CANAL
PROJ. KANAŁ ODRA - DUNAJ
Altitude above sea-level
Rzędne w m. n. p. m.
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
141
146
151
157
162
168
175
182
186
192
198
205
218
231
244
257
270
257
245
233
221
215
209
204
199
194
190
186
181.6
Devin n/Dunajem
Kuty
Otoczko
Holič
Hodonin
Straznice
Uherske Hradiste
Napajedla
Tlumacev
ad Hulin
Prerov
Ulruchovice
Osjek
ad Lipnik
Hranice
Czernotin
MORAWSKA BRAMA PASS MORAVIAN GATE
wj. Luhy
Suchdol
wj. Sedlnicy
Studenka
powj. Opawicy
wj. Opawicy
Mor. Ostrawa
Bogumin
pow. wj. Olzy
Raciborz
Osiedlisko
Slowenice
(Kanał Górnośląski)
(Upper-Silesian Canal)
2
17
50
58
67
73
78
93
113
125
149
156
160
166
173
180
185
201
209
215
226
231
236
240
247
254
264
276
287
301
Morava
kanał sztuczny
canal
morawa skanalizowana
Canalized Morava
kanał
canal
Beczwa sk.
canalized Beczwa
kan.
can.
Luha
odra skanalizowana
canalized Oder
kanał sztuczny
canal
Dunajem do Morza Czarnego
Towards the Danube R and Black Sea
Kanałem Górnośląskim do Odry lub Wisły
Towards the Upper Silesian canal, the Oder and the Vistula
H.H.

The route of the Oder-Danube canal would start in the North on the second reach of the existing Upper Silesian canal, between the lock No 2 at Nowa Wieś and the lock No 3 at Slovenice and x end in the South at the estuary of the river Morava to the Danube on the post km 1877,near Devin.

The southern section.

The Morava valley on the lower course of the river opens out and lies in flat land,on the middle course it changes into a narrow gorge near Napajedla,between the hills Vrchovina Cesko - Moravska and White Carpathian Mountains and remains as a mountain valley up to the springs at the foot of the Kralicky Sneznik peak at an altitude of 1,442 m above sea level. This mountain peak constitutes a meeting place of the principal European watersheds:

the North Sea (Elbe) , the Baltic Sea (Oder) and the Black Sea (Danube).

The river Morava by its left tributary Becva approaches the low pass called the Moravian Gate,between Czecho-Slovakian Massiv and the West Beskid, a part of the Carpathian Mountains.

The natural favourable topographical conditions, therefore, make the Morava valley a suitable route for the southern section of the proposed Oder-Danube canal,and leads along the valley of the Becva to the Moravian Gate pass by which the canal would cross at an altitude of 270 m above sea level.

The area of the basin to the mouth of the river Morava amounts to 23,010 km^2, a great part of which is occupied by the right tributary Dyje with a catchment area of 10,670 km^2. Incidentally, in the valley of this river Dyje there is a large storage reservoir, with the capacity of 165 million m^3 recently completed, which has a great influence on the regulation of the water flow in the lower course of the Morava.

The characteristic discharges, of the Morava near Sw.Jan are as follows:

yearly average water flow 116 m^3/s

minimum monthly water flow in August........................ 61 m^3/s

maximum monthly water flow in March........................ 212 m^3/s.

On the stretch of the lower course of the Morava over a distance of about 100 km from Hodomin downstream, the valley is flat and is developed agriculturally and the banks are low, the river twists and forks into several side branches.

On this stretch, except for a lower sector of 10 km, it seems to be advisable to build a lateral canal on the left bank, without using the bed of the river. The improvement of the river by means of regulation works would take a very long time and it would be difficult to obtain the desirable depth for modern large craft.

On this stretch the craft would rise above the total head of 34 m by means of 6 locks.

The first fall near Devin, at the point where the Morava joins the Danube, would be formed by a movable weir built on the river.

The tail water level at this weir , will vary , except at high water seasons , between 133.6 m i.e. the low water level on the Danube to 135.9 m above sea level i.e. the mean water level on the Danube. The head water level will be a practically constant level of 141.0 m above sea level.
The remaining 5 falls would constitude the locks on the lateral canal with a head varying from 5 to 6 m .
The length of this stretch between Hodonin and the mouth of the Morava river would amount to 78 km , 10 km of which would be the canalized lower course of the Morava , and 68 km the artificial lateral canal , instead of 104 km length of the river in its natural bed.
The middle stretch of the river Morava , between Hodonin and Tlumacov , presents conditions more convenient for canalization works than for the construction of an artificial canal. This sector has more compact banks which are high and in some places is suitable as a frame to the movable weirs. This stretch, for a distance of 74 km , would be canalized and four weirs and locks with a total fall of 24 m would be built. The individual falls vary from 4 to 7 m , and the length of reaches varies from 12 to 20 km .
The back-water caused by retaining a water level at the upper weir near Napojedla would pass along the second lateral canal, which would start near Tlumacov on the left bank of the river Morava i.e. twelve kilometers up stream from the weir at Napojedla.

After leaving the bed of the river Morava, this second lateral canal would lead by a shortcut to the valley of the river Becva near Prerov. The length of this canal would be 20 km instead of about 40 km, necessary to follow the Morava and Becva rivers. It would be necessary to build on this canal only one lock, with a head of 6 m, near Hulin to reach the valley of the Becva at Prerov.

The upper stretch of the southern section of Oder-Danube canal starts near Prerov and follows up stream along the river Becva, which requires and allows the construction of fairly high dams, owing to the steep average slope in a relatively narrow valley.

It must be pointed out that in Prerov a crossing point of two proposed navigable waterways: Oder-Danube and Elbe-Danube canals is to be expected and I shall come back to this subject later.

Returning now to the canalisation works which would be done on the river Becva, I must say that on this relatively small stretch over a distance of 36 km, it would be necessary to build 6 dams with a total head of 72 m, to reach and cross the watershed at an altitude of 270 m above sea level.

This can be done by the construction of concrete gravity dams, owing to the favourable foundation conditions in the rocky valley. The first of them would be the lowest one restricted to 7 m in height, owing to its situation near the town of

Prerov; the remaining 5 dams would have a head of thirteen m each.

The back-water from the head water of the upper dam , situated near Czernotin would extend to the watershed reach in the Moravian Gate and would link up with the upper reach on the northern side in the valley of the Luha , a tributary of the river Oder.

The northern section.

On the northern slopes of the Carpathian Mountains , the route of the Oder-Danube canal would run first in a deep , rocky valley of the torrent Luha, then follow the valley of the river Oder and finally as a lateral canal would end by reaching the Upper Silesian canal.

The first watershed reach would be obtainable by the construction of a dam , with a head of 13 m , at the entrance of the Luha to the Oder.

The next long stretch 75 km long comprising ten reaches,takes advantage of the river Oder , from the estuary of the Luha to Racibórz(Ratibor) , which is suitable for canalisation works. On this stretch , at the beginning the canalisation steps would be comparatively high with heads of 12 m , owing to the fact that the valley is more compact in this hilly country , and the slope of the river bed is fairly steep.

Further downstream from the mouth of the river Opavica to the Racibórz, where the river enters the important Ostrava-Karvin coal basin and the centres of the metal industry,there is a possibility of the construction of lower movable weir varying from 4 to 6 m in height.

As a whole the canalisation of the Oder requires the construction of 10 dams, three of which would be concrete gravity dams with a total head of 36 m and the remaining seven would be movable weirs of a total head of 31 m.

The final stretch from Racibórz (Ratibor) downstream is planned as a lateral canal on the right bank of the Oder valley. This canal would be 25 km long and the craft would rise above the head only of 4.4 m by means of one lock, between the tail water at the weir near Ratibor at an altitude of 186 m above sea level and the water level on the Upper Silesian canal near Slovenice at an altitude of 181.6 m.

The construction of the lower stretch Ratibor - Slovenice as an artificial canal forming a short-cut to the Upper Silesian canal and not the canalisation of the Oder, downstream from Racibórz (Ratibor) to Koźle, was decided upon for the following reasons:

1. Canalisation work on this section of the Oder would be very difficult to carry out, in view of the nature of its banks. This could be done only by constructing the weirs with very low heads, and would necessitate the construction of six weirs and locks with a total fall of 20 m; whereas by constructing a short-cut canal on the right bank towards the Upper Silesian canal it would only be necessary to build one lock near Osiedlisko, and in addition beyond the junction with the Upper Silesian canal there exist two

modern locks at Nowa Wieś and Klodnica,which permit of navigation towards Koźle on the Oder. The navigational conditions on the modern Upper Silesian canal,completed in 1938 , will be described in the Chapter on the Oder-Vistula Canal.

2.For the navigation downstream from Racibórz(Ratibor) along the Oder valley, the number of locks and consequently the number of lock operations which the craft have to negociate, would be reduced from 6 to 3 .

For navigation from the South-East to Poland via the Oder-Danube Canal in the direction of the river Vistula the reduction of locks would be from 8 to 1 and here also a considerable shortening of the route can be obtained.

3.The construction of an artificial canal between Ratibor and Slovenice,which would run in a flat and low terrain would be cheaper than the canalisation of the Oder from Ratibor to Koźle.

The route and longitudinal profile of the Oder-Danube canal over the distance of 301 km is represented by the sketch No.12.

During the carrying out of the detailed project certain alterations are possible to the head of particular weirs and dams, as well as to the length of the reaches,due to the local geological conditions which would provide the basis for such modificatiions in order to give the most advantageous conditions for the foundations.

Generally speaking,there should be no difficulty in finding a stratum of sandstone,or conglomerates,the resistance of which would be sufficient for such medium and low types of dams.

In addition the impermeability of the Carpathian sub-soil is due to the water-tight nature of the schists,which are widely spread and offer foundations suitable for the construction of dams.

Such alterations would not greatly change the route and would not greatly influence the total cost of the canal.

The distances between the final points of the Oder-Danube canal are as follows:

1.Towards the Baltic -

a) along the Oder from Slovenice	to Koźle	15 km
" " " "	to Stettin	656 km
b) along the Oder-Vistula canal and the Vistula from Slovenice	to Glivice	26 km
" "	to Myslovice	80 km
" "	to Warsaw	530 km
" "	to Gdańsk (Danzig)	997 km

2.Towards the Black Sea -

a) along the Danube from Devin	to Braila	1,688 km

Table No. 1. In the following table the data comprising the installations planned on the Oder-Danube canal are summarized

Waterway	Name	No lock	km post on river	km post on canal	Altitude in meter above sea level: head water	Altitude in meter above sea level: tail water	Kind of works a) dam b) lock c) power stations
Canalized Morava	Devin o/Danube	1	2	2	141	135.9	a,b,c,
Canal	Hochsetno	2		17	146	141	b,c
"	Kuty	3		50	151	146	b,c
"	Otoczko	4		58	157	151	b,c
"	-	5		67	162	157	b,c
"	Holic	6		73	168	162	b,c
Canalized Morava	Hodomin	7	103	78	175	168	a,b,c,
"	Strażnice	8	124	93	182	175	a,b,c,
"	Uherske Hradiste	9	150	113	186	182	a,b,c,
"	Napojedla	10	166	125	192	186	a,b,c,
Canal	near Hulin	11		149	198	192	b,
Canalized Becva	Prerov	12	12	156	205	198	a,b,
"	Ulrychovice	13	16	160	218	205	a,b,
"	Ossek	14	22	166	231	218	a,b,
"	near Lipnik	15	29	173	244	231	a,b,
"	Hranice	16	36	180	257	244	a,b,
"	Czernotin	17	41	185	270	257	a,b,
Canalized Luha	above the mouth	18	1	201	270	257	a,b,
Canalized Oder	Suchdol	19	732	209	257	245	a,b,
"	at the m.of Sedlnica	20	726	215	245	233	a,b,
"	Studenka	21	715	226	233	221	a,b,
"	above the m.of Opavice	22	710	231	221	215	a,b,
"	below "	23	705	236	215	209	a,b,
"	Mor.Ostrava	24	701	240	209	204	a,b,c
"	Bogumin	25	694	247	204	199	a,b,c
"	ab.m.Olza	26	687	254	199	194	a,b,c
"	-	27	677	264	194	190	a,b,c
"	Racibórz	28	665	276	190	186	a,b,c
Canal	Osiedlisko	29		287	186	181.6	a,b,c
Upper Sil.Canal	Slovenice			301	181.6		

Water supply for the lock operations for navigation and the regulation of the water level in the reaches.

The water required for lock operations is a most important question in the watershed reaches, where considerable difficulties arise with artificial water supply for the frequent filling of the locks.

The required volume of water depends on the intensity of the traffic; on the dimensions of locks and also on the frequency of lock operations during the year.

There may be assumed the relatively great transport capacity of 20 million tons per year, on the proposed Oder-Danube canal, on which the bulk of the traffic will be carried in the northern direction via the Oder to Stettin and via the Oder-Vistula canal to Gdańsk(Danzig); and to the south-east via Danube to the Black Sea; or westwards via the Elbe-Danube canal to Prague.

The second factor is the dimension of the locks, which should be sufficient for the barges which must be anticipated as 1200 - 1500 tons to be suitable for modern inland waterway traffic.

These minimum dimensions may be taken as 85 x 12 x 3,5 m .

T The problem of the water supply for filling the locks on each side of the Moravian Gate is one that requires very careful consideration.

In the lower reaches of the Morava and Oder valleys the natural flows from the rivers are more than sufficient for this purpose and, indeed, will permit of the construction of hydro-electric stations. The utilisation of the surplus power in this way, as a by-product,would give an additional profit on the Oder--Danube canal,which will itself be profitable,being a navigable waterway of the first importance.

The estimated movement of traffic passing through single locks of the type usually adopted would call for a relatively large quantity of water, on an average 12 m^3/s , or , for a navigation period of 300 days per year, a volume of about 300 million m^3.

Owing to the fact that the catchment areas of the rivers Luha and Becva are very small , it would be unlikely that the supply of water would be sufficient for the higher reaches throughout the year.

I therefore propose to introduce a new type of twin-lock, which would give a saving of nearly 50 percent of water volume, figure No. 32. By means of a connection between two locks placed side by side, it is possible to fill the lock containing the craft going up stream to nearly 50 percent of its volume, by using the water discharged from the other lock,containing the craft going downstream.

A detailed description of the twin lock is given in Chapter No.IIaVolume 2.

This type of lock would be installed at eight points, at weirs No. 13, 14, 15, 16 in the Becva river and No. 19, 20, 21 and 22 in the upper Oder and, as a result , the volume of water required would be reduced to 5.5 or 6 m^3/s.

To ensure the additional supply of water, at all seasons, it would be necessary to construct storage reservoirs in the valleys of the Becva and Luha but this would be neither difficult nor costly as the valleys are narrow, deep and rocky and provide excellent sites.

To ensure that the passage of shipping will be uninterrupted I propose to take further saving precautions at locks Nos 17 and 18 which are at the highest level.

At these points I propose to use a new type of lock a detailed description of which will be found in Chapter IIa Volume 2. The arrangement is illustrated in Fig. 30.

In this case twin-locks are also used but they are not placed side by side and , although connected together , are some distance apart and are not directly opposite to each other. To permit of this the canal is divided into channels.

Surrounding each lock is a series of six basins which act as additional storage reservoirs and contain water which may be used in case of an emergency.

In the event of a shortage of water from the main supply reservoirs the upstream lock would be filled to approximately half its volume,by discharge from the downstream lock and , for the remainder , by water from the surrounding basins.When the process is reversed emtying would take place partly by discharging into the other lock , which is now the upstream one , and partly by pumping water back into the basins.

There would thus be little loss of water and further, in order to reduce the power required for pumping, the basins are arranged at decreasing levels so as to keep the pumping head as small as possible.

By this arrangement the amount of water to be supplied is further reduced to 4 m^3/s giving additional security in the event of an exceptionally dry year.

The remaining nineteen locks on the river Morava, downstream from Prerov and on the Oder downstream from the estuary of the Opavice, would be of the usual single lock type as the locks operate under lower heads and there would be adequate water for the discharges.

The following table No. 2 gives the heads and average discharge for the operation of each lock on the Oder-Danube canal.

Table No. 2.

Type of locks	No	head m	Discharge m^3/s	Type of locks	No	head m	Discharge m^3/s
single				(85 x 12)			
85 x 12	1	7.0	6.4	twin 2	13	13.0	6.0
"	2	5.0	4.6	"	14	13.0	6.0
"	3	5.0	4.6	"	15	13.0	6.0
"	4	6.0	5.6	"	16	13.0	6.0
"	5	5.0	4.6	twin with			
"	6	6.0	5.6	basins			
"	7	7.0	6.4	2(85 x 12)	17	13.0	4.0
"	8	7.0	6.4	"	18	13.0	4.0
"	9	4.0	3.6	twin 2(85			
"	10	6.0	5.6	x 12)	19	12.0	5.5
"	11	6.0	5.6	" "	20	12.0	5.5
"	12	7.0	6.4	" "	21	12.0	5.5
"	22	6.0	5.6				
"	23	6.0	5.6				
"	24	5.0	4.6				
"	25	5.0	4.6				
"	26	5.0	4.6				
"	27	4.0	3.6				
"	28	4.0	3.6				
"	29	4.4	4.0				

Shape of cross-section of the canal.

The choice of a correct shape for the cross-section, and of suitable slopes of the banks and their protection, both depend on certain special conditions, such as special circumstances of navigation or a special kind of soil. This choice is of great importance in the case of artificial canals which have very crowded traffic, in order to reduce as much as possible the costs of maintenance.

The study of the typical cross-section of canal should be based on model experiments; for the type of boats and navigation conditions that are expected one should try to choose the section giving a minimum resistance.

In regard to the boats using the proposed canal, it would be necessary to estimate the following elements: the length, the beam, the maximum section of the frame empty and loaded, the emergence above the water-line when empty, the maximum tonnage carried, the maximum speed allowed either empty or loaded.

In regard to the speed, it would be useful to differentiate between boats towed alone and moving in convoys and those self-propelled.

It is not without interest, to gain some information conserning the shape of the cross-section and the bank protection along existing canals; but when we examine the existing canals in Europe, we note the lack of uniformity and even the lack of similarity in the types of canals, not only for different countries, but even for the same country, and we should note, that the problem is not simple.

The choice of the form of the cross section, as I have mentioned, depends firstly on local conditions, and the nature of the soil through which the canal would be built. In the case of a sandy, movable soil, which slips easily, the slopes should be flat; in the case of stable soil the slopes may be steeper.

Secondly, the cross-section of the canal must be in a favourable ratio to the submerged cross-section of the loaded vessels, with maximum capacity, which would use the canal, in order to facilitate its propulsion. It is desirable that the ratio between the wet section of canal and the submerged section of the frame of the craft should never be below 4 : 1 except in quite exceptional cases. In Holland this ratio varies on the excavated canals from 1.9 in old canals to 5.4 in modern canals.

Thirdly, the cross-section of the canal must be such that there is a sufficient depth of water, if possible no less than 1.0 m , beneath the boat when navigating fully loaded.

Lastly, it is very desirable to choose the most suitable shape of cross-section of canal in order to reduce to a minimum the erosion of the canal banks and beds caused by action of propelled craft moving with considerable speed.

It is possible to use different forms of cross-sections for navigable canals, which may be trapezoidal, trough-shaped or spoonshaped in section.

In the case of the trapezoidal form the bottom is horizontal, and the slopes rise according to a more or less uniform gradient.

As a consequence of the movement of the screws of the vessels, the speed of which is still increasing, and the counter flow of the water beneath the heavily loaded vessels, the horizontal bottom has been gradually washed away in many existing canals, and the material which is moved from the bottom forms deposits at the lower part of the slopes.

These deposits have generally formed natural flat slopes at the junction of the bottom with lower part of the slopes of the banks.

Thus in the case of many existing canals the cross-section shaped itself into the form of a trough and indicated the way in which new canals might be shaped.

The features of the proposed shape of cross-section for the Oder-Danube canal in the sections where I propose to build artificial canals - are that the bottom of the canal rises at first very slowly with a slope 1 : 15 - 1 : 20 from the centre of the canal towards the banks ~~with ratio~~, then the slope increases to 1 : 4 and meets that of the banks with ratio 1 : 2.5.

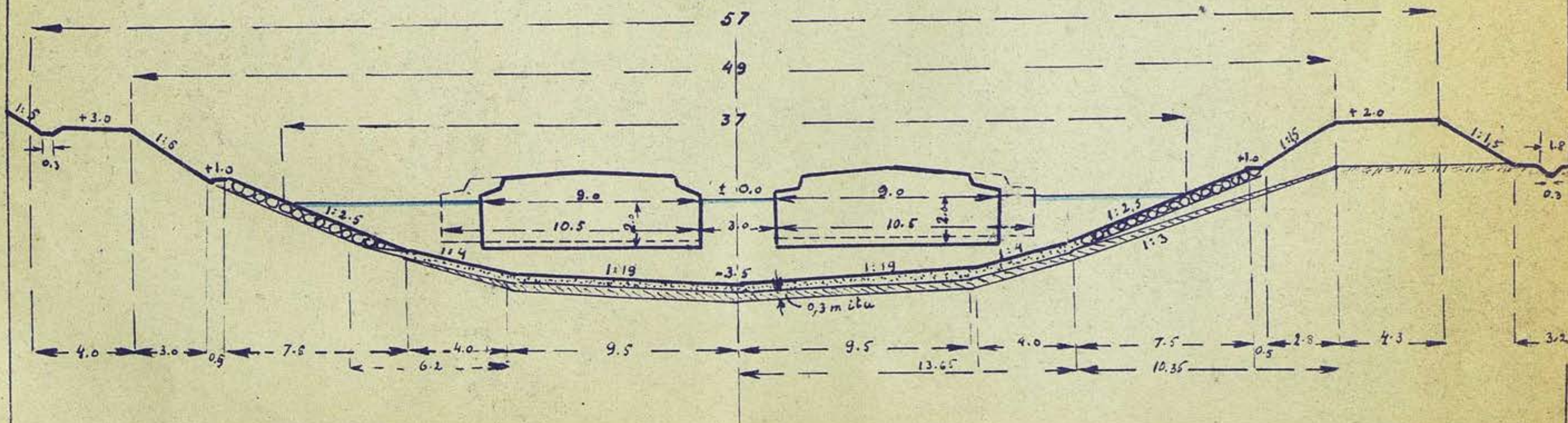
The water depth for the adopted draught of 2.5 m , that is to say for the 1,200-1,500 tons vessels, is 3.5 m , and the width of water line is 37 m , thus the wetted cross-section amounts to 92 m^2 (see sketch No. 13.).

TYPICAL SHAPE OF CROSS SECTION OF THE ODER-DANUBE CANAL (for 1200-1500 t.)

TYPOWY PRZEKRÓJ KANAŁU ODRA-DUNAJ (na 1200-1500)

SCALE 1:250
SKALA 1:250

Wetted cross section F = 92 m^2
Przekrój zwilżony F: 92 m^2



H.H.

This wetted cross section allows for the crossing of two 1,200 tons barges with breadths of 9.0 m or two 1,500 tons barges with breadths of 10.5 m . It is a typical shape of cross-section for the proposed Oder - Danube canal, but in the case of more stable soil, and the slopes can be increased owing to the fact, that there would not be so much danger of the scouring of the bottom and banks.

The second question is the choice of protection of the banks, which should be settled by the local nature of the soil and by the materials for protection work, which are available in the vicinity and on the other hand by the maximum speed of the vessels and trains of barges.

The action of the counter-currents created along the sides and beneath the barge is variable. The effect is the more important when the speed of the boats is greater and the ratio of the cross sections of the craft and of the wetted section of canal is ~~smaller~~ greater.

The wake waves are especially dangerous, when, in the case of the overtaking of a loaded train of barges by another boat sailing alone at a great speed, the screw of the latter comes too close to the bank. Also the overtaking of loaded boats by other loaded boats causes a great decrease of the cross-section of the canal.

Judging by my experience of a canal with a wetted cross-section up to 65 m^2, a depth of 3.0 m, and barges having a draught of 2.0 m, and a screw depth of 1.75 m, I can say that there is - no danger of the destruction of the bottom and banks, when the speed is not greater than 4.5 - 5 km/hour, for loaded trains of barges, ~~than~~ and 7 km/hour for selfpropelling boats and 8 km/hour for light vessels.

For a canal with a greater wetted cross-section between 90-100 m^2, and a depth of 3.5 m, at the junction of the bottom slopes which I propose for the Oder-Danube canal we can estimate that the corresponding figures of non destructive speed would be as follows: 7 km per hour for loaded train of barges and of 10-12 km/hour for propelling boats.

Tests with greater speeds were made on the modern Central canal in Germany and the following results were obtained;:

For a towed barge of 1,000 ton capacity with the hawser 100m long,

the ratio between cross-section of the canal and the wetted section of the frame of the craft was 4.27. At a speed of about 8 km/hour the bow and stern waves of the boats were relatively small. The maximum drop in the water level at the banks was observed to be 30 cm .
In the case of a tug-boat sailing alone in the middle of the canal,the maximum drop in the water level at the banks was observed to be 37 cm at a speed of 12.7 km/hour, and the waves which moved in a direction perpendicular to the bank, beyond the stern,caused a destructive effect on the bank protection. When the speed of the XXXX tug-boat was lower than 10 km/hour the effects of these waves were negligible.
The protection of the banks against the waves is more important in navigation canals than in the canalized and free flowing rivers,owing to their greater breadth.
The destructive effects caused by the towage and by self propelling vessels,are especially harmful,because the undulation lasts a long time,until it is XXXXXXX entirely absorbed by the friction at the banks. Apart from the force of impact the destructive effect of the waves and of the wake consists in the fact that the sand and fine stone material of the foundation is washed away. Thus the larger stones are loosened and hollows are created under the protection works.
Experience shows that this effect occurs more easily and rapidly in the case of stones closely set in a regular design, than in the case of irregularly shaped stones on a foundation

of gravel; owing to the fact that the vertical continuous joints offer easier conditions for the destructive effect, than the very irregular spaces between the broken stones of different dimensions.

The closely set large stones also slip more easily because it is very difficult to fix them firmly under the water surface. On the other hand very small broken stones 4-10 cm , or gravel roll too easily.

In order to render the protection more compact and stable, it is advisable to crush the larger stones into pieces of about 30 cm , after they have been discharged. The stones used for the broken stone protection should be resistant against frost and they must be heavy, with high density, so that they are likely to remain in place, in order to avoid slipping as much as possible. Further, the broken stone protection must not have too rough a surface, otherwise damage would occur when wooden boats, come into contact with the banks, an occurrence which it is impossible to avoid.

Finally I must add, that experience shows that if we use discharged broken stones of different sizes, large holes cannot easily occur in the protection works, owing to the fact that the smaller stones readily fill the holes between the larger ones.

Experience has also proved that slopes of 1 : 1.5 and 1 : 2 , are generally too steep; the saving made in the first construction work, is lost by the higher maintenance costs.

Such steep slopes must be avoided for use in navigation canals with heavy traffic.

Therefore, as is shown on the sketch No. 13. I propose for the protection of the banks a layer of broken stones 30 cm thick on a foundation layer of gravel 10 cm thick laid at a slope of 1 : 2.5 .

This typical shape of cross section of the canal is proposed for the following stretches:

Ratibor(Racibórz) - Slovenice	25 km in length
Prerov - Tlumacev	20 km "
Hodomin - Post km 10 on the Morava	68 km "
T O T A L	113 km in length

As regards the protection of the banks on the canalized rivers Oder and Morava the problem must be solved as in the case of the canal stretches. But owing to the fact that a ratio between the cross-section of the river and the section of the frame of a typical boat is more favourable - the problem is of less importance from the standpoint of the destructive effect of the waves created by the boats.

On the other hand, in this case the actions resulting from the conditions of flood water and ice must be considered.

As regards the floods, we must consider not only the action of the currents, but also the variations in level. The protecting works for the banks must be below low water and repair work must also be done, under water.

The problem for defence against the violent action of currents, is generally speaking carried out in two ways, by designing a suitable lay out and by a correct choice of slope for the banks, second by additional protection works in the facing of the banks so that they may be able to resist the further actions in the more exposed ~~sections~~ sectors of concave bends.

As regards the ice, which problem exists in the northern portion of the Oder-Danube canal, we must remember that the dangerous action is due to the destructive effect of shocks. This action is reduced where the ice can slip without violent impact against projections and discontinuities in the banks.

As a rule we may say, that the steepest slopes in concave bends, protected by broken stone, which can sufficiently resist the destructive effects, of flood water and ice are 1 : 3 .

I would like to mention that in the present canalised Oder downstream from Koźle to Ransern the banks were constructed of heavy stone bedded in a mat of fascines 20 cm thick, laid at a slope of 1 : 2 .

Even with this slope the flood water and ice had great destructive effect and the stones were frequently washed away from the protection walls of the bends.

In order ~~xx~~ to render the discharge of flood water and ice possible without inconvenience on the canalised rivers Oder and Morava, on its lower reaches the weirs should be constructed so as to be movable along their full width. They must have a free cross-section enabling the flow of high water and ice in order to avoid the raising of the water level to an inconvenient height. When the weirs are open the cross-section must be very much the same size as it is in the normal stretches of the river to be satisfactory for the discharge of high water and ice.

These widths on the river Oder vary from 40 to 50 m , and on the river Morava to 150 m .

Modern types of movable dams for the proposed canal

O D E R - D A N U B E

The movable dams for hydro-electric projects and for improvements of the rivers by means of canalisation carried out in order to facilitate navigation may be divided into four general classes:

1. Crest control gates, which lower or raise the crest, as the river disharge varies;
2. Crest gates, which are opened and closed to vary the capacitey of the spillway as desired;
3. Sluice gates, which are placed usually in the lower part of the dam to assist the spillway in the discharge of the flood flow;
4. Siphon spillways, which increase the capacity of the spillway by providing a suction head in addition to the head on the crest.

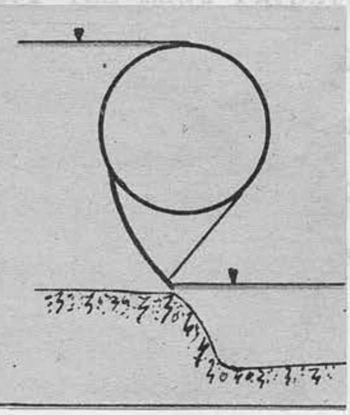
Many scientific tests for elucidating hydraulic problems, researches on laboratory models and observations on existing movable dams have been made in different countries, where an increase in weir construction is in progress. The extreme diversity of the local and hydrological conditions create new problems in the determination of the types of weirs best fitted for each position.

Before chosing the types of weirs for the projected canalisation works to be carried out on the rivers: Oder, Luha, Beczva and Morava, from which the navigable canal ODER-DANUBE would be formed - let us consider what are the modern types of movable dams in Europe and America and what are the largest dimensions of each type at the present time.

The preliminary analysis points to the use of roller weirs, lifting gates and segmental gates for this canal. Let us examine the characteristics of each of them.

Roller weirs (see sketch No. 14.)

14



The closing structure consists of a sheet steel cylinder which is made to roll down and up on slanting guide surfaces.

A cylindrical cross-section is particularly well adapted for the absorption of the torsional forces to which such weirs are subjected. In the case of large openings the resistance against torsion of the cylinder is such that there is no difficulty in operating the weir from one side. Therefore one lifting installation and one winch only are required for closing and opening the weir. This is the advantage of the roller weir over the other types, offered by the rigidity of the roller.

Owing to the cylindrical shape of the retaining side, specially good hydrostatic and hydrodynamic action of the forces is obtained in this type of weir. These advantages permit of the use of roller weirs in large openings with small and medium retaining heights. The largest longitudinal dimension which has so far been used is 45 m with 4.5 m closing height (Ladenburg) and the greatest closing height 6,5 m was installed in Dsoragen (Armenia). The most favourable ratio of closing depth to width is 1 : 8 in the case of roller weirs and a large number of such weirs have been installed in many countries.

In addition to the ordinary type of roller, variations have arisen in recent years, such as submersible rollers and rollers with flaps.

These variations were made because the simple roller weirs in certain cases have certain disadvantages: when the maximum level of the ~~top of the rollers~~ water may not exceed the level of the top of the rollers it is necessary to evacuate a small surplus of water, floating ice in winter or floating debris collecting at the weir by raising the large heavy roller very often and even for small discharge.

The water discharged with great pressure and velocity under the bottom of the roller attacks the bottom of the weir when silting materials, ice e.t.c. pass through. To overcome this defect a method is devised by allowing the crest of the roller to be lowered to a certain extent (0.60-1.20 m) .

For that purpose the lower retaining shield of the roller must be lowered and sunk below the level of the sill.

The watertight closing at the sill of the weir of submergeable rollers,has been carried out in several different ways. Some of these are very complicated. One of the most modern - is a water tank. The system consists of a sheet steel tank which is fixed to the lower end of the closing shield.

The part of the box which faces the weir sill is provided with a spring steel sheet at the free end of which the closing beam is attached. The tank is connected with the head water by means of a pipe. Owing to the hydrostatic pressure of the head water which acts in the tank the spring steel sheet and consequently the watertightening beam are pressed against the sill, which is reinforced by steel.

A drawback of this system, as opposed to the normal rollers, which rests on the sill is the fact that when the roller is raised, the kinetic energy generated by the shooting water hits the elastic edge of the watertightening system and may eventually cause damage. But actually no serious trouble has occured with submersible rollers having this watertight system especially when use is made of a spring for improving the closing system of the tank..

Another drawback in these installations is the fact that heavy rollers, when thay are in a normal position, do not rest on the bottom,but hang from the chain and racks.

In the more recent installations this unsatisfactory situation has been corrected by supporting the rolls , when they are in their normal position , on special supports placed in the concrete masonry of the recesses for the rollers. The rollers are provided with corresponding stops on which the support can act when required. The rollers move round an axis and are actuated from the winch room by means of a lever.

By these means the lifting chains and the winches are generally relieved of the load and are only put into action when the rollers are being raised or lowered.

The top of the weir sill under the rollers is usually placed at the level of the river bottom , so that any rise of the water level in the cross-section of the river at high water is avoided and navigation can pass freely without using the locks.

At the downstream side protection of the bottom of the river should be provided.

The first - the adjacent dental concrete downstream floor , the surface of which lies 1-2 m below the level of the weir sill; this deepening beyond the sill extends to a length of 1.5 - 2.0 times the retaining heights , after which point the bottom rises with a slope of 1 : 5 - 1 : 6 .

The second - protected bottom, consisting of heavy mattresses made of stone and fascine. The total length of protected bottom should be determined by experiments on laboratory models. It usually varies from 10 - 15 times the retaining heights.

In order to avoid undermining when the weir installations on the canalized rivers have to be constructed on sedimentary material , which forms the river bed , a steel sheet piling should be provided at headwater and the tailwater side of the weir sills.

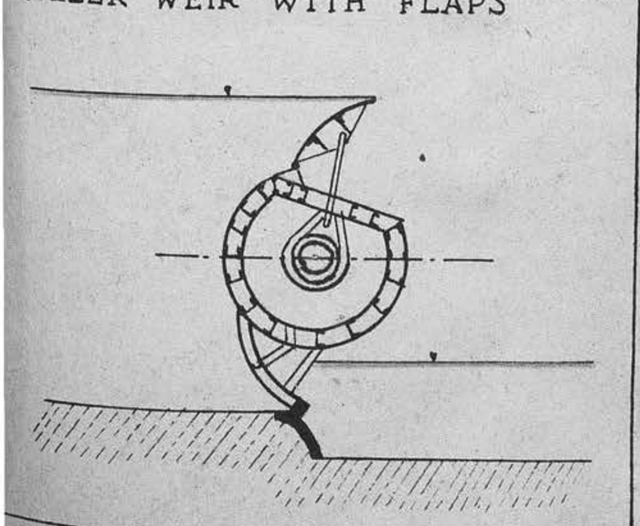
In particular these precautions would generally be necessary on all canalized rivers in Poland , where the rock is too deeply seated to be reached.

The upstream sheet piling reaching down 8-12 m below the sill of the weir , prevents or retards the trickling of the water under the weir.

The downstream sheet piling 6-8 m high serves to protect the construction against scour and sliding.

From the successful experiments made with roller weirs improvements in the ordinary or submergeable rollers were suggested leading to the adoption of <u>rollers with flaps</u> (see

ROLLER WEIR WITH FLAPS 15



The general shape of the ordinary roller with its good bottom watertightening system is maintained and on the top of the rollers torsion resisting flaps are erected.

When the flaps are lowered the roller resumes its cylindrical form.

The flap's shaft is well protected, being lodged below the surface of the roller, and the risk of damage is avoided. The flap is also actuated from one side by the winch and driving chain which are used for lifting the rollers.

This type of roller weir facilitates the regulation of water level without the roller itself having to be moved. It is especially important in the case of frequent and small regulation of water level. In the case of the ordinary rollers or of submersible rollers, the heavy closing structures have to be moved even when a small regulation of water level is necessary. Therefore the lateral and bottom watertightening systems, being frequently lifted, lose their tightness and losses of water occur. This weakness can be avoided by using the roller weirs with flaps.

The height of flaps varies from 1.0 to 1.5 m by a lenght of 30 - 40 m .

I propose this type of roller weir for the projected canal Oder-Danube, where many small operations of water regulation would be necessary, and also because there exists the problem of frost, especially on the north portion of the canal i.e. on the canalized river Oder. Therefore it would be possible to avoid the disturbanses, which are likely to arise, when it is no longer possible to keep the chains and racks free from ice during heavy frost.

As I propose a maximum lenght of 40 m for the roller weir's and a maximum height of 1.5 m for the flaps it appears to be advisable to place the torsion resisting tube of the flap inside the roller, and to support the latter on to this tube in order to avoid twisting.

The driving tube would have a diameter of 1.0 m and a length of about 2/3 of the entire closing structure. The flap would be supported on the tube by a frame in the shape of a parallelogram. At the driven end of the tube a lever would be fitted to raise or lower the flap.

When the flap is in an erect position the support from the tube would be so designed that the force transmitted to the tube would be directly downwards and would not cause torsion.

The flap rests on a hinge which runs the whole length of the plating of the roller. To eliminate secondary tensile forces emanating from the deflection of the roller, it would be advisable to provide the plating of the flaps with two or three watertight transvers joints.

The watertightening rubber would be affixed to the hinges between the flap and the roller. Watertight joints between the flap and the lateral plating ahould also be provided. In this case, for example, a replaceable rubber joint situated at the tail water side and pressed into the lateral plating by means of a brass spring, can be used.

In order to render the driving of the flap independent of the driving of the roller,separate winches would be provided for the roller and for the flap.

By this arrangement we can avoid a drawback which exists in the case of onedriving installation, and which is cansed by the fact, that when the roller is being lifted, with erected flap, the latter cannot be lowered.

I should like to add that this closing system has often proved superior to all other known systems, during periods of frost and ice, as owing to its cylindrical shape, the rollers congeal less ice and are therefore less weighted down.

For these reasons I propose this type for the north portion of the canal Oder-Danube i.e. on the canalized river Oder (members of dams: 22nd,23th,24th,25th,26th,27th and 28th), see sketch No. 12.

Single and double lifting gates

The general principles of this closing system are well known, but remarkable new improvements have been made in this system in recent years.

Single lifting gates as a means of closing large openings, over 25 m , are not generally used owing to their pronounced tendency to vibrate. When the span increases the relative mass and the rigidity of the gate diminish. The amplitude of the oscillations becomes greater, and then the resonance produces unusually great vibration. The increased strains of the material thus sometimes cause fracture of important parts of the structure. These vibrations not only overstrain the closing structures, but they are transmitted to the piers and the winches.

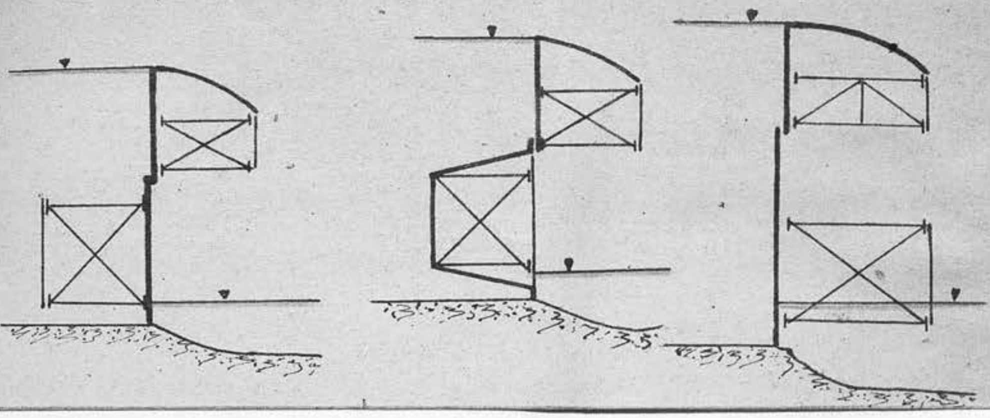
The causes of vibration have not yet been completely explained but in the case of new constructions in recent years great care has been taken to diminish this action. The first was thoroughly to examine the correct height of the tail water above the sill of the weir, as this is frequently a decisive factor in regard to the occurence of vibration.

At the same time special attention has been paid to the structural parts,near the beam, which is to render the closing watertight, and where the jet of the water passing under the construction and acting under a high pressure releases an especially large amount of energy. Next, in the case of new constructions, the weir closings are strengthened to resist the horizontal, vertical and torsional forces, which arise when they are in operation.

Owing to the increase in size and weight of the closings through the tendency to use wide spanned lifting gates, the problem of the discharge of small surplus water and of flotsam materials and ice, without lifting the heavy closing structure, has arisen.

There are two alternatives: either a system of two independent closings, called double gates, where the upper lighter gate is made to be lowered for water to pass over its crest, or a system consisting of one lower gate with a flap on the top, which can be lowered towards the tail water by rotation.

See sketch No. 16.



In the case of double gates differrent forms of construction are used. The first structure consists of two gates, usually a larger lower gate with a smaller upper one. Each gate can be moved independently. This allows a discharge over the upper and below the lower gate at the same time. The two water jets destroy each other's energy and the attack on the bottom is considerably reduced.

A comparison between old and modern double lifting gates shows that as a result of research into hydraulic conditions, the same problem is now solved much more economically.

For instance the lifting force for the lower gate in Lauferburg on the river Rhine (built in 1911.) requires to be three times the dead weight of the gate, whilst the same force in the modern double gate in Kachlet (built in 1929.) on the river Danube requires only 1.4 times the dead weight.

In the latter dam there are six openings each 25 m wide. The lower gate is 8.8 m high, the upper one is 3 m high.

The pressure of the transversal girders is transmitted by rollers and plates on the roller carriage, so that the rollers are not influenced by the deformations of the girders and can follow easily the slight irregularities of the rail. In order to keep the closing system from freezing, the following improvements were made by electrical heating. The guide faces of the lateral watertighness system of the gates at the piers have each been provided with an electric resistance heater, consisting of sheet steel, 3,600 mm long, by 225 mm wide and 15 mm thick.

They are each connected by means of copper rails to a monophase alternating current transformer for a tension of 400 Volt and for a secondary tension of 4.75 Volt and 350 Ampere, at full load. The guide faces keep sufficiently warm, even at times of heavy frost, to prevent the formation of ice.

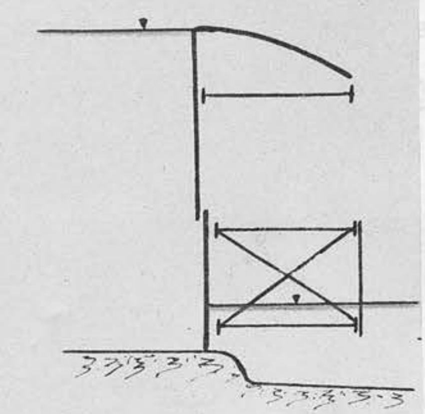
Same European dams are fitted with double gates as xxxxxxx described above: for instance in Switzerland Altbruck-Dogern (10.5 m high), Laufenburg (16 m high), Augst-Wyhlen (9.5 m), Olten-Gösgen (6.10 m high); in France Chancy-Pougny (11 m high), Kembs (11.5 m high) and several in Germany.

However effective the use and working of double gates may be, they are recommended, only when the height is such, that the conditions for the construction of the upper gate (length to height) are sufficiently favourable. An upper gate which is not sufficiently high and has a large span must be of very strong construction.

The heavy water loads passing over the lowered upper gate added to its dead weight and may produce injurious deflexion. An innovation was made in the construction of these closing structures by adopting so called Hook-gates for instance in Ryburg-Schwörstadt (12.5 m high by 24 m wide) on the Upper Rhine or in Ladenburg on the river Neckar in Germany (8.10 m high with span of 40 m).

The hook-gate is also a double gate but with a plunging top gate, in the shape of the hook. See sketch No.17.

17

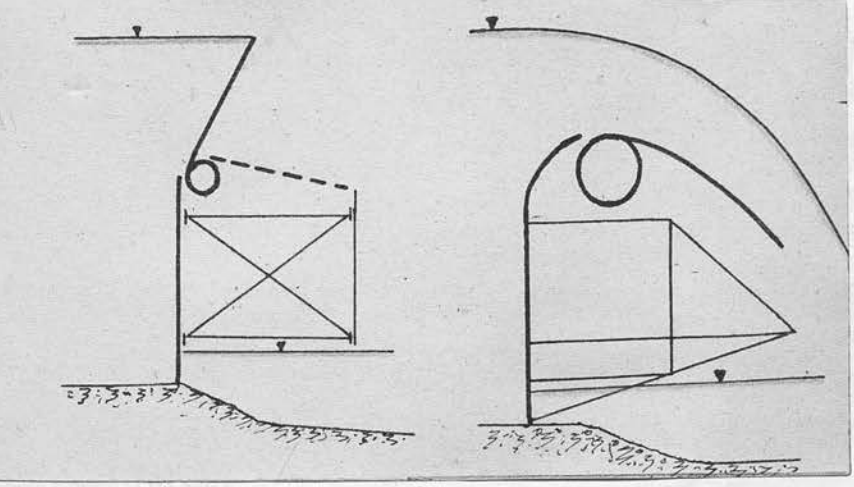


The strong top gate, which has only one top girder supports the projecting closing partition, which is directed downwards. This closing partition is supported by the fixed lower gate. This type of closing system with double gates offers the advantage - as opposed to the other previously described - that the height of the upper gate is not so dependent on the height of the lower gate. From statistics gained from many experiments made in the past, the height of the upper gate should not exceed the ratio of 1 : 4, maximum 1 : 3.4 of the total depth of the closing system. By using hook-gates, it is possible to slide the gates into one another to a height of nearly half of the total depth, and therefore there are greater possibilities for lowering the gate and for discharging water over the crest. The lifting of the gates(upper and lower)is effected as usual by chains and separate winches, of the same kind as those fitted to the ordinary double gates.

By giving the overfall crest the most hydraulically favourable shape, the maximum discharge of water may be obtained with reduced height of nappe.

When local factors militate against the construction of double gates a lifting gates with flaps can be installed. See sketch No. 18.

18

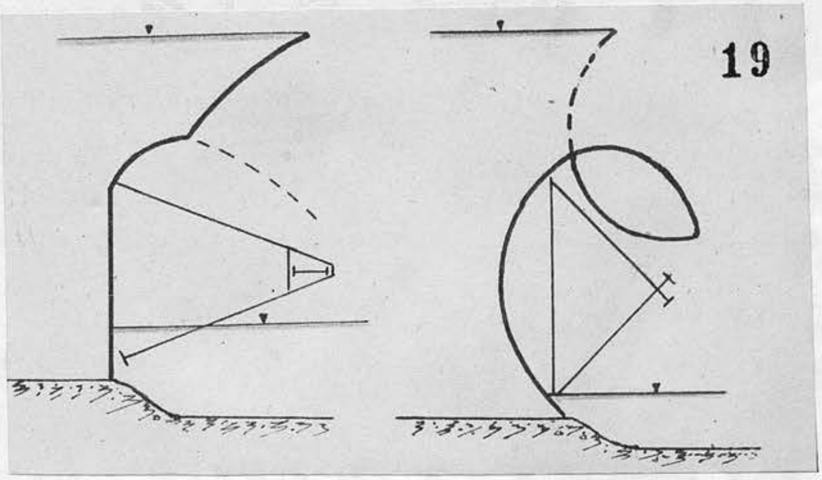


The regulation of the water level is carried out by means of a movable flap which is hinged at the bottom to a fixed lower gate.

Girders running cross ways and lengthways stiffen the plating of the flap; the latter forming a cantilever to a tube running along the top of the gate. This tube with a diameter 0.4-o.6m should be torsion resisting.

This kind of closing system is in use for example in Herkein (1929.) in Germany on the river Neckar : 3 openings, 25 m wide, the closing depth is 5.4 m ; the flaps - 1.5 m high and in Obernau on the river Main: 3 openings of 35 m wide, the closing depth is 5.50 m; the flaps - 1.0 m high.

Some improvement can be made in the installation of lifting gates with flaps.



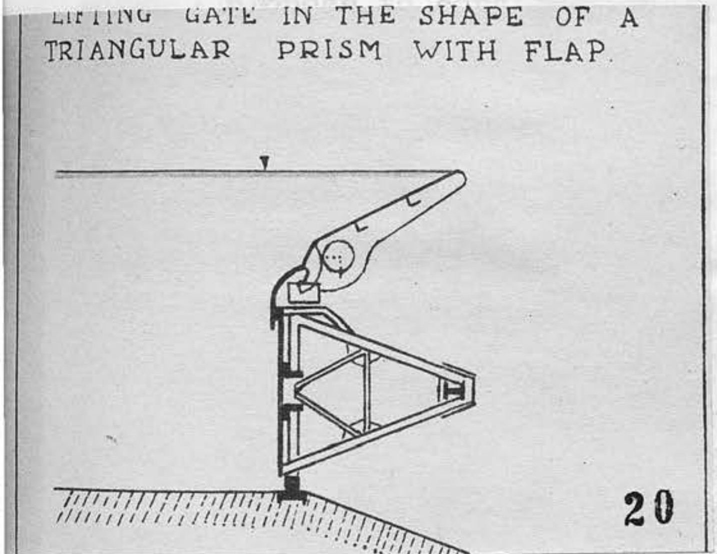
19

The lower lifting gate can be constructed in the shape of a <u>triangular prism.</u>

This idea is similar to that of the torsion resisting sheet steel cylinders in roller weirs. Triangular prisms (like rollers) possess fundamentally static qualities suited to closing systems of wide spans.

The practical experience has shown that beams should be avoided in the constructional parts, near the watertight closing systems; the gate in the shape of a triangular prism fulfils this requirement.

In addition main girders in the shape of triangular prisms are able to absorb impacts and torsional moments.



The girder on the tail water side would be constructed to stretch from one terminal partition to the other.

By this bearing system the transmission of vertical and horizontal forces, as well as moments of torsion on the piers would be very satisfactory.

This system would be superior to others because of the security which it gives against the occurrence of oscillations, occuring in closing systems of wide spans.

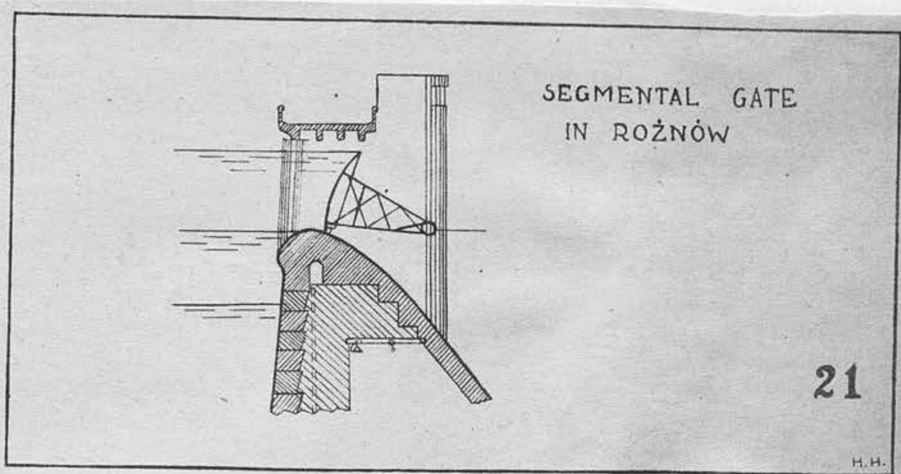
I propose this type of closing system (see sketch No.20) for the dams, which would be erected on the lower portion of river Beczva, and on the river Morava, where the water retaining heights are from

5 m to 7 m , and the regulation of flow discharges is not so great, as to make it necessary to instal such a type as hook--gate, which is especially suitable for the discharge of large water volumes.

I have marked by the numbers 1, 7, 8, 9, 10 and 12 the dams which I propose to construct on this closing system.

Segmental weirs (see sketch No. 21.)

I propose segmental weirs for nine gravity concrete dams (No 13, 14, 15, 16, 17, 18, 19, 20 and 21) in the upper portion (near watershed) of the canal Oder-Danube.



Where dams are situated at the highest points in this section they will be in narrow valleys in relatively small catchment areas and the most suitable type of gate appears to be the crest gate.

I have more fully described the construction of segmental gates in the supplement dealing with "Dam and Water Power Station Rożnów on the river Dunajec".

Here I wish only to add, that the principal advantage of using this type of closing system is its relatively small weight. The water retaining partition of the segmental gates is shaped as the sector of a circle, and the resulting force of dead weight and water pressure is directed downwards and passes through the pivot. Consequently these gates are capable of closing under free discharge by their own weight and when they are lifted a relatively small winch is required. The driving system is secured by two racks working on the ends of the closing structure. The movement of the gates can be maintained even in times of severe frost, by arranging for the heating of the lateral watertight closings.

This system of heating was provided in Rożnów.

In spite of the fact that the gates varied greatly in detail and covered a very wide range of conditions, it is remarkable, that the ratio between the weight of the gate and the value of W^2Hh is reasonably uniform (W - width of gate, H - Height of gate, h - head of center line).

The enveloping curve, based on statistics can therefore be recommended for an approximate estimate in preliminary designs.

The table No. 3 gives the dimensions and weight of a number of existing steel segmental gates.

Table No. 3.

The dimensions and weights of a number of existing steel segmental gates (all dimensions in feet).

No.	Widt "W"	Height "H"	Head to center line of gate "h"	$\frac{W^2Hh}{1000}$	Pounds weight of gate
1.	50.0	14.7	7.3	268.0	91,000
2.	20.0	20.0	20.0	160.0	46,000
3.	25.0	14.0	11.3	99.0	37,600
4.	25.0	14.0	7.0	61.3	27,100
5.	16.0	9.5	16.7	40.6	21,300
6.	25.0	10.0	5.0	31.2	17,800
7.	18.0	12.0	6.0	23.3	12.300
8.	15.0	12.2	6.1	16.7	9,700

The necessary regulation and canalisation works on the DANUBE between the mouths of the Morava and Iron Gate.

In order to form a continuous link between the Baltic and the Black Sea it will be necessary to carry out a number of improvements at the Upper and Middle Danube at Velky Zytný Ostrov and at the Iron Gate.

1. The completion of regulation works on the Danube near Velky Zytni Ostrov.

As was stated in Chapter No II/Vol.1 on "Development of Waterways in Czechoslovakia" there is a lack of stability in the bed of the river over a distance of 173 km , caused by a great variation in the slopes from 40-45 cm per km to 4-8 cm per km . Thus the Danube deposits a considerable quantity of Alpine gravel to form a mass of boulders at the junctions of the slopes, especially on the stretch post km 1835 - post km 1810 . It is most difficult to keep stability in the latter part of the river Danube and consequently to obtain the conditions necessary for modern navigation. This problem requires thorough investigation before deciding upon the method best fitted for ensuring improvement.

In addition to the natural features of this section of the Danube, already described, and the present results obtained by regulation works I would like to give a brief description of the results of gaugings of the cross-sections of the Danube at various points.

These gaugings have given the widths and depths of the cross-

-sections, the maximum and minimum areas and the radii of the curves.

From these details a "Coefficient of Shape" of the bed of the river is determined from the following equation:-

$$C = \frac{a}{b \cdot h_{max}};$$

a = area of the cross-section in m^2;
b = width of the cross-section on the water-line in m ;
h max = maximum depth in m .

Table No. 4.

Radius of curvatures m	Area of cross-section m^2 max.	min.	aver.	Coefficient of shape of bed "C" max.	min.
Section on the Danube; post.km 1880 - 1866					
2,000	817	332	684	0.69	0.49
700	238			0.67	
2,000	676			0.76	
1,100	772			0.66	
2,000	400			0.65	
Section on the Danube; post.km 1866 - 1854					
2,000	671	263	547	0.71	0.31
2,000	902	820	861	0.65	0.42
Section on the Danube: post.km 1854 - 1794					
-----	524	262	439	0.79	0.29
2,000	664	175	460	0.85	0.41
1,500	287	136	212	0.80	0.61
1,000	732	456	594	0.62	0.46
800	790	299	505	0.67	0.20
------	628	435	573	0.77	0.38
950	558			0.64	
Section on the Danube; post km 1794 - 1766					
-----	1147	557	793	0.77	0.47
-----	814	525	678	0.66	0.48
Section on the Danube; post.km 1766 - 1751					
2,000	956	550	769	0.68	0.37
1,500	1124	661	920	0.86	0.61
Section on the Danube; post km 1751 - 1716					
------	1420	654	964	0.83	0.48

From these data we can see, that the shape of the bed has a variable coefficient "C", sometimes very high viz. a flat shape, and at certain places low, which corresponds to a rectangular form.

In this case we are dealing with an alluvial river which does not have a uniform channel and which actually changes its location after floods, as a relatively unimportant side branch may become the main channel.

In alluvial rivers of this kind there is a general tendency to develop a long flat alluvial cone caused by the deposition of sand and gravel, carried down from the upper reaches in the periods of flood. As the tractive force of the river has for the most part been used up in moving the detritus carried from upstream, there is not sufficient energy left to cut the channel through the deposit.

This phenomenon is indicated by the curve of the distribution of velocity in a transverse section, obtained by gauging the flow of water. As the depth increases the subsurface velocities also decrease considerably, and at the bottom may be very low nearly zero, as ~~xx~~ opposed to the distribution of velocity in a river, with a stable bed, where it is practically uniform.

The question of regulating such an alluvial river, with a lack of stability, is one of the most difficult problems and in spite of numerous theoretical and practical investigations it has not yet been satisfactorily solved.

According to Fargue's theory, there exists a close relation between the depths and the curves of river bends and among the numerous possibilities there is one plan-shape that produces the best combination of curvatures and depths.

The principle which seems to have been generally adopted in designing a route is to lead the water by the shortest way possible but not in straight lines.

It is found that in times of flood the behaviour of the river depends on the quantity of water and the rate at which the level rises and that in long straight stretches there is much more disturbance under such conditions then there is in sections made up of a series of curves. In the latter case the water is controlled from point to point , these controlling points being the summits of the curves.

This was proved, for instance on the lower Elbe or lower Vistula, where regulation works were not successful , and where there are straight sections, or unsystematical successions of curves and straight sections.

The rules for a well designed channel which has to be stabilized are generally derived from close observations of natural phenomena. The basis for developing a channel lies in a co--ordinatined series of curves, the concave bends of which should be protected against the encroachment of water. The stability of the bends on the concave side is the most important question in regulation work.

If the regulation line is not close to the bank, it is necessary to build strong training walls.

These longitudinal works are not necessary on the convex side, but on the contrary we have to apply transverse works suitable for directing the flow line towards the concave side.
This rule was not followed on the sector of the Danube, which we are now discussing, and therefore the regulation works with their straight sections and unsystematical successions of curves, hindered rather than helped the development of a stable navigating channel. Furthermore, the longitudinal works which were constructed on both sides did not direct the flow line towards the concave banks, but caused secondary flow lines.
The results of the regulation works are still unsatisfactory and navigation still meets with many obstacles, because the lower water channel is unstable, and shallows are formed in the wide and improperly directed middle water channel.
We can conclude, that generally speaking, middle water regulation with longitudinal works on both sides is not a good method; it results only in a partial solution of flood control and of the abolition of ice blocking; it does not in any way secure the stability of the navigable channel, and therefore it can be considered only as a preliminary measure in preparation for the regulation of low water flow. This main object, the stabilisation of the low water channel, can be attained, if the axis line of the channel is designed in a series of curves in conformity with the characteristic bends of the river.
A further condition is that the water rising above the low water

level shall not be confined beteween two parallel dikes,but allowed to spread freely over the convex side,while on the other hand,the concave side is to be provided with longitudinal dikes. These dikes on the concave side confine and direct the low water in such a manner,that it continues to keep in the same direction even at rising water level.

If the form of the curve is well chosen,the longitudinal dike on the concave side completely guides the river.

The water can spread over the convex side,but care has to be taken to prevent secondary flows in the deposits on that side; this can be done by constructing transverse groins,sloping upwards to the bank.

The velocity of the current being retarded between such transverse groins, produces deposits and in the end the area between them is filled up.

Returning now to the form and length of the curves,it is found that experiments based on theoretical data are not helpful, because not only the effect of low water on the formation of the channel but also that of the varying high water have to be taken into account and these cannot be expressed theoretically. Channels) must be designed in imitation of the stable natural bends of the river which have provided perfect models.

Observation of river - bends shows that the radii of curves vary, the measure of curvature is not constant along the curve,but changes gradually, and the variation of the curvature is accompanied by variation of the depth. For this reason a circular line is not suitable for forming bends in rivers, because the curvature of the circle is constant and does not conduce to the development of gradually increasing depths.

In the summit of a good curve the radius is a minimum, and from there it increases towards the inflextion points; in conformity with this, depths gradually increase towards the summit.

As the slope has to be maintained, the problem to be solved is the number of inflexion points, or the length of the curves; when bends already exist, the number of the inflection points can be neither increased nor diminished. In the bends the water flow approching the summit runs against the bank and is driven off.

The kinetic force of water can be resolved into two components, one parallel and the other perpendicular to the bank at the point of collision. The magnitude of the perpendicular component depends on the mass of the water, the velocity and the sine of angle between the water thread and the tangent drawn to the curve.

The parallel component, which carries the water further depends on these same elements but is proportional to cosine of angle instead of sine of angle.

The component directed against the bank produces backwater, the height of which is $\frac{v^2}{2g} \cdot \sin^2 L$ for one water thread.

The water level is varied in the vicinity of the bank, and from the bank to the middle of the channel transverse slopes arise. This process is continuous, and the effect of the backwater comes into action along the whole bank, until the value of the angle L approaches zero, and the collision ceases. On account of the backwater and the corresponding decrease of velocity, the maximum velocity and depth do not appear in the immediate vicinity of the bank, but at a certain distance from it, where the effect of backwater does not prevail.

As a consequence of the superelevation and the transverse slope, a longitudinal and also a spiral motion, acting downwards and side ways, is produced along the bank, owing to which the water erodes the bank and deepens the bottom, and the detritus is gradually swept to the opposite side. This kind of movement differs from that at the inflection points, where the water threads can be regarded as moving in parallel lines.

Superelevation on the concave banks is desirable to a certain limit, because the stabilisation of the channel is dependent upon it, but the superelevation should not be so great that excessive depth would be produced along the concave banks as this might cause serious damage to the bank.

If the radius of curvature is too short, this results in excessive erosion along the concave bank and of steep deposits on the convex bank and also in the destruction of longitudinal slopes between the two inflection points.

In this case the guiding effect of the concave bank, which was mentioned above, ceases, and the flow line recedes from the

bend and moves towards the middle of the channel.
The development of the channel and the depth is greatly influenced by the angle L and the maximum value of this angle may serve as a basis for designing the curvature of bends, and this may be obtained by assessing its value from well-developed natural bends of the river.
Further, the object of maintaining the original slope is, as a rule, in itself a reason for designing the Channel in curves. We can, to a certain extent alter the slope, by shortening the length of a river having a very slight slope, but if the slope becomes too great, we cause excessive scouring, which may cause deposits and thus obstruct the lower sections.
As is known from experiment, tractive force is a function of the slope i.e. $T = 1{,}000\ d \cdot s$, where "T" is the tractive force per square metre, "d" the depth of water, and "s" the average slope.
Therefore if we do not wish to create a harmful change in the tractive force, no considerable divergence from the original slope can be allowed. This means that when the new channel is being designed in curves, the average slope should not deviate considerably from that in the original channel.
From the present discussion we can say that it would be no easy task to carry out regulation works on such an alluvial river, as the Danube on the Czecho-Slovakia Hungary frontier, owing to its great changes in longitudinal profile in geological features, and in the constitution of its soil, etc.

The aim of the past regulation works which have been carried out to ensure a minimum depths of 2 m, during low water, has not been achieved so far, even with the present emergency work of periodical dredging of bad passages.

What conclusions can we draw with regard to future improvements on this section of the Danube?

From the standpoint of the high water regimen, the transverse profile is governed by the existing protective dykes. For economic reasons it would be difficult to move them, even if at certain places they are not situated in conformity with the mean water layout of the bed, and even if, owing to that, they have an unfavourable influence on high water flow, in the navigable channel.

The mean water bed has been fixed by protective longitudinal works for mean water regulation, and it would be very costly to make any great changes in the layout.

It may also be noted that under the existing scheme there is a definite system of land irrigation and any attempt to modify the present channel would cause great difficulties in this connection.

The great differences in slopes in this section of the river make the conditions for navigation very difficult for the development of a navigation channel along the present route.

In order to find a solution to this very difficult problem it will perhaps be necessary for hydraulic engineers to arrange an international meeting to discuss the whole situation.

It seems to me that two distinct kinds of regulation work would be required.

1.According to investigations on the upper and lower sections, excluding the stretch between km post 1835 - 1810 , it would appear that a suitable depth for navigation can be attained by narrowing the width of the channel, i.e. by the low water regulation works,which have already been started.
Of the two sections between 1888 and 1835 and between 1810 and 1716, mentioned above, the former has a relatively steep slope while in the latter the slope is low. In both cases the slopes are uniform and normal regulation works can be carried out.

2.On the remaining stretch,between km post 1835 and 1810 , it would appear,that this objective cannot be attained by simple low-water regulation,and it would be advisable to create a lateral canal,similar to the Vienna-Cut,where good results were attained under similar conditions. The length of a new canal to be excavated alongside the river bank would be about 25 km.
This solution would be more expensive than low-water regulation, but it would be the quickest and most effective way to achieve a modern navigable channel.
This method would also be in conformity with the modern opinion that regulation work should be avoided when the bed of the river has not reached a state of equilibrium i.e. when considerable

erosion and deposition occurs. If one took the risk, in such a case, a continuous and unequal war would have to be waged with nature, on the one hand to consolidate eroded parts, and on the other to remove the deposits by dredging.

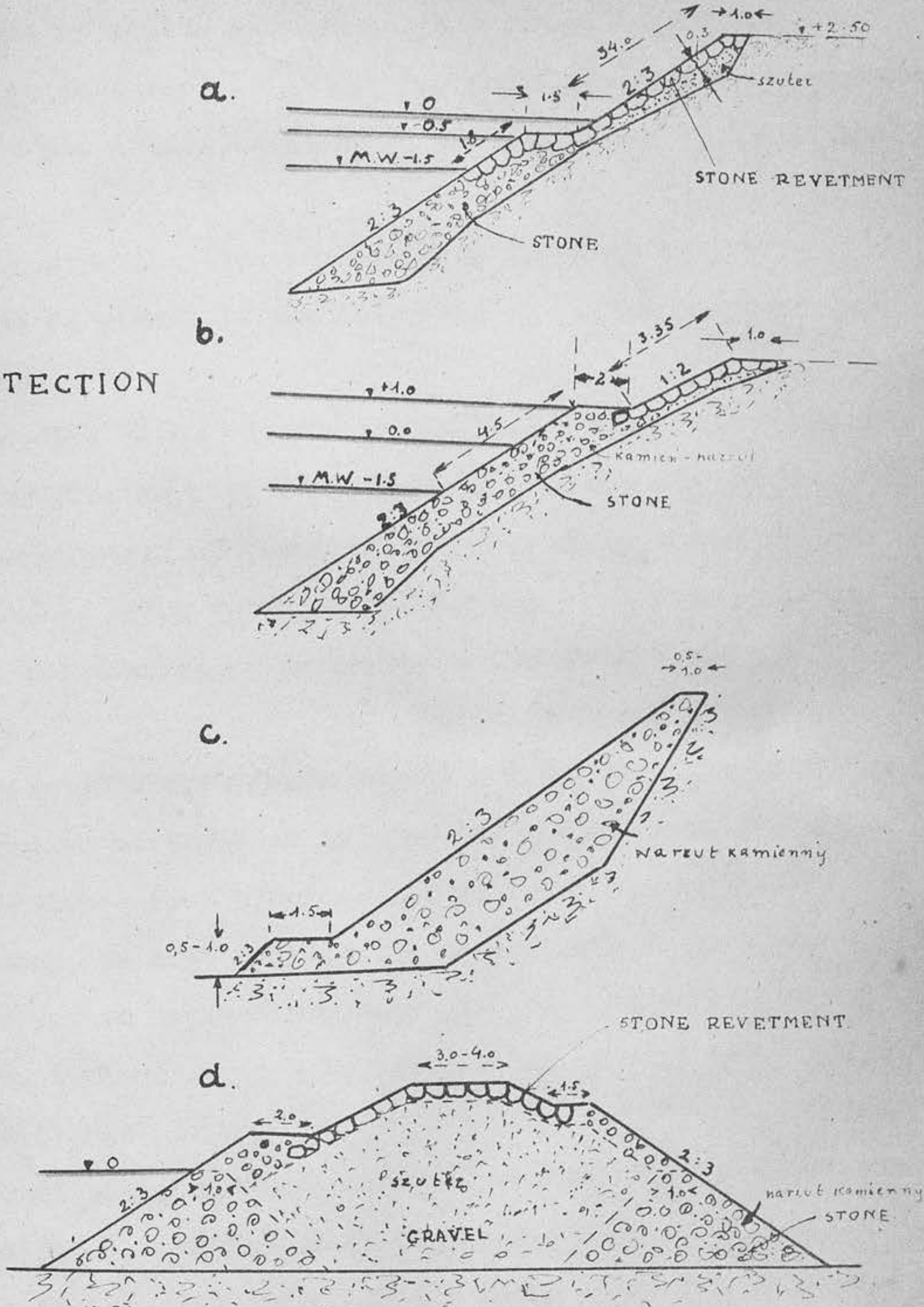
From the point of view of bank protection, there is also a difference between the upper and lower sections of the Danube. A specially strong bank protection has to be constructed on the upper section, between km post 1888 - 1835 , where the average slope is fairly steep.

Quarry stone is here the only kind of material, able to defy the strong destructive wash. Fortunately, there are great reserves of stone in the quarry near Devin km post 1880, at the mouth of the Morava, and this can be easily sent downstream to numerous points on the river for regulation works.

There may be different types of bank protection, some of which are shown in the sketch No. 22.

The types "a" and "b", both possess the same lasting qualities assuming tha same care to be taken for their maintenance. The cost of construction for type "a" is approximately 15-20% below that of type "b" but it may be noted that the maintenance cost of type "a" is about double that of type "b". The stones to be used would be of a minimum weght of 35 kg. These types can be adopted for the concave banks in average conditions, but in the more exposed sectors it would be advisable to arrange for slopes of 1 : 2.5 - 1 : 3.0 .

BANK PROTECTION



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In the case of convex bank protections,which can be lighter and cheaper constructions, type "c" which consists of discharged smaller stones indicates a method which is found to be satisfactory.

For the closing the side branches, dykes of type "d" consisting of gravel in the core, and of stones in revetments may be used.

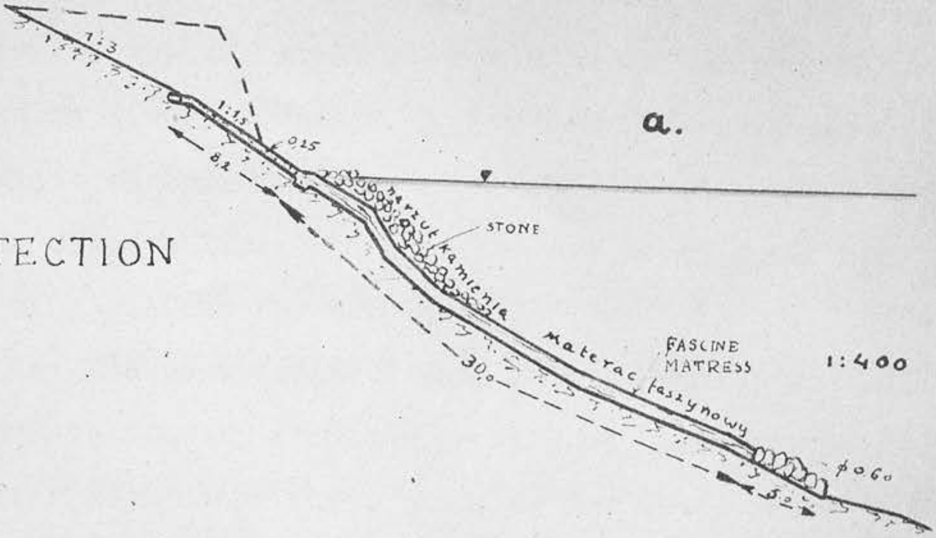
Concerning the lower section of the Danube with slight slopes, downstream from km post 1810, the protection works may be made a combination of fascines and stone,as is shown in the sketch No.23, owing to the fact that the destructive action is less, and that stone is scarce and expensive in this district.

In the case of a steep bank and of a great depth, a well prepared fascine mattress as in type "a" can be used. The edge of the mattress must be protected by large stones against undermining, as also must be the upper part, so that the mattress should not be torn away. The cost of a fascine mattress, including stone ballasting and sinking work is about 2 - 3 shillings per m^2.

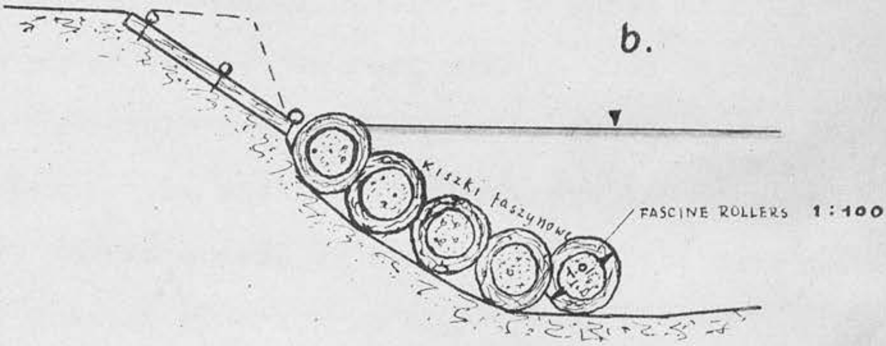
In the case,where the river bed is pebbled, the fascine works may consist of a series of fascine rollers of about 1 m in diameter,filled with river pebbles as in type "b". This type has been applied in Poland with good results.

In the case of a concave bank exposed to wave-action it is more

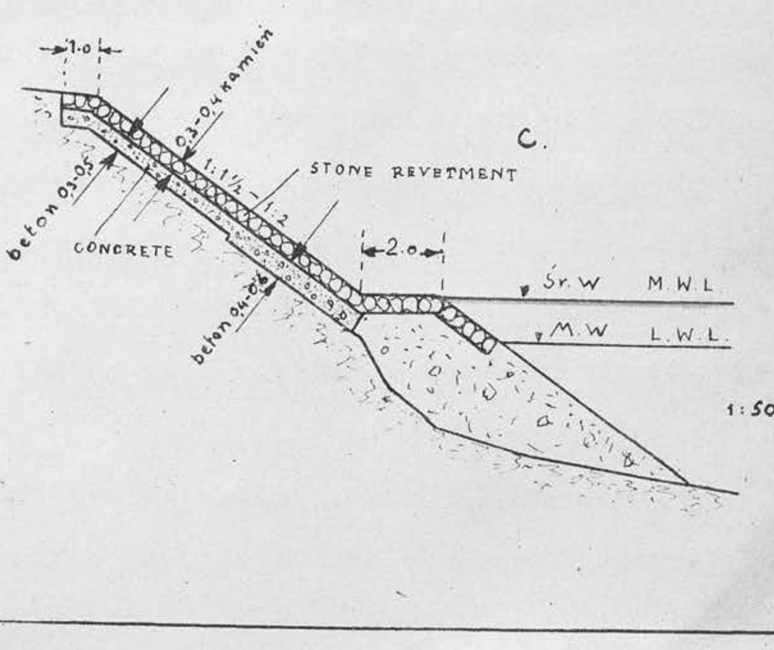
BANK PROTECTION



a.



b.



c.

H.H.

satisfactory to apply a stone revetment as in ~~the~~ type "c". When the large stones are laid on a bed of broken stone 30 to 50 cm thick, a surfacing of dry stone usually gives good results, but in many cases a layer of weak concrete 30 cm thick has been used as a seating for the stones.

The above explanations indicate that in the Danube, on the Czecho-Slovakia-Hungary frontier it will be necessary to provide for low water regulation works and also for the construction of an artificial canal along part of the route in order to obtain a navigable channel suitable for large craft.

The low water regulation work must be such that it not only provides a navigable channel by giving the necessary depth but the construction must be strong enough to withstand the destructive forces caused by floods, ice and the wave action due to the passage of boats at high speed.

2. The proposed canalisation works on the Danube near Iron Gate on the Rumania-Yugoslavia frontier.

The second section of the Danube which particularly needs further improvement is the section including the "Iron Gate", on which the cataracts are situated.

The method of regulation adopted so far was not sufficient for the alteration of this very difficult and rapid passage through the Iron Gate, into a good navigable waterway accessible to large craft.

The fairly steep average slope, the small cross-sectional area of the stream and consequently the very rapid current offer great difficulties to navigation especially for craft towed upstream, and as a result it is necessary to tranship cargoes at this part of the river.

For a distance of about 120 km the river runs through a very deep narrow rocky gorge between the Transylvanian and Banat Mountains.

Owing to the fact that the width of the river is only about 200 m , instead of several hundred meters above and below the Iron Gate, the average velocity at low water increases to about 5 m/s or 18 km/hour.

Against such a velocity the passage of towed trains of barges upstream requires a very considerable amount of power.

It is obvious that the alteration of this stretch into a ~~xxx~~ navigable waterway cannot be obtained by ordinary regulation but only by canalisation.

On the other hand, the Danube rapids constitute a very important and concentrated reserve of water power. The characteristic discharges of the Danube on this section are as follows:

lowest 1,650 m^3/s average 5,000 m^3/s highest 16,300 m^3/s.

The estimated water power resource of the cataracts at this section amount to:

1,020,000 kW at low water discharge;
1,440,000 kW at mean " " ;

and their output capacity, on the assumption that all flows, except floods, could be used, would reach 7,000 million kWh .

The Iron Gate section may be divided into two parts, the condition of the upper one being such that it must be canalised to permit of navigation. The lower part may be used for navigation in its present condition as there is an adequate depth of water but at a later date it would probably be advisable to canalise this also in order to utilise the water power.

The present obstacle to navigation caused by the cataracts in the upper part, would be overcome, by constructing two movable weirs with a total head of a 17.5 m .

The places most suitable as frames for the movable weirs are at Iron Gate itself and at Tachtalja in the district of town of Orsova .

The variation of head, according to variation of tail water level, would be from 11.40 m to 4.20 m at Iron Gate and from 6.10 m to 3.90 m at Tachtalja. The total installed capacity would be 700,000 kW with a yearly average output capacity of 3,500 million kWh.

It would be the most concetrated power in Europe as compared with the great Dnieprostroj power station with a capacity of 550,000 kW , which is installed at the dam constructed on the Dnieper , and of which the reservoir covers the cataracts over a length of 100 km .

The cost of the construction of movable weirs, locks and hydro-electric stations would be relatively small, amounting to approximately £. 28 million .

Projected schemes for later development as on extension of the Great Inland Navigable Waterway Oder-Danube-Black Sea Canal. (sketch No. 11.).

The future extension plan has as its aim on the one hand the improvement of the existing natural waterways, and on the other hand the uniting of the river and sea basins, hitherto isolated, by means of connecting canals. The completion of these schemes will form a wide spreading navigable network and will have a far reaching influence on the economic life of the whole of East-Central Europe.

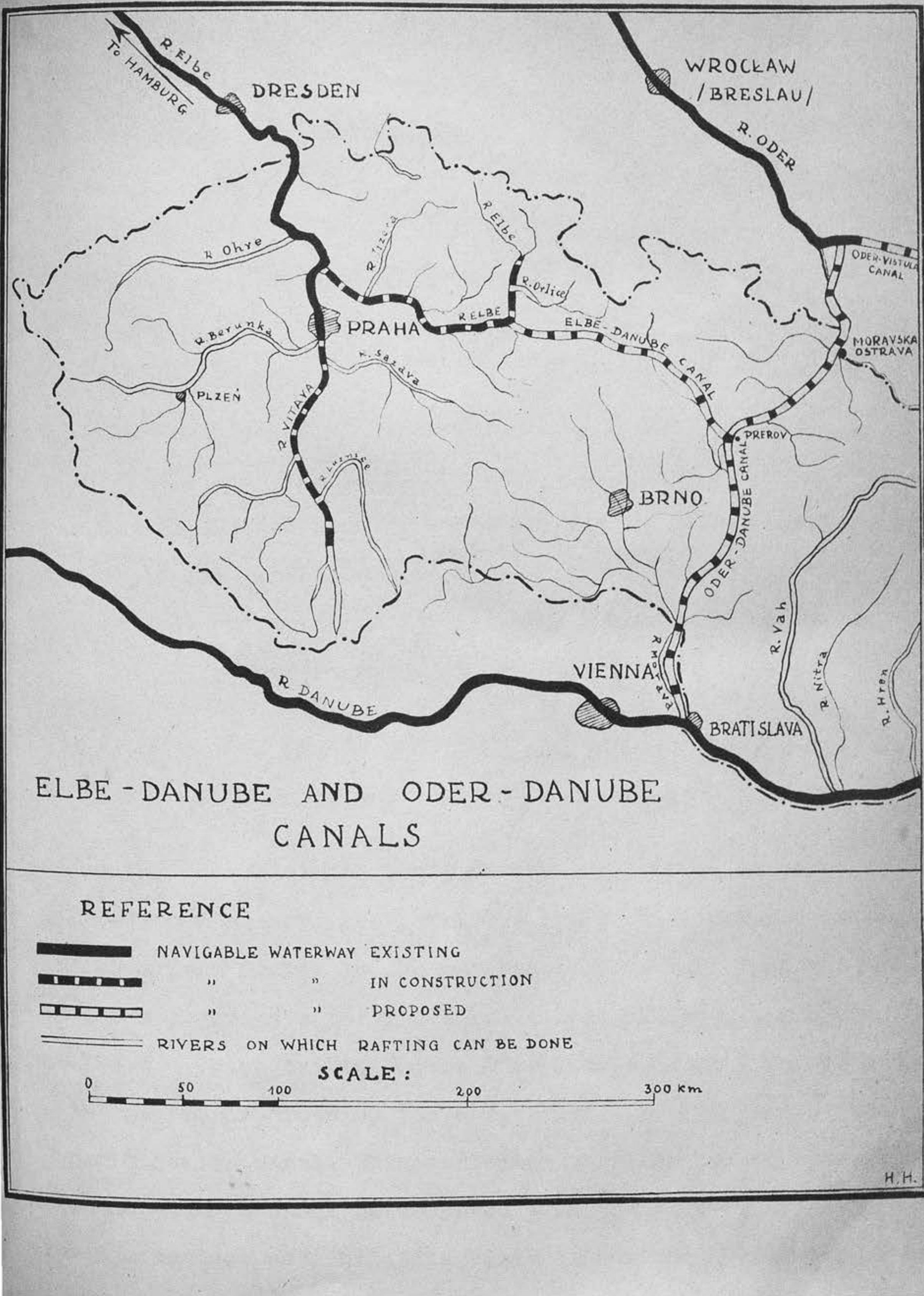
Of these schemes, it seems to me that the most important canals would be those linking the Elbe-Danube, the Danube-Constanța, the Danube-Tissa and the Danube-Aegean Sea, see sketch No. 11. For these I will suggest the possible solutions in the following very brief descriptions.

1. The Elbe-Danube Canal (see sketch No 94.)

The route starts in the East on the reach of the proposed Oder-Danube canal near Prerov, between the lock No 12 and No 13, at an altitude of 205 m above sea level, and ends in the West on the reach of the canalized Elbe near Pardubice, between the lock No 20 and No 21 at an altitude of 217 m above sea level (see table No. 6 in Volume No I).

The length of this canal would be 171 km.

This proposed branch from the Oder-Danube canal towards the North-West would cross the watershed at an altitude, which varies from 370 m to 395 m above sea level.



ELBE - DANUBE AND ODER - DANUBE CANALS

The individual falls would vary from 4 m to 10 m , and the locks would have the same dimensions of 85 m in length and 12 m in width , suitable for modern craft 1,200 - 1,500 tons, as on the Oder-Danube canal.

This canal would link up the existing and projected sectors of the navigable waterways from the North Sea to the Black Sea and create a continuous route 2875 km in length from Hamburg to Braila.

In addition this canal by connecting with the Oder-Danube canal at Prerov would link the Elbe with the Oder and Vistula.

The distances between Prague and several points towards the North are as follows:

1.Prague to Myslovice in Silesia coal basin -- 537 km
2. " Warsaw 1077 km
3. " Danzig(Gdańsk) 1494 km
4. " Stettin 1153 km.

The approximate cost of construction of the Elbe-Danube canal would amount to about £. 14-15 million .

2.The Danube - Constanta canal.

Supposing the watershed level of the canal to be at an altitude 385 m above sea level the craft would complete a rise of 180 m from Prerov to the watershed and a fall into the Elbe of 168 m , giving a total available head of 348 m , instead of 143.4 m which exists on the Oder-Danube canal from the same point at Prerov, crossing the Morava Gate and running to the Upper Silesian canal. This indicates that the construction of the Oder-Danube canal as compared with the Elbe-Danube canal has the easiest possibilities, since it has the lowest watershed.

The individual falls would vary from 4 m to 10 m , and the locks would have the same dimensions of 85 main length and 12 m in width , suitable for modern craft 1,200 - 1,500 tons, as on the Oder-Danube canal.

This canal would link up the existing and projected sectors of the navigable waterways from the North Sea to the Black Sea and create a continuous route 2875 km in length from Hamburg to Braila.

In addition this canal by connecting with the Oder-Danube canal at Prerov would link the Elbe with the Oder and Vistula.

The distances between Prague and several points towards the North are as follows:

1.Prague to	Myslovice in Silesia coal basin --	557 km
2. "	Warsaw	1077 km
3. "	Danzig(Gdańsk)	1494 km
4."	Stettin	1153 km.

The approximate cost of construction of the Elbe-Danube canal would amount to about £. 14-15 million .

2.The Danube - Constanţa canal.

The lower course of the Danube changes its general direction from West to East at Silistra and runs northwards to the ~~parts~~ ports Braila and Galaţi, on a line parallel to the coast of the Black Sea. Further downstream it again flows to the East as a maritime reach.

The point at which the Danube approaches the shore of the Black Sea most closely is at Cerna Voda,from which it is only a distance of about 45 km to the port Constanța in a direct line.

The watershed between Cerna Voda and Constanța constitutes a plateau at an altitude of 55 - 65 m above sea level.

It would not be difficult to construct an artificial canal, which would run in this flat terrain, forming a shortcut to the Black Sea. The length of this canal would be about 55 km and it would be necessary to build only two locks at each end of the canal situated on the high bank of the Danube and at Constanța.

For this purpose it would be necessary to adopt the type of lift locks (boat-elevators) which have been used with success on the Central and Hohenzollern canals in Germany in which the head amounts to 36 m.

By means of this canal the traffic coming from, or going to the Middle East, will be diverted from the present long round-about route by river, delta and sea, and shortened to about one tenth of the present length.

The cost of the new Danube-Constanța canal which I suggest as a later development would be approximately £. 3 million.

3. The Tissa - Danube canal.

An important Hungarian export is wheat, from the valley of the Tissa, which owing to its excellent quality compares favourably with the best wheat from all parts of the world.

The output of wheat in Hungary was 3,069,000 tons in 1939, a considerable part of which was exported. To obtain more favourable freight charges it is proposed to build a canal linking the Tissa at Szolnok with the Danube at Budapest.

The construction of this canal over a distance of about 100 km will be very easy owing to the fact that the route lies in flat lowland country.

By an investment of £.3.6 million to construct the Tissa-Danube canal the effect in reducing freight prices for exported grain alone may be estimated as follows:

the average difference between the freight charges actually paid for rail transport from Tissa valley to Vienna and those as calculated for waterway transport amounts to about 25 sh. per ton.

In addition the canal would serve also to import stone from the upper Danube in order to facilitate the protection works in this rich valley.

4. The Danube-Aegean Sea Canal.

The southern half of the Balkan peninsula has very little low-lying land except the xxxxxx coastal strips on the shores of the Aegean Sea.

To bring the Aegean Sea port of Salonika into direct water connection with East-Central Europe, through the existing and proposed waterways system, the only possible route is along the valleys of the Vardar and Yugoslavian Morava.

To join up the river Vardar with the Morava the new canal would have to run through a relatively high watershed at an altitude of about 460 m .

This shows that the junction has not easy possibilities.
This scheme presents difficulties similar to those which have been overcome during the construction of Rhine-Main-Danube and Rhine-Neckar-Danube canals.

The alteration of the river Vardar and Morava into a modern navigable waterway is obtainable only by canalisation over a distance of about 600 km, and would take a considerable time for its completion.

In addition to the above mentioned schemes for later development in the waterway system of the Danube I must mention two other schemes which would improve the navigation conditions and would also provide for the utilisation of water power in Hungary, where resources of energy are very scarce.

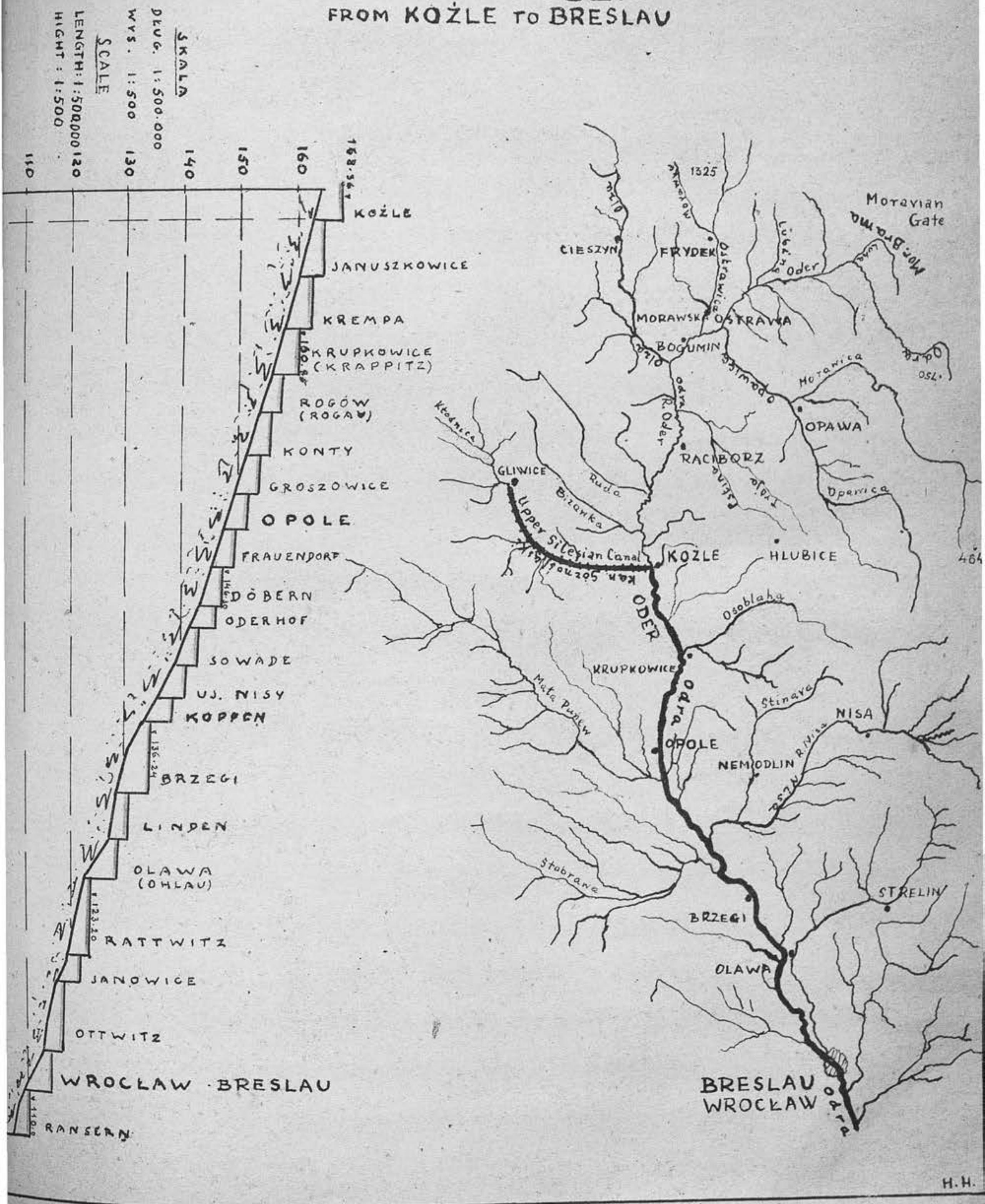
The first is the proposed canalisation fall on the Danube at Visegrad, where the very high compact banks are suitable as a frame for a movable weir in which the head would be about 5 m . The power available is 60,000 kW with a capacity output of 300 million kWh.

The second scheme would utilize the water power on the Moson arm of the Danube above Budapest, which can develop 35,000 kW and could deliver, on a yearly average, an output of 140 million kWh.

The cost of these two water power stations, weirs and locks would amount to approximately £. 3.2 million .

SKANALIZOWANA ODRA OD KOŹLA DO WROCŁAWIA

CANALIZED R. ODER FROM KOŹLE TO BRESLAU



The ODER

The extension of the Oder - Danube canal in the North to form part of a continuous network extending to the Baltic will be done via existing the waterway along the Oder and via the proposed route Oder-Vistula-Baltic canal,which will be described in the next Chapter.

The total basin area of the Oder is 118,611 km^2. The Oder has a length of 776 km , and is navigable over a total length of 705 km , but , for larger craft,only over a length of 641 km i.e. from Koźle downstream,beyond the junction with the Upper Silesian Canal.(Fig. No. 261).

The slopes of the water surface of the Oder before canalisation were:

on the upper course between Koźle and Ransern.........0.347‰

on the lower course between Ransern and Stettin.......0.233‰

The rate of flow varies,

at low water level,from 8 to 20 m^3/s,

at medium " " " 13 to 150 "

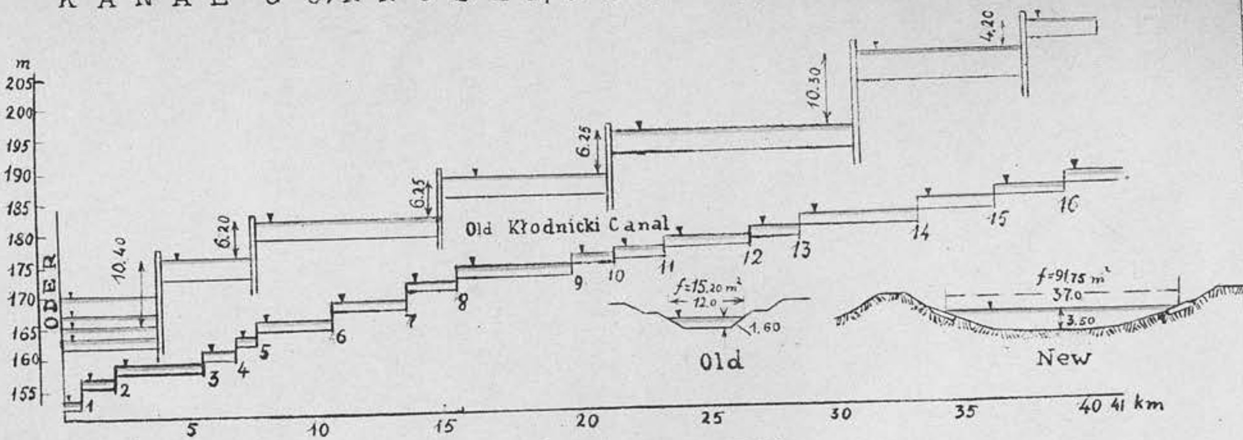
at high water level from 2,000 to 2,400 m^3/s .

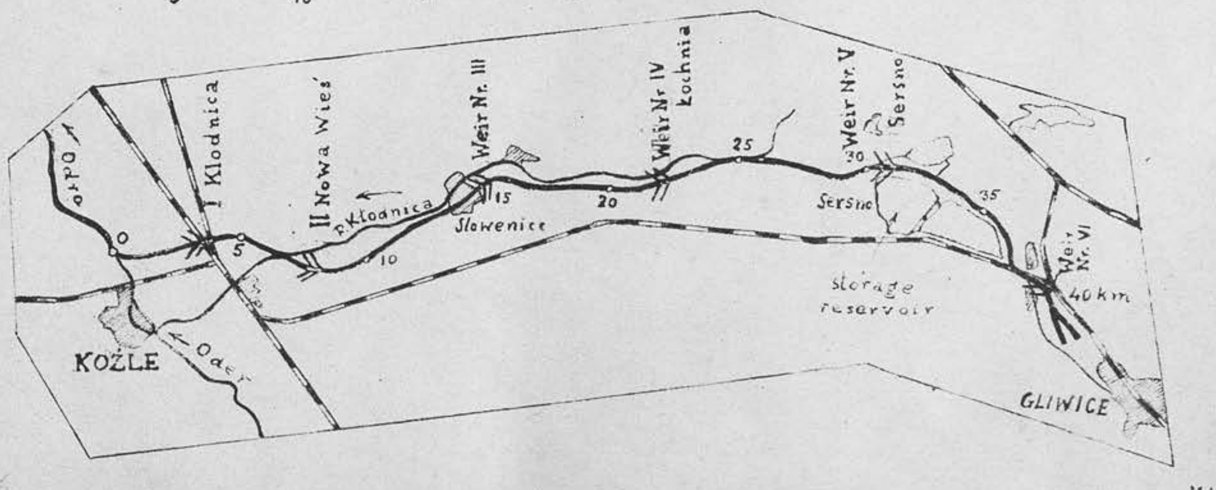
The total yearly water flow also varies considerably from 10,800 million m^3 in a wet year (1903) to 2,900 million m^3 in a dry year (1933),giving a ratio of 1 : 3.7 .

The flood water,forming a large part of the total flow,is lost for navigation purposes,for instance in 1930,the volume of flood water amounted to 1,600 million m^3,which corresponds to 30% of the total yearly discharge for that year or 55% in

UPPER-SILESIAN CANAL (new canal completed in 1939)

KANAŁ GÓRNOŚLĄSKI GLIWICE-KOŹLE





a dry year.

The first improvements made at the end of XIXth century, were regulation works, which were carried out in order to obtain suitable navigable depths at low water of 0.75 , 1.05 and 1.30 metres respectively on the upper, middle and lower stretches.

The results obtained were not completely satisfactory as it was found that during a period of drought the depth in the upper course near Opole was 0.3 m while that in the middle course near Breslau was 0.5 m .

The regulation works suffered considerable damage, as the method of construction, using fascines, was unsatisfactory and, in order to improve the conditions, it was decided to canalise the upper section, to strengthen the regulation works and to provide storage reservoirs in the upper basin to regulate the water supply.

The upper section of the Oder was gradually canalised, during the years 1891-1896 and 1906-1922, for a distance of 168 km from Koźle to Ransern below Breslau.

Twenty two weirs were built with a total head of 58 m as shown in Sketch No. 25.

General data regarding this canalised section of the Oder are given in the following table No. 5 .

Table No. 5.

1.	Length of the canalised section	168 km
2.	Number of falls	22
3.	Total fall	58 m
4.	Average length of the reaches	7.6 km
5.	Minimum depth for shipping	
	a) at medium water level	2.3 m
	b) at low water level	1.5 m
6.	Authorized draught of the boats	1.4 m
7.	Width of the weir openings	65-115 m
8.	Number of water power stations	8
9.	Water volume of the power stations	9-96 m^3/s

The regulation of the water level is effected by needle weirs xxx except on the lowest dam, at Ransern where a segmental weir is used.

These old-fashioned weirs are not satisfactory from the point of view of the regulation of water level and to ensure this it is necessary to have a very thorough system of co-operation among the personnel stationed at the numerous dams.

Every change in the discharge or in the movement of ice, in x the higher sections, which would influence the conditions in the lower sections are immediately communicated to the lower stations by telephone.

In addition to the series of locks there are two power stations situated at Koppeln and Janowice, the discharge from which varies with the load in the turbines and can be accurately estimated.

The pondage at the lowest dam at Ransern is very small and, on this account, the personnel at that point is kept regularly informed, every four hours, of the oncoming water volumes from the upper dams and power stations.

In the winter all needle weirs are removed in view of the fact that they would be exposed, during long periods of from 2.5 to 3.5 months, to the risk of the formation of icicles and to the impact of ice blocks.

At other times the weirs have to be fully opened when the natural ~~fk~~ flow of the river exceeds a discharge of 480 m^3/s.

Although the conditions for navigation on the upper course of the Oder are better than those on the lower non-canalised section, they still require much improvement if the river is to be capable of dealing with large craft and dense traffic.

It will be necessary to replace the present weirs by those of more modern type and also to improve the low water levels by means of surplus water from storage reservoirs.

On the lower course of the Oder from Ransern down-stream, the first regulation works carried out for the purpose of main water regulation and of increasing ~~to~~ the depths consisted of longitudinal training dykes and transverse groins. The groins, consisting of fascine work, were directed upstream at an angle of 70 degrees to the axis of the river, and were usually placed at intervals of from 100-150 metres apart on the concave banks, and at twice those distances on the convex banks.

The crest of the groins generally reached main water level and the width of the crest varied from 1.5 to 3.5m. The longitudinal slopes varied from 1 in 50 to 1 in 200 towards the banks and from 1 in 4 to 1 in 5 at the river end, while the side slopes were from 1 in 1 to 1 in 4.

Experience showed that the fascine work was not durable above low water level, as it was liable to damage by flood water and ice, and caused uneven settling of the groins. For this reason constructional methods have undergone several changes, such as covering portions of the groins with stone revetment placed directly on gravel or small broken stones and making the slopes towards the river 1 in 10 instead of 1 in 4 or 5.
In addition to this the groins were extended into the river for a distance of 5 m their crests being at low water level, but it was found that this arrangement increased the difficulties of navigation and the low groins were later removed.

On sharp concave bends longitudinal revetments or training dykes were constructed with slopes of 1 in 2 but as it was found that the stones were frequently washed away the slopes were later changed to 1 in 2½ or 3.
In spite of the many regulation works which have been constructed on the lower portion of the Oder, the aim of obtaining a minimum depth of 1.4m, at low water level has not, so far, been attained and, that further improvements are necessary, is indicated by the following figures:-

In 1930 the depth fell to less than 0.75 m on 57 days

1932	"	"	0.8	61 "
1932	"	"	1.0	130 "

On all those days navigation was at a standstill.

Navigation may also be stopped,during winter periods,by frost and the following table gives the number of days during which navigation was possible in particularly dry years:-

In 1917 navigation was possible on 150 days

1921	"	"	200 "
1928	"	"	210 "
1933	"	"	190 "

In order to to minimise the variation in navigation depths on the lower Oder by means of surplus water from storage reservoirs several dams have been built,in recent years,in the upper basin of the rivers and particulars of the reservoirs and dams are given below.

1. At Otmachowo on the river Nissa
   The earth dams has a length of 6,500 m and a height of 17m. The storage reservoir,having a total capacity of 143 million m^3 and a useful capacity of 95 million m^3,provides efficient regulation for natural flows which vary from 3.6 m^3/s to 1,800 m^3/s and also supplies a power station which has a capacity of 2,000 kW
2. At Turawa on the river Mała Panew
   The earth dam is 6,150 m in length and is 23 m in height. The storage reservoir has a total capacity of 105 million m^3 of which 88 million m^3 are available for use and natural

flows varying from 4 m^3/s to 280 m^3/s are completely regulated.

3. Other reservoirs are in course of construction, at Sersno in the Kłodnica valley, with a storage capacity of 80 million m^3, at Weistriz near Braslau with a storage capacity of 50 million m^3 and a smaller one at Domanze.

The effect of these reservoirs has been to give a rise of 40 cm on the reach of the river below Ransern and this gradually decreases to 20 cm at the mouth of the river Warta.

The improvement effected so far has permitted of a greater density of traffic and in 1934 the amount of goods carried had increased to 1.3 million tons.

The standard size of craft used on the Oder is about 600 tons but in recent years the tendency has been to increase this up to 1,000 tons due to the progressive improvement of the river and the increase which occurred in the traffic after the completion of the Upper Silesian Canal.

The quantity of goods at present carried amounts to approximately 5.4 million tons per year.

In Chapter VIII Vol.I statistics regarding the commercial fleet on the Oder are given for the year 1934 but since that date the figures have changed considerably and the total number of barges, tugs and other boats has probably increased from about 3,000 to 8,000 at the present time.

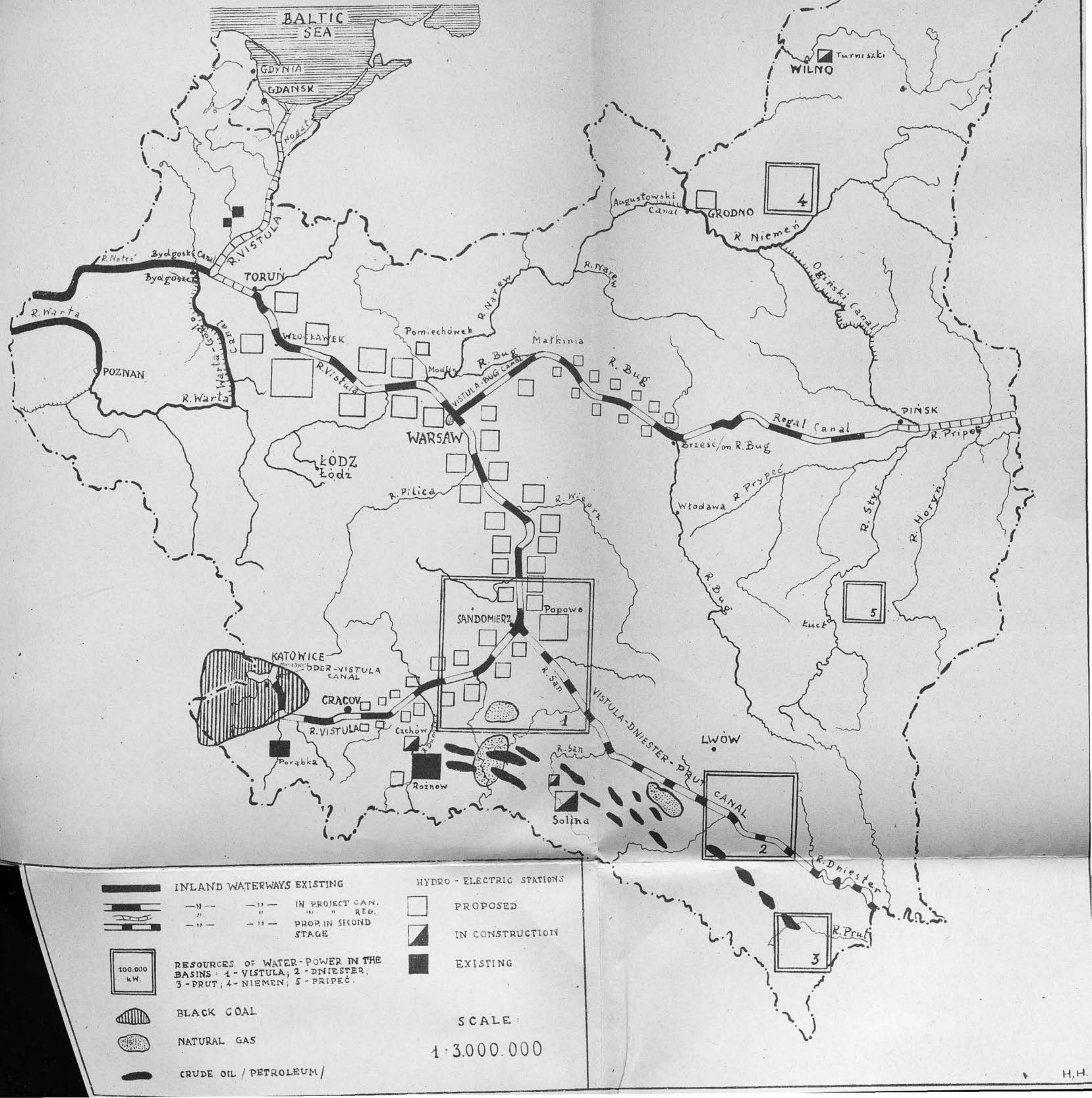
T H E

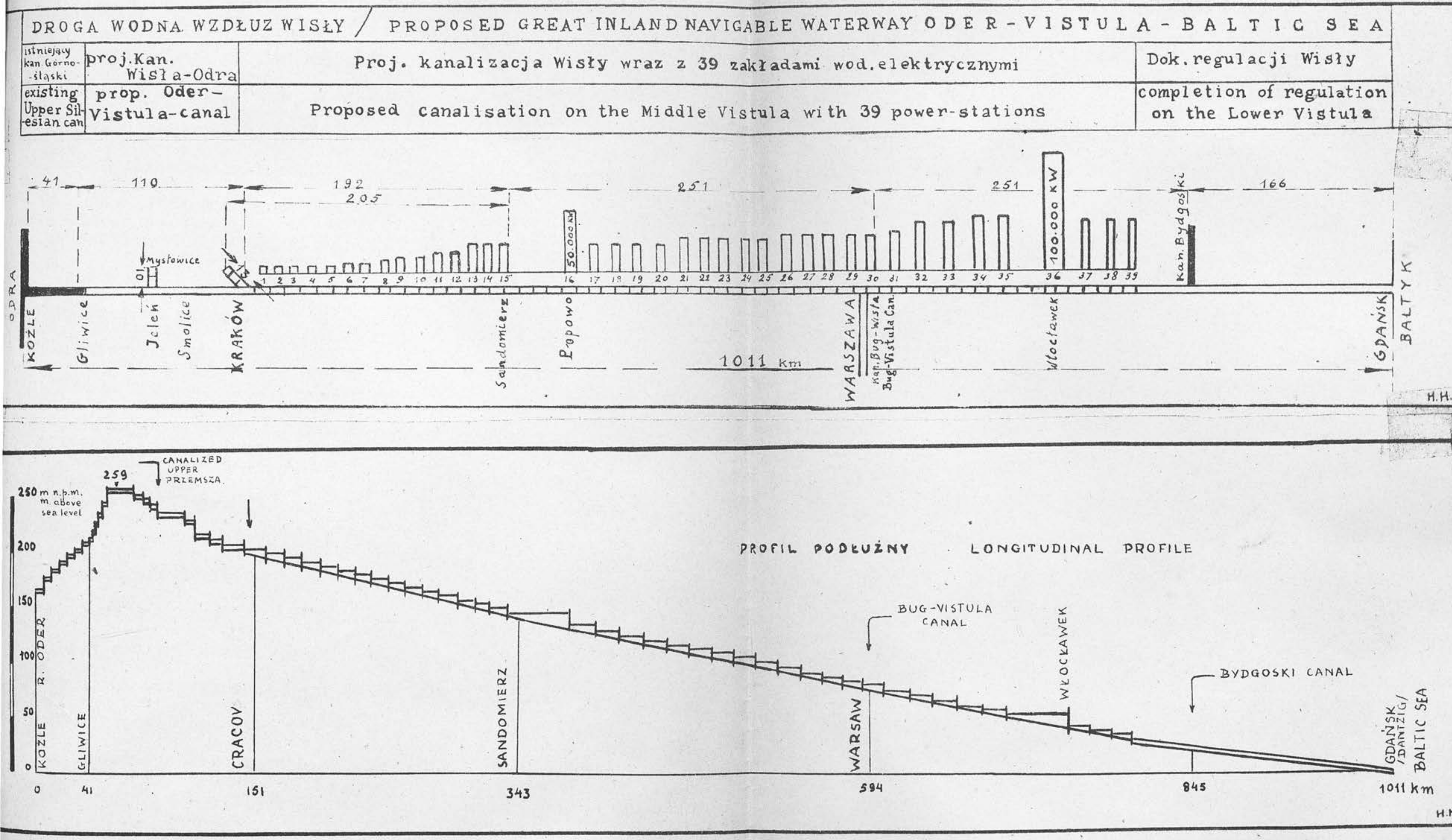
G R E A T I N L A N D N A V I G A B L E

W A T E R W A Y

A L O N G T H E V I S T U L A

POLSKA POLAND
DROGI WODNE I ŹRÓDŁA ENERGII
NAVIGABLE WATERWAYS AND RESOURCES OF ENERGY.




DROGA WODNA WZDŁUZ WISŁY / PROPOSED GREAT INLAND NAVIGABLE WATERWAY ODER - VISTULA - BALTIC SEA
istniejący kan. Górno-śląski
proj. Kan. Wisła-Odra
Proj. kanalizacja Wisły wraz z 39 zakładami wod. elektrycznymi
Dok. regulacji Wisły
existing Upper Silesian can
prop. Oder-Vistula-canal
Proposed canalisation on the Middle Vistula with 39 power-stations
completion of regulation on the Lower Vistula
41
110
192
205
251
251
166
Mysłowice
50.000 KW
100.000 KW
Kan. Bydgoski
ODRA
KOZLE
Gliwice
Jeleń
Smolice
KRAKÓW
Sandomierz
Popowo
1011 Km
WARSZAWA
Kan. Bug-Wisła
Bug-Vistula Can.
Włocławek
GDAŃSK
BAŁTYK
H.H.
CANALIZED UPPER PRZEMSZA
259
250 m n.p.m. m. above sea level
200
150
100
50
0
PROFIL PODŁUŻNY LONGITUDINAL PROFILE
BUG-VISTULA CANAL
WŁOCŁAWEK
BYDGOSKI CANAL
KOZLE R. ODER
GLIWICE
CRACOV
SANDOMIERZ
WARSAW
GDAŃSK /DANTZIG/ BALTIC SEA
0
41
151
343
594
845
1011 km
H.H.

The Great Inland Navigable Waterway along the Vistula.

Introduction

The situation of Poland in the heart of the European Continent and its suitability for the construction of navigable water-ways make it clear that a network of waterways may play not only a national role but also would be of the greatest importance from the international point of view as regards transit from South to North and from West to East.

The existing navigable waterways in Poland are, in many respects, very favorably situated for their future development, in fact much more adventageously than in other countries, for the following reasons:-

1. Poland forms, as a whole, an almost level plain, and to join up the Polish system of navigable waterways with the other systems in Central Europe, the new linking canals would run through the lowest line of the principal European watersheds. Thus the river Vistula, being the principal river in the network of waterways in Poland, offers easy possibilities for the construction of three canals, the Vistula-Oder-Danube, the Vistula-Dnieper, and the Vistula-Dniester, to connect with the general system of transeuropean inland waterways.

2. The natural direction of the rivers in Poland with reference to the shape and expanse of the country indicate the advantage to the State of this development.

The natural riches of Poland, especially its coal mines, forests and basalt quarries are far distant from the centre of the country and from its sea-ports, with the result that raw materials have to be transported over long distances of from 500 to 700 kilometres.

This applies particularly in the case of coal since the coal mines are situated in the south-west of Poland and coal must be transported over long distances to the eastern and northern districts for home consumption and to the sea-ports for export.

In spite of the abundant reserves of coal in the country the consumption of coal is relatively small, owing to the high cost of transit on railways, being only 736 kg per head, which is much below the general standard in western Europe.

The development of an efficient system of waterways would greatly reduce freight charges with very beneficial results to the country as a whole.

3. It is of the greatest importance for the future development of the Polish navigable waterways, that they should be able to accept very heavy international traffic. The end of the present war will immediately raise most urgent political and economic questions in East-Central Europe, and a future federation of these countries, on an economic basis, is already being visualised.

Among the fundamental problems with which the countries of this area are concerned both individually and jointly, the two most important are the following:-

a) It will be necessary to create between these countries a high degree of interdependance,

b) the over-population in rural districts which leads, among other things, to malnutrition demands changes in the agricultural structure and a development of industrialisation. The solution of both these problems necessitates the integration of markets, and in this connection transport must play a decisive part.

For the cheap transport of bulk materials it would be necessary to improve existing systems of waterways and to join them up in one great network.

The improvement of waterways within one country must be a matter of direct interest to the neighbouring countries by improving the international development, by giving the different countries better access to sources of supply and to markets, and by facilitating international transport.

An effective network of inland waterways to tap the resources of the vast Central European area must inevitably be linked up with the waterways in Poland.

So far as Poland itself is concerned, there is considerable scope for the development of the existing waterways and the canalisation of rivers. The latter would, incidentally, make a considerable amount of water power available.

The first new scheme, which I propose for the Polish post-war development programme, is an inland navigable waterway along the Vistula from Silesia to the Baltic Sea, with an extension from the upper course of the river to the Oder, to provide an outlet to the Black Sea.

To develop the Vistula, the largest river in Poland, as a modern navigable waterway available for craft of 1,000 - 1,200 tons capacity in the quickest and most effective way, it would be necessary to carry out:

a) the construction of the Vistula-Oder canal;

b) the canalisation of the larger portion of the Middle sector;

c) the continuation of river training in the Lower sector.

<u>The proposed new Vistula-Oder Canal.</u>

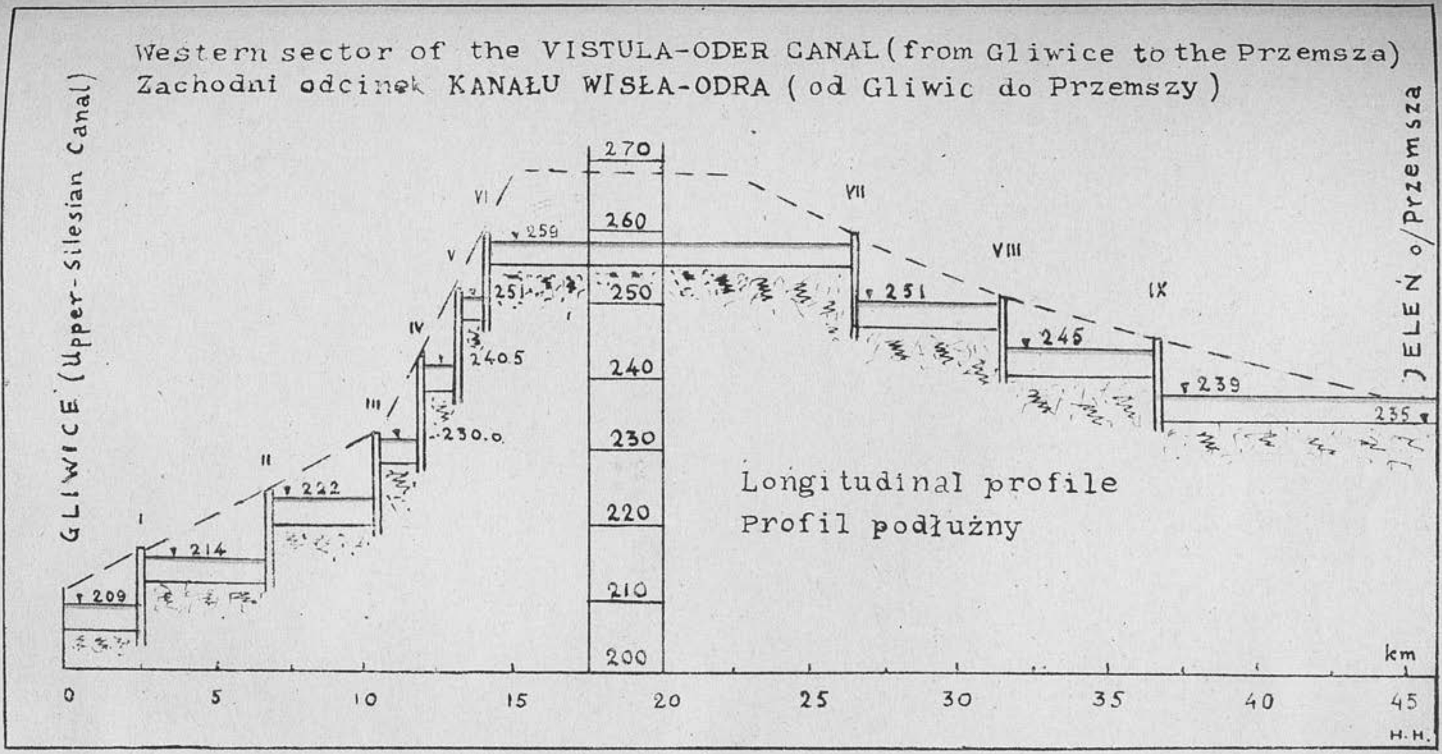
The preliminary estimate of my project in volves the carrying out of construction works, as represented by the following data:

1. Total length of the canal	110 km
2. Total available head	108 m
a) consisting of a rise in the Vistula valley of	58 m
b) and a fall in the Oder valley of	50 m
3. Number of falls and locks	15
4. The average fall about	7.2 m
a) the maximum fall	10.5 m
b) the minimum fall	5.0 m
5. The average length of reaches about	7.4 km
6. Dimensions of locks:	
a) length	72 m
b) width	12 m
c) depth	3.5 m
7. Total estimated cost of construction	£.5 million.

The route of the Vistula-Oder canal would start in the West on the last reach of the existing Upper Silesian Canal near the town of Gliwice and end in the East, at Kraków, on the first reach of the canalized Vistula river.

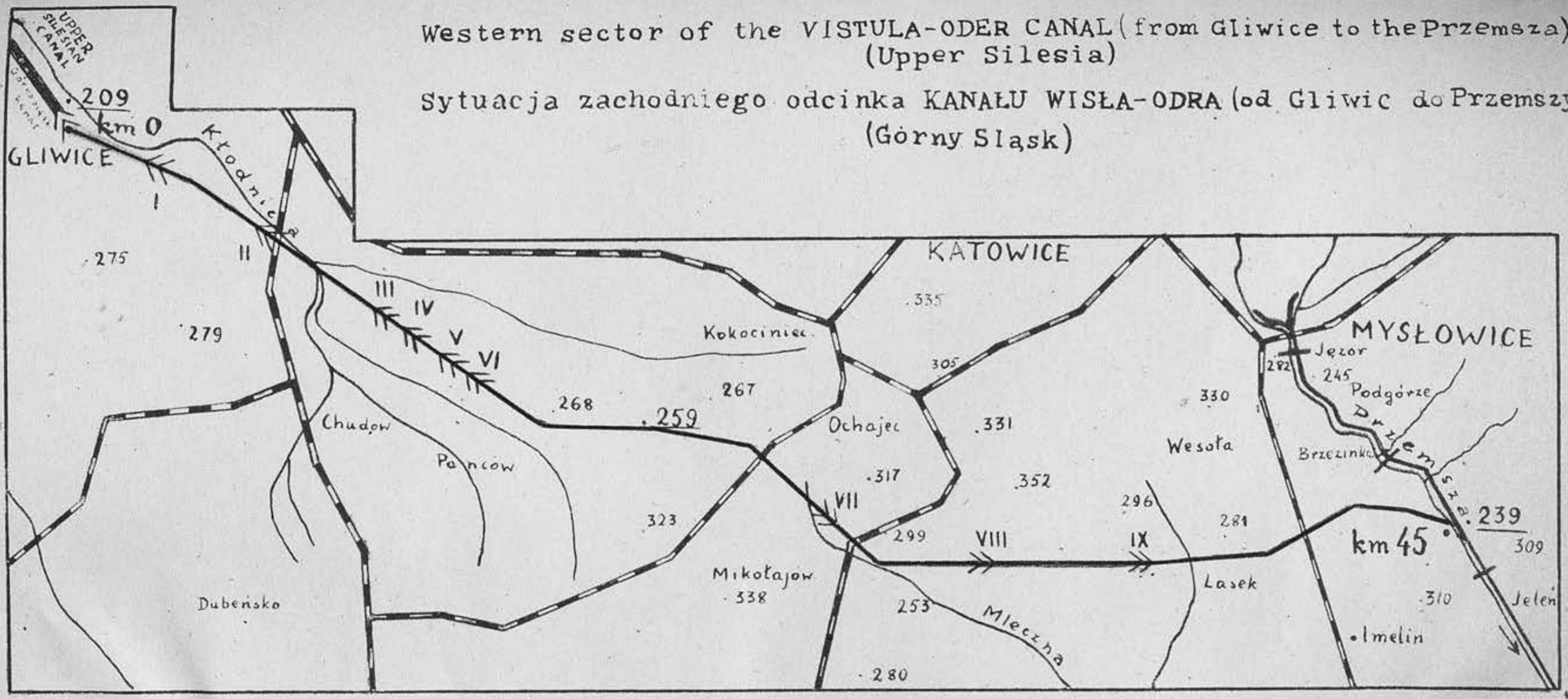
From the point of view of the nature of the work and the future estimated movement of traffic this canal can be divided into three sectors: western, middle and eastern.

Western sector of the Vistula-Oder canal, see sketch No. 28.
The most convenient route, which I have chosen from several alternatives, would start from the end of the Upper Silesian canal at the port of Gliwice, then run along the valley of the Kłodnica river and would approach the relatively low principal watershed between the Oder and Vistula, which the canal would cross at an altitude of 259 m.
From this dividing reach, the route of the canal would run to the valley of the Mleczna river and finally over fairly flat country to the river Przemsza south of the town of Mysłowice.
The total length of this sector, of canal amounts to 45 km.
The craft would complete a rise of 50 m between Gliwice and the watershed by means of six locks and the fall of 20 m from the watershed to the Przemsza river by three locks.
On the western slope, towards the Upper Silesian canal and the Oder the six locks would be closely spaced within a distance of 14.5 km. Two of these would be 10.5 m, three 8 m and one 5 m in height.
On the eastern slope, towards the Przemsza, over a distance of 30.5 km, it would be necessary to build only three locks, two with a head of 6 m and one 8 m in height.
Sketch No. 29 shows the longitudinal profile of the whole western sector of the Vistula-Oder canal, with the altitudes of the ten reaches.


Western sector of the VISTULA-ODER CANAL (from Gliwice to the Przemsza)
Zachodni odcinek KANAŁU WISŁA-ODRA (od Gliwic do Przemszy)
GLIWICE (Upper-Silesian Canal)
JELEŃ o/Przemsza
Longitudinal profile
Profil podłużny
I
II
III
IV
V
VI
VII
VIII
IX
209
214
222
230.0
240.5
251
259
251
245
239
235
270
260
250
240
230
220
210
200
0
5
10
15
20
25
30
35
40
45
km
H. H.

Western sector of the VISTULA-ODER CANAL (from Gliwice to the Przemsza)
(Upper Silesia)

Sytuacja zachodniego odcinka KANAŁU WISŁA-ODRA (od Gliwic do Przemszy)
(Górny Śląsk)



Water supply for the lock operations for navigation and the regulation of the water level in the reaches and the construction of locks.

The water required for lock operations is a most important question in the watershed reaches, as I have described in Chapter No. Ia on the Oder-Danube canal.

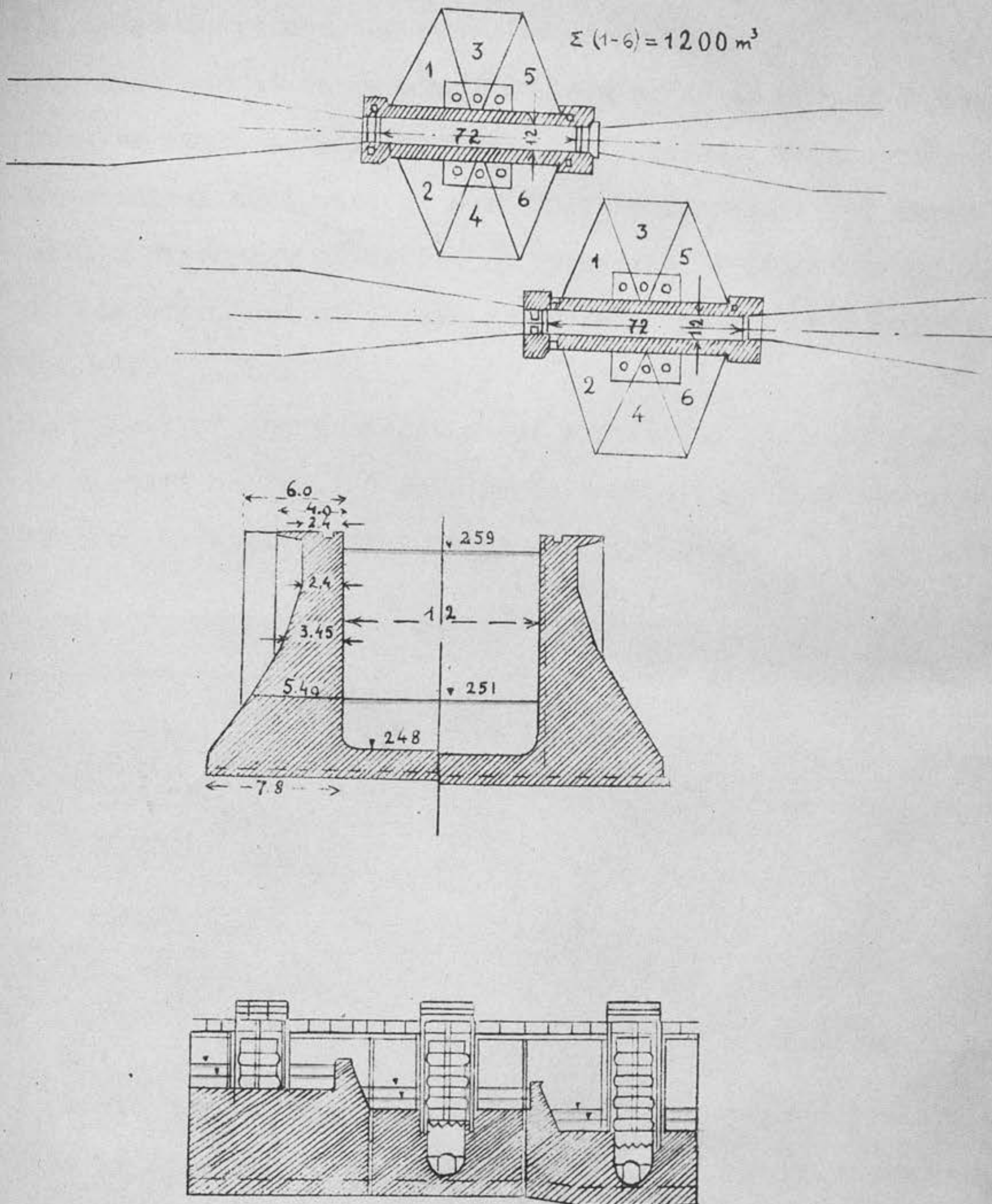
In this case it may be estimated that the transport capacity would be 10 million tons per year, which is 50% of that allowed for the proposed Oder-Danube canal, it being assumed that half of the total traffic will be carried in the northern direction via the Oder and the other half via the Vistula-Oder canal to Silesia and to Gdańsk (Danzig).

The problem of water supply for filling the locks on each side of the watershed pass, requires very careful consideration, both for the dividing reach and for the lower reaches.

Let us begin the examination of this problem with the more difficult question of the water supply for filling the locks on the watershed reach.

The dimensions of the locks: 12 m in width and 72 m in length, give a surface area of 860 m^2, and for locks No VI and VII, on the watershed reach, with a head of 8 m , the water volume amounts to 6,880 m^3 in each lock.

Supposing the average capacity of the barges to be 600 tons, since in addition to larger craft of 1,200 tons, there would also be small barges, especially during the first period, 50 lock operations per day would be necessary.

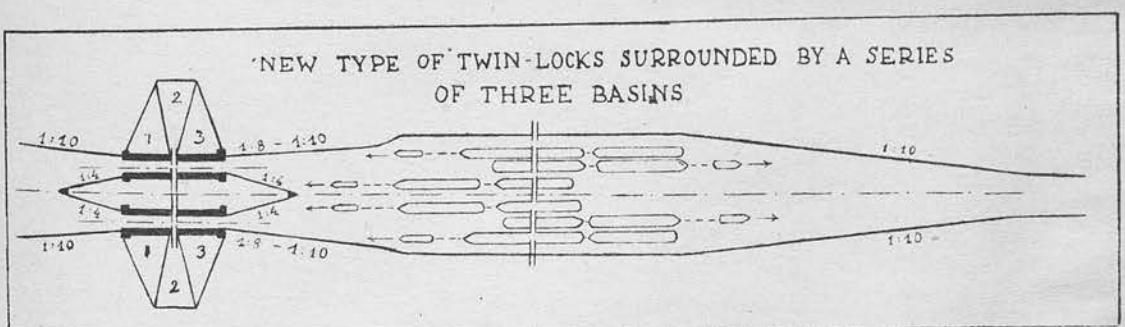


NEW TYPE OF TWIN-LOCKS SURROUNDED BY A SERIES OF SIX BASINS FOR THE PROP. VISTULA-ODER AND ODER-DANUBE CANAL ON THE DIVIDING-REACHES.

In order to reduce the power required for pumping, the basins are arranged at decreasing levels, so as to keep the pumping head as small as possible. For this purpose the electric-mechanical equipment of each lock would consist of three pumps with a discharge of 3.75 m^3/s connected by pipelines of 1.6 m in diameter, and of electric motors with total capacity of 470 kW.

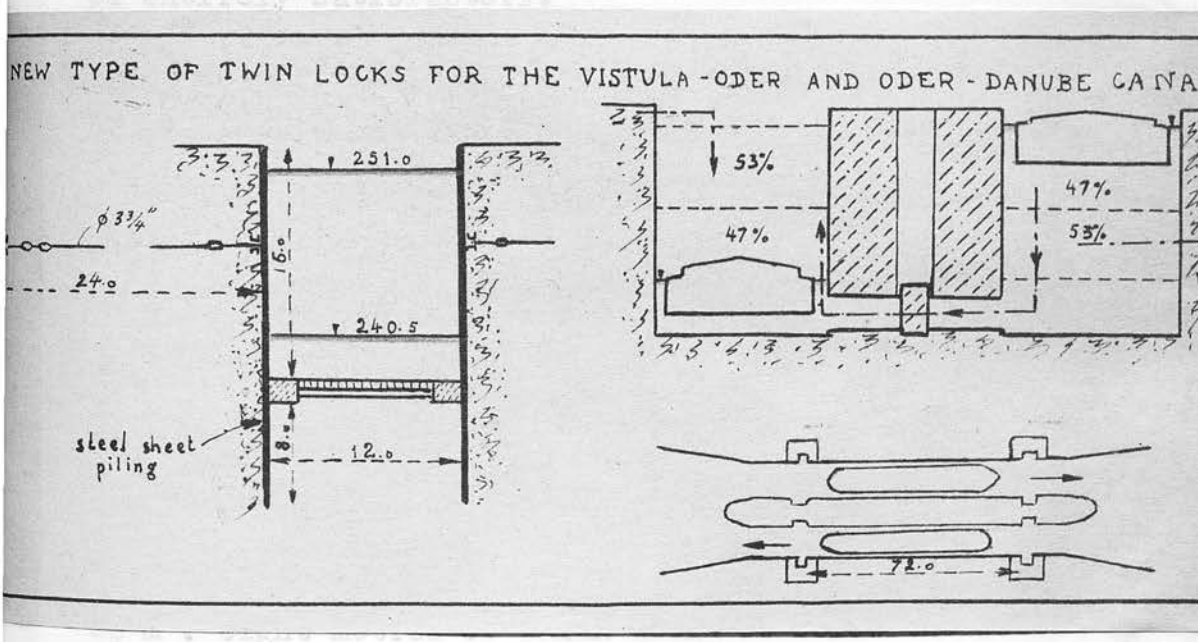
To permit of the installation of six basins for each lock the canal must be divided into two channels, thus increasing the excavation work and the length of pipelines.

31



To avoid this drawback it is possible to use twin-locks placed side by side, and to surround them by a series of three basins, see fig. No. 31. The topographical, geological and hydrological conditions at the site would determine which of the two methods would be adopted.

In the remaining locks No I,II,III,IV and V on the western slope towards the Oder and the locks No VIII and IX towards the Przemsza river the problem of water supply for filling the locks is simplified,as it would not be difficult to arrange a supply of water from the natural flow of the rivers Klodnica and Mleczna,where it would be necessary to construct storage



32

However economy of water is desirable,especially on the western slope,where the highest locks No IV and V with a head 10.5 m are situated.

The estimated movement of traffic passing these locks would call for an average quantity of water,of 5.3 m^3/s.

The river Kłodnica in the upper course cannot provide this amount of water even with the storage reservoir in the valley. For this site I propose to use a simpler form of twin - lock,which would give a saving of nearly 50% of water volume,by filling the lock containing the craft going upstream, with the water discharged from the other lock,containing the craft going downstream.

As regards the materials which must be used for the construction of twin-locks I propose steel-piling instead of concrete walls. Recent applications of this method of construction have proved it to be entirely satisfactory.

Preliminary calculations show that for each lock with a head of about 10 m in height we can save about £.25,000 by using steel-piling,which would result in considerable economies in the construction of the canal.

The steel sheet-piling would consist of single piles in the shape of joist No 40/I, driven by a steam pile-hammer,deep into the sub-soil.

For the highest locks No IV and V , see sketch No.32, with a head of 10.5 m , the length of piles would be approximately 26 m , eight metres of which would be below the bottom of the locks,until the impervious strata is reached and the lower end of the piles can be fixed in the firmer earth layers.

Each metre of length in a lock requires about three piles (3 x 0.36 = 1.08). Reckoning that the lock is 72 m long and that each fall consists of two locks,it would be necessary to drive this type of pile No 40/I in the following numbers:-

~~xnxthexlockxNoxVIIIxandxIXxxxxxxx800xpilesxl6mxinxlength~~
~~xnxthexxxVxxxNo~~

on the lock No I -- 800 piles, 16 m in length

on the locks No VIII and IX-1600 piles, 18 m in length

on the locks No II and III -1600 " , 20 m in "

on the locks No IV and V -1600 " , 26 m in "

The total number of piles would be 5,600 and the total length - 115,200 m with a weight of about 14,000 tons.

In order to eliminate the effects of earth pressure and to assure the stability of steel-sheet-piling the latter should be fastened to anchor slabs or concrete blocks by tie-rods.

The iron tie-rods would be $3^3/4$" in diameter, and the anchor slabs would have a dimensions which vary from 4 x 4 m to 4.8 x 4.8 m , according to the variation of the heads in particular locks.

The horizontal distance between the adjacent tie-rods would be 1.6 m .

The weight of these materials for the western sector of the Vistula-Oder canal would be approximately 4,700 tons.

In addition to reducing the cost of construction and giving a considerable economy in the quantity of water used, the twin-lock offers another advantage.

With ordinary lock arrangements the flow into the lower reaches is very variable and is affected by fluctuations caused by the operation of the locks, by the rise and fall of water level and by wave motion caused when a higher lock is fully opened.

These positive waves may reach a height of several centimetres over a length of from 1 to 3 km and may have velocities from

from 2 to 5 m/s.

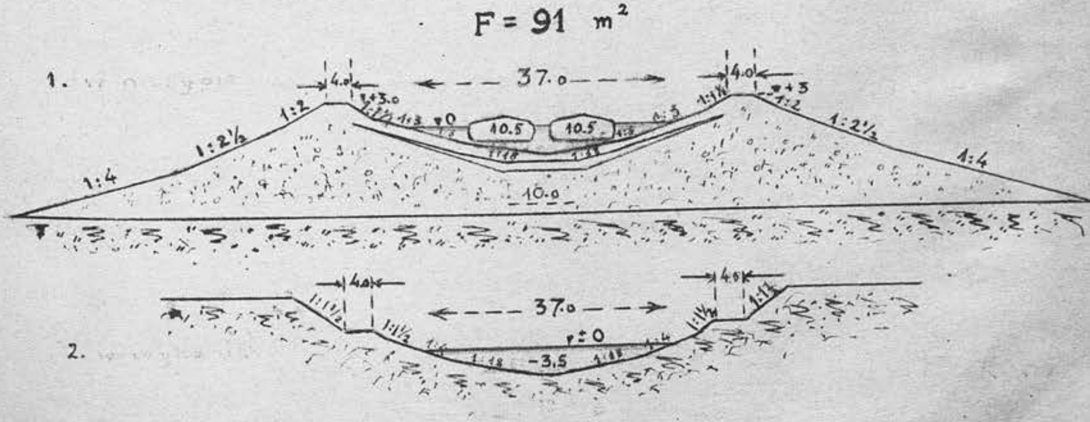
The reduction of these fluctuations in water level in a series of locks necessitates constant supervision by the personnel and there must be central control of the working.

If the proposed canal is provided with twin-locks and suitably designed approach channels I do not anticipate serious effects of the above nature.

The earth works.

The features of the proposed shape of cross-section for the Vistula-Oder canal are much the same as for the Oder-Danube canal. The bottom of the canal rises at first very slowly with a slope 1 : 15 - 1 : 20 , from the centre of the canal towards the banks, then the slope increases to 1 : 4 - 1 : 5, and meets that of the banks with a ratio 1 : 1½ - 1 : 3. The water depth is 3.5 m and the width of water line is 37 m , thus the wetted cross-section amounts to 90-92 m², see sketch No. 33 .

PROP. TYPICAL SHAPE OF CROSS SECTION OF THE VISTULA - ODER CANAL **33**



The advantages of the choice of the trough-shaped section as opposed to the trapezoidal form ~~was~~ were described in Chapter No.Ia on the Oder-Danube canal.

The excavation for the western sector of Vistula-Oder canal would amount approximately to 17 million m^3,but this figure may decrease or increase by about 20% from the estimate that will be given in the detailed plan. The excavation on the particular reaches would be as follows:

Reach	Volume of excavation in million m^3
1.	1.2
2.	2.4
3.	2.4
4.	0.85
5.	0.85
6.	0.9
7.	4.0
8.	1.6
9.	1.6
10.	2.2

Mechanical excavators are the most suitable for mass excavations made during the construction of canals,because of their much higher output.

In the Polish situation after the war,when the problem of unemployment will have to be faced, earth work must be used as a medium of preventing unemployment, and in the construction of canals,since they include a great amount of earth work, many unskilled workers may be employed. I therefore propose a combined method for carrying out the excavation,the upper (shallow)layers by hand, and the deeper layers by means of excavating machines.

The deeper layers will have be excavated mechanically because the ground water infiltrations make this excavation too difficult and costly , for underwater constructional work. Dragline excavators are very adaptable machines for such work, and many types are available for use on canal schemes. The range of dragline bucket capacity varies from 1/4 m^3 to 25 m^3 and the weight of machines from 7 to 1,380 tons, and consequently the hourly output from 20-30 m^3 to 2,500 m^3. For the Vistula-Oder canal medium sized excavators would be used with sufficiently long booms to reach the material from the banks.

The cost data and the unit of output of manual and mechanical excavation in Poland and other countries will be given at the end of this Chapter.

The guiding principles in deciding the number of workers to be employed and the limit of time for the completion of the western sector of Vistula-Oder canal can be derived from the following considerations.

Supposing that 60% of the excavation would be carried out by hand and 40% - mechanically , the total volume of manual excavation would be 10 million m^3 and of mechanical - 7 million m^3.

The first figure , as I pointed out , relates to the upper layers of the excavation.

Supposing further that the earthwork would take 2 years and that the average daily output of a worker would be 4 m^3, we find that 4,150 workers are required.

The volume of excavation,obtained in this way from manual labour would be about 110,000 m^3 a year and one kilometer. Supposing the average output of the excavators to be 75 m^3 an hour(the maximum hourly output will be considerably higher), 10-15 excavators will be required for this canal.

The total output of the excavation would amount to 188,000 m^3 per year and kilometer and as this is relatively high as compared with the output on the constructed canals in other countries, and it would be advisable not to base our estimate on higher figures.

Incidentally,on the American canals the maximum output obtained was 700,000 m^3 per year and kilometer on certain short sections, but the average on the whole distance of the canal varied from 100,000 to 200,000 m^3 per year and kilometer.

To the above mentioned figure of 4,150 workers I must add 850 workers to be engaged in the construction of locks e.t.c. so that the total would be 5,000 workers.

This figure we must multiply by a coefficient representing the weakened physical strength of the workers after the war, which gives a final total of 1.5 x 5,000 = 7,500 workers.

In addition to works connected with the construction of the canal 11 arch-bridges of 45 m span, the unit cost of which would be on an average about £. 300 per meter,several reinforced concrete culverts and other auxilary works must be built. These works would be carried out mostly in the third year of construction,and thus the number of workers would not drop considerably during the last year.

The total estimate of materials,mechanical equipment,workers and cost will be summariezed at the end of Chapter No. IIa on the Vistula-Oder-Canal.

The approximate cost of construction of the western sector of the Vistula-Oder canal would amount to about £.3.2 million.

The middle sector of the Vistula-Oder Canal.

The middle sector of this canal would start near Jeleń on the Przemsza river and end on the aqueduct across the Vistula river near Jankowice,almost below the estuary of the Skawa river, see sketch No. 34 and 35.

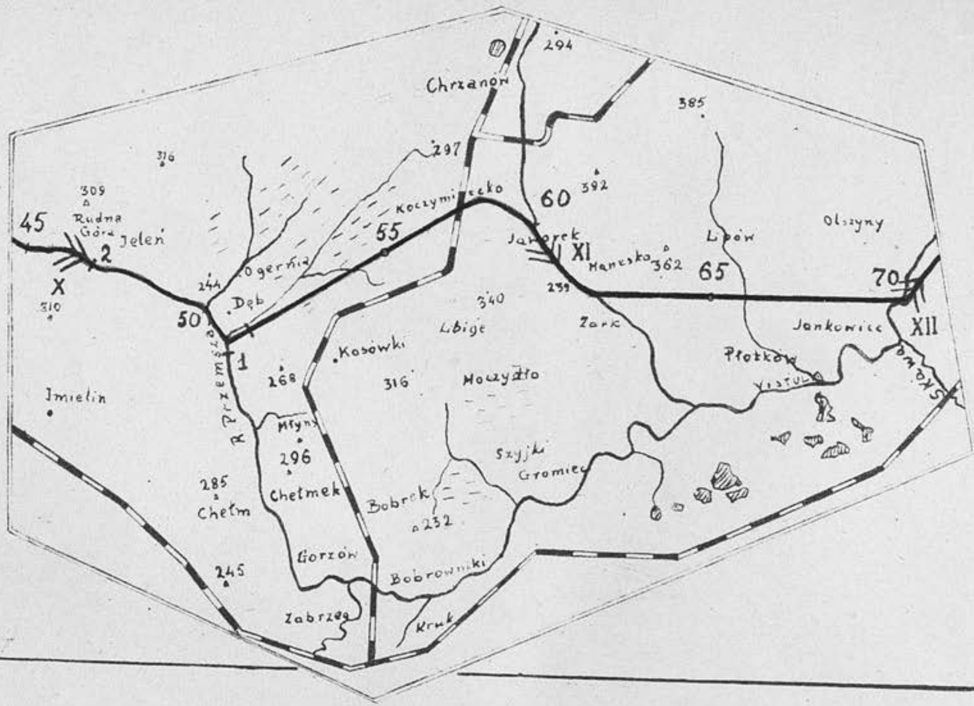
This sector would divide at the beginning into two directions:

1. running along the western sector of the Vistula-Oder Canal and further through the Upper Silesian and the Oder-Danube canal to the South, and
2. along the canalized Przemsza over a short distance to the centre of Silesia at Mysłowice. At the eastern end this canal would link up with the eastern sector of the Vistula--Oder canal, from Jankowice to Kraków,which in turn would go into the canalized Vistula towards the Baltic.

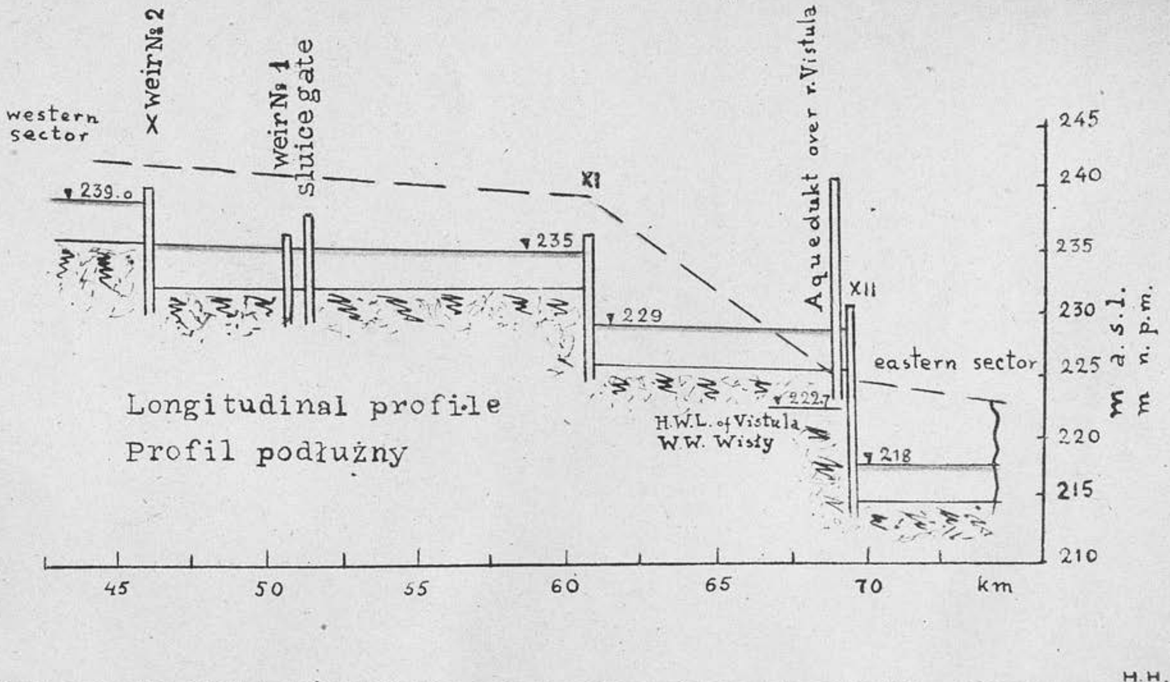
The middle sector of the Vistula-Oder canal would therefore play a double part in the network of the Polish waterways:-

1. it will take over the whole water borne traffic in Silesia and in an eastward direction, it will penetrate into the country leading
   a) to Gdańsk(Danzig)
   b) through East-Prussian waterways to Lithuania, and
   c) through the Royal canal to Russia , and

Middle sector of the VISTULA - ODER CANAL (from Przemsza to Vistula)
Środkowy odcinek KANAŁU WISŁA-ODRA (od Przemszy do Wisły)



Middle sector of the VISTULA - ODER CANAL (from Przemsza to Vistula)
Środkowy odcinek KANAŁU WISŁA-ODRA (od Przemszy do Wisły)



d) finally through the proposed Vistula-Dniester-Prut-Danube canal to the ~~Exa~~ Balkans;

2. it will co-operate in the exchange of goods between the countries situated on the Danube valley and the centre part of Poland via the Oder-Danube canal.

This means that for this traffic the last harbour will not be in Silesia, but further on in the industrial and agricultural centres, situated in Poland.

To accomplish this task the Vistula-Oder canal, both at its middle sector and at its continuation eastwards should be adjusted to the heavy annual traffic capacity.

I estimate that the quantity of annual traffic will be 15 million tons, 2/3 of which would be downstream and 1/3 upstream.

In calculating the internal traffic the probable increase of coal consumption in the country is especially emphasized, when its transport is cheaper and when at the same time the general well-being and the industrialisation of the country increases.

The railways would on the whole maintain their transport standard with a tendency to short distance runs transporting high-priced goods. The surpluses would be directed to the waterways mainly for long distance traffic.

If we examine the standard of consumption in the period of Poland's partition also that in the period of independence we find that although the latter is higher, Poland has always had a comparatively small coal consumption.

The following are the figures of coal consumption per head before the war of 1914:

In the part occupied by Russia, on the right bank of the Vistula	68 kg
In the " " by " , on the left "	660 kg
In the " " by Austria	1,068 kg
In the " " by Germany	1,170 kg

In the same year the consumption of coal per head was 2712 kg in Germany.

In recent years the consumption of coal has increased , but it is still low as compared with that of other countries:-

	1923.	1927.
Total production of coal in million tons	36	36.2
Left for home consumption in million tons	19.6	25.7
Consumption per head in kg	600	736

In Germany industry, gas and electric stations used about 66 million tons in 1932 and 110 million tons in 1936 i.e. within 4 years the increase was 67%. In 1936 the domestic use of coal was 40 million tons, thus the total home consumption was 150 million tons, or six times more than in Poland.

For the purpose of calculation it may be assumed that the waterway would take over the transport of 7.5 million tons, including 5 million tons for home consumption, and 2.5 million tons to Gdańsk (Danzig) and Gdynia. Incidentally, railway transport to Gdynia was causing losses to the State, because the

the rate was 5.2 shillings per ton or 0.105 d per t-km , while their own running costs were 0.33 d per t-km.

Besides coal the other items of the goods traffic on this waterway would be as follows.

Timber - The average annual cutting of thick wood in Poland is about 16,000,000 m^3, the maximum was 28,000,000 m^3. The railway carried about 6 million tons of timber per year, a great part of which was destined for foreign countries.

When the population in the Eastern part of Poland is able to obtain coal at a reasonable cost, several million tons of wood will be saved and it will be available for use in the mining centres. I estimate that wood transport on the Vistula - Oder canal would be 700,000 tons per year in the direction of Silesia and this may be taken as the average figure of wood requisition in that district.

Stone - The normal programme of road construction requires an annual consumption of 5 million tons of stone , from the quarries near Kraków (pophyry) and from Wołyń in the east of Poland (basalt). Town development uses yearly 1 ton of stone per head , which amounts to several million tons for towns situated along the valley of the Vistula. The transport of stone on the standard gauge - railways amounted to 3-4 million tons per year.

The quantity of stone transported by the canal to Silesia may be estimated as 1 million tons.

Iron ore - The Scandinavian iron ore transported to the Silesian district would be chiefly carried by the Oder, because this is the shorter route between Stettin and Gdańsk (Danzig) but we can estimate a fairly large quantity of iron ores from Kriwoy Rog in Russia, which would be transported to Silesia and Czecho-Slovakia by this canal.

A quantity of approximately 1.5 million tons may be allowed for.

In addition 4.3 million tons are allowed for transport in both directions during the exchange of goods with the Danubian countries.

The imports will include mainly bauxite and fodder, the latter being required because of a gradual transformation of the agricultural structure into a cattle breeding industry.

The exports will include, corn, meat products and salt.

Calculating that the agricultural crops in Poland amount to 50 million tons, on an average, with a tendency to increase, 5% of this production if directed through this canal to the west and south, gives about half of the quantity of traffic calculated above for the last group of foreign exchange.

It is quite obvious that the Middle sector of the Vistula-Oder canal should be constructed for the same capacity of barges as the previous i.e. to the 1,000 - 1,200 ton barges, and the locks installed on it would have the same dimensions 12 x 72 m .

Since this canal would commence in the canalized Przemsza at an altitude of 239 m above sea level and run steadily downstream

where,
to the eastern sector of the Vistula-Oder canal, after crossing the Vistula near Jankowice, it would end at an altitude of 218 m above sea level - supply of the water filling the locks would be obtained chiefly from the natural flow of the river Przemsza. If necessary an additional water supply would be taken from the Chechło stream, where the route of the canal would enter into the valley of this stream near Jaworów.

A calculation must be made to find out whether the discharge of water is large enough for the lock operations, using single locks of larger dimensions:- 24 x 72 m for a double set of barges, or whether twin-locks of dimensions 12 x 72 m , and giving a saving of nearly 50% of water volume, should be used.

For the lock No XII where the craft has the highest lift of 11 m , the volume of water for filling the lock with a dimensions 12 x 72 m , will be 9,500 m^3.

Assuming the average capacity of craft as sligthly lower than on the previous sector, because there would be barges of smaller capacity, coming from the eastern waterways, 90 lock operations per day would be necessary for the annual traffic of 15 million tons. That would call for an average quantity of water of 10 m^3/s.

The river Przemsza does not provide such a discharge at low water level. Therefore it is clear that the locks installed on the canal should be twin-locks, as the amount of water to be supplied would be reduced to 5.3 m^3/s.

From a series of stream gaugings made, at different stages of flow, on the river Przemsza in 1934, it is evident that this discharge 5.3 m^3/s is available except in very dry seasons. Great help in increasing the low water discharges will be given by the storage reservoir in Kozłowa Góra, situated in the upper basin of the Przemsza on its tributary the Brynica. This storage reservoir with a capacity of 15 million m^3 was built in 1938, under my supervision, chiefly for the regulation of flow for navigation purposes. Should this not be sufficient another storage reservoir ought to be built in Błędów on the Biała Przemsza river. Surveys and plans for this reservoir have already been made.

I emphasise especially the water supply problem for this sector of the Vistula-Oder canal as being decisive for the efficiency of the navigation.

From the stage-discharge curve developed from the data given in the table No. 6. the characteristic discharges were estimated as follows:

at the low water level 5.3 m^3/s

at the mean water level 9.0 m^3/s

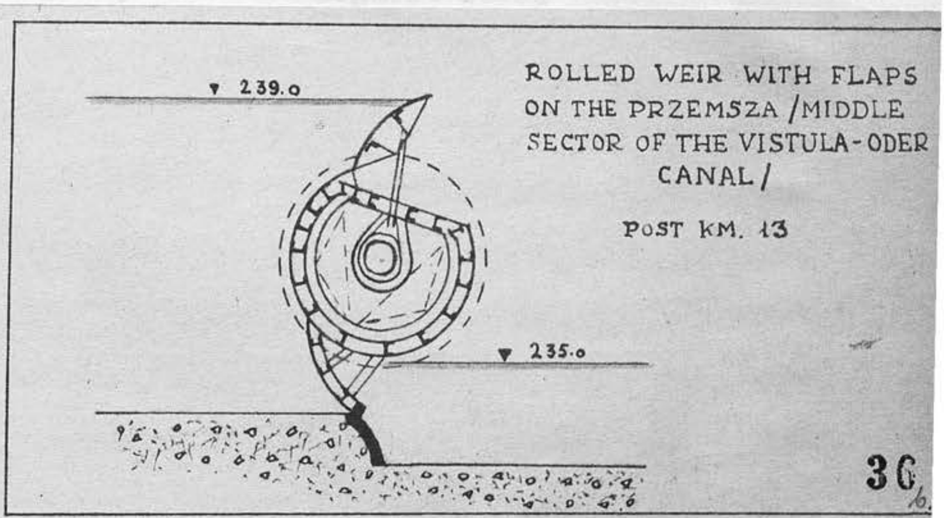
The results of these exact gaugings confirm the above conclusion that the type of locks to be used should be twin locks.

The following table No. 6 shows, that at this point we are on the lower limit of selfsufficiency based on the natural flow of the Przemsza.

Table No . Results of stream gaugings in the basin of the river Przemsza in 1934.

River	1) Gauging station 2) catchment area in km^2	Data 1934	Stage cm	Discharge $m^{3/s}$
Czarna Prze-msza	Piwoń 153.4	10.IV	172	0.209
"	Preczów	10.IV	172	1.816
"	Będzin 492.0	9.IV	174	1.848
Biała Prze-msza	Sławków410.4	27.III	296	4.620
"	Maczków625.9	27.III	116	5.270
"	"	11.IV	117	4.608
"	Błędów	12.IV	--	2.380
"	"	30.V	91	1.880
Brynica	Brynica100.2	4.IV	191	0.509
"	Józefka	5.IV	222	0.960
"	Czeladź368.5	6,IV	219	1.477
"	Sosnowiec	7.IV	161	1.608
Przemsza	Jęzor 1,928.9	28.IV	- 5	5.925
"	"	28.III	4	15.760
"	Jeleń 2,005	29.III	- 43	14.770
"	Chełmek 2,090.8	24.III	55	15.080

I shall now describe further details of construction. Downstream along the course of the Middle sector of the Vistula -Oder Canal, over a length of about 25 km , the water level at the start would be at an altitude of 239 m ,whereas that at the end would be at 218 m above sea level. Thus the total fall is 21 m and the craft would complete a fall or a rise by means of three locks, 4, 6 and 11 m in height. In order to preserve the continuity of the numbering of locks I have marked them with further consecutive numbers X, XI and XII. Let us first examine the upper stretch,which would follow the course of the river Przemsza. Owing to the fact that the Przemsza has a catchment area of 2,005 km^2, and is a small river, it would be necessary to canalize it. The figure No.41 shows this arrangement . As a site for the construction of the first weir and lock I have chosen Jeleń, post km 46.5 on the Vistula-Oder Canal reckoning from Gliwice. This site offers very favourable conditions for canalisation works,owing to the fact that the valley is compactly situated between two hills: 310 m above sea level on the left and 309 m on the right banks, and these are suitable as a frame for the movable weir. For the movable weirs on the canalized Przemsza I propose the type of submersible rollers with flaps. The description of the general principles of this closing system was given in Chapter No.Ia on " The proposed Oder-Danube-Canal", see sketch No.36a,b



36b

This type is especially suitable where the problem of frost exists, as it is of simple construction, is perfectly static and permits of large openings and easy water regulation.
In this case for the weir at Jeleń on the Przemsza two rollers with a width of opening of 40 m each, with a pier between them, 5 m in breadth, would be required. The retaining height would be 4 m .
The top of the weir sill would be placed at the level of the river bottom, so that any rise of the water level in the cross-section of the river at high water would be avoided, excepting a very small one caused by the pier.
As a protection against damage by ice the nose of the pier would be provided at the head water side with a special steel

protection extending to 1 m over normal head water level. The winches for working the closing structures would be placed at the top of the pier and would be capable of raising the rollers 50 cm higher, than the highest level known at the weir site.

At the downstream side the adjacent concrete floor would lie 1.5 m below the level of the weir sill, and this deepening would extend to a length of 6 m . After this the bottom of the weir would rise with a slope 1 : 6 , then would come the protected bottom, consisting of a heavy mattress made of stone and fascine extending 40-50 m .

The correct length of the downstream floor should be ascertained by tests made on models in the laboratory. Tests would also be made of other protective measures such as concrete prisms, so called "dental concrete" to be placed on the downstream floor, to neutralize the major part of the kinetic energy of the shooting jet.

This weir would be constructed of sedimentary material, because the rock is deeply seated and cannot be reached easily. In order to avoid undermining at the weir, a steel sheet piling must be provided which would reach down about 10 m below the level of the sill at the headwater side of the weir, and about 7 m at the tailwater side.

On the right bank, just beside the abutment of the weir the lock No.X, x would be installed as a twin-lock type, the openings of which would be used as additional open space for flow during the flood, if necessary.

The dimensions of the twin-lock would be the same as on the western sector of the Vistula-Oder Canal i.e. each 72 m long and 12 m broad. Thus the clear span of the weir and lock would be 104 m in length.

The total volume of concrete for the construction of the weir and the lock would amount to approximately 45,000 m^3, and the weight of the rollers and lock gates to about 300 tons.

The earth works on the upper reach would require relatively small excavations for the foundation of the weir but there would be a larger amount of earthwork for the raising of the crest of the existing longitudinal dikes on the river Przemsza, within the limits of the retaining and backwater level.

The problem of flood control in the valley of the Przemsza is not so difficult owing to the fact that the difference between the level of the lower water and that of the maximum high-water, is relatively small, namely:

at Jęzor 4.38 m
at Jeleń 2.71 m
at Chełmek 2.42 m .

Approximate calculations show that the total necessary earth works, excavation and elevation on this stretch between the weir at Jeleń (No.2) and the weir No.3 on the canalized Przemsza would amount to about 400,000 m^3.

On the second stretch of the middle sector of the Vistula-Oder Canal, over a length of 14.5 km, between the lock No.X at

Jeleń and lock No. XI at Dąb , it would be necessary to build the following works:-(Fig.34,35)

1. the movable weir on the river Przemsza at post km 9 near Dąb;
2. the sluice gate at post km 51.5 of the canal , just below the start of the deviation near Dąb;
3. the twin-lock at post km 61 ;
4. the excavation for the cross-section of the artificial canal , from the start of the deviation near Dąb to the lock No. XI over a length of about 10 km ;
5. the elevation of the crest of the longitudinal dikes on the Przemsza over a length of 4 km .

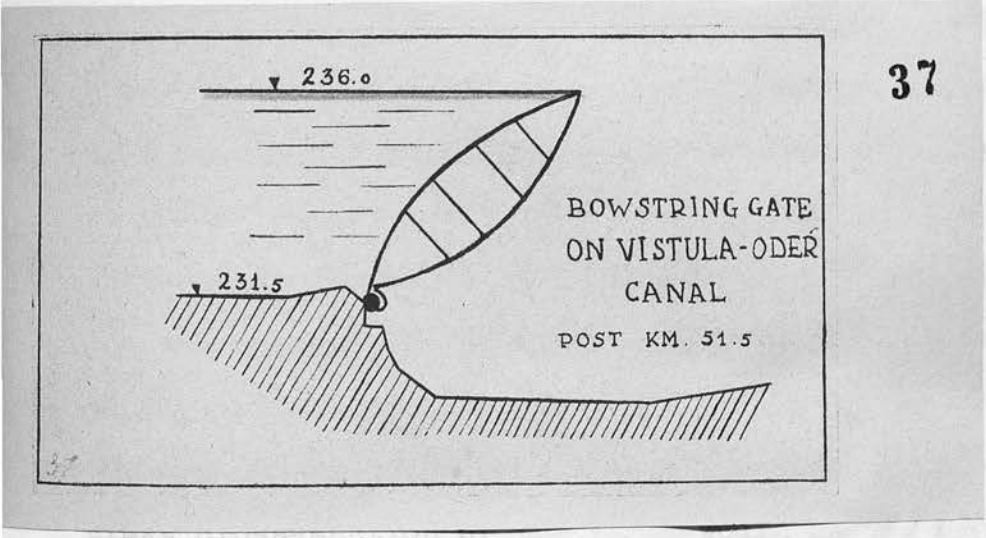
The object of the movable weir No. 1 on the Przemsza at post km 9 would be to retain the water level up to an altitude of 235 m above sea level , and form a pondage over a distance of 4 km , thus connecting with the tail water of the weir No.2 at Jeleń.
In addition the backwater caused by retaining the water level would pass along the artificial canal , which would lead east-wards by a shortcut to the valley of the Vistula.
At post km 9 on the Przemsza it would be necessary to build a movable weir with a head of only 2.5 m , but longer than that at Jeleń , because there will not be a lock here , which in the previous weir extended the opening by an additional length of 24 m , to let flood water pass through if necessary. Keeping the same condition of the discharge of flood water, there would be 3 openings , 35 m wide of the same type of sub-

mersible rollers with flaps. The total volume of concrete for the construction of the weir would be approximately 26,000 m^3, and the weight of the rollers would amount to about 100 tons.

After leaving the bed of the river Przemsza, the new artificial canal on the left bank would run eastwards to the Vistula. Just below the start of the deviation at post km 51.5 , it would be necessary to build the sluice gate. The object of the gate would be to close the canal during the flood and to prevent the passing of high water flow through it as this might cause damage to the banks and further down to the aqueduct crossing the Vistula.

The bottom of the canal at post km 51.5 is at an altitude of 231.5 m , and the normal water level at 235 m above sea level, caused by the retaining of water level at the weir No.1 on the Przemsza.

The hydrographs i.e. the graphical indications of the rate of flow of the Przemsza during the rainy year 1903 , showed the highest levels at Jeleń, and at Chełmek where the gauging stations are installed. Taking into account the average slope of the river 0.72‰ between these two gauging stations I estimate the high water level at the start of the deviation of the canal to be at an altitude of 234.7 m above sea level. But supposing a possibility of a higher water level than in 1903, I propose to allow for a maximum level of 236 m above sea level. Hence the closing depth would amount to 4.5 m ,but the difference between the head water and tail water would be only 1.0 m , except when the canal would be empty for repair. I propose in this case to install the bowstring gate, a convenient modern type hinged at the bottom, as, owing to its special shape it is torsion resisting,see sketch No.37....



The gate is fixed to the sill by means of strong hinges, and when it is lowered it x rests in a cavity in the sill. The advantage of this system is that it is quite watertight at the bottom over the whole length of the opening, and also at the sides when the weir is closed.

Furthermore, the bowstring gate is so torsion resisting that it can be worked from one side. The winches are only subject to tensile strain, resulting from the moment produced by the deadweight and the weight of the water.

Such bowstring gates, which have already been used successfully, have a width varying from 25 to 50 m and a closing depth varying from 6.5 to 2.5 m.

The dimensions of the bowstring gate for the Vistula-Oder Canal would be 25 x 4.5 m.

The third work on this stretch would be the twin-lock No.XI at post km 61 with standard dimension of 12 x 72 m, and the craft would complete a rise of 6 m. The description of the materials to be used for such a lock was given above. The total weight of the material for lock No.XI i.e. steel sheet piling tie-rods etc. would amount approximately to 2,500 tons.

The excavation for the canal which would lead by a short cut to the Vistula from Dąb to the lock No XI, over a distance of about 10 km, would amount to 5.3 million m^3. The shape of cross-section of the canal would be the same as on the Western sector of the Vistula-Oder Canal.

Additional earth works would be necessary for the raising of the crest of the existing longitudinal dikes on the river Przemsza, within the limits of the retaining level, between the weir No. 1 at post km 9 and the weir No.2 at Jeleń, post km 13.

The elevation works for this purpose would amount to about 250,000 m^3, thus the total amount of earth works, including the excavation at the weir No.1, on the whole second stretch of the middle sector of the Vistula-Oder Canal would be approximately 5.8 million m^3.

On the third and last stretch of the middle sector of the Vistula-Oder-Canal,over a length of 9 km,between the locks No.XI and XII , it would be necessary to carry out the following works:

1.the aqueduct across the Vistula river;

2.the twin-lock No XII on the right bank of the Vistula,with a head of 11 m;

3.the excavation for the cross-section of the canal.

The construction of the aqueduct across the Vistula river would be inevitable,owing to the fact that the continuation of the route of this canal eastwards to Kraków is only possible on the right bank of the Vistula,where the land is flat. Furthermore the construction of the lateral canal along the Vistula from Smolice to Kraków was started before 1939.

The governing principles for the dimensions of the aqueduct are, the open space under the aqueduct,sufficient for a discharge of flood water of the Vistula, and the type of construction.

With regard to the first condition,the Vistula at this place, near Smolice,has a catchment area of 6,714 km^2,and includes the basins of the rivers: Soła,Skawa and Mała Wisła,which are characterized by a very rapid and high flow during the flood period,and the basin of the Przemsza,which does not very much influence the flood discharge of the Vistula.

The most dangerous river in this respect is the Soła,with a catchment area of 1,388 km^2. Its maximum discharge was recorded as 1,300 m^3/s, and the possible was estimated as 1,700 m^3/s; the speed of the increase of the water level during flood amounted to 14.4 cm each hour.

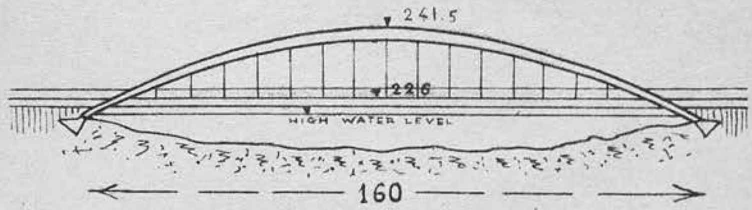
The next river Skawa has a catchment area of 1,151 km^2. Its flood flow is relatively smaller, about 1,000 m^3/s, with a less speedy increase of the water level, 9.7 cm/hour.

The Mała Wisła has a catchment area of 909.5 km^2, the length of the valley is relatively great, being double that of the Soła or the Skawa, and therefore its maximum flood flow generally reaches the Vistula river later than the other tributaries. In the past the maximum flows from all these tributaries have never occured simultaneously but it is quite possible that they may do so with particularly unfavourable destributions of rainfall and it is therefore advisable to take the maximum discharge into account in spite of the completion of the storage reservoir on the Soła at Porąbka in 1937 , which is capable of reducing the flood flow from 1,700 m^3/s to 340 m^3/s. In the construction of such an important structure as the aqueduct, the platform of which must always be above the highest water level, allowance should be made even for such an unlikely event as the impossibility of reducing flood discharge by the Porąbka reservoir.

Taking into account the maximum flood discharge of 2,500 m^3/s I estimate the span of the aqueduct as 160 m , and the level of the platform of the aqueduct to be, at an altitude of 226 m above sea level.

33

AQUEDUCT ACROSS THE VISTULA AT JANKOWICE-SMOLICE



Sketch No.38..shows the shape of the aqueduct for which I propose a large-sized reinforced concrete bridge. This type is similar to that which I applied in 1937 in the construction of the bridge with 75 m span which we built across the Soła at Tresna,on the upper course of the storage reservoir at Porąbka.

The construction of large span structures entails very careful calculations for the building and safety of the scaffoldings which form the largest item of expenditure. When the rise--span ratio is smaller, the height of the scaffolding above the flooring is considerably reduced,but the average section of the arch increases.

When planning this type of bridge in Poland we studied the relation between the shape of section,the working stresses of concrete and the rise-span ratio. The results were as as follows:- when the rise-span ratio rises from 1/7 to 1/5 by the adoption of maximum working stresses 85 kg/cm^2, the average section decreases about 20%; by the adoption of maximum working stresses 120 kg/cm^2, the reduction amounts to 15%. Thus the decrease in the volume of materials which amounts to about 15% is relatively small as compared with the considerable increase in the cost of the scaffoldings.

It seems to me that a ratio of 1/7 would probably be suitable. For the normal size of bridges with a free width of 8 m , the assumption is that each arch carries a load of about 7,000kg/m in length, in addition to its own dead weight. In the case of the construction of this aqueduct this figure would be much greater, owing to the fact that the free width would be 12 m , loaded by the channel with water 3 m in depth.

If a detailed investigation does not give entire satisfaction from the standpoint of cost, and statical strength - it might be necessary to consider the erection of a modern steel, plate girder structure.

Just below the aqueduct on the right bank of the Vistula the twin-lock No.XII at Smolice would be situated, at which point the craft would have the highest lift of 11 m . The water-supply question for this lock was described above, and from that we have seen, that in this case a simpler form of twin-lock 12 x 72 m can be used, which would call for an average volume of water of 5.3 m^3/s for lock operations.

The total weight of materials to be used for steel-sheet piling, tie-rods, sluice gates e.t.c. would amount to about 3,800 tons.

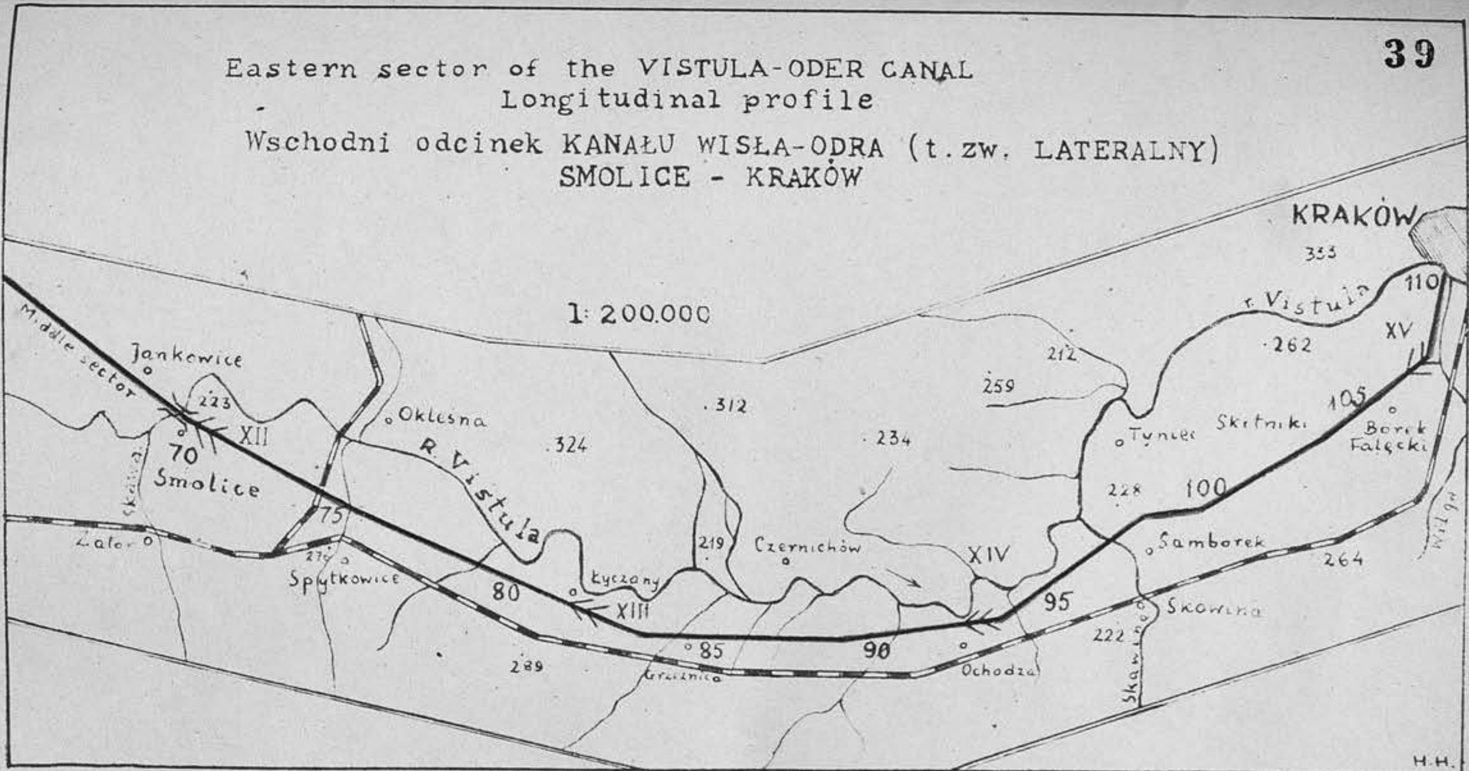
The excavation for the third stretch of the middle sector of the Vistula-Oder-Canal, with the standard shape of the cross-section described above, would amount to approximately two million m^3, over a distance of 9 km, between the locks: No.XI at post km 61 and No.XII at post km 70 .

In addition to works connected with the construction of the canal, 5 arch-bridges of 45 m in span, several reinforced concrete culverts and other auxiliary works must be built, Most of these would be carried out in the second period of construction, which in all would take roughly three years to complete.

Supposing the same combined methods are adopted for the excavation as on the Western sector of the Vistula-Oder-Canal, I estimate that 6,000 workers would be required for all the construction on this middle sector.

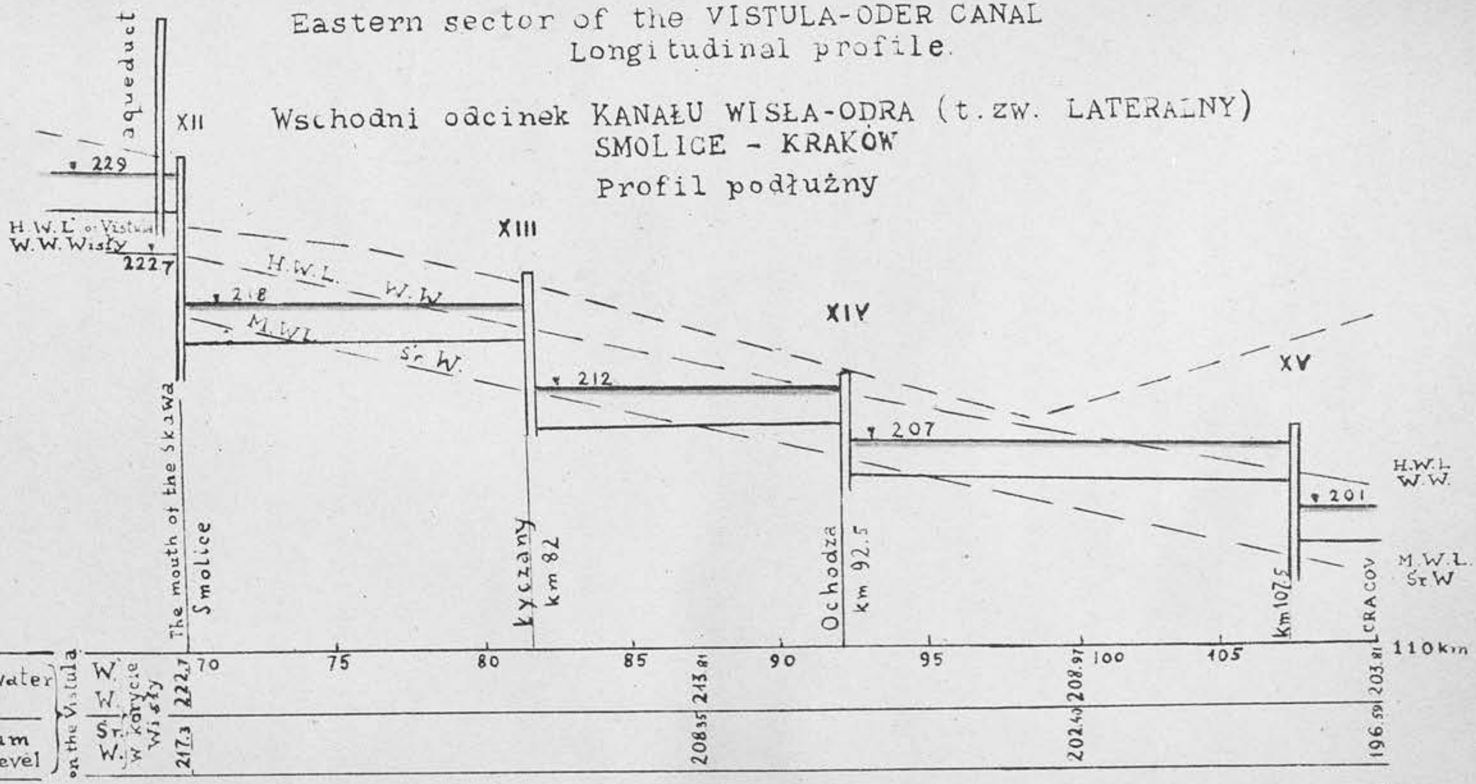
For the mechanical excavation 8-10 excavators would be necessary. Furthermore on this sector of the canal it would be necessary to use the steel-sheet-piles Larsen No.III for the construction of the weirs on the Przemsza, to allow the water of the Przemsza to be diverted, whilst the work was going on. About 400 metres of this type of steel-sheet-piling would be required.

The approximate cost of construction of the middle sector of the Vistula-Oder-Canal would amount to about £.1.6 million.


39
Eastern sector of the VISTULA-ODER CANAL
Longitudinal profile
Wschodni odcinek KANAŁU WISŁA-ODRA (t.zw. LATERALNY)
SMOLICE - KRAKÓW
1: 200.000
KRAKÓW
Middle sector
Jankowice
Smolice
Oklesna
R. Vistula
r. Vistula
Spytkowice
Zator
Łyczany
Czernichów
Tyniec
Skotniki
Borek Fałęcki
Samborek
Skawina
Ochodza
XII
XIII
XIV
XV
70
75
80
85
90
95
100
105
110
H.H.

Eastern sector of the VISTULA-ODER CANAL
Longitudinal profile.

Wschodni odcinek KANAŁU WISŁA-ODRA (t. zw. LATERALNY)
SMOLICE - KRAKÓW
Profil podłużny



H. H.

<u>The eastern sector of the Vistula-Oder Canal(see sketch</u> No.39,40).
This sector is already in course of construction, and only the completion of a relatively small part of the earth work and three locks remains to be done.

The route of this sector of the canal starts at Smolice, post km 70 , on the last reach of the middle sector of the Vistula--Oder-Canal, and follows the Vistula valley on the right bank, then ends in the east, at Kraków, post km 110 .

The river Vistula from Smolice to Kraków, over a distance of 55 km , runs through open valley, its bed being fairly steep and very twisted. For this reason we have decided to build a lateral canal instead of regulation or canalisation work for the improvement of navigation conditions.

The route of the canal would be 40 km long , and the craft would complete a rise of 17 m by means of 3 locks:

at km post 82 with a head of 6 m
at " 92.5 " " 5 m
at " 107.5 " " 6 m .

The stage which the works had reached in 1939 was as follows: about 50% of the excavation, all necessary bridges and the main part of the reinforced concrete culverts, which are quite numerous, were completed. According to unofficial news, the excavations are being continued during the war, and possibly all the earth works may be completed.

It is likely however that the construction of three locks will have been finished if they have been commenced.

The problem of water supply for filling the locks is solved on the middle sector of the Vistula-Oder-Canal by the proposed deviation from the Przemsza river at post km 50.5.

But if necessary, an additional water supply can be provided without difficulty from the river Vistula at the beginning of the second reach near post km 83 or of the third one near post km 93.

Coming back to the construction works which are yet to be accomplished on the lateral canal Smolice-Kraków, I give below the estimate of materials for the locks XIII, XIV and XV.

In case they are not built during the war, it would be advisable, for economic reasons and uniformity of types, to provide the same twin-locks, of steel construction, as I propose for the majority of the locks, previously described on the Vistula-Oder-Canal.

Apart from the economic factor it will be necessary from the general point of view to provide the foundries and steelworks with an adequate amount of orders in the post war period, when the war production will undergo the alteration into a peace time production.

The approximate weight of materials to be used for steel sheet piling, tie-rods, sluice gates etc. for the construction of the twin-locks No. XIII, XIV and XV with a dimensions 2 x 12 x 72 m would amount to 8,000 tons.

The total estimate of main materials, workers and cost for the construction of the Vistula-Oder Canal from Gliwice to Kraków, over a distance of 110 km, with 15 locks and two weirs on the

Przemsza river, may be summarized as follows:

1. Excavation	25,270,000	m^3
2. Concrete	180,000	m^3
3. Cement	48,000	tons
4. Iron and steel constructions	37,000	tons
5. Workers required	13,800	
6. Cost	£.5,000,000	

Some data of cost of engineering works.

The general cost of constructing a canal varies considerably, according to locality and size of cross-section of the canal. According to the costs of the construction of modern navigable canals, capable for craft 1,200 tons, i.e. with 3.5 metres in depth, and a wetted cross-section of the canal about 90 m^2 - the average cost amounted to about £.110,000 - 120,000 per kilometre in Germany.

The unit cost varied from 22 sh to 25 sh per 1 m^3 of the wetted cross-section of the canal in the recently completed canals such as: Upper - Silesian Canal, Central Canal and Saale-Elster Canal, which is in course of construction.

Previously built canals in Germany and France, capable for 300--600 ton crafts, cost on an average from £. 20,000 to £.30,000, and the smaller ones, running through the valleys of the rivers in good topographic conditions, cost from £.8,000 to £.12,000.

In Great Britain the boat canals, for inland navigation cost from £.12,000 to £.22,000 per kilometre, and for ship canals £.300,000-500,000.

In U.S.A. the cost of the construction of the Welland Ship Canal with a navigation depth of 4.2 m , with 25 locks of a total head of about 160 m was £.640,000 per kilometre.

In Poland, where labour is relatively very cheap, the cost per 1 m^3 of the wetted cross-section of the canal for modern navigation, taking a craft of 1,200 tons, I estimate as about 15 sh-16sh, or about 30% cheaper than in Germany. Engineering works completed in recent years in Poland proved the accuracy of this ratio.

The probable costs of the Western and Middle sectors of the Vistula-Oder-Canal which I have just calculated, based on the unit prices for different materials and labour amount to about £.70,000 per kilimetre, or 15 sh per m^3 of wetted cross-section.

In the following table I have summarized the unit prices of engineering works in the construction of dams and canals, executed in Poland in the years 1935-1939, under rather difficult conditions of foundation.

These prices comprise all costs of administration, such as wear and tear of machinery and equipment used for the construction, pumping required for works below surface of ground water, fuel, use of engines, electricity, steel sheet piling scaffoldings, personnel salaries etc.

(see next page)

Table No. 1.

Excavation	Cost per m³..... as for dam sh	d	Cost per m³ as for canal sh	d
digging not exceeding 2m deep	3	01	1	07
" in the layers 2-4m "	4	00	2	09
" " 4-6m "	4	10	3	07
" " 6-8m "	5	10	4	05
" " 6-10m "	6	10	5	03
" " 10-12m "	8	00	6	00
" " 12-14m "	8	09		
" " 14-16m "	9	07		
" " 16-18m "	10	05		
" " 18-20m "	11	07		
" " 20-22m "	12	10		
" " 22)24m "	14	00		
" " 24-26m "	15	01		
supplementary in hard rock requiring blasting			4	05

Drilling	Cost per metre sh	d
made by diamond drilling by the Crealius apparatus		
to a depth 4 m	16	0
" 8 m	17	8
" 12 m	19	2
" 16 m	24	0
" below 16 m	44	0

Injection	Cost per kg. sh	d (excluding cement)
of liquid cement in the holes drilled in the rocks to a depth of 35 m	00	02

Concrete(vibrate)	Cost per m³ sh	d (excluding cement)	
as for construction a dam comprissing 4 aggregates and 250 kg of cement per m³ of concrete	25	00	
Supplement for superior concrete as for outer facings with 300 kg of cement per m³ of concrete	4	00	
Portland Cement-depending on kind from - to			Cost per 100 kg 2/5 - 3/2
Iron for reinforced concrete			0/7 per kg.

<u>Hand Excavation</u>. The output of a worker depends on the compactness of the ground. In a light material as sand it comes to 10 m^3/daily; in ordinary conditions such as soft clay,gravel - 4-6 m^3/daily; and in a stiff clay - to 3 m^3/daily, at the pre-war rates. At a standard daily wage of 2/5 in Poland the net price was between 3 d and 10 d per m^3.

A worker with a wheel-barrow is able to push 1/10-1/15 m^3 of earth on a truck or a plank over a total distance of 25 km per day.

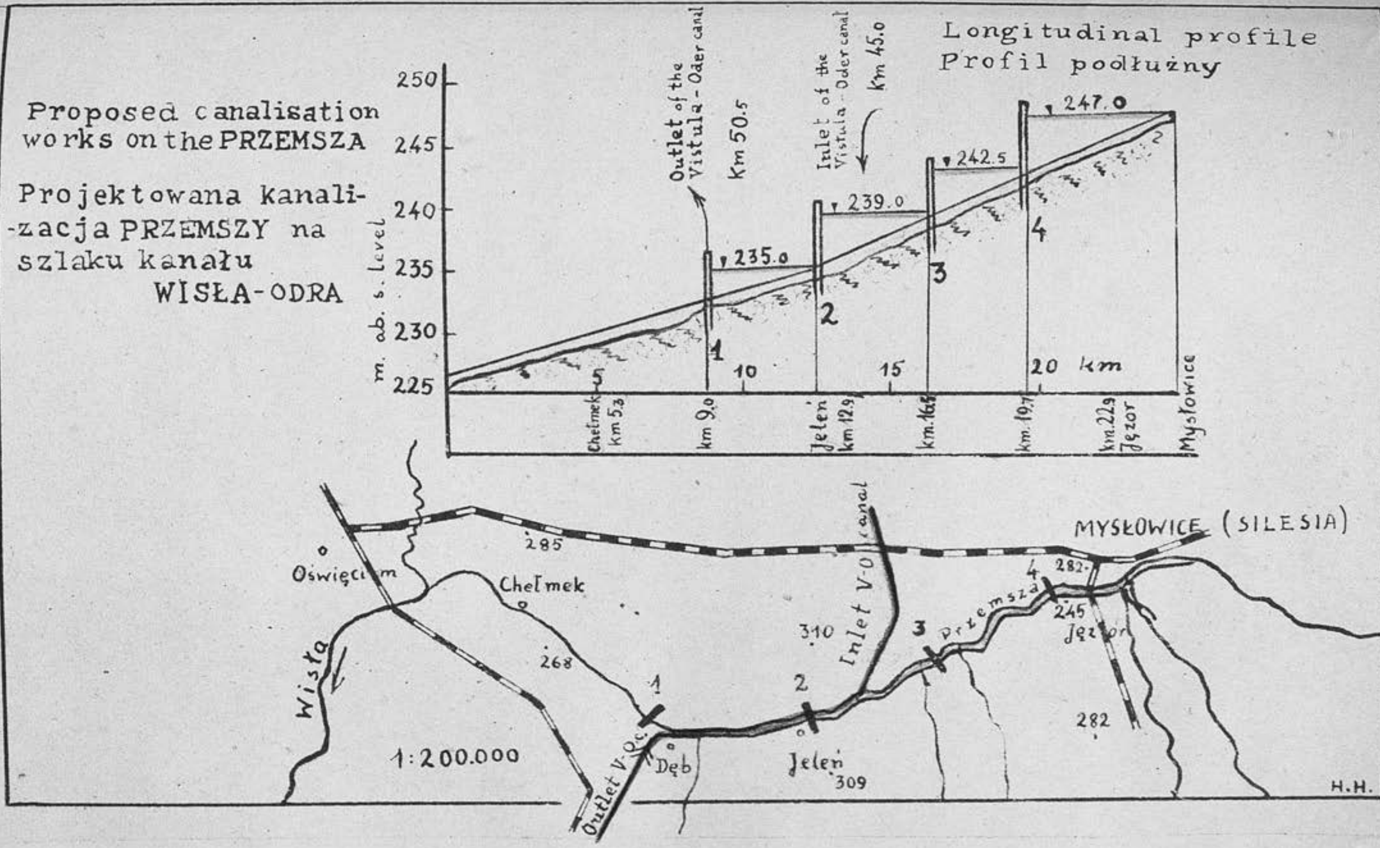
At a distance of 100 m from the place of excavation to the dumping ground,the cost comes to about 6d/m^3.

A horse cart with 2-3 assistants,so called Dutchmen,are often used in Poland for dredging in the upper layers of excavation. The daily output varies from 20-40 m^3/daily,and the price is relatively lower than by hand excavating.

As a comparison I shall add that in Great Britain the unit prices of hand dredging as for rivers and canals varies between 6 sh to 12 sh per yd.^{3} ~~cube~~, and the mechanical excavations from 2/9 to 3/3 in large areas not exceeding 5 ft.deep .

<u>The proposed canalisation works on the Upper Przemsza as an extension of the Vistula-Oder-Canal to Silesia</u>(see sketch No.41)

It follows from the previous Chapter,relating to the Middle sector of the Vistula-Oder-Canal,that the route of this canal runs partly along the Przemsza over a length 5.5 km,between post km 14.5 and 9.0 . For this purpose two movable weirs were proposed No.1 at Dąb and No 2 at Jeleń.


Proposed canalisation works on the PRZEMSZA
Projektowana kanalizacja PRZEMSZY na szlaku kanału WISŁA-ODRA
Longitudinal profile
Profil podłużny
m. ab. s. level
250
245
240
235
230
225
Outlet of the Vistula - Oder canal
Km 50.5
Inlet of the Vistula - Oder canal
Km 45.0
235.0
239.0
242.5
247.0
1
2
3
4
5
10
15
20 km
Chełmek km 5.3
km 9.0
Jeleń km 12.9
km 16.5
km 19.7
km 22.9 Jęzor
Mysłowice
MYSŁOWICE (SILESIA)
285
Oświęcim
Chełmek
268
310
Inlet V-O canal
Przemsza
282
245
Jęzor
282
Wisła
1:200.000
Outlet V-O c.
Dęb
Jeleń
309
H.H.

If we left the scheme of the Vistula-Oder-Canal in this conditions,this new navigable waterway which is to be a link between the centre of Poland and the Oder towards the Baltic, and via the Oder-Danube towards the Black Sea - would not fulfil the other important factor which is to include the coal and industrial centre of Upper Silesia in the district Mysłowice--Katowice in the range of water-transport on this route.

This is the reason why the construction of a modern navigable waterway as an extension running xxxx northwards along the Przemsza would be necessary.

Owing to the fact that the river Przemsza is a small river with a flow on an average,of 9 m^3/s and with a fairly steep slope 1.1$^0/_{00}$, the only possible method for the alteration of this river into a good navigable waterway for 1,000-1,200 tons craft is canalisation.

Of the total length of 15.2 km of this future extension along the Przemsza,nearly half was described above , as the proposed canalized sector comprising two reaches. For the remaining upper sector from post km 16.5 to post km 24.2 at Mysłowice it would be necessary also to build two canalisation falls,by means of movable weirs,provided with twin-locks,with a total head of 8.0 m .

The numbering of the weirs No.3 and No.4 follows in succesion from the two lower weirs,at Dąb and Jeleń.

There are no topographical or hydrological reasons for an alteration of the type of weirs, i.e. the sub-mersible rollers with flaps, and the twin locks, which I proposed for the previous two weirs situated downstream.

The use of the same type on all four stretches will produce economy in the cost of the mechanical parts, as well as in the working costs by the cooperative use of the concrete making equipment liquid cement injection machines, steel-sheet piling for diverting the flow river etc.

The following table gives the general data of the arrengements of the proposed canalisation works on the Upper Przemsza.

Table No. 8

1. Length of the canalized region	7.7	km
2. Number of falls	2	
3. Total head	8	m
a) of which at the weir No.3 at post km 16.5	3.5	m
b) of which at the weir No.4 at post km 19.7	4.5	m
4. Twin-locks		
a) number	2	
b) dimensions: length	72	m
width	12	m
depth	3.5	m
5. Average water volume required for lock operations, assuming transport capacity of 15 million tons per year	2.3	m^3/s
6. Weirs: a) type of submersible rollers with flaps		
b) width of two openings	80	m
7. Workers required	2,500	
during	2.5	years
8. Total estimated cost of the construction	£. 300,000	
9. Total estimate of mean materials:		
a) excavation	850,000	m^3
60% of which comprises dikes		
b) concrete	100,000	m^3
c) cement	27,000	tons
d) iron and steel construction	1,000	tons
10. Some mechanical equipment required for the construction:		

Some mechanical equipment required for the construction:

a)Larsen's steel sheet piling.........400 m

b)number of excavators............... 6

c)several power drilling machines,
air compresors,concrete mixers etc.

The port at Mysłowice is assumed to be the end of navigable waterway along the canalised Przemsza which would connect the mining and industrial centres of Silesia with the network of waterways in Poland and its outlets outside the country.

This assumption is not quite accurate because,for the estimated future annual transport capacity of 15 million tons,the dimensions of the commercial port would be too large,to be situated in one town.

The necessary length of quays to accommodate shipping,loading and unloading would extend to about 15 km . The last figure is based on the estimate that loading and unloading capacity would be a maximum of 1,000 tons per metre of the quay per year.

This means that the extensions of the harbour would stretch further than Mysłowice. The lengthening of these quays would be done in successive stages,depending on the requirements of the market,and the development of traffic.

Fortunately the topographical and hydrological conditions are favourable to such an extension into a large port,as the forks of the Przemsza along the Black Przemsza,the White Przemsza and the Brynica, may be developed along their low banks,which are not covered with many buildings.

In the years 1938-1939 the dredging works and improvement of the banks were started but on a small scale near Mysłowice, and further surveys and works would be required on a large x scale.

As regards mechanical equipment for the Mysłowice port I may mention that the requirement would be very large for different kinds of quay cranes and conveying and elevating machinery. As is known the working load of quay cranes varies from 1-90 tons, but for this port, generally cranes with 2,3 and 5 tons working loads would be required.

The number of cranes after the development of the port would amount to several handreds. As an example I should mention That Paris has 420 quay cranes, for its transport capacity of 13 million tons per year, while Berlin has for its traffic of 11 million tons per year about the same number.

The Proposed Canalisation works on the Vistula.

Introduction.

The basin of the Vistula, in Poland alone, comes to 92% of the total of its catchment area of 193,254 km^2, or 46% of the total area of the country.

The existing canals: Royal and Augustowski link up the Vistula with the basins of Niemen and Prypeć rivers, thus increasing the hinterland of the Vistula to about 270,000 km^2 or to 70% of the total area of Poland.

In spite of such a large hinterland, water transport to the Polish ports play a very small role in export, from 1.9% to 3.5% of the total. To make a comparison I take the figures from U.S.A., where the Mississippi basin constitutes 64% of the total area of the country, playing the same part in the U.S.A. as the Vistula does in Poland. This river with its system of waterways, takes a large part of the exports of the U.S.A. namely 68% of the total. The differences in the freights, as a result of the differences in exploitation costs of navigation and those of railway traffic yields a great economy of some hundreds of million dollars yearly.

The present state of river traffic on the Vistula and on the waterways directly connected with it cannot be accepted as an accurate view of the future role of the Vistula in the economic life of Poland.

For over a century the Middle sector of the Vistula in Central Poland was neglected during the period of Poland's partition.

At the same time some regulation works were done on the Upper and Lower Vistula, but they did not contribute to the improvement of depths, suitable for modern navigation.

Although the basin of the Vistula is but little smaller than that of the Rhine and in spite of the regulation works carried out on the Lower Vistula, navigation, during low levels of water encountered and had to cope with considerable difficulties and obstacles. Regular navigation really stopped at Warsaw. On the Upper Vistula only small boats sail as far as Sandomierz and connection with the Lower Vistula, through the Middle Sector is practically non existent.

The only commodity which reaches the Lower Vistula from the whole hinterland is timber floated down in rafts.

The Vistula, excluding the Middle sector which looks extremely deserted due to the lack of regulation works, is for the most part contained within a single bed, but at low water level the flow of water does not keep in a uniform navigable channel; sandbanks and islets appear at many points and vessels have constantly to seek new channels. When a low level of water ensues, navigation is almost completely stopped, and even vessels with a cargo of under 100 tons can only navigate with difficulty.

The reason for the unsatisfactory results from the river regulation works carried out on the Lower Vistula during the period of Poland's partition, is not far to seek:- mistaken and fallacious principles were accepted and applied during the course of the work; proper hydrological surveys fixing the normal profile of the river were not made; the course of the stream was too much straightened out; the application of unsuitable meander-radii resulted in the main current not keeping to the concave bank.

I will come back to this question later when describing the necessary improvement works on the Lower Vistula.

When the Polish authorities took over the Vistula basin they had to create a waterway over a long distance, without the necessary equipment, without records and surveys and with only a few properly trained personnel, having a special knowledge of river regulation work.

During the years 1920-1939 all necessary surveys and hydrometrical gauging were undertaken and the preliminary research work and plans of storage reservoirs for feeding the rivers in time of drought were carried out, and several of these have already been completed. Furthermore, nearly all the damage done to the regulation works was repaired, and some new regulation works on the worst sectors have been carried out in order to deepen the main channel. The building of ports and wintering-berths e.t.c. has also been started.

The average expenditure of the Polish Government on the Lower Vistula was about £.1,500 per km and per year, and about £.1,000 per km and per year on the Middle and Upper Vistula, over a total length of about 940 km.

This expenditure was necessary to cover the cost of the normal

maintenance of the works and of the channel,by means of systematic dredging operations on the most difficult sectors.
As will have been learned from the foregoing description the state of the Vistula when it was taken over by the Polish authorities was far from satisfactory,and the present state is not much better,because difficulties were encountered in financing a large scheme for the alteration of the Vistula into a modern navigable waterway over the whole of its length. There can be no doubt that this river could,if properly improved,bear vessels of at least 1,000 tons,while at present the Vistula is navigable for craft of over 600 ton storage capacity over a distance of only 32 km; for boats of 400-600 tons capacity over a distance of 394 km and on the remaining distance of 519 km it is navigable only for boats of under 200 ton capacity.
Slopes on the Vistula - Before considering and proposing the best method for improving the Vistula we have to look into the distribution of longitudinal slopes on the particular sections.
The following table shows the characteristic data for the Vistula,comprizing the catchment areas,post km , the altitudes of the average water level in 1934 ,falls on the particular sections and the average slopes there.

(see the next page)

Table No. 9. Mała Wisła

Gauging stations	Catchment area km²	Post km km	Altitude of water level m above sea level	Fall m	Length of section km	Average slope 0/00
Skoczów	-----	86.3	288.01	37.04	13.1	2.850
Drogomyśl	320	73.2	250.95			
				3.73	4.1	0.911
Strumień	399	69.1	247.24			
				6.51	29.1	0.217
Goczałkowice	739	40.0	240.95			
				5.34	16.3	0.326
Jawiszowice	909.5	23.7	235.59			
				7.79	20.1	0.387
Nowy Bieruń	1779	3.6	227.80			
				60.21	82.7	0.725

Table No. 10. Vistula between the mouth of the Przemsza and the mouth of the San.

Gauging stations	Catchment area km^2	Post km	Altitude of water level m above sea level	Fall m	Length of section km	Average slope 0/00
				1.20	4.1	0.293
Pustynia	3848	0.5	226.60			
				1.02	3.3	0.308
Dwory	5240.0	3.8	224.58			
				8.27	19.8	0.417
Smolice	6714.0	23.6	216.31			
				7.96	28.0	0.332
Czernichów	--	47.6	208.35			
				5.86	15.9	0.369
Tyniec	7401.0	63.5	202.49			
				5.90	15.0	0.393
Kraków	8021.0	78.5	196.59			
				0.94	3.0	0.313
Płaszów	--	81.5	195.65			
				1.98	7.6	0.261
Przewóz	--	89.1	193.67			
				3.48	12.0	0.291
Niepołomice	--	101.1	190.19			
				1.23	3.7	0.333
Koźlica	--	104.8	186.96			
				3.04	10.0	0.304
Nowa Wieś	--	114.8	185.92			
				5.34	15.7	0.341
Starosławice	9110.0	130.5	180.58			
				2.55	7.6	0.336
Popędzynka	10637.0	138.1	178.03			
				4.39	15.0	0.292
Jagodniki	12826.0	153.1	173.64			
				3.32	12.9	0.252
Karsy	19184.0	166.0	170.32			
				3.38	11.7	0.289
Pawłów	23668.0	177.7	166.94			
				4.49	16.4	0.274
Szczucin	23752.0	194.1	162.45			
				4.06	16.0	0.253
Otałąż	--	210.1	158.39			
				3.65	15.5	0.270
Ostrówek	26332.0	223.6	154.74			
				4.41	16.3	0.271
Koło	30634.0	239.9	150.33			
				4.53	15.4	0.294
Dzików	30758.0	255.3	145.80			
				3.82	13.1	0.292
Sandomierz	31781	268.4	141.98			
				1.47	6.2	0.237
Dąbrowa Wrzawska	33358	274.6	140.51			
				87.29	278.2	0.315

Tabela No. 11 The Vistula between the mouth of the San and Warsaw.

Gauging stations	Catchment area km²	Post km km	Altitude of water level m above sea level	Fall m	Length of section km km	Average slope 0/00
Chwałowice	50585.0	284.7	137.93			
				2.58	10.1	0.256
				0.66	2.9	0.227
Zawichost	50653.0	287.6	137.27			
				2.76	10.8	0.256
Annopol	51.605.6	298.4	134.51			
				8.32	33.6	0.247
Solec	54693.0	332.0	126.19			
				9.32	39.1	0.238
Puławy	57303.0	371.1	116.87			
				5.13	22.3	0.231
Dęblin	68447.0	393.4	111.74			
				9.95	38.9	0.269
Kłoda	71.973.5	432.3	101.79			
				9.04	33.6	0.256
Królewski Las	82321.9	465.9	92.75			
				12.98	47.9	0.271
Warszawa	85176.0	513.8	79.77			
				60.74	239.2	0.253

Table No. 12. The Vistula between Warsaw and Bydgoszcz.

Gauging stations	Catchment area km²	Post km km	Altitude of water level m above sea level	Fall m	Length of section km	Average slope 0/00
				9.15	37.7	0.243
Modlin	---	551.5	70.62			
				0.84	4.5	0.187
Zakroczym	---	556.0	69.78			
				5.78	30.7	0.188
Wyszogród	159632.0	586.7	64.00			
				9.05	45.7	0.198
Płock	168362.0	632.4	54.95			
				9.16	47.0	0.195
Włocławek	171250.0	679.4	45.79			
				4.30	23.0	0.187
Nieszawa	173111.0	702.4	41.49			
				3.36	17.4	0.193
Silno	174146.2	719.8	38.13			
				2.61	15.0	0.174
Toruń	179990.0	734.8	35.52			
				4.72	28.2	0.167
Solec Kujawski	--------	763.0	30.82			
				2.49	11.9	0.209
Fordoń	185615.0	774.9	28.31			
				51.46	261.1	0.197

Table No. 13. The Vistula between Bydoszcz and Gdańsk (Danzig).

Gauging stations	Catchment area km²	Post km km	Altitude of water level m above sea level	Fall m	Length of section km	Average slope 0/00
				5.96	31.9	0.187
Chełmno	186277.0	806.8	22.35			
				4.92	28.0	0.175
Grudziądz	189077.0	834.8	17.43			
				5.73	32.2	0.178
Korzeniowo	191227.0	867.0	11.70			
				3.90	19.4	0.201
Mątawski Cypel	193009.0	886.4	7.80			
				0.57	2.2	0.259
Piekło	--------	888.6	7.23			
				1.96	10.1	0.194
Mała Słońca	------	898.7	5.27			
				1.76	9.9	0.178
Tczew	193170.0	908.6	3.51			
				3.51	30.0	0.117
Schiewenhorst	----	938.6	0.00			
				28.31	163.7	0.174

From the above data we can see that the Vistula over its total length of 1,024.9 km , including the upper course , called the Small-Vistula(Mała Wisła) , has a fall of 288.01 m .

The average slopes of the water surface of the Vistula on its different stretches at medium water level are:-

1.From Skoczów to the mouth of the Przemsza	0.725 0/00
2.Between the mouth of the Przemsza and the mouth of the San	0.315 0/00
3.From the mouth of the San to Warsaw	0.253 0/00
4.From Warsaw to the mouth of the Brda	0.197 0/00
5.From the mouth of the Brda to Gdańsk(Danzig)	0.174 0/00

We must discard the first stretch , called the Small Vistula, which is unsuitable , for being altered into a modern navigable waterway because of its lack of discharge and also because it changes its course to the south away from the industrial centre in Silesia. For this stretch I propose the construction of the Vistula-Oder canal , described above.

Selection of the method of improving the Vistula.-

Before deciding the principle question , namely the selection of the method of improving the Vistula , I have studied the results of regulation works on several rivers in Europe and America , the hydrological conditions , slopes and lengths of which are similar to those of the Vistula. I will mention only four rivers:- the Elbe and the Oder on the Continent and the Ohio and the Tennessee in U.S.A. , the first two of which were regulated and the second two canalized.

The river Elbe on its upper course has been successfully canalized or the canalisation works are still in course of construction, as I have described in the Chapter No.II Vol. 1/ "On the development of waterways in Czecho-Slovakia." On the contrary, on the lower course, over a distance of 725 km in Germany, regulation works have been carried out to improve navigation depths. It is known, that the improvement of the waterways by means of regulation works must of necessity be a long operation. In this case, on the Elbe, these works were carried out over a period of 50 years. It may be said, however, at once that the main object of obtaining a modern navigable waterway has not been reached, in spite of the relatively low average slope, which is much lower than that on the Vistula.

The slopes on the Elbe vary from 0.218 0/00 in the upper sector to 0.191 0/00 in the middle sector and to 0.132 0/00 in lower sector.

The rate of flow varies:

at Torgau from 3,950 m^3/s to 47 m^3/s;
and at Wittenberge " 4,000 m^3/s to 115 m^3/s.

During the specially low water in 1904, 1911, 1928, 1929, 1933 and particular-ly in 1934, the minimum depth of the navigable channel dropped considerably to 0.60 m at Magdeburg, to 0.70m between Magdeburg and the mouth of the Havel and to 0.80 m below the mouth of the Havel.

Although these minimum depths were displayed at few crossings, the average depth being greater, nevertheless the presence of these shoals compelled the river craft to reduce their draught.

It became apparent that a further deepening of the river, by narrowing the width, by means of training groins, was necessary. On the other hand if the bottom is too narrow and the bends are sharp the channel becomes dangerous for navigation, and at low water levels the meeting or overtaking of tug trains cannot safely take place.

Several methods of so called subsequent regulation or low water regulation have been adopted but these have given unsatisfactory results. The subsequent regulation was mainly carried out by means of long submerged groins, having flat slopes 1 : 25 and established, below average low water, at the heads of the existing groins, as a prolongation of these groins. Towards the concave bank the groins have steeper slopes than towards the convex banks. This was an unsatisfactory experiment, especially where the medium water breadths were to wide, and the heads of groins, extending far into the river and not visible to shipping, were a constant source of danger. The constructions were frequently damaged by shipping and ice without its always being possible to discover the damage soon enough to prevent further destruction. The improvement for navigation could not be achieved with these regulation works, even with the added help of extensive dredging.

In the places where low water training dikes had been built, instead of submerged groins, there was also no considerable improvement of the river conditions. At certain places behind the works deep erosions occurred, which had to be filled in at a great expense, so as not to endanger the constructions.

Also the sandbanks at the inflextion points have not disappeared. The failure of the low water training dikes is explained by the fact that the most effective forces which modify the cross sections of the river, act at higher water levels. The water levels in the vicinity of medium water, are of particular importance for the scour of the river bed, chiefly at the period of falling high water, when the cross-sections on certain stretches were estimated at too large a figure at medium water level, thus causing the velocity of the flow to be too low for transporting and distributing uniformly the silt, - even a severe contraction at the level of low water by training dikes was of no avail.

The next regulation work was done by means of a contraction of the medium water breadth by 20 m or 30 m , as an experiment over a short distance below the mouth of the Havel. The local results were better and on the basis of these experiments important modifications were made in the years 1929-31. The new plans provide for a general and continuous contraction of medium water breadths and the works are in course of construction Time will show if this method of improving the navigation depths is successful.

In spite of the many regulation works which have been constructed the aim of obtaining a minimum depth 1.25 m above and 1.40 m below the mouth of the Saale at low water level has not, so far, been attained.

In order to to minimise the variation in navigation depths by means of surplus water from storage reservoirs two dams have been built and others planned in recent years. These are:-

a) At Bleiloch in the Saale valley, a storage reservoir was built in 1932 , having a total capacity of 225 million m^3 capacity;

b) At Hohenwarte in the Saale valley, a storage reservoir was completed in 1939 , having a total capacity of 185 million m^3.

The total storage capacity 400 million m^3, 340 million m^3 of which is the useful capacity, will provide a maximum discharge of 60 m^3/s in times of extremely low levels on the Elbe. It was expected that a rise of 0.45 m in the regulation level of the Elbe at the mouth of the Saale, and of 0.30 m further downstream would be obtained and so ensure a minimum depth of 1.7 m .

The total expenditure on the low water regulation, since 1934 over an estimated period of eight years, and on the construction of the above mentioned reservoirs amounts to about £.39,000,000.

From available records, after the completion of the first storage reservoir in Bleiloch, and before the completion of regulation works, the standard Elbe barges of 700 tons capacity and with a draught of 1.70 m could navigate, fully loaded only during 54 days in 1934, which was an exceptionally dry year. But on an average in the years 1931-1936 this period extended to about 140 days. It is quite abvious, that the task of improving the navigable conditions on the Elbe has not been completely achieved through the low water regulation works and by means of surplus water from the valley dams of the Saale.

The final aim is to obtain a minimum water depth of 2.2 m for modern craft of 1,000 - 1,200 tons capacity which could be attained after still further improvements.

The proposal of the German engineers is to pump out the water from the Elbe, when it is carrying a higher water flow than is required for navigation.

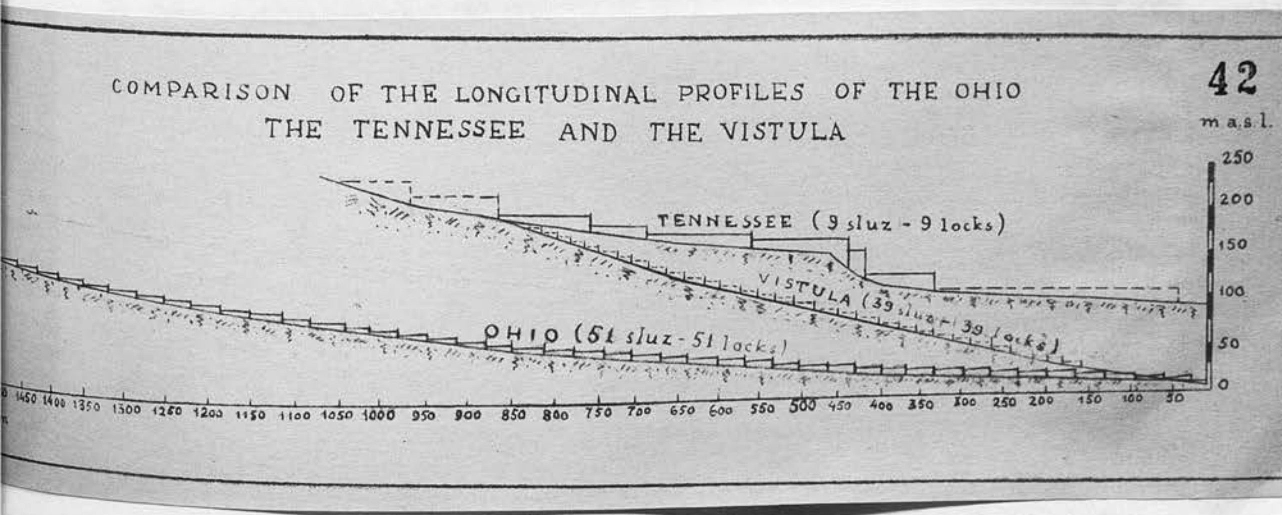
The surplus water would be pumped out by utilising cheap night electric current and would be stored in basins situated along or in the vicinity of the river. This surplus water could be returned to the river in times of ~~th~~ low water level. It is considered that the improvement in the water level could be effected with considerably greater accuracy and without the loss of time required to convey the water from the dams on the Saale which are at a distance of 200-240 km.

These so called compensation basins with a useful capacity of 300 million m^3 were planned near Pirna and Riesa in Saxony just before the war. Questions conserning the height of level improvement, the manner of working and the ascertainment of costs and rentability were still being considered and the construction was not decided upon.

Furthermore there was discussion about a question of local canalisation or the construction of a seperate canal in the district of Magdeburg, which offers special difficulties to navigation.

The regulation of the navigable channel of the Elbe corresponds

in general to the method adopted on the Lower Oder,which I gave as a second example of unsatisfactory regulation works.
The improvement of the Oder was described in the ChapterNo.Id Vol.2 on "The Great inland navigable waterway Oder-Danube-Black Sea Canal".
These two examples prove the principle that the regulation of a river may be successful when the average slope of the latter is slight, but it becomes difficult and very costly and takes a very long time to complete when the slope is steep. In that case it is much better to canalize a river; the additional cost entailed by this can be off-set by the construction of hydro--electric power stations alongside the lock-dams.
The Vistula belongs to this group of rivers,because on the upper and middle sectors the slopes are too steep, steeper even than on the Elbe and the Oder,for the achievement of a modern navigable waterway,by a simple regulation works.
The other two examples,which I have given to compare with the Vistula are the Ohio and the Tennessee,see sketch No. 42.



The Ohio has a length of about 1,570 km, or 1.5 times of that of the Vistula, and the total fall of 128 m or 57% of that on the Vistula.

The average slopes vary from 0.18 0/00 in the upper sector, to 0.09 0/00 in the middle sector and to 0.06 0/00 in the lower sector.

In spite of relatively slight slopes, the river was canalized, to maintain a navigable depth of 2.4 m even at low water level. Fifty one movable weirs and locks were constructed with heads of 2-4 m owing to the fact, that the elevation of the banks did not permit a higher retaining water level. The dimensions of the locks are 33 x 180 m and a tug with a train of 8 barges can be negotiated in these locks in one operation. The results of the improvement of the river are very good and there are 41,000 barges and 16,000 tugs in action and the average annual traffic on the Ohio amounts to 28 million tons.

The Tennessee river has a length of 1,050 km, similar to the Vistula, its catchment area is 105,150 km^2, or 53% of that of the Vistula, and the total fall is 153 m, as compared with 226.6 m on the Vistula, from the mouth of Przemsza downstream. Thus the average slope on the Tennessee is 0.146 0/00 as opposed to 0.240 0/00 on the Vistula.

Also in this case, it was decided to canalise the Tennessee by means of only 9 dams, seven of which are completed. The total capacity of the nine storage reservoirs will be about 5,000 million m^3, serving for flood control. The additional storage of water in reservoirs which are already completed situated in the upper basin on the tributaries with a capacity of about 5,200 million m^3 help to regulate the flow and considerably reduce the flood. At the same time the utilization of water power of 2 million kW is provided.

The dimension of the locks are:- 33 x 183 m on the lower stretch, and 18 x 110 m on the upper stretch of the river.

The minimum navigation depth is 2.75 m .

Resistances in the channel - As the technical and economic conditions of the transport problem have steadily improved in recent years, the hydro-technicians have to revise their views on the necessity of improving the natural waterways.

The natural advantages of waterways must be exploited to the utmost, by the simultaneous development of the maximum water power available and by the reduction of resistances in the channel.

The importance of water power, which is becoming ever greater, due to the demands for electricity, is quite obvious, and leads to the maximum utilisation of rivers which is the watchword for the future planning of the development of water resources.

The question of resistances in the channel and their influence on navigation is important and cannot be neglected in modern navigation.

The average resistance to traction, calculated for a ton of merchandise, depends not only on the speed of haulage, but also on the slopes of the river.

From our experience of river traction in Poland I have gathered the following data showing the relation between the necessary horse-power for a tug towing 600 tons barge upstream and the different conditions of slopes and speeds of haulage, see sketch No. 43.

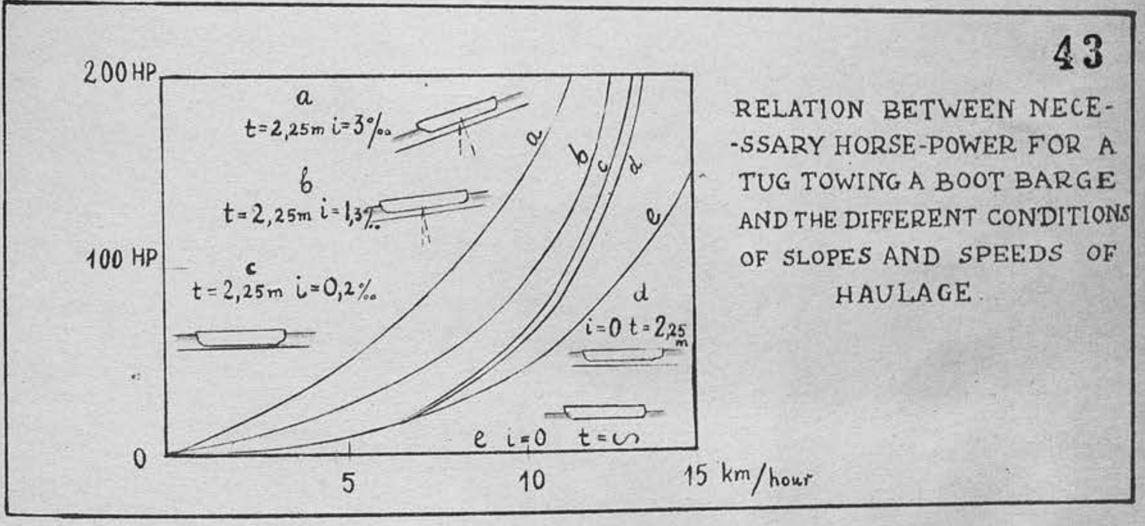


Table No. 14.

Average slope of the river	depth m	Capacity of barge	Speed of haulage	Power of the tug HP.
0.2 0/00	2.25	600	5 km/h	6
1.3 0/00	"	"		24
3.0 0/00	"	"		52
0.2 0/00	"	"	10 "	64
1.3 0/00	"	"	" "	96
3.0 0/00	"	"	" "	148

===

Summing up the problem of resistances on the waterway one comes to the conclusion that it is desirable to construct modern waterways so as to obtain a big depth,great breadth in the bed,and slopes as slight as possible. This can be achieved in the most effective way by canalisation rather than by regulation works,which lead generally to a reduction of the cross-section of the channel,and consequently to an increase in the velocity of the water.

Non scouring non silting canal - Before considering the proposed canalisation works on the Vistula,let us think over the alternative of the construction of a separate lateral channel along the Vistula valley. Such a channel constructed with a natural slope might avoid or reduce the construction of locks. The first principle for a canal is that it must be non silting and non scouring. To establish these conditions it is necessary to consider a number of factors:-

a) the quantity and nature of silt transported by the river;

b) the hydraulic factors of the most suitable slope, hydraulic radius and mean velocity;

c) the channel shape; width,depth and side slopes.

To prevent scouring or deposit of silt in the channel,it is necessary that the velocity along the bed is sufficient to move all the material brought into the channel from the river, and should be yet not so high as to cause scouring.

Thus there are two limits:- the lowest is the point at which the deposit of silt begins; the upper,is the point at which the scouring begins.

To establish the extent between them is a very difficult task, because data and formulas from various existing canals may be unsuitable for the new canal in which conditions of quantity and nature of silt may be different and may change considerably from time to time.

The first study of non ~~sx~~ silting canal sections was made by G.Kennedy in 1895 and his work is a classic in this question, and has resulted in the saving of millions of pounds in reducing the cost of cleaning canals in India and elsewhere.

He developed a formula of the type:

$$V_o = C \cdot d^n$$

which expressed the relation between the critical mean velocity "Vo", and the depth "d" ; the coefficient "C" varies with the quality and quantity of silt, and "n" is nearly constant.

For the Lower Bari Doab Canal this formula is expressed as follows:-

$$V = 0.84 \cdot d^{0.64} \quad \text{in English units}$$

or

$$V = 0.56 \cdot d^{0.64} \quad \text{in metric} \quad "$$

A number of other equations of the same type as those of Kennedy were developed, suitable to the various local conditions in U.S.A., Egypt, South America - and the coefficient "C" varied from 0.38 to 1.83 and exponent "n" from 0.44 to 0.73 , but generally was about 0.64, the value developed by Kennedy.

For many years little further progress was made.

In 1917, W.Woods proposed a general formula covering velocity

"V" , average depth "d", mean width "B", slope "S" and discharge "Q", based on an analysis of data from the Lower Chenab Canal System, as follows:

$$d = B^{0.434}$$

$$Vo = 1.434 \log B$$

$$S = \frac{1}{2,000 \log Q}$$

According to this formula for a given discharge there is a single condition of depth, width and slope that will produce a stable channel. Woods makes no suggestion that these relations might be influenced by the quantity or the quality of the silt.

In 1930, G. Lacey developed the formulas:-

$$Q \cdot f^2 = 3.8\ Vo^6$$

and

$$Vo = 1.17 \cdot \sqrt{fR}$$

in which "f" is a silt factor, related to the diameter "D" of the bed material in inches by the expression:-

$$f = 8 \sqrt{D}$$

Lacey stated also that the wetted perimeter of a stable channel is a simple function of the square root of the discharge:-

$$P = 2.668 \sqrt{Q}$$

and that the shape of a stable channel approximated to an ellipse, in which the ratio of the major (horizontal) to the minor axis was larger when the silt became coarser. Lacey introduced the effect of the size of the silt, but did not consider the quantity of silt to be transported.

In 1936, R. Pettis from experiments on the Miami river developed a formula which indicates the proper value for the main velocity in a stable channel as

$$V = 0.8\ Q^{0.2}$$

Assuming C = 1 from a Kennedy type of formula for average conditions in alluvial sections, he developed an equation for the maximum depth "d" as follows:-

$$d = V^{1.5} = 0.715\ Q^{0.3}$$

Pettis suggests that the cross-section of a stable canal should be a parabolic type indicated by dB^k and that the exponent of involution "K" should be not less than 2 nor more than 3, and a value of 2.5 probably gives the ideal shape for a stable channel. Assuming that "B" is so large that it may be taken as being equal to the wetted parimeter P. Pettis has given the following formulae:-

hydraulic radius $R = 0.511\ Q^{0.3}$

$$B = 2.45\ Q^{0.5}$$

$$\frac{B}{d} = 3.43\ Q^{0.2}$$

The Pettis formula was developed from the standpoint of preventing scouring and represents the upper limit of safe velocities, beyond which erosion will occur; on the contrary Lacey's formula was developed from the point of silting and represents the lower limit of safe velocities, below which the silting will occur.

Between values so obtained, giving the limits of velocity, there is a one which can be applied as the best velocity for non-scouring and non-silting canal, but the interval between these limits is relatively great , and the proper choice is not easy. The above formulae and many others which have been developed have the disavantage that while they suit the particular cases for which they were developed they cannot be used with accuracy for the calculation of problems in which the conditions may be very different.

In 1922-23 I was responsible along with M[r] Okęcki for carrying out research on the question of silting problems on the Vistula. This work was continued later by Born and Dębski and much information obtained as to the quality and quantity of the silt. From many gaugings which have been made in different places and at different levels of water , each class of sand carried in each gauging station has been determined and also its quantity. But the results were very variable and did not lead to any definite relation between the velues of width to depth, together with slope and silt character to form a formula suitable for a channel design.

It was found that silt percentages i.e. the weight of dried silt over the weight of clean water is quite considerable in the Vistula and increases with the increase of flow , but not in the same degree for every high water even when the discharge was the same. The proportional quantity of suspended silt and the bed load(drag on the bed) carried by the river is variable at different stages of water level but not in an uniform way.

Although these measurements have not been completed , we may definitely conclude, that as the Vistula flows in alluvial material, a serious silt problem exists; consequently stability in a channel deviated from the river would be difficult to attain.

Finally by this alternative, which would not be much cheaper, than canalisation, the scheme would be limited only to the navigation problem. But navigable inland waterways can and must be as far as possible a source of diverse public utility.

The ultimate possibillities of a navigable river should be determined with a view not only to navigation, but also to hydro-electric power. This two-sidedness of the utilization of a river results in a higher profit from water development over a long period of exploitation.

The proper arrangement of the river in its middle and lower sectors for improvement of the navigation as well as the development of the water power should coincide with flood and silt control in the upper basin by means of the construction of storage reservoirs and the control of the mountain torrents.

The plan, which I now propose, for the first time, for the post-war improvement of the Vistula is based on the principle of the coordination of the arrangements in the whole basin to develop the maximum utilisation of the river for all purposes.

Canalisation works - The alteration of the Vistula into a modern navigable waterway accessible at its ordinary water level to craft 1,000-1,200 tons with a possibility of a speed, of 10-12 km an hour, and to trains of barges towed up the stream is obtainable in the quickest and most effective way by:-

a) canalisation of the larger portion of the upper and middle sectors, from Kraków to Toruń,

b) continuation of existing regulation in the lower sector, from Toruń to Gdańsk (Danzig).

The preliminary estimate of my project involves the carrying out of construction works, the general details of which are represented by the following data:

1. Length of the canalized region	657 km	
2. " of the regulated "	203 km	
3. Total available head on the canalized stretch	177 m	
4. Number of falls	39	
a) the maximum fall	11 m	
b) the minimum fall	3.5 m	
5. Average length of the reaches	17 km	
6. Number of movable weirs and locks	39	
7. Width of the weir openings vary from	180 m - 480 m	
8. Dimensions of locks:	above Warsaw	below Warsaw
a) length	105 m	225 m
b) width	20 m	12 m
c) depth	3.5 m	3.5 m
9. Estimated yearly quantity of goods traffic	20 million tons	
10. Number of hydro-electric stations:		
a) the power capacity	807,000 kW	
b) the output capacity per year	4,325 million kWh	

Total estimated cost of construction -- £. 36 million .
From the point of view of the nature of the work, and the future estimated movement of traffic the canalized stretch on the Vistula, over a distance of 657 km can be divided into three sectors:-

1. The upper sector from Kraków to Sandomierz,
2. The middle sector from Sandomierz to Warsaw,
3. The lower sector from Warsaw to Toruń.

The upper sector of the Vistula from Kraków to Sandomierz, see sketch No. 44, 45, 46.

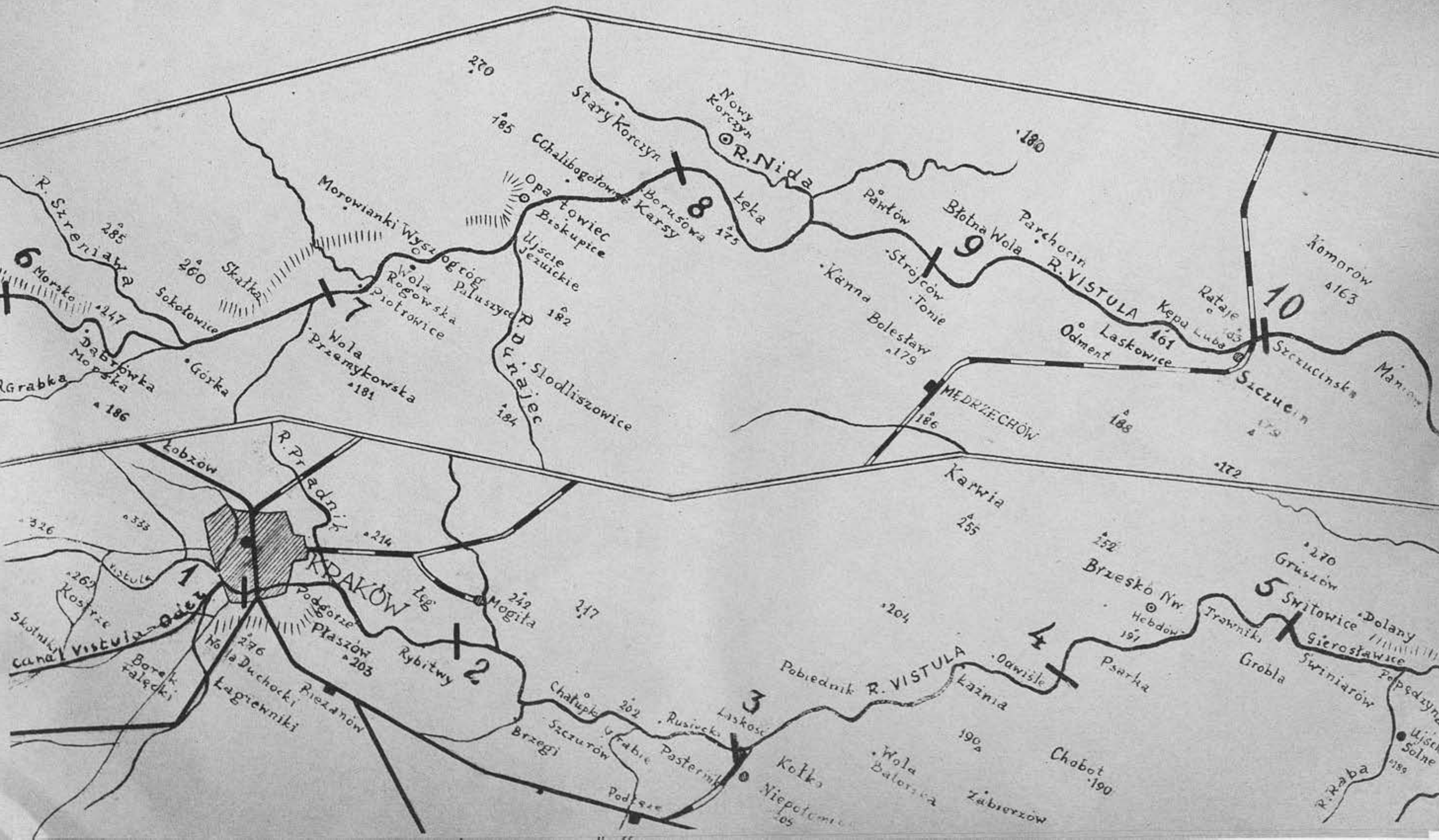
From the outlet of the Vistula-Oder Canal at Kraków to the Sandomierz, just above the mouth of the San, viz. over a distance of 192 km, the Vistula would be canalized by means of 15 movable weirs with a total head 59 m .

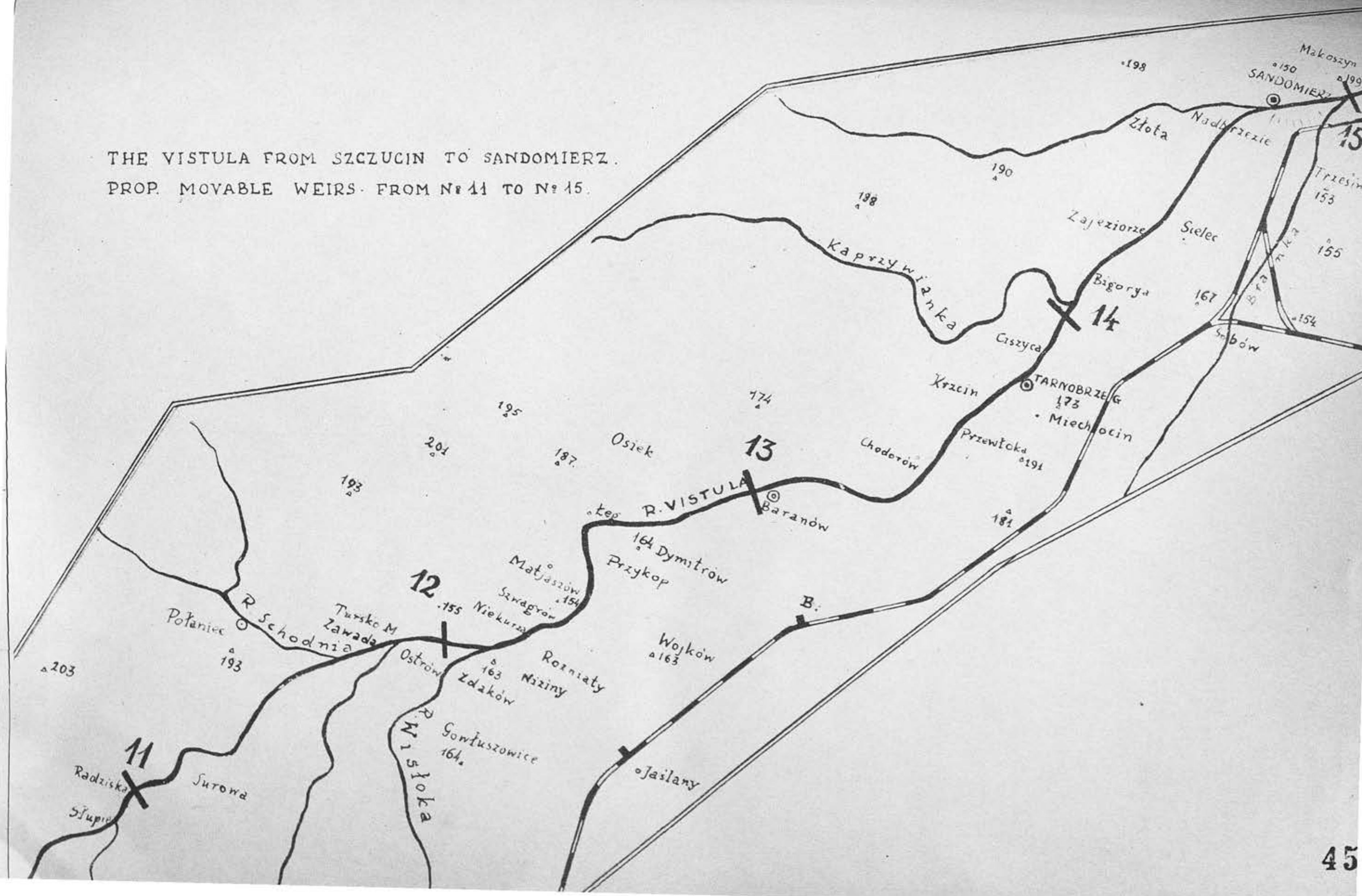
First of all I must mention the results achieved up to the present by regulation works, which were begun in the first decade of the present century and were continued during the years 1920-1939.

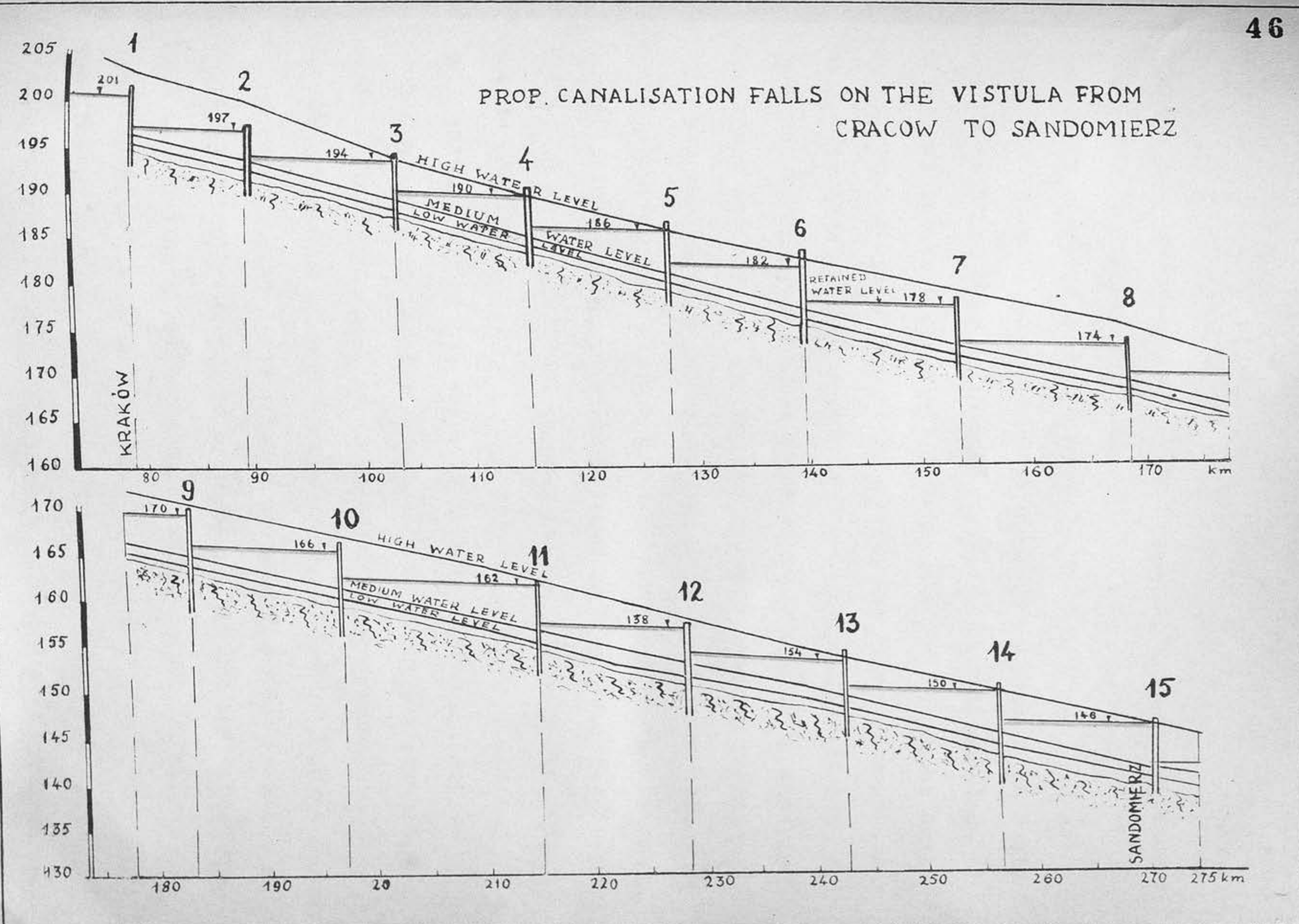
On the one hand the creation of a single river bed and the consequent contraction of the flow by longitudinal walls or transversal groins into a medium water channel permanently fixed on both sides is almost completed over the whole length of this stretch.

On the other hand it can be said, that there still is an ~~inan~~ inadequate development of the low water channel which alters its position within the medium water bed, with the

THE VISTULA FROM CRACOV / KRAKÓW / TO SZCZUCIN
PROP. MOVABLE WEIRS FROM No 1 TO No 10.




THE VISTULA FROM SZCZUCIN TO SANDOMIERZ.
PROP. MOVABLE WEIRS. FROM № 11 TO № 15.
Makoszyn
150
199
SANDOMIERZ
15
Trzesin
153
155
154
198
Złota
Nadbrzezie
190
188
Zajeziorze
Sielec
Kaprzywianka
Bigorya
167
14
Sobów
Ciszyca
Krzcin
TARNOBRZEG
173
Miechocin
174
195
201
187
Osiek
13
Chodorów
Przewłoka
191
193
R. VISTULA
Baranów
181
Kep
164 Dymitrów
Przykop
Matjaszów
154
Szwagrów
Niekurza
12
155
Turska M
Zawada
R. Schodnia
Połaniec
193
203
Ostrów
163
Zdaków
Niziny
Rozniaty
Wojków
163
B.
R. Wisłoka
Gawłuszowice
164
Jasiany
11
Radziska
Surowa
Słupiec


PROP. CANALISATION FALLS ON THE VISTULA FROM
CRACOW TO SANDOMIERZ
KRAKÓW
SANDOMIERZ
HIGH WATER LEVEL
MEDIUM WATER LEVEL
LOW WATER LEVEL
RETAINED WATER LEVEL
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
201
197
194
190
186
182
178
174
170
166
162
138
154
150
146
km
275 km

result that navigation has to be abandoned at low water, because the lowest navigable depth may drop to below 1.0 m.
Generally speaking such low water regulation works have not been carried out. It seems to me that the desired depth could not be obtained over an channel sufficiently wide and deep solely by low water regulation works, owing to the facts that the average slope is too steep, and the low water flow is too small for developing a modern navigable channel.
In order to raise the water level it is advisable to canalize the river and replace the natural slope by several steps.
But the contraction and embankment works which have been carried out on this stretch would be very helpful for future canalisation because they would serve as frames for movable weirs, and as longitudinal embankments, in a single bed, for future pondages.
Incidentally, during the years 1921-1933 about 90,000 m^3 of training walls and groins were built and dikes for protection against flood are still in course of construction.
As the embankment of the Vistula serves as the only means of flood-control, the first step in the choice of the height of the retained water level should be to adopt the low type of movable dams in order to alter the natural hydrological conditions in the valley as little as possible.
The present differences between the level of the low and medium water and that of the maximum high-water are summarized in the following table No. 15.

Table No. 15.

Gauging station	Post km	Altitude of the water level at low water	at medium water	at high water
		in metres above sea level		
Kraków	78.5	195.77	196.59	203.91
Płaszów	81.5	194.94	195.65	202.17
Przewóz	89.1	192.84	193.67	200.04
Niepołomice	101.1	189.18	190.19	194.84
Koźlice	104.8	187.99	188.96	193.39
Nowa Wieś	114.8	184.89	185.92	189.72
Sierosławice	130.5	179.52	180.58	185.52
Popędzynka(uj.Raby)	138,1	177.19	178.03	183.58
Jagodniki	153.1	172.51	173.64	179.51
Karsy(uj.Dunajca)	166.0	168.96	170.32	176.65
Pawłów	177.7	165.73	166.94	172.33
Szczucin	194.1	161.21	162.45	168.91
Otałęż	210.1	156.98	158.39	164.18
Ostrówek	223.6	153.55	154.74	159.75
Koło	239.9	149 15	150.33	154.77
Dzików	255.3	144.54	145.80	150.27
Sandomierz	268.4	140.67	141.98	147.03
Dąbrowa Wrzaska	274.6	139.15	140.51	145.07

The altitudes of the high water level in this table do not correspond to the same flood flow, but to the highiest recorded at the particular gauging stations.

Beginning from Niepołomice downstream they correspond to the flood flow of the year 1925, and upstream to Kraków of the year 1813. To complete my review I must add that the recorded high water level below Karsy is lower than it may be in the future, for the following reason. A break in the levee at Karsy caused by extremely high flood water, running from the Dunajec valley, inundated a large area between the tributaries Dunajec and Wisłoka in 1934, thus creating a temporary storage of water, and in consequence a lowering of the water level in the river bed of the Vistula.

From the above table No. 15 we can see that the differences between the low water level and that of the maximum vary from about 5 to 8 m and those figures constitute the limits within which the Vistula valley is almost protected against the flood. These figures give us an idea of the permissible heads for the canalisation falls without risk of flooding, but taking into account that the movable dams will cause a back-water heightening, I propose that the standard head should be lower, namely about 4 m at medium water for each weir.

By such an arrangement there would be a considerable difference between the present and future conditions. While at present the high water levels last a short time, only in flood periods, in future the highest, retained water level would be steady.

From this the following conclusions should be drawn:

1. The levees should be stable enough to restrain the flow and withstand the prolonged pressure of the head water;
2. The size of the structures should be increased by broadening the crests and by lengthening and decreasing the land-side slopes. In this way we can avoid the unstable condition, due to the hydrodynamic forces created by seepage acting on the slopes. The top-most flow line of seepage travelling through a ~~xxxxxx~~ section should be covered by the shape of the levees and the outlet should not be above the elevation of the natural ground surface;
3. In the interests of agriculture on the adjacent lands, great care must be taken not to exceed the normal ground water level. Any surplus of water must be discharged immediately along side the levees downstream to below the dam, by means of trenches, situated at the land-side.

In addition, at the places, where the level of natural ground is especially low, pumping stations would be installed to lift the water collected at the land-side of the levees.

The matter of pumping would not be a very big problem, as I have calculated that for one reach it would be necessary to provide a power of 0.3 - 0.5 % of the energy which is available at each fall.

All these precautions against the adverse influence of canalisation works are normal in such improvements of rivers and are insignificant compared with the advantages gained by the creation of a modern navigable waterway with the simultaneous utilization of water-power.

Incidentally, the levees on the Vistula are so worn out, that even irrespective of the canalisation works which I propose, they would have to be rebuilt.

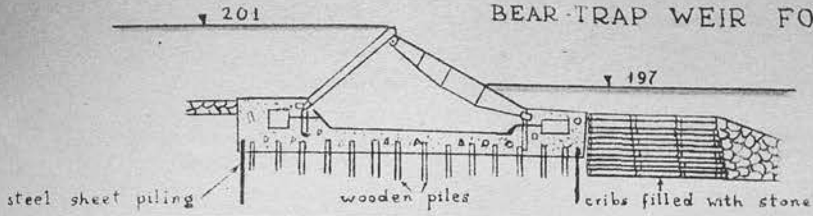
The necessity for this was proved by the occurence of flood flow in 1934.

I will come back later to the description of the shape of the levees.

Canalisation works on the upper sector of the Vistula from Kraków to Sandomierz would be done by constructing 15 weirs, locks, and hydro-electric stations, some data of which are summarized in the following table No. 16.

Table No 16.

Nos. of weir	Post km	WEIR altitude of head water m.ab.s.L.	WEIR fall at medium water m	Dimensions of locks m	Hydro-electric stations capacity kW	Hydro-electric stations output million kWh
1. at Kraków	80.0	201	4	105 x 20 x 3.5	4,000	21
2.	89.7	197	3	"	4,000	17
3.	103.2	194	4	"	4,000	22
4.	116.0	190	4	"	4,000	23
5.	127.0	186	4	"	4,000	22
6.	139.0	182	4	"	5,000	27
7.	152.6	178	4	"	5,000	28
8.	168.9	174	4	"	8,000	42
9.	183.0	170	4	"	10,000	53
10.	197.8	166	4	"	10,000	53
11.	213.4	162	4	"	12,000	64
12.	228.2	158	4	"	12,000	65
13.	242.7	154	4	"	15,000	82
14.	256.3	150	4	"	15,000	82
15	270.5	146	4	"	15,000	83
			59		127,000	685

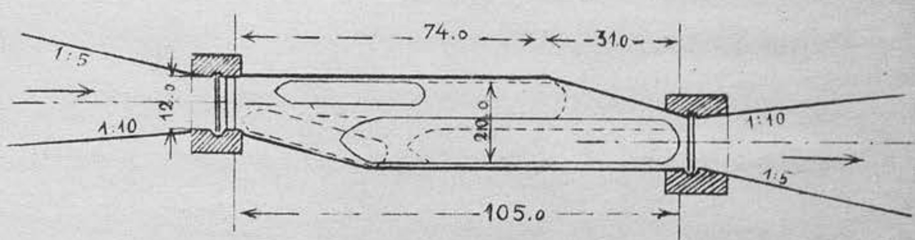


BEAR-TRAP WEIR FOR THE VISTULA

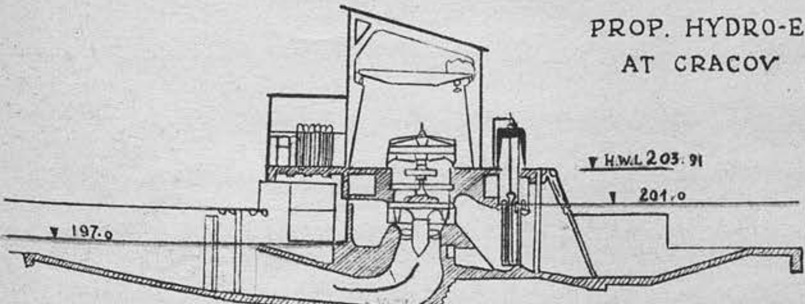
47

48

PROP. RHOMB SHAPED TYPE OF LOCKS FOR THE VISTULA FROM CRACOV TO WARSAW



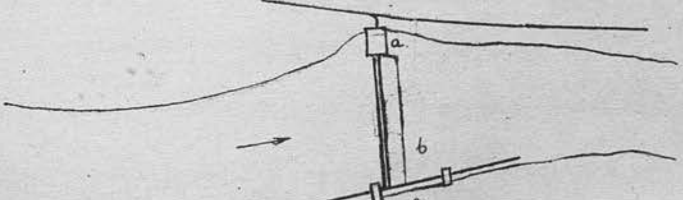
PROP. HYDRO-ELECTRIC STATION AT CRACOV / ON THE VISTULA/



49

H.H.

TYPICAL SITUATION OF THE CANALIZATION STEP ON THE VISTULA 50



a - power station
b - movable weir
c - lock with upper and lower guide-walls

The weirs -- Before chosing the types of weirs, best fitted for the Vistula, I wish to emphasize that this river would require a very extensive continuous system of dams. Three of the necessary weirs, would be built one at Popowo and a second at Włocławek which would have comparatively high heads, owing to the favourable topographical conditions, and a third at Warsaw which would have special local conditions necessitating separate treatment; but the remaining thirty six weirs would be constructed in very much the same topographical and hydrological conditions. It would be advisable to adopt a standard type of movable weir and/ owing to the considerable total length of the openings amounting to about 14,000 m to use not only the most suitable type, but also the most economical in cost and in maintanance.

Roller weirs which I have described before would be a very suitable type, but they would be expensive.

Bear-trap weirs (see sketch No. 47), are generally recognized as the cheapest type of low-head movable weir, and it is also very satisfactory owing to the fact that it may be operated with greater ease, safety and speed, than other types.

They are advisable for wide sluice-ways with moderate heads and very suitable for rivers that carry down ice e.t.c.

A bear-trap weir consists of two leaves which, when down, rest upon one another; one being hinged downstream and one upstream. Its cost is relatively very low, for example, for a head of 4 m and a opening of 30 m it amounts to £.3,000 , which is much less than for any other type, except the needle weirs.

The features of this type of movable weir are as follows:-

1. They are actuated with either water or air pressure or both and the slowness of raising can be overcome by the feeding of compressed air beneath the downstream leaf. The time required to raise the bear-traps to a heigth of 4 m is 8-12 minutes, and they may be lowered within 4-6 minutes. Mud or fine matter that remains deposited in the recess below the trap may cause some trouble in the working of the dam, but this drawback can be remedied by means of water discharged under pressure;
2. The best ratio between the length of upper leaf to that of lower leaf is about 7 : 10.

   The most severe stresses occur under the following two conditions of operation. In xxxx the girders of the lower leaf with low water in the lower pondage, and full pondage above, when the trap is partly up, and a head of water applied with sufficient force to raise the trap to the top. In the girders of the upper leaf, with the same maximum difference between head and tail water, when the water is emptied from the recess under the trap;
3. The widths of the piers from which the bear-traps are operated and supplied with water or compressed air are 4 m while the openings may be 30 m in length;
4. Considering the question of tightness, it is proved that bear-trap weirs can be made as tight as any other type of dam;

5. To avoid trouble from sanding the sill should not be placed too low;

6. Apart from the saving of money, this type of movable weir effects a considerable saving in time of construction.

Finally I must add that with the general adoption of this type of movable weir it would be necessary to build a special weir in one opening, to regulate the height of the water in the upper pondage. In this case the submersible roller with flaps would be required.

Protection against scour below the dams would be provided by rock filled cribs, 7.5 metres in width, placed against the downstream edge of the sill, and by a thick layer of stone below the crib to an extent of 15 times the retaining height.

The exact length of protected bottom should be determined by experiments on laboratory models.

A steel sheet piling cat-off diaphragm would be provided at the toe of the sill to a depth of 12 m, and the same on the downstream edge of the sill to a depth of 7 m.

These precautions would be necessary owing to the fact that rock is too deeply seated to be reached.

Because rock is not available, the weirs and sills would be supported on wooden piles, 10 m long.

The closings for the weirs would have the following spans:-

1. at the dams Nos. 1,2,3,4 and 5 the movable weirs would consist of 6 openings 30 m wide;

2. at the dams Nos. 6 and 7, these would consist of 8 openings 30 m wide;

3. at the dams Nos. 8,9,10,11,12,13,14 and 15, the weirs would consist of 10 openings 30 m wide.

Locks -- The second item on each canalisation step would be the lock. On the Vistula the water supply problem for lock operations would not be difficult as at every water level there would be an excess of water. This is why the single lock type could be applied.

On the modern waterway with a large quantity of traffic the length of lock has increased up to 330 m and the width to 33 m . For the previously assumed annual traffic of 15,000,000 tons for this stretch two dimensions are to be considered 12 x 225 m or 20 x 105 m .

In the latter lock type, a tug with a 1,200 ton barge or a tug with a train of 2 barges of 600 tons, or 3 barges of 400 tons can negotiate in one operation.

The rhomb shape (see sketch No. 48) of this lock, which I propose, instead of a rectangular shape usually employed creates an economy in the installation of the gate, which would remain the standard width of 12 m , while the lock is 20 m broad. It seems to me that this type of lock will form an improvement on the existing type by decreasing the cost of construction.

The situation of the lock would be on the opposite bank from the hydro-electric station.

Both of these structures should be based on the banks, as they will form abutments and the centre will be left free for the passing through of flood waters.

The water side (river) wall of the lock ought to be continued by the upper and lower guide-walls of the lock, upwards 150 m long and downwards 100 m so that while entering and waiting for entrance to the lock the craft might be in quiet water.

Rolling or mitre lock gates may be used. On the river wall of the lock, there would be installed a small turbine pit in which the water wheel would be directly connected to an air compressor at locks provided with rolling gates, or to an oil pump at those provided with the mitre gates. When the head exceeds 1.5 m the turbine would furnish the compressed air or oil to provide the necessary power to operate the lock gates.

When the movable dam is down, and the head is lower than 1.5 m air or oil would be supplied through compressors or pumps by prime movers situated in the power station.

To prevent underscouring the side walls of the entrances and the lock-chamber would be made up of steel sheet piling, which would be driven to a depth of 4-5 m below the bottom of the lock. Steel sheet piling would also surround the gate chamber and the transverse sheet piling which would be driven to the same depth as the piling for the lock walls, should be provide with watertight connections to the latter at both ends.

The bottom of the lock chamber would consist of reinforced concrete with a thickness of 0.5-0.7 m, so that the weight of the concrete will be greater than the lift of the water which may come into action from beneath the bottom of the lock. Each gate chamber would rest on 8-10 piles brought down to bearing ground.

Hydro-electric stations -- The surplus of slopes of the Vistula concentrated in the heads of movable weirs would be used for the purpose of electrification as a by-product. The utilization of such water power is regarded as an additional profitable development of canalisation works, the chief object of which is the improvement of the navigation conditions on the river.

The profits to be gained by the canalisation work for improving the navigation conditions would be so great that it may be possible to charge the hydro-electric stations with only a part of the costs of the canalisation work i.e. only with the cost of the construction of sub and super - structure of the power stations.

The hydro-electric stations on the Vistula, would collaborate with the steam power stations some times as the base power stations, some times as the peak power stations, depending on natural stream flow and on the possibility of regulation of the stream flow during the day by the storage pondages.

I have undertaken an analysis of the many factors which enter into the determination of the most economical capacity of the installations for water-power development and the extent of storage pondages in order to utilize the flow of the river to the greatest economic extent.

The description of this analysis will be given ~~in the~~ in the Chapter IV.
~~in this Chapter on the calculation works on the Vistula.~~
Now I would like only to mention that the solution from this calculation shows that there would be an economic collaboration between the water power stations on the Vistula and the steam power stations, due to the daily storage action by the pondages; so that by avoiding losses of water through the spillways the water power station might be utilized to the utmost. This would also provide a reduction of reserves in the steam power station, and consequently a reduction in the average cost--price of the energy produced.

The hydro-electric power stations on the Vistula, would be of low-head types (see sketch No. 49) and in this case the best type of the turbines to be used is Kaplan turbine, with a vertical axis and adjustable runner blades. The Kaplan turbine gives higher speed and, permits the use of lower-priced generators.

The efficiency of a Kaplan turbine is equal to or higher than that of a Francis turbine at its point of best efficiency, but the alterations in efficiency of the Kaplan turbine are insignificant, about 5%, in spite of the great variations in the working conditions of the power stations.

In the case of the Rożnów power station in Poland it was calculated that the use of Kaplan turbines would allow 7% more energy than could be obtained with Francis turbine .

On account of the relatively high velocites in the discharge from the Kaplan turbine, the design of the draft tubes and the most efficient setting of the runner (its elevation) are of the first importance - and should be tested on models, in order to avoid cavitation and to determine the greatest elevation of runner above tail-water, at which cavitation does not occur.

The following table No. 17 gives the general estimate of materials and works for carrying out the canalisation works on the upper sector of the Vistula, from Kraków to Sandomierz.

Table No. 17

1. the earth work for heightening of embankments of the Vistula	33,000,000	m^3
2. Concrete	800,000	m^3
3. Iron and steel constructions for the movable weirs and lock-gates	9,200	tons
4. Wooden piles	100,000	m^3
5. Steel-sheet piling of 7-12 m in height	9,000	m
6. Turbines and generators of capacity	127,000	kW
7. Workers required during	37,000 3-4 years	
8. Total estimated cost of the construction	£. 8,800,000	

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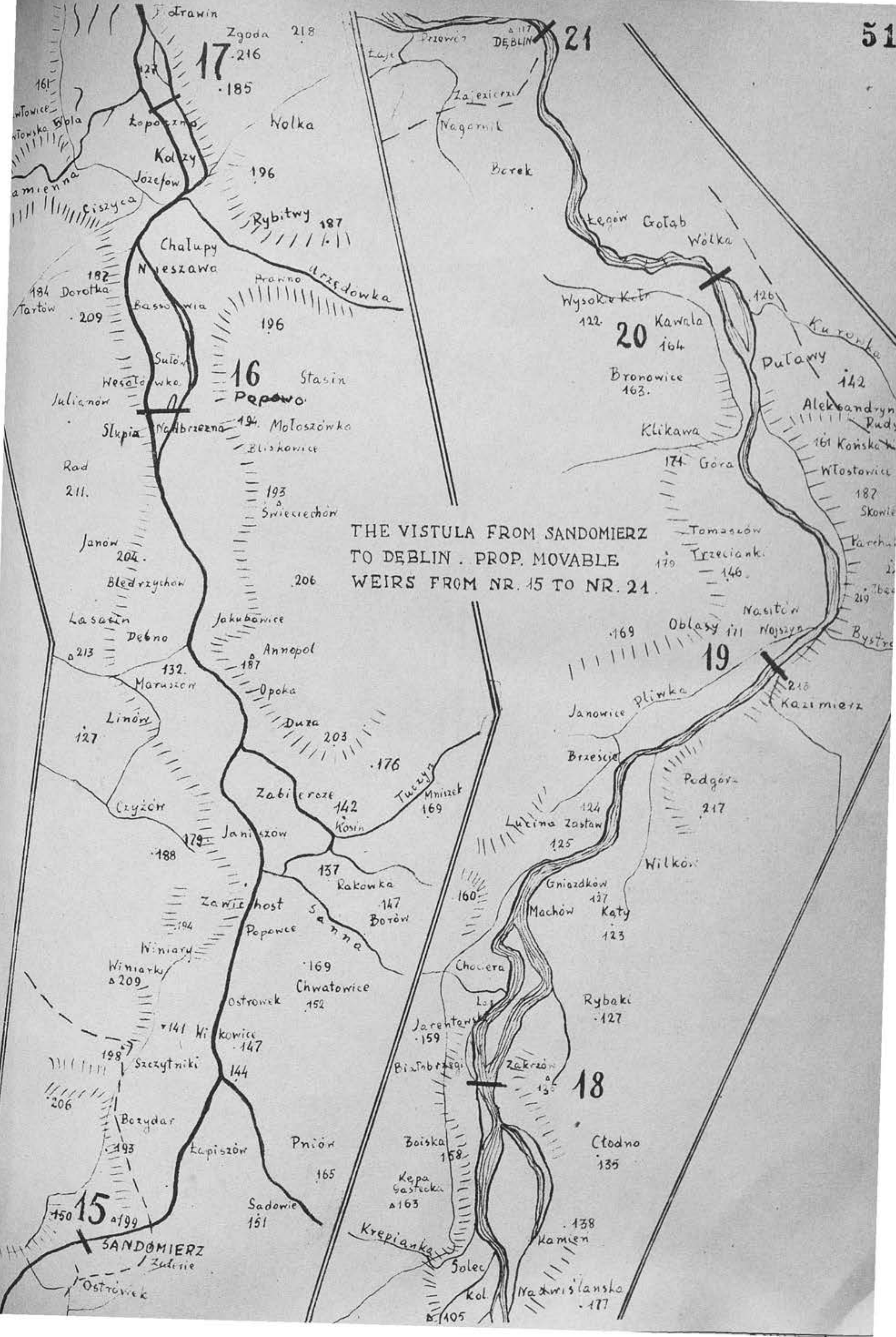
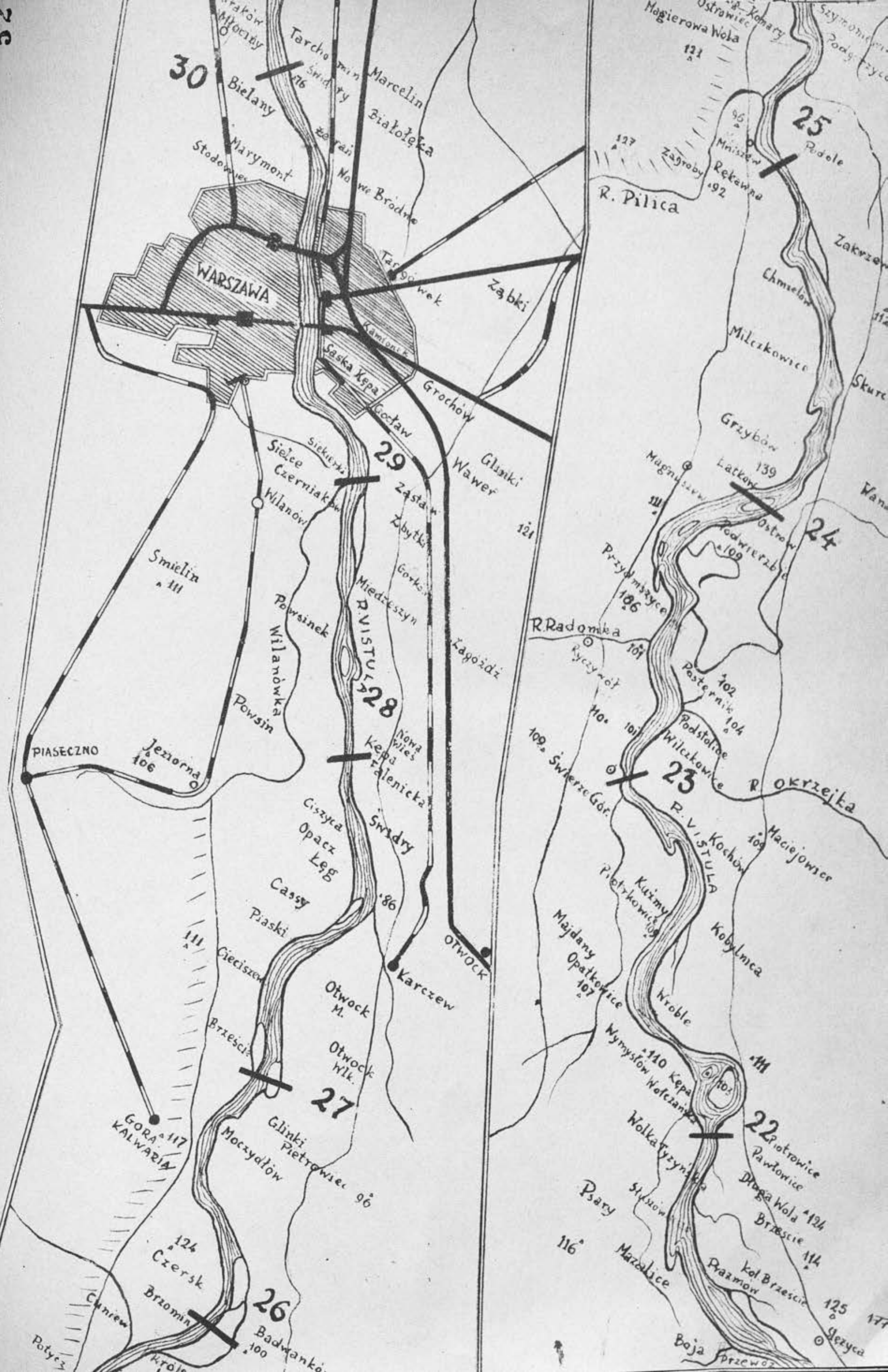
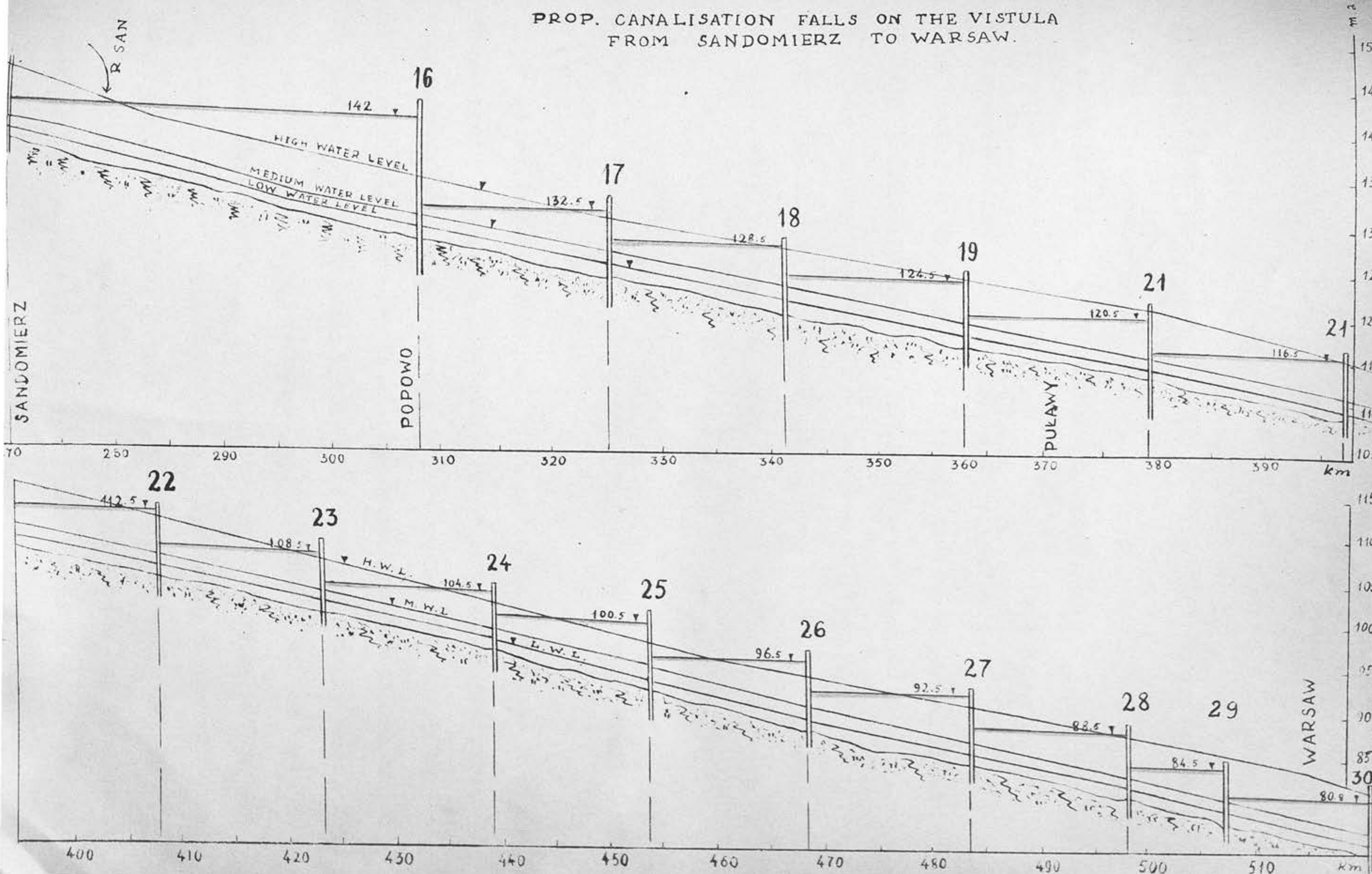

THE VISTULA FROM SANDOMIERZ TO DĘBLIN . PROP. MOVABLE WEIRS FROM NR. 15 TO NR. 21.
21
DĘBLIN
20
19
18
17
16
15
SANDOMIERZ
Zgoda
Wolka
Kolczyn
Józefów
Rybitwy
Chalupy
Nieszawa
Urzędówka
Dorotka
Tartów
Basonia
Sulów
Wesołówka
Julianów
Słupia
Popowo
Mołoszówka
Bliskowice
Rad
Świeciechów
Janów
Bledrzychów
Lasasin
Dębno
Jakubowice
Annopol
Maruszów
Opoka
Duża
Linów
Zabierzów
Kosin
Mniszek
Czyżów
Janiszów
Rakowka
Zawichost
Borów
Popowce
Sanna
Winiary
Chwatowice
Ostrowek
Szczytniki
Bożydar
Łapiszów
Pniów
Sadowie
Ostrówek
Nagórnik
Borek
Łęgów
Gołąb
Wólka
Wysoki Kąt
Kawala
Puławy
Kurówka
Bronowice
Klikawa
Góra
Aleksandryn
Końska Wola
Włostowice
Tomaszów
Trzcianki
Nasiłów
Oblasy
Nojszyn
Kazimierz
Janowice
Pliwka
Brzeście
Podgórz
Lucina
Zastaw
Wilków
Gniazdków
Machów
Kąty
Chociera
Rybaki
Jarentowskie
Zakrzów
Boiska
Kępa Gąsiecka
Cłodno
Krępianka
Solec
Kol
Kamień
Nadwiślańska



THE VISTULA FROM DĘBLIN TO WARSAW . PROP. MOVABLE WEIRS FROM Nº 22 TO Nº 30.

PROP. CANALISATION FALLS ON THE VISTULA FROM SANDOMIERZ TO WARSAW.



The middle sector of the Vistula from Sandomierz to Warsaw, see sketch No 51,52,53.

The middle sector of the Vistula from the tail water of the proposed dam No.15 at Sandomierz to Bielany, just below Warsaw, over a distance of 251.3 km would be canalised by means of 15 movable weirs with a total head of 64.7 m .

This sector of the Vistula, as I have mentioned above, looks extremely undevelopend due to the lack of regulation works. For this reason the route of the river is frequently too bread being forked in several arms, with a constant movement of silt and a tendency to change the shape of the cross-section and the slopes of the bed.

On this account the navigation has been so far confined to an irregular traffic of passengers and goods on a very small scale.

There is no doubt that this sector having too steep an average slope would require canalisation in order that an efficient modern navigable waterway may be created in the shortest possible time. In contrast to the upper and lower sectord, there is on this sector considerable scope for preliminary regulation before starting canalisation works. The object of the regulation works would be to concentrate the flow at medium and high water level, within a single bed, with consolidated banks. These preliminary works would not affect the whole length of the middle sector, for the upper reach at Popowo and the lowest reach at Warsaw would not be included. In the first of these the topographic conditions are favourable for the construction of a high dam and storage reservoir in a compact hilly valley. In the second reach in the district of Warsaw the preliminary, concentration works are completed.

These existing conditions of the river lead to the division of the programme of works into two stages.

The first - the construction of the dams locks and power stations No 16 at Popowo and No 30 at Warsaw and the ~~xinmixkx~~ simultaneous regulation works for the concentration of flow and consolidation of banks on the remaining stretch, comprizing the future 13 reaches which should be canalised.

The second - the construction of 13 movable weirs locks and power stations between Popowo and Warsaw.

The first stage --

1. The dam and hydro-electric station at Popowo.

The compact Vistula valley over a distance of 38 km between the mouth of the Kamienica has hilly banks at an altitude of 170-230 m above sea level, while the mean water level of the Vistula is at an altitude of about 140 m in the upper and 130 m in the lower point of this stretch.

The narrowest part of the Valley, suitable for the construction of a dam is at post km 308, where it would be necessary to ~~rx~~ retain the water level up to an altitude of 142 m above sea level, in order to reach the tail water at the movable weir No 15 at Sandomierz. Thus the head of the dam No 16 at Popowo would be 10 m at medium water level or 11 m at low water level and the length of the reach would be 37.5 km . The available water power would be 50,000 kW and the yearly output of energy about 200 million kWh.

The nature and depth of the alluvial subsoil of the dam at Popowo is suitable for the construction of an earth dam on the right bank of the valley with a movable weir in the bed of the river.

For long time it was considered that an earth dam should not be built unless impervious material is available. But in recent years earth dams have been successfully built of alluvial sand and gravel of every degree of fineness and coarseness. All that is necessary, is to carefully design a suitable shape, based on thorough investigations and tests of the materials to be used for the construction of the proposed earth dam.

The chief rules for the design of an earth dam, on which we have based the construction of the dam of Turniszki, near Wilna, for which I have been responsible, are as follows.

The control of seepage through the earth dam is the prominent feature of its design. The outlet of the top-most flow line should be well under the downstream toe, and the velocity of the flow passing through and under the dam should be so small, that it would not be capable of lifting any materials of the foundations and dam. It is recognized that the slopes of the infiltration line should be at a minimum 1 : 8 - 1 : 10. For lowering the slopes of the infiltration line and for increasing the distance which the water must traverse, impervious core-walls of clay , concrete and steel sheet piling are very often used , and the stability of the structure is increased.

For this same precaution blankets of fine materials are used spread over the bottom of the reservoir and one part of the upstream slope of the dam.

Furthermore , in many earth dams the downstream part is drained in order to lower the line of infiltration , and to prevent the saturation of the downstream toe. In the dams at Turniszki and Czchów (on the left bank , where the earth dam is constructed) a system of drainage is used , by constructing trenches filled with broken stone perpendicular and parallel to the axis of the dam.

The material adjacent to the Popowo dam would be used for its construction , whether it is sand or clay.

I believe that there would be enough clay pits to design a normal shape with core-wall extending from the top to the impervious foundation layers , if not , a concrete core-wall might be used.

However let us consider another alternative for a dam without a core-wall , in the centre of the dam. In this case the more important features are the side slopes and foundation.

The application of soil mechanics makes it possible to develop a design for the dam , based on the strength of the material, to obtain the desired factor of safety.

The method of design depends on the nature of the material, on whether it is cohesion-less, as sand, or cohesive, as silt, and clay, or mixed fine sand and clay.

For the side slopes formed of sand the slopes must not be steeper than the angle of internal friction. The stability of slopes formed of cohesive materials depends upon the xkxx shearing strength of the material along a deep-seated cylindrical surface, called the arc of failure, see sketch No. 54 (see page 172).

The segment of the slope lying above the arc of failure, has a tendency to slide downward, rotating about the centre of the arc.

The method of locating the approximate position of the centre of rotation for various slopes has been tested in some laboratories. I had the opportunity to visit the laboratory of Prof. W. Fallenius in Stockholm in 1933, and the laboratory of Prof. Charles Tarzaghi in U.S.A. in 1936, and I have been responsible for carrying out research in the laboratory in Poland in connection with the construction of the dams at Turniszki and Czchów, on the question of the failure in shear due to the over-stressing of the material.

If we disregard the effect of seepage on the stability of the dam, the steps to be taken in the design are relatively simple. We must fix the approximate position of the centre of rotation for the arc of failure and the gravitational force, which is resolved into its normal and tangential components acting along the arc.

For the calculation of the tangential force, the part of the downstream slope above the surface, defined by the arc of failure, is divided into vertical segments.

The tangential components on each of the segments, acting along the arc at the vertical projection of the centre of gravity of the segment on the arc of failure are added together, giving the total force "T", tending to produce displacement.

The force resisting this tendency is the sum of frictional and cohesive forces acting along the arc. The frictional force "N" is the sum of the normal components of gravitational forces multiplied by the tangent of the angle of internal friction "ϕ". The cohesive force may be obtained by multiplying the unit cohesive strength "C" by the length of the arc "l".

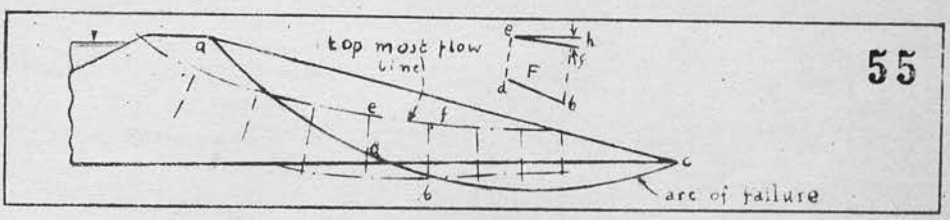
The cohesive strength is to be obtained by a shear test made upon a specimen of the material, prepared in a condition to simulate the most adverse situation that could be expected in natural circumstances. Cohesive strength is considered to be independent of the pressure and dependent upon the material and its condition.

Thus the factor of safety may be estimated by the formula

$$S = \frac{N \cdot \tan \phi + c \cdot l}{T}$$

which should be multiplied by a coefficient 1.25 in order to obtain a greater assurance of stability, if we adopt the shape of the dam, based upon the laboratory tests.

Another element enters into the stability of the tailwater slopes of the dam when we take into account the hydro-~~static~~ -dynamic force created by seepage water,which produces an over-turning moment in the part of the slope lying above the arc of the failure,see sketch No. 55 .



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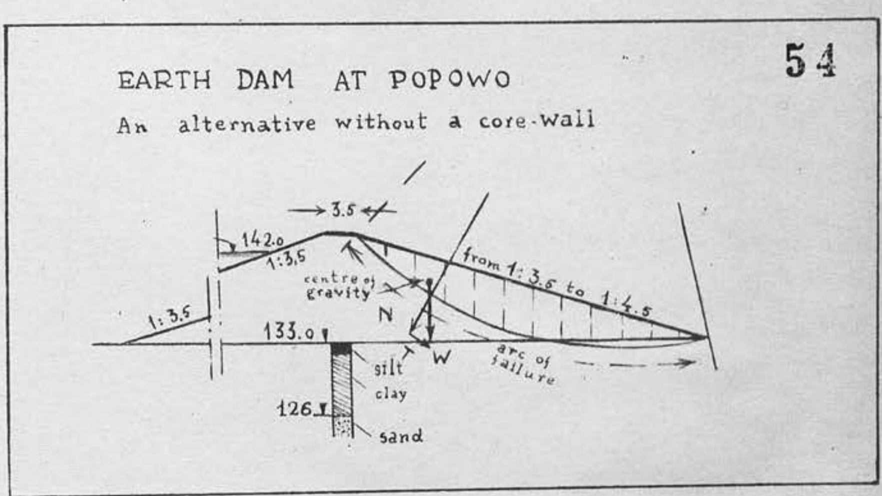
The loss of head "h" occuring through the part above the arc of failure "bdef" is due to the friction over-come by the seepage water through the material. The effect of this loss of head is considered as a force acting in the direction of the tangential component which tends to produce failure. The force "F" tending to cause displacement in the direction of seepage is equal to the loss of head "h"; multiplied by the weight of water and by the area surface "fb" of unit thickness. The proper design for an earth dam without a core-wall should be considered very thoroughly and based on laboratory tests upon available material adjacent to the proposed dam. The results of experiments made with the soil of other localities, where the material was very much the same classification,can-not be applied to new places unless local conditions are tested first,because there is no such thing as a standard side-slope. In the case of the dam at Popowo the detailed plan and laboratory tests would fix the best slopes, which might vary from 1 : 3.5 to 1 : 4.5 , if such a type were adopted instead of a type with core-wall, see sketch No. 54.



On the left side of the dam, i.e. in the bed of the Vistula a movable weir would be constructed for the discharge of high water and for the regulation of water level. The spillway capacity should be so great that there would be no danger of overtoping the dam.

An approximate calculation shows that the total opening should be 320 m wide.

Owing to the fact that the head at Popowo is 10 m at mean water level it would be necessary to install a type of weir suitable for the discharge of large water volumes, and for the easy discharge of ice. I propose in this case to use the hook-double gates.

This type of movable weir was described in Chapter No.Ia Vol.2

on the proposed Oder-Danube Canal. This system offers the advantage that the height of the upper gate is not dependent on the height of the lower gate, and can be lowered at least 5 m and therefore the discharge of ice can be very successfully accomplished over this structure. In the times of very high water it would be possible to raise the lower gate, so that its bottom would be placed above the high water level. On account of the fact that the two gates slide into each other, the winches can be placed fairly low and a saving in expense can be effected in the height of the piers.

The shape and the lengths of the weir bottom and the further downstream side protection of the bed would be fixed from the results of test on models.

The power station would contain 4 Kaplan turbines with a capacity of 12,500 kW each, and the triphase generators, each having 15,600 kVA .

The lock with dimensions 105 m in length and 20 m in width would be constructed in this same way, as was described above Chapter No.IIc.1.Vol.2

The second part of the first stage of the works on the Middle sector of the Vistula would be the consolidation of banks and concentration of flow in a single bed.

The method of regulating rivers with a view to the improvement of navigable conditions, some principles and examples of which I have described above, is only successful in the case of rivers in a state of equilibrium, and when the slopes are slight.

It must be replaced by canalisation,when the slopes are steeper and when hydraulic power can economically be turned to account. The middle sector of the Vistula belongs to the latter group and the preliminary regulation works which I propose are not designed to develop a navigable channel,but only to concentrate the flow in a single bed at medium water level,to improve the layout of ~~px~~ protective dikes and to stregthen and heighten them to an elevation suitable for the future retained water level caused by canalisation works.

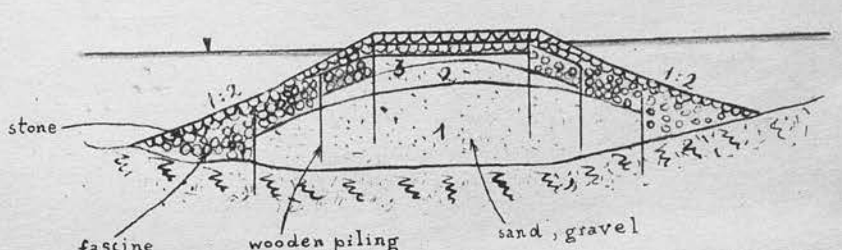
The first aim would be obtained by the construction of groins, training walls and revetments on the concave banks,but above all by closing the lateral arms.

The material to be used for the construction of the groins would be stone,fascine and gravel.

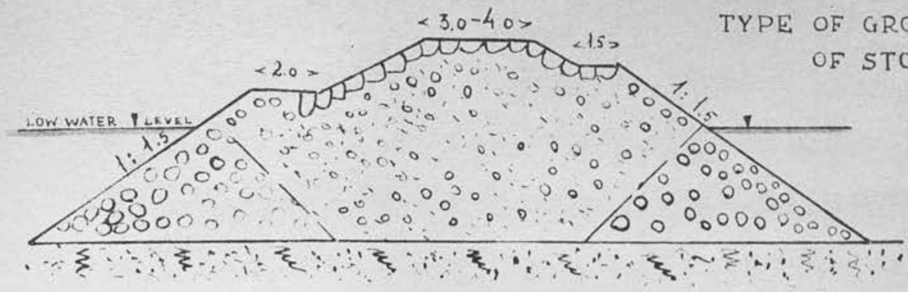
The cores of the groins,where erosion by the current is not too great,would consist of gravel or sand,covered with fascines and broken stones, and in the deepest places an additional piling would be used,see sketch No. 56 ,the slopes would be 1 : 2

56

TYPE OF GROIN.



TYPE OF GROINS OF STONE 57



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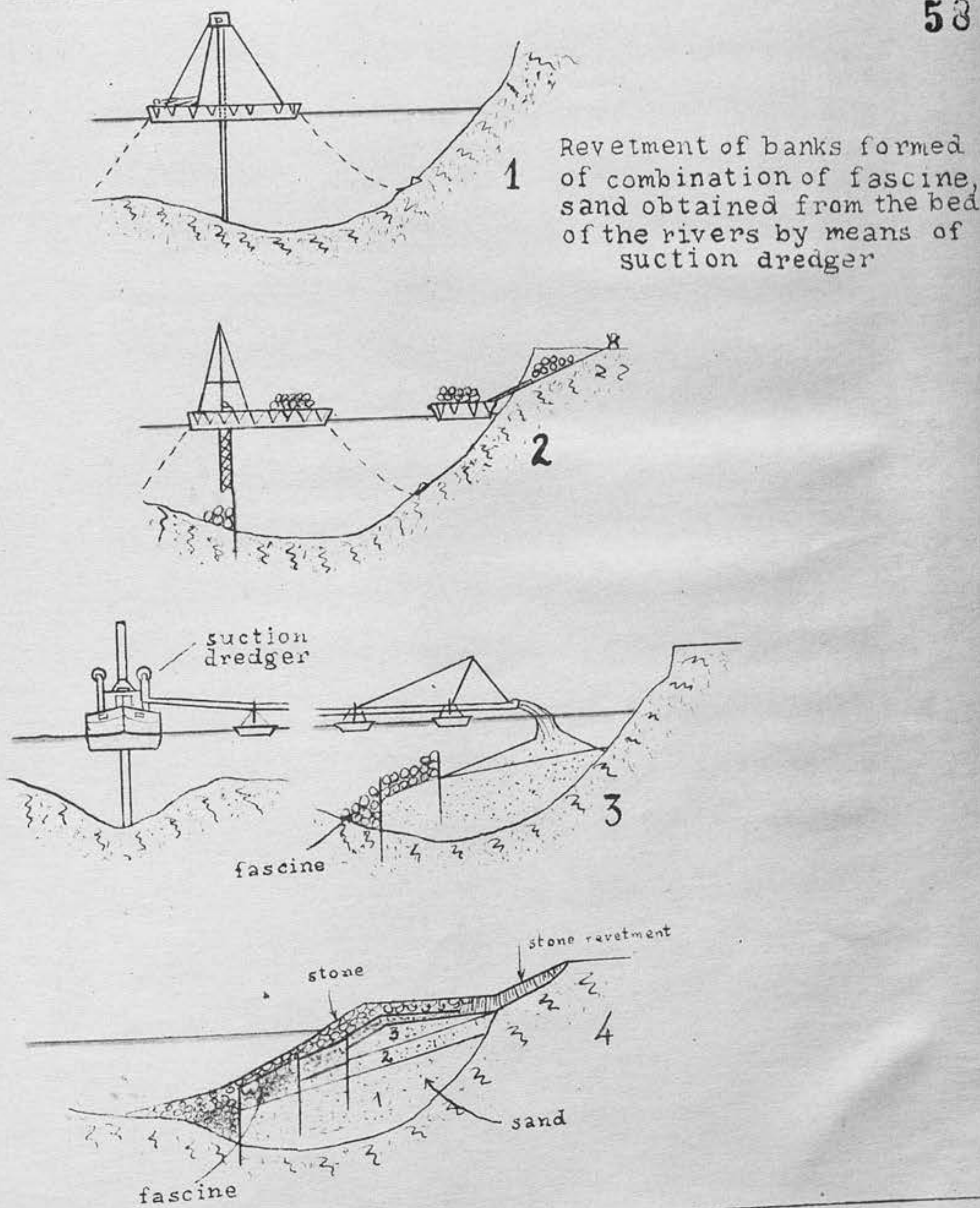
Revetment of banks formed of combination of fascine, sand obtained from the bed of the rivers by means of suction dredger



In the sections where the flow is more rapid the groins would be built of stone fig.No.57 with slopes 1 : 1.5. On concave bends, longitudinal revetments or training walls would be constructed of broken stones with slopes of 1 : 2 , and on the sharp bends 1 : 2.5 or 1 : 3 .

In the case of a steep bank with a great depth and moderate velocity of flow, revetments formed of a combination of fascine and sand, obtained from the bed of the river, by means of a suction dredger would be adopted. This arrangement is illustrated in the sketch No. 58.

The high water regulation would provide for the discharge of the highest spring and summer flood flows between longitudinal levees, which would be erected for a distance of 400-600 m . Between these levees it would be necessary to excavate at many places on the banks between the medium water level and the levees so that the ground level between the levees would be made to lie 1-2 m above medium water level and to rise in an average slope of 1 : 800 - 1 : 1,000 towards the longitudinal levees. This regulation of the shore level would lead to uniform and quick evecuation of the high water discharge and ice during the first period and also during the second period when the canalisation works would be completed. The consolidation and the raising of the existing protective levees or construction of new levees in those sections where they do not exist would require a shape similar in many xxxx respects to that of modern earth dams, taking into account the prolonged action of the retained water level, caused by canalisation works.

The bases for the determination of the elevation of the longitudinal levees are the existing records of high water level, taking into account the increase of the high water channel constructed in a single bed.

The following table No. 18 shows the differences between low and medium water level and that of the highest water level over the distance between Sandomierz and Warsaw.

Table No. 18 .

Gauging station	Post km	Altitude above sea level at flow: low	medium	high
Sandomierz	268.4	140.67	141.98	147.03
Dąbrowa Wrzaska	274.6	139.15	140.51	145.07
Chwałowice	284.7	136.31	137.93	141.33
Zawichost	287.6	135.38	137.27	141.43
Annopol	298.4	133.22	134.51	137.80
Solec	332.0	124.95	126.19	129.84
Puławy	371.1	115.52	116.87	122.64
Dęblin	393.4	110.08	111.74	115.62
Kłodawa	432.3	100.89	101.79	104.60
Królewski Las	465.9	91.64	92.75	95.92
Warszawa	513.8	78.57	79.77	84.68

From this table it is evident that the amplitude of water levels varies from 3.7 m in Kłodawa where a very large inundation area of the river is formed by flood flow, due to the lack of protective dikes, to 7.12 m at Puławy .

The high water levels in the above table correspond on the whole to the flood in 1934, except at Zawichost and Puławy where a higher water level was noted in 1819. The same relates to Warsaw, where the highest level was recorded in 1844.

It must be mentioned that the flood flow in 1934 on this sector of the Vistula was not the biggest which could be expected , because it was caused by an extremely high flow running only from two tributaries the Raba and the Dunajec , whereas the tributaries running below Sandomierz had not a very high flow at that particular time. For a similar reason the 19 th century showed even greater and more catastrophic floods. The greater part of these floods happened during the period when there where no protective dikes ~~in~~ on the Vistula, and therefore when the natural retention action of the valley was unrestricted. That is to say that should the same flow be repeated now, or in future , the high water levels would be even greater , considering the narrowing of the channel by longitudinal levees. I emphasise this fact as a rule for the raising of the levees. Unfortunately the only records made during the 19 th century are at the gauging stations at Zawichost, Puławy and Warsaw , therefore for the remaining sections of the Vistula the data for calculation must be obtained by deduction. The comparison between the highest water levels at Warsaw during the floods , where the gauging records have been kept since 1799 is as follows:-

Year	high water level
1813	605 cm
1839	595 cm
1844	635 cm
1845	564 cm
1867	592 cm
1884	546 cm
1934	549 cm

The sketch No. 59 gives the typical shape of cross-section of the protective levees for sectors where the difference between low and high water levels is very great.
The estimate for the materials required for the construction of the levees and regulations works to concentrate the flow will be summarized in the table No. 20 .
Regarding the Vistula valley, I think that the area inundated at high water, comprising also the land at the mouth of several tributaries, cannot be greatly improved and protected by embankments or other methods of enclosure, as the accumulated effects of such measures would produce inconvenient rises in the high water of the river, and consequently lead to still further heightening of the crests of the levees.
In this way later devastating floods could occur in the valley, in spite of the protective measures which were previously devised to keep the flood waters within bounds.
Therefore a plan for a system of reservoirs should be carried out at the same time and it should include the control of flood waters at or near their sources.
The co-ordination of all the improvements in the upper and lower courses is essential in the Vistula valley.
The study of flood frequencies and magnitudes led me to the conclusion that the improvement of the Vistula by regulation or canalisation works in the middle and lower sectors and the flood control there, cannot be successfully planned if the flood

and silting control in the mountainous areas were not solved in the same time.

For this reason, after the flood in 1934 I proposed a programme for the construction of 22 storage reservoirs, the effect of which would be to decrease the high water level from 2.0 m in the middle sector of the Vistula to 1.0 m in the lower sector.

Therefore the pre-war water development in Poland was chiefly concentrated on the construction of a number of storage reservoirs, for which I have been responsible. The largest of them was the Rożnów storage reservoir on the Dunajec with 8,000 million cubic feet capacity.

I present below some cost for the construction of the regulation works, which vary considerably, according to locality and size.

In U.S.A. the cost of groins and training walls:-

a) on the Tennessee the unit cost of stone groins 8sh 3d per m^3

b) on the Little River " " " " " 9sh 4d " "

c) on the Mississippi (upper) for the construction of 9 million m^3 of training walls in stone and fascine the average cost amounts to 3 sh 6 d per m^3, which corresponds to 74 sh per one metre of walls. Later the prices rose and amounted on the average to 4 sh 4 d per m^3, during the construction of 400,000 m^3 of training walls. The cost of stone for this work was 6 sh 8 d per m^3 and of fascine it was 2 sh 9 d per m^3;

d) on the middle and lower Mississippi the unit prices of the construction of training works varied from 54 sh to 435 sh per one metre of dikes, according to their height and size.

In France the cost of groins and training walls:-

a) on the Garonne the unit price of training walls and groins, for the construction of 21,000 metres was on an average 62 sh per one metre of dikes.

In Russia on the Don where fairly high dikes have been built the unit price amounted to 85 sh per one metre of dikes.

The maintenance and the up-keep costs of the regulation works varies between 1% on the Weser to 6% on the Rhone.

The third part of the first stage of the works on the middle sector of the Vistula would be the construction of the movable weir, lock and hydro-electric station at Bielany in the Warsaw district.

This canalisation fall will have to fulfil some special functions as I previously pointed out. They are as follows:-

1. the improvement of navigation conditions in the district of Warsaw;
2. providing the Warsaw district with a part of its electric power consumption, especially for the electrification of the railway system in the Warsaw area;
3. enabling the sewage pipe-lines to be carried across the Vistula by placing them in the sill of the dam. This would lead them to a dump, which would be xix situated on the other bank of the river from the outskirts of Warsaw;
4. carrying the gas pipe-lines and electric cables across the

5. the linking up of the construction of the dam with the building of the bridge, which is urgently required;

6. to build a communication tunnel placed in the concrete sill of the movable weir.

This project was worked out by Prof. K. Pomianowski, H. Herbich and Z. Zmigrodzki before the war, and a summary was published in the "Proceedings of Polish National Committee of Energy" in 1938 and in "Water Economy of Poland" in 1939.

The available power at this site would be 20,000 kW and the output of energy would amount to 140 million kWh per annum.

The cost was estimated as £. 1,320,000.-

The second stage of the works on Middle sector of the Vistula.

After the completion of the preliminary regulation works with the object of concentrating the flow in a single bed, and of consolidating the longitudinal levees, which would take a period of 3 years, the remaining works for the improvement of navigation conditions would be the construction of 13 movable weirs, provided with locks and hydro-electric stations. This number does not include those at Popowo and Warsaw which were included in the first stage.

The type of constructions would be similar to the canalisation works on the Upper sector of the Vistula described above. The difference consists only in the fact that the movable weirs would have larger openings due to the increased flood water.

The total length of the bear-trap weirs would amount to 5,040 m for 13 canalisation falls of about 4 m in height at medium water level. The smallest opening would be 330 m and the largest 420 m in width.

Also the available water power on the Middle sector of the Vistula would be greater than on the Upper sector i.e. it would amount to 300,000 kW with an average output of energy 1,630 million kWh per annum.

The following table No. 19 gives some data of the proposed installation of hydro-electric stations.

The total estimate of main materials, mechanical equipment, labour required, and cost for the proposed canalisation works on the Middle sector of the Vistula is summarized in the table No. 20.

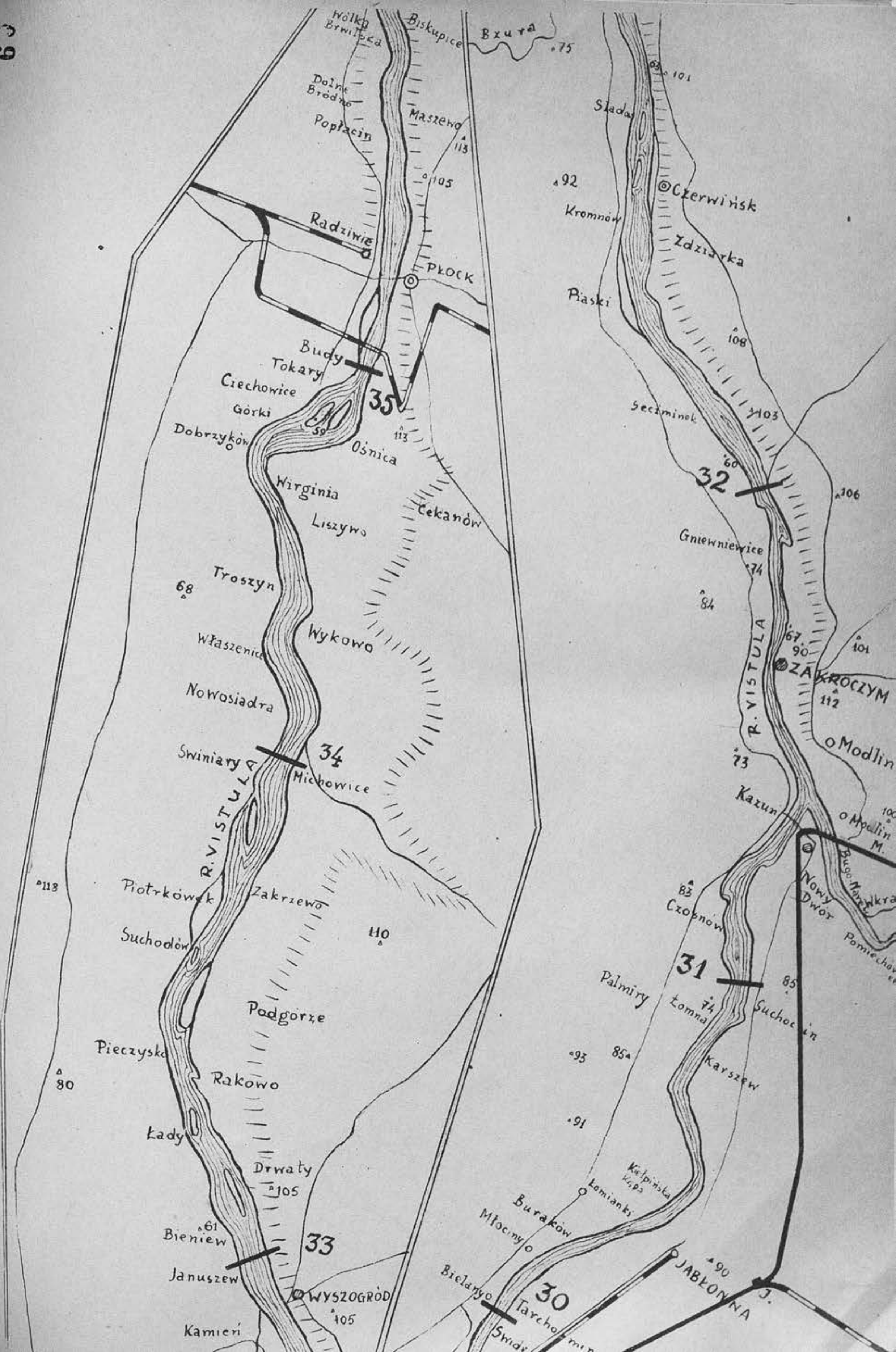
(see next page)

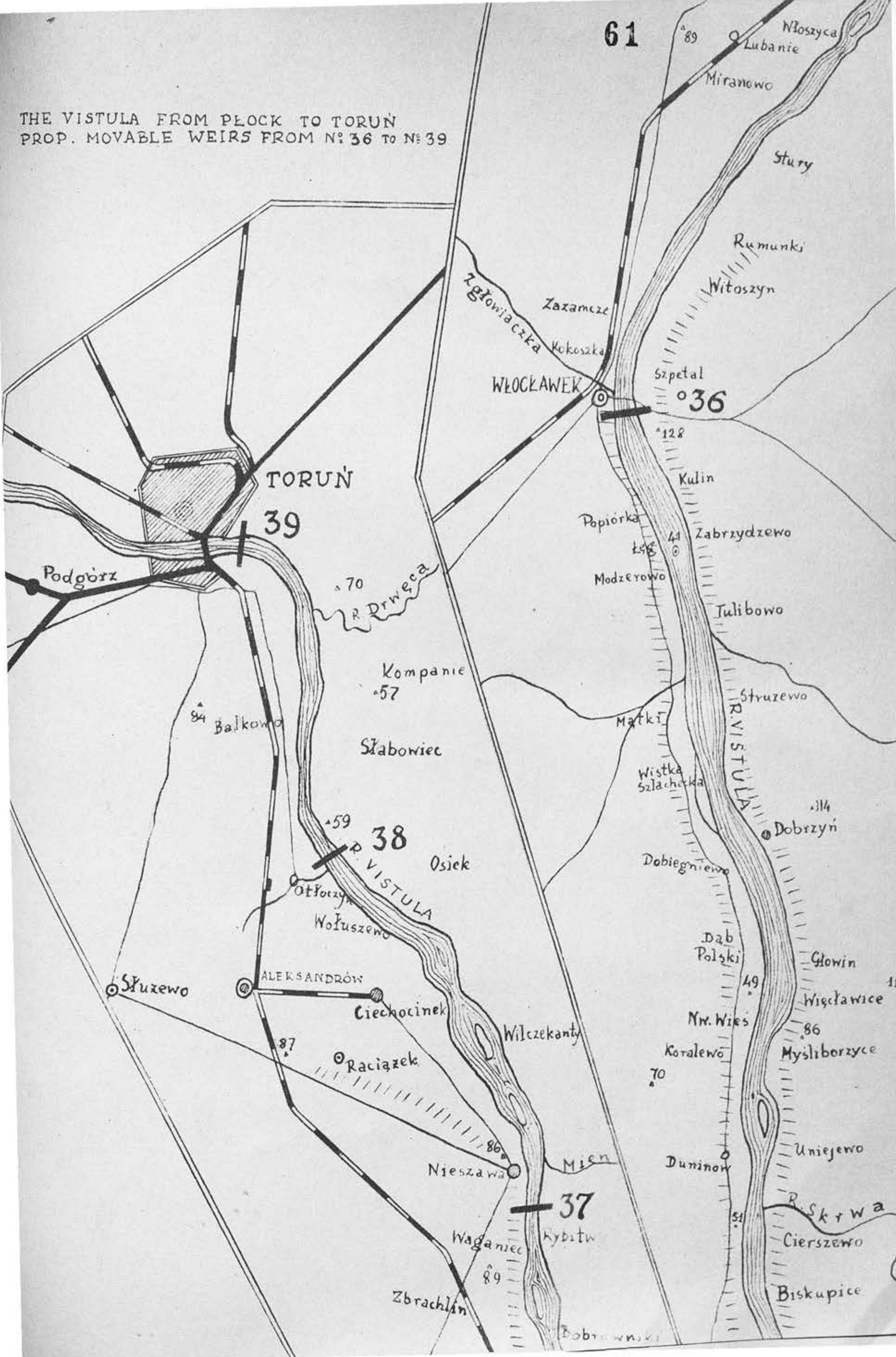
Table No. 19 . The following table gives some data of the proposed installation of hydro-electric stations.

Number of weir	Post km	Head at medium water level m	Hydro-electric station capacity kW	Hydro-electric station output million kWh
16 Popowo	308.0	10	50,000	200
17	325.6	4	15,000	70
18	341.2	4	15,000	85
19	357.8	4	15,000	85
20	374.3	4	15,000	90
21	392.4	4	18,000	95
22	407.9	4	18,000	100
23	423.7	4	18,000	100
24	439.0	4	18,000	100
25	453.8	4	18,000	105
26	468.8	4	20,000	110
27	483.5	4	20,000	110
28	498.2	4	20,000	120
29	507.0	3.7	20,000	120
30 (Bielany-Warsaw)	521.8	3	20,000	140

Table No. 10. The total estimate of main materials, mechanical equipment, labour required, and cost for the proposed canalisation works on the Middle sector of the Vistula.

	First stage	Second stage	Total
1. Earth work million m^3	36	3	39
2. Concrete thousand m^3	400	1,000	1,400
3. Groins and training walls			
a) length thousand m	160		160
b) volume " m^3	2,400		2,400
stone " "	1,000		1,000
fascine " "	1,400		1,400
4. Wooden piles " "	22	85	107
5. Steel construction for weirs and lock-gates thousand tons	3.2	11	14.2
6. Steel-sheet piling m	2,000	5,000	7,000
7. Installation of Kaplan turbines thousand kW	70	230	300
8. Generators " kVA	87.5	287.5	375
9. Workers required	40,000	20,000	
10. Period of construction years	3-4	3-4	6-8
11. Cost of construction £.million	7.8	7.0	14.8


Bzura
75
101
Biskupice
Maszewo
113
105
Dolne Brodno
Popłacin
Radziwie
PŁOCK
Budy
Tokary
Ciechowice
Górki
Dobrzyków
35
59
113
Ośnica
Wirginia
Liszywo
Cekanów
Troszyn
68
Wykowo
Właszenice
Nowosiadra
Swiniary
34
Michowice
R. VISTULA
118
Piotrkówek
Zakrzewo
Suchodołów
110
Podgórze
Pieczysko
Rakowo
80
Łady
Drwały
105
61
Bieniew
33
Januszew
WYSZOGRÓD
105
Kamień
Słaboszewo
92
Czerwińsk
Kromnów
Zdziarka
Piaski
108
Secyminek
103
60
32
106
Gniewniewice
74
84
R. VISTULA
67
90
101
ZAKROCZYM
112
Modlin
73
Kazuń
Modlin M.
Nowy Dwór
Bugo-Narew
Wkra
83
Czosnów
Pomiechów
31
85
Palmiry
74
Łomna
Suchocin
93
85
Karszew
91
Kiełpińska Kępa
Łomianki
Buraków
Młociny
90
JABŁONNA
Bielany
30
Tarchomin
Świdry
J.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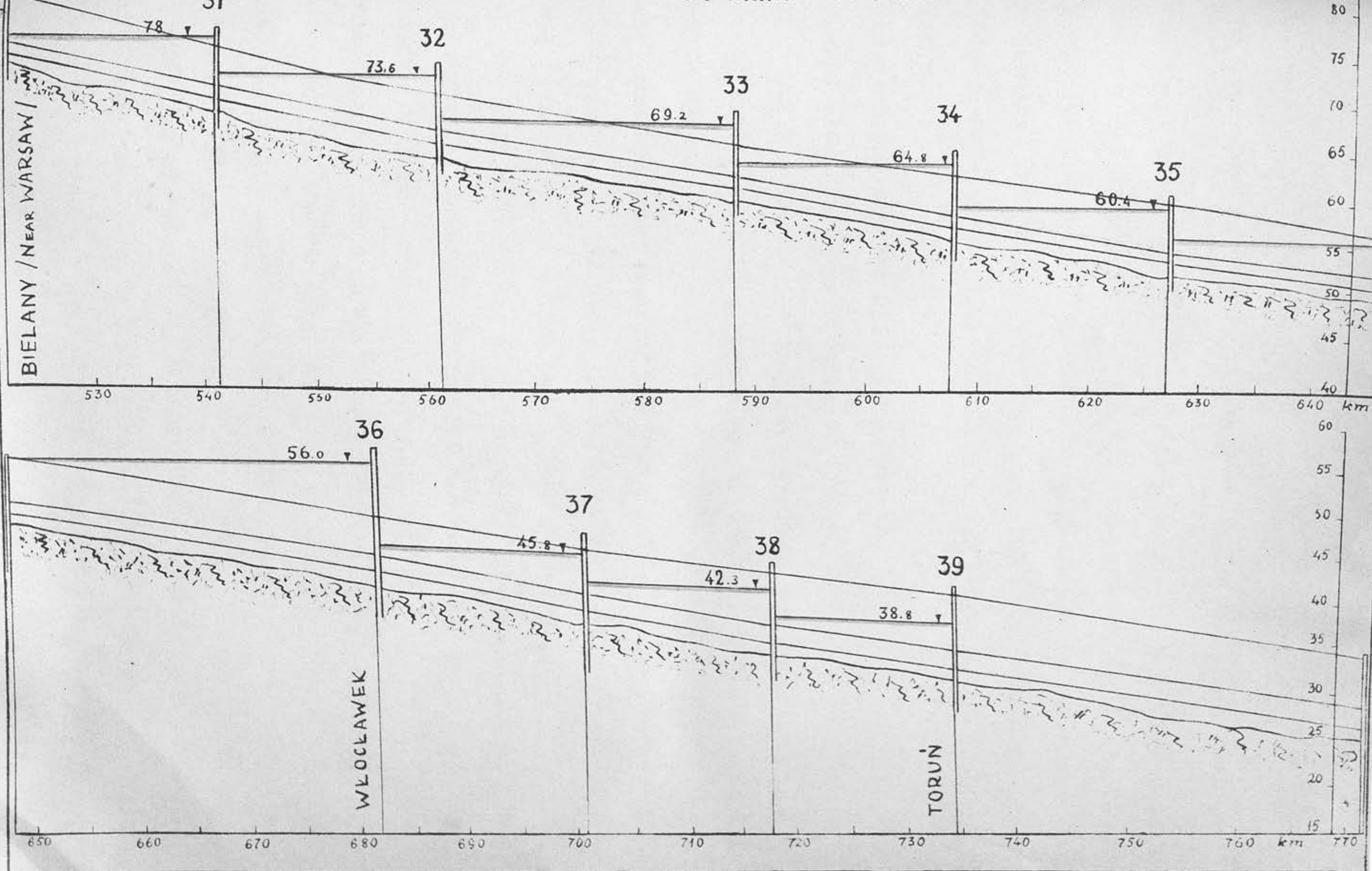
THE VISTULA FROM PŁOCK TO TORUŃ
PROP. MOVABLE WEIRS FROM No 36 TO No 39
Nłoszyca
Lubanie
89
Miranowo
Słury
Rumunki
Witoszyn
Zazamcze
Zgłowiączka
Kokoszka
WŁOCŁAWEK
Szpetal
36
128
Kulin
TORUŃ
39
Popiórka
41
Zabrzydzewo
Modzerowo
Podgórz
70
R. Drwęca
Tulibowo
Kompanie
57
Strużewo
84
Balkowo
Matki
Słabowiec
R. VISTULA
Wistka Szlachecka
114
59
38
Dobrzyń
R. VISTULA
Osiek
Dobiegniewo
Otłoczyn
Wołuszewo
Dąb Polski
Głowin
ALEKSANDRÓW
Służewo
49
112
Ciechocinek
Więcławice
Nw. Wieś
86
Wilczekanty
Koralewo
Myśliborzyce
87
Raciążek
70
Uniejewo
86
Nieszawa
Mień
Duninów
37
R. Skrwa
Waganiec
51
Cierszewo
89
Biskupice
Zbrachlin
Bobrowniki

PROP. CANALISATION FALLS ON THE VISTULA
FROM WARSAW TO TORUŃ



<u>The lower sector of the Vistula</u> from Warsaw to Bydgoszcz, see sketch No. 60, 61, 62.

The lower sector of the Vistula from Warsaw to Toruń has been treated separately in the plan for canalisation works, to emphasize its double importance in the network of Poland's waterways. This sector with its extension to the mouth of the Brda forms a common link between the two international water--ways:-

1.S.N. along the Vistula to the Baltic;

2.W.E. along the Transeuropean waterway.

This overlapping of the two main navigable waterways in one route will result in a bigger annual traffic, than that carried on the previous sectors.

The economic importance of the Vistula from Warsaw downstream has been recognized for a long time in the past, and rafting and navigation dates back to the 13th century.

In the 13th century the export of timber was commenced with shipments of Mazovian wood; whilst the export of corn through Gdańsk (Danzig) arose during the 14th century.

The economic upheaval which took place in Europe towards the close of the Middle Ages, the decline of trade with the East and the rising demand for corn in West Europe caused the corn trade to develop very rapidly. Thus, at the end of the XV th century, about 700 vessels annually were navigating the Vistula to Gdańsk (Danzig) with goods mostly destined for West Europe. The rapid growth of the corn trade was likewise favoured by the opening of the Baltic Sea, as a result of which the number of countries, including Scotland, having direct trade relations with Poland, increased considerably.

An average of 1,200 vessels entered Gdańsk(Danzig) every year at the close of the 16th century and at the beginning of the 17th century, the peak figure of 1,867 vessels was reached in the year 1618.

From the middle of the 17th century, with the destructive wars afflicting Poland, at that time, and with the breakdown of economic life, river traffic on the Lower Vistula began steadily to decline.

Only once, during the reign of King John III Sobieski did the returns of goods traffic rise to their former level, to about 400,000 tons.

The second rise of traffic took place in the second half of the 18th century, whilst the construction of the Regal Canal and Ogiński Canal were completed, thus the hinterland of the Lower Vistula increased in area from 74,430 sq miles to 188,400 sq. miles. The goods traffic on the Vistula to Gdańsk(Danzig) reached at this time 300,000 tons.

After the first partition, when Prussia annexed Pomerania, but not Gdańsk(Danzig), Frederick II, took over the Customs House at Fordon, in 1772, where he levied an increased duty of about 12% "ad valorum" on all goods passing that point, the duty thus charged by him being nearly ten times greater than that levied in Polish times. So at the end of XVIII century the export of corn through the Vistula to Gdańsk (Danzig) fell to 25,000 tons.

When the congress of Vienna undertook the delimitation of the new frontiers of the countries of Europe, it endeavoured to minimize the economic difficulties, which were sure to arise as a result of the changed conditions. Freedom of navigation upon the rivers of the former Polish territory was guaranteed, to the inhabitants of the partitioned state. This resolution of the Congress was of great significance for the sea-borne export of farm produce from Poland, as navigation on the lower Vistula was then obviously of prime importance to that trade. But it so happened that it was just in this question, that the decission of the Congress remained but a scrap of paper. Prussia raised the duty, once again, on agricultural produce passing in transit through Pomerania to Gdańsk (Danzig).

As a result the export from the Kingdom of Poland through that port fell year by year, and reached the low level of less than 20,000 tons in 1822.

At this time Poland checkmated the schemes of Prussia by setting up a plan for a waterway, along the Narew, through Augustowski Canal, along the Niemen river and the Windau Canal to the port of Windau, and so to avoid the Lower Vistula.

But before the works necessary for putting this plan in action were commenced, Prussia concluded a new commercial treaty, in 1825, which envisaged better treatment of Polish economic interests.

The quantity of goods traffic on the Lower Vistula increased and the export of corn grew to 150,000 tons of the middle of XIX th century , and the number of timber rafts varied from 1,500 to 2,000 and the highest figure for timber was of about 1.7 million m^3.

The enormous economic development of Europe during the past century as a result of inventions and a growth in overseas trade, caused a revival of interest in waterways as a medium offering cheap and easy facilities for goods transport. In many countries new canals were bult, the rivers were improved by regulation and canalisation.

The Lower Vistula was not entirely overlooked but the regulation works were carried out very slowly and the river remained in the condition for the navigation of small sized craft.

The highest goods traffic on the Lower Vistula was reported to be only 600,000 tons while that on the Rhine was 50 times greater.

The economic history of the Lower Vistula, briefly reviewed here, clearly shows that there are not only very close ethnical but also close economic bonds connecting the Baltic and Pomerania with the rest of Poland , which furnishes an enormous hinterland served by the Lower Vistula and its mouth near Gdańsk(Danzig). The Lower Vistula area can only benefit by serving this interland when it is bound by close political ties with the rest of Poland. The same applies to Gdańsk (Danzig) and its port. Whenever these ties become loosened or fall apart, a period of stagnation ensues for navigation on the Lower Vistula and for the port of Gdańsk(Danzig). But the river must be regulated and the improvement should be such, that the creation of a modern navigable waterway would be obtained in the quickest and most effective way.

With a system of waterways planned to embrace about 75% of the whole of Poland, the chief export commodities which would pass along the Lower Vistula would be coal, farm and forest products and also those goods manufactured by the industries working up forest and agricultural raw materials. In that case, the erstwhile role of the Vistula would in a great measure to be restored. The import trade would consist of raw materials necessary for the industries set up on the areas served by the waterways.

The Vistula from Warsaw to Toruń is more or less in the same conditions from the standpoint of surplus of slopes as on the upper or middle sectors. Secondly, the navigation conditions, though better than on the middle sector, are very far from those required in a modern navigable waterway.

The past regulation works which have been carried out did not improve the river in the strictest meaning of this word, therefore we must state that the regulation must be done almost from the beginning. I put this "almost" because some regulation works preliminary to the next canalisation works were carried out by the Polish Water Service. So there would be less preliminary work having the object of concentrating the flow in a single bed at medium water level and keeping the flood waters within levees , compared with the middle sector Sandomierz-Warsaw.

Therefore it would be possible in a short time to start the proper regulation by canalizing the river. The lower sector of the Vistula from Warsaw to Toruń presents various possibilities for retaining water level from the topographic standpoint of view. There is the stretch between Włocławek post km 679.4 and Płock post km 632.4 with a compact valley with high banks , allowing the construction of dams with a high head of about 10 m , similar to the proposed dam at Popowo on the middle sector of the Vistula. On the other reaches the conditions are worse requiring the construction of a lower type of movable weir , with heads varying from 3.5 m to 4.4 m , at medium water level.

There is no doubt at all that the right plan would be to start the works in several places so that the final effect would be to complete the modern navigable waterway , with the utilisation of water power along the whole route at the same time.

The total length of the Vistula sector between the tail water at the dam No. 30 at Bielany in the Warsaw district , to the last dam No. 39 at Toruń would be 213 km .

The remainding stretch from Toruń to Bydgoszcz over a distance of 37 km i.e. to the outlet of the Transeuropean navigable waterway from the West to the East , requires only additional regulation works relatively on a small scale to improve it for taking craft of 1,000 tons.

The canalisation works on the lower sector of the Vistula downstream from Warsaw would present many similarities with the previous middle sector upstream from Warsaw.

In the first stage the following works would be undertaken:-

1. concentration of flow in a single bed at medium water level by means of groins;
2. consolidation and raising the protective levees to a proper level , taking into account the future retained water level due to the canalisation falls;
3. construction of the dam No. 36 at Włocławek , for which the reach over a distance of about 55 km does not require preliminary work owing to the existing high banks.

In the second stage after the completion of the preliminary regulation works , which would take a period of 3 years , the remaining work of canalisation would involve the construction of 8 movable weirs , locks , and water-power stations.

The rules for the preliminary regulations works have been described above as well as the design of the longitudinal protective levees.

The bases for the projection of elevation of these levees might be drawn from the existing records which are summarized in the following table No.21 , taking into account , in xxxx in addition , the retaining effects caused by movable weirs and by the enclosure of the flood flow within the levees.

Table No. 21 .

Gauging station	Post km	Altitude above sea level at flow		
		low	medium	high
Bielany	521.8	76.52	77.80	(82.50)
Modlin	551.5	68.99	70.62	74.57
Zakroczym	556.0	68.00	69.78	74.46
Wyszogród	586.7	62.75	64.00	68.19
Płock	632.4	53.56	54.95	60.05
Włocławek	679.4	44.53	45.79	50.66
Nieszawa	702.4	39.74	41.49	47.25
Silno	719.8	35.49	38.13	44.29
Toruń	734.8	33.58	35.52	41.86
Solec Kujawski	763.0	28.78	30.80	36.05
Fordoń	774.9	26.49	28.31	35.60

The altitudes of highest water levels do not correspond to the same flood. A part of it applies to early records as in Płock in 1844 , in Toruń in 1871 , in Nieszawa in 1888 , the others at Modlin and Zakroczym which are more recent apply to the flood in 1929 , the remaining are derived from the spring flood of 1924 .

From the foregoing data we can see that the difference between the low water level and that of high water varies from 5.6 m at Modlin to 8.8 m at Silno.

The dam at Włocławek with a head of 10.2 m at the medium water level, would be of very similar construction to that at Popowo, described above. The estimate of works would be slightly different, because the abutment as an earth dam would be shorter, but the length of the movable weir consisting of the hook-gates type would be greater.

The biggest difference would be in hydro-electric arrangement for water power station. The available power and the output of energy would be much greater namely 100,000 kW and 550,000,000 kWh per annum. This would be the greatest power station on the Vistula, and its unit cost per kWh would be the lowest. The economical features of this power station come from the favourable topographical and hydrological conditions.

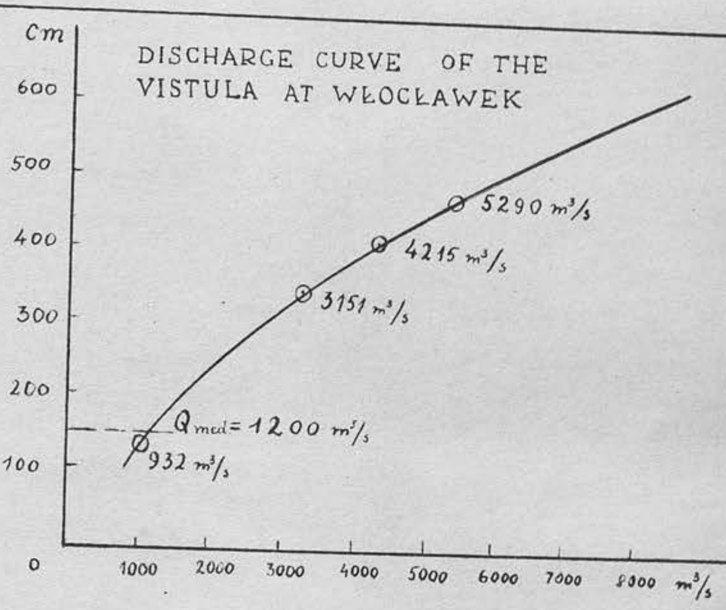
The high head coincides with a large quantity of flow.

The following table No. 22 shows us the range of flow obtained from the discharge gauging made on the Vistula at Włocławek in 1934.

Table No. 22.

River	Gauging station	Date	Gauge height cm	Discharge m^3/s
		1934		
Vistula	Włocławek	9.11	134	932
		30.7	350	3,151
		23.7	413	4,215
		24.7	480	5,290

From the developed stage-discharge curve, see sketch No. 63 it is evident that for the medium water level discharge amounts to 1,200 m^3/s or 42,500 cubic feet.



63

The remaining 8 movable weirs which would be built in the second stage, would be of the standard bear-tap type, which I have proposed on the upper and middle sector of the Vistula, because they permit easy lowering in order to discharge. The dimensions of locks would be 225 m in length, 12 m in height and 3.5 m in depth, owing to the fact that the estimated traffic would be greater on this sector of the Vistula, and that the problem of water supply for lock operations does not present any difficulty since it constitutes only a very small proportion of the Vistula flow.

The canalisation of the lower sector of the Vistula from Warsaw(Bielany) to Toruń will develop the following values of power and energy.

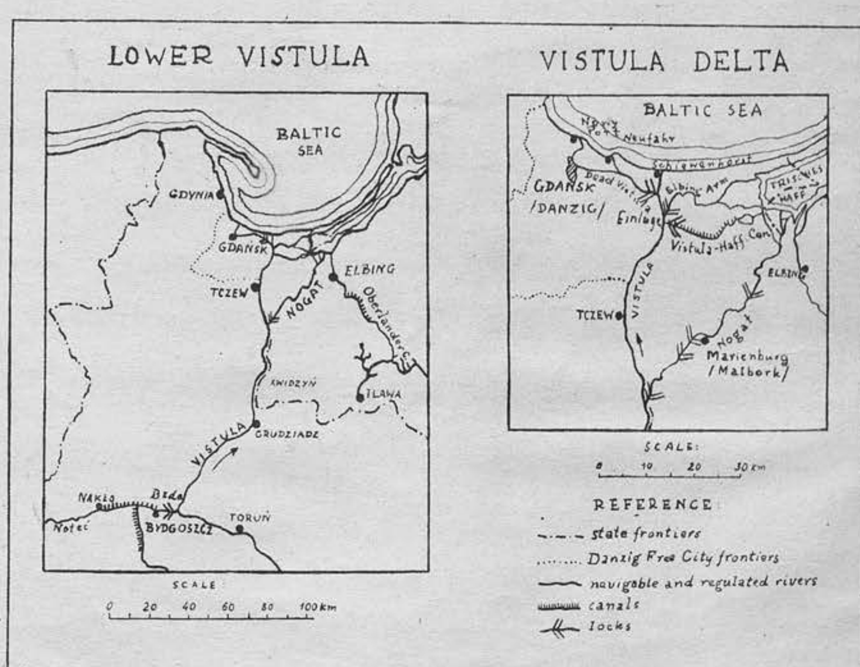
Table No.23

Number of weir	Post km	Hydro-electric station capacity kW	Hydro-electric station Output million kWh
31	541.3	25,000	130
32	561.2	35,000	180
33 Wyszogród	588.3	35,000	180
34	607.5	40,000	200
35	627.7	40,000	200
36 Włocławek	682.0	100,000	550
37	700.8	35,000	190
38	719.0	35,000	190
39 Toruń	734.0	35,000	190
		380,000	2,010

The total estimate of main materials and equipment for carrying the canalisation works on the lower sector of the Vistula from Warsaw to Toruń, over a distance of 213 km , and the regulation works from Toruń to Bydgoszcz over a length of 37 km is summarized in the approximate figures as follows:-

Table No. 24.

		First stage	Second stage	Total
1. Earth work	million m^3	27	2.5	29.5
2. Concrete	thousand m^3	200	1,000	1,300
3. Groins and training walls of stone and fascine	thousand m^3	1,300	--	1,300
4. Wooden piles	" m^3	16	75	93
5. Steel construction for weirs and lock gates	thousand tons	3.8	9.6	13.4
6. Installation of Kaplan turbines	kW	100,000	280,000	380,000
7. Generators	kVA	125,000	350,000	475,000
8. Steel sheet piling of 10-12 m in height	m	700	5,000	5,700
9. Workers required		29,000	16,000	
10. Period of construction		3-4	3	
11. Cost of construction	£.	4,900,000	6,400,000	11,300,000



LOWER VISTULA
BALTIC SEA
GDYNIA
GDAŃSK
ELBING
TCZEW
NOGAT
Oberländer C.
KWIDZYŃ
IŁAWA
VISTULA
GRUDZIĄDZ
NAKŁO
Brda
Noteć
BYDGOSZCZ
TORUŃ
SCALE
0 20 40 60 80 100 km
VISTULA DELTA
BALTIC SEA
Neufahr
Schiewenhorst
GDAŃSK
/DANZIG/
Einlage
Elbing Arm
Vistula-Haff Can.
ELBING
TCZEW
VISTULA
Nogat
Marienburg
/Malbork/
SCALE:
0 10 20 30 km
REFERENCE
state frontiers
Danzig Free City frontiers
navigable and regulated rivers
canals
locks

Regulation Works on the Lower Vistula.

The remaining sector of the Lower Vistula from the mouth of the Brda to the Baltic, runs northwards through the fertile valley called Pomerania (Pomorze). If we look into the dim past Pomerania appears as an area freed from the bondage of the last Ice Age as a belt of hills; the northern slopes of which decreased to the Baltic, whilst at the foot of the southern slopes a great post-diluvial river flowed from east to west along the primeval Toruń-Eberswald valley.

During some geological cataclysm the Vistula broke through northwards and its huge discharge with the help of time eroded a wide valley which offered a convenient passage to the sea from East-Central Europe. Thus the Vistula at that time acted as a route linking up the wide plains of the hinterland with the rest of the world; this state of affairs has lasted to the present, albeit conditions have greatly changed. Other kinds of transport pass through the valley of the Vistula and the river itself plays an exceptionally small part in Poland's transport traffic because the improvement of the Vistula especially in the upper reaches has not been completed.

The first regulation works were projected by Severin in 1830. The longitudinal profile of the new river channel was determined on the basis of insufficient hydrological data. The breadth of the river and the dimensions of cross-sections were calculated by Severin on the basis of a survey of 27 cross-sections at a period of medium water level, the average area of which amounted to 940 m^2. Taking the necessary depth of 2.5 m , Severin calculated a breadth of x 375 m , just above the mouth of the Nogat. Maintaining the same depth and wishing to direct two-thirds of the flow through the Vistula and one-third through the Nogat, the breadths of 250 m for the Vistula and of 125 m for the Nogat were applied. In spite of very extensive hydrological studies conducted subsequently the width of the river was not changed during the Prussian occupation.

When in 1880 improvement works were undertaken on a larger scale the aim was to create a channel with a depth of 1.67 m at low water level to permit the uninterrupted navigation of 400 ton barges, having a draught of 1.47 m . In effect, however the downward moving sand-bars have caused the main channel to become so tortuous that depths of up to 10 m have appeared at the bends, whilst sand shoals have arisen at the inflexion points and often reduced depths to less than one metre with a consequence stoppage of all navigation.

In 1903 more than two hundred shoals and a like number of sand-bars were counted and it was estimated that they usually occupied about two-thirds of the regulated channel and in addition the sand-bars constantly changed their positions. The vagaries of the flow not only hindered navigation but also destroyed or damaged the regulation works. Furthermore the very costly work in dividing up the volume of water with two-thirds brought down by the Vistula and one third by the Nogat failed to yield the results expected. The mass of water passing through the Nogat was greater, fluctuated very widely, and the entrance was being constantly damaged or eroded. This led the German Waterways Board to take the radical step of closing the entrance to the Nogat by means of a lock and of regulating the flow of water to a fixed volume by means of a sluice gate. These works were finally completed in 1915.

This method of solving the problem could not but have its effect on the Vistula, whose channel below the Nogat had been planned to hold only two-thirds of the high-water volume. Every period of high-water was marked by enormous erosion of the river-bed, often approaching the 20 m sounding.

The German authorities also conducted certain regulation works in the Vistula delta.

In 1847 the Vistula as a result of its course being dammed up by ice-packs broke its way through the sand-dunes near Neufähr and entered the Baltic at a new place some 12 km from its former mouth.

In order to enable vessels to reach Gdańsk (Danzig) the abandoned river bed was cleared up and closed by sluice-gates near Danzig-Krakau. When, however, during the course of regulation works conducted later the volume of sand brought down by the Vistula increased, it was feared that ice-packs would again arise and dam up the channel; it was then decided to excavate a new channel for the river by the simple extension of its bed

to the north through the chain of dunes at Schievenhorst. This work was completed in 1895 and the Danzig (Gdańsk) and the Elbing arms were closed by means of locks. In consequence of this additional shortening of the river's course the longitudinal slope increased and became very much steeper during high-water flow, thus causing enormous erosion of the river bed and consequent considerable damage to the river regulation works. The shortening of the course of the Vistula by the creation of a new mouth at Sxhievenhorst has had no favourable effect on navigation vessels which are still obliged to pass through the Dead Vistula to Gdańsk (Danzig) or through the Elbing arm. Passage through the main mouth is still not easy as Poland's experience in 1926 and 1927 demonstrated. The medium water channel over the last seven kilometre of its course has been broadened from 200 m to 400 m , whilst the distance between the dikes has been reduced from 1,000 m to 750 m .
This facilitates the current carrying the sand out to the sea but simultaneously is the cause of sand-bars arising immediately beyond the mouth and further off-shore.
This state of affairs made it necessary to undertake dredging operations with a view to obviating dangerous accumulations of ice packs which might again dam up the river.
As we have ~~been~~ learned from the brief foregoing report, the state of the Lower Vistula when it was taken ~~xx~~ over by the Polish authorities from the German Administration in 1919 was far from satisfactory.

There can be no doubt that this river could if properly regulated bear vessels of at least 1,000-1,200 ton capacity. Polish authorities have undertaken detailed studies with a view to transforming this sector into a modern navigable waterway.

Research works and gauging on the question of dragged and suspended silt have been continually conducted to afford the basis for a scheme for regulating the river at low-water conditions in accordance with Girardon's principles. This plan was being tried out on a trial sector of the river just before the war broke out.

In the meantime since 1920 nearly all the damage done to the regulation works especially during the war 1914-1918 was repaired by the Polish authorities over the total length of the Lower Vistula, and additional dredging works have been carried out continually, to maintain navigation for medium sized boats. Thus the state of the river bed for navigation conditions has been at least at the same or higher level as during the Prussian (times) occupation.

According to the records 1901-1910 the number of sand-banks and shoals was over 200 where the depth was 0.6 m less than that required for 400 ton barges. After the completion of the most urgent regulation works, the soundings showed that there were in recent years 45 inflexion points having a depth of 0.35 m less than that required for 400 ton barges at the lowest water level. During only four months in the year at higher than medium water level the Lower Vistula was capable for 1,000 ton barges. Therefore the size of the craft navigated on the Lower Vistula is rather small. The vessels can be divided into three categories:-

26% are those of under 200 ton capacity , 50% between 200-300 ton and 24% are vessels of over 300 tons.

The Lower Vistula is equipped with a large number of quays and has several wintering ports at Toruń, Fordoń , Korzeniowo , Grudziądz and Tczew. The only large river port which has proper railway connections and which is equipped with trans-loading equipments is at Toruń; it also has a special basin for timber rafts. The smallest one with transloading equipment and railway connections was built in Tczew some years before the war.

The flood control on the Lower Vistula is satisfactory, the longitudinal dikes having been improved. The largest ~~xxx~~ improvements works have been done in the sector where the Kwidzyń valley was menaced. The maintenance of the banks have been kept at a proper standard by conservation works and these protected the Vistula valley over the highest recorded high water levels , the figures of which are summarized in the following table No. 25 .

(see the next page)

Table No. 25.

Gauging station	Post km	Altitude above sea level		
		low water	medium water	high water
Fordoń	774.9	26.49	28.31	35.60
Chełmno	806.8	20.17	22.35	28.36
Grudziądz	834.8	15.09	17.43	24.43
Korzeniowo	867.0	9.37	11.70	19.06
Mątawski Cypel	886.4	5.90	7.80	15.64
Mała Słońca	898.7	2.91	5.27	12.85
Tczew	908.6	1.15	3.51	11.59
Schievenhorst	938.6	--	--	--

The construction of a modern waterway has not been realized to date since the detailed project for low-water regulation had to be based on fairly long studies, which have already been undertaken.

These regulation works for improving the river navigation conditions to take the 1,000-1,200 ton vessels over a distance of 166 km from the mouth of the Brda to the Danzig (Gdańsk) would call for the following main materials and investigations:-

1. Training works and groins in length .... 180,000 m
2. stone .... 1,000,000 m^3
3. fascine .... 1,700,000 m^3
4. wooden piles .... 13,500 m^3
5. workers required........................5,000
6. cost of construction .... £.920,000

The completion of the regulation works on the Lower Vistula must coincide with the canalisation works and with the improvements in the centre, east, and south of the contry. If this is not done, only a part of Poland would use the Lower Vistula for its transport trade. This fact is all the more striking when it is considered that rich and fertile regions are in the Middle Vistula valley(Lublin and Sandomierz district); the mining and industrial centres are in the Upper Vistula valley (in Silesia and Carpathian district); the forest and basalt quaries in the east district, situated on the Prypeć and the Vistula basins.

With the modern system of waterways which I propose and which would embrace 75% of the whole of Poland, the chief export and import trade would pass along the Vistula.

If this is accomplished the former role of the Vistula will be re-established and so the ambitions of the economists and the visions of the poets will be realised.

In closing this technical report I should like to quote from two of the most famous of the latter:

"Flow, beloved Vistula to Danzig's port
And rescue, since you can from every hurt
The Common wealth"

M. Rey
(XVI Century)

and

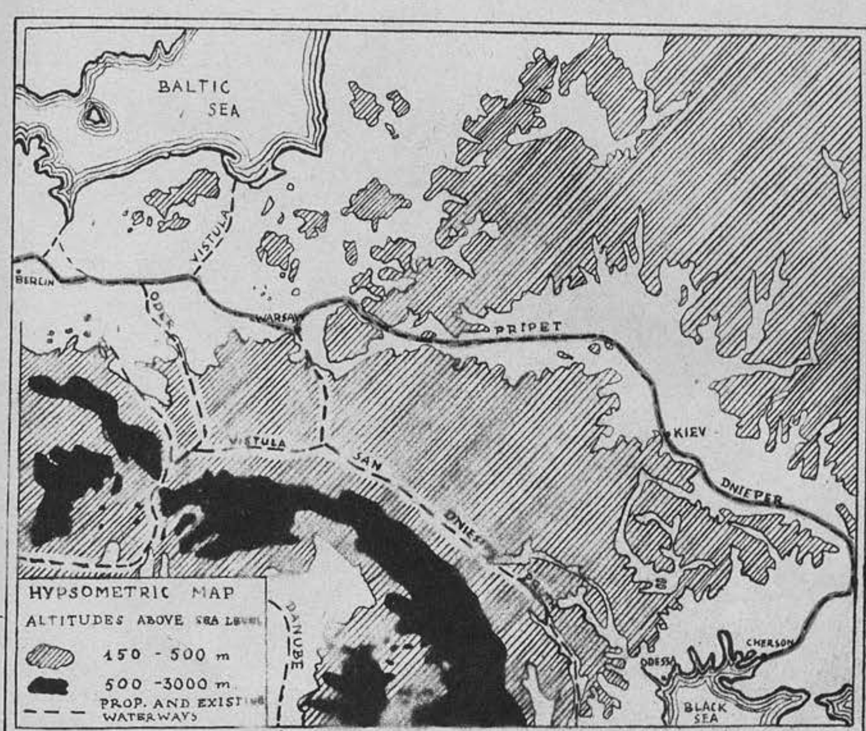
"Silence, dear one, stay your weeping
Vistula her course is keeping,
While her flow our lands may nourish
Poland's people shall not perish!"

Lenartowicz
(XIX Century, in the period of Poland's partition)

T H E W E S T - E A S T

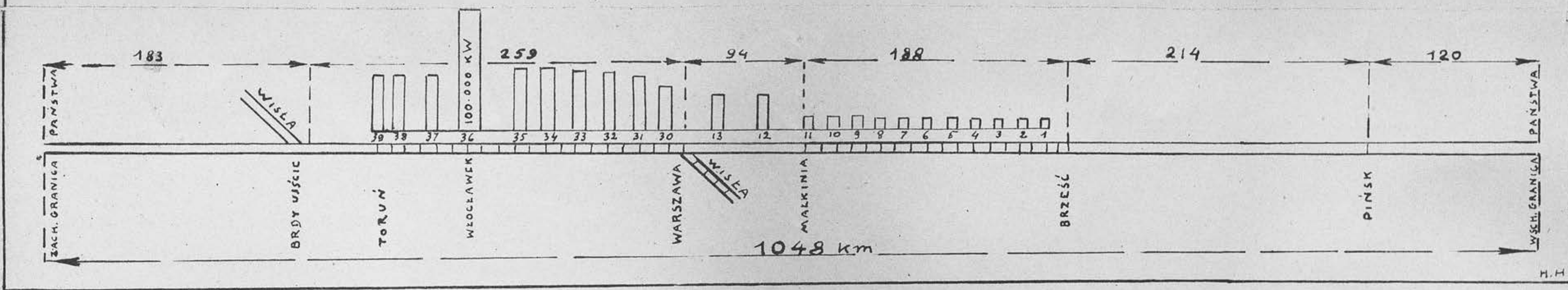
I N L A N D T R A N S E U R O P E A N

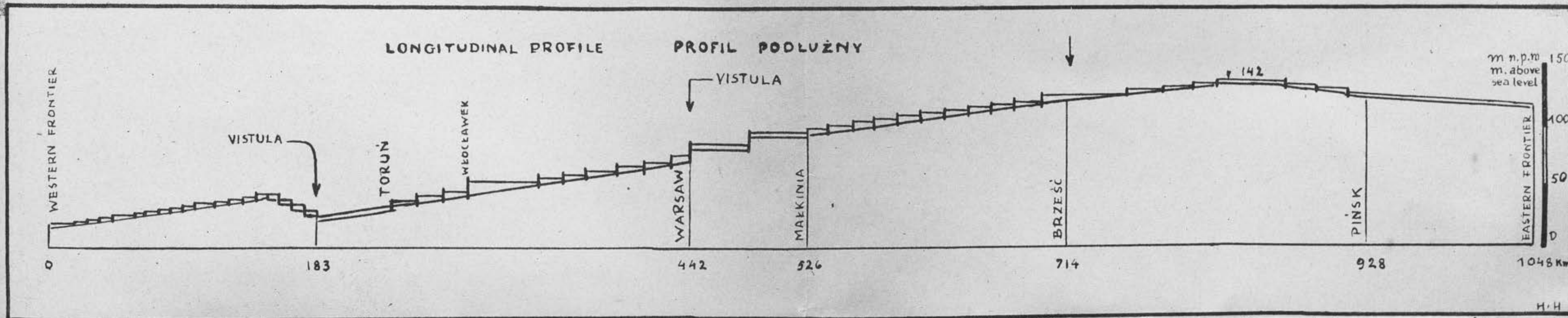
N A V I G A B L E W A T E R - W A Y

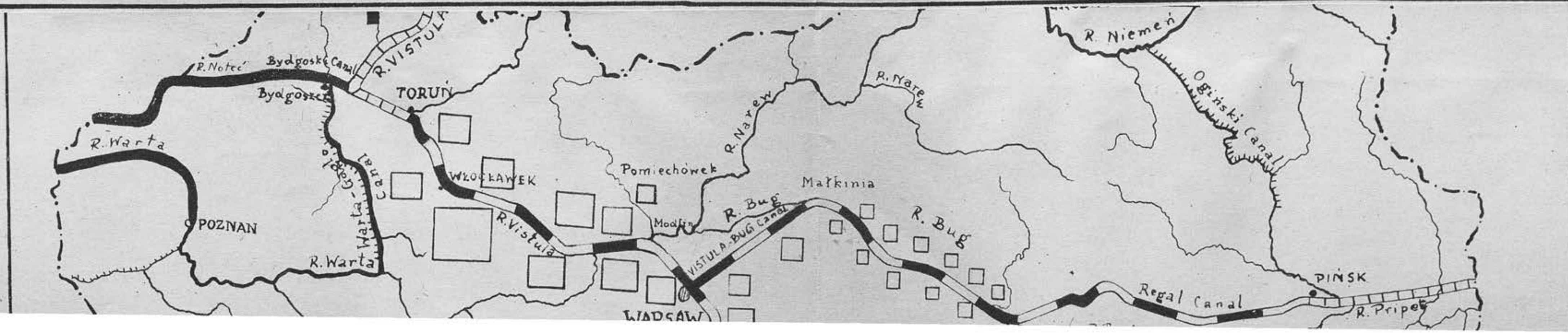

BALTIC SEA
VISTULA
BERLIN
ODER
WARSAW
PRIPET
KIEV
DNIEPER
VISTULA
SAN
DNIESTR
DANUBE
ODESSA
CHERSON
BLACK SEA
HYPSOMETRIC MAP
ALTITUDES ABOVE SEA LEVEL
150 - 500 m
500 -3000 m
PROP. AND EXISTING WATERWAYS

DROGA WODNA WZDŁUŻ TRANSEUROPEJSKIEJ DROGI ZACHÓD-WSCHÓD | PROPOSED GREAT TRANSEUROPEAN INLAND NAVIGABLE WATERWAY FROM THE WEST TO THE EAST.

Skan.Noteć i kan.Bydgoski	Proj. odc.Kanalizacji Wisły z 10 zakł.wod.-elek.	kan. Bug-Wisła	Proj.kanalizacja Bugu z 11 zakł.wodn.-el.	Przebudowa kan.Królewskiego	Regulacja Prypeci
Canalised Noteć	Proposed canalisation on r.VISTULA	Prop.Bug-Vistula can.	Proposed canalisation on the BUG	Improvement of Royal Canal	Completion of reg. on the PRYPEĆ







The West-East Inland Transeuropean Navigable Water-way (see sketch No.65,66).

The second scheme, which I propose for the Polish post-war development programme, is an inland navigable water-way, which would create a middle link across Polish territory, between:-

1. the canalisation system on the West, stretching from the Rhine to the Polish frontier, and
2. the system to the East, connecting the Polish frontier with the Black Sea, along the Dnieper.

Such a link across Poland would be 1,048 km in extent and the route would run over the lowest line of the principal European watershed in the Polesia area at an altitude of 142 m above sea level.

This is the lowest point along the whole length of the watershed extending from the Ural Mountains to the Pyrenees and, for this reason, the water-way which I propose, would be the most easily constructed to form a connecting link between the network of navigable waterways in Central Europe and the Danubian or Ukrainian systems and the Black Sea.

The great importance of this new waterway as a part of the West-East system lies in the ~~faxxx~~ fact that it would be available for heavy two-way transport of coal, stone, timber, corn etc. over long distances for home consumption and it would be capable of accepting very heavy international traffic.

It is likely that there would be a great deal of traffic by this route to and from Russia in preference to the long journey by sea, an instance of which is the transport of iron ore from Krivoi Rog in the Dnieper Basin, which hitherto has gone round via Gibraltar.

In order to form an idea of the proportions which the traffic may reach in the future, on this waterway, it is perhaps advisable to base the estimate, not on the traffic of the past twenty years, but rather on that carried between Russia and the West and Central Europe before the war of 1914-1918 . This amounted in all to about 35 million tons per annum.

In 1911 the following quantities of goods were carried:-

	Export	Import
1. at the Russian ports		
(a) on the Baltic	6,400,000 tons	6,600,000 tons
(b) on the Black Sea	5,600,000 "	3,000,000 "
(c) on the Azov Sea	4,200,000	450,000 "
2. by rail via the present Russo-Polish frontier	5,800,000 "	2,600,000 "
	22,000,000 tons	12,650,000 tons

Thus, the railway lines crossing the present Russo-Polish frontier, carried altogether 8,4 million tons of goods.

From the standpoint of navigable conditions the ~~Black Sea via Dnieper~~ West-East waterway, connecting the Rhine with Black Sea via Dnieper can be divided into three sections:-

1. the Western, 1074 km long;
2. the Central or Polish 1048 km long;
3. the Eastern or Ukrainian 1426 km long.

The Western Section.
By the completion of the Central Canal (Mittel-land Canal) by the Germans, the rivers Rhine, Weser, Elbe, Warta and Oder were joined up. A great part of this waterway is suitable for large craft of 1,000-1,200 tons, except on the Warta and Oder on which the conditions are not suitable for barges over 600 tons.

The Eastern Section.
This section is formed by the Dnieper and its tributary the Lower Prypet and as these rivers have slight slopes, 0.07 0/00 - 0.09 0/00 the existing regulation works have given satisfactory results for navigation.

These regulation works were commenced, before the war of 1914/18, at certain places on the Upper Dnieper and the navigable depth which was originally about 1 m was increased to 1.2 m, 1.8 m and finally to 2.0 m by additional dredging work.

The lower part of the river, 330 km long, below the cataracts called "porohy" had been partially regulated, on a stretch of about 50 km above Nikopol, before 1914. These works were continued, on a very extensive scale, during the second five years plan (1934-38) and included canalisation work on the part where the cataracts are situated.

The reservoir at Dnieprostroi, which was completed at this period covers the cataracts over a length of about 100 km, and the power station has an installation of 550,000 kW capacity.

Generally speaking the eastern section has been developed to accomodate craft of 1,600 tons.

The Central or Polish Section.

In order to form a suitable connecting link between the Western and Eastern sections a considerable amount of work will require to be undertaken in the Polish portion of the waterway.

This will involve river training, the canalisation of certain rivers and the construction of some new artificial canals.

It will also be necessary to reconstruct some of the existing canals to make them suitable for modern requirements. The following table shows the length, depth and number of locks on each section of the existing waterways with notes on the regulation work already undertaken or proposed for future development.

Table No. 26.

Stretch	Length km	Depth m	Number of locks	Remarks
Western section				
Rotterdam-Rhine-Ruhrort	215	3.5	-	
Rhine-Herne Canal	38	3.5	7	
Dortmund-Ems Canal	101	2.5	1	
Ems Can.-Weser	169	2.5	-	
Weser-Elbe	155	2.5	2	
Ihle-Plauen-Havel	135	1.8	6	
Hohenzollern Canal	94	2.5	6	
O d e r	49	1.5	-	regulation works in construction
W a r t a	69	1.4	-	
N o t e ć	49	2.5	12	
	1,074		34	

Table No. 27 .

Stretch	Length km	Depth m	Number of locks	Remarks
Central Section (proposed improvement to obtain a depth of 2.5 m)				
Noteć	142	1.5	11	proposed dredging works
Bydgoszcz Canal	27	2.0	9	" " "
B r d a	14	1.8	2	" " "
Vistula to Warsaw	259	0.9	-	" 10 locks
Vistula-Bug Canal	84	-	-	" 2 "
B u g	188	0.6	-	" 11 "
R e g a l Canal	214	0.9	7	" rebuilding
Prypet	120	0.8	-	" regulation
	1,048		31	
Eastern Section				
Prypet	375	0.8	-	canalisation works
Dnieper to Kiev	101	0.9	-	completed during 1934-1938
" to Aleksandrovka	625	1.0	-	" " "
" to Kakhovka	210	2.0	-	increased the depth for craft
" to Kherson	115	3.0	-	of 1,600 tons
	1,426		-	

The navigational conditions throughout the Central Section vary considerably but plans have already been worked out by the

Polish Water Service to deal with most of the problems. I have discussed these fully in my Polish report but in this thesis I wish to refer to additional schemes which I now propose for further improvements.

The improvement of the canalized Noteć and Bydgoszcz Canal.

The waterway along the canalized Noteć and Bydgoszcz canal is utilised by vessels up to 600 tons capacity and in the past the greatest quantity of traffic amounted to 537,000 tons per year.

The construction of the eastern part of the Bydgoszcz canal was commenced in the second half of the XVIII th century by the Polish Government and, after the first partition in 1772, Prussia resolved to complete the Polish project. The object in view was to divert the entire goods traffic, passing to the sea, from Danzig to Stettin, since Danzig was not in Prussian hands. Prussia at that time determined to ruin Danzig and her efforts were rewarded with almost complete success. Exports of corn and timber through Danzig fell to a minimum at the end of the XVIII th century.

This waterway at present comprises four sections:-

(a) the canalised Noteć, 79 km long, on the German-Polish frontier,

(b) the " " 65 km long in Poland,

(c) the Bydgoszcz Canal, 25 km long , which is now linked up with a new canal, completed in 1939 coming from the south from the river Warta at Konin, through the Gopło lake,

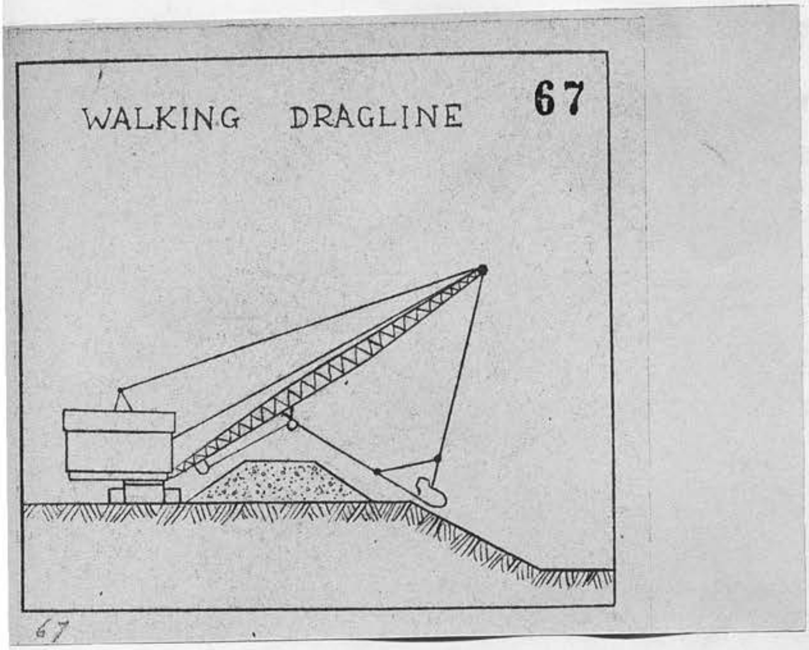
(d) the canalized Brda, 14 km long.

The whole length is provided with 22 locks,eleven of which are on the frontier section of the Noteć. Many of the locks were rebuilt at the end of the XIX th century and the remainder were altered in 1915 .

In order to make this waterway suitable for craft of 600 tons over its whole length at the lowest water level it is only necessary to carry out dredging operations. This would form a first stage,but later,as the development of the whole Polish network proceeded,it would be necessary to reconstruct this waterway to take craft of 1,000-1,200 tons.

Dredging work was carried out continuously on this waterway during the years 1893-1926 On a small scale but with modern equipment the final necessary depth could be obtained repidly. The suggested present first stage would consist mainly of the removal of silt,from the slopes and the bed, and some repairs to the locks.

For the removal of the silt I advise the use of a medium sized walking dragline excavator as this is capable of cleaning and deepening the existing canals and at the same time throwing up the banks or levees. For this purpose the boom of the machine is specially constructed with a guide pulley on the underside of the beam so that the bucket may be lifted clear of the banks and deposit the material on the levees behind the towing path.



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This work although carried out for improvement of the waterway would at the same time increase the protection against floods.

Allowing two years for the completion of this work it would be necessary to use 5 or 6 dragline excavators and the amount of material to be removed would be about 1,000,000 m^3.

The approximate cost of the excavation and repairs to the locks would be £. 160,000.

The proposed Vistula-Bug Canal.

Craft, proceeding to the south-east of Poland, after passing the last lock on the canalised Brda, near the junction with the canalised Vistula, would go upstream along the latter for a distance of 259 km and would rise above a total head of 45.5m, by means of 10 locks, to reach Warsaw. This stretch of the Vistula was described in Chapter No.IIc.3.Vol.2.

Further to the east it is proposed to construct an artificial canal to link up the Vistula at Warsaw, with the Bug at Małkinia and so with the whole of the eastern waterway system in the Prypet basin.

This artificial canal seems to be the only retional plan for obtaining this connection since it would not be possible to canalise the lower part of the river Bug owing to the unsuitable nature of its banks.

The new canal which I propose would accomodate craft up to 1,200 tons and, in addition, would offer several important advantages.

By this arrangement the two great navigable waterways, from South to North and from West to East would cross in Warsaw and not in Modlin at the mouth of the Bug.

This would give the capital city great opportunities for influence over the whole waterway network and a large share in the export and import traffic.

The Vistula-Bug canal, on its approach to Warsaw would enable us to build a commercial and industrial port, with a constant water level, on the right bank at the junction with the Vistula. Such a port is much needed by the city on account of the differences in levels which occur at present on the Vistula.

Another advantage which would be obtained by the building of this canal would be the shortening of the navigational distances in all directions. The distance from Warsaw to Małkinia along the proposed canal would be 84 km as compared with 170.5 km along the rivers Vistula and Bug and again for the transport from the West and from the lower Vistula the curtailment would be about 30%, a sufficiently remarkable figure.

This proposed canal would also be suitable for the utilisation of water power. The difference of water levels would be 17.3 m and the power available would amount to 30,000 kW with a yearly capacity of 180,000,000 kWh .

In my opinion it would not be satisfactory and indeed might be impossible to obtain a waterway suitable for craft of 1,200 tons simply by the regulation of the lower Bug, and even if this could be done, the utilisation of the water power could not be achieved at all.

In addition to the advantages already mentioned the canal would have great urban importance for the xxxx capital. Suburbs and holiday settlements could be erected along its route, as in other cities, thus developing the land on the river banks and in the forests through which it would pass.

From the last reach of the canalised Bug the canal would deviate on the left bank, at Małkinia, above weir No. 1.

Just below the start of the deviation an intake sluice gate would regulate the flow into the canal up to a maximum discharge of 210 m^3/s, which corresponds to the maximum consumption of the turbines installed on the canal. The lowest flows into the canal would be about 60 m^3/s in winter and 80 m^3/s in a dry summer.

The total head between the inlet level at Małkinia and the outlet

level at Warsaw would be 17.3 m and two locks would be required. The locks would be of the standard dimensions used on the Vistula, 105 m long, 20 m broad and 3.5 m deep .
The following table give the general data and the quantities of materials for the proposed Vistula-Bug Canal.

Table No. 28 .

1. Length of the canal	84 km
2. Total head	17.3 m
3. Number of locks	2
4. Available water power	30,000 kW
5. Yearly output of energy	180,000,000 kWh
6. Estimate of main materials:-	
(a) excavation	26,000,000 m^3
(b) concrete	100,000 m^3
(c) iron and steel construction	600 t
(d) steel-sheet piling 10-12 m in height	600 m
7. Workers required	14,000
during	3 years
8. Cost of construction	£.4,000,000

<u>The proposed canalisation works on the Bug between Małkinia and Brześć</u> (see sketch No. 66).

The fourth sector of the Transeuropean waterway from the West to East covers a distance of 188 km on the Bug from Małkinia to Brześć.

The area of the Bug basin to Małkinia, just above the start of the deviation of the Vistula-Bug Canal, amounts to 33,853 km^2, or about ~~on 22%~~ 40% of that on the Vistula at Warsaw.

The average slope on the Bug is fairly steep, being 70% of that on the middle sector of the Vistula, between Sandomierz and Warsaw.

Taking into account the fact that the regulation of the Bug, with its inadequate flow and fairly steep average slopes, may not give sufficient depths for boats of 1,200 tons, the only rational plan seems to be the canalisation of the river.

The alteration of the river Bug into a modern navigable waterway, by means of canalisation works, would present no difficulties calling for special attention.

Owing to geological and climatic conditions of the basin the water flow is not liable to sudden changes, particularly by increase of flood water and decrease of low flow. The ~~xxxxx~~ differences between them are relatively small, which is evident from the following table No. 29 . In addition there is practically no silt problem. The quantity of suspended silt and the bed load (dragged detritus) carried by the river during flood flow is very small and practically negligible.

Table No. 29.

Gauging station	Post km	Catchment km^2	Altitude of water level at flow: low	medium	high
Brześć	320.8	22,496	129.4	130.5	133.6
Kołodno-Łęgi	294.5	28,242	125.2	126.5	130.0
Małkinia	132.8	33,853	96.0	97.1	100.8
	L= 188 km			h = 33.4	

From these records kept at the gauging stations we can see that the maximum difference between the low water and high water levels varies from 4.2 m to 4.8 m , and these constitute the limits within which the Bug valley is almost protected against the flood.

These figures give also the permissible heads for the canalisation falls, without risk of flooding.

Taking into account that the movable dams would cause a back-water heightening, I propose a standard head of 3 m at medium water for each weir.

Thus the available water power would be 48,200 kW , with an average output of energy of 272 million kWh per annum.

Canalisation works on the Bug would require the construction of 11 movable weirs, 11 locks, and 11 hydro-electric stations, some data of which are summarized in the following table.

Table No. 30.

Nos. of weirs	Post km	Altitude of head water m above sea lev.	Dimension of locks	Hydro-electric stations capacity kW	Hydro-electric stations output million kWh
1.	132.0	100	(105.20.3.5)	5,000	28
2.	148.2	103	"	5,000	28
3.	164.5	106	"	5,000	28
4.	180.7	109	"	4,300	25
5.	197.0	112	"	4,300	25
6.	203.3	115	"	4,200	24
7.	229.5	118	"	4,200	24
8.	245.8	121	"	4,100	23
9.	262.0	124	"	4,100	23
10.	278.3	127	"	4,000	22
11. Kołodno	294.5	130	"	4,000	22
		Total		48,200	272

Locks. On the Bug the water supply problem for lock operations would not be difficult, as at every water level there would be an excess of water. I propose therefore to use the single lock type with a rhomb shape, which would afford an economy in the installation of the gates. These would be of the standard width of 12 m with a lock width of 20 m .

The hydro-electric stations, installed on the Bug, of low-head types, provided with Kaplan turbines, would collaborate with the steam power stations in the interconnection system of electrification. They would be mostly used to carry some of the base load parts of the demand, but sometimes, at low water seasons, especially in the winter, they might be used to carry peaks, or the upper part of the load curve, due to the daily or nightly storage action of the pondages, so that the turbine installations might be utilized to the utmost, thus saving steam consumption. These elastic working conditions covering the best positions in the load curve, either at the top or at the lower part, depending on the natural steam flow and the market requirements would call for maximum variation of level in the pondages within a margin of 27 cm above or below the normal retained level.

This subject is dealt with in Chapter No. IV which also contains the table of analysis for the power stations on the canalized Bug.

The hydro-electric working conditions and the utilisation factor, i.e. the ratio of power output to available power would be considerably improved if a storage reservoir were built on the Bug at Włodawa. This storage reservoir at post km 419.3 or 98 km above Brześć was planned before the war, with the great storage capacity of 500 million m^3. The cost of the storage reservoir at Włodawa would be relatively small, owing to the fact that it would include several natural lakes, of which Switeź and Pulmo are the largest.

The reservoir at Włodawa was designed:

(a) to reduce flood water to a flow which corresponds to a medium discharge;

(b) to improve the conditions for navigation considerably over the whole length of the Bug, and also of the Vistula;

(c) to improve the working conditions in the hydro-electric power stations on the Bug and the Vistula and to increase their output by an additional supply of water in times of drought.

Type of weirs. In the canalisation of the Bug where the falls are low and where the ice problem exists, bear-trap weirs or shutter weirs may be used.
The first type which I have proposed for the Vistula, would also be very suitable for the Bug. I have mentioned before, that this type of weir is a very simple installation, and may be very easily controlled from one point and special gangways or foot-bridges across the river can be dispensed with.
Moreover, a very slight difference in level between the head and tailwater is sufficient to raise the lowered weir, since the span under the leaves are brought into connection with the headwater.

An additional precautionary measure for the rapid raising of the dam, can be obtained, by the use of a compressed air installation, which involves only a small expense, and which provides very good means of flushing the space under the leaves from time to time , so that the unavoidable deposits of silt may be washed away.

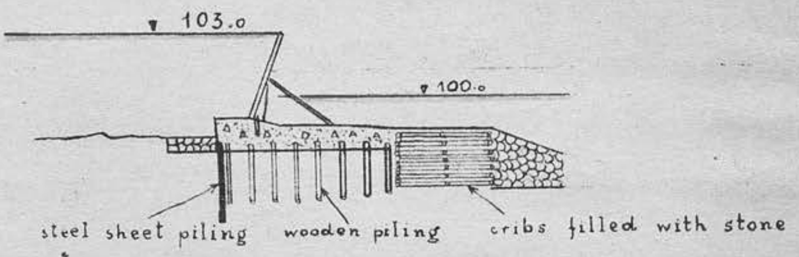
But these advantages although very important are not the chief ones for the river Bug , where the problem of ice is more difficult.

Owing to the fact that both leaves of the bear-trap can be built of wood which is a bad conductor of heat,this type of dam can easily be kept in good working condition as the water below the leaves has never been known to freeze even in times of severe frost. The working of the bear-trap weirs during the frost and particularly during times of evacuation of ice, which can be very easily effected, are the most interesting features of this type of movable dam , for low and medium heads. When the dam is fully raised the leaves can be interlocked in a simple manner , so that at any time the space under the leaves can be emptied , inspected and repaired , the head water level being fully maintained.

I believe that this type would be most suitable for the conditions on the Bug. However let us consider another alternative for the movable weir , which is already being successfully used in Poland on the Regal Canal.

(see sketch No. 68 the next page)

SHUTTER WEIR FOR THE BUG /ALT. 2/ 68



It is a shutter or wicket weir, on the Chanoine Pascand system improved in keeping with modern construction (see sketch No. 68). This system is very popular in the U.S.A. but in Europe, on the contrary, it was considered as being absolutely out-of-date and for a long time was not built, until an improved model was perfected on the Upper Seine in France about 1930-1932 , and in Poland about the same time.

The complete abandoning of this type of dam was fully justified, in spite of the other advantages of the system, by the fact that it is not possible to raise the shutters of the old types when the head is too great. But if the head does not exceed 6 m this type has many advantages.

1. The width of the sluiceways is in this case not restricted

by the permissible dimensions of the shutters or wickets, but solely by the span of the service bridges and in effect it is easy to build passes of over 50 m width;

2. The water pressure is borne directly by the floor and not by the piers as in most instances, with the result that the the closure-weight is much less than that of large gates;
3. The running-off of the water is done by overflowing and it is possible to incline the shutters in three positions, thus increasing the discharge, without completely lowering the dam. This overflowing discharge is advantageous from the standpoint of scouring downstream, and it is possible to restrict the length of the floor and consequently to lower the cost of the structure;
4. As the shutter is articulated on trestles it is possible for floating matter, ice or boats, that have broken adrift, to cross a weir without causing damage over the whole length;
5. In order to reduce the number of piers, and provide wide navigable passes, in the case of high water, there is a tendency, by constructing movable weirs of various types, to use large openings. Some times these openings (elements) have a width of 50 m or more between piers. Nevertheless, such dams with large elements have the drawback, in case of damage caused for instance by a blow from a barge, of not being able to be repaired without being dried. A much less costly design for a dam is with small elements such as shutters, having a width of 1 - 1.5 m.

6. The early shutter weirs were worked from barges, but such a process required a large staff and could not be rapidly carried out. This drawback can be avoided if the various successive elements are worked from a truck running on a flying bridge placed above the weir. Such a service bridge may be a very light structure as the working of the various shutters is successive, and the bridge never has to bear more than the strain caused by the water on a single element at one time.

I think that this type of weir with its advantages from the constructional point of view, and with some possible alterations to speed up its working, by using a manoeuvring truck driven electrically, may be considered as a good type in many cases.

Before the construction of new dams on the Bug, numerous tests on models would be necessary in order to study, in each case, the best shape of dam, the probable scour and the minimum thickness of foundations. The final design of the dams would be then adapted to the results of the tests.

In the following table No. 31 are summarized the general data of the arrangements of the proposed canalization works on the Bug and an estimate of main materials in approximate figures:-

Table No.31.

1.	Length of the canalized region	188 km
2.	Total head at medium water level	33.4 m
3.	Number of weirs,locks and power stations	11
4.	Average length of reaches	17.1 km
5.	Dimensions of locks:	
	(a) in length	105 m
	(b) in width	20 m
	(c) in depth	3.5m
6.	Water power available	48,200 kW
7.	Average yearly output of energy	272,000,000 kWh
8.	Total length of movable weirs	1,740 m
9.	Estimate of main materials:	
	(a) earth work in which excavation 15% in which consolidation of levees 85%	14,000,000 m^3
	(b) concrete	650,000 m^3
	(c) wooden piles	50,000 m^3
	(d) steel constructions	3,000 tons
	(e) steel sheet piling	3,500 m
10.	workers required	23,000
	during	3-4 years
11.	Cost of construction	£.5,400,000

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The reconstruction of the Regal Canal (Królewski Canal).

The fifth sector of the Central section of the Transeuropean waterway West-East is the Regal canal covering a distance of 214 km . This canal already exists, and consists of the canalized Muchawiec(tributary of the Bug) and canalized Pina (tributary of the Prypet) about 114 km in length, and of an artificial canal, 100 km long, which crosses the watershed at an altitude of 142 m above sea level, connecting the Vistula and Prypet waterway systems.

This waterway with total head of 19.5 m is provided with seven old fashioned sluice gates and must be rebuilt to make it suitable for modern requirements.

The Regal Canal affords such extensive possibilities for the future development of water transport, both for domestic and foreign trade, that it can be safely stated that the present traffic could be increased a hundred times.

This waterway must be regulated apart from any considerations of navigability,because of the losses in crops suffered by the population living in the vicinity of this route. The improvement works would be carried out at the same time as a large drainage canal in the marshy Polesia area.

In such an area every artificial waterway such as the Regal Canal must necessarily also serve for the drainage of the adjacent marshes and swamps.

During the years 1926-1933 a very thourough investigation was undertaken over the whole marshy region of Polesia by the Polish Water Service. This work comprised all necessary surveys and hydrometrical, geological and meteorological gaugings in order to find the best solution for the coincidental schemes for drainage, navigation and flood control.

On the bases of these surveys, some of the improvement works have already been commenced, by starting the rebuilding of the Regal Canal, by the regulation of the Prypet and by starting the artificial canal linking up the Horyń basin, where there are important basalt quarries, with the Prypet.

To complete the improvement of the Regal Canal the following works would be required:-

1. the deepening of the canal to a proper depth, by means of dredging;
2. the cleaning of the water supplying canal from the lakes Białe, Wolańskie and Orzechowskie to the dividing-reach;
3. the rebuilding of six locks (a seventh is already completed).

The general estimate for this development scheme has been calculated by Polish Waterway Service as £. 270,000 - .

The completion of the regulation of the Prypet from Pińsk to the Polish frontier.

Beyond the junction of the three rivers: Prypet, Pina and Strumień at Pińsk, the Prypet for a distance of 120 km is a navigable waterway accessible at medium water level to craft of 400 tons, except in some sectors where the navigable conditions are not suitable.

At present it serves as the only means of communication in the marshy Prypet valley.

Owing to the slight slopes (0.07 0/00 - 0.09 0/00) the Prypet belongs to that group of rivers, on which regulation works may be very successful and it is hoped, that we shall be able to get a sufficient depth to take large craft, after the completion of the training works.

The regulation of the Prypet however is a delicate task,because the problem is a very large and complex one,comprising not only the improvement of the river from an irrigation standpoint but also the problem of flood control.

The regulation of the river in order to obtain sufficient navigable depth at low water level would actually be the final stage of the whole process of river control.

The most urgent need in the Prypet valley is the regulation of the high water flow by narrowing the space between the embankments so that there may be a quicker evecuation of flood water and ice in spring.

It is not impossible however to combine these two problems and, by doing so, a considerable saving would be effected in carrying out the work.

Another important factor which must be taken into account in this area is that of drainage and the river control work must be done in such a way that the ground water is maintained at a proper level. With correct drainage it will be possible to develop large new agricultural areas but on the other hand suitable for 600 ton craft:-

1.	Length of regulation region	120 km
2.	Groins and training walls	350,000 m
3.	Stone	4,000,000 m^3
4.	Fascine	1,000,000 m^3
5.	W o r k e r s	5,000
6.	during	6 y e a r s
7.	Barges for transporting materials	100
8.	Dredging machines	10
9.	Cost of construction	£.1,440,000

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Auxiliary schemes in Poland.

In addition to the two above schemes for creating navigable waterways in Polish territory, along the Vistula and the West--East Transeuropean inland waterway, I propose a number of projects of an auxiliary nature. These relate to the construction of several storage reservoirs in order to regulate the flood flow and to control the movement of the large amount of silt which is carried down by the rivers.

Both of these factors influence considerably the stability of the bed and banks in the lower courses of the rivers and the working conditions of the hydro-electric stations and to minimize their effects it is essential that there should be co-ordination between all the technical operations in the upper and lower courses of the rivers.

I have discussed these projects in my Polish report but I submit as a supplement to my thesis, a description of the large storage reservoir, on the river Dunajec, and the water--power station at Rożnów which have been completed and for the design of which I was responsible.

The description was published in the French journal"Travaux" but I have also given a shortened translation in English.

THE SURVEY OF THE POSSIBILITIES OF HYDRO-ELECTRIC DEVELOPMENT IN THE POLISH POWER SYSTEM

The survey of the possibilities of hydro-electric development in the Polish power system.

The total available water power on the proposed canalized rivers in Poland amounts to:

1.On the Vistula...............	807,000 kW	with yearly output of 4,325 million kWh
2.On the Transeuropean waterway East-West	78,200 kW	" " 452 " "
3.by the completion of 7 storage reservoirs in the first stage (which are already in course of construction)	113,000 kW	" " 455 " "
T o t a l	998,200 kW	" "5,232 million kWh

These hydro-electric stations with those already existing would form part of the future programme of electrification in Poland and would be in close cooperation with the steam power stations so that interchange of ~~xx~~ energy between them may be made to a greater extent.

The interconnection of the steam and water stations by means of an extensive network of transmission lines would reduce the cost of power,but the actual profit which would accrue cannot at present be accurately calculated,as it depends on a number of unknown quantities/such as the future market requirements, the variation of the load factor, the necessary stand-by capacity, the possible fuel economy in steam stations etc.

From the point of view of this report however it is possible to give definite information regarding the effect of the regulation of flow in the rivers, and the extent to which the hydro-electric stations,which I propose,would assist in dealing with the general supply and with peak loads in particular. The supply of energy for peak loads is always very expensive since it is ~~xxxxxx~~ found that the top 20% of the annual load curve,containing the peaks, represents only from 1-2% of the total annual output of energy.

Thus for a single station the capacity factor i.e. the ratio of the average load per annum to the installed capacity may only be from 2-3% whereas the annual capacity factor for the electrification system as a whole may be from 30-40%.

It is obvious that the cost of supplying high peak loads from steam stations is very great and that water power stations, especially when provided with ample reservoirs, offer great advantages in this respect.

In the first stage of the Polish development it is proposed to complete seven peak load stations and at a later date, as the peak loads increase, to construct further stations in the Carpathian Mountains. This development would coincide with that of flood control and would extend over a considerable number of years.

It is also proposed to construct hydro-electric stations in connection with the canalisation of the rivers Vistula and Bug and,if these are provided with adequate pondages,they would form an important supplement to the steam stations and would probably be able to supply the average daily variation in peak load. They would also be able to supply the peak load energy during the periods of low flow.

The most economical results are obtained from such a combination of steam and "run-off" river stations,by working the system in two ways.

(a) During periods of medium flow the hydro-electric stations generate maximum energy and carry the basic load, while a portion of the steam stations deal with the peak load demands, with a consequent saving in fuel costs;

(b) At times of low flow the steam stations carry the basic load with a high load factor and the hydro-electric stations take the peak loads. In this way steam is used economically and in spite of low natural flow the hydro-electric stations can carry from 30-50% of the peak load capacity, which corresponds to from 10-15% of the daily energy, depending on the type of load curve and the load factor.

Such a combination generally results in a reduction of the total cost of power production.

In the case of the rivers Vistula and Bug the major part of the hydro-electric development, the dams, weirs and pondages would be constructed in the first instance for the purpose of improving the navigational conditions and a large proportion of their cost would fall on the transport services.

The actual cost of particular items varies considerably, depending on the topographical, hydrological and local conditions, for example, dams, pondages etc., 50-70%; power station 30-10% and expropriation 5-20%.

In order to obtain the highest utilization factor, ie. the ratio of possible power output to the power available at the site, the installation capacity should be fairly high. In earlier "run-off" river schemes it was usual to provide an installation capacity corresponding to the low water flow which was available for from 80 to 90% of the year. Such an arrangement is not suitable for a modern development based upon an interconnected system of electrification.

Modern hydro-electric stations are based on a much higher water flow , available during 50-30% of the year or , in other words , the installation capacity of the station is six to eight times greater than that corresponding to low water flow.

The ration for special peak load stations is very much greater , for instance at Porąbka it is 60 and at Rożnów 40 times greater than the low water capacity.

The provision of additional capacity in a hydro-electric station , to deal with peak loads and an increasing utilisation factor , is relatively low in investment cost as this is generally limited to electro-mechanical equipment only , whereas, in a steam station an increment cost must include the whole plant. It is found in practice that the increment cost in a steam station is 1.5 - 2 times greater than that for water power.

It may also be noted that the operating cost of a hydro-electric station represents only a small part of the total cost , the principal part being the fixed investment charges for the dam and pondages for which the depreciation period is very long , generally from 50-75 years.

When the construction work has been completed an increase in the installation does not greatly increase the total fixed charges and the operating costs are practically independent of the output of energy. This is a remarkable difference between of the water and steam power stations.

The modern trend in hydro-electric stations is to develop the maximum economical capacity and for this reason the initial storage or pondage must be designed to regulate and utilise the natural flow to the utmost extent.

I shall now examine the possibilities, in the above respects, of the proposed installations on the rivers Vistula and Bug and discuss the results of the calculations which are summarised in table Nos. 34-42.

It is extremely difficult to make a forecast of the future collaboration between water and steam power stations in Poland particularly for the first period of electrification, when the load factor for the whole area would be very variable from year to year and when the demands on the power stations would be subject to varying market requirements.

I have therefore based my calculations on a probable future load curve, when the load factor, ie. the ratio of the average power to the peak power would be fairly high, corresponding to a stabilised condition in industry.

The typical summer and winter load curves which I have chosen for consideration are shown in sketches Nos. 69 and 70.

and in these the load factor in summer is 65%, in winter 54% and the demand of peak capacity is estimated at 35% higher than in summer.

I have made calculations for the following five typical stations:-

I.	on the Vistula above the mouth of the Dunajec,		station	No.1
II.	" below " "		"	No.9
III.	" " the mouth of the San		"	No.19
IV.	" " " of the Bug		"	No.35
V.	on the Bug at Małkinia		"	No.1

The natural low discharges are calculated from the hydrographs and duration curves which have been developed for these rivers by the Polish Hydrographic Institute.

To these low discharges I have added the daily supply from the reservoirs which have been recently completed or are in course of construction and the improvement of the low flow of the Vistula by these additions in dry seasons and in winter would be as follows:-

1. from the reservoir(existing) on the Brynica at Kozłowa Góra $5 m^3/s$
2. " " on the Soła at Porąbka 12 "
3. " " on the Dunajec at Rożnów 34 "
4. " " (in construction) " " at Czorsztyn 6 "
5. " " on the San at Solina 26 "

The additions to the flow and the number of days on which the natural flow of the Vistula could be improved will be still further increased when the additional storage reservoir in the Carpathian Mountains are constructed for flood control and the regulation of flow.

Meantime, without taking into account this further improvement the available low flows, in the near future, for the five stations mentioned above are as follows:-

On the Vistula	for station	No. 1. at Kraków		30 m^3/s
"	"	No. 9 below the Dunajec		85 "
"	"	No. 19	" San	170 "
"	"	No. 35 at Płock		440 "
On the Bug	"	No. 1 at Małkinia		60 "

To meet all power demands it will be necessary to effect the maximum regulation of the natural flow in order that the hydro-electric stations may be available for use at the time of the peak load on the system.

The number of hours per day during which water could be used and the hours required for storing water in the pondages would differ and depend on the volume of natural flow.

From the tables Nos. 34, 35, 36, 37, 38, 39, 40, 41, 42 it is evident that pondage requirements, for increasing the natural flow to the value necessary for the maximum possible use of the installations vary from 33 cm in the Upper Vistula to 104 cm in the Lower Vistula and are about 30 cm on the Bug.

These figures correspond to the maximum variations in water level in pondages, above the normal head water level to obtain the necessary storage of water during the night and part of the day, when the flow would not be used for the generation of power.

These figures are relatively small and indicate that the pondages, which I have suggested, would be adequate for economical collaboration between "run-off" river stations and steam power stations, with changeable operations in which the water power stations carry the basic load at medium water, and the peak load at low water.

Tables Nos. 32 33 show the final results of these calculations and indicate the maximum power and maximum daily output which the 52 proposed power stations, on the canalised rivers Vistula and Bug, would develop.

Table No.32 A Power capacity

Season	Hydro-electric stations kW	%	Auxilary power from steam stations kW	%	Total peak demand kW	%
Summer	622,500	70.5	262,900	29.5	885,200	100
Winter	827,400	70.1	351,600	29.9	1,179,000	100

Table No.33 B. Output capacity

Season	Hydro-electric stations kWh thousand	%	Auxilary power from steam stations thousand kWh	%	Total demand per day thousand kWh	%
Summer	7,834	57	5,916	43	13,750	100
Winter	7,726	50.9	7,524	49.1	15,250	100

The following index refers to information contained in tables Nos. 34 – 42 and the corresponding sketches Nos. 69 and 70.

These tables give data regarding the distribution of loads between hydro-electric stations and steam stations under varying conditions of flow in the river:-

"A" the case , when the flow is greater than that required for the average demand during the day. Some of the excess flow must be discharged over the spillway;

"B" the case, when the flow is equal to that corresponding to the average demand flow. No loss of power occurs and no auxilary power required;

"C_1" the case, when the flow is rather low, but not the lowest i.e. 38%-50% of that corresponding to the average demand during the day, and also if the hydro-electric stations have to carry base loads. Not an economic solution;

"C_2" the same case with an available flow as in "C_1", but with correct assumption , that the hydro-electric stations would carry the upper part of the daily load curve , including the peak load. In this case the necessary auxilary steam power is very much lower than in the case "C_1";

"D" the case, when the river flow is the lowest available in the summer time , and when hydro-electric stations would carry the peak load;

"E" the case, when the river flow is the lowest in winter time and also when the hydro-electric stations would carry the peak loads which at that time are higher than in summer.

Further explanation of marks in these tables:-

(1) The required market power capacity in kW ;

(2) The load factor ;

(3) The daily demand energy capacity in kWh ;

(4) The daily available capacity of energy in the river in kWh ;

(4a) The " " " of energy in the river in percentages of the total demand capacity of energy ;

(5) The power capacity in the river which corresponds to the uniform flow during the day in kW ;

(5a) The power capacity in the river which corresponds to the uniform flow during the day in percentages of the demand peak capacity ;

(6) The necessary and possible collection of water in the pondages reduced to equivalent kilowatt-hours ;

(6a) The required pondage energy in percentages to the total daily demand energy ;

(7) The maximum available power capacity in the day obtained from the power in the stream and that available from the pondage ;

(7a) ditto in percentages to the installation capacity in hydro-electric station ;

(7b) ditto in percentages to the peak load capacity ;

(8) The flow which cannot be used and must be washed over the spillway reduced to kWh equivalent ;

(9) The necessary variation in the height of water level in the pondage above the normal head water level to obtain the required pondage energy for peak purposes in cm ;

(10) The required auxilary output capacity from steam stations in kWh ;

(10a) ditto in percentages of the total daily demand ;

(11) The required auxilary power capacity from steam power stations in kW ;

(11a) ditto in percentages of the installation capacity in hydro-electric stations ;

(11b) ditto in percentages of the total daily peak load capacity ;

(12) The average power capacity in the steam station).

Table No.34 Typical distribution of load for the stations on Upper sector of the Vistula above the mouth of the Dunajec.
Water power station No.1. at Kraków
the installation capacity 4,000 kW
max.discharge of turbines Q= 123 m^3/s

		187 m^3/s	80 m^3/s	main low flow alt.1	main low flow alt.2	lowest flow in summer	lowest flow in winter
		A	B	C_1	C_2	D	E
	Power and output capacity demand						
1.	kW	4,000	4,000	4,000	4,000	4,000	5,320
2.	%%	65	65	65	65	65	54
a.	kW	2,600	2,600	2,600	2,600	2,600	2,860
3.	kWh	62,200	62,200	62,200	62,200	62,200	68,800
	Hydro-electric station						
4.	kWh	68,000	62,200	36,200	36,200	23,500	23,500
a.	%%	109	100	58	58	38	34.8
5.	kW	2,850	2,600	1,520	1,520	980	980
a.	%%	71	65	38	38	24.5	24.5
6.	kWh	6,550	11,200	3,270	10,600	8,100	11,200
a.	%%	10.5	18	5.3	17	13	16.3
7.	kW	4,000	4,000	2,370	2,840	2,180	3,120
a.	%%	100	100	59	71	54.5	78.3
b.	%%	100	100	59	71	54.5	58.5
8.	kWh	5,800	-	-	-	-	-
9.	cm	18	31	9	29	23	31
	Steam power station						
10.	kWh	--	--	26,000	26,000	38,700	45,300
a.	%%	--	--	42	42	62	65.5
11.	kW	--	--	1,630	1,160	1,820	2,200
a.	%%	--	--	41	29	45.5	55
b.	%%	--	--	41	29	45.5	41.5
12.	kW	--	--	1,080	1,080	1,610	1,890

Table No. 35 Typical distribution of load for the stations on Upper sector of the Vistula below the mouth of the Dunajec.
Water power station No.9 in post km 183
The installation capacity 10,000 kW
max. discharge of turbines Q= 305 m^3/s

		216 m^3/s	198 m^3/s	main low flow		lowest flow in	
				alt.1	alt.2	summer	winter
		A	B	C_1	C_2	D	E
		Power and output capacity demand					
1.	kW	10,000	10,000	10,000	10,000	10,000	13,300
a.	%%	65	65	65	65	65	54
2.	kW	6,500	6,500	6,500	6,500	6,500	7,200
3.	kWh	156,000	156,000	156,000	156,000	156,000	172,000
		Hydro-electric station					
4.	kWh	170,000	156,000	91,000	91,000	67,000	67,000
a.	%%	109	100	58	58	43	39
5.	kW	7,100	6,500	3,800	3,800	2,800	2,800
a.	%%	71	65	38	38	28	28
6.	kWh	16,400	28,000	8,200	26,000	22,300	28,700
a.	%%	10.5	18	5.3	16.6	14.3	16.7
7.	kW	10,000	10,000	5,900	7,100	5,800	8,150
a.	%%	100	100	59	71	58	81.5
b.	%%	100	100	59	71	58	61.4
8.	kWh	14,000	-	-	-	-	-
9.	cm	28	47	14	43	38	47
		Steam power station					
10.	kWh	--	--	65,000	65,000	89,000	105,000
a.	%%	--	--	42	42	57	61
11.	kW	--	--	4,100	2,900	4,200	5,150
a.	%%	--	--	41	29	42	51.5
b.	%%	--	--	41	29	42	38.6
12.	kW	--	--	2,700	2,700	3,700	4,400

Table No. 36 Typical distribution of load for the stations on the Middle sector of the Vistula, below the mouth of the San.
The installation capacity 15,000 kW
max. discharge of turbines Q= 460 m^3/s

Water power station No 19 in post km 358

		325 m^3/s	300 m^3/s	main low flow alt.1	main low flow alt.2	lowest flow in summer	lowest flow in winter
		A	B	C_1	C_2	D	E
		Power and output capacity demand					
1.	kW	15,000	15,000	15,000	15,000	15,000	20,000
a.	%%	65	65	65	65	65	54
2.	kW	9,750	9,750	9,750	9,750	9,750	10,800
3.	kWh	234,000	234,000	234,000	234,000	234,000	257,000
		Hydro-electric station					
4.	kWh	255,000	234,000	157,000	157,000	133,000	133,000
a.	%%	109	100	67	67	57	52
5.	kW	10,650	9,750	6,525	6,525	5,550	5,550
a.	%%	71	65	43.5	43.5	37	37
6.	kWh	24,600	42,000	17,300	42,500	37,500	52,000
a.	%%	10.5	18	7.4	18.1	16	20.2
7.	kW	15,000	15,000	9,950	11,800	10,500	14,350
a.	%%	100	100	66.2	79	70	95.4
b.	%%	100	100	66.2	79	70	71.8
8.	kWh	21,000	-	-	-	-	-
9.	cm	34	57	24	58	52	70
		Steam power station					
10.	kWh	--	--	77,000	77,000	101,000	124,000
a.	%%	--	--	33	33	43	48
11.	kW	--	--	5,050	3,200	4,500	5,650
a.	%%	--	--	33.8	21	30	37.6
b..	%%	--	--	33.8	21	30	28.2
12.	kW	--	--	3,200	3,200	4,200	5,170

Table No. 37 Typical distribution of load for the stations on the Lower sector of the Vistula.
Water power station No.35, post km 627.1 at Płock
The installation capacity 40,000 kW
max. discharge of turbines 1,100 m^3/s = Q

		790 m^3/s	720 m^3/s	main low flow alt.1	main low flow alt.2	lowest flow in summer	lowest flow in winter
		A	B	C_1	C_2	D	E
Power and output capacity demand							
1.	kW	40,000	40,000	40,000	40,000	40,000	40,000
a.	%%	65	65	65	65	65	54
2.	kW	26,000	26,000	26,000	26,000	26,000	28,730
3.	kWh	624,000	624,000	624,000	624,000	624,000	686,000
Hydro-electric station							
4.	kWh	681,600	624,000	432,000	432,000	384,000	384,000
a.	%%	109	100	69	69	61.5	56
5.	kW	28,400	26,000	18,000	18,000	16,000	16,000
a.	%%	71	65	45	45	40	40
6.	kWh	65,800	112,000	53,000	112,000	109,000	146,000
a.	%%	10.5	18	8.5	18	17.5	21.2
7.	kW	40,000	40,000	28,000	32,000	29,750	39,200
a.	%%	100	100	70	80	74.5	98
b.	%	100	100	70	80	74.5	73.6
8.	kWh	57,600	-	-	-	-	-
9.	cm	47	80	38	80	78	104
Steam power station							
10.	kWh	-	-	192,000	192,000	240,000	302,000
a.	%%	-	-	31	31	38.5	44
11	kW	-	-	12,000	8,000	10,250	14,000
a.	%%	-	-	30	20	25.5	35
b.	%%	-	-	30	20	25.5	26.4
12.	kW	-	-	8,000	8,000	10,000	12,600

Table No. 38 Typical distribution of load for the stations on the Bug.
Water power station No.1 post km 132 at Małkinia
The installation capacity 5,000 kW
max discharge of turbines Q= 203 m^3/s

		$145\ m^3/s$	$132\ m^3/s$	main low flow alt.1	main low flow alt.2	lowest flow in summer	lowest flow in winter
		A	B	C_1	C_2	D	E
Power and output capacity demand							
1.	kW	5,000	5,000	5,000	5,000	5,000	6,650
a.	%%	65	65	65	65	65	54
2.	kW	3,250	3,250	3,250	3,250	3,250	3,590
3.	kWh	78,000	78,000	78,000	78,000	78,000	86,000
Hydro-electric station							
4.	kWh	85,000	78,000	60,000	60,000	47,400	35,400
a.	%%	109	100	77	77	61	41.2
5.	kW	3,550	3,250	2,500	2,500	1,975	1,475
a.	%%	71	65	50	50	39.5	29.5
6.	kWh	8,200	14,000	8,500	14,300	13,600	15,000
a.	%%	10.5	18	10.9	18.3	17.4	17.5
7.	kW	5,000	5,000	3,850	4,250	3,680	4,225
a.	%%	100	100	77	85	73.6	84.5
b.	%%	100	100	77	85	73.6	63.5
8.	kWh	7,000	-	-	-	-	-
9.	cm	15	26	15.5	26	25	27
Steam power station							
10.	kWh	--	--	18,000	18,000	30,600	50,600
a.	%%	--	--	23	23	39	58.8
11.	kW	--	--	1,150	750	1,320	2,425
a.	%%	--	--	23	15	26.4	48.5
b.	%%	--	--	23	15	26.4	36.5
12.	kW	--	--	750	750	1,280	2,110

Table No. 39 The total distribution of load for 52 hydro-electric stations on the Vistula and Bug in the case "B" the flow is equal to that corresponding to average demand flow.

	Group of water power stations 1	2	3	4	5	Total
Nos. of stations	8	7	16	8	13	52
Inst. cap. kW	38,000	89,000	325,000	355,000	78,200	885,200
%% of total	4.3	10	36.8	40	8.9	100
Power and output demand						
1. kW	38,000	89,000	325,000	355,000	78,200	885,200
2. %%	65	65	65	65	65	65
a. kW	24,700	57,850	211,250	230,750	50,830	575,380
3. kWh thous.	580	1,385	5,040	5,525	1,220	13,750
Hydro-electric stations						
4. kWh thous.	580	1,385	5,040	5,525	1,220	13,750
a. %%	100	100	100	100	100	100
5. kW	24.700	57,850	211,250	230,750	50,830	575,380
a. %%	65	65	65	65	65	65
6. kWh thous.	105	250	905	990	220	2,470
a. %%	18	18	18	18	18	18
7. kW	38,000	89,000	325,000	355,000	78,200	885,200
a. %%	100	100	100	100	100	100
b. %%	100	100	100	100	100	100
9. cm	30-35	40-50	50-60	70-80	20-25	∽ 58
Steam power station						
10. kWh thous.	-	-	-	-	-	-
a. %%	-	-	-	-	-	-
11. kW	-	-	-	-	-	-
11a. %%	-	-	-	-	-	-
b. %%	-	-	-	-	-	-
12. kW	-	-	-	-	-	-

Table No. 40 The total distribution of load for 52 hydro-electric stations on the Vistula and Bug in the case "C_2" the uniform flow in the river correspond to the main-water flow.

	Group of water power stations					Total
	1	2	3	4	5	
Nos.of stations	8	7	16	8	13	52
Inst.cap. kW	38,000	89,000	325,000	355,000	78,200	885,200
%% of total	4.3	10	36.8	40	8.9	100
Power and output demand						
1. kW	38,000	89,000	325,000	355,000	78,200	885,200
2. %%	65	65	65	65	65	65
a. kW	24,700	57,850	211,250	230,750	50,830	575,380
3. kWh thous.	580	1,385	5,040	5,525	1,220	13,750
Hydro-electric stations						
4. kWh thous.	336	800	3,380	3,820	940	9,276
a. %%	58	58	67	69	77	67.5
5. kW	14,400	33,900	141,000	160,000	38,000	387,300
a. %%	38	38	43.5	45	50	43.7
6. kWh thous.	99	230	920	990	223	2,462
a. %%	17	16.6	18.1	18	18.3	17.9
7. kW	27,000	63,000	256,000	284,000	66,500	697.500
a. %%	71	71	79	80	85	78.9
b. %%	71	71	79	80	85	78.9
9. cm	30-35	35-45	50-60	70-80	20-25	∾ 57
Steam power station						
10. kWh thous.	244	585	1,660	1,705	280	4,474
a. %%	42	42	33	31	23	32.5
11. kW	11,000	26,000	69,000	71,000	11,700	187,600
a. %%	29	29	21	20	15	21.2
b. %%	29	29	21	20	15	21.2
12. kW	10,200	24,400	69,000	71,000	11,700	185,200

Table No. 41 The **total** distribution of load for 52 power stations on the Vistula and Bug in the case "D" when the rivers flow is the lowest available in summer.

	Group of water power stations 1	2	3	4	5	Total
Nos. of stations	8	7	16	8	13	52
Inst. cap. kW	38,000	89,000	325,000	355,000	78,200	885,200
%% of total	4.3	10	36.8	40	8.9	100
Power and output demand						
1. kW	38,000	89,000	325,000	355,000	78,200	885,200
2. %%	65	65	65	65	65	65
a. kW	24,700	57,850	211,250	230,750	50,830	575,380
3. kWh thous.	580	1,385	5,040	5,525	1,220	13,750
Hydro-electric stations						
4. kWh thous.	220	597	2,870	3,400	747	7,834
a. %%	38	43	57	61.5	61	57
5. kW	9,300	24,900	120,000	142,000	31,000	327,200
a. %%	24.5	28	37	40	39.5	37
6. kWh thous.	76	197	810	970	212	2,265
a. %%	13	14.3	16	17.5	17.4	16.4
7. kW	20,700	51,800	227,000	265,000	57,800	622,300
a. %%	54.5	58	70	74.5	73.6	70.5
b. %%	54.5	58	70	74.5	73.6	70.5
9. cm	15-25	35-40	45-50	70-80	20-25	~54
Steam power station						
10. kWh thous.	360	788	2,170	2,125	473	5,916
a. %%	62	57	43	38.5	39	43
11. kW	17,300	37,200	98,000	90,000	20,400	262,900
a. %%	45.5	42	30	25.5	26.4	29.5
b. %%	45.5	42	30	25.5	26.4	29.5
12. kW	15,000	32,800	90,500	89,000	19,700	247,000

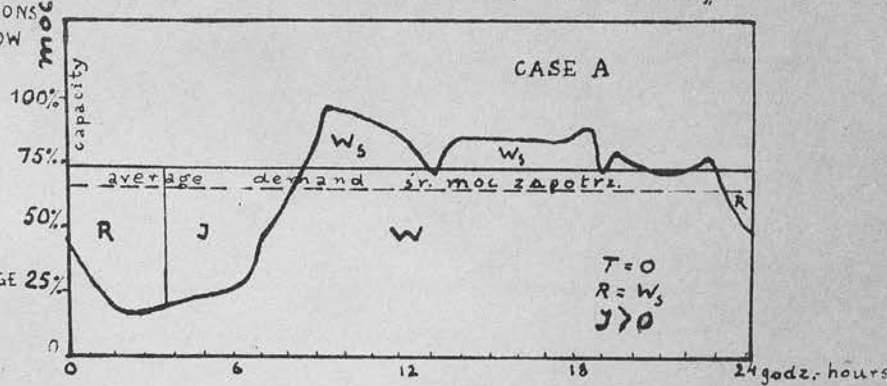
Table No. 42 The total distribution of load for 52 power stations of the Vistula and Bug in the case "E" when the rivers flow is the lowest available in winter.

		Group of water power stations					Total
		1	2	3	4	5	
Nos.of stations		8	7	16	8	13	52
Inst.cap.	kW	38,000	89,000	325,000	355,000	78,200	885,200
%% of total		4.3	10	36.8	40	8.9	100
Power and output demand							
1.	kW	50,300	119,200	433,000	472,000	104,500	1,179,000
2.	%%	54		54	54	54	54
a.	kW	27,400	64,000	234,000	255,000	56,000	637,000
3.	kWh thous.	650	1,535	5,610	6,110	1,345	15,250
Hydro-electric stations							
4.	kWh thous.	224	599	2,920	3,430	553	7,726
a.	%%	34.5	39	52	56	41.2	50.9
5.	kW	9,300	24,900	120,000	142,000	23,000	319,200
a.	%%	24.5	28	37	40	29.5	36
6.	kWh thous.	106	256	1,135	1,295	236	3,028
a	%%	16.3	16.7	20.2	21.2	17.5	19.9
7.	kW	29,700	72,600	311,000	348,000	66,100	827,400
a.	%%	78	81.5	95.4	98	84.5	93.2
b.	%%	59	61.4	71.8	73.6	63.5	70.1
9.	cm	30-35	40-50	60-70	95-105	25-30	72
Steam power station							
10.	kWh thous.	426	936	2,690	2,670	792	7,524
a.	%%	65.5	61	48	44	58.8	49.1
11.	kW	20,600	46,600	122,000	124,000	38,400	351,600
a.	%%	55	51.5	37.6	35	48.5	39.8
b.	%%	41	38.6	28.2	26.4	36.5	29.9
12.	kW	17,800	39,000	112,000	111,000	33,000	314,000

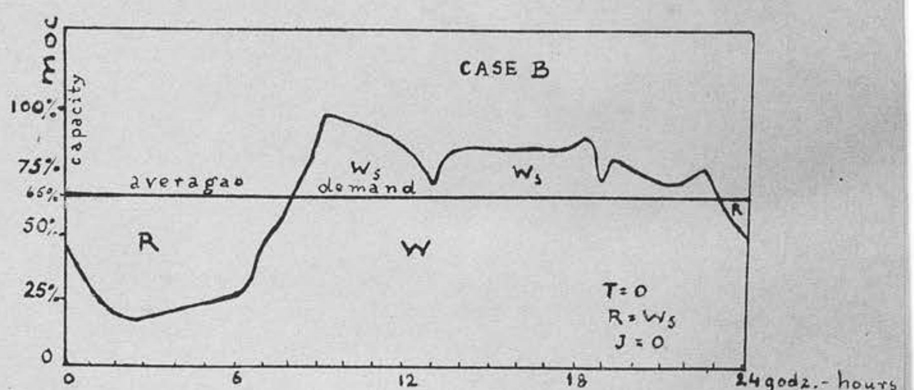
DISTRIBUTION OF LOADS BETWEEN HYDRO-ELECTRIC AND STEAM STATIONS UNDER VARYING CONDITIONS OF FLOW IN THE RIVER.

W - WATER POWER
T - STEAM "
R - PONDAGE FILLING
W_s - WATER POWER FROM PONDAGE
J - LOST WATER POWER.

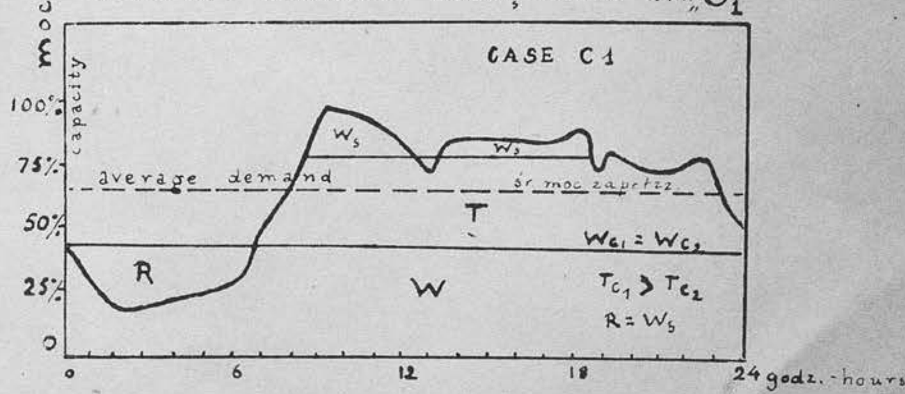
PODZIAŁ POKRYCIA OBCIĄŻENIA WYP. „A"



PODZIAŁ POKRYCIA OBCIĄŻENIA WYP. „B"



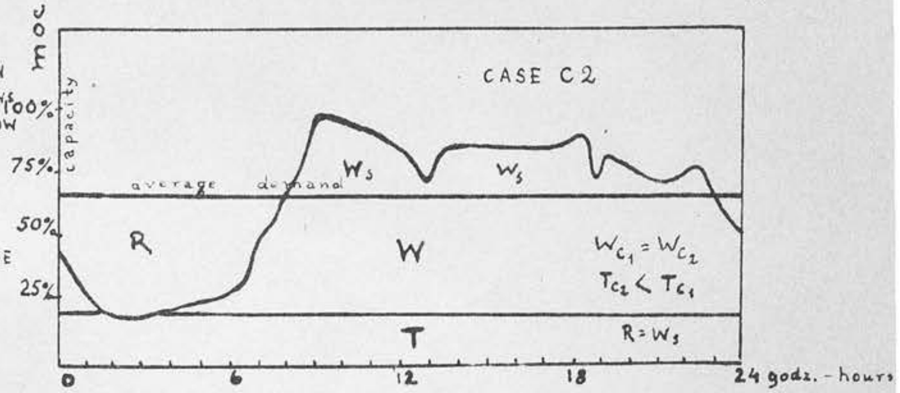
PODZIAŁ POKRYCIA OBCIĄŻENIA WYP. „C₁"



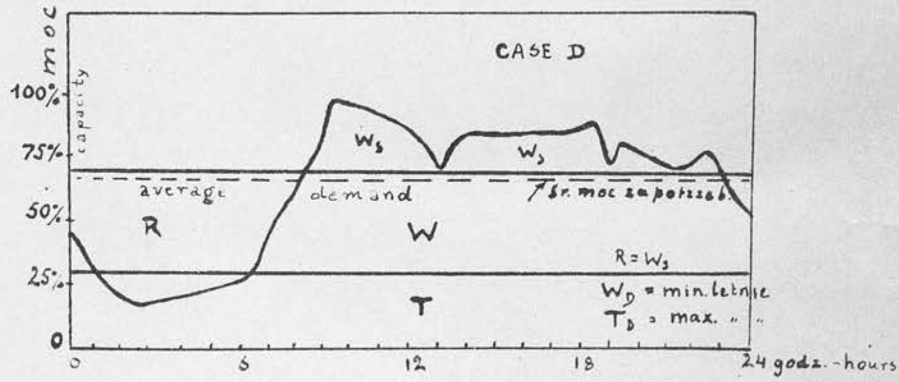
DISTRIBUTION OF LOADS BETWEEN HYDRO-ELECTRIC AND STEAM STATIONS UNDER VARYING CONDITIONS OF FLOW IN THE RIVER

- W - WATER POWER
- T - STEAM "
- R - PONDAGE FILLING
- W_s - WATER POWER FROM PONDAGE

PODZIAŁ POKRYCIA OBCIĄŻENIA WYP. „C_2"

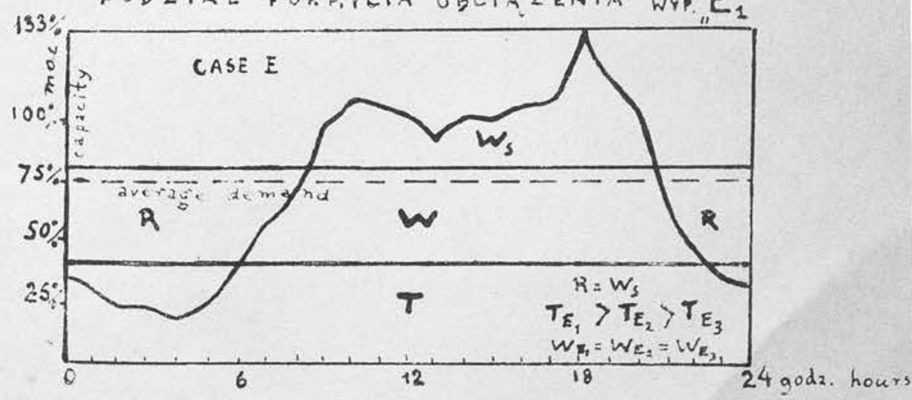


PODZIAŁ POKRYCIA OBCIĄŻENIA WYP. „D"



MINIMA ZIMOWE

PODZIAŁ POKRYCIA OBCIĄŻENIA WYP. „E_1"



A SHORT ENQUIRY INTO THE RELATIVE COSTS OF WATERWAY AND RAILWAY TRANSPORT

A short enquiry into the relative costs of waterway and railway transport.

It is generally recognized that one of the principal factors in the economic development of a country is a transport network, in which the various means of communication cooperate in harmony.

General principles of cooperation must be established so that each means of communication may play the role best suited to the kind of transport with which it has to deal to ensure, the greatest national profit.

In order that all means of transport may work smoothly together, there must be careful consideration of all their elements such as weight, volume and value of the loads, the distance of haul and the frequency of the journeys.

For heavy traffic of goods of lesser value over long distances running in a definite constant direction the inland waterways are the most effective means of transport in spite of a heavy initial capital cost.

Goods of lesser value can compete in the more remote markets of consumption only when the freight charges are in accordance with the costs of production.

The profit accruing to agriculture and industry and indirectly through these to trade from cheap water-transport, proves the economic value of inland waterways.

At the end of this Chapter I have shown the profits which would be obtained by the use of the proposed modern inland waterways in Poland, in order to give some idea of the economic value o-f this scheme.

The calculation of the saving due to the differences in ~~expkm~~ exploitation costs between water and railway transport is based on the principles and statistics presented, in a brief summary, below.

The primary measure of the economic value of a waterway system is the saving in transport costs which it effects.

In the cost of water transport the charges of interest on capital investment in the waterway improvements plus the annual cost of operation and maintenance should be included.

From these charges a part of the investment cost which corresponds to the improvements for other purposes such as flood control, water power utilisation and drainage problems may be excluded.

Many statistics are available regarding the costs of water and railway transport but they are not always strictly comparative as all countries do not take the same items of cost into account. In this respect I may mention, in particular the total capital expenditure, reckoned over a long period of years, for the improvement of a river and the proportion of that expenditure which may be charged to the navigation service or to flood control, irrigation etc.

The assessment of these charges varies widely in different countries.

The remaining items of water transport costs also vary in different countries, due to the local conditions and standard of life, but are more comparable.

I shall now examine some examples of these costs.

Operating cost.- Operating costs include the costs of wages, fuel, lubrication, repairs to craft, supervision and miscellaneous charges.

The wage item depends upon the size of the train of barges employed. For a train, which would be perhaps the normal in Poland, consisting of a tug and barges with a total capacity of 5,000 tons, the crew would comprize 20-25 men. The wages of towboat crews vary on an average rate from £. 200 - 300 per year and per man; the barge-men's wages may vary from £.40 (in Poland) to £. 180. To this must be added subsistence costs, from 3 to 5 sh per man per day.

Fuel and oil requirements are best expressed in ton-km of cargo transported per barrel. For towboats worked by Diesel -engines this ratio varies from 4,000 to 8,000 km t-km per barrel of fuel and it depends upon the slopes of the rivers or canals and navigable depths.

Lubricating costs for towboats with Diesel engines vary from 0.2 to 0.4 d per HP and per full day of service.

The costs of repairs to barges depends chiefly upon the service for which they are used. If used for handling bulk cargo, which is unloaded by heavy machinery, the total annual costs are higher, being about 5% of the first cost of the barges, and in the case of package-freight barges it is much less, about 1%. Costs of supervision vary with the character of service and the area covered by the water system, and may vary from 1% to 2% of the cost of the crews.

Equipment costs. Although there is a wide variety in costs of towboats, due to differences in size and class of operating machinery, the modern type of steam tow-boats varies as follows, in approximate figures:-

for towboats with capacity	average cost per HP
from 500 to 1,000 HP	£.50
" 1,000 to 1,500 HP	£.45
" 1,500 to 2,000 HP	£.40 .

Towboats using Diesel engines are slightly higher in cost. There is also a wide range in the costs of barges, but they may be grouped, approximately, as follows:-

Hopper type	£. 3-4	per ton of cargo capacity
Deck barges	£. 4-5	" " " "
Package freighters	£. 6-8	" " " "

The fixed charges which include all items, such as interest, depreciation, insurance, taxes and annual overhaul usually applied to transport cost are 16-18% of the original cost of towboats and barges.

Incidentally, these equipment costs are much less in water, than in railway transport. I have calculated that under Polish con-

conditions the craft charges would be 40% cheaper than that of railway rolling stock. Thus for each million t-km of transport the saving effected on the purchase of the means of transport alone would be about £.1,000 .

Returning now to the whole costs of water transport and taking into account the items of operating and equipment costs, these costs may vary from 0.02 to 0.1 d per t-km, depending on the distances, wages and prices of equipment and fuel and also very much on the load factor.

The load factor in water transport is the ratio between the total number of ton-km resulting from one year's operation of a unit and the theoretically possible total output.

Thus the load factor, the difference between these two figures, springs from the normally lower average loading of barges and towboats as compared with the theoretical load capacity. In addition the number of hours during the year in which the craft is in commission is less than the total theoretical number of hours and a deduction must be made for terminal and mechanical delays, and for channel delays, such as time lost in passing through locks, etc.

The load factor varies considerably on the existing waterways, the lowest recorded being 20% for towboats and only 6% for barges.

The average figures are about 40% for towboats and 25% for barges and the maximum figures, recorded in Germany before the war, were about 50% greater than the average.

Thus the load factor may influence the exploitation cost of w water transport considerably.

Finally I should like to mention some cost data of water transport on existing waterways.

In U.S.A. the cost of water transport on an average amounted to about 0.05 d per t-km, as opposed to the average cost of rail transport 0.33 d per t-km .

In this comparison the cost of water transport requires adjustment as the water distances are generally longer than those by rail. This coefficient on an average is about 1.5 , thus the comparable cost of water transport increases to 0.075 d per t-km .

The cost on the different kinds of waterways varied considerably for instance:

on the canalized rivers	0.09 d/per t-km
on the great free rivers	0.033 " " "
on the great lakes	0.02 " " " .

On particular waterways in U.S.A. the following costs of transport have been recorded:-

on the Monongahela River		0.05 d per t-km
on the St.Marys Falls canal		0.036 d " "
on the Mississippi	from	0.03 d " "
	to	0.05 d " "
on the New-York Barge canal		0.09 d " " .

In Germany, where there are chiefly canalized rivers or artificial canals, and where the average distances of water transport are not so great, the cost of water transport varies from 0.06 to 0.09 d per ton-km .

In Poland we have developed the following formula for the cost of water transport, based on the local conditions:

$$C = \left(\frac{111}{n} + 0.29\right) \times 0.01 \text{ d per t-km}$$

where "n" is the distance of haulage.

To this cost should be added the charges of interest on capital investment which would be different for particular distances, but on an average may estimated as 0.06 d per t-km . Thus the total cost of water-transport would vary in the region of 0.1 d per t-km, and is from 1/2 to 1/3 of the cost of railway transport.

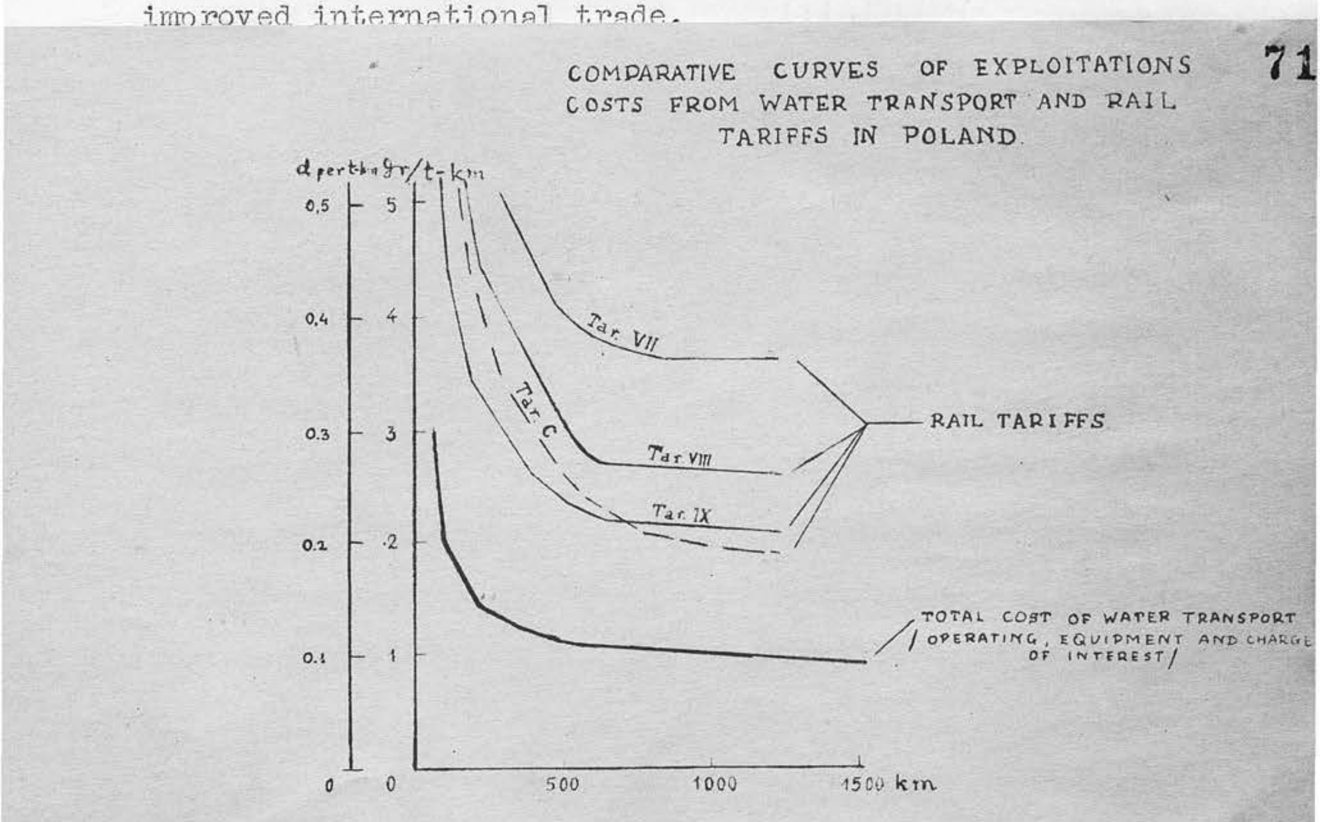
Taking into account some modifications in the cost of water transport based on recent prices, I have developed comparative curves of exploitation costs from recent water transport and rail ~~traffic~~ tariffs in Poland; see sketch No. 71 .

In order to form an estimate of the quantities of goods carried and the probable costs of transport for the completed system of navigable waterways, I have visualised a period some years after the completion and calculated probable values as follows:

(a) The amount of traffic estimated from recent figures of existing traffic by adding to this the amount of the increase which may be expected to follow from the natural increase in population and the constant development of agriculture and industry based on the consumption of coal per head;

(b) Extra traffic which may be expected owing to the transference of goods from rail to water transport due to lower freights;

(c) Increased traffic to and from neighbouring states which would be attracted by the x shortening of routes and improved international trade.



By considering the centres from which the goods would be despatched and to which they would be delivered I have fixed for each group, the cost of water transport and the saving as compared with rail costs, taking the lowest tariffs for bulk materials.

These ~~xxx~~ tariffs are indicated by the indexes "C" and IX in sketch No. 71 .

From this provisional estimate it appears that, within a period of about ten years, after the completion of the network of waterways, the amount of water-borne traffic in the interior of Poland may be expected to be in the region of 13 million tons of domestic trade and 7 million tons of foreign trade per year.

By transporting this total quantity of 20 million tons by water the saving in freight charges would amount to about 13.5 million sterling per year as compared with the railway costs.

================================

C O N C L U S I O N

Conclusion.

If this great development of the Polish system of rivers and canals takes place, nearly the whole of Poland would become the hinterland of the Lower Vistula and would be provided with an outlet to the Baltic Sea.

In addition, by the creation of a wide-spreading international network, these waterways would provide all the neighbouring countries with outlets to the Baltic and Black seas, and with direct and shortened through-routes.

I stress the importance of the international character of the waterways, for their development would be a vital factor in the economic co-operation between East-Central European countries and their neighbours, lying to the East and West, as they would provide cheap transport for mass products over long distances.

In my Polish report, and in this thesis, I have discussed the possibilities of improving the existing natural waterways in the basins of the rivers Danube, Elbe, Oder, Vistula, Bug, Prypet and Pruth and the means of uniting ~~thexx~~ these river basins by important connecting canals.

I have given an account of the civil engineering work which is required for the improvement of the rivers and the existing canals, and I have also given details of new connecting canals. The suggestions and designs are original and are now published for the first time.

I am strongly of the opinion that, along with the construction of the navigable waterways, every effort should be made to develop hydro-electric power to the maximum extent , and also to deal with the problems of irrigation , drainage and of flood and silt control and I have kept these objects in view in preparing my schemes.

In the political sphere discussions are already taking place regarding post-war political and economic plans for East - - Central Europe , in order to facilitate and accelerate the re-organisation of social economy and to formulate schemes for the development of agriculture and industry.

In such schemes well-developed waterways would be of almost inestimable value and I hope that amongst the post-war measures for reconstruction , the question of inland navigable waterways will be considered as a matter of primary importance.

In this thesis I have endeavoured to produce a comprehensive scheme to ensure the maximum utilisation of the vast available water power resources of the East - Central European countries in the hope that it may form a basis for discussions which will lead to the enrichment and peaceful development of many countries and peoples.

In conclusion I desire to express my grateful thanks to the University of Edinburgh, for affording me facilities for research in the Engineering and Geography departments , and to the various libraries in Edinburgh , for giving me access to all sources of information.

Edinburgh, 25th March 1943.

H. Herbich

/-/ Henryk HERBICH

Volume 3

THE DAM AND HYDRO-ELECTRIC POWER STATION AT ROZNOW ON THE RIVER DUNAJEC

H. Herlez
25 th March 1943

The Dam and Hydro-electric Power Station at Rożnów on the DUNAJEC (Poland).

1 The basis of the scheme

The dam at Rożnów which has just been completed is one of the largest constructions made before the outbreack of war. It protects the basin of the river Dunajec and its inhabitants against the destructive effects of flood and conduces to the improvement of navigable conditions in the basin of the Vistula.

The construction of a water power station with a capacity of 50.000 kW and of an approximate yearly output of 142 million kWh , and the installation of transmission lines with a voltage of 30 kV and 150 kV will allow the provision of current to the central industrial district of Poland in the triangular piece of country between the Vistula and the San.

The dam at Rożnów, which was begun in June 1935 , is situated 30 km from Nowy Sącz and 50 km from Tarnów, and 80 km from the junction of the Dunajec with the Vistula.

In order to decide upon the power to be installed and the average annual output of energy to be produced by the electric power station, the hydraulic regimen has been based on observations made over a period of 34 years.

The automatic gauging recorder at Tropie, situated 8 km down-stream from Rożnów, was used to calculate the flow of the Dunajec, in order to determine the productive capacity of the power station.

The result of these observations has shown that in order to carry out the plan for spillway arrangements and for their construction, it was necessary to take into account the great variations in their **flows**, the limits of which are from $Q_{min.} = 4.5\ m^3/s$ to $Q\ max. = 3,500\ m^3/s$. The extent of their variations is therefore enormous for it is 1 : 800 .

The average annual flow is $Q_m = 67.5\ m^3/s$. The average monthly flows vary from $111.2\ m^3/s$ to $34.4\ m^3/s$, taking into account that the minimum flows are reached in the spring and summer.

A table based on the law of probabilities shows that the flood flows of the Dunajec are as follows:

Table No 1

Average	Once in 3 years	Once in 4 years	Once in 10 years	Once in 100 years	
5o	33.3	20	10	1	%% of probability
1,195	1,436	1,692	1,953	2,695	m^3/s

The average altitude above sea-level of the bed of the Dunajec in the section of the axis of the dam is, on a rough estimate, 237.50 m , whereas the average elevation of the water-level is roughly about 239 m .

The bed of the river, about 90 m wide, is bordered on the left bank by hills of the Bilsko mountain range, which run down steeply straight into the river and rise roughly to an altitude of 450 m . The right bank forms a plain comprising an area of 300 m , running progressively to an elevation of rage for exceptional floods will, therefore be about 116.1 million m^3. In this way all the floods known up to the present will be much reduced and rendered completely harmless.

The regulation programme provides other precautionary defence measures against constantly recurring floods, a phenomenon that often occurs in the rivers of the Carpathians.

It is only in September that the storage water reaches its maximum retaining level of 270 m, and maintains it during the autumn.

The above scheme necessitates the installation of seven crest gates 12 m x 6 m at an elevation of 264.0 and five sluice-gates 3.5 m in diameter at an elevation of 242.5 .

The retaining of the water level at 270 m entailed the necessity of buying land up to an elevation of 271.5 - 272.0 m .

The amount of land purchased covered a surface of about 1,950 hectars.

In the electric power station, which was designed to overtake the peak loads, there have been installed 4 Kaplan turbines each of 12,500 kW . Taking into account the considerable variations produced in the reservoir as a result of the hydraulic regimen adopted for protection against floods, it was necessary to instal Kaplan turbines with adjustable runner blades. Experience having proved that these turbines, even with the fairly large variations in the height of the head or discharge vary little from their maximum efficiency.

With regard to the turbines at Rożnów their efficiencies are guaranteed within the limits of 5% of variation according to the loads(from 0.4 to 1.0), and of the head (from 19.6 to 31.1 m).

The reservoir at Rożnów was designed also to improve the conditions of navigation in times of drought by raising the water level with water stored during the floods.

This is how navigation on the Vistula will be improved:

1. The daily supply from the reservoir in dry seasons will increase the natural flow of the Vistula at the mouth of the San to 40% .

2. The duration of the flows necessary for navigation will be prolonged, with the result, that during the year, the navigation period will be extended from 30 to 40 days.

3. The number of days in the year, during which the Vistula will receive additional flows from the reservoir may be approximately 120 days, thus improving the navigable conditions.

4. The interruption of the navigation periods on the sector of Vistula as far as Sandomierz will be reduced to a few days a year, excluding the winter period during which the rivers are frozen.

The advantages to navigation obtained by storage expressed in figures, represent a profit rising on an average to £. 22,000. a year, an increase that, reckoned at a rate of interest of 5%, represents about £. 440,000.

In the same way, the profits resulting from the reduction of damage as a result of floods, rise on a average to £. 17,160 £ a year, which at a rate of 5% interest represents a sum of about (9 million zlotys) £. 360,000 £.

Consequently, the importance of the saving realized by the Rożnów reservoir, is indicated by the figure of £. 800,000 £, taking into account only the two above mentioned aims, and not including the profits from the hydro-electric output.

This sum, reduces proportionately the cost of constructing the electric power station at Rożnów, when we calculate the production of energy; that is to say, the water board services (navigation and protection against flood) would cover part of the total cost and the remainder would be charged to the electric power station.

2. Geological conditions

The geological conditions existing in the Carpathians are such, that it is difficult to find a stratum of sandstone sufficiently extensive to form a continuous foundation for a dam over its whole length.

One must, therefore, reckon with the fact that in the Carpathians, it will be necessary to make provision for foundations placed on a sub-soil composed of sandstone, clayey schists and conglomerates covered by a stratum of alluvia (gravel, clay, chalk and sand).

It is well known that sandstone has a great resisting power; it is, on the other hand, of relatively great permeability.

On the contrary clayey schists, although they are impermeable, have little resisting power. The conglomerates, the resistance of which is greater than that of the schists, but less than that of sandstone, have the defect of being too porous. Schists, as well as conglomerates, appear in thin seams that are generally mixed. The impermeability of an Carpathian sub-soil is, generally speaking, based particularly on the water-tight nature of the schists, which makes it suitable for the construction of dams.

Close collaboration between the engineer and the geologist is necessary when a choice and examination of a site is being made, and in order that every precaution may be taken to ensure the security of the dam during the course of construction.

At Rożnów, elements such as: the resistance of rocks, the water-tight nature of the sub-soil, and the slope of the strata are satisfactory.

On the other hand, the following conditions are not satisfactory: the homogeneity of the sub-soil and the coefficient of friction between the strata.

These conditions were revealed in the course of construction, when deep excavations were being made; they were not shown during geological explorations, which were made by diamond drilling by the Crealius apparatus (to a depth of 60 m), which cost £4,000.

3. Foundations

The above mentioned geological conditions were the cause of some modifications made in the foundamental priciples of the plan for the dam and power station.

The following plan was adopted:

a) the foundation of all the blocks received a slope of 1 : 10 towards to the head-water;

b) the pneumatic gunnite method of placing concrete was used over the whole lenght of the important surfaces of clayey schists, in order to prevent infiltration, either while excavations were being carried out or while the concrete was being set;

c) the foundations of the blocks of the power station are laid deep into the sub-soil and are triangular in shape at the bottom to correspond with the slopes of the seams, towards the head-water;

d) the foundations of the blocks of the power station and a part of the blocks on the left bank are firmly fixed in the sub-soil by means of a series of anchorages from 1.5 : 2.0 m in diameter and from 6 to 7 m in depth, strongly reinforced by railway lines.

Moreover, taking into account the inequality of elasticity in the sub-soil, a reinforced concrete slab was constructed in the lower part of the dam, sufficiently rigid and with sufficient flexion and shearing resistance. This slab comprises two nappes of reinforcement(lower and upper) at the top and at the bottom of the slab, at the rate of 4 Ø 36 mm per meter. The lower nappe was placed on the bottom of the foundations, which were made level by a layer of cement at a gradient of 1 : 10 ; whilst the upper nappe was placed horizontally at an altitude of 241.0 m . The total weight of reinforcement for one block was about 33 tons. The blocks of the power station are more strongly reinforced and about 150 tons per block was used.

4. Concrete Laboratory.

For testing the concrete to be used for the construction of the dam, a laboratory was set up, for that special purpose, and it was the first in the operations at Rożnów excluding hydrometric and geological explorations for the works that had just begun.

The large extent of the concrete production has involved the necessity of finding a solution to the foundemental problem concerning the preparation of concrete for the dam at Rożnów with the materials at our disposal.

The principal aim of these tests was to determine:

1) the resistance, 2) the impermeability and 3) the compact nature of the concrete to be used.

In order to solve these problems it was necessary:

a) to find a suitable gravel-pit;
b) to determine the best proportion and size of the components;
c) to make a choice of suitable cement and the exact proportion of its ingredients(dose);

d) to decide upon the quantity of water necessary;
e) to analyse the properties of the water.

Next it was necessary to test the setting of the concrete that had already been made for the construction of the dam.

The laboratory is fitted with indispensable instruments such as: an Amsler hydraulic press of 200 tons pressure, a set of instruments to test permeability, pumps, mixers, mallets, apparatus for determining the shrinkage of the concrete (Amsler), sets of sifters, balances, Graff-tables, moulds for cylinders and plates, a Vicat needles etc.

Two kilometres from Rożnów a sufficiently large gravel-pit was found and after an analysis of the quality of the products of this pit, it was found to be suitable for development. A reserve pit was discovered higher up, at Załęże on the Dunajec.

The quantity of different sizes was determined by sifting the components through a fine sieve. Next the question of the choice of cement and the proportion of its ingredients was studied. In the construction of ordinary buildings rapid hardening cement is often used, because its resistance quickly increases, but this is not suitable for dams. By the use of quick setting cement a chemical reaction is produced, accompanied by a discharge of heat, a phenomenon that causes perceptible variations in temperature in the large blocks, which results in supplementary tensional strain and thus causing fissures. In spite of their small dimensions, these fissures lessen the resistance of the whole construction.

That is why for dams a special xxxxx cement must be used, that has a lower heat evolution.

The Large dams Committee of the World Conference in which I took part is still dealing with the question of special cements for Mass-Concrete, with a view to reducing shrinkage--cracking.

The proportion of water depends especially on the way of placing the concrete. Tests which have been carried out have shown that the vibration of cement by means of apparatus called vibrators, makes the concrete more compact. Needle vibrators transmit the vibration of the concrete uniformly; they are easily handled because of their simple construction.

The vibratory method produces a drier concrete, containing less sand and water in proportion to the same quantity of cement, which increases its resistance and water-tightness.

In this way an amalgamation of sand, cement and water produces a mortar that would be sufficient to fill up the gap between the different sizes of gravel and to "coat" them. On the basis of these analyses and after a series of tests, a suitable cement was chosen and its proportion was determined at 250 kg per cubic meter of concrete; this proportion becames 300 kg to every cubic meter of concrete for outer facings.

Finally, it is necessary to point out, that concrete is placed in layers 2 m thick. Before pouzing in the next layer of cocrete, the surface with which it comes into contact is cleaned by means of jets of clear water under fairly high-pressure, and by wire brooms, and then it is pricked to a depth of

3 cm and cleaned again. These surfaces are then covered over with a layer of special concrete,called "super special", several centimeters thick. This process prevents seepage through the seams of the dam.

Further tests were carried out on the resistance and water tightness of the concrete blocks. Holes were drilled to a depth of 75 cm in the outer facings of the blocks,into which water was injected under a pressure of 8 atmospheres;next, the lowering of pressure and reduction of infiltration were observed on the surface of the blocks. Repeated tests continued to give results consistent with these obtained from model experiments carried out in the laboratory.

5. The Dam.

At km 80 from its mouth,the Dunajec disappears into a gorge that offers favourable conditions for closing the valley by a relatively short dam.

This site is the more advantageous because of the dip of the rocky strata rising up stream and the direction of the strike running parallel to the axis of the dam.

The length of this dam is 550 m ; its total height including the foundation is 50 m at the lowest point of the foundations, and the net head reaches 31.5 m .

The storage capacity is, as I have already said, 228.7 million m^3, and the backwater stretches as far as Marcinkowice,that is to say a lenght of about 22 km .

Plastic concrete has been used as the material for building the dam. For its construction, the total length was divided into 36 principal blocks 15 m long (the blocks of the power station are 17 m long and those of the left abutment less than 15 m) separated by expansion joints made necessary by thermic conditions resulting from the hardening of the cement caused by variations in temperature, which may subsequently result from atmospheric conditions.
Each expansion joint is made watertight by a copper plate fixed into two adjacent blocks by a vertical shaft 20 x 20 cm, running up to the crest (upstream from the dam) and filled with a special kind of asphalt. Further, the surfaces in contact were coated with bituminous paint and in the shafts, electric wires have been placed to heat the asphalt.
The volume of concrete used for construction was 390,000 m^3.
Before choosing the type of dam, all the principal designs for this kind of construction were examined, and the initial rough-draft showed the sketch of a "T" shaped dam, i.e. each of the blocks was to be in the shape of the letter "T", the arm of which would be turned towards the storage water, whilst the jamb, 7.5 m wide, would form a buttress (contrefort) to support the arms and, seen in outline, would be triangular.

After the excavation had been carried out, consequent on the results of geological investigations, the initial plan was partially modified, but, at the same time, a triangular section was kept.

A slope of 0.8 (0.1 and 0.7) was given except in the case of the spillways, where the slope is 0.9 (o.1 and 0.8), because of the gaps made in the dam to dispose of the spillways discharges.

For the power station, the type of dam was adopted which is composed of blocks, forming the shape of the letter "C", and the turbines and alternators have been installed in it.

The change in the type of dam has entailed an increase in the concrete volume of about 20%. In order to observe the working of the dam arrangements more easily, arrangements have been made for:

a) lift shafts, control galleries (horizontal and vertical) and

b) the installation of measuring apparatus for deformation, tensions (strains), temperatures and displacements.

6. Construction.

The construction of the dam began in June 1935 with the fitting up of the laboratory, the construction of hutments, a telephone line, roadways and many other preparatory labours. Next came the construction of a narrow gauged railway (750 mm) from Marcinkowice to Rożnów, 19 km long, so as to carry materials rated at about 120,000 tons to the buildings yards. The construction of the railway made it necessary to arrange for a temporary wooden bridge over the Dunajec 166 m long and 15 m high. At the same time, the regional electric power station at Tarnów (Mościce) built a temporary electric power station (in reserve) with a Diesel engine 300 kW together with a transmission line with a voltage of 30 kV and a capacity of 1,200 kW .

The whole length of the foundations were only finished in 1938. The excavation for the foundations and the tailwater canal amount to 570,000 m^3. This figure includes that of the rock excavation which is 215,000 m^3.

The plan that was adopted did not provide for the costly construction of subterrenean galleries which should allow the water of the Dunajec to be diverted, whilst the work was going on. This is the reason why the bulding programme had to provide against several successive diversions, which, in view of rather restricted space, was not an easy task, in spite of the use of steel sheet piles(Larssen-Rombas piles).

The year 1936 was devoted to preparatory work: the building called "a concrete factory" was completed, and the machinery for the preparations of concrete set up there; machinery for transporting and placing the concrete was also set up. These fittings were provided by Allied Machinery Co. At the same time: 1) a crane with a range of 600 m and a lifting power of 3 tons, to lift the materials above the excavation; this work was carried out by Societe Bleichert; 2) Machine for injecting cement were installed; 3) Derrick cranes and ~~at~~ other apparatus were brought; 4) a narrow gauge railway leading to the gravel-pit on the Dunajec was constructed; 5) a steel sheet of Larssen-Rombas piles 450 m long was ~~xxxxxx~~ driwen in; 6) a group of 5 dwelling houses (excluding several barracks) were erected for temporary office use,but they will be used later for the workers in the power station, and towards the end of 1936 concreting of the rocky sub-soil was started and of the same time it was made water-tight by the injections of cement. Concreting was carried out in a direction parallel with the axis of the dam. The liquid cement was (injected) compressed at a pressure of 2 to 30 atmospheres in the holes drilled in the rocks to a depth of 35 m .

In the third and fourth season of the work,excavations were finished and concreting went on; the daily concrete production reaching 1,000 m^3; the total volume of concrete placed up to April 1939 was 312,000 m^3 , i.e. about 80% of the total volume that was planned.

Further,the installation of outlet pipes and sluice gates, and the equipment of turbines was begun.

During this same period,work was also carried out on spillway gates on the crest of the dam,for the discharge of flood water and two rows of "chicanes" for the destruction of spillway water energy,based on tests made on small scale models in the laboratory.

During the winter 1937-1938 , the first diversions took place from the river into temporary channel,prepared towards the end of 1937. This channel passes over the foundations of 5 blocks of the dam, it is bordered by the blocks 13 and 18 , which had been constructed beforehand and by the adjacent defence walls. To connect the separate parts of the building yard over

this temporary channel, a wooden bridge was built with 5 spans ~~of~~
of 16.2 m , supported on 4 concrete piles.

7. The concrete works.

The works were built on the right bank and consist of several buildings connected together. The railway lines that carry the materials run between the buildings. The machinery consists of a riddle to sift the materials, silos for the components, mixers and conveyers.

The riddling apparatus, consisting of cylindrical riddles, washers, crushung machines and grinders, produces 4 kinds of components:

fine sand	0.25 - 2 mm
coarse sand	2 -10 mm
fine gravel	10 -30 mm
coarse gravel	30 -80 mm

The materials brought from the pit to the concrete work pass through the silos and the riddling apparatus, whence it is conveyed by means of conveyers to the place where the components undergo a preliminary riddling through perforations (90 mm x 90 mm) with a diameter of 1.22 m and length of 4.27 m . The coarse gravel eliminated by the riddle falls into the primary crushing machine. The other materials are carried by a bucket elevator to the secondary riddle which is 1.53 m in diameter and 6.70 m in length, cylindrical in shape, with perforations 30 mm in diameter and occupying 4/5 of the whole length of the riddle; the remainding 1/5 of the length of the riddle has a perforations 80 mm in diameter. The materials are riddled in this machine by redividing the components and putting then through an intensive washing process by means of powerful water jets inside the riddle. The products that are more than 80 mm in diameter pass through a channel to the secondary crusher. The materials that have been crushed by machine are mixed with the products of the secondary riddle. From this riddle they are carried by conveyers to the silos beneath which are placed dosing apparatus(ingredient apparatus) into which they fall by force of gravity.

From there, the components in well defined proportion, reach the machine for making concrete with a capacity of 1.6 m^3 and with a (output)production capacity of 50 to 70 m^3 per hour. There are two dosing(ingredient) machines, each supplying one concrete-making machine.

The dosing of coarse materials is calculated by volume, whereas that of fine sand, water and cement is calculated by weight. The sand and water are proportionately mixed together, because the degree of humidity of the sand alone is much too variable.

The conveyer for the transport of concrete consists of one belt, placed paralled to the axis of the dam, and another placed transversally, which is moved according to the position of the placing of concrete(building-yards).

The conveyers are suspended on cables, resting in the middle of their span on a metal cross-bar(portique) 87 m high from the base to the top.

The conveyers consist of a series of sections about 30 m long.

The concrete when it reaches the end of one section,falls into the next one. Each section is made of a steel girder encircled by a belt with no join and moved on a roller and each has an independant motor. The belt is made of reinforced rubber 10 mm thick and 80 cm wide.

The machinery in the concrete works is ~~workedxworked~~ worked by electric motors.

To complete the full description of the concrete work, I must add that the gravel is extracted by means of a bucket excavator(steam); the production capacity of which reaches $150m^3$ per hour. The gravel-pit has been dug to a maximum depth of 7 m and an average depth of 4.50 m .

Auxilliary Constructions. 8. Fish ladder

The closing of the valley of the Dunajec by the dam gave rise to the problem of fish ladders. Investigations show that in American dams fish lifts have been adopted, whereas in Europe types of pool or cascade ladders are used; in these the fish are forced to leap from one pool to another over the whole course of the pools. The difference in level between the consecutive pools varies between 0.20 m and 0.60 m.

After a study of the construction and working of existing ladders in Germany, Switzerland, France and Scotland, the guiding principles for the plan for a ladder at Rożnów were settled. This ladder is composed of 60 pools on the right slope of the valley; each pool is 3 m x 6 m in dimension and 1.60 m deep. Each baffle-board between two adjacent pools has an opening 0.5 m x 0.45 m at the bottom and at the top a notch 0.4m x 0.15m. The difference in water levels between two adjacent pools is 0.4 m. Every hundred metres there is a larger pool which forms a resting place for the fish. The total length of the 60 pools is 360 m and the difference in level between the first and last pools is 24 m. The second part of the ladder leads into the body of the dam to make up for the remaining difference in level (7.20 m) between the elevation 270.00 and 262.80. It is composed of 18 pools.

9. Roads.

As a result of the construction of the dam a lake with/ a surface measurement of 18 km^2 has been created.

At one end of this are a number of hamlets,buildings and roads among others being the road that connects Nowy-Sącz with Tarnów through Zakliczyn - on the one side and by the pass of Justów on the other side of the river. In order to keep up communications between the hamlets situated above the storage reservoir, and the business centres, it was necessary to plan new roads, taking into account the growing needs of the tourist traffic in the Beskides of Nowy-Sącz. The building of roads was begun on the right bank of the Dunajec by the year 1938-1939 (and the embankments have already been constructed) on the sector from Rożnów to Dąbrowa. The construction of 56 reinforced concrete culverts, both large and small, and 5 bridges was completed. The width of the road is 7 m , 5 m of which is allowed for the roadway and 1 m for each footway.

On the left bank embankments were begun and the construction of a bridge at Smolnik and of 24 fairly large culverts. The road is 8 m wide, 5 m for the roadway and 1.50 m for each footway.

The length of the newly marked out roads is 6.1 km on the left bank and 17.8 km on the right bank.

The cost of the construction of roads,culverts and bridges with a higher level than that of the future level of the river ~~xixer~~ was 180,000 £.

Further, to create and complete the network of roads from Rożnów, the roadways have been widened and improved(by means of concrete slabs or regular sized paving stones); and certain xxxx sectors of the roads with gredients that are too steep and bends that are too sharps have been remade. This relates to the sections of roads on both sides of the river, particularly from Dąbrowa and Marcinkowice to Nowy-Sącz. The cost of this work was about 180,000 £.

In order to complete the roadway construction, 3 km of roadway have been made, connecting the network of roads on the left bank with that on the right bank, near the crest of the dam, as well as 6 km of public roads and side roads which connect the villages with the system of roads from Rożnów.

The plan for the roads in the Rożnów system was made with a view to the mountainous lie of the land, so that on certain sectors, the largest possible surface of the newly made lake may be seen.

10. Appropriation of land.

The appropriation of land at Rożnów which included arable land was carried out by the Government and assessed on an evaluation by experts. A special commission set up by the Ministry of Transport dealt with various problems connected with the survey of the land and the legal aspect of the matter.

At the same time steps were taken to buy up properties in the district, to divide them up into lots and to transplant the dispossessed owners so that they might create new homes and means of livelihood. As far as possible land is bought and sold by mutual agreement before the time for appropriation has expired. The property bought comprised 1,950 ha of arable land,forests and fallow land (flood surface including banks).

Cont

11. Control of torrents and streams in mountainous districts.

At the same time as the work on the construction of the dam was being carried on, work on the control of the torrents and streams was also going on. Storage water absorbed a number of fairly large torrents.

Their special characteristics are a small discharge pool, a narrow course and a very steep slope to their beds. The sub-soil of the pool is formed by impermeable strata, the result of which is a fairly rapid discharge of flood water and consequently a large quantity of silt is deposited downstream. To protect the reservoir against silting or the deposit of gravel it was necessary to include the control of streams in the scheme of work connected with the construction of the dam.

12. The Equipment of the Dam.

The dam at Rożnów necessitated the installation of spillway--gates and sluice-gates, also arrangements for destroying the energy of spillway water.

The site of the spillway-gates is dependent on the regularisation of the bed beyond the dams, so that the out-let of the drained water regulated by passing through the chicanes does not injure the bottom of the bed. In this way an even discharge of water from the spillway-gates and sluicegates into the bed of the river is obtained whatever the state of the water downstream may be.

The shape of the crest of the spillway-gates was calculated by data verified on small sized models. The shape chosen appeared the best in the case of maximum discharge. The contraction of the nappe through the spillway-gates must be so adjusted that the presure exerted on the sloping surface of the facing of the dam is a minimum.

Further, in order to reduce the contraction of the surface water through the spillway-gates, a console was installed on the head-water side.

13. Segmental Crest-Gates.

At the same time a plan was made for 7 segmental crest-gates which were ordered in the country from Rudzki and Ltd Soc.An. The machinery of these gates is fitted up in the crest of the xxxxx dam, under the road; the gates are 6.2 m high(the elevation of the sill is about 263.80 , so the maximum elevation will reach 270.00) and their length is 12 m . They are made of riveted and welded steel.

The plating of the gates is made of sheet-steel and is cylindrical in shape(radius 8 m) on which the presure of the water is exerted according to the radius. The axis of rotation of the sector is at an elevation of 261.20 and is placed 10 m from the axis of the dam. The sheet-steel is reinforced by U shaped iron joists No 16,welded to it and placed horizontally at intervals so that the pressure on the iron joist is approximately equal. The plan necessitates vertical guides of sheet-iron armour-plating 8 m , of varying height and two iron U shaped joists 80 x 80 x 8 . The main guiders consist of lattice work frames resting on jointed supports, placed on the axis of rotation of the sectors. According to the plan the main guiders are made of riveted angle-iron.

The segmental crest-gates turn on steel pivots 240mm in Ø , fitted up on plummer-blocks furnished with bronze pads(a pressure of 180 kg : cm^2 has been alloved for).

Water-tightness at the bottom has been secured by sealing a steel sill which is let into drilled holes and fixed by means of bolts.

The regulation of water-tightness is rendered possible by lowering the crest-gates and, under the full pressure of water, assuming that access to the bolts by tightening will be down-stream from the crest-gates. Lateral water-tightness is obtained by steel plates with a high resistance, about2.5 mm thick and 20 cm broad, ending in a drilled hole made in the corresponding iron plating of the piles.

Theoretical lifting forces of 25.8 t and 35 t have been allowed for the winches.

The two Galle chains of S.M. steel, each link of which measures 95 mm , hooked to the ends of the segmental crest-gates, are worked by a single electric motor, with the help of two hydraulic levers, connected by a shaft 12 m long. Each lever is composed of a screw dipped in oil and fixed into cog-wheels. The motor and the screw have ball-bearing plummer-blocks, the other parts have ordinary plummer blocks.

The apparatus is provided with an electro-mechanical brake. These brakes may also be actuated by hand.

14. Sluice-Gates.

As has been said above, in the dam are set up 5 sluice-gates with grooves and with sliding gates and hoists. The axis of the sluice-gates are at an elevation of 242.50, i.e. about 21 m below the sill of the segmental crest-gates. The sill of the grooves of the sluice-gates is at an elevation of 240.00. Each sluice-gate at the entrance is 6,000 mm in diameter and funnel-shaped; over a length of 2,200 mm its diameter is reduced to 3,500 mm but keeps a circular section.

The sluice tube is made of steel plate 12 mm thick. According to the working conditions certain sectors of the tube are more or less strongly reinforced by welding a collar of sheet-iron 15 x 120 mm. The various sections of the tube are as follows:

the first-circular section-l=2,800 mm; the second (l=3,500mm) composing the passage between the circular section and the rectangular one (reinforced in the shape of a cross); the next 3,700 mm containning the sluice-gates, then l=3,400 mm with an increasingly rectangular section (h=3,500 mm to 4,750 mm); and the last -9,850 mm long is made up of only three walls: the bottom and lateral walls (to an elevation of 244.8 m) evenly reinforced by welding sheet-iron.

These sections are welded or riveted together on the building side.

15. Sliding Gates.

Each sluice gate is closed by two sliding gates 2700 mm x 3500 mm According to the plan these sliding gates are made by a frame work welded together and they are calculated for a maximum pressure, allowing for a tension limit of 100 kg : cm^2. These gates consist of an iron girder in the shape of a double "T", horizontal, placed at intervals of about 0.5 m and covered (towards the tail head and at the sides) by a plate 14 mm. Towards the gross-head, watertightness at the sides and at the top is obtained by bronze bars that are easily changeable and slide on steel bars fixed on the frames that form the grooves of the gates.

When the sluice-gates are wide open, the sliding gates jut out a little so that they may be kept, resting against the groove by the pressure of water, to avoid oscillation. Water tightness at the bottom is secured by a cast steel or by a steel bar attached to the sill. The sliding gates are worked by hydraulic hoists (servo-motors) fitted with centrifugal pumps and with hand brakes. The length of time taken to open and close a sliding gate mechanically is about 30 min. The hydraulic hoist (servo-motor) of the sliding-gates is provided with a long distance control (worked from the power station or from the control room of the gates) and with a signal apparatus.

16. Turbines (the electro - mechanical equipment of the Power Station).

The building of the electric power works is situated on the right bank of the Dunajec. It is built of strongly reinforced concrete and provides for the installation of 4 groups with a total capacity of 50,000 kW .

The floor of the machine room is at an elevation of 246.00 m; the distance apart between the axes of the turbines is 17 m, the axis of the spiral casing is at an elevation of 236.75 m and the axis of the adjustable runner blades of the wheel at an elevation of 235.50 m.

The power works contain 4 Kaplan type turbine with vertical axes, a runner and 6 adjustable runner blades and with a capacity of 12,500 kW and 214 revolutions per minute.

The runner of cast-steel has bronze plummer-blocks for the axis of the blades, which are made of rustless steel.

The operating cylinder for the runner blades and for the guide vanes ensures the closing of the spiral case within 2.5 to 5 seconds, and that of the runner is 40 to 50 seconds.

The guaranteed efficiency of each turbine is: -

1. for minimum head (h = 19.6 m - 85.5 %) for full loads; 88.5 % for 0.6 of the load ; 86.0 % for 0.4 of the load;
2. the maximum head h = 31.5 m i.e. the corresponding figures are 91%, 90% and 87.5%.

Thus alterations in efficiency are insignificant in spite of the great variations in the working conditions of the power stations; it is precisely this quality that represents the advantage of Kaplan turbines over the Francis make. For the choice of the type of turbine to be used at Rożnów it was calculated that the use of Kaplan turbines would allow an estimated production of 11 million more kWh a year i.e. 7% more than could be obtained with Francis turbines,which will effect a saving of several hundred thousand zlotys a year, reckoning on a basis of a selling price of a few "grosze" a kWh . The weight of 4 turbines is 375 t.

The intake tubes are welded;they are 5.5 m in length and have a diameter of 3.8 m;these tubes are of sheet-iron 12 mm thick strengthened by collars.

The spiral casings are also welded and furnished with cast--steel rings supporting the fixed vanes and joining the spirals to the operation cylinder.

The installation of the turbines has been carried out by Society Escher Wyss.

The ~~installation~~ intake tubes are supplied with double sliding gates on a roller train 2 x 2.55 m x 6 m , that close by their own weight under the pressure of a maximum discharge; so they must be supplied with steel rollers on both sides. The sliding gates have a strong welded frame work 6 m high.

The sliding gates are worked by servo-motors. The length of time taken to open them is about 10 minutes and they may be closed in 40 seconds.

The power station comprises in addition;sets of cast-steel stop log gates on the intake and draught tube sides,which can be lowered to control the sliding gates or to close the exit from the draught tubes. A cross-bar to manipulate the stop log gates on the intake side and to the turbines, is installed on the bridge of the crest of the dam at an elevation of 270.00 m. The cross-bar for the stop log gates on the draught tube side with racks and pumps for the discharge from the draught tubes and of infiltration water are also installed in the dam.

The above machinery has been made in Poland.

17. Generators.

Triphase generators have been constructed, each having a rating (24) of 15,600 kVA, and a speed of 214 revolutions per minute. The character-istics of the generators are 6,300 V; 50 cycles, cos Ø = 0.8, which corresponds to 1,430 A.

The efficiency of the generators for cos Ø = 0.8 varies within the limits of 96.7% to 93.0%. The first figure is for full loads - 15,600 kVA, the second corresponds to -0.25 of full loads i.e. 3,900 kVA.

The generators with a vertical axis are supplied with upper bearings and its two girders that support the weight of the rotors of the generators and the turbine, and also the weight of the water. These girders are made of plated steel. The lower girder of the bearings serves as a support to the brakes of the hoist. The oil cylinders of the brakes are set in them, thus making sure that the brake of the rotor of the generator can be applied in 5 minutes.

The total weight to be borne by the bearing is about 325 t.
The total weight of the steel constructions in the groups including the rolling bridge, sliding gates, stop-log-gates for the intake and draught tubes, as well as the equipment of the spillway apparatus i.e. segmental crest gates and sliding gates, is 2300 tons.

18. Hydro-electric system.

In the hydraulic power station the problem arose as to what capacity should be installed, from the economic point of view. In a steam power station, the maximum output capacity can be calculated by starting from a fixed capacity with reserves and then by simply multiplying that figure by the number of hours in the year or by the estimated number of hours of use; on the other hand, for a hydraulic power station, the first estimate to be made is the possible maximum yearly output in kWh and the choice of the power capacity most appropriate to the purpose for which the power station in question is destined, is of secondary importance. If it is a question of a power station without pondage, an estimate for the construction of the production plant is a simple matter.

Theoretically the total amount of flow, excluding the flood flow, is used for the turbines; that is why the choice of the power to be installed is easy, for it is fixed for the largest possible period of use, in order to make the production of the maximum of energy possible. This period varies between 6000 and 7000 h.

The problem is more difficult in the case of a power station with storage reservoir;for it has to fulfil two or even three different functions,which are incompatible, for example - protection against floods,the production of energy and navigation purposes.

With a view to protection against floods,it is necessary to arrange for frequently emptying the upper volume of the storage reservoir in order that it may receive and store flood water,and this is detrimental to the production of energy which is immediately reduced. For,if this was the only object in view,the level of the storage water would be maintained as high as possible.

For navigation purposes it is necessary to have the outlet from the draught tubes of the turbines as invariable as possible in order to ensure the continuity of navigation during the course of the year as well as during the day.

On the other hand,an hydraulic power station must be completely free to work so that it may be able to adapt itself to the variations in the demand for power,especially if it is to be used to cover the peak loads.

A compromise between these incompatible functions when the plan is carried out and a judicious use of the storage water and the plant may lead to the best use of a power installation.

In the present case,the power station at Rożnów is the property of the Government which is obliged to allow for all the above mentioned functions;there the storage water is used in such a way as to get the greatest economic adveantage from it for the country.

The development programme published by the Office of Navigable Waterways shows that during the period when flood may be ex expected,i.e. during the summer half-year,the level of the storage water is maintained at 3 m below the maximum level, which gives a reserve capacity of 50 million m^3 of water. After that,other discharge apparatus is used only if there is warning of an unusual flood. The time during which a forecast of the possible height of the flood can be obtained (about 24 h) is long enough to allow the reservoir to be emptied down to the necessary level (the volume of storage water necessary for the greatest flood would be 11.5 m deep) so that the water flowing from the reservoir at that time may create spillway discharges that are not dangerous for the valley downstream.

Thus,by sacrificing a relatively negligeable quantity of energy,the use of the total capacity of the reservoir is ensured in view of the fact that during the year flood precautions are of short duration and are rarely necessary (often once only) - specifications show that for this purpose,i.e. protection against flood,it is necessary to use,on an average, only 6% of the annual flow passing through the sluice gates and spillway gates. This means that the working coefficient of the power station would be 94% and it would produce, on an average 141.8 million kWh instead of 150.8 million kWh, which would have been produced of it had not been necessary to take precautionary measures against floods.

The coordination of electric power problems with those of navigation has been obtained by the construction downstream (13 km downstream) of another daily equalizing reservoir at Czchów, the function of which is to retain and store the uneven spillways discharges from the turbines at Rożnów (often the discharge of a whole day's supply during a few hours) then to send this downstream in an average discharge lasting a whole day of 24 hours. Thus the lower course of the Dunajec and after that of the Vistula gets a steady discharge which is regularised seasonally by the storage reservoir at Rożnów and daily by the pondage at Czchów. The power station at Czchów has as a second function the production of power to cover the base loads; the output capacity of this power station is 10,000 kW with an average yearly output capacity of 47 million kWh.

The result of the programme for the production of energy by the reservoir at Rożnów is that this production is distributed over each month as follows: -

Table No 2

Month	Production of energy in million of kWh
I	8.2
II	7.1
III	11.3
IV	16.5
V	17.2
VI	14.8
VII	15.9
VIII	14.7
IX	10.7
X	9.1
XI	8.5
XII	7.9
T o t a l	141.9

This is an average distribution calculated according to observations made during a number of years of the gauging power in the streams; it may happen that considerable deviations are ascertained.

The result of this monthly distribution of output capacity is that the variations in the available power capacity over a period of 24 hours runs from 10,507 kW in February to 23,087 kW in May. But the power station does not work in this way; the length of time it works in 24 h. is much shorter and is adapted to the demands of the market. The huge reservoir has a very great storage capacity which permits:

1. a choice of the length of working time, 2. the supply at any moment of any capacity up to a maximum of 50,000 kW. For example basing my opinion on the assumption (which is purely theoretical) that the market demand is a steady maximum capacity

of 50,000 kW , I should say that in 24 h. the length of the use of this power would vary in the different months of the year between ~~504xhxin~~ 5.04h in February and 11.02 h in May, i.e. an average of 7.74 h per 24 h over a period of many years.

In the same way, the heights of the net head vary on an average between 26.01 m and 30.01m~~xx~~; the maximum head being 31.5 m (in spring and autumn), and the minimum being 19.5 m during the very short period of a few hours during which preparations are made to ~~xxxixx~~ receive and store flood waters.

19. Assessment of the Profits to be made by a Power Station.

In conclusion it is necessary to add a few words about the cost of the hydro-electric power station at Rożnów and its possibility as a profit making concern. As I have already said, the profits to be gained by the plant may allow the Government to have part of the cost of the dam and power station covered by other branches of the Water Services.

The following estimate has been made, based on two different principles:-1. to saddle the power station with the whole costs, 2. to charge it with only a part of the costs which would be obtained after the deduction of expenses increased by navigation and defence against floods.

The rate of interest on the capital invested in these projects has been assessed at 4.5% making allowance for the security of this assessment, the sale of power being assured.

The length of the amortization of the capital invested in ciⱱil engineering works was fixed at 60 years, which is the normal length of concessions for hydro-electric power stations, and at 20 years for electro-mechanical equipment. Allowance has also been made for a period of 20 years for the formation of a sinking fund with which to buy spare parts for the electro -mechanical equipment. In addition, allowance must be made for maintenance costs (20% for the mechanical and 1% for thecivil engineering part) and a general/expenses fund for the running costs based on the normal figures in similar establishments.

The total cost of construction was assessed at £ 1,800,000 , £ 1,140,000 of which were estimated for the civil engineering side, £. 200,000 for the electro-mechanical equipment, £. 280,000 for the purchase of land, and £ 180,000 for new roads (neces-xxxx sitated by the creation of the artificial lake).

The annual expences of the power station may be estimated as follows:

1. Amortization and payment of interest on the mechanical equipment	£. 15,360
2. Amortization and payment of interest on the civil engineering works	£. 77,600
3. Sinking Fund	6,160
4. Maintenance of the Machinery	4,000
5. " of the civil engineering works	11,400
6. Working expences	10,000
7. Taxes and general expences	8,000
Total	£.132,520

Starting from our first principle, i.e. by charging the electric power station with the whole cost, the cost price per unit reckoned in kWh can be estimated at 2.36 grosze (0.23 d), for a yearly output of 142 million kWh, this being the net cost per unit when it leaves the power station. On the other hand (second principle), allowing for the fact that it is necessary to charge part of the costs to the navigation and flood defence services, which allow for a profit estimated at £.40,000 a year the cost price of the kWh would be 1.65 grosze (0.16 d). This estimate does not allow for the cost of transportation and the transmission of current. In practice, and generally speaking, when the cost price of current is being estimated one must not count as the whole being sold, so it is necessary to include in the estimate the coefficients that allow for estimated general expenses. Generally speaking the first years are thin for all normally planned power stations, and their profit making capacity cannot be assessed in exact figures and for the first few years of development, but it must be reckoned over a working period of several years. In the case in question, the power production at Rożnów and Czchów, the first working years promised to be quite profitable. The two power stations, i.e. the peak power station and the base power station, with a total output capacity of about 200 million kWh and having a very different distribution of loads, are connected with the steam power station (worked by coal and gas) also situated on the territory of the C.O.P. at

Mościce and Nisko to feed that industrial region and to transmit current to the centre of the country. By this collaboration the distribution of loads at the steam power station are specially adapted to the output capacity of the water power station during the different seasons of the year, and the length of working hours per day, so that the water power station may be utilized at about 100% to avoid losses of water through the spillways.

Such a collaboration allows not only the sale of electricity, but also a saving in running expenses at all the power stations working together, by the reduction of reserves in the steam power station, and consequently a reduction in the average cost-price of the power produced.

I wish to emphasize this fact all the more, because there are people who maintain:

1. that it is not considered possible to reconcile the work of an electric power station, the function of which is to answer the demand for power, with the simultaneous part the dam is to play in regularising the spillways discharges of the river in order to prevent floods;

2. that it is not believed possible to use the whole of the available energy from the reservoir, which means that there is no belief in the low price of the unit of energy produced with very low working expenses in the power-station.

The above survey of the cost and profit making possibilities of the power stations at Rożnów and Czchów emphasizes this truth, that has been recognized relatively late, that the development of hydraulic force must be treated in the same way as the development of any other source of energy, with the object of collaborating with the electrification of the country that has already been begun and based on all the sources of energy scattered over the whole country.

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25th March 1943