MASTER PLAN AND REPORT

ENGINEERING AND ECONOMIC STUDY

DOURO RIVER
AND
TRIBUTARIES WITHIN PORTUGAL

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50% iron, 8% silica, 1.3% phosphorous and 0.15% sulphur. The siderite, containing about 40% iron, 6% silica, 0.7% phosphorous and 0.15% sulphur, can be improved by roasting to about 48% iron and 7% of silica.

The estimated reserves, positive and probable, are as follows:

1 - Barreiras Brancas deposit	-	1,000,000 Tons
2 - Monte da Gandeira	-	500,000 Tons
3 - Barreiras Brancas No. 1	-	500,000 Tons
Total	-	2,000,000 Tons

Three-fourths of the ore will have to be mined underground and conditions are not favorable for cheap mining. Percentage of extraction from underground operations will probably be between 60% and 75%. Possibly one-fourth can be mined in open pits by stripping both walls, but the cost per ton will be high, because the ore is narrow and would have to be cleaned by heavy media operation or by hand sorting before shipment. The limonite ore is not susceptible of concentration. The roasting of the siderite can be performed either at the mines or near Porto, whichever location shows the greatest economy, taking into consideration transportation and fuel costs. The mines should have a life of at least 10 years, with production of 800 to 1000 tons a day, which is about all the railway would be able to handle. Truck haul to the rail head at Braganca would probably be prohibitively costly. If the narrow gauge railway were extended to the mines, there would be a haul by narrow gauge cars of about 172 km from the mines to Tua, where the ore could be transferred to the broad-gauge Linha do Douro - or, if the river were improved for navigation, to barges.

If the railroad were extended to the mine, the freight rate to Leixoes probably would be about 106$00 a ton, to which must be added costs of mining, delivery to rail head, roasting, and general expenses, all amounting to about 80 escudos a ton. Dock charges and government tax aggregating 20$00 a ton at Leixoes would bring the total cost FOB ship to about 206$00 a ton. Since the probable selling price of the roasted ore at Leixoes would be about 209$00 a ton, the profit margin would be only 3$00 a ton which is so narrow that it is not felt that it would justify the risks involved. In any event, the exploitation of only 2,000,000 tons would not contribute significant tonnage for a long enough period to have much influence upon the economics of improvement of the Rio Douro for navigation, nor could it have, save briefly, much effect upon the general economy of the Nation.

4. Moncorvo Deposits

The Moncorvo deposits are the largest in Portugal and are important both to the National economy and to the question of improving the Douro River for navigation. They are situated on the hills east of the town of Torre de Moncorvo in the Braganca district of the Province of Tras-os-Montes, 22 km by narrow gauge railroad from Pocinho, and 20 km by road. They are 800 to 900 m above sea level and 200 to 300 m above the railroad, which in turn has a drop of 300 m from the little station of Carvalhal near the mines, to Pocinho. The ore caps the tops of hills which form a curve somewhat like a giant fish hook, 3 to 4 km long. On the slopes there are widespread deposits of float ore, which take the form of pebbles and small boulders as the bottom of the hill is approached.

The deposits must have been known to the Romans but they probably found the ore too hard to mine and too silicious for them to smelt. There are 35 ncessions of 50 hectares each. The more prominent deposits were filed on by the Germans some years ago and were held by them until the last war. They are now in the name of Companhia Mineiro De Moncorvo and are in litigation. The French Company of Schneider & Compagnie also acquired 23 concessions, most of them having float ore only. Currently, a company called Ferrominas Lda., is operating on the concession Fragas da Carvalhosa, No. 290. It has shipped between 30,000 and 40,000 tons of ore to England and will probably furnish 60,000 to 70,000 tons more under its contract.

Positive and probable reserves are estimated at 78,000,000 tons. The largest single deposit is that of Cabeco da Mua - 40,000,000 tons. The Fragas da Cotovia and Creto de Mendel aggregate 25,000,000 tons. The Santa Maria and Fragas da Carvalhosa deposits contain about 5,000,000 tons each. There are estimated to be about 3,000,000 tons of float ore. Except for the float ore, the mining operation involves stripping, cleaning and the removal of the ore from open pits.

The ore is too high in silica to serve as the only feed for a blast furnace. Furnace-men do not like to use ore which contains more than 18% of silica as a rule, and the average silica content of the furnace charge should be 8%. The Carvalhosa ore shipped to Britain is mixed there with a Welsh ore, very low in silica, and the mixture apparently has been found to be satisfactory, but this provides a rather limited market. In general, the ore will have to be cleaned and concentrated. In order to avoid transportation of the waste material, beneficiation should be effected at the mine. Concentration can be accomplished readily by cleaning by heavy media separation or by cyclone separators followed by fine grinding and flotation. This should yield a product containing 60% iron and less than 10% silica, in the ratio of one ton of beneficiated ore for each two tons of crude ore mined. If a central mill is set up for beneficiation, the deposits can be worked one at a time, so that the one mill will suffice for the entire exploitation. After beneficiation, the ore would be pelletized, i.e., formed into pellets about 1 or 2 cm. in diameter. An aerial tramway would carry the pelletized ore down the mountain side to narrow gauge cars which would transport it to Pocinho. Unless the Douro were improved for navigation to permit barge haul, the ore would be transferred at Pocinho to the broad-gauge cars of Linha do Douro, and, if it were destined for export, hauled to Leixoes.

The cost of mining, beneficiation, pelletizing, delivery to narrow-gauge railroad cars and general expense is estimated at 110$00 a ton. Present rail charges from Carvalhal to Leixoes, exclusive of transfer from narrow-gauge to broad-gauge cars at Pocinho, is 70$00 a ton. Transfer at Pocinho costs 2$00 a ton. Government royalty tax and harbor costs at Leixoes add 22$00/ton. If the ore is concentrated to 60% iron and less than 10% silica, it should sell for about 244$00 a ton at Leixoes and should find a ready market at almost all times. This indicates a profit of about 40$00 a ton, which should be ample to attract capital to the enterprise.

It should be practical to mine 2,000,000 tons a year, and to find ready markets for the resultant 1,000,000 tons of beneficiated ore if it were desired to export it. At this rate of production, the reserves would last about 40 years.

With production stepped up to 1,000,000 tons a year, some reduction in cost of transportation and in cost of handling at Leixoes should be realized. The railroad has kindly consented to consider the problem of handling large volumes of ore to Leixoes, and has indicated that if traffic amounted to as much as 2,000,000 tons a year, it probably would move it from Carvalhal to Pocinho by aerial tramway or would run a broad-gauge track from Pocinho to Carvalhal. In such event, it would hope to establish a rate of 60$00 a ton from Carvalhal to Leixoes. Since no transfer at Pocinho would be entailed, this figure would be net to the shipper - a saving of 12$00 a ton under the present rate. With only 1,000,000 tons a year to handle, a broad-gauge extension apparently would not be undertaken, but there would, it is believed, be a substantial reduction from the present charge.

At Leixoes, it is anticipated that the handling of 1,000,000 tons a year would mean the enlargement of existing facilities and the installation of special equipment for the economical handling of the ore - with resultant reduction in charges to the shipper.

If the Douro were improved for navigation, still larger savings (and profits) would be made possible. The pelletized ore would be ideally suited to water transport, and its movement in the annual volume herein contemplated would be the deciding factor in the economics of navigation improvement to Pocinho. The barge loading point probably would be about 4 km westward from Pocinho. It would be quite simple to continue the narrow-gauge tracks between the rails of the broad-gauge line for the small additional distance required to reach a favorable site for loading.

In so far as navigation is concerned, the prospect would be equally favorable if a domestic iron industry were established, since if the ore did not have to be moved, other raw materials, and the finished products would require transportation.

5. Domestic Iron Production

If, instead of exporting all of the ore, it were desired to establish a local iron industry, a number of factors would require careful consideration.

In order to convert the ore into iron, two other principal ingredients are required namely, coal or charcoal, and limestone. Location of these necessary materials has an important bearing on the choice of a site for a plant, and still more important perhaps, is the location of the market for products. Of compelling importance also are power and water supply. In Portugal, most of the factors involved are near Porto, the ore being the only ingredient requiring extensive transportation. This statement should be qualified somewhat by noting that the development of the Douro River for power will provide large sources of electric energy in the general region of the ore deposits.

Portuguese anthracite is not a coking coal, although some sort of coke could probably be made by mixing it with petroleum distillation residues or high volatile imported coals. The absence of coking coal requires considerable research to determine the best type of furnace to use, but it does not per se preclude the production of iron. Iron was produced for years in the United States without coke. Recent developments in South Africa with the German Krupp-Renn process, may be applicable to the Portuguese problem. The matter is far too complex to be resolved by an investigation of the limited scope of the one just completed. The potentialities are, however, interesting, and the importance of the iron ore deposits, particularly those of the Moncorvo region, are so significant to the National economy as well as to that of the Douro valley, as to warrant their thorough exploration and detailed study, to develop the most profitable methods for their exploitation.

CHAPTER V

IRRIGATION

1. Climatic Characteristics

From the standpoint of hydrologic characteristics alone, irrigation of garden crops and orchards in the Douro Basin in Portugal is desirable. The annual precipitation has a distinctly seasonal pattern with a marked deficiency of average precipitation in the months of June to September, inclusive. The duration of the summer dry season may vary from year to year, from three to five months, and there may be individual months of deficiency even in the winter or spring seasons.

2. Topographic Conditions

Even though irrigation may appear to be desirable from a hydrologic standpoint, there are several obstacles to the establishment of irrigation projects on a considerable scale. The first of these is the almost total absence of relatively level tracts of land which could be served by a system of canals radiating outward from a central source of supply. The largest tracts are in Vilarica Valley at the mouth of the Sabor River and the Chaves Valley ("Veiga") in the Tamega Basin near the town of Chaves. The latter valley is now served by an irrigation system. Development of the former valley is discussed below.

3. Present Land Use

The second obstacle to the development of large scale irrigation is the fact that a large percentage of available land is devoted to vineyards for the production of port wine. The irrigation of such vineyards is prohibited by law as irrigation is considered to be detrimental to the quality of the port wine. The arable land not devoted to vineyards is used for garden plots and small fields of corn, small orchards of oranges, lemons, figs, pears and apples. With the exception of the vineyards the pattern of agriculture use is broken up into many small plots because of the rough topography wich often necessitates extensive terracing. In the downstream reaches of the Douro near Porto there are many small land holdings. Under the above conditions irrigation by a system of canals is impracticable. The only alternative is to supply water by wells to individual tracts, a practice which is often followed now.

4. Vilarica Valley

A. Location - The most promising site for a large-scale irrigation project is the Vilarica Valley. This valley is located in the lower reaches of the Vilarica River, a small tributary of the Sabor River. The two rivers join at a point 3 km north of the junction of Sabor and Douro Rivers. The main valley extends from the mouth of the Sabor River to the junction with the Vilarica River and then up the Vilarica River for a total distance of about 9 km. The average width of the level land within the main valley is 0.8 km, making an area of about 700 hectares. The main valley floor varies in elevation from 104 m above sea level at the mouth of the Sabor River to 126 m at the upper end. Above the end of the main valley, there is a second smaller valley of about 100 hectares in area and at an elevation about 25 m higher than the first valley.

B. Previous investigations - Extensive investigations of the land use and agricultural economics of the valley were made by the Junta Autonoma das Obras de Hidraulica Agricola (now incorporated in the Hydraulic Services) in the period 1935-42. The area was mapped topographically to a scale of 1:2500 and a detailed survey was made of the soils classification and land use. The survey was conducted for an area far beyond the limits of the main valley floor, in that it extended 19 km upstream from the mouth of the Sabor River and to elevations 80 to 90 m above the lower valley. A total area of 2500 hectares was classified. Of this total, 1744 hectares were considered to be irrigable by waters of the Sabor River, in accordance with a plan outlined below.

The irrigation of the Vilarica Valley was proposed by the Portuguese government in an overall plan for the multiple-purpose development of the Sabor River. The plan included a dam with pool elevation at 207 m above mean sea level, to be constructed near Quinta das Laranjeiras on the Sabor River, for irrigation and power. A similar project has been studied in this report and is described in Chapter X. Because of the high elevation proposed for the Sabor River dam, it would be possible to transfer water to the Vilarica Valley through a tunnel at about elevation 180 m. This tunnel would discharge into canals which would command an area 1,000 hectares greater than the main valley. In addition to the gravity distribution system supplied by the tunnel, a pumping station would be constructed to lift water to areas located about 200 m above mean sea level. There is considerable doubt as to whether the areas with steep slopes and poor soil, located at elevations up to 75 m above the main valley, could be irrigated at a justifiable cost.

The 10 year old estimates for the diversion tunnel, canals, pumping station, and the proportionate part of dam and reservoir costs chargeable to irrigation, total 28,000 contos, or 16 contos per hectare. Because of subsequent increase in construction costs, the unit cost for irrigation under present day conditions would be about 30 contos per hectare. The above analysis is based on the assumption that the proposed hydroelectric development is justified and able to contribute about 98% of the dam and reservoir costs. As a development on the Sabor River for power production has low priority, it is not possible to justify irrigation of the Vilarica Valley from reservoir storage at the present time.

C. Alternative developments - Before discussing any possible alternative developments, it should be noted that the area of relatively level land that can be easily served by a system of canals is 700 to 800 hectares. The average unit capital cost for justified irrigation projects in Portugal is 30 contos per hectare at present price levels and for crops other than rice. On this basis, the capital expenditure for irrigation alone for the Vilarica Valley would be only 21,000 to 24,000 contos. It is obvious that such an expenditure will not pay for a dam and reservoir, no matter how small, and a canal system.

(1) Diversion dam - A possible alternative is the construction of a diversion dam on the Douro River for the purpose of directing water into main canals that would flow north against

the natural valley slope. If the distribution were made by gravity to the upper end of the main valley, the diversion dam would need to be 30 m high and would then become a major structure that could only be built at a cost many times the allowable expenditure. When the proposed Pocinho project is built, it might be possible to divert water above this dam to the Vilarica Valley.

(2) High-head pumps - In lieu of a high diversion dam on the Douro River, water could be pumped into the system of canals mentioned above by high-head pumps located on the bank of the Douro. The required total capacity of the pumps would be about 1 m^3/sec. Because of the shallow depths prevailing in the Douro River in the summer it would be necessary to construct a low dam to raise the water to the required level of the entrance weir for the pumping station. Such a dam would also be necessary to provide sluicing facilities in order to prevent sediments from entering the pumping station. The pumping station would require protection against great floods. The entire installation would be less costly than a high diversion dam, but could not be built for the allowable capital cost. The construction of the Pocinho power project would obviate the need for the low dam.

(3) Deep-well pumps - The third alternative would be to irrigate the valley by a series of deep-well pumps driven preferably by electric motors and serving a simple system of small canals. Before undertaking such a project, test wells should be driven to determine the quality and dependability of the ground water supply. If an adequate supply of hydroelectric power at reasonable rates can be obtained from the International Douro, an irrigation project of this type probably can be justified.

CHAPTER VI

FLOOD CONTROL

1. Flood Characteristics

The great floods in the Douro River are generally concentrated in the six-months period from December to May, but may occur infrequently in the months of October, November and June. The river is not continually in flood in this period and there may be periods of a month or more of low flow in these fall, winter and spring months. The floods result from widespread meteorologic disturbances that generally approach the basin from the west and southwest. Because of the great extent of the drainage area comprising the Portuguese and Spanish Basins (97,000 km^2) all of the component tributary areas do not receive heavy rains and produce flood peaks simultaneously. As a result of the general west to east movement of the storms, the peak floods in the Portuguese tributaries and in the National Douro generally occur before the flood peaks from Spain arrive. As 78% of the Douro Basin is in Spain, it is inevitable that there is a substantial contribution to flood flows from this area. In major floods the Spanish contribution appears as a secondary peak in the National Douro one or two days after the major peak from the Portuguese tributaries, or merely causes a prolongation of the peak of the Portuguese flood. A chronological list of flood peaks in the National and International Douro are given in Tables VI-1 and VI-2. (See pages VI-8 and VI-9).

The basin of the National Douro is mountainous and the main river and tributaries flow through narrow valleys, portions of which are canyons with almost vertical sides. The International Douro is an extraordinary canyon for 100 km. A similar topographic formation extends into Spain for another 35 km. About 45 km above the International Douro and near the city of Zamora, the river flows through a broad plain for a distance of about 300 km. The important point to note about the topographic features in Portugal and along the Spanish border is that they do not provide any appreciable modification of flood peaks by natural valley storage. In Spain, peak flows on the main river are modified to a large extent by storage in the great flood plain above Zamora and by artificial storage in the Ricobayo Reservoir on the Esla River, a tributary that enters the main river about 20 km above the International Douro. Prior to the construction of this reservoir, the Esla River was the greatest flood producing tributary in the entire basin. The estimated flood peaks on the Esla River have always exceeded the corresponding flood peaks contributed by the entire basin above Zamora. Although the Ricobayo Reservoir may always cause some reduction of flood peaks on both the Esla River and on the main Douro River, the effectiveness will depend upon the elevation of the power pool and the residual storage remaining at the time of a flood. In the great flood of January 1939, the peak inflow to the reservoir was 6,000 m3/s and the resulting peak outflow was 3,500 m3/s. The estimated maximum discharge at Puente Pino in Spain, below the Esla River, was 5,220 m3/s on Jan. 19 but the maximum daily discharge in Portugal at Regua was 6,570 m3/s Jan. 18. Without the reservoir, it is quite probable that there might have been a second peak in Portugal that was considerably higher than the first. The distribution of runoff in the 1939 flood appears to have been unusual, because in most floods the peak contributed by the area in Spain is less than that resulting from runoff from the Portuguese tributaries. Because of these basin characteristics, the Ricobayo Reservoir can, in general, provide only minor flood control benefits in Portugal.

2. Flood Damage

Flood damage in the International and National Douro is small except in very rare floods such as those of 1860 and 1909. The International Douro suffers no appreciable flood damage in spite of the extraordinary range in stage of about 30 m between low water and the stages of major floods. The sides of the canyon are uninhabited and the only structures are a few grist mills. The simple machinery in these mills is dismantled in winter. Floods completely submerge the stone shelters and rubble weirs, but partly because of the small differences in head above and below the installations, the damage is not great and is repaired each summer.

On the National Douro the principal damages in great floods are at Regua, Porto and several small resort towns. In ordinary floods these places as well as the many "quintas" for the production of port wine are well above the flood level. The railroad, most highways and all railroad and highway bridges are above all but the rare floods.

The greatest floods of which there is dependable knowledge in the National Douro were those of 1860 and 1909. Substantial damage occurred in these floods to waterfront property at Regua and Porto and to river shipping in the latter place. The most important floods in the last 33 years were those in 1936 and 1939 which had stages about 10 to 12 m less than those of 1860 and 1909 in the river above Porto. Minor damage and interference with shipping occurred at Regua and Porto. At both places the river bank rises sharply so that inundation even in the greatest floods extends only a few hundred meters from the normal river channel.

Economic justification for flood protection must be based on the average annual damages prevented, or the so-called flood control benefits. These benefits must at least equal the annual charges (interest, amortization and maintenance) resulting from a capital expenditure for flood protection. In economic analyses for flood control, it has usually been found that the greater part of the total annual damages results from relatively frequent flood damages. The annual damage resulting from a great flood is relatively small because it is obtained by dividing the total damage by a recurrence interval of perhaps 50 years or more. For example, a 50-year flood may cause a 14,400 contos total damage but only 288 contos annual damage. If a particular protective work can prevent 80% of this damage, the annual benefits for the work will be 230 contos. However, at a 5% annual charge, the capitalized value of the benefits will be only 4600 contos which would not permit very extensive works. If there were annual damages resulting from smaller floods, and if these damages were prevented, the amount would be added to the benefits (damages prevented) from the great flood against which protection is provided.

The above rather academic discussion is inserted in this report to show that extensive flood control projects in the National Douro can not be justified, because of the infrequency of important damage even if there were not other physical obstacles. A brief discussion of possible methods of flood protection is given below.

3. Possible Flood Protection Methods

The two most common methods of flood protection are by upstream reservoirs, and by levees and channel improvements at damage centers. To obtain effective protection by reservoirs it is necessary to regulate the flow from a large percentage of the total drainage area above the damage centers.. In addition, it is necessary to have relatively broad valleys for reservoir areas. There are very few such valleys in the National Douro.

The best reservoir sites in the basin of the National Douro have been studied for power development. If developed for effective flood control, all the projects combined would control only 27% of the area within Portugal and 5 to 6% of the Total area. Even if there were some reduction of the major flood peaks from Portugal, the contribution from Spain would pass through unmodified. Because of the narrow valleys on the main river, no effective flood control storage could be obtained on the National or International Douro.

The second flood protection method would be to construct levees or walls at important centers such as Regua and Porto. Earth levees are eliminated at once because of the scarcity of suitable constructive material and because, by reason of the wide base needed, the levees would occupy almost the entire area to be protected. Narrow vertical walls of reinforced concrete could be constructed, but they would be objectionable because of their interference with water front commerce at both Regua and Porto. To protect against the rare floods, the walls at Regua would need to be so high that they would also be objectionable in appearance to property owners.

A third but rarely applied method for preventing urban flood damages is to remove the property subject to damage, and to prevent further building in areas subject to damage. As property becomes obsolete, it can be torn down and replaced by dock loading facilities, parking lots, parks and recreational areas. Resettlement of the inhabitants must be at government expense, but the net benefit to the regional economy, in the case of Regua and Porto, would appear to be greater than an investment in rarely used protective works.

Protection of the Vilarica Valley from frequent inundation would be desirable if it could be obtained at a reasonable cost. Flooding of the valley results from either high stages in the Douro River alone or from the coincidence of flood stages in both the Sabor and Douro Rivers. Protection from Douro River floods might be obtained by constructing a dam about 30 m high across the mouth of the valley. However, such construction would require provision for passing floods from the Sabor River. If the latter floods occurred during high stages in the Douro, it would be necessary to create a differential head within the Vilarica Valley in order to pass the Sabor River floods through sluices in the dam. The creation of such differential head would result in interior flooding of the valley. If the tributary area within the protective works were small, interior flooding could be prevented by providing large drainage pumps. Such a solution for disposing of Sabor River runoff would be prohibitively expensive. If topographic and hydrologic conditions were more favorable, consideration might be given to diverting the Sabor River directly to the Douro River and by-passing the Vilarica Valley, but such a solution is out of the question.

A second method for protection of the Vilarica Valley would be to construct levees along one or both sides of Sabor River and Vilarica Creek channels. Such levees would connect with the hills at convenient points in order to inclose completely the areas to be protected. Such levees would need to be more than 20 m high near the mouth of the valley and for such a height would require a minimum base width of 125 m. It is obvious that the cost of such large structures could not be justified for the protection of such relatively small tracts of agricultural land. Pumping plants might also be required for the leveed areas, to evacuate local rainfall and seepage during periods of high stages in the Sabor or Douro.

TABLE VI-1

FLOODS OF DOURO RIVER AT PUENTE PINO -

DRAINAGE AREA = 63,300 Km^2

YEAR		FLOOD (m^3/s)
1930	-	2250.000
1931	-	1968.750
1932	-	2250.000
1933	-	2015.625
1934	-	1459.375
1935	-	2500.000
1936	-	3425.000
1937	-	1828.125
1938	-	1100.000
1939	-	5250.000
1940	-	2062.500
1941	-	2250.000
1942	-	1100.000
1942-43	-	1781.250
1943-44	-	875.000
1944-45	-	543.750
1945-46	-	1875.000
1946-47	-	2918.750
1947-48	-	2250.000
1948-49	-	375.000
1949-50	-	403.125
1950-51	-	2625.000

TABLE VI-2

STATISTICAL STUDY OF THE GREATEST ANNUAL FLOOD FLOWS

AT BITETOS

Hydrologic Year	Highest flood (m^3/s)
1922-23	2,910
1923-24	6,025
1924-25	2,600
1925-26	6,225
1926-27	4,980
1927-28	4,980
1928-29	1,350
1929-30	4,275
1930-31	2,950
1931-32	1,925
1932-33	3,750
1933-34	1,925
1934-35	3,150
1935-36	7,050
1936-37	6,100
1937-38	5,500
1938-39	7,250
1939-40	4,025
1940-41	5,250
1941-42	1,700
1942-43	4,475
1943-44	1,510
1944-45	1,080
1945-46	3,150
1946-47	4,675

CHAPTER VII

NAVIGATION

1. Present Commerce

The present water-borne commerce of the Douro River consists mainly of coal and wine. About 260,000 tons of coal per annum are produced by the Pejao Mines and almost all of it is transported 33 km downstream to Porto by a fleet of 90 raboes wooden craft with model (streamlined) hulls 21.7 m long by 4.95 m wide and measuring 1.45 m from keel to rail (see Plate 5a). The normal cargo, carried loose in the hold, is 60 tons. The rabao has very little freeboard under full load. The raboes are steered by a long stern sweep; are propelled downstream by the current; and upstream by means of a sail when the wind is favorable. When there is no wind, they are pulled by a motor boat, poled, or (in certain reaches) towed by oxen. Sometimes the river stage falls so low that 6-ton cargoes have to be lightered from Germunde past the Carvoeiro shoal, a few kilometers downstream, and combined at the latter point to form the standard loading. Occasionally, truck haul over poor roads all the way from the mines to Porto is necessary.

The port wine now carried by the river is loaded at a number of points between Cinfaes and Pocinho, 39 and 179 km by river, respectively, above Gaia (directly across the Douro River from Porto), which is the clearing point for wine produced in the Douro region. During the period 1939-1951, an average of a little over 5,000 casks a year moved by river and over 32,000 casks a year by rail. A full cask weighs

750 kg. The empty casks, which are returned upstream for refilling, weigh 100 kg each.

While coal and wine constitute the significant river commerce from the standpoint of tonnage, there is some downstream movement of miscellaneous cargoes such as firewood, brush, cork, grain, flour, chestnuts and fruit.

2. Potential Commerce

A. Miscellaneous commodities - For purposes of appraising the economic justification for improving the Douro River for navigation, the future movement of the miscellaneous commodities mentioned above is not believed likely to prove decisive, because the tonnage is comparatively slight. A significant addition might be the future upstream movement of fertilizer. Portugal as a whole, imported over 370,000 tons of fertilizer in 1951, but data as to the tonnages and destinations of that used in the Douro basin are not available.

B. Coal - The mining program approved by the management of Empreza Carbonifera do Douro, the operators of the Pejao mines, contemplates the production, beginning with 1953, of 360,000 tons of coal a year. If the procedures advocated by Pierce Management in its Coal Report (Appendix A) are adopted, the annual output would be about 383,000 tons, but if a thermal power plant were built at Germunde to burn the processed coal, it probably would consume about 92,000 tons of that output. This would reduce the down-river shipments to about 291,000 tons a year.

For purposes of the navigation study, the last mentioned figure has been used, which may be too conservative from the navigation standpoint. If a thermal plant were built to burn the low grade 45% ash coal, normally left in the ground, a washing plant would not be built. It is then conceivable that the proposed output of 360,000 tons of fuel, for sale on the open market, would be mined, in addition to the 168,000 tons of low grade 45% ash coal, to be consumed locally.

Pierce Management estimates a probable life of about 38 years for the mines, if 383,000 tons a year of cleaned coal are produced by processing the products of full seam mining, but these estimates are based on drilling done to date. The regional geology indicates the possibility of reserves under large tracts that have not been drilled. It therefore seems reasonable to assume at least a 40 year life for the mines under whatever program of exploitation that may be adopted.

C. Wine - The Douro Valley produces annually a large volume of table wines and is the source of all port wine. The annual production of port wine is about 28,000 tons and of other wines is almost twice that amount.

The handling of the crop entails, in addition to the downstream movement of the wine, the upstream movement of 12,600 tons of empty wooden casks and over 3000 tons of brandy. A small portion - perhaps 15% - of the crop now moves by water, and it does not appear too far-fetched to assume that with provision of adequate navigation improvement, as much as 85% might do so for the following reasons: (1) water transport is cheaper; (2) the wine originating inland must in any event be hauled in trucks or carts or in narrow gauge railroad cars to the broad gauge railroad which traverses the river bank and there unloaded and transferred; (3) shippers seem to prefer water transport because it eliminates the damage to casks from the jostling and rubbing received on the sharp curves of the railroads.

D. <u>Ore</u> - As pointed out in paragraph 4 of Chapter IV, there is a potential movement of about 1,000,000 tons a year for about 40 years of beneficiated martite ore from the Moncorvo area to Porto or Leixoes.

3. Navigation Improvements Required in the Douro River

A. <u>General</u> - Because there appears to be no river traffic of consequence, either present or potential, above Pocinho, the portion of the stream considered for improvement of navigation is the distance of about 184 km between the mouth and Pocinho. The total distance in turn divides naturally into the portion between Porto and the sea, called for convenience Foz do Douro, or the mouth, the portion (67 km) between Porto and Carrapatelo, the most downstream of the hydroelectric dams considered, and the reach between Carrapatelo and Pocinho, improvement of which for the generation of electric power is under consideration.

B. <u>Type of navigation selected</u> -For purposes of planning for navigation improvement and computing costs and savings, a navigable depth of 2.7 m (9 ft.) has been selected. It is a depth widely employed for inland waterways of the United States and found usually to afford a satisfactory balance between economy of transport and first cost and maintenance cost of waterway improvements - although the trend of late years has been toward still greater depths. The greater the depth, the greater in general, is the capacity of a given tow, and the lower the cost per ton-mile of freight movement.

On the Douro River, the principal tonnage will be iron ore from the Moncorvo mines. It is believed, therefore, that the character of the works for improvement of navigation should be governed in large measure by the needs of that traffic. On the basis of experience elsewhere, a steel hopper barge 175 ft. long by 26 ft. wide (53.5 m by 7.95 m) weighing about 136 metric tons was selected as best meeting the Moncorvo ore trade requirements. Considering the sinuousity of the stream, the length of haul involved, and lockage requirements, it appeared that four such barges, lashed two abreast and propelled ahead of the tow boat, would constitute the most satisfactory size of tow. Where conditions permit, it is believed that propulsion of the barges ahead, rather than towing them astern by means of hawsers will be found the most economical means of moving cargo.

C. Development from Carrapatelo to Pocinho - The rise in the river's normal water surface in the 116 km from Carrapatelo to Pocinho is about 94 m or an average slope of a little over 0.8 m per km. The swiftly flowing stream twists its way through granite and schistose hills which rise sharply on both sides - sometimes, in the case of the granite, so steeply as to form canyons. Occasionally its course is interrupted by rapids. In places patches of rock protrude above its surface. When the stage permits, a few shallow draft rabelos and rabees negotiate its difficult course, with cargoes of wine, fruits or chestnuts or various other products of the region.

Improvement for navigation by means of low dams only would be costly and would require many locks, but the very features which are unfavorable to shipping are favorable to the development of power. The reach could be most advantageously developed for power production by the construction of three dams at the Carrapatelo, Regua and Valeira sites respectively (see Plate 16), which would create slack water pools having depths of 27 to 36 m at the dams, and gradually diminishing in depth upstream, until, near their upper ends, deepening would be required to provide 2.7 m depths.

As there is some navigation at the present time, it would appear that even though they were built solely for the generation of electric power and without thought of improving the stream for navigation, the three dams would have to provide some means for passing the craft that now ply the river. It has been assumed, therefore, that each dam would be equipped with a small lock, about 11 m wide by 45 m long, capable of locking through 4 craft at a time of the rabelo type. Because of the difference in elevation to be overcome, it seems probable that the lift would be in two stages at each dam. As traffic is not heavy, and schedules are probably rather casual, it is believed that operation of the locks 16 hours a day would prove acceptable.

For ore tows of the type planned after improvement for 2.7 m depth of navigation, the locks again would be double-lift structures, but larger lock chambers would be required. The dimensions selected were a width of 56 feet (17 m) and a usable length of about 280 feet (85.5 m). Such a chamber will accommodate two ore barges abreast, with a 32 m tow boat astern. It is easy to break a barge tow crosswise and reassemble it, but time-consuming to break it lengthwise and reassemble it. In using a lock chamber of 17 m by 85.5 m, a four-barge tow would place the two forward barges in the chamber and back out: then, when they had been locked through, enter with the two remaining barges; and be locked through; and then reassemble its tow and proceed.

The lakes created by the power dams would raise the water surface to such high elevations, that the distance between banks would be greater than at normal stream levels. This would permit vessels to pursue a less sinuous course than would be necessary if they had to follow the low water meanders closely. In the upper ends of the pools, however, original conditions of depth and sinuosity would continue to prevail and in order to provide for tows of the type envisioned, some work of channel deepening would be required.

(1) Cost of locks - The estimated costs of the locks required for ore tows are as follows:

	Contos
Carrapatelo Dam	102,325
Regua Dam	76,743
Valeira Dam	55,664
	234,732

The estimated costs of locks of 11 by 45 meters required if navigation is not improved, are as follows:

	Contos
Carrapatelo Dam	57,266
Regua Dam	42,949
Valeira Dam	31,153
	131,368

The differences between the costs of the large and small locks, chargeable to navigation improvement, are as follows:

	Contos
Carrapatelo Dam	45,058
Regua Dam	33,794
Valeira Dam	24,511
	103,363

(2) Cost of channel excavation - As, where power is involved, the pool of one dam cannot be allowed to raise the tailwater of the next installation upstream, it would be necessary to excavate a channel in the rock of the river bed immediately below each of the three power dams at an estimated aggregate cost of about 46,645 contos.

(3) Operation and maintenance of locks - Lock crews are assumed to include, for operation 24 hours a day, 7 days a week, one lock master and six laborers. For a lock with two lifts, the cost per annum would be about 402.5 contos.

For the small locks, operated only 16 hours a day, the cost per annum would be 307.3 contos. Thus, the operating cost chargeable to navigation would be 100.6 contos for each of the three dams. If the additional ordinary maintenance and repair charges of 115.0 contos which the larger locks would entail are added, the annual cost of operation and maintenance chargeable to improvement of navigation becomes 215.6 contos a year for each set of locks. To this total must be added about 521.5 contos for annual channel dredging below the dams.

D. Development from Porto to Carrapatelo -

(1) General considerations - Between Carrapatelo and Porto the river gradually widens, and as the sea is approached, the slope flattens.

The range in stage between low water and extreme flood, almost 30 m at Carrapatelo, is not much more than 12 m at Ponte de Maria Pia in Porto. The effect of ocean tides is felt for about 23 km upstream, to Pe de Moura. The range in tide at the mouth is about 4 m.

Hydrographic zero is 1.93 m below mean sea level and mean low tide is 1.03 m below mean sea level. The bottom of the proposed navigation channel was taken as 2.7 m below mean low tide. This means, of course, that during extreme low tides, which have been known to reach minimum elevation of 2.13 meters below mean sea level, there will be less than 2.7 meters depth in the channel unless the volume of river discharge is large. As extremes of low tide are rare, however, mean low tide is believed to be a rational datum for river navigation.

While the lower Douro River flows between rock banks, its bed is sand, to depths beyond those to which explorations thus far have penetrated. The bed profile is irregular, with shoals and deeps alternating, but upstream from Ataes, 9 km above the D. Luis Bridge, the river bottom lies almost continuously above the elevation selected for the bottom of the navigation channel, i.e., it is almost continuously less than 2.7m below mean low tide.

The lower Douro River moves so much sand during floods, and the rise in river bed, while less per kilometer than in the upper reaches, is still so steep, that maintenance of a channel by dredging between Ataes and Carrapatelo, a distance of some 53 km, seems impracticable. Even after the power dams are built, the Tamega, Paiva, Arda, Sousa and other lesser tributaries will continue to bring down sand, and it is believed that much sand also will pass the main river dams during floods.

The alternative to channel dredging is the creation of pools of sufficient depth by the construction of navigation dams. To provide 2.7 m depth for navigation to Carrapatelo, two dams will be needed - one near Ataes and one farther upstream. Inquiry among boatmen plying the river elicited the information that while the river bed is of sand almost everywhere, there are two places at which it is rock. One was said to be at Ataes and the other near Entre-os-Rios. There are no probings or borings to substantiate this contention, and as the river never falls low enough for the bed to become visible from shore to shore, there is an element of doubt; which can, and certainly must be resolved before final decision as to the exact location and type of dam is made.

On the basis of the statements made, however, it was decided to select Entre-os-Rios as the site of the upper navigation dam. The elevation of the river bed fixes the position of the lower dam at or near Ataes.

(2) Ataes Dam and Lock - The height of Ataes Dam is dictated by the requirement that a depth of not less than 2.7 m be maintained to the vicinity of Entre-os-Rios under all conditions of flow, which calls for a normal pool of elevation of 6.7 m above mean sea level. The most economical means of providing such a pool would be a solid concrete weir with crest at elevation 6.7 m, equipped with a lock for passing boats and tows. There would be continuous flow over the crest of the weir so that the water surface would always be above elevation 6.7 m, by amounts which would vary with the changing volume of the river's discharge. The greater the volume of flow in the river, the higher would be the stage

at Ataes, of course, but the less would be the surcharge - that is, the less would be the difference between the stage at Ataes corresponding to a given rate of flow under present conditions and the stage which this same rate of flow would produce after the weir was built. The increases in water level occasioned by the weir would extend upstream for varying distances dependent upon the volume of flow. The following comparison illustrates how the effect of the weir varies with volume of discharge.

Flow at Ataes m^3/s	Elevations in meters above sea level		Surcharge caused by weir (meters)
	Below weir (natural stage)	Upstream from weir (increased stage)	
4000	6.7	10.18	3.48
6000	9.0	11.18	2.18
7000	10.1	11.75	1.65
9000	11.9	13.13	1.23

The surcharge would gradually disappear. In the case of the 9000 m^3/s flood for example, the influence of the weir should not be apparent for more than about 12 km. Inspection of the contour maps of the river's banks above Ataes does not indicate that significant flood damage would be likely to result from the stage increases which a solid weir would induce.

It is evident, however, that with differences of the order indicated above between headwater and tailwater elevations, there will be extremely high velocities in the vicinity of the weir. It would be essential to make a careful study of this aspect of the problem before deciding upon a solid weir, and either to make certain that the bank materials contiguous to the end of the weir were sufficiently rugged to withstand the high velocities, or to take measures to prevent damage if the rock were too weak in its natural state.

If the gates of the navigation lock were carried to about elevation 10.7 m above mean sea level, the lock could be used until volume of flow reached 4000 m^3/s. For greater flows, the lock would drown out and navigation would have to be suspended until volume of flow again decreased below that figure. A flood of 4000 m^3/s corresponds to about the flood of two year frequency. It would be feasible to carry the lock gates and walls higher, but as this would increase costs, and as maneuvering in the river near its mouth must be quite difficult during large Douro River floods, it is assumed that there will be little traffic moving at such times, and that perhaps, as representing the absolute minimum of construction cost, a lock to this height and interruption of navigation at 2 year intervals would be permissible. Of course, the lower the flow at which the lock drowns out, the longer and the more frequently will it remain out of commission.

A single-lift lock, excavated from solid rock on the left bank would have a usable chamber length of 450 feet (138 m) and a width of 56 ft. (17 m) and would accommodate an ore tow of four barges, two abreast, with the tow boat astern.

The construction cost of a lock and solid weir at Ataes, of the character and dimensions discussed above, founded upon sound rock

MASTER PLAN AND REPORT

ENGINEERING AND ECONOMIC STUDY

Exemplar oferecido pelo Eng Elesiário Monteiro quando ambos fazíamos parte da Comissão Directiva da Repartição Nacional de Cargas

DOURO RIVER
AND
TRIBUTARIES WITHIN PORTUGAL

PREPARED FOR

MINISTER OF THE PRESIDENCY
GOVERNMENT OF PORTUGAL

MARCH 1953

KNAPPEN-TIPPETTS-ABBETT-McCARTHY
ENGINEERS NEW YORK, N. Y.

KNAPPEN-TIPPETTS-ABBETT-McCARTHY

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March 16, 1953

The Minister of the Presidency
Government of Portugal
Lisbon, Portugal

Your Excellency:

Pursuant to the terms of Article I of the Agreement, dated November 1, 1951, between the Government of Portugal and Knappen-Tippetts-Abbett-McCarthy, Engineers, covering an engineering and economic study of the Douro River and its tributaries within Portugal with recommendations as to the successive steps to be taken in the coordinated development of the river, there are submitted herewith twenty-five (25) copies of the completely documented Master Plan and Report.

This report summarizes the studies made during the period since December 1951 and includes economic, capacity, dimensional, quantitative and cost information, and an analysis of how the development would fit into Portugal's overall power requirements.

It verifies the selection, made in the Memorandum Report, of the Picote Hydroelectric Project as the one of first priority. In addition, it makes recommendations concerning: The operation of existing power generating facilities; the order of construction of proposed power generating facilities; coal and iron ore mining operations; and navigation improvements (see Summary and Chapter XV, Recommendations).

In accordance with our Agreement, we respectfully request your approval of our recommendation of the Picote Hydroelectric Project as the one of first priority, in order that we may proceed with the preparation of the general plans, specifications and estimates relating thereto.

Very truly yours,

KNAPPEN-TIPPETTS-ABBETT-McCARTHY

Gerald T. McCarthy

Gerald T. McCarthy
Partner

GTM:rb
Enclosure

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ACKNOWLEDGEMENTS

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SUMMARY

1. Objectives

The objectives of the report on the "Engineering and Economic Study of the Douro River and its Tributaries in Portugal" undertaken by Knappen-Tippetts-Abbett-McCarthy, Engineers, under an agreement with the Government of Portugal dated November 1, 1951, are to discuss and recommend the successive steps to be taken in the coordinated development of the Douro River and its Portuguese tributaries for hydroelectric and thermal power, navigation, flood control and irrigation.

2. Considerations

In arriving at the objectives, the principal aspects of the national economy considered are: the present electric power production and transmission system of Portugal; present and indicated future power requirements; the generation of additional hydroelectric energy by the construction of new projects on the International Douro, the National Douro, and its Portuguese tributaries; generation by a thermal plant burning Douro Basin coal; the manner in which the output of the proposed new projects would fit into the overall power requirements of the nation; the extent and character of coal and iron ore deposits in the Douro Basin, and the methods of exploiting them; flood control; irrigation; and navigation.

3. Findings

A. Present facilities - The study has disclosed that the electrical generating facilities now existing (or under construction and soon to become operative) including thermal plants with a total firm capacity of about 100,000 kw, are capable of supplying firm energy in sufficient quantity to meet all requirements until sometime in 1956, if completely integrated and operated as a power pool. The present method of operation, however, influenced by a rate structure which provides revenue for energy only, tends to result in the depletion of storage reservoirs to such extent in years of normal stream flow that the recurrence of sustained periods of low stream flow will be attended by power shortages and interruption of industrial production. The thermal supplement is not capable of compensating for the deficiencies in hydro generation during sustained dry periods.

B. Integration of facilities - Complete integration and power pool operation will require, in addition to a revision of rate structure to incorporate demand as well as energy charges, a network analysis to insure proper physical and electrical coordination between the numerous items of equipment and transmission networks comprising the system, and a National Load Dispatcher fully empowered to operate the facilities to the best advantage.

C. Growth in demand - Even with power pool operation, the indicated growth in demand is such that by 1960 there will be a shortage of about 67,000 kw of dependable capacity, unless additional plants are built. By 1965 the deficiency will be 151,000 kw, and by 1970, about 263,000 kw.

D. Douro hydro plants - The volume of flow of the Douro River is sufficient to operate large run-of-the-river hydroelectric plants.

The plants will have no storage of consequence, but fortunately their output can be firmed up by the large storage plants of the Zezere and Cavado Rivers. By taking advantage of this ideal situation, 244,800 kw of dependable capacity can be provided by plants on the main Douro River, at a construction cost including transmission lines and accessories, of 2,863,200 contos. Of the total dependable capacity, 146,200 kw can be provided by development of the International Douro at a cost of 1,348,700 contos, and 98,600 kw by development of the National Douro at a cost of 1,514,500 contos.

The most advantageous sites are on the International Douro as the foregoing figures indicate, and of these the site 22.4 km above the mouth of the Tormes River is the best. It is known as the Picote site. A gravity concrete dam about 100 m high at Picote with head of 74 m, will cost, including a 150,000 kv two-circuit transmission line to Ermesinde substation at Porto, ~~529,000~~ 596.000 contos. With 93,000 kw of installed capacity, it will provide, assuming power pool operation and 1960 load conditions, 63,600 kw of dependable capacity (almost the total 1960 indicated deficiency) and will deliver 529,000,000 kwhr of usable energy to the Ermesinde bus bar at a cost of 0.111 escudos per kwhr. Two other dams, at Miranda and Bemposta, 62 km and 8 km respectively, above the Tormes River, are needed for full development of the International Douro. Four dams, at Carrapatelo, Regua, Valeira, and Pocinho, respectively, are required to develop the National Douro. The projects on the latter are nearer to the Ermesinde substation than are those on the International Douro, and the three lower national river projects have modest collateral benefits from navigation, but these combined advantages are insufficient to counteract those inherent in the narrower, deeper, canyon and steeper slopes of the international portion of the river. On the basis of 1960 demand, the cost of energy at Ermesinde from Carrapatelo, the best of the National Douro projects, with optimum installation of 87,300 kw (if built as the first plant), and a dependable capacity of 45,800 kw, will be 0.135 escudos per kwhr after crediting the project with navigation benefits. This compares with 0.124 escudos per kwhr for Miranda, the least favorable of the International sites.

E. Plants on tributaries - The economics of the power projects investigated on the Portuguese tributaries are less favorable than those of the projects on the main river, because of the low flows of the tributaries and the costly dams required, supplemented in some instances by long waterways to the generating stations. A number of good storage sites exist, but because of the long duration of the critical drought period, the dependable capacity each could add to the system in the absence of main river plants, or even with the International Douro developed, would be relatively small.

F. Coal reserves and thermal power - The study has disclosed at Sao Pedro de Cova mine, near Porto, "certain" and "probable" coal reserves totaling 10,783,000 tons. If the certain reserves plus half of the probable reserves be taken as the most probable measure of available tonnage, a mine life of about 25 years with present production rate of 260,000 tons a year is indicated, on the basis of 75% recovery.

At Pejao, there are certain reserves of 10,583,000 tons and probable reserves of 20,069,000 tons. Again, assuming the most probable measure of the reserves to be the "certain" plus half of the "probable", and assuming a recovery of 70%, a mine life of about 55 years is indicated on the basis of present production rate, which is about 260,000 tons a year. The explorations of the coal deposits are far from complete, and it may be that significant increases in the "certain" reserves will be found.

On the basis of present knowledge it appears that the Pejao mines could, without depriving present customers, supply a 25,000 kw thermal generating plant for some 38 years, which is a little more than the nominal economic life of a thermal station. The most satisfactory procedure is indicated to be the adoption of full seam mining (the poorer grades are not mined at present) with air separation of fines and washing of the residue. This would yield, on the basis of 575,000 tons mined, about 383,000 tons a year of marketable fuel, uniform in grade, of which about 120,000 tons would be fines and about 263,000 tons washed coal. A 25,000 kw thermal plant designed to burn the fines would absorb about 92,000 tons, leaving all the washed coal (18% ash content) and 28,000 tons of the fines (20% ash content) for other customers. If designed for the washed coal, the thermal plant would consume about 88,000 tons, leaving for other customers, 175,000 tons of washed coal and all of the fines, which probably would be pressed into briquettes. If the coal were not air cleaned and washed, about 500,000 tons of marketable fuel could be produced and if the thermal plant were designed to burn the low grade, 45% ash fuel, it would consume 167,000 tons a year, and

333,000 tons would be available to other users, but it would not, of course, be of the quality of the processed coals.

Based on the coal prices tentatively quoted by the mine operators, the Pejao thermal plant would deliver energy at Ermesinde for 22.9 centavos per kwhr. This assumes 75% time operation at full capacity. It is about 16½ centavos less than the variable component of the cost per kwhr of energy from existing thermal stations. This variable component, which is the only saving that could be realized by closing down existing plants, as their fixed charges would remain unaltered, is 39.44 centavos per kwhr.

G. Replacement of existing thermal generation - It is apparent that if the variable component of the cost of energy produced by existing thermal plants is over 39 centavos a kwhr, it would be advantageous to replace as much as possible of the existing 100,000 kw of thermal supplement by Pejao, and by hydroelectric plants on the Douro, all of which with the exception of Pocinho, are even more economical than Pejao.

H. Iron ore - Although the iron ore deposits occur in the Douro Basin in the vicinities of Vila Cova, Moncorvo, and Guadramil, only the Moncorvo deposit, comprising positive and probable reserves of martite totaling about 78,000,000 tons, appears to be suitable for profitable exploitation at the present time. Too high in silica to command a universal market in its native state, and relatively low in iron content, it can be beneficiated economically at the mines to a pelletized concentrate containing 60% iron and less than 10% silica. Two tons of ore from the mine would yield a ton of the concentrated ore which can be hauled by rail to Leixoes, where it should find a ready market at prices yielding attractive profits. These profits could be materially increased if the Douro River were improved for navigation, so that water haul could replace rail haul below Pocinho. At a mining rate of 2,000,000 tons a year, the deposits would have a life of about 40 years.

The possibility exists of manufacturing iron and steel in Portugal from a part of the ore, but inasmuch as domestic coals do not coke, their employment for the purpose would involve the use of processes other than those customarily adopted for commercial production. It is possible that some adaptation of a circular-kiln process such as the Krupp-Renn might be worked out. The present study has only superficially considered the problem of domestic steel production.

I. Irrigation - The ruggedness of the topography that characterizes most of the Douro Basin, and the wide prevalence of viniculture devoted to the production of Port wine, combine to minimize the opportunity and the desire for irrigation. In only two areas does irrigation appear to be of importance. One is in the vicinity of Chaves, where a project is already in operation, and the other is the valley of the Vilarica River, a tributary of the lower Sabor River, where an area of some 700 hectares would be benefited.

Construction of a dual-purpose dam for power and irrigation near Quinta das Laranjeiras on the Sabor River would provide irrigation water for the Vilarica Valley at an elevation permitting distribution by gravity, but at costs commensurate with indicated benefits only in the event that most of the charges involved could be allocated to the power phase of the undertaking. As a power project, Quinta das Laranjeiras has so low a priority that irrigation by means of a reservoir cannot be considered as likely to become economically justified in the immediate future. The most promising possibility appears rather to lie in the direction of an electric power supply cheap enough to warrant pumping from ground water.

J. Flood control - Aside from important urban centers on the Douro, such as Porto-Gaia and Regua, and the low-lying agricultural lands in the Vilarica Valley, flood damage in the basin is almost negligible. No flood control projects are in existence or proposed. Only extreme floods materially damage the urban centers, and their occurrence is so rare, and the structures required to protect against them would be so costly and so inconvenient to normal waterfront activities, that protection does not warrant serious consideration. The damage to crops in the lower Sabor and Vilarica valleys is more frequent, but protection either by means of levees or high dams would entail costs far in excess of resultant (somewhat problematical) benefits.

K. Navigation - Between the Pejao coal mines and the mouth of the Douro there is, at present, water-borne coal movement of some 260,000 tons a year which would increase to at least 291,000 tons with recommended expansion of output at Pejao. Between the mouth and Pocinho there is currently a somewhat sporadic water movement of miscellaneous commodities and wine which conceivably would increase, with the advent of modern tows, to about 94,000 tons a year of wine, brandy and casks, and perhaps 70,000 tons of miscellaneous commodities.

The exploitation of the Moncorvo iron ore at the rate of 2,000,000 tons a year would yield a potential barge tonnage of 1,000,000 tons a year of beneficiated ore which would be transferred to the river just below Pocinho, and which would move towards the coast for export or perhaps in part to a possible steel industry near Porto. There is little prospective of commerce above Pocinho.

Savings of about 23,110 contos a year in the line-haul costs of moving iron ore, wine, coal, and miscellaneous commodities, in the annual volumes indicated above, will be effected by building navigation dams and locks at Ataes and near Entre os Rios; providing adequate locks in the power dams at Carrapatelo, Regua, and Valeira, and excavating certain channels below the dams; improving Foz do Douro so that vessels for the export of iron ore and wine could dependably and safely enter the Porto-Gaia harbor; and establishing 2.7 m navigation by barges between Porto and Pocinho. To this basic saving 5,075 contos a year should be added for port charges at Leixoes that would be avoided by virtue of improvement of the Foz do Douro bringing the total annual benefits to 42,173 contos. Annual charges against the navigation improvement for interest, amortization, maintenance, and operation would be about 36,060 contos. If the charges were absorbed by the Government, as has generally been the practice in the United States, annual savings to the shippers would be the full 42,173 contos. If tolls were assessed sufficient to defray all charges, the net saving to shippers would be reduced to 6,130 contos. The ratio of benefits to costs in either event would be about 1.17.

Nothing less than complete improvement to Pocinho will show a profit on the basis of probable tonnages to be handled and types of structures likely to be required, but the disparity between annual benefits and annual costs would not be very great if the Ataes lock and dam only were constructed to permit 2.7 m navigation to the Pejao mines. If the remainder of the navigation project were constructed without too long a delay, the over-all economics would not be seriously impaired by the initial development losses at Ataes, and it is probable that the experience gained during the interval between construction of the Ataes lock and dam and final completion of the project to Pocinho would prove valuable.

4. Conclusions

A. <u>Electric generating facilities</u> - It is concluded from the findings of the study that there is no immediate necessity for new electrical generating capacity in Portugal to supply firm energy sufficient to meet present demand, if exisiting facilities are fully integrated and operated as a power pool to meet energy demands in periods of drought. The steps required to attain this end comprise a network-analyzer study with such corrective measures as it may indicate, a rate structure revised to include demand as well as energy charges, and a National Load Dispatcher fully empowered to operate all components of the system to the best advantage.

While the addition of new units (other than those now under construction) is not essential to satisfy demand until sometime in 1956, if successful power pool operation is achieved, it would be highly desirable to begin construction immediately in order to replace as much generation by expensive existing thermal plants as possible, in addition to providing for load growth.

B. Hydroelectric plants - The hydro projects on the International Douro will furnish the most economical power, and as the Picote project is the best of these, it is concluded that Picote should be started as soon as possible, and should be followed immediately by the remaining projects on the International Douro, then by those on the National Douro, and finally by those on the tributaries.

C. Coal reserves and thermal power - In the light of present information the best program for the Pejao coal reserves appears to be their exploitation by full-seam mining at the rate of about 575,000 tons a year, the separation of the output into fines and washed coal, and the allocation of approximately 90,000 tons a year of the processed fuel to a 25,000 kw thermal generating station at Germunde. On the basis of announced probable coal prices, the relative cost of Pejao power would call for its introduction into the system immediately following construction of the Valeira hydroelectric plant on the Portuguese Douro, but inasmuch as the Pejao plant can be built and placed on the line and begin the replacement of existing thermal generation much sooner than any hydroelectric plant can, it would seem wise to begin its construction as soon as a decision is made as to the grade of coal it is to be designed to burn.

D. Iron ore - It is concluded that the rate of exploitation of the Moncorvo iron ore reserves should be gradually expanded to an annual total output of about 2,000,000 tons, and that the ore should be beneficiated and pelletized at the mines to increase iron concentration and reduce silica content. Definite conclusions regarding the establishment of a domestic iron and steel industry cannot be drawn without further detailed investigation which, it is believed, should be undertaken.

E. Flood control - The study has indicated that flood control is not a problem of great importance in the Douro Basin and that the annual cost of works to prevent the occasional flood damage sustained probably would be more than the annual damage, and in addition would interfere with normal business activity or land use.

F. Irrigation - Irrigation is needed in the Vilarica Valley and probably can be provided at costs commensurate with benefits, in conjunction with power generation at the Quinta das Laranjeiras project on the Sabor River. The priority of the latter is so low, however, that a number of years may elapse before it is built. In the meantime the advent of cheaper electric power may make it possible to pump from wells for irrigation at costs which the returns from the land can justify.

G. Navigation - It is concluded from the study that improvement of Foz do Douro and of the river itself from the mouth to Pocinho, will be justified if the power dams at Carrapatelo, Regua and Valeira provide the needed pools above Carrapatelo, and the volume of ore, wine, coal, and miscellaneous barge traffic reaches the volume which the provision of economical and dependable water transport should induce (see Chapter VII).

The profits from navigation would not be large enough to warrant the construction of the lower Douro power projects in advance of those on the International Douro however, and this will operate to postpone navigation improvement to Pocinho, the period of deferment being contingent upon the program adopted for power-dam construction. If the complete displacement of existing thermal generation were accomplished, in addition to meeting load growth, Carrapatelo, Regua, and Valeira dams would be required by about 1965, unless construction in other basins intervened.

There should be no impairment of the economics of the navigation project because of delay in its initiation, unless reserves of the raw materials counted upon to provide its commerce were so seriously depleted in the interim as to shorten unduly the useful life of the project or unless interim investments in rail or other improvements below Pocinho for ore haul or handling had been so extensive that their continued use was imperative.

These questions cannot be resolved at the present time. There is, however, one commodity, namely coal, which currently needs and would continue to use improved navigation facilities to the extent of about 300,000 tons a year. Navigation to the Pejao mines could be provided by a single feature of the overall navigation project, the lock and dam at Ataes. The annual profits from coal and from a moderate amount of miscellaneous traffic apparently would not quite offset the annual charges under the conditions which must be assumed from the information now available. If policy points to the eventual and not unduly distant construction of the improvement to Pocinho, the present construction of Ataes probably would not result in losses great enough to seriously impair the economics of the over-all project, and would provide both valuable experience and needed relief.

5. Recommendations

It is recommended that:

A. The power generating facilities now available and under construction be fully integrated with such adjustments as a network analysis may show to be needed, and be operated as a power pool controlled by a fully empowered National Load Dispatcher, to provide dependable energy under a rate structure revised to include demand as well as energy charges.

B. Power requirements in excess of present capacity be met by hydro-electric development of the International Douro, the National Douro, and the tributaries, in that order, and by a 25,000 kw thermal generating plant at Germunde.

C. The Picote project be considered the hydro-electric project of first priority and that it consist of a gravity concrete dam on the International Douro, 22.4 km above the Tormes River developing a normal head of 74 m, having an installed capacity of 93,000 kw, and an estimated construction cost of 426,000 contos exclusive of transmission line.

D. The sequence of subsequent hydro-electric construction in the Douro basin be as listed below:

Order of Priority	Project	River	
1	Bemposta	International	Douro
2	Miranda	"	"
3	Carrapatelo	National	"
4	Regua	"	"
5	Valeira	"	"
6	Pocinho	"	"
7	Plants on tributaries		

E. In order to eliminate existing expensive thermal generation, hydro-electric development and construction of the Pejao thermal plant be started immediately.

F. Full-seam mining at the Pejao coal mines, of about 575,000 tons a year and separation of output into uniform grades of fuel be adopted and that the rate of exploitation of the Moncorvo iron ore reserves be increased gradually to about 2,000,000 tons a year with beneficiation at the mines to a readily marketable concentrate.

G. Contingent upon extending the hydro-electric power development of the Douro River to Valeira, before depletion of ore and coal reserves, or before extensive investments in rail or other facilities seriously impair the economics of navigation improvement as proposed herein, the river's mouth be improved, and 2.7 m navigation be made possible from Porto to Pocinho. This should be accomplished by construction of two navigation locks and dams, at Ataes and Entre os Rios respectively, and by provision of adequate locks in the Carrapatelo, Regua, and Valeira power dams, and such incidental channel excavation as may be found requisite.

H. Study and investigation be prosecuted to ascertain more positively the actual tonnage of coal and iron ore resources, to determine the feasibility and desirability of establishing a domestic iron and steel industry and the best location therefor, and to verify analytical conclusions as to the position and probable efficacy of jetties for the improvement of Foz do Douro. If the comprehensive navigation project does not for the moment appear assured of realization, detailed examination of foundation and bank conditions at Ataes and of sand movements be made in order to determine the least expensive of the several types of structures analyzed in the report that can be used at Ataes with reasonable assurance of safety and of satisfactory operation, so as to provide 2.7 m navigation to Entre-os-Rios or Germunde.

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CHAPTER I

INTRODUCTION

1. Authorization

Under date of November 1, 1951, Knappen-Tippetts-Abbett-McCarthy, Engineers, New York, entered into agreement with the Government of Portugal to prepare and submit to the Government:

a. An engineering and economic study of the Douro River and its tributaries within Portugal with recommendations as to the successive steps to be taken in the coordinated development of the river, with full consideration given to both hydro and thermal power (including the Pejao Thermal Project), flood control, irrigation and navigation. The studies will include preliminary economic, capacity, dimensional, quantitative and cost information and an analysis of how the development would fit into Portugal's overall power requirements. These studies are to be made, utilizing principally existing governmental and private data. Additional data needed will be small. The above will be presented in two stages:

i) A Memorandum Report presenting the order of economic priority of the projects as soon as the studies have progressed sufficiently to so permit;

ii) The completely documented Master Plan and Report.

b. The general construction design, general specifications and estimate of quantities and costs for the hydro project of first priority as recommended in the above Memorandum Report and approved by the Government

This contract followed the approval of a technical assistance request from the Portuguese Government to the Mutual Security Agency covered by T. A. Authorization No. 50-9 (50-102-2009) which authorized the foreign currency requirements for the present study and report.

2. Scope of Report

The Memorandum Report, called for under a. i) above, was submitted October 15, 1952. It presented, as briefly and with as little space devoted to background as seemed compatible with a reasonable degree of clarity, the general data, assumptions and reasoning leading up to recommendations of the hydroelectric project of first priority and the sequence to be followed by subsequent construction. This report does not depart in any significant particular from the reasoning and conclusions of the Memorandum Report. It seeks rather, to cover the same ground; to document the earlier report and to fill in the details of concepts which could be sketched only in broad outline therein;to discuss more fully the bases and reasoning underlying the various recommendations and suggestions presented; to consider to the extent that appears warranted, certain aspects of the Douro River Basin's economy which were not covered by the Memorandum Report because of their slight relevance to the questions it was especially designed to resolve; to revise cost estimates where review or further study showed necessary; and to describe the physical aspects and present aspects and present state of development of the basin sufficiently to provide the reader unfamiliar with the area with at least a general concept of its character and development.

The study, insofar as the exploitation of new hydroelectric power sites is concerned, deals only with sites on the national and international reaches of the Douro River and on its tributaries in Portugal. The schedules of development proposed therefore, disregard the possibility that in adjacent regions of Portugal there may exist sites of such excellence as to warrant their development anterior to development of some of the Douro system sites.

3. Physical Description of Douro River Basin

A. Topographic features of basin - In the northern part of Portugal a narrow coastal province, comprising a slightly elevated plain with deeply incised streams, fronts the Atlantic Ocean with rolling hills extending almost to the beaches.

A considerable hilly area lies to the east of the coastal province. Although the summits are generally accordant, the original surface is almost entirely dissected by deep and extensive valleys wherein the Douro River and tributaries follow entrenched and meandering paths. Numerous scattered villages and farmed land are found in this intermediate section.

Farther eastward to the Spanish border, and beyond, the upland surface is well preserved. Normal relief of about 200 m is expressed by open basins, scattered hills and ridges. The Douro River and local tributaries remain deeply incised, indicative of regional uplift but only partial dissection. Contrasted to the intermediate hilly and coastal areas, the eastern upland province is more arid.

B. Douro River valley - The Douro River is 850 km in length, and drains an area of about 97,000 km^2 of which about 75,500 km^2 (78%) are in Spain and the remaining 21,500 km^2 in Portugal (See Plate 2). From its headwaters in the Montes Ibericos, it flows a little south of east some 225 km to Soria, Spain, whence it is deflected by the mountain ranges through a sweeping curve to a westerly course, maintaining the latter for almost 300 km across a high plateau to the Portuguese border (see Plates 1 and 2). There it is deflected sharply to the southwest, to constitute the boundary between Portugal and Spain for about 113 km. Turning sharply again near Barco de Alva to resume its westerly course, it flows the final 200 km of its length entirely through Portuguese soil, to enter the Atlantic at Porto. Under the terms of the covenant of 1927 with Spain, utilization for the development of hydroelectric power of that portion of the Douro River which forms the Portuguese-Spanish boundary from the mouth of the Tormes River downstream is the prerogative of Spain, while the right to development of the international portion of the river upstream from the mouth of the Tormes River vests with Portugal.

In the first 75 km of its length, the Douro River descends about 700 m from its headwater elevation of about 1700 m above mean sea level. This precipitous slope of almost 9.5 m per km flattens to average slopes of 1.6 m and a little less than 1 m per km respectively in the succeeding reaches of 150 km and 265 km, but, in the 63 km between Zamora, Spain and the Portuguese border, it steepens again to average about 1.6 m per km. The slope of the international portion of the stream averages about 3.33 m per km. The Portuguese Douro has an average slope of only about 0.55 m per km.

The river banks in the national and international reaches in general rise steeply from the water's edge as thinly earth covered schist or granite hills, to elevations increasing from 100 or 200 m above mean sea level at Porto and Gaia, to about 800 m where the stream emerges from Spain to serve as the boundary between the two countries. The slopes of the banks in the lower reaches of the Portuguese Douro, are frequently gentle enough to be terraced and cultivated, although even here, occasional canyons as well as quintas are encountered. The principal crop is grapes, processed into port and table wines. The other important crops are maize, small grains, cork, oranges and olives. While the hills are often without forest cover, there is some woodland, and firewood is an important product in certain localities. As the Spanish border is approached, the scenery increases both in grandeur and in austerity. Even the olive trees begin to disappear and the narrowing river flows between increasingly steep and forbidding mountain slopes, largely devoid of cover and of habitation.

C. Tributaries - The major Spanish tributaries, proceeding downstream, are the Cega, Pisuerga, Adaja, Valderaduey, Esla, Tormes, Huebra and Agueda Rivers.

The significant Portuguese tributaries, named in order of occurrence from east to west, are the Sabor, the Tua and the Tamega entering from the north, and the Coa, Tavora and Paiva from the south. All six are steep mountain streams whose watersheds sometimes reach altitudes of more than 1300 m.

Table I-1 lists the component drainage areas of the basin.

D. General Geology - The Douro River basin is largely underlain by crystalline and metamorphic rocks. No immediate aid exists towards separation of formations and classification according to geological age.

It is apparent that two principal groups of rocks occur. Con-

TABLE I

DRAINAGE AREAS IN THE DOURO RIVER BASIN

PRINCIPAL TRIBUTARIES		AREA (KM^2)	MISCELLANEOUS DRAINAGE AREAS (KM^2)		CUMULATIVE DRAINAGE AREA (KM^2)
LEFT BANK	RIGHT BANK		LEFT BANK	RIGHT BANK	
			8,093	4,787	12,880
Cega		2,510			15,390
			18	10	15,418
	Pisuerga	15,710			31,128
			2	3	31,133
Adaja		5,283			36,416
			4,255	1,567	42,238
	Valderaduey	3,575			45,813
			607	222	46,642
	Esla	16,352			62,994
			366	530	63,890
Tormes		7,075			70,965
			863	315	72,143
Huebra		2,833			74,976
			75	204	75,255
Agueda		2,622			77,877
			295	35	78,207
Coa		2,500			80,707
			60	105	80,872
	Sabor	3,817			84,689
			350	235	85,274
	Tua	3,608			88,882
			273	350	89,485
Tavora		495			89,980
			850	860	91,690
Paiva		805			92,495
			7	4	92,506
	Tamega	3,347			95,853
			415	712	96,980
	TOTAL AREA (KM^2)	70,532	16,529	9,919	96,980

siderable areas contain metamorphics including schists, quartzites, gneisses, phyllites, slates, limestone (and marble) and variant types of these rocks. This series probably includes several formations of different geological ages. Apparently equivalent members extend with interruptions from Porto to the Spanish border. In this group are the parent rocks containing iron ore in the form of hematite,martite and magnetite and bands of limestone and marble as well as coal beds. The age of the coal beds is probably carboniferous and that of the metamorphics is paleozoic or older. The iron ore and coal deposits are discussed at length in Chapters III and IV and Appendices A and B.

These older formations were broadly folded. Afterwards, the entire region was extensively invaded by granite of probable late Paleozoic Age. The granite, intruded at considerable depth, is predominantly coarse-grained or porphyritic. Border facies, interbedded dikes and metamorphics, contain silver and gold in some districts and the tungsten mineral, wolframite, in the Spanish frontier zone. The latter is the most important of the three in volume of production, but the workings are scattered and most of them small, and its production is not a factor of material importance either from the standpoint of electrical power consumption or of river commerce, the two features with which the present study is primarily concerned.

Regional uplift with consequent erosion stripped the overlying metamorphics from large areas. Granite was exposed, particularly along canyons of the Douro and principal tributaries, but also in upland places.

(1) Structural features in rock - Persistent patterns are encountered in the bedrock series. These form sets of joints, fracture zones and probable faults that trend NE-SW, and with steep to vertical dip. Topography in many places is controlled, especially in direction of valleys and ridges.

A second set of joints has a complementary orientation NW-SE, likewise vertical or steep. In some places this system predominates but both patterns are common at all dam sites investigated.

Subordinate joint systems include steeply dipping features and the very common flat or gently dipping 'lift joints', conspicuous in the upper portion of cliffs.

The Douro canyon in places runs parallel to strong joint patterns exposed in the walls. From this evidence it is concluded that bedrock at many of the proposed dam sites is similarly jointed and will require careful grouting to avoid seepage.

(2) Seismicity - The Lisbon earthquake of 1755 is famed for intensity and consequent devastation. No equal experience is recorded for northern Portugal during that event or other years. It is common to find pedestal or perched rocks along the walls of the Douro which signify the absence of strong seismic disturbance in this area, perhaps for centuries.

Despite probable lack of seismic activity within the Douro River basin, it is felt that design of dams should include a factor of additional safety based on acceleration of seismic waves of one twentieth gravity. In this connection it may be noted that concrete gravity and rock-fill dams are relatively stable against earthquake shocks.

(3) Silt deposits - The Douro River transports large quantities of sand in the lower valleys, as reflected by deposits bordering the channel and by the bar at the mouth near Porto. Some gravel beds are found of material chiefly granite and the more resistant (quartzose) metamorphic rocks (in cobbles not exceeding 8 cm in diameter). The sand is poorly graded, medium to coarse-grained, clean and with about 10 percent mica.

It is believed that the river flows virtually on bedrock in the canyon through the international section. Scarcely any natural aggregate is therefore available.

4. Hydrology

A. Precipitation - Although Portugal is not a large country, the distribution of the average annual rainfall in it is very uneven. The basin of the Cavado River and of the other streams in the extreme north enjoy heavy rainfall. The basin of the Zezere River in central Portugal receives moderate precipitation, while the river basins to the south as a rule exist under conditions of semi-drought. This general north to south trend of decreasing precipitation is modified by topography. The presence of various mountain ranges results in concentrations of rainfall, an effect especially noticeable in the high Serra da Estrela. Precipitation is heavier all around the mountain rim of the Douro Basin, than it is on the central plateau (see Plate 4). The annual rainfall on the entire Douro basin averages about 635 mm. The Portuguese portion receives a greater depth than the average for the Spanish portion, a fact borne out by the figures for runoff. For the water years 1941-1942 to 1949-1950, the runoff in $m^3/sec/km^2$ was 0.0040 for the Spanish portion of the basin, as derived from the gage at Puente Pino, and 0.0042 at the Regua gage on the Portuguese Douro. The Portuguese tributaries of the Douro have a markedly greater runoff per unit of drainage area than the Douro River as a whole, and this increases towards the Atlantic Ocean. The Sabor River at Laranjeiras has a yield of 0.0064 $m^3/sec/km^2$, the Coa River at Vale do Areal 0.0091 $m^3/sec/km^2$, the Tavora River at Ponte Nova 0.0113, $m^3/sec/km^2$, and the Paiva River at Fragas da Torre, the farthest downstream of the four, 0.0244 $m^3/sec/km^2$.

B. Discharge - The flow of the Douro River varies between unusually wide limits. The great flood of 1909 had a peak discharge estimated at more than 12,500 m^3/sec at Carrapatelo (some 67 km above the mouth) while during prolonged dry periods monthly average flows of less than 50 m^3/sec have been common in the past. Regulation by Spanish reservoirs has improved low water discharge since 1934. Tables of average monthly flow at various stations for the periods of record appear in Appendix C which discusses the question of stream flow throughout the basin.

5. Existing Development

A. Population - The 21,500 km^2 of the Douro basin in Portugal include all of the District of Braganca, practically all of the Districts of Vila Real and Porto, most of the District of Guarda, and portions of the Districts of Aveiro and Viseu. The population of these 6 Districts, on the basis of the 1950 census, is a little more than two million, of which slightly more than one half is concentrated in the Porto District of less than 2200 km^2, the industrial center of northern Portugal-and to a large degree, of Portugal itself. This leaves a population of one million for the remaining 19,300 km^2 of the basin which corresponds to an average of about 50 persons per km^2, or about 83 persons per square mile. The largest concelhos (municipalities or groups of boroughs having the same municipality) in the basin are, according to the 1950 census, in the Porto District.

A tabulation of population by concelhos follows:

TABLE I-2

POPULATION OF CONCELHOS IN THE DOURO BASIN

District	Concelho	Population
Porto	Porto	279,738
	Penafiel	45,741
	Mario de Canaveses	38,036
	Paredes	36,166
Vila Real	Chaves	54,772
	Vila Real	47,025
	Regua	23,728
Braganca	Braganca	38,294
	Mirandela	31,200
	Macedo de Cavaleiros	25,198
	Vinhais	23,739
	Mogadouro	19,556
	Torre de Moncorvo	19,078
Aveiro	Arouca	26,185
Viseu	Lamego	38,379
	Cinfaes	31,947
Guarda	Guarda	52,418
	Sabugal	42,886
	Pinhel	22,030
	Trancoso	20,919

B. Manufactures - The Porto area is an important center for textiles and paper products, soaps, leather goods, coal briquettes, beer, flour, fish and other processed foods, cork products, resins and building materials. Together with Gaia, directly across the Douro River, it handles almost all of the wine produced in the Douro Basin. There is little manufacturing of importance in the basin outside the Greater Porto area save for the production of wine and olive oil.

C. Transportation facilities - A broad gauge single track railroad, the Linha do Douro extends easterly from Porto. After leaving the river on a brief swing to the north through Penafiel and Livracao, it returns near Aregos and thenceforth follows along the north bank to Tua, at the mouth of the Tua River. A little beyond it crosses to the south bank of the Douro, following that bank to Pocinho where it returns to the north bank, and thence proceeds to the border and on to Madrid. It is fed by four narrow gauge (1m) lines which tap the hinterland to the north. Named in order from west to east, they are Linha do Vale do Tamega, Linha do Vale do Corgo, Linha do Tua, and Linha do Sabor. They connect with the Linha do Douro at Livracao, Regua, Tua, and Pocinho, respectively, at which points the contents of the narrow gauge cars are transferred to the cars of the Linha do Douro when the destination is beyond the junction point. There are no rail connections to the Linha do Douro from the south east of Porto. At Porto itself, the double track, broad gauge Linha do Porto leads south to the capital, and the single track broad gauge Linha do Minho extends north partly along the coast, to Moncao. A single track narrow gauge line, called the Linha do Litoral do Minho, connects Porto with Povoa de Varzim and then turns east to connect with the Linha do Minho at Vila Nova Famalicao. There is another narrow gauge line connecting Porto and Guimarais. These other lines, radiating outward from Porto, lie, in general, outside the Douro Basin but are important to the commerce of the basin. The highway network in the basin is suprisingly good; the more so when the comparative sparseness of population and the mountainous character of the terrain are considered. Sight distances are often short, and grades and curves numerous and sometimes abrupt, as a consequence of the ruggedness of the country, but repairs are meticulously kept up. Much of the surfacing is bitumen.

The Douro is navigated by wooden vessels, called rabelos when they have a high stern deck for the steerman, raboes when they do not. They are propelled downstream by current or oars, and upstream (usually during the spring and summer) by sail, when the wind blows in from the Atlantic and by oars, poles or oxen teams when it does not. They are steered by means of long stern sweeps. Most of the traffic originates below Pocinho and moves downstream.

D. Electric power - There are two hydroelectric generating stations in the Douro basin (see plate 2). One, the Chocalho plant on the Varosa River a small south bank tributary, has an installed capacity of 10,240 kw. The other, Freigil, on the Cabrum River, another tributary entering from the south, has an installed capacity of 2,500 kw. In the Porto area there are two important thermal stations, Massarelos and Freixo, with capacities of 11,300 and 14,656 kw respectively. The Porto industrial area is connected by transmission lines to the nation's generating facilities, but aside from a 60 kv line connecting the Canáços steam plant in the Ave River Basin with the Chocalho plant, and then running south to the Serra da Estrela system (see Plate 5) the rest of the basin is practically devoid of transmission and distribution facilities. The 60 kv line mentioned above supplies Vila Real, Jales (silver mines), Lamego and Castro Daire; and the southern branch is connected to the Freigal plant at Castro Daire.

E. Irrigation - There is one existing irrigation development in the basin. An area in the valley of the Vilarica, a right bank tributary of the Sabor, is susceptible of irrigation, and considerable study has been given it by the State. It is discussed later in Chapter V.

F. Flood control - The Douro basin has been inhabited for so many years that in general its populace has learned through experience of many floods, not to encroach with vineyards or vulnerable structures into the normal flood zone. In general, there are no flood control improvements along the Douro or its tributaries. The question of flood Control is considered further in Chapter VI.

CHAPTER II

METHODS OF PRESENT STUDY

1. Field Work

The study has entailed operations both in Portugal and in New York. From January to late April of 1952 a staff consisting of a resident engineer, a geologist, a hydroelectric engineer, a hydraulic engineer, and a navigation engineer was quartered in Portugal. From time to time the group was augmented by special consultants in the fields of electrical engineering, dam construction, mining, and geology, retained under the provisions of the contract. The special consultants included: Mr. Maurice R. Scharff, Consulting Engineer, and his associates, Mr. Franklin J. Leerburger, Consulting Electrical Engineer and Mr. Joseph R. Weiss, Consulting Mechanical Engineer; Dr. William P. Creager, Consulting Hydraulic Engineer; Mr. James Pierce and other engineers of Pierce Management, Inc., Engineers and Mine Managers; and Dr. F. A. Nickell, Consulting Geologist. All the special consultants except Mr. Joseph R. Weiss visited Portugal.

A central office was maintained in Lisbon. A great many of the necessary data were in the files of the various Government agencies and private business organizations having their headquarters in the capital. There also were available for consultation many of the key personnel in both State and private establishments. Much time, however, was spent in the Douro Basin, particularly in Porto. The field aspects of the study included numerous trips of inspection up the valleys of the Douro and its tributaries;

visits to all important power projects both hydroelectrical and thermal in Portugal; inspection of coal and iron ore deposits and mining operations; and conferences with various port authorities, mining interests, the Port Wine Institute in Porto and in Regua, electric power interests both public and private, manufacturing and marketing organizations, Government officials, economists, and, of course, engineers.

It seems appropriate at this point to express appreciation for the courteous, intelligent and willing cooperation and the unfailing patience encountered in all relations with Government officials, their assistants, and private individuals.

2. Work in New York Office

Upon return of the staff (with the exception of the resident engineer) to New York, the group was reinforced by specialists in several fields drawn from the Engineer's staff, as the varying needs of the work required, and by computing, drafting and stenographic personnel. The data procured in Portugal were processed in such fashion as the nature of each particular phase of the study demanded. Many conferences were held with the special consultants regarding matters pertaining to their respective field.

3. Coal and Iron Ore Studies

The studies of coal and iron ore were made by Pierce Management Inc. and its Associates but close contact was maintained both by means of mail and telephone and by personal visits to Scranton, Pa., by members of the Engineer's staff, and to New York by members of the staff of the consultant.

4. Thermal Power Plant Studies

The problem of using Pejao coals to generate thermal power, was exhaustively explored by both the electrical and mechanical departments of the Engineer's organization; by discussions with the electrical, mechanical, and coal consultants; and by conference with foreign and domestic manufacturers of the various types of equipment involved.

5. Navigation Studies

In connection with navigation studies, discussions were held with the staff of the Mutual Security Agency in Paris, and visits were made to navigation tunnels in France, in addition to field investigations in Portugal. In the United States, contacts were arranged with representatives of the Corps of Engineers, U. S. Army, in Washington, D. C., and Vicksburg, Mississippi, with special consultants, and with various private organizations engaged in the manufacture of boats and barges and in commercial towing operations. The problems encountered proved to be quite complex. The study involved consideration of the means for improvement of the river to provide dependable navigation, the potential river commerce that would follow improvement, and the savings that it would effect over the use of the transportation media presently available. Various alternative methods of improving the river proper and of improving its mouth or providing means for barge cargoes for export to reach ships at Leixoes instead of at Porto, had to be considered, as well as means for handling the commodities onto and from the barges.

In general, when structures or improvements similar to those planned were found to be existent in Portugal, local practice in design was adhered to, but in many instances, unfortunately, no parallel existed.

6. Hydroelectric Power Studies

In order to compute the output of existing hydroelectric installations and to determine the performance of future proposed projects it was necessary to study, correlate, adjust, and in some instances to synthesize flow records, which in most cases, however, were found to be existent and of satisfactory length. A large volume of records for the entire country was brought to New York where the figures were studied and analyzed, concurrently with study and correlation by the resident engineer in Lisbon, with whom close liaison was maintained, throughout. In one case a synthetic 30-year record of daily flows (the Douro River at Regua) was computed from basic data with the cooperation of the staff of the Hydraulic Services working under the direction of the resident engineer.

Power and load studies were made on a national scale. Data on all hydroelectric plants in Portugal were assembled and operating characteristics evaluated, because the Douro basin project cannot be considered except as a contributor to the power of the nation and has to be fitted into the national production and consumption characteristics.

Close contact was maintained with the electrical and mechanical engineer consultants during the power studies.

7. Arrangement of Report

The coordinated development of the Douro River involves numerous projects, many of which are so interrelated as to make it apparent at an early stage that it would be impractical to discuss each independently, and would be confusing if it were necessary to intersperse observations relating to one with references to others which might not previously have been considered or mentioned. It has not proved feasible to avoid situations of the latter type altogether, but the attempt has been made to minimize them by selecting an order of presentation with that specific objective in view.

The value of hydroelectric power is measured commonly and conveniently by the cost of equivalent thermal power, so the latter is discussed before the former.

Annual benefits in the cases of three of the hydroelectric proposed for the National Douro depend in part upon savings which would be made possible by navigation improvement, to which latter in turn, the creation of their power pools is indispensable. Navigation benefits themselves will depend in a large measure upon the water borne tonnage provided by exploitation of iron ore and coal reserves; and the system adopted for exploiting the latter affects thermal power generation also. Therefore the report takes up the subject of hydroelectric power last and discusses the questions of thermal power just in advance of it. Discussion of thermal power is preceded by discussion of navigation, and navigation by discussion of coal and iron ore potentialities.

To avoid an anticlimax, it has seemed best to dispose of the questions of flood control and irrigation (which do not materially influence conclusions relating to the river's development) before taking up the more important and related subjects of navigation and power; and finally, in order not to interrupt the train of thought more than necessary, discussions of hydrology and of routing of flows through the power reservoirs, to the extent that appeared requisite to a clear apprehension of the particular problem being discussed, have been made from time to time in the body of the report, instead of being assembled and segregated in a separate chapter on Hydrology. The numerous statistical data supporting them, detailed discussion of flow records and methods of obtaining them, are collected in Appendix C, entitled "Hydrology" and of routings as they pertain to individual existing projects and to proposed projects on the International and National Douro, and tributaries are in Appendix D, entitled "Power Computations".

CHAPTER III

COAL

1. General Occurrence

The principal coal deposits of northern Portugal extend for about 35 km from a point about 10 km N-NW of Sao Pedro da Cova, near Ermesinde, SE to the vicinity of Pejao, crossing the Douro River at Germunde. The portion lying within the Douro Basin is shown on Plate 2. In considering the development of the Douro Basin, their potentialities as a source of water-borne commerce for the river and as a source of thermal electric power were deemed to be of such compelling importance as to warrant their special investigation by qualified specialists in the field of coal mining. Arrangements were made accordingly, for a special coal study to be made by Pierce Management, Inc., as Consultants to the Engineer. A comprehensive report, covering the subject of the Douro Basin coals has been submitted by Pierce Management and is reproduced herewith in full, including illustrations, as Appendix A.

The Douro Basin's carboniferous formation, overlain by pre-cambric and siluric rocks, outcrops in places and disappears in others. The maximum width of outcrop - in the vicinity of Sao Padro da Cova - is about a kilometer. The deposits are mined at Sao Pedro da Cova (near Porto) and at two workings south of the Douro, namely at Germunde, and at Fojo. These two mines are covered by a single concession and are known collectively as the Pejao mines. The Sao Pedro da Cova and Pejao areas are the only parts of the deposit which exploration thus far has indicated to be susceptible of profitable exploitation. The coal is a medium grade anthracite with a specific gravity, as mined, ranging from 1.7 at Sao Pedro da Cova to 1.5 at Fojo. It is quite friable. Much of it occurs mixed with clay, which imparts a dull, greasy appearance and a plastic consistency. In places, the coal is more solidly massed, but is still quite friable and can be reduced to dust by pressing between the fingers. Ash and sulphur contents both are high, decreasing its heating and industrial value.

2. Sao Pedro da Cova Mine

The Sao Pedro da Cova workings have been operated since about 1820. There are six seams of coal, of which four, varying in thickness from 0 to 10 m and averaging 2.5 m are being worked at the present time. The current rate of production is about 260,000 tons a year. On the basis of 10 bore holes, information gained from the workings, and records of production since 1945, "certain" and "probable" reserves as of January 1952 are estimated to be about 10,783,000 metric tons. Recovery, in terms of marketable fuel, is estimated at about 75%. If the "most probable" reserve be taken as the "certain" reserve plus ½ the "probable", the indicated economic life of the mine with present rate of production is about 25 years.

Numerous grades of coal are produced, ranging in ash content from 10% to 47%, and in heat value from 7170 to 4210 kilo calories per kilogram (12,900 to 7,600 Btu/lb.). The lump sizes are hand-picked, and fines are screened and washed in a Rheolaveur cleaning plant. Rejects from both processes were found to aggregate 22.4%

of the run of mine production.

The coal is hauled to Porto over two roads, (distances 14 and 17 km respectively). There is also an electric railroad, and a 9100 m aerial tramway of 30 tons an hour capacity.

Sao Pedro da Cova is not on the Douro River and has no occasion to use water transportation. Because of lack of water supply, it would not be practical to establish a thermal electric generating plant at the mine. The nearest practical location would be about 7.5 km distant, on the north bank of the Douro, about 5 km east of Porto. The Sao Pedro da Cova mine could expand its production and furnish fuel, consisting of washed dust having an ash content of about 26% and heating value of 5500 kilo-calories per kg (9900 BTU/lb.), at a cost, at the plant, of about 188$00 a ton, exclusive of profit to the mine owner. Expansion of production rate would, of course, shorten the life of the mine. Since the nominal economic life of a steam electric plant is about 35 years, it is apparent that even the 25 year mine life based on present rate of production is too short for comfort.

For Sao Pedro da Cova to supply a steam power plant for the duration of the plant's useful life would require a reduction in present total rate of coal output (in order to lengthen the life of the mine to 35 years) and diversion of a portion of this reduced output away from present customers to the new steam plant. Unless the new steam plant was quite small, there would not be much coal available for other users.

3. Pejao Mines

The Germunde and Fojo mines, which are operated by a single concessionaire, and together are known as the Pejao Mines, are located respectively on the left bank of the Douro River at the northwest and of the concession, and at the south east end of the concession, about 7 km inland. They are connected by a narrow gage (60 cm) mine-owned railway about 10 km long. All of the coal is processed at Germunde. Hand-picking alone is used and the marketable products, which comprise grades ranging from 17.73% to 27.71% ash content and from 6160 to 5340 kilogram calories per kilogram in heating value, are loaded from the picking sheds into rabaos of 40 to 60 ton capacity for water transport to Porto. The present annual output is about 260,000 tons, of which about 25% is formed into briquettes at Porto. The briquettes are sold to railroads, industry and householders. The concessionaire expects to increase cutput to 360,000 tons in 1953.

It is estimated that the average run-of-mine coal in both the Sao Pedro da Cova and the Pejao workings will average about 37½% ash content. Since in the case of Sao Pedro da Cova, the results of full seam mining, combined with hand-picking, screening and washing yield coals ranging in ash content up to 47%, the production at Pejao by hand-picking alone of fuels having maximum ash content of 27.71% indicates that the selective mining as now practiced at Pejao must leave in the ground a considerable tonnage from which generally usable fuel might be recovered by the use of cleaning and wahing devices, or which might, with a modicum of hand-picking, and employment of special combustion equipment, be used in a local steam plant to produce electric power. The estimated Pejao reserves are listed in Table III-1.

TABLE III-1

ESTIMATED PEJAO RESERVES

	Certain Reserves (tons)	Probable Reserves (tons)	Probable Total (tons)
Germunde	6,383,396	5,068,747	11,452,143
Fojo	4,200,000	15,000,000	19,200,000
TOTAL -	10,583,396	20,068,747	30,652,143

The Germunde reserves are calculated from the results of 8 bore holes and the mining operations, while the Fojo reserves are computed from the mining operations, plus the evidence of only one bore hole. The drilling of additional bore holes is in progress in the Fojo area, and the results are expected to increase the "certain" reserves. It seems quite likely also, that additional reserves will come to light in the area to be exploited by the Germunde mine, which is a fairly new development.

If the "most probable" reserves again be considered to be the sum of those in the "certain" category, plus one half of those in the "probable", a reserve of about 20,618,000 tons is indicated; of which it is estimated that 70% could be recovered in the form of marketable coal by the use of full seam mining and modern cleaning procedures. At the present rate of output (260,000 tons a year) this indicates a mine life of about 55 years, from which it follows that production could be increased to supply a sizeable steam power plant without depriving present consumers, and without shortening the life of the mines below the normal life span of a thermal generating station.

Two operational procedures are feasible. One is to continue present methods of hand-picking coal for the general trade, but in addition, to mine for delivery to the power plant the lower grade fuels which are not presently marketable and so are not exploited. The other course would be to use full-seam mining, separate the fines by air, and wash the residue. The fines, which would include everything less than 0.04 cm in size, would have an ash content of about 20% and heat value of about 5694 kilo-calories per kilogram (10,250 B.t.u. per pound). The washed coal, which would comprise about 70% of the marketable product would have about 18% ash content and 5840 kilo-calories per kg (10,526 B.t.u. per pound). Both the fines and the washed coal would be fuels uniform in character and of considerably higher quality then the general run of domestic coal now available. The washed coal would be marketable without further processing. The fines probably would have to be pressed into briquettes before being marketed unless they were burned in the thermal generating station.

It is estimated that by full seam mining of 575,000 tons a year, some 383,000 tons a year of marketable fuel can be produced for a period of about 38 years, i. e., for the normal life span of a thermal electric station, assuming it is built within a reasonable time. The fuels produced would consist of about 120,000 tons of fines and 263,000 tons of washed coal.

It is estimated that the 20% ash Pejao fines, which represent the fuel nearest that considered for the Sao Pedro da Cova thermal plant previously discussed, would cost to produce, without profit, about 175$00 a ton. At the time the coal study was made, it was planned to build the steam plant, if one were built, on the right bank of the Douro across the river from the mines, and the estimated cost of delivery and storage of fuel was about 25$00 a ton. Further study, however, indicated for reasons which are discussed in Chapter IX the preferability of a site near the picking sheds on the left bank. Delivery to a plant located near the picking sheds would cost probably not more than 3$25 a ton, making cost at plant about 173$25 a ton. Thus, since the heat value would be 10,250 Btu./lb., as compared with 9900 for the Sao Pedro da Cova fuel, it seems safely assumable that Pejao would offer lower fuel cost as well as satisfactory length of life. It is to be noted in this connection that the production costs discussed above are just that, and that their relationship to actual selling prices named by the producers remains to be determined.

If the 20% ash fines were used as fuel, a 25,000 kw generating plant at Germunde would require about 92,000 tons a year, which would leave about 291,000 tons a year for present customers and for water haul between Germunde and Porto. This would exceed the present output of 260,000 tons available to the market, but would fall short of the 360,000 tons output which the concessionaire has premised for. It was intimated by the concessionaire that still greater increases were planned for subsequent years.

The use of the washed coal as fuel would reduce thermal plant requirements to 88,000 tons a year, which would leave 295,000 tons for the trade and for river commerce.

Pierce Management estimates that if cleaning procedures are not adopted, the mine production could be expanded sufficiently to produce 500,000 tons of hand-picked coal a year, but its quality and uniformity presumably could not compare with that of the products of the screening and washing process. No doubt, under such a plan of operation, the very lowest grade fuels would be used for power production. If it used 45% ash fuel, the thermal plant would require 167,000 tons a year, which with total production of 500,000 tons would leave 330,000 tons a year for other markets.

Thus, the Pejao mines could support a 25,000 kw thermal plant throughout its useful life and at the same time provide existing markets with 333,000 tons a year of low grade fuels or with 291,000 to 295,000 tons of uniform, high grade fuel.

It is believed that the greatest benefits would result from the adoption of full seam mining operations and the separation of the coal into 20% ash fines and 18% ash washed coal. On this basis, the tonnage to be barged via river to Porto would be from 291,000 to 295,000 tons a year.

- Por aqui se vê como é indispensável assentarem-se ideias sobre o combustível a utilizar na C.T. Nenhuma previsão está feita para a alimentação, c/ mistura de carvões S. P. da Cova e Pejão o que se pode tornar indispensável, no ponto de vista [illegible] e económico, tendo em conta a curva ~~[illegible]~~ média da produção de S. P. da Cova.

CHAPTER IV

IRON ORE

1. General

The iron ore deposits of the Douro basin were from the inception of the study, recognized as important potential sources of river commerce. As field work progressed, it gradually became apparent that in order to reach sound conclusions as to the probable usable tonnage of the deposits, and also as to their economic significance, (which bade fair to be profound if they turned out to be susceptible of profitable exploitation) it would be desirable to call in experts in the field of iron mining who would be competent to appraise both the probable volume of the reserves and the marketability of the ores at the prices at which they could be produced; and also to suggest the most advantageous treatment and disposition with respect of each of the several deposits.

The time available was not sufficient for a complete study and analysis, but an agreement was consummated with the Portuguese Government, represented in this instance by the Presidente Comissao Tecnica de Cooperacao Economica, by the terms of which Pierce Management, Inc., was engaged to make, through the Engineer, a preliminary examination of the quality of the ore reserves of the Vila Cova, Guadramil and Moncorvo areas, and their suitability for the production of pig iron and steel, using Portuguese coals; to suggest the proper location for possible pig iron or steel plants in the Douro basin with respect to sources of raw materials; estimate production and delivery costs of the ore for domestic and foreign use;

assess its competitive position on the present and future world market; and make preliminary recommendation for its exploitation and use in Portugal or other countries. The study and the report thereon have been made, and the latter, transmitted to the Portuguese Government under date of July 25, 1952, is reproduced in full herewith as Appendix B, including maps and illustrations.

2. Vila Cova Deposits

The Vila Cova deposits are on the southeast slope of the Alto do Siao, about 1 km north of the village of Vila Cova, which is about 9 km northwest of Vila Real, the nearest railway shipping point. The distance by present road from Vila Cova to Vila Real is 22 km but a new road is being built which will reduce it to 14.5 km.

The ore is a hard magnetite containing about 35% iron and 33% silica. The bands are narrow and the rocks in which it occurs are closely folded. There are positive reserves of about 25,000 tons and probable reserves of an equal amount. Possibly an additional 50,000 tons may be inferred. Including the "inferred" reserve, the aggregate amounts to 100,000 tons. Most of the ore will have to be mined underground and the percentage of extraction is unlikely to exceed 75%. The only concentration practiced at the present time is by picking out the less desirable material by hand, but magnetic concentration should be entirely feasible, and by proper application should be able to beneficiate to 65% iron, or, if fine grinding is resorted to, possibly to 69%. If the ore is concentrated to 65% iron or better, it should find a ready market in England, France and Belgium. It can be truck-hauled to

Vila Real, placed aboard the narrow gauge railroad at that point, and transferred to broad-gauge cars at Regua; or, in the event that the Douro is improved for navigation before the deposits are worked out, transshipped to barges at Regua.

Production probably will not exceed 30,000 tons a year. The size of the deposit is so small that unless extensive additional reserves should come to light, exploitation would appear to have little bearing upon the National economy, or upon the economic justification of the improvement of the Douro River for navigation.

3. Guadramil Deposits

The Guadramil iron ore deposits are near the top of a low range of hills on the high plateau about 37 km by road northeast of the town of Braganca in the province of Tras-os-Montes. The road between the deposits and Braganca consists of 7 km of ungraded single track earth road, 10 km of graded highway with earth or gravel surface, and 20 km of graded water bound macadam. The deposits cover about 325 hectares and are taken up by 7 concessions, one of which has been abandoned and one of which is for gold. None of the concessions is being worked.

The ore occurs in three beds. Two stand nearly vertical and the third, lying between the other two, dips north about 35°. The strike is northwest-southeast. The outcrop ore where any remains, is almost typical "brown ore", but only the harder ores are left, the Romans having mined the softer material. Above water level the ore is limonite and hydrous hematite. Below water level it is siderite, hard and gray and unoxidized when first mined, but changing rapidly to reddish brown. The limonite contains about which would not require the construction of energy dissipating devices below the weir, are estimated to be:

	Contos
Weir.	37,463
Lock.	64,383
	101,846

Annual charges would include:

1.	Operation of lock	201.3
2.	Maintenance of lock	100.6
3.	Maintenance of weir	52.6
4.	Dredging in Pool	57.5
5.	Interest 2.75%	2800.8
6.	Amortization, (1.403% @ 2.75%, int., 40 years sinking fund)	1428.8
		4641.4

This is believed to represent the cheapest structure that can be anticipated.

If it should develop, that instead of being sound rock, the foundation is sand to great depths, the structure should be pile supported and protected against failure through erosion of the river bed. Protection upstream probably would entail the construction of a 50 foot wide reinforced concrete blanket with a sheet pile cut-off and riprap protection at its upstream edge. Immediately below the weir, heavy riprap and mattress protection should be provided, and the latter probably should be carried downstream as much as 100 feet beyond the stilling basin in order to insure stable slopes below the structure if floods pouring over the weir should excavate the river to great depths. An articulated concrete mattress has been assumed for this duty, but an 18 inch layer of riprap probably would suffice if the river bed were deepened by dredging and paved in advance of the flood season; and it might be safe to pave without dredging if the situation were kept under close observation and the blanket of riprap renewed or extended as the erosion pattern required.

The construction cost with a sand foundation would increase about 32,602 contos to the new total of 134,440 contos and annual charges would rise to about 6,105 contos.

The lift required at Ataes is so great that it has not seemed practical to provide a movable crest dam with a navigation pass. It would, however, be feasible, and in many ways desirable to provide a movable crest which would enable the operating crew to maintain pool stage at 6.7 m except during sizable floods. Designs using Sidney gates and those using combinations of Chanoine-Pascaud wickets and bear traps for the movable crest have been investigated. Construction costs for the two types do not differ greatly. The use of Sidney gates would eliminate many operational difficulties inherent in wicket manipulation. Plate 7 shows cross sections of the dam both with Sidney gates and with wickets and bear traps. The Sidney gates, 10 in number, would be 60 feet wide and 16 feet high (18.3 m by 4.88 m), thus placing the sill level at elevation 1.82 m mean sea level. The final 72 m of the structure next the left bank would be a solid weir with crest of 6.7 m.

If the movable dam were comprised of bear traps and Chanoine-Pascaud wickets instead of Sidney gates, a length of 80 m of solid weir at elevation 6.7 m would be used next to the bank; three bear traps each 27.8 m long with a sill at 1.82 m elevation, 72.5 m of wickets with sill at 1.82 m elevation, and 30 m of longer wickets, with sill at 0.6 m elevation.

There would be advantages in the adoption of a movable crest weir, in addition to the advantage of a reduction in the length and height of the backwater line. For example, with all gates open during floods, the sand movement would be practically uninhibited and, while only 57.5 contos has been estimated for annual dredging in the case of the solid weir, there would be additional benefit in having a weir so low that even if sand accumulated to the top of it, there would be ample depth for navigation. Opening the crest gates would obviate the extremely high velocities during moderate floods which the large differences in elevations between the upper and lower pools created by a high fixed weir would engender. Control of the pool would also permit reducing the height of the lock while still keeping it in operation during larger floods. With the lock gates carried only to elevation 9.7 m they would have about 1 m of freeboard when flow reached 6,000 m^3/s, which corresponds to a frequency of once in about $4\frac{1}{2}$ years. With a movable crest weir, the operation and maintenance of the lock would cost no more than with a fixed weir, but annual costs of the weir would increase materially.

The estimated construction cost of a lock and movable dam composed of bear traps, wickets, and solid weir section, assuming a rock foundation will be 125,239 contos and 157,953 contos on a sand foundation. The estimated construction cost of the alternative employing Sidney gates will be 140,398 contos on a rock foundation and 172,626 contos on a sand foundation. Table VII-1 shows annual costs for both types, on rock and on sand foundations, respectively.

TABLE VII-1

ANNUAL COSTS OF ATAES LOCK AND MOVABLE CREST WEIR

Items	Bear Traps, Wickets & Weir		Sidney Gates	
	Rock foundation Contos	Sand foundation Contos	Rock foundation Contos	Sand foundation Contos
Operation of lock	201.3	201.3	201.3	201.3
Maintenance of lock	100.6	100.6	100.6	100.6
Operation of bear traps and wickets	616.7	616.7	-	-
Maintenance of bear traps	83.4	83.4	-	-
Operation of Sidney gates	-	-	270.2	270.2
Maintenance of Sidney gates	-	-	74.8	74.8
Maintenance of dam	63.2	129.4	109.3	172.5
Maintenance of articulated mat	-	67.3	-	67.3
Interest	3,443.9	4,343.5	3,861.1	4,746.6
Amortization	1,757.1	2,216.0	1,969.4	2,421.9
Totals	6,324.3	7,816.3	6,586.7	8,055.2

It would be perhaps too optimistic to assume, for purposes of estimating the overall economics of the proposed navigation improvement, that sound rock foundations will be found both at Ataes and at Entre-os Rios; and too pessimistic to assume sand at both sites. A conservative compromise would seem to be the assumption of a movable crest dam on sand at Ataes and a movable crest structure on sound rock at Entre os Rios. The data presented permit the computation of net benefits by the substitution of less costly structures at Ataes however, and the concluding pages of the chapter briefly discuss them.

(3) Entre os Rios Lock and Dam - The lift from lower pool to upper pool at Entre os Rios is only 3.55 m (from 6.7 m to 10.25 m above mean sea level), so the dam is a much smaller structure than the one at Ataes. It would consist of a low concrete weir with Chanoine-Pascaud wickets and bear traps, and would have a navigable pass which tows could traverse when the lock was overtopped. It is assumed to be founded on rock.

The lock again would be 56 by 450 feet (17 by 138 m) in usable chamber size, with top of gates at elevation 12 m.

The cost of construction is estimated to be 83,238 contos, including 49,838 contos for the lock and 33,400 contos for the dam.

TABLE VII-2

ANNUAL COST OF ENTRE OS RIOS LOCK AND DAM

Items	Contos
Maintenance of Lock	201.3
Operation of Lock	100.6
Operation of Bear Traps and wickets	616.7
Maintenance of Bear Traps	83.4
Maintenance of Wickets	43.1
Maintenance of Dams	61.8
Interest	2,289.0
Amortization	1,167.8
Total	4,563.7

4. Navigation Improvements Required at Foz do Douro

A. Existing conditions - In order for iron ore from Moncorvo or other river-borne freight to be exported, they must reach ocean-going ships at or near the coast. The Douro River empties directly into the open ocean. There is no embayment, no outlying protection of any kind, against Atlantic storms. The river brings down large quantities of sand in floods, which, after deposition just off shore, is reworked by the ocean to form a sand cape (cabedelo) across the river's mouth. The sea itself brings sand southward along the shore, and the water frequently is so rough that the combination of sand and waves and weather makes the passage between sea and river usually a difficult, hazard operation, often a hazardous one, and all too frequently impossible. Once inside the river, a channel (maintained by dredging) is found to the docks along the water fronts of both Porto and Gaia, but as illustrated by Plate 6, the thalweg, directed by the rocky right bank into the cabedelo and deflected northward by the latter is likely to be difficult to navigate. Many fishing craft and some small freighters brave the hazards and accept the uncertainties of the entrance. Portuguese engineering literature has suggested various plans for remedying the situation, but no comprehensive improvement has been undertaken. Instead, an artificial harbor has been created by means of breakwaters and dredging at the mouth of the little Rio Leca about 5 km northward of the mouth of the Douro River. This harbor, known as Leixoes, is now the principal port. It handles about 1,000,000 tons of cargo a year, which almost represents its saturation point. Plans are being considered for enlarging its capacity by dredging an additional basin farther inshore and building additional docks, and it is understood that the six-year plan for public work, 1953-1958, contemplates the allocation of 175,000 contos to the undertaking and also includes provision of a quai at Gaia costing 35,000 contos.

The sea is too rough between Foz do Douro and Leixoes to permit river tows to proceed to the Leixoes docks with regularity and safety. The export of river commerce accordingly requires the improvement of Foz do Douro so that ocean vessels can enter the harbor of Porto-Gaia safely and easily to load, or the employment of some method of transporting barge cargoes to the Leixoes docks, safer than putting barges into the open ocean, and preferably cheaper than transfer by means of ocean going lighters. Four plans which seem physically possible have been considered in the course of the present study.

At the D. Luiz Bridge which is about 5 km upstream from the Cantareira tide gage, the river is about 160 m wide and quite deep - some 8 m or so below hydrographic zero, which is 1.93 m below mean sea level. River widths and depths vary between the bridge and the mouth. Wherever the width of the river is about 200 m, a good channel of 6 m depth obtains. But in the lower 1.5 km of its course, where widths of 400 to 500 m prevail, depths of 4 to 4.5 m are the maxima. The river bed is predominantly sand, although rock occurs at elevation of about 6 m below hydrographic zero in the vicinity of the mouth. Plate 8a shows low water conditions of November-December 1951 at the mouth of the Douro River.

In winter, southwest and northwest winds blow with about equal frequency, but the southwest winds are the strongest. During the other three seasons of the year, the most frequent and likewise the strongest winds blow from the north and northwest; and southwest winds are infrequent. Thus, there are north and northwest winds throughout the year, but in winter time the strongest winds are from the southwest, and their frequency is also about the same as the north and northwest winter winds. It is the southwest winds which presumably extend the cabedelo farthest northward across the river's mouth.

The tidal range at the mouth is 3 to 4 m, but the tidal basin, because of the steep high banks of the river and the absence of tributaries near the sea, is small. The advance of the sand cape across the river's mouth progressively reduces the volume of tidal inflow and so reduces the daily scouring action - particularly upon the sand deposits landward of the entrance.

The summer flows of the Douro River often are quite low and such flows do not carry much sand. But they do carry some, and sand also deposits in the broad reach near the mouth during the falling stages of floods. It is averred that a dredge cut made through the shoal in the river proper, stays open until a new flood comes along - which means, in general, that it stays open throughout the low water season.

(1) Jetties plan - If sea jetties were built, the inference would seem to be that if they were spaced more than 200 m apart, the waters of subsiding river floods would leave fluvial deposits, shoaling the channel between them just as the wide channel of the river itself shoals; but that if a navigation cut were dredged through this shoal, it would stay open just as it does in the river. It is believed that for the types of ocean vessels that would be used for the movement of iron ore, wine and such miscellaneous cargoes as the ports of Porto and Gaia might offer a channel 200 m wide and 6 m below hydrographic zero would suffice.

The frequent winds not only move sand into the river's mouth, but they also make the sea rough and the passage hazardous even when depth of entrance channel may be adequate. In heavy seas the port has to be closed to ocean traffic. Because the major hazards to navigation entering the harbor of Porto stem from the winds and resultant sand movements, the first step toward improving the port for dependable 6 m ocean navigation would appear to be construction of sea jetties.

The least expensive system would be a pair of jetties carried to an elevation 6 m or more above hydrographic zero (4.07 m above mean sea level) and constituting extensions respectively, of the existing north jetty, and the Mohle Luiz Gomez de Carvalho on the south. If directed somewhat south of west, as indicated on Plate 6, the jetties would shelter shipping from the most prevalent gales (northwest) while it was entering the mouth of the river; would protect it fairly well against southwest winds; and would prevent the rebuilding of the cabedelo northward of the south jetty line, after the sand once had been removed. The opening between jetties so located is about 400 m - ample to admit flow to the tidal prism upstream, and it is believed, to permit shipping to enter and leave without undue difficulty of hazard.

The jetties should be carried out at least to the minus 10 m contour, and farther if funds permit, and should be built to that limit during a period of low river flow which has permitted the waves to move the sand inshore. A channel 200 m wide would be dredged through the sand, and through such rock as will be encountered, from the minus 6 m contour below hydrographic zero in the ocean to the minus 6 contour in the river.

When a sizable flood in the river occurs, it will deposit sand seaward of the jetties - but as the depths there are considerable, it seems unlikely that a channel will need to be dredged through the deposit to attain a depth of 6 m below lowest low tide; and as the action of the waves seemingly is always to wash away the bar after the flood subsides, the deposit should not be cumulative from flood to flood.

There is, however, another source of sand. It is brought southward along the coast from the mouths of the rivers north of the Douro River by the wave action induced by the prevailing north and northwest winds. Before the building of the artificial harbor of Leixoes (1883 to 1892), the shore above the Douro River was a sand beach. The Leixoes breakwaters trapped the sand, and the wave action which formerly had kept the beaches replenished, forthwith proceeded to denude them. After about 30 years, sand began finding its way around the outer end of the upper breakwater at Leixoes. Dredging at the harbor entrances has been required annually since 1903, and the beaches below Leixoes are again receiving sand. Some years ago the north breakwater at Leixoes was extended to the minus 18 m contour, but construction was by means of such large monoliths that sand can pass through it, so dredging continues to be necessary. The annual requirement seems to have substantially stabilized at some 200,000 m^3. The present charge for the hopper dredging required is 8$00/$m^3$, or about 1600 contos a year. The sand always appears at the same place.

It seems certain that in the course of the years, the southward moving sands will accumulate along the north jetty of the Foz do Douro, if one is built, and ultimately will advance across the entrance to the jetty channel. There they will encounter the combined river and tidal flow, but it seems too optimistic to expect this action to prevent the formation of a shoal area around the end of the north jetty. The annual volume of required dredging should not exceed that at Leixoes, however, and if delayed for possibly 20 years by the time required for sand to work to the outer end of the jetty, the annual dredging requirement throughout a 40 year economic life would average only 100,000 m^3. Just how the sands brought down by the Douro River will affect those moving down the coast, is difficult to predict.

Between the jetties, shoaling would be pre-eminently due to fluvial rather than to marine deposits. It has been noted previously that where the width between river banks is 200 m or less, a satisfactory channel of 6 m depth exists, whereas shoaling occurs when widths increase to 400 m. It may prove desirable eventually to create a 200 m low stage flow channel through the lower, broad, portion of the river and through the jetty channel itself, by means of low training walls.

The cost of jetty and training wall construction would greatly exceed the cost of the simple jetty system first discussed, and it is possible that the increase in resultant annual charges for the more ambitious system would nullify the savings represented by reduction in dredging costs. In any event, it would not be desirable to make the training walls landward of the jetties very high. To do so could be to induce harmful velocities in both the river and jetty channels.

The execution either of the simple jetty scheme or the jetty and training wall scheme would require removal of sand and rock between the confining structures, seaward of the east edge of the cabedelo and northward of the Carvalho Mohle. In either scheme, the spoil would be deposited in the existing channel north of the present cabedelo. In the scheme for jetties only there would be the hope that the permanent channel could be induced to form as an extension of the present alignment of the river thalweg. In the jetties and training walls scheme, the low-water flow would have no alternative but to follow this desired course.

Flood flows of the river would spill over the training walls both to the north and south. A saddle should be maintained in the cabedelo sufficiently low to provide an outlet for floodwaters before harmful velocities could develop in jetty or training wall channel.

If the jetties scheme is adopted, a training wall should be built from Cantareira to the shore end of the north jetty, in order to eliminate the eddy and turbulence engendered by the rock projection at Cantareira.

Construction cost of the jetty plan, including 1,566,600 m^3 of sand removal at 5$00/$m^3$, and 70,000 m^3 of rock removal at 330$00/$m^3$, is estimated at 239,575 contos. Of this sum, the jetties and the training wall below Cantareira account for 197,805 contos.

Based upon experience at Leixoes, an annual maintenance charge of 1% of construction cost has been assumed for the proposed jetties and training wall. Annual dredging requirements have been assumed as 100,000 m^3 at 8$00 and 592,000 m^3 at 5$00; the latter representing annual maintenance of the channel and any necessary work required to insure the existance of a saddle in the cabedelo for relief of floods. Adding interest charges of 2.75% per annum and amortization on a 40 year basis brings total annual charges to 15,694 contos.

The improvement of the mouths of rivers, involving ocean currents, winds, waves, sand movement and variable stream flow is quite likely to prove disappointing as well as expensive if undertaken without exhaustive research and study of local conditions. The construction of the works outlined above under no circumstances should be undertaken until experiments with a movable bed model of appropriate scale have indicated that results are likely to approximate those desired. The Hydraulics Laboratory in Lisbon is well equipped to make such a study - which in all probability will suggest various adjustments or modifications of the layout here presented.

(2) Tunnel plan - As an alternative to improvement of the river's mouth, a subterranean canal to Leixoes, similar to those in use in France, has been studied. Leaving the river at a small valley about 1000 m above Cantareira (see Plate 6) the first 500 m of the route would be open cut, and the next 4800 m tunnel, with a second open cut leading to the proposed new basin at Leixoes. The tunnel (see Plate 6) would be 13 m wide by 9.5 m in height from floor level of 5.6 meters elevation to the center of the arched roof. A lock, 9 m wide by 214 m in length would be provided at each end. Water level in the tunnel, nominally at hydrographic zero, would be kept at levels consistent with the prevailing tides and the elevation of the tunnel roof, by pumping.

Loaded barges would be delivered into the Douro River lock by river tow boats; would be hauled through the tunnel by an electrically operated towing mechanism pulling itself along a submerged chain; and would be picked up and moored in the Leixoes basin by a harbor tug. Traffic in the tunnel would be one-way only, the towing mechanism delivering empty barges at the Douro River lock on return trips.

Unfortunately, little is known of the rock formations thru which the tunnel would pass. Its course - a straight line whose termini are fixed within rather narrow limits - apparently traverses the zone of contact between granite and schist, so some fragmented rock may be encountered, in which tunnel lining will be required. Pleistocene formations appear on the ground surface in places, but are thought to be only superficial. It has been assumed that 25% of the length of the tunnel would require lining.

The cost of the approach cut and lock at the Douro end was approximately computed, and the assumption made that costs at the Leixoes end would be the same.

On the foregoing basis, the first cost of the project, including open-cut, tunnel, locks, towing devices, ventilating shaft and equipment, and illumination is estimated at about 352,738 contos. Annual operating and maintenance costs are estimated at 5,670 contos. Interest and amortization bring the total annual charges to 20,320 contos. The figures do not include any allowances for rights of way and damages, which however, would be small, it is believed, probably not more than 2900 contos.

(3) Coastal canal plan - A third method of transporting river cargoes to Leixoes would be by means of a canal along the coast. Two routes have been considered. Both leave the river at Cantareira

and pass through a lock which will compensate for differences in elevation between river level and tide level at Leixoes.

Leaving the lock, the first route (see Plate 6) follows in general the highway which traverses the water front. A profile along this general alignment was surveyed in 1877.

The least expensive canal would be one whose width would be just sufficient for the passage of a canal tug propelling one ore barge. This would require for the ore traffic about four round trips a day for the tug, which would bring back an empty ore barge on each return trip. In straight reaches the canal would be 15 m wide on the bottom, at elevation 4 m below hydrographic zero. This would provide, at extreme low tide, about 1.25 m of water beneath a loaded barge, and 3 m on each side between the barge and the bank. With so small a water prism, speed of movement would have to be slow. At higher tides it could be increased somewhat. On curves, the canal width would have to be increased in proportion to the sharpness of curvature. The landward edge of the canal, along which a protective parapet 1.25 m high would be provided for safety to pedestrians and vehicular traffic, would lie, in so far as practicable, at the seaward edge of the highway. This would not be feasible at all points. Near the Douro River end, the route would require the removal of a number of buildings. Considerable park property would be destroyed also.

At places, the seaward edge would be exposed to the ocean. About 900 m of breakwater protection to elevation + 8 m would be provided.

The channel would pass through the south breakwater at Leixoes, and a dredged basin equipped with mooring dolphins would be provided just beyond it, where the canal tug could tie up loaded barges pending final placement shipside by a harbor tug and could pick up empties delivered by the latter. Two railway crossings, for which bascule bridges are proposed, would be required at the Leixoes end of the route. Foot bridges would be provided at intervals of a few blocks between Leixoes and the Douro River, for access to the bathing beaches.

No attempt has been made to estimate property damage, nor to appraise the nature of public reaction to the effect of the work upon the esthetic and recreational developments that now characterize the water front, and nothing has been allowed to cover any special problems of rock disposal that the presence of the beaches might introduce.

With the foregoing qualifications, the estimated construction cost is 273,616 contos and annual charges for interest, amortization, maintenance and operation of lock, bridges, dolphins, transfer basin at Leixoes and entrance bay at Cantareira, canal and harbor tugs are estimated at 15,892 contos.

Even tows consisting of a single barge could not pass one another in a canal 15 m wide, and as rather slow speeds would probably be required, it is conceivable that the canal could become a bottleneck. It differs from the navigation tunnel, in that the latter being straight from end to end, is able to use a chain propelled towing mechanism which can pull a long train of barges each trip. If the canal width were increased to 23 m in straight reaches, and widened enough in the bends to accommodate a tow of 4 ore barges, it would have a very much greater capacity, its use would be much more flexible, and it probably could never become a bottleneck. The estimated construction cost of a channel of these dimensions, illustrated in cross section on Plate 6, is, (again excluding property damage) about 329,386 contos with annual charges of about 17,429 contos.

The second canal route investigated lies off-shore along the coast, so would require a continuous breakwater, but would not require as much rock excavation as the first route, nor would it destroy any private property of consequence, nor as much park property. Data on elevations in the zone it would traverse are few, so elevations have had to be deduced in a large measure from known and observed local characteristics. The off-shore route also would be provided with foot bridges to the beaches. The latter would be destroyed temporarily in all likelihood, but the ultimate effect should be to reestablish them seaward of their present position.

The estimated first cost of the works, on the basis of 23 m width is 571,094 contos and the annual charges 30,900 contos. For the 15 m width the corresponding figures are 553,193 contos for first cost, and 30,966 contos for annual charges. The decrease in fixed charges being a little more than offset by the charge for the harbor tug at Leixoes, which was included in each case for the narrow canal but was not considered necessary for it, the wider cross section was used.

(4) <u>Overland transport</u> - Ore for export arriving by

river, instead of being hauled to Leixoes by barge, through a tunnel or a coastal canal, might be transported overland by railroad, truck, or aerial tramway.

If an unloading area could be developed on the right bank near the site of the south portal of the proposed navigation tunnel, a truck haul of about 6.5 km or an aerial tramway about 5.5 km in length following the alignment of the suggested subterranean canal, would suffice to make the transfer. It is estimated that the cost per ton via either method would approximate 7.5 escudos. Charges for dock, unloading from barge, and loading in trucks or stock-piling, would be about 2.4 escudos, making the total, from barge to Leixoes, about 10 escudos.

If the unloading area had to be across the river on the left bank below Gaia, a truck haul of about 14 km, plus some expensive road construction would be entailed; or if an aerial trainway were employed, a crossing of the navigable channel. It is anticipated that costs per ton under such conditions would rise to perhaps 20 escudos. An unloading point on the right bank above town would entail still longer truck or tramway hauls with costs per ton rising perhaps to about 24 escudos. Transfer to railroad cars with rail haul to Leixoes has not been investigated, nor has lighterage.

5. Method and Cost of Water Transport of Various Commodities, and Indicated Savings

A. <u>Iron Ore</u> - In reply to inquiries, the Companhia Nacional de Caminhos de Ferro has very kindly considered the problem of hauling the Moncorvo district ores to Leixoes harbor via rail under various assumptions as to annual volume of movement. The present annual tonnage is about 100,000. The normal rate per ton according to established tariffs would be:

From Carvalhal (mine) to the Leixoes docks (205 km) . .	104$62
From Carvalhal (mine) to Pocinho (23 km)	17$60
From Pocinho to Leixoes docks	81$19

By special agreement, however, the rate of 70$00 a ton from Carvalhal to the Leixoes docks has been made, the shipper to pay for cost of transfer to broad gauge cars at Pocinho. It is understood that he has contracted for this transfer at 2$00 a ton, making the total cost to him from Carvalhal to Leixoes docks 72$00 a ton.

The railroad has stated that in the event 2,000,000 tons a year were to be moved, it will run a broad gauge track to Carvalhal from Pocinho or will use an aerial tramway, and in either event, will hope to make a price from Carvalhal to Leixoes of 60$00 a ton exclusive of any transfer costs at Pocinho. Since with a broad gauge line there will be no transfer, the total cost to shipper presumably would be 60$00. Whether this low rate would hold for 1,000,000 tons instead of 2,000,000 is not known. The data supplied by the railroad company indicate that it will not be necessary to convert the Carvalhal feeder line to broad gauge in order to handle 1,000,000 tons a year. There will therefore be a transfer cost of about 2$00 a ton at Pocinho if the annual tonnage were only 1,000,000. It seems questionable that the 2,000,000 ton line haul rate would apply to a movement of only 1,000,000 tons, but assuming that it did, the total cost to shipper from Carvalhal to Leixoes will be 62$00 a ton.

To haul the Moncorvo ore by barge, two tows were set up, each utilizing a 900 HP diesel engine tow boat costing 9500 contos. The barges, 10 of which will be needed, will be steel, hopper barges, all welded construction, 175' x 26' x 10' -8" (57.5 x 7.92 x 3.3 meters) with a cargo capacity of 845 metric tons when loaded to 8½ feet (2.6 m) draft. This is a standard barge manufactured in the United States, weighing about 136 metric tons. Its cost in Portugal is estimated at 1725 contos.

In order to place the ore in the barges, it will be necessary first to haul it by rail from the mine station - Carvalhal - to the barge loading point, about 4 km west of Pocinho, (see Plate 8) where the railroad lies close to the river. It is assumed that with 1,000,000 tons of traffic a year in prospect, the railroad will agree to extend the narrow gauge tracks 4 km beyond Pocinho. If it is further assumed that, despite the ten-fold increase in tonnage represented by the change from the present 100,000 tons a year to 1,000,000 tons a year, the rail charge per ton-kilometer would not be reduced, then the cost from Carvalhal to the Pocinho loading point will be 20$66.

At the loading point below Pocinho, the shipper or shippers will build rail sidings at track level for delivery of loaded cars and storage of empty cars, and would provide an incline, equipped with cable and winches, leading to a masonry quai along the river bank from which the cars will side dump into waiting barges - or, in the unlikely contingency of no barges being available, into a stock pile landward of the quai for subsequent rehandling into barges. The construction cost of the installation is estimated at 14,360 contos and the cost per ton from rail car F.O.B. siding into hold of barge, 2.02 escudos a ton.

The tows probably will be operated by the owners of the mines, acting in concert. Each boat will handle 4 barges holding an aggregate of 3,380 metric tons. The speed of the loaded tow will be 10 km an hour, and the speed of return of empty barges, 14 km an hour. The distance to be traversed, measured along the middle of the river, is 163 km, but because of the more direct course that could be followed in the lower portions of the pools, the distance will be shorter. A lockage time of 2 hours for each passage of a power dam and of ½ hour for passage of a navigation dam is allowed, making a 14-hour lockage for the round trip. The total round trip time (including delays for picking up loads and empties at the ends of the trip) will be 46 hours. Because a tow boat has to lay up for overhaul and repairs about one month each year, the actual annual operating time is taken as 330 days, and because there are always delays due to weather, fogs, floods, minor breakdowns, taking on fuel and stores and various unforeseeable causes, a 20-hour day is assumed.

On this basis, each tow can make 143 round trips a year, and the two together can deliver an annual aggregate of 964,680 tons. To haul the remaining 35,320 tons required to bring the total to the 1,000,000 tons of annual production, it will be necessary to rent a tow boat. Fortunately, as will be seen later, a 450 horsepower boat, will be available from the wine trade for 2 months, to make 21 trips with a two-barge tow of 1690 cargo tons.

All the boats will operate 24 hours a day (20 effective hours) 7 days a week. The crew, working in shifts, will include a master, a pilot, an engineer, two assistant engineers, a mate, 3 deckhands, and a laborer. Crews will subsist themselves. Salaries, (including overtime at $1\frac{1}{2}$ times the regular rate for week days and double time for Sundays and holidays) social security charges, and employer liability bring annual personnel costs to 536,000$00 a year. Adding interest on investment at 5%, amortization at 5%, repairs to boats at 8% and to barges at 2% of first cost, insurance of various sorts, costs of fuel, lubricant, and engine room supplies, the annual cost for 330 days operation of the two tows is 11,500 contos. Adding 15% for overhead, and adding the cost of the rented boat, brings the total line-haul cost for 1,000,000 tons of beneficiated ore to 13,600 contos. The total cost per ton from Carvalhal to Porto then would be:

	Escudos
Carvalhal to Pocinho loading point	20.67
Loading into barges	2.02
Line haul, Pocinho loading point to Porto	13.61
Total	36.30

As the cost per ton from Carvalhal to Leixoes by rail would be not less than 62$00 the indicated saving in line haul is at least 25$70 a ton, and, for the annual total 25,875 contos.

It would be more convenient in so far as maintaining a uniform flow of iron ore is concerned, if a 900 HP boat could be rented for use during overhaul periods instead of a 450 HP craft, but it is believed that with some forethought in scheduling mine production, ocean vessel arrivals, and in taking advantage of the fact that when river flow is abundant the barges can be loaded to a greater draft than that assumed, the need for excessive stockpiling can be avoided. In estimating transfer from barges to ocean ships at Porto, a stock pile representing a 10-days' supply was assumed. Increasing it materially would involve the use of an additional boom machine or bulldozer.

B. Wine

(1) Production and shipment - The average tonnage of wine production in the Douro Valley for the years 1934 to 1949, as derived from figures presented in Table A, Table Series A-K, Port Wine Institute, 1951, is as follows:

	Must	Brandy added	Untreated Wine	Total
Tons of Wine	23,052	5,338	53,645	82,035
Tons of Casks	-	-	-	12,600
			Total Tonnage	94,635

Based on a study of the map of wine producing areas published in Girao's "Geographea de Portugal", an estimate was made of the tonnages shipped from the principal collecting points. The results are shown in the following table:

TABLE VII-3

ANNUAL WINE TONNAGE OF PRINCIPAL SHIPPING POINTS

Shipping point	Km above Gaia	Percent of total output handled	Total tonnage	Waterborne tonnage	Remarks
Cinfaes-Aregos	68	15.7	14,900	12,700	Carrapatelo Pool
Regua	101	27.0	25,490	21,500	Carrapatelo Pool
Pinhao	125	27.1	25,590	21,800	Regua Pool
Tua	137	12.7	12,090	10,300	Regua Pool
Pocinho	179	17.5	16,530	14,200	Valeira Pool
		100.0	94,600	80,500	

The wine is shipped to the port of Gaia, directly across the Douro River from Porto.

With the exception of Cinfaes, the shipping points names are on both the broad gauge railroad of the Linha do Douro and on the Douro River itself. The casks of wine are delivered to the storage yards at the collecting points by ox team, truck, or by the narrow gauge railroads which bring the produce of the hinterland down to the broad gauge tracks which parallel the Douro. Large stock piles of filled casks awaiting shipment may be seen in the storage yards, whence they are eventually loaded on the cars of the broad gauge railroad and shipped to Gaia, or are loaded on rabelos and sent down the river. Only a small part of the total tonnage, perhaps 15%, moves by water at the present time, despite the fact that water transport is preferred because of the damage sustained by the casks from the rubbing and shifting which they receive in freight cars when passing around the sharp curves of the railroad.

The movement of the wine is, to a large degree, seasonal. It has been assumed, for purposes of computing the benefits of improvement for navigation, that about 85% of the total tonnage produced would move via barge to Gaia, during the six-month period following the harvest provided that 2.7 m navigation was established. This assumption is based on the following facts: (1) the wine can move more economically by water than by rail; (2) the wine has to be delivered to the Douro River ports, in any event, for transfer to the broad gauge cars; and (3) the wine moves with less damage to the containers by water than by rail.

The waterborne tonnage of the several ports then would be as indicated in Table VII-3. This would leave 15% of the crop to be handled during the remaining six months of the year, and the assumption has been made that it would move by rail or truck. Probably part of the wine would move by rail throughout the year, since there no doubt would be occasions when barge transport would be too slow or perhaps not immediately available when the movement was desired.

In addition to the movement of wine downstream, there would be a reverse movement of empty casks and of brandy, upstream. The upbound tonnage of empty casks would be the same as the downbound tonnage, namely 12,600 tons.

According to Table G of the Port Wine Institute for 1951, half of the brandy used is brought into the Douro area from outside. It is assumed that at least half of that brought in from the outside comes by way of Gaia. The upstream tonnage of brandy, including the weight of the casks in which it is shipped, would be about 3,100 tons. The assumption has been made that 85% of the empty wine casks and the brandy would be hauled upstream without imposing any extra expense additional to the cost of returning the empty wine barges upstream to receive fresh loads. This could be the case, of course, only in the event that the empty casks and the brandy moved upstream during the active part of the wine shipping program.

(2) Shipping costs by barge - It is assumed that associations of growers or marketers of the wine would operate a tow boat and barges for moving the crop. The operation would require a tow boat of 450 HP and about 18 steel barges of 160 tons capacity. The tow would consist of from one to seven barges, with tow boat pushing from the rear. The tow would originate at Pocinho in the form of the boat and one barge. It would pick up another barge at Tua, two more at Pinhao, two more at Regua and another at Cinfaes-Aregos, arriving at Gaia with seven barges. Picking up seven empties at Gaia, it would set them off by ones and twos at the ports of call on the upbound trip. The round trip would consume 57 hours, and the six months' operation, involving the movement of 80,500 tons downstream and 13,350 tons upstream would cost, including 258.75 contos estimated for overhead, about 2860 contos. Of the six months period in which the equipment would not be engaged in towing wine, one month would be needed for overhaul. Of the remaining 5 months it probably would be

used for two months in the ore trade and one month for towing coal.

(3) Shipping costs by rail - About 35% of the wine produced by the Douro growers is port, and 65% table wine. From a study of current rail tariffs, the conclusion was reached that the cost per ton-kilometer for broad gauge rail haul from the Douro shipping points to Gaia would average about 94 centavos for port and brandy in casks, 66 centavos for table wine in casks, and 66 centavos for empty casks. Applying these figures to the shipments considered to originate at the respective ports, the total cost of rail haul for the tonnage assumed to be potential waterborne commerce if the navigation improvement is effected, is about 8,710 contos. As the cost of hauling the same tonnage by water is 2860 contos, the indicated saving which can be credited to navigation is 5850 contos.

The assumption has been made throughout the foregoing analysis that the wine casks could be loaded onto barges at the shipping points as cheaply as they could be loaded onto cars. It is possible that at Gaia, some increase in handling charges might be entailed. If it is assumed that there might be an increase in cost of handling of approximately 5 escudos a ton at Gaia, the savings would reduce to about 5460 contos.

C. Coal - As explained elsewhere, the exact annual tonnage of coal which will move from the Pejao mines to Porto in future years will depend upon a number of questions which cannot be resolved completely at this time. It presumably will be not less than 291,000 tons a year, nor more than 360,000 tons a year, depending upon the mining methods adopted and the construction of a thermal plant near the mines. For the purpose of the navigation study, both the figure of 360,000 tons a year and that of 291,000 tons a year have been used to bracket the range of possibilities. Since the best procedure appears to be to separate and wash the coal and use the fines in a Pejao thermal plant, the most probable annual tonnage for river commerce is considered to be 291,000 tons.

According to the mine owners, the cost of transporting the mined coal during the year 1951 from Germunde to Porto averaged 21$20 a ton. Transportation is practically all by means of rabaos with an occasional requirement for truck haul and an occasional need to lighter small cargoes to a point below the Carvoeiro shoal for combining into 60 ton cargoes for transport thence downstream.

If, the annual tonnage to be moved totalled 360,000 tons, the equipment best suited for use after improvement of the stream for 2.7 m navigation, probably will be a 200 HP diesel tow boat propelling a barge similar in design to those employed for moving the iron ore, but smaller in dimension, 26' x 100' (7.92 m x 33.6 m) with a cargo capacity of 460 tons at 8½ ft. (2.59 m) draft. The cost of such a barge would be about 109 contos. Three will be required; one in transit, one being loaded at Germunde and one unloading at Porto. The round trip between Germunde and Porto will require about 5½ hours running time. Allowing half an hour each way for the single lockage required at Ataes, an hour for turn around time at each end of the trip, and a delay of 15% for weather, flood, etc., the total time between successive arrivals at Porto will be about 10 hours. The boat will have to lay-up for overhaul and repairs about one month out of the year. During this period, the 450 HP wine boat will be rented as a substitute. Total operating costs for both boats, including an overhead charge of 15%, will amount to about 2271 contos a year. As the cost of moving 360,000 tons by rabaos at 21$20 a ton will cost about 7632 contos, the indicated saving will be about 5361 contos a year. If, instead of delivering the coal to Porto at a uniform rate throughout the year it will be satisfactory to move the entire 360,000 tons in 11 months, the cost will reduce to 2056 contos and the savings would be 5580 contos. This might, however, entail too much stock piling if the movement of only 291,000 tons a year is required, a tow boat of 150 HP costing 1930 contos and three 340 ton capacity barges about 85 ft. (26 m) long and costing about 862.5 contos apiece will suffice. Annual costs, assuming delivery throughout the year, will be 2100 contos, with indicated savings of 4074 contos under line haul costs by present methods of transport.

In this instance, however, instead of assuming rental of an idle 450 HP wine boat during the one month allocated to repair of the 150 HP tow boat, it has been assumed that a spare 150 HP diesel boat will be acquired for use during annual repair and overhaul periods. The annual costs will be about the same as for a rented wine boat, and the arrangement will permit year around deliveries even though improvement for navigation were carried only as far as Germunde, and no wine boat was in existence.

The saving in either instance should be reduced by the interest charges on the remaining value of the fleet of rabaos-which would be discarded presumably when replaced by steel barges. There are about 90 rabaos in service at the present time. They cost about 37 contos each and require repairs amounting to rebuilding every three years. It would appear conservative to assume the value of the fleet at any time as equal to 1/2 the cost to reproduce it. On this basis, assuming interest at 5% per annum, and no salvage value, the charge against the savings effected by changing to steel barges will be about 86 contos a year.

To recapitulate: On the basis of 360,000 tons a year of coal traffic, the net savings in line haul, after writing off the existing fleet of rabaos, would be 5275 contos or 5494 contos depending upon whether deliveries were uniform throughout the year or concentrated within a period of 11 months. On the more probable basis of a 291,000 ton annual movement over a 12-month period, the net savings in line haul costs, again writing off the present complement of rabaos, would be 3988 contos. This is independent of any improvement above Germunde. If the improvement were carried to Pocinho, the spare 150 HP tow boat assumed could probably be rented 2 months each year to the iron ore interests.

D. Miscellaneous commodities - It is not possible to predict with any semblance of precision, how large a waterborne tonnage in miscellaneous commodities would develop with improvement of the stream to accommodate 2.7 meter navigation. Consideration of the present tonnage moving into and out of the Douro Valley by rail may, however, furnish a basis for approximating the traffic. The Linha do Douro has made available figures for the total tonnage of freight and express handled by it during the period 1947 to 1951. The data were not classified to show the nature of the commodities involved nor the origins or destinations of the shipments. The average annual movement for the period, including both outbound and inbound traffic, was 285,286 tons. Some of it was wine, which already has been claimed as potential river traffic. No doubt much of the other tonnage was of such character that it would not be adaptable to water transport, and some that would be inherently suitable, probably would have so short a movement along the course of the river as to make water transport with the attendant handling charges, uneconomical.

If it is assumed that annual traffic, exclusive of the wine, would average about 200,000 tons, of which possibly a third might move by barge, with an average saving per ton equal to the average saving per ton indicated for the three commodities already considered, namely, iron ore, wine and coal (which represent traffic originating at points distributed throughout the entire length of the portion of the river considered for improvement), a saving of about 25$30 a ton on 70,000 tons a year of miscellaneous freight would be indicated, and the 1,775 contos which this represents might be considered to constitute a not unreasonable estimate of annual benefits from that source.

E. Savings in export costs - The analyses thus far have concerned themselves with: transportation of iron ore from Carvalhal to the station of Leixoes by rail, versus transportation to Porto by rail-barge; transportation of wine from various river ports to Gaia by rail versus barge; the transportation of coal from Germunde to Porto by rabao versus barge. In the case of the coal, all of which will be consumed in Portugal, this is all the analysis needed, but the wine and iron ore require further consideration. Some of the wine will continue to be exported, as it now is. Much of it is loaded at Gaia under existing conditions, but the port of Leixoes handles over 30,000 tons of wine a year. This probably involves wines from other areas as well as from the Douro. All of the ore may be exported and will be, unless a domestic iron and steel industry is created.

At present, the ore is delivered to Leixoes station by rail. Switching the cars to the quai, unloading them, storing the ore until the ship arrives and then loading it into the vessel costs 15$52 a ton, exclusive of duties and levies and charges of customs brokers and transportation agents. When the ore can be loaded direct from cars to ship, the charge is only 10$42, of which 4$00 is for switching the cars.

If the mouth of the Douro River were improved so that the ore could be loaded onto ocean vessels at Porto, a simple U-shaped pier of the type shown on Plate 6 would permit transfer by means of a crane between barge and ship moored on opposite sides of the north leg of the U; or loading from barge to stock pile landward of the south leg if no vessel were available, and later loading from stock pile to vessel. Costs are estimated to be about 5$00 a ton, on the basis of having to rehandle about 20% of the tonnage.

It would not be correct to compare this loading cost with those at Leixoes, because, with a million tons a year to handle, either port would probably use handling methods especially designed for the commodity. It probably should be assumed that the actual handling of the ore into the vessel would be accomplished as cheaply at one port as at the other. In either case, however, there is the expense of maintaining jetties and channels and there are interest and amortization charges on the initial cost of making the harbor usable and safe. In the case of Porto, this is reflected by the annual charge of 17,500 contos against improvement of the mouth of the river.

In the case of Leixoes, there is an annual dredging cost of about 1,600 contos. If the jetties cost at least 150,000 contos, as they must have, their annual maintenance costs about 1,500 contos, and interest and amortization should add at least another 4,500 or 5,000 contos. Thus, quite aside from any charges against the docks or cranes or other facilities directly used by shippers, there must be an annual cost of about 7$60 a ton on the approximately 1,000,000 tons of shipping now using the harbor. With the extension of facilities contemplated under the 1953-1958 Six Year Plan, the cost of overhead per ton should diminish, but it does not seem unreasonable to suppose that it may remain as high as 4 or 5 escudos. Thus, in the case of a commodity which is to be exported, a true comparison of costs necessarily must take cognizance of the fact that if annual costs pertaining to improvement of Foz do Douro are to be taken into account, these must be off-set or reduced by 5$00 or so per ton of harbor expense that would be incurred if the shipment had to use the port of Leixoes. This differential would apply to goods transported overland from Porto or Gaia to Leixoes, and to those hauled between the two ports through a navigation tunnel or a coastal canal.

If it is assumed that all of the iron ore and 15,000 tons of Douro wine which would be exported from Leixoes if the river's mouth were not improved, would be exported from Porto or Gaia if it were improved, then the annual benefits to iron ore already deduced should be increased by 5,000 contos, and benefits to the wine industry by 75 contos. The total savings on iron ore would then become 30,875 contos and those on wine 5535 contos.

If the iron ore were transported by truck or tramway to Leixoes from a right bank unloading point above Cantareira, and the wine moved to Leixoes from Gaia by present methods, the improvement of the river's mouth could be omitted, and the annual charges against the navigation project thereby reduced by 15,694 contos.

Since it would cost at least 10$00 a ton to unload and transport the ore overland, the total cost of its transportation from the mine to the ship would increase by that amount, in addition to which, there would be a cost of 5$00 a ton represented by fixed charges and maintenance of the Leixoes channel and breakwaters as discussed above.

The same 5$00 a ton would apply to the 15,000 tons of wine assumed to be involved, plus perhaps 24$00 a ton for rail or truck transport from Gaia to Leixoes. The net result therefore would be a saving of 15,694 contos in annual charges, against the navigation project, versus an increase of 435 contos in the costs of wine movement and 15,000 contos in costs of ore movement. The net result is an increase of 259 contos in savings.

An aerial tramway, for transport of iron ore, would be unsightly, and use of 10-ton trucks would require 274 trips each way for 365 days a year. This would mean that at every point between Cantareira and Leixoes, a 10-ton truck, loaded or empty, would be passing at intervals of about 2½ minutes all day and all night, weekdays, holidays and Sundays - or at correspondingly more frequent intervals if shorter hours of work were used. Unless the operation was more or less continuous, extensive stock piling with corresponding reduction in savings probably would be necessary. For these reasons, it is felt that overland transport is not likely to prove acceptable.

The annual charges for a navigation tunnel exceed those for the improvement of Foz do Douro by jetties. Those for the least expensive of the canals along the coast line are almost the same as those estimated for the jetties plan, but when it is considered that the canal cost do not give effect to property damage and public inconvenience, and that for all traffic using either the tunnel or the canal, a harbor charge of perhaps 5$00 a ton should be added to cover cost of providing and maintaining facilities at Leixoes of the character which the improvement of Foz do Douro would provide it is apparent that nothing would be gained by substituting either of them for the jetties plan if model experimentation supports the estimates and conclusions previously reached regarding the latter.

F. Annual savings, all commodities - The indicated annual savings from all types of river traffic is summarized in Table VII-4.

TABLE VII-4

ANNUAL RIVER TONNAGE AND SAVINGS

Commodity	Tons per annum	Transportation	Annual savings Leixoes overhead	Total
		Contos	Contos	Contos
Iron Ore	1,000,000	25,875	5,000	30,877
Wine, Brandy & Casks	93,850	5,460	75	5,535
Coal	291,000	3,988	-	3,998
Miscellaneous	70,000	1,775	-	1,780
TOTALS:	1,454,850	33,110	5,075	42,190

It is proverbial that cheap transportation stimulates the development of a region, particularly its industrial development.

It is by no means improbable that in the case of the Douro Basin, with cheaper electric power soon to become available, and with coal, iron ore and other raw materials immediately at hand, the provision of water transport would operate to attract various industries and that these in turn would increasingly add to the waterborne tonnage and savings as well as to the general prosperity of the region.

G. Summary - Having computed the difference in cost between commodity movements by the present means of transportation and movement by barge or rail-barge, it is possible to compare the saving which this difference represent, with the annual charges which must be levied against the improvements required to make navigation and the export of certain commodities possible. Table VII-5 shows for each of the several navigation improvements needed, the first cost (which includes in each case an allowance of 35% for engineering, overhead and contingencies) and the annual charges for operation and maintenance, interest, (which, as the projects are estimated to be Governmental undertakings is taken at 2.75% per annum) and amortization. The sum of the annual charges for operation and maintenance, interest, and amortization, for the several individual navigation improvements, represents the total annual charge against the navigation project. This total must be compared with the savings realized from barge or rail-barge movement of commodities in lieu of their movement by the transportation media currently available. At the bottom of the table the total of these annual savings is compared with the total of the annual charges. The comparison indicates a net annual benefit from the improvement of navigation of 6,130 contos.

In computing the costs of barge movement, no allowance has been made for profit or for Government tax. Since for the significant commodities concerned, the tows will be owned and operated by the producers and/or marketers of the products handled, or by groups of such owners and/or producers or marketers, the towing cost is simply a marketing expense. As such it presumably would not be subject to Governmental levies; and any profits charged would have to be paid both to and by those charging them.

TABLE VIII-5

NAVIGATION IMPROVEMENT COSTS

Project	First Cost	Annual Charges in Contos			
	Includes 35% for Overhead & Contingencies	Operation & Care	Interest 2.75%	Amortization 1.403%	Total
1. Foz do Douro Jetties plan	239,575	5,744.2	6,588.3	3,361.1	15,693.6
2. Ataes Lock & Dam (Movable crest dam, with bear traps and wickets, sand foundation)	157,953	1,256.8	4,343.5	2,216.0	7,816.3
3. Entre-os-Rios Lock and Dam (Movable crest dam, with bear traps and wickets, sound rock foundation)	83,238.0	1,106.9	2,289.0	1,167.8	4,563.7
4. Carrapatelo Locks (Double lift)	45,058.1	215.6	1,239.1	632.2	2,086.9
5. Regua Locks (Double lift)	33,794.2	215.6	929.3	474.0	1,618.9
6. Valeira Locks (Double lift)	24,510.9	215.6	674.0	343.8	1,233.4
7. Channels Below Douro Dams	46,718.0	1,106.9	1,284.7	655.5	3,047.1
	630,847.2	9,861.6	17,347.9	8,849.6	36,059.9

	CONTOS
Total of annual savings -	42,190.0
Total of annual charges -	36,059.9
Net benefits with bear traps, wickets and sand foundation -	6,130.1
Net benefits with a solid weir on sound rock at Ataes -	9,304.7
Net benefits, Sidney gates and sand foundation at Ataes -	5,891.2

H. Benefit - cost ratio - Table VII-5 indicates a net saving of 6,130 contos from improvement of the Douro River for navigation to Pocinho, over and above all costs of line haul and the fixed charges, operation and maintenance costs of the work required to provide 9 ft. (2.7 m) navigation. The benefit-cost ratio derived by dividing total annual benefits of 42,190 contos by total annual charges of 36,060 contos is 1.17.

I. Allocation of benefits to power dams - For the purpose of comparing the economics of constructing power dams at Carrapatelo, Regua, and Valeira with the economics of producing power by other hydro plants elsewhere, or by thermal plants, each has been credited with 1/3 of the net saving indicated for the entire navigation project. This is perhaps too generous as the power dams are not needed in connection with coal traffic out of Pejao.

J. Absorption of annual costs - No attempt has been made to distribute the annual charges pertaining to the navigation improvement between the Government and the shippers. Theoretically, the shippers could pay tolls equal to the entire annual charge against the project and still save money as compared to cost of transportation by present means. Their saving would be only about 20% in such case, however, and as its realization would entail the procurement and risk of capital in the purchase and operation of floating plant and loading facilities, there might be some question as to whether they would immediately convert from present methods, except perhaps, in the case of the Pejao mines. The timing of the improvement also would have a bearing. If, for example, it was delayed until exploitation of Moncorvo ore deposits had seriously depleted reserves, or even had reached such volume that the railroad had made major adjustments to handle large ore movements, this would constitute a further deterrent.

In the United States the Federal Government assumes practically the entire burden of first cost and annual costs of navigation improvements designed to facilitate interstate commerce. It requires local interests to furnish rights of way for construction and maintenance, and in some cases to provide and maintain necessary adjuncts such as highway bridges etc., but assesses no tolls for lockage or for use of the water way. The question obviously is one of policy and beyond the scope of the present study.

K. Consideration by reaches - In order to yield full benefits, the navigation improvement must be carried to Pocinho. Termination short of that point will eliminate the major source of traffic, namely the Moncorvo iron ore.

If only the Carrapatelo power dam and the two navigation dams are built, the benefits will reduce to those contributed by the coal traffic and perhaps half of those pertaining to wine and miscellaneous commodities. These will total about 7,643 contos a year as compared with annual charges of twice that sum.

The coal savings can be realized if Ataes lock and dam alone are built. If rock foundation can be found and a solid weir and a lock with gates to elevation 10.7 meters m.s.l. are employed, the annual charges will be about 4,400 contos. Annual coal savings will be from 3,988 contos (291,000 tons, delivery throughout the year) to 5,580 contos (360,000 tons, delivery over an 11 month period). If, in addition, it is assumed that as much as 20% of the savings from miscellaneous commodities might also be realized, the range in total potential savings will be from 4,343 to 5,935 contos, again depending upon the volume of coal tonnage available, and whether delivery rate needs to be essentially uniform.

It thus appears that if improvements at Ataes are held to the minimum, and a sound rock foundation is found, the potential savings from coal, and miscellaneous commodities combined might in the aggregate be just sufficient to defray the annual charges against improvement for navigation to and a little above Germunde.

If the more desirable, gated structure, with lock less frequently subject to drowning out were employed, again with rock foundation, there apparently would be an annual deficit, as there would be with either type structure founded upon sand.

It might, however, even in the face of an indicated slight annual deficit, be considered desirable to construct the Ataes lock and dam without waiting for the completion of all of the other works required to handle the Moncorvo ore. If the remaining works are to be constructed without too much delay, the accumulation of operating deficits at Ataes during the development period would not be very great, and would simply result in a slightly decreased benefit-cost ratio for the economic life of the whole navigation project. Off-setting this would be the experience acquired, which would be extremely valuable in planning both the operation and the design of the succeeding navigation works and of the larger tows which the ore movement would require.

CHAPTER VIII

ELECTRIC POWER

1. General

The most important resource of the Douro Basin, which as yet is practically undeveloped, is the capacity for production of electric power inherent in the large volume of flow and the steep slopes which characterize the main river, and in the steep slopes with occasional storage potentialities characteristic of its Portuguese tributaries.

In considering the subject of electric power, it seems appropriate to survey the probable national demand, to discuss the generating facilities currently available in the Nation, and finally, to consider how continuing growth in demand best may be supplied.

2. Forecast Power Requirements

In the study of power requirements, data on past consumption and estimates of future market growth made by local agencies were analyzed carefully. In addition, representatives of governmental bureaus, of utility companies, and of industrial organizations were interviewed, and past power problems and probable future requirements were discussed with them at considerable length. The Ministry of Economy, through the Office of the Director General of Electrical Service, was particularly helpful in supplying a wealth of pertinent statistical data, including an estimate of future requirements which an independent evaluation of available data has substantiated.

In the present study, it has been taken as basic, that industry, in order to compete successfully, has to be assured of a dependable power supply. The high fixed charges appertaining to modern industrial plants make shut-downs costly. Add the disruption of orderly procedure, the disappointment and perhaps resentment of customers, the labor difficulties, and the expense entailed in laying-by and starting-up a complicated system of machinery, and it is apparent that work stoppages must inevitably result in high production costs. A dependable supply of power is as important as a dependable supply of labor, materials and transportation. If it cannot be provided, the manufacturer either must be subsidized or must charge more for his product, if indeed, he can be induced to undertake an operation on the basis of secondary power. Cases in point are the newly built electro-chemical plants for the manufacture of ammonium sulphate fertilizer, the provision of which in abundant and assured supply at costs competitive with those at which it can be imported is understood to be one of the basic needs of the country. The Amoniaco Portugues plant, located at Estarreja in the north, has an installed capacity of 24 megawatts and requires for continuous operation about 210,240,000 kwhr annually, which corresponds to a monthly average of 17,520,000 kwhr. The Uniao Fabril do Azoto plant at Alferrareda in the south has an installed capacity of 20 megawatts and requires for continuous operation 175,200,000 kwhr annually or about 14,600,000 kwhr as a monthly average. Continuous operation is the normal procedure for plants of this character, but Amoniaco Portugues and Uniao Fabril do Azoto are the junior industries of the country, so their power needs are reasonably enough subordinated to those of older establishments, with resultant forced suspensions of operation during drought-induced power shortages, and high production costs.

Table VIII-1 and subsequent calculations of power needs, have been worked up on the basis of assuring to all power users, including the fertilizer plants and such future industries as may be induced to establish plants in the country, an adequate supply of power whenever it is needed. This is what is meant by the term "dependable power" as herein employed.

3. Monthly Requirements and Peaks

Associação Industrial Portuguesa was able to furnish daily production curves of the output of the principal producers of electrical power for the third Wednesday in each month and the following Saturday and Sunday. The third Wednesday has been assumed to represent the normal weekday load and the succeeding Saturday and Sunday to be characteristic of week-end production. After these curves had been adjusted to compensate for the difference between the output which they represented and the industry total, they were integrated to obtain the daily, monthly and annual load-duration curves. The load-duration curves in turn were integrated to obtain the peak percentage curves. After study of the probable economic and sociological trends, it was concluded that the general shape of the curves would be unlikely to change materially within the period of the next couple of decades with which the present study is primarily concerned. From them therefore, the future peaks could be and were calculated beginning with the year 1956 which, in view of the considerable periods of

TABLE VIII-1

PAST AND ESTIMATED FUTURE POWER REQUIREMENTS OF PORTUGAL

Year		Required Annual Production in Millions of kwhr
1940	-	460.1
1941	-	479.5
1942	-	465.2
1943	-	477.3
1944	-	505.0
1945	-	545.8
1946	-	638.4
1947	-	722.1
1948	-	811.5
1949	-	836.3
1950	-	941.6
1951	-	1,043.4
1952	-	1,250.0
1953	-	1,550.0
1954	-	1,825.4
1955	-	1,945.4
1956	-	2,075.4
1957	-	2,205.4
1958	-	2,345.4
1959	-	2,485.4
1960	-	2,635.4
1961	-	2,785.4
1962	-	2,945.4
1963	-	3,105.4
1964	-	3,275.4
1965	-	3,445.4
1966	-	3,525.4
1967	-	3,805.4
1968	-	3,995.4
1969	-	4,185.4
1970	-	4,385.4

time required for design, financing, legal authorization, procurement of materials and construction operations, seemed the earliest year that might be properly considered from the practical view point. Table VIII-2 tabulates by months, with a summary for each year, the production in millions of kilowatt-hours and the peak demand in megawatts.

4. Per Capita Production and Consumption

Table VIII-3 gives the past and estimated future per capita consumption and production of electricity for Portugal. It is to be noted that the 1960 per capita consumption is estimated to be 2½ times that of 1950, and 1970 four times that of 1950.

Prior to 1950, the population of continental Portugal increased at a relatively consistent rate. The 1950 census figures indicate a slight tapering off in the percentage of increase. Based on our census study, it is estimated that the 1960 population will be approximately 8,600,000 and that by 1970 it will increase to about 9,150,000.

In 1951 the kwhr production in Portugal increased 10.8% over production for the previous year, as compared with an increase of 14.1% for Spain, 14.8% for Italy and 14.6% for France. Production and consumption have heretofore been retarded by an insufficiency of central stations and of transmission and distribution facilities, coupled with limitations of output imposed in the case of existing thermal stations by fuel problems, and in the case of hydro plants by droughts. In 1940 the per capita production of electricity was 64.1 kwhr. By 1951 it had risen to 130.9 kw-hr - an increase consistent with trends in other countries as can be

TABLE VIII-2

ESTIMATE OF TOTAL MONTHLY AND ANNUAL REQUIREMENTS AND PEAK DEMANDS

YEAR	REQUIREMENTS IN MILLIONS OF kwhr PEAK DEMAND IN MEGAWATTS	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	ANNUAL
1956	Requirement	183.2	166.9	176.8	160.4	163.2	159.5	166.5	166.5	159.8	184.0	191.6	196.9	2,075.4
	Peak demand	347.0	372.5	354.0	354.0	331.0	338.0	336.0	337.0	330.3	364.6	387.0	395.6	395.6
1957	Requirement	194.7	177.5	187.9	170.3	173.3	169.3	176.8	176.8	169.7	195.6	203.9	209.5	2,205.4
	Peak demand	370.0	398.4	377.7	377.7	353.3	360.4	358.4	359.4	352.7	389.1	413.5	423.4	423.4
1958	Requirement	207.2	188.9	199.9	181.0	182.0	179.9	187.8	187.8	180.3	208.1	217.1	223.2	2,345.4
	Peak demand	395.3	425.7	403.7	403.7	377.0	384.7	383.5	384.3	376.4	415.6	441.9	452.8	452.8
1959	Requirement	219.7	200.2	211.8	191.7	194.9	190.5	198.9	198.9	190.9	220.7	230.3	236.8	2,485.4
	Peak demand	420.5	452.8	429.2	429.2	400.8	409.1	406.6	407.6	400.2	442.3	470.2	481.9	481.9
1960	Requirement	233.0	212.4	224.6	203.1	206.5	201.8	210.8	210.8	202.3	234.1	244.5	251.4	2,635.4
	Peak demand	448.0	482.0	456.5	456.5	426.0	436.0	433.0	434.0	426.0	470.0	500.0	512.0	512.0
1961	Requirement	246.4	224.6	237.4	214.5	218.1	213.2	222.7	222.7	213.6	247.5	258.7	265.9	2,785.4
	Peak demand	475.0	511.3	484.0	484.0	451.8	462.8	459.3	459.9	451.8	498.6	530.6	543.3	543.3
1962	Requirement	260.6	237.6	251.0	226.7	230.4	225.3	235.4	235.4	225.7	261.8	273.9	281.5	2,945.4
	Peak demand	503.6	542.4	513.5	513.5	478.9	490.7	487.1	487.7	478.9	528.9	563.2	576.7	576.7
1963	Requirement	274.9	250.6	264.7	238.9	242.8	237.3	248.0	248.0	237.9	276.2	289.0	297.0	3,105.4
	Peak demand	532.5	573.6	543.0	543.0	506.2	518.4	514.6	515.3	506.3	559.3	595.6	609.9	609.9
1964	Requirement	290.0	264.4	279.2	251.8	255.9	250.2	261.5	261.5	250.8	291.4	305.1	313.5	3,275.4
	Peak demand	563.0	606.7	574.1	574.1	534.9	548.1	544.1	544.9	535.3	591.5	630.0	645.3	645.3
1965	Requirement	305.1	278.3	293.7	264.8	269.1	263.1	274.9	274.9	263.6	306.6	321.1	330.1	3,445.4
	Peak demand	592.0	639.0	604.0	604.0	564.0	576.0	574.0	575.0	561.0	613.0	664.0	679.0	679.0
1966	Requirement	321.1	292.9	309.0	278.5	283.0	276.7	289.2	289.2	277.3	322.7	338.2	347.5	3,625.4
	Peak demand	624.2	673.9	636.9	636.9	594.0	607.3	605.5	606.3	592.2	646.9	700.3	716.6	716.6
1967	Requirement	337.2	307.5	324.4	292.2	296.9	290.3	303.4	303.4	290.9	338.8	355.2	365.1	3,805.4
	Peak demand	656.6	708.8	669.9	669.9	625.1	638.6	636.6	637.5	622.6	680.3	736.7	754,3	754.3
1968	Requirement	354.1	322.9	340.6	306.7	311.5	304.7	318.5	318.5	305.3	355.8	373.2	383.5	3,995.4
	Peak demand	690.6	745.7	704.7	704.7	657.3	659.4	669.6	670.6	654,7	715.7	775.3	793.6	793.6
1969	Requirement	371.0	338.4	356.8	321.2	326.2	319.0	333.5	333.5	319.7	372.8	391.2	402.0	4,185.4
	Peak demand	724.5	782.8	739.5	739.5	689.6	704.6	702.5	703.5	686.9	751.0	813.8	833.1	833.1
1970	Requirement	388.8	354.6	373.9	336.4	341.7	334.1	349.3	349.3	334.9	390.8	410.1	421.4	4,385.4
	Peak demand	760.4	821.5	776.2	776.2	723.7	739.3	737.0	738.1	720.8	788.5	854.3	874.5	874.5
1975	Requirement	483.3	440.7	464.4	417.1	423.7	414.2	433.3	433.3	415.3	485.8	510.4	524.5	5,446.0
	Peak demand	945.2	1,021.0	964.1	962.4	897.4	916.6	914.2	915.6	893.8	980.2	1,063.2	1,088.5	1,088.5

Notes: 1) All numbers have been rounded off.
2) Continuous operation was assumed for the two Ammonium Sulphate Plants.

TABLE VIII-3

PAST AND ESTIMATED FUTURE
PER CAPITA CONSUMPTION AND PRODUCTION OF ELECTRICITY IN PORTUGAL

Year	Population	kwhr Consumed**	Per capita consumption kwhr	Production kwhr	Per capita production kwhr
1940	7,173,338	387,850,032	54.1	460,091,927	64.1
1941	7,246,263	404,655,456	55.8	479,543,536	66.2
1942	7,319,188	387,860,953	53.0	465,230,706	63.6
1943	7,392,114	397,452,345	53.8	477,292,854	64.6
1944	7,465,039	419,459,190	56.2	504,962,303	67.6
1945	7,537,964	452,335,915	60.0	545,755,560	72.4
1946	7,610,889	528,464,044	69.4	638,376,292	83.9
1947	7,683,814	593,281,864	77.2	722,101,941	94.0
1948	7,756,740	673,259,483	86.8	811,462,238	104.6
1949	7,829,665	693,904,781	88.6	836,297,963	106.8
1950	7,902,590	780,066,603	98.7	941,611,173	119.2
1951	7,972,000	862,550,000	108.2	1,043,420,000	130.9
1952*	8,042,000	1,032,600,000	128.4	1,250,000,000	155.4
1953*	8,112,000	1,280,500,000	157.9	1,550,000,000	191.1
1954*	8,182,000	1,508,000,000	184.3	1,825,400,000	223.1
1955*	8,252,000	1,607,100,000	194.8	1,945,400,000	235.7
1956*	8,322,000	1,714,500,000	206.0	2,075,400,000	249.4
1957*	8,392,000	1,821,900,000	217.1	2,205,400,000	262.8
1958*	8,462,000	1,937,500,000	229.0	2,345,400,000	277.2
1959*	8,532,000	2,053,200,000	240.6	2,485,400,000	291.3
1960*	8,600,000	2,177,100,000	253.2	2,635,400,000	306.4
1961*	8,660,000	2,301,000,000	265.7	2,785,400,000	321.6
1962*	8,720,000	2,433,200,000	279.0	2,945,400,000	337.8
1963*	8,780,000	2,565,400,000	292.2	3,105,400,000	353.7
1964*	8,840,000	2,705,800,000	306.1	3,275,400,000	370.5
1965*	8,900,000	2,846,300,000	319.8	3,445,400,000	387.1
1966*	8,950,000	2,994,900,000	334.6	3,625,400,000	405.1
1967*	9,000,000	3,143,600,000	349.3	3,805,400,000	422.8
1968*	9,050,000	3,300,600,000	364.7	3,995,400,000	441.5
1969*	9,100,000	3,457,600,000	380.0	4,185,400,000	459.9
1970*	9,150,000	3,622,700,000	395.9	4,335,400,000	479.3

* Estimated

** Production minus central station use and transmission and distribution losses.

Assuming full operation of Ammonium Sulphate Plants by 1954.

seen from Table VIII-4; and from Plates 9 and 10 which depict, respectively, the production per capita for the countries covered by Table VIII-4 and world production.

TABLE VIII-4

PRODUCTION IN KWHR PER CAPITA

	1940	1951
United States	1073	2400
United Kingdom	600	1190
France	450	854
Italy	460	608
Spain	150	256
Portugal	64	131
Greece	60	120

5. Use of Electricity by Classes

After careful consideration of past statistics of consumption and indicated economic and industrial trends, the following conclusions have been reached regarding the future usage of electricity by classes:

A. Public use will probably increase at the rate of 1,000,000 kilowatt-hours per year.

B. Use of electric traction probably will increase at the rate of 500,000 kilowatt-hours per year.

C. The consumption of electricity produced by private service plants should remain essentially the same for the first five years, the addition of the 6,000 kw unit at the Companhia Portuguesa Cellulose at Cacia compensating for normal retirements during that period. Subsequently, the annual production by private service plants and corresponding consumption would probably decrease by about 10% per year. This reflects the effects of normal retirements and the cheaper power available from large public installations.

D. The percentage consumed in the central stations will remain essentially the same as in 1951.

E. Transmission and distribution losses will remain essentially the same in percentage as in 1951.

F. The large increases will be in the categories of private lighting and domestic use, industrial and agricultural use, and electrochemical use.

Table VIII-5 tabulates by classes the figures for past annual consumption, and estimates of annual production and consumption for the years 1956 to 1970.

TABLE VIII-5

PAST AND ESTIMATED FUTURE CONSUMPTION OF ELECTRICITY

IN PORTUGAL BY CLASSES

(Thousands kwhr)

Year	Public illum.	Private light & domestic	Traction	Indus. & Agric.	Electro-chemical	Consumers fed by private service plants	Consumed in central stations	Losses	Import	Total
1940	21,096	54,582	53,638	176,169	18,141	63,415	18,181	54,345	284	460,092
1941	21,844	57,495	54,100	188,578	18,764	63,875	20,102	55,112	321	479,54[illegible]
1942	15,314	50,085	53,924	188,532	21,730	58,276	19,068	58,671	369	465,23[illegible]
1943	13,265	53,201	54,853	200,637	22,767	52,730	21,880	58,366	345	477,29[illegible]
1944	13,336	64,910	56,802	209,219	17,355	57,837	23,534	62,291	322	504,962
1945	14,401	71,201	59,197	234,775	15,066	57,695	27,737	65,931	249	545,750
1946	16,370	87,082	63,230	276,471	18,956	66,355	22,847	87,414	349	638,370
1947	20,618	115,360	65,876	305,424	19,336	66,668	27,358	101,740	277	722,102
1948	22,978	138,001	69,050	348,566	27,927	66,738	30,957	107,571	325	811,462
1949	23,273	146,977	70,378	347,798	25,482	79,996	41,560	101,256	423	836,298
1950	27,076	175,367	70,592	402,349	28,977	75,705	38,229	123,742	427	941,611
1951	29,030	203,910	73,190	449,690	35,350	71,380	22,120	159,310	560	1,043,420
1956**	34,000	358,900	75,700	793,600	380,800	71,500	44,000	316,900		2,075,400
1960**	38,000	495,900	77,700	1,096,400	404,100	65,000	55,900	402,400		2,635,400
1965**	43,000	693,000	80,200	1,532,500	439,100	58,500	73,000	526,100		3,445,400
1970**	48,000	922,000	82,700	2,038,700	478,700	52,600	93,000	669,700		4,385,400

* Including two ammonium sulphate plants

** Estimated

6. Facilities for Electrical Power Production and Transmission

A. Existing thermal installations - At the end of 1951, there were 17 thermal plants in Portugal having rated capacity of 1,000 kw or more (see Table VII-6). It is anticipated that a 6,000 kw unit will go into service sometime in 1952 at the celulose plant at Cacia making a total of 18 plants with a rated capacity of 149,381 kw. Of this total, 122,826 kw are installed in public service plants, and the remainding 26,555 kw in private service plants. Of the public service thermal installations 38,356 kw are in the north and 84,470 kw are in the south. The private service plants have 10,072 kw of installed capacity in the north and 16,483 in the south. In the aggregate, the thermal plants have been evaluated as representing an existing firm dependable capacity of approximately 100,000 kw. While their installed capacity exceeds that figure by almost 50%, it has to be heavily discounted because of age of some of the plants, deficiencies in boilers, feedwater pumps, ash handling facilities and the like. The estimate of 100,000 kw as the measure of dependable capacity is understood to be generally accepted.

The principal thermal stations are listed below:

Name and location	Capacity (kw)
Tejo-Lisbon	59,192
Freixo-Porto	14,656
Santos-Lisbon	11,198
Canicos-Vila Novo de Famalicao	12,400
Massarelos-Porto	11,300
Cachofarra-Setubal	10,260

The average thermal efficiency of these major stations is about 15% to 17%. Santos Station in Lisbon and Massarelos Station in Porto serve the traction systems of their respective communities.

TABLE VIII-6

THERMAL PLANTS 1,000 KW AND LARGER*

Name of station	Operating company	Location	Public or private service	Rated capacity (kw)	Cap. public ser. north (kw)	Cap. private ser. north (kw)	Cap. public ser. south (kw)	Cap. private ser. south (kw)
Tejo	Companhias Reunidas Gas E Electricidade	Lisbon	Public	59,192			59,192	
Freixo	Uniao Electrica Portuguesa	Porto	Public	14,656	14,656			
Santos	Companhia Carria De Ferro De Lisboa	Lisbon	Public	11,198			11,198	
Canicos	Companhia Hidro-Electrica Do Norte De Portugal	Vila Nova De Famalicao	Public	12,400	12,400			
Massarelos	Camara Municipal Do Porto	Porto	Public	11,300	11,300			
Cachofarra	Uniao Electrica Portuguesa (Sul)	Setubal	Public	10,260			10,260	
Barreiro	Companhia Uniao Fabril	Barreiro	Private	6,280				6,280
Maceira	Empresa De Cimentos De Leiria	Leiria	Private	4,290				4,290
Negrelos	Fabrica De Fiacao E Tecidos Do Rio Vizela	Santo Tirso	Private	2,572		2,572		
Beato	Manutencao Militar	Lisbon	Private	1,972				1,972
Olhao	Alianca Electrica Do Sul	Olhao	Public	1,720			1,720	
Hortas	Companhia De Fiacao De Crestuma	Vilanoua de Gaia	Private	1,500		1,500		
S. Domingos	Mason and Barry, Ltd.	Mertola	Private	1,455				1,455
Graca	Societe Anonyme de Produits et Engrais Chimiques du Portugal	Setubal	Private	1,416				1,416
Lisbon	Companhia Uniao Fabril	Lisbon	Private	1,070				1,070
Aljustrel	Alianca Electrica do Sul	Aljustrel	Public	1,100			1,100	
Lena	Sociedade Electrica do Oeste, Lda.	Porto de Mos	Public	1,000			1,000	
Celiulose**	Companhia Portuguesa de Celiulose	Cacia	Private	6,000		6,000		
	TOTALS			149,381	38,356	10,072	84,470	16,483

*Source: Estatistica Das Instalacoes Electricas em Portugal, vol. I, - 1950.
**To go into service in 1952.

The Massarelos plant is the only large station that has been able to operate entirely on domestic coal with any degree of success. All the others have been obliged to use mixtures of foreign and domestic coals, with the domestic component small. This condition is brought about by the basic designs of the stations, coupled with many combustion problems present in the available grades of domestic coal. During the war years, the unavailability of foreign coal caused major curtailments in thermal power production.

B. Hydroelectric installations existing or under construction - The hydroelectric plants which either are actually operative as of 1952 or soon are to become so, are listed in Table VIII-7. In estimating their output, the effects of the new Spanish Salas reservoir on the Lindoso plant, the effect upon the Serra da Estrella system of the reconstrucion of the Senhora do Desterro plant, and the new irrigation projects of Maranhao and Pego Longo all are considered.

The results of routing the existing hydroelectric plants are given in Table VIII-8 which lists the output, month by month, of the existing hydroelectric plants without Zezere, the output of the Zezere River system, and the total existing hydroelectric output.

TABLE VIII-7

HYDRO ELECTRIC INSTALLATIONS EXISTING OR SCHEDULED FOR EARLY CONSTRUCTION

Plant	River	Basin	Installed Capacity (kw)
Zezere System			
Castelo do Bode	Zezere	Tejo	135,000
*Cabril	Zezere	Tejo	107,000
Santa Luzia	Pampilhosa	Tejo	19,200
Cavado System			
Vila Nova	Cavado-Rabagao	Cavado	76,800
*Canicada	Cavado	Cavado	45,000
*Salamonde	Cavado	Cavado	38,000
Penide	Cavado	Cavado	1,840
Lindoso	Lima	Lima	60,000
Tejo River System			
Belver	Tejo	Tejo	32,000
Pracana	Ocreza	Tejo	12,800
Serra da Estrela System			
Sabugueiro I	Alva	Mondego	12,800
Ponte de Jugais	Alva	Mondego	12,000
Vila Cova	Alva	Mondego	11,000
Senhora do Desterro	Alva	Mondego	8,300
Ave System			
Ermal	Ave	Ave	10,400
Senhora do Porto	Ave	Ave	5,240
Ponte da Esperanca	Ave	Ave	2,720
Guilofrei	Ave	Ave	1,920
Niza System			
Velada	Niza	Tejo	4,480
Poio-Bruceira	Niza	Tejo	1,712
Povoa	Niza	Tejo	736
Foz	Niza	Tejo	560
Alforfa System			
Alforfa	Alforfa	Tejo	2,600
Pedra da Figueira	Alforfa	Tejo	1,616
Estrela	Alforfa	Tejo	1,100
Covao da Nave	Alforfa	Tejo	1,000
Irrigation Projects			
Maranhao	Seda	Tejo	5,000
Cabeco Monteiro	Ponsul	Tejo	2,080
Pego do Altar	Sa Catarina	Sado	2,000
Vale do Gaio	Xarrama	Sado	1,030
Pego Longo	Campilhas	Sado	440
Run of River			
Chocalho	Varosa	Douro	10,240
Freigil	Cabrum	Douro	2,500
Mesa do Galo	Borralha	Cavado	1,470
Corvete	Bugio	Ave	1,000
Covas	Coura	Minho	648

* Under construction and soon to be operative.

TABLE VIII-8

ENERGY OUTPUT OF EXISTING HYDROELECTRIC PLANTS

IN MILLIONS OF KILOWATT-HOURS PER MONTH

(BEFORE ZEZERE RE-REGULATION)

YEAR		JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	
1942	Output of existing plants with the exception of the Zezere system.	87.9	70.8	233.6	223.6	235.4	145.8	62.9	60.2	59.4	71.4	128.8	196.4	1,576,2
	Output of the Zezere system.	32.7	29.6	190.8	146.7	112.5	32.6	32.7	32.7	31.7	32.7	80.9	171.8	927,4
	Total output of existing hydroelectric plants.	120.6	100.4	424.4	370.3	347.9	178.4	95.6	92.9	91.1	104.1	209.7	368.2	2,503.6
1943	Output of existing plants with the exception of the Zezere system.	245.6	167.7	158.4	105.9	83.0	64.8	62.5	60.8	63.6	200.7	116.3	110.8	1,440,1
	Output of the Zezere system.	192.7	164.2	192.7	73.8	38.3	31.7	32.7	32.7	31.7	32.7	31.7	32.7	887,6
	Total output of existing hydroelectric plants.	438.3	331.9	351.1	179.7	121.3	96.5	95.2	93.5	95.3	233.4	148.0	143.5	2,327,7
1944	Output of existing plants with the exception of the Zezere system.	75.7	57.2	71.3	133.5	82.1	64.3	58.6	56.3	56.2	59.7	68.2	96.6	879,7
	Output of the Zezere system.	43.1	32.1	32.7	66.0	32.7	31.7	32.7	32.7	31.7	32.7	31.7	32.7	432,5
	Total output of existing hydroelectric plants.	118.8	89.3	104.0	199.5	114.8	96.0	91.3	89.0	87.9	92.4	99.9	129.3	1,312,2
1945	Output of existing plants with the exception of the Zezere system.	88.4	68.8	63.4	61.4	58.5	54.4	56.0	56.0	53.9	55.9	81.2	197.3	895,2
	Output of the Zezere system.	32.7	29.6	32,7	31.7	32.7	31.7	32.7	32.7	31.7	32.7	31.7	32.7	385,3
	Total output of existing hydroelectric plants	121.1	98.4	96.1	93.1	91.2	86.1	88.7	88.7	85.6	88.6	112.9	230.0	1,280,5
1946	Output of existing plants with the exception of the Zezere system.	114.4	122.0	216.5	167.6	222.7	186.2	63.3	61.7	58.4	82.1	127.8	117.9	1,540,6
	Output of the Zezere system.	39.9	29.6	70.0	62.6	192.7	80.3	32.7	32.7	31.7	32.7	31.7	32.7	669,3
	Total output of existing nvdroelectric plants	154.3	151.6	286.5	230.2	415.4	266.5	96.0	94.4	90.1	114.8	159.5	150.6	2,209,9
1947	Output of existing plants with the exception of the Zezere system.	138.8	220.2	242.3	235.6	181.0	70.2	65.1	61.7	62.3	69.8	61.8	97.0	1,504,8
	Output of the Zezere system.	32.7	174.0	192.7	171.9	40.5	31.7	32.7	32.7	31.7	32.7	31.7	32.7	681,1
	Total output of existing hydroelectric plants	171.5	394.2	435.0	407.5	221.5	101.9	97.8	94.4	94.0	102.5	93.5	129.7	2,185,9
1948	Output of existing plants with the exception of the Zezere system.	241.0	171.8	141.0	115.1	146.6	90.7	62.1	61.4	57.1	56.2	58.9	136.3	1,338,2
	Output of the Zezere system.	139.7	131.2	99.0	35.8	57.8	39.4	32.7	32.7	31.7	32.7	31.7	32.7	697,1
	Total output of existing hydroelectric plants	380.7	303.0	240.0	150.9	204.4	130.1	94.8	94.1	88.8	88.9	90.6	169.0	2,035,3
1949	Output of existing plants with the exception of the Zezere system.	104.0	78.0	72.3	62.6	67.2	56.8	56.5	56.5	59.3	62.3	114.2	103.6	893,3
	Output of the Zezere system.	32.7	29.6	32.7	31.7	32.7	31.7	32.7	32.7	31.7	32.7	31.7	32.7	385,3
	Total output of existing hydroelectric plants.	136.7	107.6	105.0	94.3	99.9	88.5	89.2	89.2	91.0	95.0	145.9	136.3	1,278,6
1950	Output of existing plants with the exception of the Zezere system.	87.2	209.7	178.8	83.6	154.9	115.8	59.0	57.7	55.1	55.5	128.9	88.3	1,274,5
	Output of the Zezere system.	32.7	29.6	32.7	31.7	32.7	31.7	32.7	32.7	31.7	32.7	31.7	32.7	385,3
	Total output of existing hydroelectric plants.	119.9	239.3	211.5	115.3	187.6	147.5	91.7	90.4	86.8	88.2	160.6	121.0	1,659,8

Notes: 1. Existing system is assumed to include the Salamonde, Canicada and Cabril plants now under construction.
2. Zezere system consists of Castelo do Bode, Cabril and Santa Luzia hydroelectric plants.

C. Transmission lines - Prior to 1945, Portugal was served by a number of isolated utility systems, but under the National Electrification Act of that year, and subsequent correlative legislation, a program for the expansion of transmission lines has been carried out by the Companhia Nacional de Electricidade (CNE), so effectively that to all intents and purposes the country now is served by an interconnected system which, however, has not yet been developed into a completely integrated system. This, of course, has introduced many operating and administrative problems, identical with those encountered in the United States.

From a power standpoint, Portugal can be divided into a northern zone, comprized of the area served by the Ermesinde substation of the CNE, in Porto, and a southern zone -- the area served by the Zezere substation. The two zones are interconnected by a 150 kv steel tower high tension line with a normal capacity of 60 mva and an emergency capacity of 90 mva. It is anticipated that during normal operation, no power-interchange between the zones will take place, but the line enables the bulk transfer of power from one to the other to alleviate any power shortage in either area.

Ordinarily the major producing utilities sell their available power to CNE, which in turn transmits it to the distributing companies. In order to schedule the operation of the producing companies to the fullest advantage, the position of Repartidor Nacional de Cargas (National Load Dispatcher) has been established.

Table VIII-9 lists the principal features of the main components of the transmission network. Plate 5 shows both the transmission lines and the principal power plants of the country.

TABLE VIII-9

CHARACTERISTICS OF TRANSMISSION LINES OF COMPANHIA NACIONAL DE ELECTRICIDADE

	Zezere-Lisbon, 1st line	Porto-Cavado	Zezere-Porto	Zezere-Lisbon, 2nd line	Lisbon-Setubal	Porto-Estarreja
Voltage (kv)	150	150	150	150	150	60
Normal capacity (mva)	100	80	60	100	100	16
Emergency capacity (mva)	150	120	90	150	45	25
Size of conductors - ACSR (mm^2)	3 X 327	3 X 261	3 X 327	3 X 327	3 X 327	3 X 152
Length of line (km)	111	76	189	111	73	50
Total resistance (ohms/phase)	12.55	10.66	21.15	12.55	8.18	11.10
Total reactance (ohms/phase)	46.12	31.86	80.25	46.12	31.04	18.89
Total susceptance (mhos X 10^{-3}/phase)	0.31	0.20	0.54	0.31	0.21	0.15

7. Methods of Operation and Bases of Payment

The present system of hydroelectric installations includes run-of-river plants and plants at which storage is provided - in some instances large volumes of storage. Under the existing rate structure, payment is made to the operating companies for energy alone, at a uniform rate. Since energy is the only source of revenue, each operator is entirely preoccupied with producing all the energy possible with the stream flows that nature provides. This is sound enough for the run-of-river plants, but it results in operating storage plants much as though they too were run-of-river installations and so inevitably places a great part of the burden of providing power during seasons of drought upon the nation's steam plants, whose capacity is far from adequate to assume the burden, and whose operation, largely on imported coal, is costly both in escudos and in foreign exchange.

The result of depleting the storage in the reservoirs is to leave the storage plants in much the same condition as the run-of-river plants when the rains fail and a long period of drought is experienced. There is little more than drought stream-flow with which to operate either type.

The only way in which dependability of power supply can be attained under a policy of drawing down storage reservoirs in such manner as to produce the maximum amount of energy during years of normal rainfall (with the hope that they will refill before the ensuing dry season) is to provide more thermal capacity as a standby, for use when the reservoirs do not refill.

The present study (see Chapters III and IX) indicates that, based upon certain plus one half of probable reserves, the domestic coal supply is too limited to support much more than 25,000 kw of thermal capacity for the normal life of a steam plant, without encroaching upon the fuel requirements of present coal users. It is quite possible, of course, that further drilling will disclose additional reserves permitting material increase in the supply of thermal energy from domestic fuels. In order to meet the peaks of the constantly growing power demand during prolonged periods of drought a large amount of thermal capacity would have to be installed. Rough estimates indicate that by 1960 perhaps 80,000 kw of capacity, in addition to that of existing installations, would be needed, and by 1970 perhaps 200,000 kw. The fixed charges alone on standby stations of this magnitude would impose a serious burden.

In a hydroelectric system which embraces as much storage as does that of Portugal, power supply may be made dependable by conserving enough storage in the large reservoirs to tide over periods of drought. Since it is not possible to foresee just when a drough will begin, it is necessary, under this method of operation, to assume that each year in turn may repeat the stream-flow hydrograph of the critical drought year, and accordingly, to keep enough water on hand at all times to avoid a power shortage if and when that turns out to be substantially the case - as, of course it always does, sooner or later.

This means that the reservoir can not be emptied during the dry months and allowed to refill during the wet months, for the plan of operation recognizes the possiblity that the dry months may be succeded by other dry months instead of by wet months. When they are not, some of the flow of the wet months is wasted. There is a compensating factor in that all of the water that does pass through the turbines will do so under high head and so, cubic meter for cubic meter, will produce more power than would the flow resultant from emptying and refilling the reservoir.

It can not be gainsaid, however, that there is a net loss of energy production by conserving storage for drought periods. If, as it is believed to be, dependability of power supply is almost the sine qua non of successful industrialization, the sacrifice is unavoidable unless the continuing installation of larger and larger thermal standby units operating on imported fuel is to be undertaken. From the data available, it appears that considerations of economy would limit the use of steam operation with imported fuel to the minimum possible, by full utilization of storage potentialities, and the studies have been made on that basis - the sacrifice in total volume of energy generation on the part of the storage plants entailed by conserving storage apparently being far less from the monetary standpoint than the cost of providing steam standby power.

The sacrifice entailed by conservation of storage should not, however, be asked of the producer who happens to have developed a site that affords storage. He should - indeed must, if he is to be expected to cooperate - be paid on the basis of being able to deliver energy during drought periods when others can not, as well as on the basis of the total energy that he actually delivers. It is his abstention from the production of a portion of the energy he could have produced in a normal year by emptying his reservoir, that enables him to deliver during the drought year, and he must be compensated equitably for such abstention if he is to be relied upon to practice it.

In the present study, all investigations of available power and of future installations for its generation have been based without exception upon the premise that the National Load Dispatcher will have full opportunity to utilize all generating and transmission facilities available, both thermal and hydro, in the most economical way. A complete legal basis for meeting this requirement appears to exist in Article X of the National Electrification Act No. 2002 dated December 26, 1944; and in Article XI of the National Load Dispatcher Decree No. 38186, dated February 28, 1951.

The necessary cooperation of the private, public and semi-public owners of hydroelectric and steam generating facilities and transmission lines will not be obtained, however, unless a reasonable and logical basis of compensation is worked out which will reimburse them for fixed charges and operating expenses, and provide a fair measure of profit both when the National Load Dispatcher requires that their facilities be held in reserve for the benefit of the entire system and when they are operated by his direction.

8. Network Analyzer Study

What is contemplated is a completely integrated operation - a power pool-the device which in the United States has been found to be the soundest basic mechanism for developing and making available adequate and economical power supplies - and which Portugal has taken the preliminary steps to establish by the creation of the comprehensive transmission network that has received laudatory mention previously herein.

It has been the experience in the United States that the integration of a complex system of electrical installations introduces problems peculiar to itself and that to achieve satisfactory results, the electrical characteristics and relationships of all existing generating units, transmission lines, substations and loads on the interconnected system must be established and coordinated, and that all additional generating units, transmission lines, substations and expected loads must be correctly planned and designed in proper relation to each other and to existing facilities. Such coordination, planning and design can only be accomplished by an A-C calculating board or network analysis of the interconnected system.

Every generating unit, transmission line, substation, and load center is unique in its electrical characteristics. Static and transient stability and control of frequency and voltage between desirable limits can not be accomplished unless their relationships are properly taken into account. In addition to providing for more satisfactory operation, coordination by means of a network analyzer study permits the realization of construction economies by the specification of the characteristics of equipment in new installations in proper relation to those of existing installations.

The Douro River study assumes both that a network analyzer study will be made, and that an equitable system of rates will be devised on the basis outlined above; in short, that satisfactory and efficient integrated or power pool operation will be effected.

9. Plan of Operation for Power Pool

In this study, the power pool was assumed to include all of the plants listed in Table VIII-7, for although three of them (Cabril, Canicada and Salamonde) are not yet fully completed and in operation, it seems certain that they will be in operation in the near future. Thermal capacity of 100,000 kw was assumed in addition to the hydroelectric capacity.

The period 1942-1950 was selected for investigation. This period contains the two driest sequences of the past 25 years, namely those of 1944-45 and 1949, which are about equally critical for the entire Portuguese power system. Stream-flow records for the period were available for most of the important projects, either directly at the site or at near-by gaging stations. Where no records could be obtained, they were synthesized by proportioning on the basis of area from records of drainage areas with similar characteristics (see Appendix C, "Hydrology").

Operation of the component systems was assumed to be as follows:

A. <u>Steam-electric plants</u> - These were assumed to operate in the base of the load-duration curve.

B. <u>Run-of-river plants</u> - Run-of-river plants include the Chocalho, Freigil, Mesa do Galo, Covas and Corvete, with a total installed capacity of 15.86 megawatts (one megawatt=1000 kw). Since there is no storage available upstream from these plants, they were assumed to use all the stream flow as it came, up to the limit of their installed capacity.

C. <u>Irrigation projects</u> - The Maranhao, Cabeco Monteiro, Pego do Altar, Vale do Gaio and Pego Longo projects were assumed to be operated during the irrigation season, as much as possible according to the schedules outlined in the Portuguese irrigation report dated 1945 "Hidraulica Agricola". The power output would be available whenever water was released for irrigation purposes.

D. Alforfa system - This system of four small plants aggregating 6.32 megawatts of installed capacity has some storage, and the system was operated to obtain a uniform output during the critical dry period.

E. Niza system - The Niza system also comprises four small plants aggregating 7.49 megawatts of installed capacity. It has some storage, and was operated to obtain a uniform output during the critical dry period.

F. The Ave system - This system, likewise consisting of four plants aggregates 20.28 megawatts of installed capacity, has storage and was similarly operated to obtain a uniform output during the critical dry period.

G. Tejo River system - The Tejo system consists of the Belver plant on the Tejo River which is essentially a run-of-river plant, and the storage reservoir and plant at Pracana on the Ocreza River, a tributary which enters upstream from Belver. The two plants, with a total capacity of 44.8 megawatts were operated as a unit to assure the maximum uniform output from both combined during the critical dry period. Under this scheme, the Pracana plant would be shut down to conserve storage at times when ample flow was available at Belver, and would operate when the run-of-river output was deficient.

H. Lindoso plant - This plant, on the Lima River, obtains its regulation from two reservoirs located in Spain which were assumed to be operated to give a uniform output at the Lindoso plant during the critical dry period. It was also assumed that the entire output would be used in Portugal. However, a line has recently been built to the border, and from information supplied by engineers connected with the Lindoso plant, it is indicated that whatever traffic goes over that transmission line will be all in one direction, toward Spain. The amount, however, has not yet been determined, and is understood to depend on the result of negotiations between Spain and Portugal. Any power taken out of the Lindoso output would have to be made up by a future plant or plants.

I. Serra da Estrela system - This system consists of four plants which will have a total installed capacity of 44.10 megawatts by 1956. The system contains storage which was operated to obtain a fairly uniform output during the critical dry period.

J. Cavado system - This is one of the two large systems in Portugal and includes the existing Vila Nova plant and the Salamonde and Canicada projects which are under construction. It also includes the small Penide run-of-river plant. The Cavado system contains a large volume of storage. Installed capacity will total 161.64 megawatts. Based on a study of operation of the system as a whole, routing energy rather than flow, it was found that the capability of the Cavado system would be approximately 38 megawatts of continuous capacity during the critical dry period. *

K. Zezere system - This is the largest system in Portugal, and includes the existing Castelo do Bode plant, the Cabril project, which is under construction, and the existing Santa Luzia

* See Footnote on Paradela project in Appendix D.

project. The latter belongs to another utility company but logically forms part of the Zezere system, as it is located on the Pampilhosa River, a tributary of the Zezere. The system contains a large amount of storage. The installed capacity will total 259 megawatts. Based on a study of operation of the system as a whole, routing energy rather than flow, it was found that the Zezere system would provide approximately 44 megawatts of continuous capacity during the critical dry period.*

L. Re-regulation - Routings made on the basis of maintaining the maximum uniform output from the storage plants during critical dry periods yielded a variable relationship between output and demand. During certain months there would be a surplus of energy, while at other times there would be a deficiency of variable proportions.

The output from the Zezere system was then re-regulated as required to obtain the smallest possible uniform deficiency for the entire Portuguese system through the critical dry period. In the process of re-regulating, the total amount of energy withdrawn during the drought periods was the same as was used in the previous routing when the Zezere system was operated at uniform output through the droughts.

It was found that by re-regulating Zezere, the "existing" system (including in addition to the now-operative hydroelectric plants, the three under construction, and the 100,000 kw of thermal capacity) would be capable of supplying enough dependable power to meet present demands (including that of the ammonium sulphate plants)

*See Footnote on Bouca[illegible] project in Appendix D and keep abreast of predicted growth in load, practically until 1956.

By the latter date, the demand will have increased so much, if it follows the predicted trend, that in order fully to satisfy it, an additional 4,000 kw or so of dependable capacity will be needed in the system. If the addition is not made, there would be a deficiency of that magnitude in the event of a recurrence in 1956 of a drought like that of 1944-1945 or 1949; and if, as the most recent establishments, the ammonium sulphate plants were required to absorb the deficiency, they could operate continuously at only about 90% of capacity during the drought.

10. Power Deficiencies Subsequent to 1956

By 1960, the uniform deficiency during the critical drought period would amount to about 67,000 kw; by 1965 to about 151,000 kw; and by 1970 to about 273,000 kw.

Plate 11 shows the estimated 1960 relationship between demand and output on the assumption that the storage plants are operated to produce maximum uniform output during the critical dry periods. Plate 12 shows the relationship after the Zezere system has been re-regulated to reduce unsatisfied demand during the dry periods to a uniform minimum of 48.9 millions of kwhr per month, corresponding to 67,000 kw of capacity at 100% load factor.

Both plates show by different shading symbols, the total power outputs, month by month, that the several elements comprising the "existing systems" respectively could have supplied with the stream flows actually experienced between the years 1942 and 1950. The capacity of the steam component is, of course, not affected by the stream flow and varies only with the number of hours in the month under consideration. Since the outputs of the several components of the system are shown one above the other, the top of the graph represents the total output of which the system is capable. There has been superimposed, a heavy line depicting the estimated month-by-month power demand for the year 1960. When the graph extends above this demand line, a surplus of power is indicated. When the top of the graph lies below it, a deficiency in output is indicated, which is depicted by heavy line shading. In actual operation, the thermal supplement represented by the small dots at the base of the graph would be used only to the extent to which the hydroelectric components of the system were unable under their rule curves of operation, to satisfy the demand. Thus, whenever and to the extent, that the graph of aggregate output extends above the line depicting demand, it indicates that an equivalent shutdown of steam generating units (often a complete shut-down) is possible.

Should it be proposed to add a new hydroelectric plant to the system, its dependable capacity would be determined by adding its monthly output to the system, and re-regulating the Zezere system anew to obtain the minimum uniform discrepancy between system output and national demand, with the new plant included. The difference between the minimum uniform deficiency during the critical dry period obtainable without the new plant and that obtainable with the new plant incorporated in the system, is the capacity contributed to the system by the new plant, i.e., its dependable capacity. This method of establishing the dependable capacity is based on the assumption that the load dispatcher, assisted by an equitable schedule of tariffs for capacity and energy, has the authority to operate the Portuguese power system in the national interest, using run-of-river energy when available, and scheduling the output from storage and thermal plants as needed. The method is realistic, since it takes into direct account the existing power system and utilizes it to the maximum practicable extent. It reduces to the minimum the gap that must be filled by new capacity. It automatically integrates proposed new plants of widely differing characteristics into the Portuguese system on a common basis, and thus makes it possible to evaluate their actual contributions to the system capacity. The devising of a rule curve to accomplish the end sought with a stream flow record of the length and character of that available in Portugal, is entirely feasible, as has been demonstrated in the operation of power pools in the United States, where length of stream flow record usually is much shorter.

11. Capacity Requirements

The installed capacity of the existing system is quite large. A study of the relationship of output to the load-duration curve indicated that even by 1960 there would be no lack of capacity to meet the peaks - the deficiency lies entirely in the supply of firm energy. Thus there appears to be no necessity for the installation of peaking capacity in such new plants as may be considered for early construction.

As an example of excess of installed capacity over capacity required to produce firm energy during critical periods, the Zezere system may be used as an illustration. The installed capacity of the system aggregates 259 mw. The firm energy which the system can produce during the critical periods of low stream flow is 44 mw. It is apparent from these figures that the employment of the Zezere system to tide over periods of drought is an arrangement ideally suited to the satisfactory exploitation of its installed capacity. During periods of plentiful stream flow, it is in competition with the various run-of-river plants. The problem of the national system at such times is not how to produce more energy, but how to allocate the market equitably among the various producers. The use of the Zezere system's surplus installed capacity under such conditions would operate simply to take market away from other producers. But if a large portion of its storage is conserved for the dry periods, when the run-of-river plants and those of smaller storage capacity are unable to absorb much of the load, its generous capacity installation will be found invaluable.

Because of the large capacity which the existing system will have upon completion of Cabril, Canicada and Salamonde, it has been assumed, in scheduling new hydroelectric plants on the load duration curve, that the existing hydroelectric plants would be placed in the peak. The thermal supplement would, of course, occupy a position in the base of the curve. Thus the new plants would occupy the vacant band between the existing hydroelectric plants and the thermal supplement, and would operate at 100% load factor or close to it.

CHAPTER IX

THERMAL INSTALLATIONS CONSIDERED FOR SUPPLYING FUTURE POWER DEFICIENCIES

1. General Considerations

One of the specific requirements contained in the Agreement covering the Douro River study was consideration of a Pejao thermal plant for the generation of electric power by combustion of domestic coal. As indicated in Chapter III, Pierce Management, Inc., was called in as the Engineer's Coal Consultant, and the study of the employment of domestic fuels for power generation was broadened to include consideration, not only of the Pejao mines, but of the mine at Sao Pedro da Cova as well. The study indicated that the Pejao site was to be preferred, and that the indicated coal reserves were sufficient to support a thermal plant of about 25,000 kw capacity for the approximately 35 years which is normally considered to be the economic life span of such an installation.

At the time the investigation was being conducted, it had been assumed that because of the flatter topography that characterized the right bank of the Douro, the site of a plant built for Pejao fuels would be across the river from Germunde. Subsequent study, however, indicated that an installation on the north side of the river might experience extended shut-downs and require costly rehabilitation as the result of large floods. With this in mind, a site was finally selected on the left bank (see Plate 13) just downstream from the Germunde picking sheds, high enough above the river to insure continuous operation unhampered by a river stage of 30 m above mean river level (see Plate 15) which is believed to correspond to the 100 year flood. This introduced the problem of bringing cooling water up to a high elevation in an economical manner. The solution finally adopted is discussed later under the caption "Power House". No foundation investigations were made, but it is assumed from such data as are available that the rock structure is suitable for foundations.

2. Fuel

At the present time, the Pejao mining interests are practicing selective mining with an output in 1951 of approximately 260,000 tons. Only those grades of coal which are readily marketable are mined, the poorer grades for the most part being left in the ground. An average analysis of these poorer grades is:

Característica do carvão do Pejão que era deixado na mina.

Moisture	5.6%
Volatile Matter	4.1%
Fixed Carbon	44.5%
Ash	45.8%
Kilo-calories	3600

Such coal is more or less unmarketable because of low heat content, high ash content, and resulting combustion problems. At the present time, there are very few boiler installations in Portugal capable of burning it with any degree of success. It is assumably this fuel which would be made available to the thermal plant if present mining procedures are retained.

As discussed in Chapter III, Pierce Management, Inc., considers that after making certain recommended changes, the output of the mine could be increased to 383,000 tons of marketable coal, of two grades:

(a) Up to 120,000 tons per year unwashed air separated mine fines under 1/64 inch (0.04 cm) in size containing about 20% ash and 5694 kilo-calories per kilogram.

(b) The balance of the product, a washed coal, of plus 0.04 cm sizing, with ash content of about 18% and a heat content of about 5848 kilo-calories per kilogram.

3. Plant Design Considered

Since it is not known which grade of fuel finally will be selected, it appeared necessary to consider three distinct preliminary designs of thermal stations:

One for a plant utilizing the 45% ash coal, one for a plant utilizing 20% ash coal, (mine fines) and one for a plant utilizing 18% ash (washed) coal. The essential differences would be in the boiler plants required. The power house would be the same in each case.

Studies of power demand and supply indicate that the plant would operate at full load about 75% of the time regardless of just when it was introduced into the system. With this in mind, it was considered that it should be designed for base load operation. Based on preliminary heat balance analyses, it was concluded that the operating temperature should be 900° F, (482° C) and operating pressure 850 pounds per square inch (59.76 kg/cm^2).

Combustion experts consulted concurred with the conclusion that any of the three grades of coal could be used successfully, provided the grade was of a fixed quality. However, prior to final design and the ultimate definitive orders for boiler equipment, reputable manufacturers should have the opportunity to burn from 35 to 50 tons of the respective grades in suitable boiler equipment.

4. Boiler House Design for 45% Ash Fuel

The first boiler installation considered was one utilizing the low grade Pejao coal of the following characteristics, which would be made available if present mining methods are retained:

Heat Content	-	3600 Kilo-calories
Ash Content	-	45%
Sizing	-	100% thru 1/4" (.635 cm)
		80% thru 3/16" (.476 cm)
		60% thru 1/8" (.318 cm)
		40% thru 1/16" (.159 cm)
		25% thru 1/32" (.079 cm)

Preliminary studies indicated that two stoker-fired boilers, each capable of producing 125,000 pounds of steam per hour at 850 psi and 900° F, (56,715 Kg/hr at 59.76 Kg/cm^2 and 482° C) were best suited to meet the steam requirements utilizing this quality of coal. A stoker installation is mandatory because of the difficulties of establishing and maintaining combustion; and a very large grate area is required, - so large that two boilers are essential. It is impractical to design a single unit with sufficient grate area. Although the combustion problems are many, successful firing can be maintained, provided the quality of the coal remains constant.

The boiler design considered would have an efficiency of about 73% with a resulting overall thermal efficiency for the station of 23.55%. Coal would be brought to the plant by a belt conveyor and fed into a bunker in the building. A diversion chute would be provided in the conveyor system to an out-door storage area adjacent to the plant, and an auxiliary conveyor would move the coal from the storage area to the bunker in case of failure of the main conveyor from the mine. It is anticipated that a plant of this design would require about 609 metric tons per 24 hours at full load (25,000 kw output) operation. About 300 tons of ash per day would result, an abnormally high figure for a plant of this size.

The ash would be removed from the boilers by conveyor to a silo, thence trucked away to available disposal areas.

A building of approximately 25,500 m^3 would be required to house the pertinent equipment.

5. Boiler House Design for 20% Ash Fuel

The second boiler installation considered was one utilizing the unwashed mine fines which would result from adoption of the recommendations made by Pierce Management, Inc. (see Plate 18 & 19). Coal of this grade presumably would have the following characteristics:

Fixed Carbon	-	72.1%
Volatile Matter	-	2.9%
Ash	-	20 %
Moisture Under	-	10 %
Sulphur	-	1.5%
Heat Content	-	5694 Kilo-Calories
Fusion Temperature of Ash not less than	-	1372° C
Hardgrove Grindability	-	# 65
Sizing 100% less than	-	1/64" (0.04 cm)

Preliminary studies indicate that coal of the foregoing characteristics can be used successfully in a pulverized coal boiler. A single boiler would produce the necessary 250,000 pounds per hour of steam at 850 psi and 900° F (113,430 Kg per hour at 59.76 Kg/cm^2

and 482° C). Its design would be such that the firing would be downward vertically through a refractory chamber of the furnace and then a U travel of the flame back to give longer burning time to compensate for slow ignition and combustion. This is accepted practice in the United States for combustion of low volatile anthracite coal. A boiler of this design operative under the given conditions would have an efficiency of 84% and the resulting overall thermal efficiency of the station would be 27.1%.

The coal from the mine is of such fineness that a pneumatic conveying system would be most practical. The coal would be blown into a bunker located in the building. A diversion pipe would be provided so that coal could be diverted to a storage building adjacent to the boiler house carrying a 5 days supply only. A conveyor from the coal storage building to the bunker would be provided. Open storage for this grade of coal is not practical and because of the impracticability of providing closed storage for a 30 day emergency supply of it, open storage for 18% ash coal (which is of larger sizes) would be provided to insure against shut-down in the event of an interruption to the supply of fines.

Whether the fines or the 18% ash coal were being used, it would feed into an air-swept tube mill for pulverization before being fired. Because of the character of the fuel, it is felt that only a tube mill would provide the requisite degree of fineness and still maintain a very high degree of reliability of service.

The coal would be withdrawn from the mill by means of two air extractors and blown into the boilers. The boiler would be started on oil and after a time the combustion would be sustained entirely by the coal.

A forced draft fan, induced draft fan, and a regenerative type of air preheater would be utilized. A stub stack is contemplated.

Under full load operation, approximately 360 tons of pulverized coal would be consumed in a 24-hour period, producing about 72 tons of ash, the greater part of which would pass out through the stack. About 20 tons of ash would require disposal. It would be conveyed to a hopper and thence trucked away.

The building required to house the boiler and pertinent auxiliaries would have a volume of about 11,400 m^3.

The cost of moving mine fines from the air separator at the washery to the boiler house would be about 3$21 a ton. This figure is based upon a capital cost of 1,236 contos for equipment (including installation) with fixed charges of 11.86% or 147 contos a year and annual costs of 114 contos and 33.5 contos for power and labor respectively.

6. Boiler House Design for 18% Ash Fuel

The third boiler installation considered was one utilizing the washed coal resulting from adoption of the recommendations made by Pierce Management, Inc. This fuel would be similar to the unwashed mine fines with the following exceptions:

a.	Heat content	-	5843 Kilo-calories
b.	Ash content	-	18%
c.	Sizing	-	100% greater than 1/64" (0.04 cm)

The boiler design would be similar to that considered for the 20% ash coal, the only marked difference in the two designs being in the coal handling systems. Because of the sizing of the washed coal, a belt conveyor would be employed to bring it from the washery at the mine to the bunker. A diversion chute would be provided to the open air stock pile. The other design features would be the same as for the 20% ash installation.

Using the better grade of coal will result in a boiler efficiency of 85% and an overall thermal efficiency of the station of 27.4%. Under full load operation, approximately 322 metric tons would be consumed in 24 hours and approximately 58 tons of ash would require disposal, the residue passing off through the stack as in the case of the plant burning 20% ash fuel.

As in the preceding design, the building required to house the boiler and auxiliaries would have a volume of 11,400 m^3.

7. Power House

Under all three boiler designs, the turbine room installation would be identical (see Plate 14). It is anticipated that approximately 14,200 m^3 would be required to house the required generating equipment. The turbo-generator set would be of the condensing type with four extraction stages capable of delivering continuously 25,000 kw, three phase at .8 P.F., 50 cycles. The generator would be directly connected to the station transformer with suitable relay protection. The generator would be air cooled and operated at 3000 RPM. The turbine would utilize steam at 850#/sq in and 900° F (59.76 kg/cm^2 and 482° C). It is anticipated that the steam rate in the unit will be 8.54 lbs. (3.87 kg) per kw hour. The condenser would be of the double pass type. Four extraction heaters would be used in the regenerative feedwater heating cycle.

Two boiler feed pumps would be provided, one steam driven, the other motor driven. The flow of the Douro River is more than adequate to meet the condensing water requirements, estimated at 20,000 gallons/minute (75,700 litres). The temperatures of the water, ranging from a low of 6° C in the winter to a high of 24° C in the summer are within good working limits. Since the station would be located 36 m above sea level in order to be above the 100 year flood stage, and the mean level of the river at Pejao is 6 m, the average difference in elevation between river and station level would be 30 m. This at first seemed likely to entail a costly pumping operation, but a solution was found which would reduce the cost considerably. The design finally selected would utilize a motor driven pump to supply one-half of the required water, while the other half would be obtained from water turbine driven pumps utilizing the 30 m head on the circulating water discharge. Designs of this character have been used with marked success in the United States.

The generator voltage would be stepped up to the transmission voltage by a 31,250 kva, three phase, 50 cycle transformer. A circuit breaker of suitable interruptive capacity would be provided on the high voltage side. Transmission to Ermesinde Substation of the COMPHANIA NACIONAL DE ELECTRICIDADE was deemed to be most economical at 60 kv. Ermesinde is approximately 24 km from Germunde. It is recognized that for ultimate development of the Douro Basin at least a 150 kv transmission system would be required. However, for the economic comparisons involving the proposed Pejao Thermal Station, a single 60 kv line is considered adequate.

Power for the station auxiliaries would be obtained from a 2500 kva three phase, 50 cycle 60 kv/2.3 kv transformer supplied from the high line. Larger auxiliaries would operate at 2,300 volts, while lighting and smaller auxiliaries would obtain power from a 500 kva, three phase, 50 cycle 2300/380/220 transformer.

TABLE IX-1

ESTIMATES OF COST OF CONSTRUCTION 25,000 KW PEJAO STEAM PLANT

	Design 1 45% Ash (Contos)	Design 2 20% Ash (Contos)	Design 3 18% Ash (Contos)
Land	14	14	14
Structures & Improvements	27,100	18,129	16,414
Boiler Plants Complete	40,347	36,421	37,910
Turbo-generating Equipment	23,030	23,030	23,030
Acces. Elect. Equipment	6,108	6,108	6,108
Miscellaneous Power Plant Equipment	4,000	2,857	2,857
SUB-TOTAL	100,599	86,559	86,333
Freight	5,714	4,286	4,286
SUB-TOTAL	106,313	90,845	90,619
Indirect Cost - 35.5%*	37,741	32,250	32,170
TOTAL COST OF POWER PLANT (Exclusive of Step-up Substation)	144,054	123,095	122,789
Cost per kw.	5.762	4.924	4.912
Step-up Substation 12 KV/60 KV	5,714	5,714	5,714
Transmission Line - 60 KV Pejao to Ermesinde	4,800	4,800	4,800
GRAND TOTAL	154,568	133,609	133,303

* Interest During Construction	6%
Financing Charges	3.5%
Studies, Supervision, etc.	9%
Residences for personnel	2%
Contingencies	15%

Note: A detailed breakdown of the estimate is given in Appendix E.

8. Cost Estimates: Construction

Table IX-1 entitled "Estimates of Cost of Construction, 25,000 kw Pejao Steam Plant", shows the estimated construction costs of the three plants discussed to be respectively:-

Plant Burning 45% Ash Coal	- 144,054 Contos	or 5,762$00/Installed kw
" " 20% " "	- 123,095 "	or 4,924$00 " "
" " 18% " "	- 122,789 "	or 4,912$00 " "

In each case the total cost is to be increased by 10,514 contos for a step-up substation and the 60 kv transmission line to Ermesinde.

9. Annual Costs and Considerations

The annual costs of the several plants are the final determinants of their relative economies. Annual costs include fixed charges, cost of operation and maintenance, and cost of fuel. Fixed charges are taken at 9% of construction cost (interest and dividends 5.7%, depreciation 2.86%, taxes and miscellaneous 0.39%). Operation and maintenance costs are estimated on the basis of typical labor forces and normal maintenance expenses.

Tables IX-2 and IX-3 respectively listing typical operating forces for the plant burning 45% ash coal and for a plant using mine fines or washed coal, indicate annual labor costs of 1,473 contos for the 45% ash plant, as compared with 1380 contos for either of the others.

The annual costs per kwh exclusive of fuel costs were found to be:

For the plant burning 45% ash coal - 0$0964

For the plant burning 20% ash coal - 0$0815

For the plant burning 18% ash coal - 0$0813

Fuel costs have not been determined, except in relation to assumed prices per ton. In Appendix A the costs of production for various grades and types of coal are estimated but the actual prices of the fuel selected will be named by the producer, perhaps with some guidance from the Government. But while the prices at which these several grades of coal can be purchased are not known, the quantity required to be burned by each plant to produce annually 164,250,000 kwhr by 75% time operation at full capacity is known. The quantities are 166,700; 91,600 and 87,900 tons of 45%, 20% and 18% ash fuels respectively. It follows that if a price per ton be assumed for one grade - e.g., the 45% ash grade - the corresponding maximum prices that can be paid for the other grades without increasing the cost of electricity per kwhr can be adduced readily.

In Table IX-4 various prices have been assumed for the 45% ash coal and the corresponding "break-even" prices have been computed for the other two grades.

TABLE IX - 2

TYPICAL OPERATING FORCE

THERMAL PLANT UTILIZING 45% ASH COAL

Job Description	# of Men Per Shift	Shifts Per 24 Hours	Days Per Year
Plant Superintendent	1	1	365
Assistant Plant Superintendent	1	1	365
Watch Engineer	1	3	365
Clerk	1	1	365
Main Control Room	2	3	365
Boiler & Turbine Controls	2	3	365
Coal & Ash Handling-Boiler House	2	3	275
Yard Men	2	1	275
Truck Driver	1	1	365
Truck Drivers	3	1	275
Laborers	2	3	275
Turbine Room Attendants	2	3	275
Maintenance Crew			
Boiler Maker	1	1	365
Certified Welder	1	1	365
Electrician - Control	1	1	365
Instrument Man	1	1	365
Machinist	1	1	365
Millwright	1	1	365
Pipe-Fitter-Control	1	1	365
Unskilled Labor			
Foreman	1	1	275
Helpers	2	1	365
Laborers	3	1	275

Estimated Total Annual Labor Cost, Including Taxes on Salaries = 1,473,207$

TABLE IX-3

TYPICAL OPERATING FORCE

THERMAL PLANT UTILIZING 20% ASH COAL OR 18% ASH COAL

Job Description	# of Men Per Shift	Shifts Per 24 Hours	Days Per Years
Plant Superintendent	1	1	365
Assistant Plant Superintendent	1	1	365
Watch Engineer	1	3	365
Clerk	1	1	365
Main Control Room	2	3	365
Boiler & Turbine Controls	2	3	365
Coal and Ash Handling			
Boiler House	2	3	275
Yard Men	2	1	275
Truck Drivers	1	1	365
Turbine Room Attendants	2	3	275
Maintenance Crew			
Boiler Maker	1	1	365
Certified Welder	1	1	365
Electrician - Control	1	1	365
Instrument Man	1	1	365
Machinist	1	1	365
Millwright	1	1	365
Pipe Fitter - Control	1	1	365
Unskilled Labor			
Foreman	1	1	275
Helpers	2	1	365
Laborers	3	1	275

Estimated Total Annual Labor Cost, Including Taxes on Salaries = 1,379,600$

TABLE IX-4

BREAK-EVEN COAL PRICES AND RESULTANT COST OF POWER

GENERATED BY PLANTS USING DIFFERENT GRADES OF FUEL

45% Ash Coal Price Per Ton	* 20 % Ash Coal Equivalent Price Per Ton	* 18% Ash Coal Equivalent Price Per Ton	Resulting Total Cost of Elect. Per kwhr at Bus Bars (including fixed charges and operating expenses)
90$	191$	199$	0$18 78
95$	200$	209$	0$19 30
100$	209$	218$	0$19 79
105$	218$	228$	0$20 31
110$	227$	237$	0$20 81
115$	236$	247$	0$21 33
120$	245$	256$	0$21 82
125$	254$	266$	0$22 34
130$	263$	275$	0$22 86
135$	272$	285$	0$23 38

* Corresponding price of this grade so that total cost per kwhr shall be identical. Prices on coal have been rounded off to closest whole escudo.

The Pejao mining interests have indicated that they anticipate pricing coal (presumably coal for which there now is little market) to the thermal plant at 115$00 to 120$00 a ton. If 120$00 a ton were to be paid for 45% ash coal, and the corresponding break-even prices for the mine fines and the washed coal, the cost of power at the Pejao bus bars would be, as indicated in Table IX-4, 21.8 centavos per kwhrwhichever plant were employed to generate it. If 45% ash coal could be bought for 120$00 a ton and mine fines cost less than 245$00 a ton, the plant burning the latter would be the more economical - and vice versa.

It will be noted from Table IX-5 that annual costs first are broken down into capacity costs (Item #B) and energy costs (Item #C) and subsequently combined (Item #D) to yield the 21.8 centavos per kwhr referred to above. The breakdown is more or less arbitrary, but is based on the sound general consideration that certain costs are inevitable regardless of how many or how few hours of annual energy production are required of the plant. In the three examples here considered, it will be noted that while the total cost per net kwhr is 21.8 centavos in each case, the annual capacity or "readiness to serve" cost is 678$78 for the plant using 45% ash coal as compared with 597$46 and 596$66 for the plants using mine fines and washed coal respectively. The variable operating costs pertaining exclusively to the direct generation of energy are 11.48 centavos per kwhr for the plant burning 45% ash coal and 12.71 and 12.75 centavos respectively for those burning mine fines and washed coal.

10. Cost of Power at Ermesinde

In order to be usable, Pejao energy has to be transmitted to the load center - in this case the Ermesinde Substation. Table IX-6 shows the first and annual costs of the necessary transmission line and Table IX-7 the capacity, energy and total costs per kwhr at the 60 kv bus of Ermesinde after giving effect to costs of generation, transformation and transmission. The cost per kwh (including both capacity and energy) at Ermesinde is 22.9 centavos. Table IX-7 shows the annual cost per kw at Ermesinde, again including both capacity and energy costs to be 1508$16.

- Os custos ressentem-se duma longa amortização, e da central estar localizada junto do Pejão e não estarem previstos longos transportes

- É pena não haver uma maior discriminação dos encargos

TABLE IX-6

ANNUAL COST OF THERMAL-ELECTRIC TRANSMISSION FACILITIES - 24 KM. - 60 KV. LINE PEJAO TO ERMESINDE

	Step-up Substation Escudos per kw	Transmission Line Escudos per kw	Total Escudos per kw
A. Unit Investment	228$56	192$00	420$56
B. Annual Costs			
1. Fixed Charges 9%	20$57	17$28	37$85
2. Total Operating Costs			
a) Operation & Maintenance	8$42	0$88	9$30
b) Administrative & General	1$26	0$13	1$39
Total Operating Costs	9$68	1$01	10$69
Total Annual Costs	30$25	18$29	48$54
	(13,2%)	(9.54%)	(11.5%)

TABLE IX-7

ANNUAL COST OF OUTPUT AT 60 KV. BUS ERMESINDE SUBSTATION - 25,000 KW. PEJAO THERMAL STATION

		Escudos Per kw
A. Bus-Bar Cost of Steam Electric Output		
1. Output Cost		
a) Capacity	597$46	
b) Energy	834$80	1432$26
B. Steam Electric Step-up Substation		
1. Total Annual Cost	30$25	
2. Step-up Losses		
a) Capacity	6$28	
b) Energy 6570 kwhr @ $001	6$57	43$10
C. Cost of "At Site" Steam Electric		
1. Output at High Tension Terminal		1475$36
D. Transmission Lines from Pejao Station to High Tension Connection at Ermesinde		
1. Total Annual Cost	18$29	
2. Line Losses		
a) Capacity	7$94	
b) Energy $001 x 6570 kwhr	6$57	32$80
E. Cost of Pejao Output at 60 kv Bus of Ermesinde		1508$16

NOTE: Based on assumption plant operates 6570 hours per year.

TABLE IX-8

CAPACITY AND ENERGY COSTS OF OUTPUT AT 60KV BUS - ERMESINDE SUBSTATION

	Design 1. Utilizing 45% Ash Coal @ 120$00 per Ton*		Design 2. Utilizing 20% Ash Coal @ 245$00 per Ton*		Design 3. Utilizing 18% Ash Coal @ 256$00 per Ton*	
	Escudos per kw	Escudos per kwhr	Escudos per kw	Escudos per kwhr	Escudos per kw	Escudos per kwhr
A. Bus bar cost of Pejao Output						
1. Capacity Cost	673$78		597$46		596$66	
2. Energy Cost		0$115		0$127		0$128
B. Pejao Step-up Substation						
1. Total Annual Cost	30$25		30$25		30$25	
2. Step-up Losses						
a) Capacity	7$09		6$28		6$27	
b) Energy		0$001		0$001		0$001
C. Cost of "At Site" Pejao Output at High Tension Terminal						
1. Capacity	716$12		633$99		633$18	
2. Energy		0$116		0$128		0$129
D. Transmission Line from Pejao to High Tension Connection at Ermesinde						
1. Total Annual Cost	18$29		18$29		18$29	
2. Line Losses						
a) Capacity	8$81		7$94		7$82	
b) Energy		0$001		0$001		0$001
E. Cost of Pejao Output at 60 KV Bus at Ermesinde						
1. Capacity	743$22		660$22		659$29	
2. Energy		0$117		0$129		0$130
F. Total Cost of Pejao output at 60 KV Bus bar of Ermesinde (Capacity and Energy)		0$229		0$229		0$229

*Price of Coal assumed
See Page IX-17 for discussion of comparative prices for various grades.

NOTE: Costs have been rounded off to closest whole number.

In the final analysis, the comparative costs of the several grades of coal considered probably will determine the type of plant to be built. In the light of present knowledge, it would appear that cleaning and washing the products of full seam mining at Pejao would be desirable and that in the event that it is adopted, the plant burning mine fines (20% ash) would be the proper one to build. Because of the necessity for the costly procedure of pressing the fines into briquettes if they are not burned locally, and the difficulties of shipping and storing such finely divided material if the briquette plant remains at Porto, it seems not improbable that the 20% ash fuel may become available to the thermal plant at a relatively attractive price.

11. Cost of Pejao Power Versus Cost of Generation at Existing Steam Plants

Cost data furnished by Comphania Reunidas Gas e Electricidade indicate that fuel cost of the Tejo thermal plant in 1950 was 0$34 a kwhr. Total 1950 Tejo generating costs were reported as the equivalent of 0$3944 a kwhr. The total cost apparently represents only the total of the variable costs, (i.e., it excludes fixed charges). Assuming, as it is believed safe to assume, that it is representative of the variable component of cost of thermal production elsewhere in the country as well, a basis is found for computing the savings that would result from the replacement of existing thermal generation by generation at Pejao. Fixed charges on existing plants continue whether or not the plants actually operate, so the net benefit from Pejao would be the difference between the latter's total cost per kwhr and the variable cost perkwhr for present plants. Since on the basis of fuel costs of 120$00 a ton for 45% ash coal or 245$00 a ton for mine fines, Pejao's total cost at Ermesinde is 0$229 per kwhr, the indicated difference or saving is about 16.54 centavos per kwhr, or about 27,167 contos a year on the basis of 75% time operation. In addition, since most of the fuel used by existing plants is imported, a saving of about 55,845 contos a year in foreign exchange would be realized. Load studies indicate that under 1956 conditions, and as long thereafter as the present 100,000 kw of steam capacity are needed in the system, thermal generation in excess of 25,000 kw will be required for about 75% of the time on the average. (see Plate No.22) Table IX-9 on the assumption of 75% time base load operation of Pejao (164,250,000 kwhr per annum) indicates that if the variable costs of Tejo be compared with the total cost less the depreciation component, of Pejao energy delivered at Ermesinde, a differential of 0$1884 or 0$1924 per kwhr is found depending upon which of the Pejao plants is selected. On the basis of 164,250,000 kwhr a year, this represents 30,945$00 or 31,602$00 annual savings, again depending upon the Pejao plant considered. If this annual difference all be allocated to straight line amortization, it would amortize the cost of the Pejao plant and its transmission facilities in from 4.31 to 4.89 years depending upon which of the three plants is selected. Expressed more simply, this merely means that the difference between total costs of Pejao power and variable costs only of existing steam power would pay for Pejao and its transmission facilities in from 4 to 5 consecutive years of average (75% time) operation.

Since Pejao can furnish power so much more cheaply than existing thermal plants, it manifestly would be advisable to build it at once for the purpose of replacing existing thermal generation unless it was found practical and even more economical to replace all thermal power at once and altogether with hydroelectric power. This question is considered in Paragraph 4, Chapter XIII.

TABLE IX-9

COMPARISON OF SAVINGS OF PEJAO STEAM PLANT OVER EXISTING STEAM PLANTS

		Design 1. (45% Ash)	Design 2. (20% Ash)	Design 3. (18% Ash)
1.	Cost of Entire Project - Contos	154568	133609	133303
2.	Cost of Output at Ermesinde - Esc/Kwhr	0$229	0$229	0$229
3.	Deprec. Component-of Cost - Esc/Kwhr (2.36% x Item #1 ÷ 164,250,000 Kwhr)	0$027	0$023	0$023
4.	Cost of Output at Ermesinde Less Depreciation - Esc/Kwhr (Item #2 Less Item #3)	0$202	0$206	0$206
5.	*Tejo Fuel Cost - Esc/Kwhr	0$34	0$34	0$34
6.	*Tejo Operating Cost - Esc/Kwhr	0$0544	0$0544	0$0544
7.	*Total Var. Cost-At Tejo Bus Bars-Esc/Kwhr	0$3944	0$3944	0$3944
8.	Allow. Deprec. Per Kwhr (Item #7 less Item #4)	0$1924	0$1884	0$1884
9.	Allow. Deprec. Per Year - Contos (Item #8 x 164,250,000 Kwhr)	31,601.7	30,944.7	30,944.7
10.	Years Operation to Amortize Cost	4.89	4.32	4.31

*As Furnished by Comphanias Reunidas Gas E Electricidade

CHAPTER X

HYDROELECTRIC INSTALLATIONS CONSIDERED FOR SUPPLYING FUTURE POWER DEFICIENCIES

1. General

It seems appropriate to preface the discussion of specific hydroelectric projects considered for overcoming indicated power deficiencies of the post-1956 period, by recapitulating the premises upon which conclusions concerning them are based.

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The fundamental premise is that the primary objective sought is the provision at minimum cost of enough dependable power to keep abreast of load growth, so that all users may be assured of a continuing supply of energy when and to the extent that their operations require; and that a secondary objective is the replacement of existing thermal energy to the fullest extent possible with generation at lesser cost, while still keeping abreast of load growth.

Conclusions rest upon the further assumption that both the hydroelectric and thermal components of the national power-generating system will be fully integrated to form a power pool; that the National Load Dispatcher will be fully empowered to schedule the use of all generation and transmission facilities to the best national advantage, and that to the ends respectively of insuring full cooperation on the part of producers and transmitters of power, and of insuring effective and trouble-free operation of the system as an integrated unit, a rate structure will be created that will embody equitable compensation for standing by (providing firm capacity) as well as for delivering energy. It is also assumed that an A.C. calculating board study will be made of the power transmission system in order to provide data for better operation and for design of future additions to the system.

The conclusions assume also that full advantage will be taken of the ability of the great storage reservoirs of the Zezere and Cavado systems to firm up power produced by the main Douro River plants. The latter, while benefiting from the regulated flow from the Ricobayo Reservoir on the Esla River in Spain, will, for reasons later explained, have no appreciable storage of their own, and will therefore have to use the water essentially as they receive it. The normal flow of the Douro is quite large, which means that its plants can turn out a great deal of energy. The presence of enough storage on other water sheds to make this large output dependable, creates a situation verging upon the ideal.

The two systems, Zezere-Cavado and Douro, will complement each other. The storage systems convert the large Douro capacities into dependable capacities, and in doing so, are themselves enabled to benefit to a degree which hitherto and otherwise would be impossible, from the investment in their own unusually large installed capacities. The planning which led to the development of the Zezere and Cavado sites in such fashion as to take full advantage of their large capacities for storage will come to full fruition with development of the Douro.

2. Portuguese Douro

Plate 16 shows schematically the proposed hydroelectric development of the Douro River and its Portuguese tributaries. The best potential development of the Portuguese Douro was found to consist of the four dams originally considered by the Hydraulic Services. The lowermost site at which the existence of a satisfactory rock foundation for a power dam has been proven is at Carrapatelo, about 67 km above the river's mouth. Between that point and the Spanish border, about km 210, a series of four dams is proposed, namely at Carrapatelo, Regua (km 108), Valeira (km 148) and Pocinho (km 183), with pool levels at 46, 73, 104 and 124 m respectively above sea level, representing a combined net head of 114 m above normal Carrapatelo tailwater elevation of 10 m above sea level. The Pocinho pool will extend 10 or 12 km into the Spanish portion of the International Douro, to the mouth of Rio Huebra - an encroachment authorized by the treaty agreement of August 11, 1927, which provides a limiting elevation of full pool equivalent to low-water at the mouth of the Huebra.

3. International Douro

Between the Pocinho pool and the mouth of the Tormes River (about km 280) development of the International Douro for power vests with Spain. From the mouth of the Tormes River to the point some 55 km upstream, where the Douro emerges from Spain to form the Portuguese-Spanish boundary, hydroelectric development again becomes the prerogative of Portugal. It is proposed to effect it by means of three dams located at sites known respectively as Bemposta, (4.88 km above the mouth of the Tormes) Picote (km 22.40), and Miranda (km 43.50).

Various means were explored to develop the head on the international portion of the stream. A rapid computation showed at an early stage that a long-tunnel scheme with a low dam and a single plant developing the entire available head would not be economical in comparison with a development by several dams. Preliminary studies were then made of the costs of developing the total head by combinations involving two dams and three dams, using various heads for each. One two-dam scheme appeared to be somewhat more economical than those using three dams, if a rock fill dam could be used at Picote, but the height of such a rock fill structure so far transcended experience and precedent, that in view of the character of rock and of several other factors, it was considered impractical, and decision was made to investigate the three-dam alternative further. In the reach farthest downstream, the Bemposta reach, the available dam sites are not as good as they are in the middle, or Picote reach. In the reach farthest upstream, the Miranda reach, favorable dam sites exist, but the head which can be developed is limited by elevation 527, which must not be exceeded, if flooding of the Spanish Castro plant is to be avoided. The Picote reach is the most favorable of the three.

A number of sites in the Picote reach were investigated. The two most desirable appeared to be at km 18.35 and km 22.40, respectively, measured upstream from the mouth of the Tormes River. The site at km 18.35 is an excellent one for a rock fill dam, which would, however, even in a three-dam development scheme, be much higher than any heretofore constructed. In view of this, in view of the lack of suitable material for an earthen core, and the possibilities of power losses by reason of reservoir drawn-down for repair of settlement cracks if a rigid core or curtain were used, and finally because the saving in cost of over-all development of the International Douro would not be very great by use of rockfill, it was decided to consider only concrete structures.

For a concrete dam, the site 22.4 km above the mouth of the Tormes is superior both topographically and geologically and was therefore selected.

At Bemposta, full pool elevation would be at elevation 397, and the head, 59 meters; at Picote, full pool would be at elevation 471 m and head, 74 m. At Miranda the head would be 55 m at the full pool level of 527 m.

4. Storage

A. General - None of the proposed main river plants on the Douro River will have enough storage to furnish pondage for more than a day of low flow, or possibly for the weekend. The valley is narrow, so the gain in storage capacity with increase in dam height is small. In many instances an increase in height is impracticable. On the National Douro, an increase in the height of Carrapatelo Dam would flood the city of Regua, and increasing the height of the Pocinho Dam would violate treaty provisions. However, the Regua Dam could be raised so as to eliminate the Valeira Dam. To raise the Valeira Dam would drown out the fertile Vilarica valley near the mouth of the Sabor, where an irrigation project is possible.

On the Portuguese International Douro, Miranda Dam obviously could not be raised because of the Spanish Castro plant. Raising the Bemposta Dam would flood the most favorable site in the entire reach, namely, Picote. The Picote Dam could be raised to eliminate Miranda, and the possibility was studied.

B. Alternative project at Regua site - The full pool at the proposed Regua dam site was assumed to be raised to elevation 104 m, the elevation of the proposed Valeira pool upstream. The head would be 58 m. Using 437,000,000 m^3 of storage, a maximum dependable capacity of 42,000 kw could be developed. With the assistance of re-regulation from the Zezere reservoirs, the maximum dependable capacity added to the system would be about 65,000 kw. However, a routing for the combined low-head projects at

Regua and Valeira, developing the same total head, indicated that the identical capacity of 65,000 kw could be obtained without using storage. A cost estimate showed that the high Regua project would be very expensive, chiefly because of the extensive railroad relocation which would be required. The total cost of the project would be 1,134,000 contos and its annual cost would be about 99,000 contos, or more than 1,500 escudos per dependable kw, as compared with 1,300 escudos per kw for the proposed low Regua project, and 1,200 escudos per kw for the proposed Valeira project. Since the high Regua project has nothing to recommend it, and is much more costly than its alternatives, it was dropped from further consideration.

C. Alternative project at Picote site - A plan was studied in which the dam at an alternative Picote site on the International Douro at km 20.6 upstream from the Tormes River would be raised to full pool elevation 527 m, which represents the limit of development upstream. The maximum head would be 134 m. Using about 366,000,000 m^3 of storage, a maximum dependable capacity of 79,000 kw could be obtained during the critical dry period. With Zezere re-regulation, the maximum dependable capacity added to the system would be 105,000 kw. However, a comparative study showed that if the project were operated at maximum head, without using any storage, the dependable capacity in the system, using Zezere re-regulation, would be 104,000 kw or substantially the same value as when storage was used. The indicated result would be achieved by the construction of two lower dams situated at the Picote and Miranda sites, respectively, developing the same total head. Consequently, it appears that storage at Picote would not result in any appreciable advantage. The scheme has several disadvantages, as follows: it would probably be unacceptable to the Spanish interests, who will operate plants downstream on their section of the International Douro, and who might object to drastic modification of the river's flow, and it would require a very high dam at Picote, which would not be economical and would lengthen the time of construction and delay the beginning of operation of the project. Therefore, a storage project at the Picote site was likewise eliminated from further consideration.

5. Portuguese Tributaries

Referring again to Plate 16 it will be noted that plants on four of the Portuguese tributaries of the Douro have been considered: Fragas da Torre on the Paiva River, Vilar-Tabuaco on the Tavora River, Laranjeiras on the Sabor River (a dual purpose, power and irrigation project), and Vale de Madeira on the Coa River. There is a storage reservoir in connection with each of the proposed projects. One of them, the Vilar-Tabuaco project, already has been granted a concession by the Government. Its function being, apparently, to reduce the required output of existing thermal plants during periods of normal stream flow. It will effect economies in that field if capacity is properly selected, but will not, if so employed, add materially to dependable dry season production.

The various sites investigated for power dams and the individual projects considered for their development, including two projects involving pumped storage and diversion, respectively, are described and discussed in full detail in Chapter XII.

6. Basis of Comparison

A. Selection of plant capacity - As mentioned previously, it was found that peaking capacity would not be required in 1960; that the new plants would operate in, or close to, the base of the load; and that the proposed run-of-river projects on the International Douro and Portuguese Douro would provide relatively large dependable capacities by reason of the firming-up effects of the existing storage plants. It was found that the new reservoir plants considered on the tributaries would not be effective in firming-up the proposed main river plants, beyond their own continuous capacities, until a comparatively distant date, because the existing storage plants would be sufficient to fulfill that function. Consequently the installed capacities required at the plants on the tributaries would be comparatively small, and would not be sufficient to carry the costs of the high dams and long waterways of the tributary projects in competition with the main river projects.

B. Costs in terms of capacity and energy - In comparing the projects to arrive at an estimate of their relative economic attractiveness, it is necessary to consider several factors. Comparison was based first on the total cost per kilowatt-hour at the generating station, assuming in each case that the plant was added to the "existing" system in 1960. Annual costs, and costs per kilowatt-hour were used rather than costs of construction, because they provide a means for comparing projects of widely differing characteristics, for example, steam-electric as against hydroelectric plants. The results are shown in Table X-1 which lists the principal features of the projects as well as their comparative costs of capacity and energy at the bus bar. The results indicate that the projects on the International Douro would be more economical than those on the National Douro, and that the latter would be superior to those on the tributaries.

TABLE X-1

PRINCIPAL FEATURES OF PROJECTS

1. Name of project	Picote	Bemposta	Miranda	Carrapatelo	Regua	Valeira	Pocinho	Vilar-Tabuaco	Fragas de Torre	Vale de Madeira	Laranjeiras
2. River	Int'l. Douro	Int'l. Douro	Int'l. Douro	Douro	Douro	Douro	Douro	Tavora	Paiva	Coa	Sabor
3. Drainage area in 10^3 km^2	63.7	63.8	63.5	93.5	92.2	87.8	82.8	0.4	0.7	1.1	3.5
4. Dam type	Gravity	Gravity	Gravity	Gravity	Gravity	Gravity	Gravity	Gravity	Gravity	Gravity-Arch	Gravity
5. Dam height in meters	98	83	79	43	40	50	34	49	85	105	104
6. Length of waterways in km	-	-	-	-	-	-	-	17.7	14.4	2.2	-
7. Full pool elevation in meters above main sea level	471	397	527	46	73	104	124	552	250	530	207
8. Useful storage in reservoir in 10^6 m^3	-	-	-	-	-	-	-	86	258	311	460
9. Gross head in meters	74	59	55	36	27	31	20	410	240	195	95
10. Installed capacity in kw	93,000	76,000	72,000	87,300	70,000	77,000	57,000	7,600	18,000	8,700	6,400
11. Continuous capacity (corresponding to minimum monthly flow for run-of-river plants, and to regulated flow for reservoir plants) in kw	22,200	17,700	16,500	14,300	10,300	11,200	7,100	7,250	18,000	8,700	6,400
12. Dependable capacity contributed by the plant to the entire power system in kw	63,600	52,000	50,000	45,800	37,000	41,000	30,000	7,250	18,000	8,700	6,400
13. Usable average annual energy in 10^6 kwhr (based on 1960 demand)	520	415	385	379.3	250.0	316.1	212.4	48.1*	118.4*	57.2*	42.1*
14. Capital cost of project, exclusive of transmission cost, in 10^3 contos	466.8	393	340	552	526	494	420	169	346	225	427
15. Annual cost of project, exclusive of transmission cost in 10^3 contos	43.8	38.1	33.4	52	49	47	40	15.9	28.8	19	34
16. Annual cost per dependable kilowatt in escudos	689	733	668	1,100	1,300	1,200	1,300	2,200	1,600	2,200	5,300

*Based on the assumption that 75% of the energy generated at the tributary plants would be usable.

C. Computation of benefits - Comparative cost per dependable kwhr at the bus bar of the generating plant is not per se a complete criterion of relative worth, however, for the power must be transmitted to the load center - in this case Ermesinde substation at Porto - in order to be used. There is, moreover, a distinction between capacity benefits and energy benefits at the load center, so each should be evaluated; and in the case of the lower three projects on the National Douro, the collateral benefit to navigation must be taken into account also. The simplest way to arrive at a true economic comparison is to add together for each project its various annual benefits - i.e., energy, capacity, and collateral benefits - and divide their sum by the annual charges pertaining to the project. The quotient is the ratio between annual benefits and annual costs, usually referred to as the benefit-cost ratio. The higher the ratio, the greater is the relative value of the project. Benefit-cost ratios have been computed for all the Douro River and tributary projects and are given in Table X-2.

In allocating navigation benefits, 1/3 of the total net saving effected by improvement for navigation as computed in Chapter VII has been assigned to each of the lower three power dams on the national portion of the river.

In arriving at the measure of capacity benefits at Ermesinde, the capacity cost per annum per kilowatt at Ermesinde derived for the proposed Pejao steam plant has been used as the basis of comparison.

In computing energy benefits, it has been assumed uniformly that of the total dependable, usable, energy generated by the particular plant under consideration, the first 164,250,000 Kwhr would have a value equal to Pejao energy costs at Ermesinde, while the remaining output would have a value equal to the fuel costs of Tejo for equivalent output. Usually, when the benefit-cost ratio is less than unity, a project is considered uneconomic. In the present instance, it merely means that it is less economical than Pejao, since by the foregoing definitions, the ratio for Pejao is unity.

The order of economic priority established by Table X-2 is not altered by the more comprehensive analysis afforded by Table X-3.

7. Hydroelectric Project of First Priority

The analysis, as explained at the beginning of the chapter, premises dependable power and the employment of Zezere storage to ensure dependability; but while the figures would change if either or both of these tenets were disavowed, it is believed that they would, under any basis of assumption, continue to point to Picote as the most economical of all the plants considered, and the hydroelectric project which should be accorded first priority in construction.

TABLE X-2

ECONOMIC COMPARISON OF VARIOUS PROJECTS

BASED ON 1960 DEMAND

1. Name of project.	Picote	Bemposta	Miranda	Carrapatelo	Regua	Valeira	Pocinho	Vilar-Tabuaco	Fragas de Torre	Vale de Madeira	Laranjeiras
2. River	Int'l. Douro	Int'l. Douro	Int'l. Douro	Douro	Douro	Douro	Douro	Tavora	Paiva	Coa	Sabor
3. Installed capacity in kw.	93,000	76,000	72,000	87,300	70,000	77,000	57,000	7,600	18,000	8,700	6,400
4. Dependable capacity (based on 1960 demand) in kw.	63,600	52,000	50,000	45,800	37,000	41,000	30,000	7,250	18,000	8,700	6,400
5. Usable average annual energy output (based on 1960 demand) in 10^6 X kwhr.	520	415	385	379.3	250.0	316.1	212.4	48.1	118.4*	57.2*	42.1*
6. Capital cost of project, exclusive of transmission cost, in 10^3 contos.	466.8	393	340	552	526	494	420	169	346	225	427
7. Capital cost of transmission system, including switchyard, in 10^3 contos.	129.2	77.3	96.3	33.3	40.2	51.8	54.0	4	6	8	5
8. Capital cost of project, including transmission system and switchyard, in 10^3 contos.	596.0	470.3	436.3	583.3	566.2	545.8	474.0	173	352	233	432
9. Annual cost of project, exclusive of transmission and switchyard cost, in 10^3 contos.	43.8	38.1	33.4	52.0	49.0	47.0	40.0	15.9	28.8	19.0	34.0
10. Annual cost of project, including transmission and switchyard cost and losses, in 10^3 contos.	63.1	52.5	48.8	59.10	57.20	58.00	49.80	17.61	31.87	22.18	37.8
11. Annual cost including transmission, less navigation benefits, in 10^3 contos.	63.1	52.5	48.8	57.06	55.16	55.96	49.80	17.61	31.87	22.18	37.8
12. Cost of usable energy at Ermesinde (terminus of transmission line) in escudos per kwhr.	0.121	0.124	0.128	0.150	0.221	0.177	0.234	0.366	0.270	0.388	0.900
13. Value of capacity at Ermesinde based on fixed charges of Pejao steam plant, in escudos per kw	660.22	660.22	660.22	660.22	660.22	660.22	660.22	660.22	660.22	660.22	660.22
14. Value of energy at hydroelectric plant based on fuel cost at Pejao steam plant, in escudos per kwhr	0.121	0.121	0.120	0.127	0.126	0.125	0.124	0.125	0.127	0.122	0.124
15. Value of energy at hydroelectric plant based on fuel cost at existing steam plants, in escudos per kwhr.	0.318	0.319	0.316	0.334	0.331	0.328	0.325	0.329	0.335	0.321	0.324
16. Average annual energy assumed to replace fuel at Pejao steam plant in 10^6 kwhr.	164.0	164.0	164.0	164.0	164.0	164.0	164.0	48.1	118.4	57.2	42.1
17. Average annual energy assumed to replace fuel at existing steam plants in 10^6 kwhr.	356.0	251.0	221.0	215.3	86.0	152.1	48.4	0	0	0	0
18. Total annual capacity benefits at Ermesinde in 10^3 contos.	42.0	34.4	33.0	30.3	24.4	27.1	19.8	4.8	11.9	5.7	4.2
19. Total annual energy benefits from replacing fuel at Pejao steam plant in 10^3 contos.	19.8	19.8	19.7	20.8	20.6	20.5	20.4	6.0	15.0	7.0	5.2
20. Total annual energy benefits from replacing fuel at existing steam plants in 10^3 contos.	113.2	80.0	69.8	71.8	28.4	49.9	15.7	0	0	0	0
21. Net navigation benefits in 10^3 contos.	-	-	-	2.04	2.04	2.04	-	-	-	-	-
22. Total annual benefits in 10^3 contos.	175.0	134.2	122.5	124.94	75.44	99.54	55.9	10.8	26.9	12.7	9.4
23. Annual benefits ÷ annual cost including transmission.	2.77	2.56	2.51	2.11	1.32	1.72	1.12	0.61	0.84	0.57	0.25

*Based on the assumption that 75% of the energy generated at the tributary plants would be usable.

TABLE X-3

ECONOMIC COMPARISON OF PROJECTS

BASED ON INSTALLATIONS

WHEN REQUIRED IN ECONOMIC SEQUENCE

2 Years After Installation

Year of Incorporation Into Portuguese System	1959	1962	1964	1966	1967	1968	1969
1. Name of project.	Picote	Bemposta	Miranda	Carrapatelo	Regua	Valeira	Pocinho
2. River.	International Douro			Douro			
3. Installed capacity in kw.	93,000	65,500	60,600	69,000	30,400	35,000	22,300
4. Dependable capacity (at time of installation) in kw.	63,600	42,000	40,600	33,600	23,600	25,200	16,200
5. Usable average annual energy output in 10^6 x kwhr.	540	405	360	310	165	185	100
6. Capital cost of project, exclusive of transmission cost, in 10^3 contos.	466.8	368.1	316.5	490.7	354.6	329.5	263.3
7. Capital cost of transmission system, including switchyard in 10^3 contos.	129.2	74.8	93.5	28.9	18.6	26.8	19.6
8. Capital cost of project, including transmission system and switchyard, in 10^3 contos.	596.0	442.9	410.0	519.6	373.2	356.3	282.9
9. Annual cost of project, exclusive of transmission cost, in 10^3 contos.	43.8	37.37	30.38	45.50	31.71	30.45	23.48
10. Annual cost of project, including transmission and switchyard cost and losses, in 10^3 contos.	63.1	50.3	44.70	51.40	36.00	36.30	27.90
11. Annual cost including transmission, less navigation benefits, in 10^3 contos.	63.1	50.3	44.70	49.36	33.96	34.26	27.90
12. Cost of usable energy at Ermesinde (terminus of transmission line) in escudos per kwhr.	.117	.124	.124	.159	.206	.185	.279
13. Value of capacity at Ermesinde based on fixed charges of Pejao steam plant, in escudos per kw.	660.22	660.22	660.22	660.22	660.22	660.22	660.22
14. Value of energy at hydroelectric plant based on fuel cost at Pejao steam plant, in escudos per kwhr.	.121	.121	.120	.127	.126	.125	.124
15. Value of energy at hydroelectric plant based on fuel cost at existing steam plants, in escudos per kwhr.	.318	.319	.316	.334	.331	.328	.325
16. Average annual energy replacing fuel at Pejao steam plant in 10^6 kwhr.	164	164	164	164	164	164	100
17. Average annual energy replacing fuel at existing steam plants in 10^6 kwhr.	376	241	196	146	1	21	0
18. Total annual capacity benefits at Ermesinde, in 10^3 contos.	42.0	27.7	26.8	22.2	15.6	16.6	10.7
19. Total annual energy benefits from replacing fuel at Pejao steam plant in 10^3 contos.	19.8	19.8	19.7	20.8	20.6	20.5	12.4
20. Total annual energy benefit from replacing fuel at steam plants, in 10^3 contos.	119.7	76.9	62.0	48.8	0.3	6.9	0
21. Net navigation benefits in 10^3 contos.	-	-	-	2.04	2.04	2.04	-
22. Total annual benefits in 10^3 contos.	181.5	124.4	108.5	93.84	38.54	46.04	23.1
23. Annual benefits ÷ annual costs including transmission.	2.88	2.48	2.43	1.83	1.07	1.27	0.83

5 Years After Installation

Year of Incorporation Into Portuguese System	1959	1962	1964	1966	1967	1968	1969
1. Name of project.	Picote	Bemposta	Miranda	Carrapatelo	Regua	Valeira	Pocinho
2. River.	International Douro			Douro			
3. Installed capacity in kw.	93,000	65,500	60,600	69,000	30,400	35,000	22,300
4. Dependable capacity (at time of installation) in kw.	63,600	42,000	40,600	33,600	23,600	25,200	16,200
5. Usable average annual energy output in 10^6 x kwhr.	580	425	385	355	190	210	130
6. Capital cost of project, exclusive of transmission cost, in 10^3 contos.	466.8	368.1	316.5	490.7	354.6	329.5	263.3
7. Capital cost of transmission system, including switchyard in 10^3 contos.	129.2	74.8	93.5	28.9	18.6	26.8	19.6
8. Capital cost of project, including transmission system and switchyard, in 10^3 contos.	596.0	442.9	410.0	519.6	373.2	356.3	282.9
9. Annual cost of project, exclusive of transmission cost, in 10^3 contos.	43.8	37.37	30.38	45.50	31.71	30.45	23.48
10. Annual cost of project, including transmission and switchyard cost and losses, in 10^3 contos.	63.1	50.3	44.70	51.40	36.00	36.30	27.90
11. Annual cost including transmission, less navigation benefits, in 10^3 contos.	63.1	50.3	44.70	49.36	33.96	34.26	27.90
12. Cost of usable energy at Ermesinde (terminus of transmission line) in escudos per kwhr.	.109	.118	.116	.139	.179	.163	.215
13. Value of capacity at Ermesinde based on fixed charges of Pejao steam plant, in escudos per kw.	660.22	660.22	660.22	660.22	660.22	660.22	660.22
14. Value of energy at hydroelectric plant based on fuel cost at Pejao steam plant, in escudos per kwhr.	.121	.121	.120	.127	.126	.125	.124
15. Value of energy at hydroelectric plant based on fuel cost at existing steam plants, in escudos per kwhr.	.318	.319	.316	.334	.331	.328	.325
16. Average annual energy replacing fuel at Pejao steam plant in 10^6 kwhr.	164	164	164	164	164	164	130
17. Average annual energy replacing fuel at existing steam plants in 10^6 kwhr.	416	261	221	191	26	46	0
18. Total annual capacity benefits at Ermesinde, in 10^3 contos.	42.0	27.7	26.8	22.2	15.6	16.6	10.7
19. Total annual energy benefits from replacing fuel at Pejao steam plant in 10^3 contos.	19.8	19.8	19.7	20.8	20.6	20.5	16.1
20. Total annual energy benefit from replacing fuel at steam plants, in 10^3 contos.	132.4	83.3	69.9	63.8	8.6	15.1	0
21. Net navigation benefits in 10^3 contos.	-	-	-	2.04	2.04	2.04	-
22. Total annual benefits in 10^3 contos.	194.2	130.8	116.4	108.84	46.84	54.24	26.8
23. Annual benefits ÷ annual costs including transmission.	3.08	2.61	2.60	2.12	1.30	1.49	0.96

10 Years After Installation

Year of Incorporation Into Portuguese System	1959	1962	1964	1966	1967	1968	1969
1. Name of project.	Picote	Bemposta	Miranda	Carrapatelo	Regua	Valeira	Pocinho
2. River.	International Douro			Douro			
3. Installed capacity in kw.	93,000	65,500	60,600	69,000	30,400	35,000	22,300
4. Dependable capacity (at time of installation) in kw.	63,600	42,000	40,600	33,600	23,600	25,200	16,200
5. Usable average annual energy output in 10^6 x kwhr.	630	460	425	415	215	245	155
6. Capital cost of project, exclusive of transmission cost, in 10^3 contos.	466.8	368.1	316.5	490.7	354.6	329.5	263.3
7. Capital cost of transmission system, including switchyard in 10^3 contos.	129.2	74.8	93.5	28.9	18.6	26.8	19.6
8. Capital cost of project, including transmission system and switchyard, in 10^3 contos.	596.0	442.9	410.0	519.6	373.2	356.3	282.9
9. Annual cost of project, exclusive of transmission cost, in 10^3 contos.	43.8	37.37	30.38	45.50	31.71	30.45	23.48
10. Annual cost of project, including transmission and switchyard cost and losses, in 10^3 contos.	63.1	50.3	44.70	51.40	36.00	36.30	27.90
11. Annual cost including transmission, less navigation benefits, in 10^3 contos.	63.1	50.3	44.70	49.36	33.96	34.26	27.90
12. Cost of usable energy at Ermesinde (terminus of transmission line) in escudos per kwhr.	.100	.109	.105	.119	.158	.140	.180
13. Value of capacity at Ermesinde based on fixed charges of Pejao steam plant, in escudos per kw.	660.22	660.22	660.22	660.22	660.22	660.22	660.22
14. Value of energy at hydroelectric plant based on fuel cost at Pejao steam plant, in escudos per kwhr.	.121	.121	.120	.127	.126	.125	.124
15. Value of energy at hydroelectric plant based on fuel cost at existing steam plants, in escudos per kwhr.	.318	.319	.316	.334	.331	.328	.325
16. Average annual energy replacing fuel at Pejao steam plant in 10^6 kwhr.	164	164	164	164	164	164	155
17. Average annual energy replacing fuel at existing steam plants in 10^6 kwhr.	466	296	261	251	51	81	0
18. Total annual capacity benefits at Ermesinde, in 10^3 contos.	42.0	27.7	26.8	22.2	15.6	16.6	10.7
19. Total annual energy benefits from replacing fuel at Pejao steam plant in 10^3 contos.	19.8	19.8	19.7	20.8	20.6	20.5	19.2
20. Total annual energy benefit from replacing fuel at steam plants, in 10^3 contos.	148.2	94.5	82.5	83.8	16.9	26.6	0
21. Net navigation benefits in 10^3 contos.	-	-	-	2.04	2.04	2.04	-
22. Total annual benefits in 10^3 contos.	210.0	142.0	129.0	128.84	55.14	65.74	29.9
23. Annual benefits ÷ annual costs including transmission.	3.33	2.83	2.89	2.51	1.53	1.81	1.07

CHAPTER XI

THE PICOTE PROJECT

1. General

The Picote project would be for power only. The full pool with normal water-surface elevation at 471 m, would be formed by a dam 100 m high developing a head of 74 m. The powerhouse would contain three units having a total installed capacity of 93,000 kw. The total turbine discharge at full pool and rated output would be 155 m3/sec. For a concrete dam, either arch or gravity, the site 22.4 km above the mouth of the Tormes River is superior to others both topographically and geologically. For reasons which are discussed at length in subsequent paragraphs, a gravity dam with an overflow spillway will permit the most economical development of the site. An arch design which would require a chute and tunnel spillway through the right abutment was investigated, but it was found to be more expensive. A hollow or buttress type of dam would also probably be more costly because of the chute spillway which it would require.

2. Geology

A. Surface conditions - A steep-walled canyon section is found at km 22.40 where normal river is at elevation 397 m. At about the elevation of the proposed normal pool, the right (north or Portuguese) wall flattens and a natural cove with a low knoll of disintegrated rock is encountered.

The crest of the proposed dam will be readily accessible to a farm road following a descending spur from the upland southeast of Picote, which can be improved; or the topography is favorable for the construction of an entirely new access road.

The canyon is entirely in porphyritic to somewhat pegmatic granite. Disintegration forms a shallow, granular soil on the outer canyon slopes. No river deposits are visible and the stream apparently flows on rock.

Joint and fracture patterns are as follows:

(1) Strong vertical joints transverse (N 45° E) to the canyon.

(2) A less conspicuous complementary system of regional and nearly vertical joints almost paralleling the canyon.

(3) Flat or gentle joints visible on the left (south or Spanish) side, dipping 18° NW towards the river, striking N 25° E.

The diversion tunnel will be in porphyritic granite on the right abutment and explorations to date indicate that there will be apparently no special problems. At present, the average stripping to sound rock is estimated to be about 5 m within the area of the dam.

B. <u>Construction materials</u>: - Granite rock is the only material abundantly available. It has a coarse and porphyritic texture, but preliminary test pits in quarry sites near the dam indicate that satisfactory concrete aggregates can be made from the available granite. Similar material has been found satisfactory for other large dams in Portugal and Spain.

Soil in fields 1 1/2 km northeast of Picote, within 3-4 km of this site, is composed of sandy silt with rock fragments. The deposits would be more suitable for a semi-pervious fill than for the water-tight membrane of a rock-fill dam of this height. This factor precludes the use of a rock-fill dam with an impervious earthen core.

C. Foundation conditions and treatment:-- The formations in the reservoir area indicate granitic and schistose rocks. No caverns or solution channels have been observed and none would normally be expected in these types of rock. Considering this factor in conjunction with the height of the plateau on both sides of the river channel, the watertightness of the Picote reservoir is assured.

The dam will rest on a foundation of granite which exhibits strong joint patterns. The result of the first borings indicate that grouting will be necessary. Consolidation grouting at a comparatively shallow level will be used to tighten the foundation, including the abutments, and then a deeper grout curtain will be placed at the upstream edge of the dam on the foundation and along the abutments for seepage control. The curtain grouting can be done effectively from inside the gallery, shown in the cross-section of the dam on Plate 18, after the dam has been constructed above that elevation. Drain holes to relieve uplift pressure from the reservoir water would be drilled into the foundation immediately downstream from the grout curtain, and vertical drains would be installed the full height of the dam. The seepage from this and other parts of the drainage system will be collected in a gutter along the edge of the gallery floor and eventually discharged to the downstream side of the dam. The final details of foundation treatment will be determined after more complete subsurface explorations or during construction.

D. Exploration: - Design in detail of the dam should be preceded by some preliminary exploration program consisting at least of the following:

(1) Vertical drill holes in mid-river to a depth of 30 m below rock surface at the selected axis and downstream toe of the dam; or preferably, in order to disclose the presence of faults, angle holes cutting under the river reaching to the same depth.

(2) A steep angle hole, across the jointing, drilled into the base of each abutment.

(3) A similar steep angle hole near the crest on each abutment.

(4) A gallery into each abutment above normal high water level.

(5) Field and standard laboratory tests to demonstrate the availability and character of construction material.

A contract for the above work was approved by the Minister of Public Works in October 1952 and work was initiated at once. As of January 1953, two drill holes and a gallery on the right bank, and a test pit at a quarry site have been completed. The preliminary results have not revealed any unforeseen conditions.

3. Spillway Design Flood

The spillway of the proposed Picote project will be designed for a peak discharge of about 11,000 m3/sec. To justify this choice, the following circumstances are adduced:

(1) The projects immediately upstream, with the same drainage area, are designed for a maximum spillway discharge of about the same amount. Unless the upstream dams fail, they are not likely to release flows much in excess of that figure. In the event of such a failure, an extraordinary condition would be created against which it would be futile to try to design the spillway.

(2) The extremely long period of historic record indicates that the largest flood of record, the 7000 m3/sec experienced in 1909, is the greatest event in several hundred years or more, and can be considered to be representative of the flood producing potentialities of the basin. The proposed discharge of 11,000 m3/sec exceeds this rare event by fifty-seven percent and therefore contains an adequate factor of safety for such a large drainage area.

(3) The Ricobayo Reservoir with its vast amount of storage, is likely in the future, as it has in the past, to reduce the flood peaks.

(4) The valley storage upstream from Zamora will continue to modify floods from about 75% of the total drainage area.

(5) Meterological considerations reinforce the view that the proposed spillway capacity is adequate. For example, storms generally approach the basin from the southwest and travel upstream, causing the various tributaries to peak in advance of the peak from the drainage area upstream from the Esla River.

In view of all these factors, it is believed that 11,000 m3/sec is a reasonable and adequate figure for the design of the spillway.

4. Dam and Spillway

The dam will be the gravity concrete type with an overflow spillway having a gross width of 80 m controlled by four Tainter gates each 16.25 m wide by 17 m high separated by 5 m wide piers. The total net width of the spillway will be 65 meters. The water surface at the top of the gates at full pool elevation will be 471 m. The spillway crest will be at elevation 454 m. At the spillway design discharge of 11,000 m3/sec, the maximum water surface elevation will rise to 474 m, and the head on the spillway crest will be 20 meters.

The economics of a gated as against an ungated spillway were investigated. If an ungated spillway were used, maintaining the same normal pool elevation, the elevation of the maximum water surface, and of the dam, would be some 17 m higher, and the structure would contain considerably more concrete. Also, an additional area of land in the reservoir would be flooded frequently and would need to be purchased. Investigation showed that the cost of the gates would be much less than the additional cost of concrete and land incurred by omitting them. The use of crest gates would therefore be economical. Rather deep gates would be necessary because of the narrow spillway, but past experience with this type of problem indicates that deep gates are usually more economical than shallow ones.

As may be seen from the topography on Plate 18 the dam would be located at a constricted portion of the canyon formed by two massive rock knolls projecting toward each other. The possibility of an economical gravity dam with an overflow spillway at this location arises from the narrowness of the bottom of the section, where the gravity profile is normally widest in the direction of the flow of the stream. At the same time the width of the canyon at the top of the dam is adequate for the gross spillway width of 80 m. As the bottom of the canyon widens out immediately downstream from the constriction, the spillway discharge can be carried along the downstream slope of the spillway to a roller bucket stilling basin of adequate width, as shown on Plate 18. Since the bucket would be 50 m wide as against 80 m for the spillway, the spillway training walls must be brought together toward the bottom. This contraction can be accomplished most effectively by curving the spillway in plan as shown on the drawing. Some rock excavation will be necessary in order to provide the space for the downstream part of the spillway and the stilling basin. In areas near the abutments of the spillway there will be a concrete lining resting on the rock excavated on a slope and the training walls will consist of a concrete lining against the rock excavated vertically. The dam section shown in the drawing is conservative, and it may be possible in making a more detailed design, to reduce the section materially. Data are lacking, especially with regard to the roughness coefficient of the river channel, with which to compute with certainty the tailwater elevation for the higher discharges, but the probable depth of tailwater combined with the practical width of stilling basin makes a roller bucket practicable. This type is more economical than the hydraulic-jump basin. According to the elevations on the cross section shown on Plate 18, the depth of tailwater over the bucket at maximum spillway discharge will be about 18 percent in excess of that required to form the hydraulic jump, which is well within the limit of depth to assure the dissipation of the energy in the overfalling water by means of the system of hydraulic rollers developed with this type of structure. During operation, the spillway crest gates will have to be opened gradually, so as always to have a tailwater elevation consonant with the given discharge, and to avoid flip-bucket action which would deliver a jet near the foundation of the powerhouse in the location shown on Plate 18. In order to avoid unsymmetrical action, the gates should all be opened to the same extent. Training walls, or lining with top at maximum tailwater elevation, are required on each side of the bucket to protect the foundation of the dam. For estimating purposes these structures, together with concrete lining on the bottom, are shown as extending 50 m downstream to the beginning of the powerhouse. The training wall on the right bank is needed to protect the powerhouse, which otherwise would be exposed to direct impact (to an unknown degree) from the water in the stilling basin, but it is quite possible that further investigation will indicate that downstream from the bucket, the lining, both bottom and sides, and the left-bank training wall, as well, can be omitted, and that the rock beyond the bucket proper can be left unexcavated. It is believed that a hydraulic model test should be made of the stilling facilities, which will help to settle these points, among others.

With the powerhouse as shown on the drawing, a flip bucket could not be used, as the jet issuing from it would strike directly in front of the powerhouse. However, in the final design of the project, serious consideration will be given to an underground power plant location. In that case a flip bucket set high can be used or, if it were cheaper and confirmed by model tests, the roller bucket as illustrated, but without the downstream training walls and lining.

Located as it is on a river forming the boundary between Portugal and Spain, a necessary requirement of the project is that all possible elements be placed on Portuguese territory. The diversion tunnel and power facilities would therefore be located on the right bank. The attractive possibility is excluded of placing the power plant in the canyon at the base of the dam and directing the spillway discharge from a flip bucket over the powerhouse roof.

5. Diversion

The only feasible method of diversion during construction will be by means of a tunnel, because of the narrowness of the canyon. As may be seen from Table XI-I and Plate 19

TABLE XI-1

DAILY FLOOD PEAKS ABOVE 600 m^3/s. AT PUENTE PINO

DRAINAGE AREA = 63,300 Km^2

	JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
1937	-	-	-	-	-	-	-	-	-	-	-	912.5
1938	1100.0	-	-	-	-	-	--	-	-	-	840.6	600.0
1939	5250.0	875.0	806.2	1137.1	871.0	668.7	737.1	-	-	-	912.5	-
1940	1137.5	2062.5	1337.5	-	1137.5	-	-	-	-	-	-	-
1941	2250.0	2250.0	2062.5	1137.5	2109.4	1459.4	840.6	-	-	-	-	840.6
1942	-	-	950.0	950.0	1100.0	-	-	-	-	-	-	840.6
1943	1781.3	1197.5	912.5	840.6	875.0	-	-	-	-	-	875.0	634.4
1944	-	-	-	-	-	-	-	-	-	-	-	-
1945	-	-	-	-	-	-	-	-	-	-	-	-
1946	-	-	-	634.4	1875.0	840.6	-	-	-	-	-	-
1947	-	1875.0	2918.8	1640.6	806.3	-	-	-	-	-	-	-
1948	2250.0	2250.0	806.2	-	737.5	-	-	-	-	-	-	-
1949	-	-	-	-	-	-	-	-	-	-	-	-
1950	-	-	-	-	-	-	-	-	-	-	-	-
1951	-	1215.6	2625.0	840.6	771.9	-	-	-	-	-	-	-

which show the seasonal distribution of runoff, discharge in excess of 600 m3/sec have never been experienced during August, September, and October while the six-month period from July through December has not had flows exceeding 1000 m3/sec. With the recommended diversion capacity of 600 m3/sec, the chances are excellent that the coffer-dams would not be overtopped in the three driest months (August, september and October) but about once a year they would be overtopped in the remaining three low-flow months (July, November and December). Construction must be suspended during floods and the costs of the work interruption plus the subsequent dewatering and cleanup would have to be included as a contingency in the contractor's estimate. No great damage would result to the unfinished concrete dam. It would be economically out of reason to construct a cofferdam high enough to handle even those floods (2000 m3/sec) which can be expected yearly during the high-flood season, let alone the really large floods. An unlined tunnel 12 m in diameter and about 400 m long would divert the water around the dam and powerhouse area. The required head would be 6 m and would be provided by an upstream rockfill cofferdam. The cofferdam will need to be made watertight, and will be designed to act as a spillway for the larger floods, functions which might be fulfilled by covering the cofferdam with a concrete lining, both upstream and downstream. No impervious material exists in the area which could be used for a watertight core. The downstream cofferdam will be a concrete gravity section at a lower elevation. The diversion tunnel will have a concrete bell-shaped entrance provided with gate slots so the tunnel may be closed with a bulkhead. There will also be provisions to shut off the exit. The construction schedule must be adapted to the scheme of diversion. First will come the excavation of the tunnel, which can be started at any time after the flood season. The upstream cofferdam would then be constructed, say in June, and finally the downstream cofferdam will be built. During the low-flow months the foundation of the dam will be poured and the structure brought up as high as possible. When the floods arrive, the portion of the dam already constructed above the cofferdam level would act to increase the head and the discharge through the diversion tunnel. The higher the dam was built, the less the progress of construction would be hindered by floods. If the reservoir area is kept empty, some flood control benefit can be obtained by temporary use of the storage below the finished portion of the dam. The power facilities will be constructed behind the protection of the dam and of the downstream cofferdam.

6. Power Intake and Water Passages

The power intake will be located on the right side of the spillway in a non-overflow section which will be a continuation of the dam. It will consist of a concrete tower equipped with semicircular trashracks and having slots for service and emergency gates. The water passages will be controlled by broome-type gates actuated by hydraulic hoists, one gate for each of the three proposed units, with one emergency gate for the three openings. Each gate opening, 3.5 m wide by 6.0 m high, will be connected to a penstock by a transition section.

There will be three welded plate steel penstocks, each with a diameter of 4.3 m, which is an economical size for the discharge and the head under which they will operate. After running along an excavated open bench for about 120 m each penstock will connect to a tunnel, with a steel lining about 60 m long which will supply a turbine.

7. Factors Affecting the Capacity to be Installed

A. Firm energy - The primary function of the new plant will be to provide firm energy for the national system as required by the growing load. An increase in the assumed installed capacity of the run-of-river plant will result in an increase in the dependable capacity up to a certain point, after which no more capacity can be firmed up. It will be economical to install capacity at least corresponding to this point, which is 93,000 kw.

B. Increased capacity - Increased capacity might be desirable to aid in reducing fluctuations of daily flow during the month so as to be able to utilize some high discharges in a month of average low flow. A similar function will be fulfilled by the use of a moderate amount of pondage.

C. Peaking capacity - Although the proposal plant will be operating near the base of the load curve nevertheless there will be occasions when its band on the load-duration curve will have a load factor of less than 100%, which will require a certain amount of peaking capacity. In order to fit the energy corresponding to 93,000 kw on the load-duration curve above the full steam-electric output, an installed capacity of about 100,000 kw will be required (for September 1960), corresponding to a load factor of about 93%. The plant, on these very rare occasions, will be operating under maximum head, and can readily furnish this capacity through a generator overload of 8%, without violating the criteria of good practice.

D. Effect of load growth - As the load increases with the years, additional plants may be placed in the base, and the Picote plant may take a higher position on the load-duration curve, which again may require increased peaking capacity.

E. Additional storage developments in Spain - If additional regulation is developed in Spain on the Spanish Douro and its tributaries, the dependable capacity of the project will be increased, and it will be desirable to increase its installed capacity.

F. Future development of storage reservoirs and plants in Portugal - If additional storage capacity is developed elsewhere in Portugal, it may have the effect of firming up additional capacity at the Picote project, which will make it advisable to increase its installed capacity.

G. Situation during flood periods - The Douro River, both in its international and its national sections, runs through a narrow channel which in many places becomes a gorge. Consequently, during floods, a great rise in tailwater occurs which has reached 30 m at some of the sites. Depending on the head for which the turbines were designed, the capacity of the power plant will be somewhat curtailed during the flood periods. The effect will be more serious at the comparatively low-head plants on the National

Douro than at such a plant as the proposed Picote project, whose capacity will be only slightly curtailed even during the most severe flood. Actually, however, the effect of floods on the system output will be negligible even on the National Douro, for the following reasons:

(1) Douro River floods almost invariably occur at times when there is abundant water at other run-of-river hydroelectric plants, and the system capability at such times will be ample.

(2). The floods continue for only for a comparatively short time, a day or two at most for the really severe stages. During these short periods, the decrease in capacity easily can be supplemented, if necessary, by temporarily increasing the output of the existing plants at the storage reservoirs.

H. Additional capacity for standby - It might be desired to provide increased capacity for standby in the event of failure at other plants. However, this is not a critical matter in Portugal, because of the existing large installed capacity, and even if it were, Picote would not be the ideal location for it because of its long transmission line.

I. Energy - The theoretical energy output of the Picote plant will be very great. In an average year it will nearly equal the full plant capacity operating continuously, or about 815,000,000 kwhr. In practice, much of this energy can not be used, as it will be available when other existing plants will be producing a surplus, and consequently must be wasted. The actual usable output with an installed capacity of 93,000 kw would reach 630,000,000 kwhr annually 10 years after construction. Very likely it will become in time economical to increase the installed capacity of the plant above 93,000 kw in order to obtain additional secondary energy and save fuel at the existing steam-electric plants. However, this is contingent on whether or not it will be economical to replace the fuel-burning plants altogether. In any event, it is believed advisable to build other plants which will furnish firm energy and dependable capacity before increasing the capacity at Picote for the purpose of obtaining secondary energy.

It might be desired to increase the Picote capacity if winter and spring uses of secondary energy, such as domestic heating, were developed.

Weighing the factors enumerated above, it is concluded that 93,000 kw should be installed initially, but that provision be made in the design and construction of the power plant, intake and waterways, for future expansion to twice that capacity; or a total of 186,000 kw.

8. Powerhouse

A. Location and general plan - The generating plant will have three units with a total capacity of 93,000 kw at a head of 74 m corresponding to the full pool elevation 471 m. Dependable capacity will amount to 63,600 kw, which is almost the equivalent of the estimated capacity deficiency for 1960. Picote will, therefore, in conjunction with existing thermal plants and hydro-electric plants built and building, certainly meet the estimated national requirements beyond 1959. To do so by development of the Portuguese Douro would require the construction of two plants.

As mentioned previously, it will be necessary to place the Picote powerhouse wholly on Portuguese territory. Owing to the narrowness of the canyon, the longitudinal axis of the powerhouse must be parallel to the river, and the structure will be benched into the rock of the right bank. As shown on Plate 20 the power plant will consist of a substructure and turbine room, a generator room which will be about 15 m wide and 16 m high, and about 54 m long, including the service bay. A wing on the inside will contain various auxiliary facilities. The transformers will be placed on top of this wing and the switchyard proper will be suitably located on top of the right abutment. It is anticipated, from such information as is available, that the tailwater during maximum spillway discharge will rise about 30 m above its normal level. This condition dictates that the walls of the generator room be designed against a considerable head of water. They will be assumed to be cantilevers fixed at the bottom and simply supported laterally at the roof, and will be suitably reinforced. No windows will be provided. Access will be by means of a road at the level of the powerhouse roof or by other means if found to be more economical. A large opening provided with a hatch cover will be located in the roof over each of the generators. A hatch will also give access to the service bay. A gantry crane on top of the roof will move the equipment as required. The powerhouse substructure of concrete will need to be fairly massive to secure the building against flotation. As an additional precaution, anchor bars would engage the foundation rock, as shown on Plate 20. The substructure will contain the turbine scroll cases and the draft tubes, which will be reinforced to withstand the extreme rise in tailwater resulting from the maximum spillway discharge. One set of two draft tube bulkhead gates will be provided to permit dewatering one unit at a time. They will be handled by an extension of the gantry crane on the roof. The sump pumps will also be located in the substructure. A pit for untanking the transformers will be provided in the service bay substructure. The turbine floor will house the pipe gallery and cable tunnel, oil storage and purification facilities, and carbon dioxide cylinders for fire protection. The wing flanking the generator room will contain the control room, the switch gear, station service transformers, communications equipment, batteries and motor-generator sets, ventilating fans, a repair shop, offices and other facilities. A diesel electric set will be provided for standby service. A governor control cabinet will be located adjacent to each unit on the generator floor. The unit control board will also be on this floor.

B. Number of units - From the practical viewpoint, the choice in the number of units for the initial installation will lie between two and three. Three was thought to be preferable for the following reasons:

(1) With the smaller units, the rock excavation for the powerhouse will not be as great because of the less width of the power plant and the reduced depth of the draft-tube excavation.

(2) Transportation of the equipment to the site will be facilitated.

(3) The transmission line operation will be improved, if one of the units is suddenly thrown off the line.

C. Hydraulic turbines and accessories - The turbines will be of the vertical shaft Francis type, rated at 44,000 metric hp at full gate and a head of 64 m. The output will increase with the head up to 15% overload capacity of the generators. At higher heads, the generator capacity will limit the capability of the turbines which will be operated at part gate. They will operate near best efficiency at rated output and a maximum head of 74 m.

The turbines will have plate steel scroll cases. Their design and construction will be entrusted to manufacturers with a record of satisfactory achievement in this field. They will be equipped with all necessary accessories to insure adequate performance. The governors will be of the standard cabinet-actuator type.

D. Electrical equipment - The estimates have been based on having a normal rating of 38,750 kva, 0.8 power factor, 13,800 volts and a speed of 166.7 rpm. These characteristics are subject to review and revision in light of the results of the proposed network analyzer study. The generators will be provided with direct connected exciters and pilot exciters and each will have an enclosed ventilating system with watercooled heat exchangers. The air-operated brakes used to stop the revolving elements will also serve as hydraulic jacks to lift them. The generator neutral will be grounded through a disconnecting switch. Neutral impedance will be used if it is found desirable. The generator will be equipped with surge protective devices and current and potential transformers as required. The generator leads will be carried up to the main power transformers on the roof of the wing off of the generator room, through ducts in the massive powerhouse wall separating the two. Provision will be made to distribute local power. A local circuit breaker of suitable characteristics will be installed to isolate disturbances which may occur on these lines.

The estimates have also been based upon the transformation of the generator power to 150 kv, carried through a 150 kv circuit breaker to a 150 kv bus where, along with the output of other generators, it will be carried to a 150 kv transmission line. The transformers will be three-phase 13,800 volt Delta to 150,000 volt Wye grounded neutral. Transformers will be oil-insulated, self-cooled, with no-load tap changing. Station power will be carried at 440 volts to the load centers in the station. The generators and transformers be equipped with differential relaying of the proper characteristics. Central control of the installation will be provided by a control switchboard and annunciator in the control room.

9. Transmission Line to Ermesinde

Plate 5 shows in heavy dashed lines the approximate route selected for the transmission line between the International Douro and Ermesinde. It follows in general the course of the Douro River in order to serve the proposed future installations. For the Picote plant, two 150,000 volt circuits are planned to be carried by the same steel towers, each circuit consisting of three aluminum cable steel reinforced conductors, each with a cross-section of 636,000 circular mills. The total cost of the line was estimated to be 520 contos per km or 101,600 contos for the 1955 km from Picote to Ermesinde. The switchyard at Picote was estimated to cost 27,600 contos.

The Picote-Ermesinde line, using two circuits for the normal load of about 116 mva transmitted through a distance of about 195 km, closely follows existing Portuguese practice as exemplified by the 189 km Zezere-Porto high-tension line which uses a single circuit for the transmission at 150,000 volts, of a normal load of 60 mva that in emergencies may increase to 90 mva.

A two circuit 150,000 kv line was selected for transmission between Picote and Ermesinde because preliminary studies indicated that losses in initial operation will not be excessive and it seemed likely that operation at the same voltage as that of the existing national network will be feasible for a number of years, although obviously no firm determination can be made on this point until after the proposed network analyzer study has been completed.

Even if the network analyzer study indicates the desirability of operation of the Picote-Ermesinde line initially at 220 kv, the increase in cost of transmission and substation facilities including step-down transformation at Ermesinde will be less than 10% of the cost of the two circuit 150 kv line and substation accessories and therefore will not materially change the economic comparison between the Picote project and the other projects with which it has been compared.

In either case the selection of the project of first priority at this time will not have any substantial effect in determining the time in the future, if ever, when it will be economical to develop a national transmission network at a voltage higher than 150 kv. If and when such development becomes economical, it may best be determined at that time, taking into consideration the developments that have occurred in the system during the intervening period, whether such provision can be made most economically by the conversion of the existing system to 220 kv or by supplementing it with a separate grid at a higher voltage with transformer connections between the two networks.

10. Reservoir and Relocations

The reservoir area at full pool elevation 471 m is 241 hectares (see Plate 17). First-hand inspection of the International Douro revealed very little vegetation that would have to be removed and as it is understood that clearing has not been practiced on existing reservoir areas in Portugal, none is recommended here. The improvements that would be flooded out by the reservoir are negligible. Property will be acquired to full pool level and flowage rights obtained on land affected by the maximum spillway surcharge elevation of 474 m. No railroads, bridges or roads are known to exist within the reservoir area.

11. Stage Development

Provisions should be made for eventual expansion of the power plant to twice the initial capacity, for the reasons advanced above. Such provisions will include an extension of the non-overflow intake section, with the water passages bulkheaded off and with the stubs of the three future penstocks projecting from the concrete. They will include also the excavation for the future powerhouse substructure, and the necessary tunnel excavations, so that there will be no danger of damaging the functioning power plant and equipment through future blasting of the rock.

12. Alternative Designs

Various alternative modifications of the Picote project have been considered. Some appear to be uneconomical. Others will be investigated further.

A. Dam - In addition to the rockfill design, which will not be suitable for this site, and the gravity design, which is considered best, an arch dam was given considerable study, and a hollow dam was also investigated. An arch design was made, using a stress of 800 pounds per square inch. Precautions were taken in laying it out so that the thrust would be directed properly into the abutments. This matter is believed to be of some importance at this site because there might otherwise be danger of shearing off the knolls which form the constriction in the canyon, especially as geological inspection has shown the existence of a system of vertical joints paralleling the canyon. Therefore, the arch must be built in a wider section of the canyon than that selected for the gravity dam. The volume of concrete in the arch was found to be about 143,000 m3 as against 230,000 m3 for the gravity dam. However, whereas the spillway discharge will be taken over the top of the gravity section, it was believed inadvisable to do so in the case of the arch, because of the unprecedented volume of the discharge, and the 20 m head on the spillway. Consequently, a chute and tunnel type of spillway was laid out through the right abutment. The spillway works consisted of approach excavation, a gated concrete weir control, transition section, tunnel sections, and flip buckets. In order to carry the arch thrust over the spillway, the latter in the critical region was run through three parallel 15 m diameter tunnels each about 100 m long. A preliminary computation for the total cost of dam, spillway, diversion facilities during construction, and reservoir showed that the cost, including contingencies, would be 248,000 contos for the arch scheme against 232,000 contos for the gravity dam, showing that the latter would be the more economical.

Further consideration was given to taking the spillway discharge over the arch. If the jet were to spring free of the crest, it would strike the stream bed not far beyond the base of the dam. In addition to the possibility of dangerous vibration, it is likely that the annual maintenance and repairs resulting from a jet 20 m thick falling from a height of 100 m would make such a design undesirable. The destructive effect of the jet might be ameliorated by constructing a secondary dam downstream to create a permanent cushioning pool of water at the base of the spillway. This in itself would be a fairly costly structure and data upon which to base the depth of the pool are lacking. If on the other hand, the jet were diverted downward at the crest by a hood similar to the one at the existing Castelo do Bode project, the hood with its massive dimensions and heavy reinforcing, would also be quite expensive. In order to fit the jet somewhat better to the downstream face to minimize vibration and improve the hydraulic conditions at the base, the dam section would need to be thickened. A 60 per-cent increase in the arch section would make the volume of concrete equivalent to that for the gravity section. The concrete in the arch would be under heavy stress throughout. The concrete in the gravity dam would be under appreciable stress only in the lower-lying exterior portions, while the great mass in the interior of the dam would not be highly stressed. Consequently, economies could be obtained by making the interior of the gravity dam of leaner concrete than the surfaces, as has been done in some recent American dams. There is an additional advantage in that the leaner concrete is less susceptible to shrinkage cracks. The foundation conditions in the abutments may be found during construction to be critical for the arch dam and may require extensive further excavation and additional concrete whereas they are likely to be satisfactory for the gravity dam without any more excavation than has been assumed in the preliminary estimate. For these reasons it is believed that there will be no economic advantage in modifications of the arch design, while the practical disadvantages may be marked.

A hollow dam (round-head buttress type) with an overflow spillway would have the same disadvantages as the arch under the same conditions, namely the unprecedented head and discharge, and the risk of injury to the thin sections from excessive vibration. A hollow dam with a spillway through the abutment would be a possible solution, but it is believed inadvisable for the following reasons:

(1) The steepness of the canyon walls together with the character of the rock jointing would lead to serious problems in preparing a suitable foundation for the buttresses next to the abutments.

(2) There would be danger that the water pressure would build up behind lateral fissures in the abutments and scale off masses of rock which might injure the buttresses and even cause failure of the dam. The unusually high maximum tailwater might tend to aggravate this condition.

(3) The concrete in the hollow dam, as in the arch, would be under heavy stress throughout, and no economies would be practical through reduction in cement content.

(4) The cost of the formwork would increase the unit cost of the concrete still further.

(5) The net result probably would be that the cost of the hollow dam scheme, even with half the volume of concrete, would still exceed that of the gravity dam. Finally, the hollow dam at this site would be of unprecedented height, some 60 or 70 feet higher than the highest hollow dam ever built.

B. <u>Power facilities</u>: - It is intended to investigate a number of alternatives in the design of the intake, waterways and power plant. The scheme shown on Plate 20 offers the advantage of being able to shut off each unit and its penstock individually at the intake, along with easier access for maintenance and repairs, but it involves several areas of heavy open rock excavation. Other alternatives, however, would also permit shutdown of individual penstocks. Such would be the alternative of an underground power plant which would utilize the downstream portion of the diversion tunnel as a tailrace tunnel. The intake would connect with the plant by means of vertical shafts, one for each unit, controlled by butterfly valves at the turbine and, of course, also by gates at the intake. The advantage of this design would be to eliminate a large amount of open rock excavation, shorten the waterways and permit substantial economies in the spillway stilling basin. The disadvantages would be the necessity for much additional tunneling, the provision of butterfly valves at the turbine which might otherwise be omitted, and especially the provision for future expansion which would involve excavation of the penstock shafts and of the machine hall for the three future units so as not to disturb the installed machinery by blasting. The roof of the unused space would also need to be properly supported.

An alternative using the conventional powerhouse will be investigated using individual tunnels throughout, instead of steel penstocks.

Still another alternative to be studied would involve the use of the downstream portion of the diversion tunnel as a power waterway. The upstream portion would be shut off by a concrete plug. An intake placed fairly high would connect by means of a Wye branch with the downstream part of the tunnel. The latter would be lined with reinforced concrete and would have smaller branch tunnels leading to the turbines in the conventional type of powerhouse, each branch controlled by a butterfly valve at the turbine.

The most economical and generally satisfactory variant of the alternatives described will be adopted for the final design of the power facilities.

CHAPTER XII

DETAILED DESCRIPTION OF PROPOSED PROJECTS

1. Sequence of Development

The objective of Tables X-2 and X-3 was the determination of the hydroelectric project of first priority. They necessarily, therefore assumed in every case that the project under consideration would be the first plant to be added to the existing system; that it would accordingly have first claim on the market, following the claims of plants already in operation; and that the entire storage resources of Zezere and Cavado remaining after firming up existing run-of-river plants, would be available for firming up the energy generated at the new plant. It was assumed for purposes of comparison that whatever the plant selected, it would be added to the system in 1960; so the 1960 estimated power demand was used as the basis for the energy and capacity characteristics selected for each project investigated. It may have been too generous to include full navigation benefits when considering the lower three Portuguese Douro projects as "firsts", as navigation benefits would not be realized in full until all three projects had been completed.

In order to establish the characteristics and potentialities of the plants following Picote, if they are to be added in sequence over a period of years, further investigation was necessary. Successive installations deplete the reserves of storage available for firming-up the output, and the market available for power at the time of the next plant's installation. Conversely, with the passage of time following construction of a plant, load growth effects continuing improvement of the market for its power.

Using the sequence suggested by Table X-2, Table X-3 has been prepared (for the main stem, run-of-river projects) upon the assumption that each succeeding plant would be integrated into the system at the time at which growth in power demand required the use of its full dependable capacity; and that in each instance, all senior installations would have prior rights with respect both to the power market and to the storage available for firming-up the output. Total cost per kwh at Ermesinde, and the benefit-cost ratio have been worked out on the basis of the size of installation best suited to the needs of the system at the time the new plant is incorporated into it, and on the basis of the quantity of usuable dependable energy generated (1) in the second year of service, (2) in the fifth year of service and (3) in the tenth year, all as indicated by the curves of load growth developed by the survey.

The reduction in unit cost of energy with increase in length of service, and concurrent increase in demand which permits the absorption of a greater percentage of total output, is evident. It is apparent also that in some cases, economies in initial costs will be effected by a delay in the construction. In the case of Carrapatelo, for example, incorporation into the system in 1960 would require for proper development of the site, the installation of 87,000 kw of capacity at a cost of 552,000 contos. If introduced in 1966, only 69,000 kw of capacity would be required for optimum development of the site, at a cost of 490,700 contos.

In order to keep abreast of load growth, the plants must follow each other at intervals averaging less than two years. The proper sequence of construction would appear to be that indicated by the benefit-cost ratios of the second group of Table X-3; the second rather than the first group because the lower three Portuguese Douro projects would not actually realize full navigation benefits until all three were completed - say about five years after completion of Carrapatelo. On the basis of the cost per kwh at Ermesinde, and on the basis of benefit-cost ratio, the Pejao thermal plant would appear to take its permanent place in the system just ahead of Pocinho.

All of the foregoing comparisons and conclusions are based upon the assumption that the existing 100,000 kw thermal component is retained in the system. As the Pejao thermal plant could supply energy much more economically than existing thermal plants, it would be advantageous to build and use it at the earliest possible date if the existing thermal supplement is to be retained. As long as there is a need for as much as 25,000 kw of thermal power, it can be supplied most economically by Pejao. The Pejao total cost per kwhr at Ermesinde, that is, the additional cost that would be incurred if Pejao were built and operative is, 22.9 centavos. The cost of thermal power from existing plants, exclusive of fixed charges, that is, the costs that could be eliminated if their output were replaced by that of the Pejao plant, appears to be about 39.4 centavos. Thus by replacing 25,000 kw of existing thermal capacity by Pejao, an annual saving of 16.5 centavos per kwh on 164,250,000 kwhr of energy or about 27,167 contos would result. In addition, as imported fuel is predominantly employed in existing steam plants, an annual reduction of some 55,845 contos in foreign exchange would be realized.

2. Elimination of All Existing Thermal Generation

It is apparent from Table IX-8 that if Pejao energy costs 22.9 centavos at Ermesinde, the immediate replacement of existing thermal generation by construction of the best of the Douro hydroelectric plants would be even more advantageous than replacing a portion of it by the Pejao plant. Picote, for example, would furnish energy for about half the Pejao cost. The first conclusion is therefore, that it would be proper, in a program for immediate replacement of existing thermal power, to build all hydroelectric projects on the international part of the river and all but Pocinho on the Portuguese portion, before building Pejao.

It would, however, be physically possible to complete construction of the Pejao steam plant more rapidly than that of a hydroelectric plant. Pejao probably could be placed in service by 1955, while under the most optimistic assumptions as to funds, legal problems, engineering, and construction progress, it could scarcely be hoped that the three International Douro projects could be placed in operation before 1957. Yet, to replace thermal power completely and at the same time provide for growth in power demand, all three will be needed by 1957. During the two years 1955 to 1957 the Pejao plant would accumulate savings of about 54,000 contos, and would effect 111,600 contos reduction in foreign exchange. As soon as the low cost hydroelectric power from the three International Douro plants become available, Pejao theoretically would be relegated to stand-by status until after Carrapatelo, Regua and Valeire had been built, and their combined capacity was no longer able to supply the growing power market. At that time, about the middle of the year 1963, under the construction schedule premised, Pejao would resume as a permanent operating unit in the system. During the period of its lay-up, fixed charges would have continued on the thermal plant, and would have depleted the savings accumulated during the years of its advance operation. If the three International Douro plants actually were to be completed by 1957, and the Pejao plant retired from that time until mid-1963, its immediate construction still would show a saving of about 8,000 contos if it were designed for combustion of 20% or 18% ash coal, and of slightly under 500 contos if the design was for 45% ash fuel. If, as seems much more realistic, completion of the three International Douro plants is not accomplished for several years after 1957, or if there are delays in constructing subsequent plants, Pejao savings would increase many fold. It also might be possible to employ Pejao to advantage as a means of postponing for a year or so the construction of some of the hydroelectric plants and thereby bringing them into production less in advance of the growth of the market to proportions requiring the full output of their dependable capacity. It therefore appears advantageous to construct Pejao as soon as possible under whatever construction program may be adopted with respect to the hydroelectric plants.

The Pejao plant would supply the indicated deficiency of 4,000 kw indicated for 1956, if no additions other than Salamonde, Cabril, and Canicada were made to the presently operative hydro and steam installations in the meantime, and would eliminate the

"Remaining Deficiency" indicated on the August 1960 load duration curve of Plate 22.

Plate 23 shows, beginning with the year of 1956, curves of the annually increasing discrepancy between power demand and the firm capacity which can be supplied by the existing generating system, under four assumptions as to the magnitude of the latter's steam component. The lowest of the four curves assumes the present 100,000 kw of steam capacity is supplemented by Pejao, making a total of 125,000 kw of thermal power. The remaining three lines taken in order from right to left, assume, respectively, that the thermal component consists only of the present 100,000 kw; then that it includes Pejao only; and finally that there is no steam at all in the system. Plate 23 shows, for 1957 load conditions, assuming no thermal component other than Pejao, the contributions of existing hydroelectric plants and of Picote, Bemposta, and Pejao respectively, and the wasted energy from existing plants under a repetition of the stream flow experienced between 1942 and 1950.

If Picote, Bemposte, and Mirande could be completed by 1957, Carrapatelo by mid-1958, Regua by the middle of 1960, and Valeira by 1962, all thermal generation could be dispensed with for a period of about 6½ years by hydroelectric generation which would be cheaper than Pejao. Even under such a schedule the Pejao plant probably could be built and operated profitably for two years before cheaper hydro power could displace it, and 6½ years later it would become a permanent unit in the system, its re-activation to be followed within 18 months by completion of Pocinho. The Pocinho project presumably would be followed by plants on the tributaries, in the order suggested by the benefit-cost ratios of Table X-2.

As long as the order of construction is not changed, the graphs of Plate 22 may be used to analyse conditions and requirements under any fiscal program which it is desired to consider. The program depicted is probably more ideal rather than realistic as to timing, but to the extent to which it is realizable, existing thermal generation can be eliminated by hydroelectric and Pejao power with savings of great magnitude.

It seems hardly necessary to point out that this development study relates only to sites on the Douro River and its tributaries, and that the schedule of development shown ignores the possibility that sites may exist upon other river systems of such excellence as to warrant their development anterior to that of some of the Douro system sites.

After the Douro River and Douro tributary plants have been built, and the sites on other river systems developed, additional thermal power will be needed. It seems quite possible that before that time, continued exploration of potential coal deposits will have disclosed further reserves of sufficient magnitude to support additional thermal generating plants which will postpone the necessity of reverting to the use of imported fuel.

3. Sites and Plans Considered for Hydroelectric Development Following Project of First Priority.

The remainder of this chapter is devoted to a description and discussion of the hydroelectric projects that would follow Picote and would be required for development of the full hydro hydroelectric potential of the Douro and of the best sites on its Portuguese tributaries. Included are the Vilar-Tabuaco project on the Tavora (which, although it has already been authorized, is inserted to make the record complete), and certain pumped storage and flow diversion plans which appeared to offer promise but were found upon investigation to be uneconomical.

A. Bemposta Project - Bemposta, the most downstream of the projects on the International Douro, would be located at km 4.88 measured upstream from the Tormes River. The nearest Portuguese village is Urros. The location was chosen in preference to an alternative site at kilometer 1.25 because the cross-section of the valley at km 4.88 is relatively narrow and would result in a more economical project. It is also considered to be the best site geologically in the downstream section of the Portuguese part of the International Douro.

A long, gentle spur descends from the upland on the right (Portuguese) side. The crest of the dam would be readily accessible by construction road from Urros. Beyond Urros, a road 5 km long connects with the main road and the railroad.

This section of the canyon is comparatively narrow between opposing steep cliffs. The canyon is in granite, mostly medium to coarse-grained, however, with considerable amounts of the porphyritic variety. The river entirely occupies the narrow gorge and probably flows on bedrock.

Vertical joints trending N40°W - N55°W are common, at right angles to the river. It is a reasonable expectation that complementary vertical joints will be found beneath the river and in both abutments, paralleling the channel. Horizontal or gently dipping joints are normal to the rock in both abutments. These are in the nature of "lift" joints. Open, vertical joints appear on opposite abutments, especially downstream from the axis. All fractures would be investigated (and treated, if necessary) in the critical portion of the foundation.

A diversion tunnel on the right side would be entirely in granite of good quality. For the purpose of estimating, depth to fresh rock was assumed to be 5 meters into canyon walls and 10 meters over flat benches.

From a geologic standpoint, the site is suitable for any type of properly designed dam for which construction materials are available. No impervious alluvial material for an earth dam is visible in the vicinity of the canyon, although the search was not exhaustive for the upland area. The soil on the canyon slopes is only disintegrated rock, without significant clay content. Selected granite especially a medium-grained variety would probably make suitable crushed aggregate for concrete (assuming 20% waste). Tests would be required to confirm this. Sand, medium to coarse-grained, can be obtained in limited quantities from scattered deposits along the river. The mica content is perhaps 10%. Laboratory experiments, using standard test methods, and field search for construction materials, are needed before design studies are made in detail.

Existing serial cartographs (1/2,000 with 5 m contours) are reasonably satisfactory for general studies. They are inadequate for design and construction.

Preliminary exploration is required before detailed designs can be made. A minimum drill program would consist of:

(1) Vertical holes in mid-river at the axis and the downstream toe of the dam.

(2) Angle hole into the base of each abutment at the selected axis.

(3) Steep angle hole near crest of the dam on each abutment

(4) One exploratory gallery is desirable into each abutment at an elevation above the normal high water.

The elevation of the full pool would be limited to 397 m by the tailwater of the Picote Project upstream. Three (3) types of dams would be possible at this site, namely rockfill, arch and gravity. However, the saddle spillway in the right abutment would require too much excavation for an economical rock-fill dam. An arch dam with a saddle spillway would also be uneconomical, for the same reason. It is believed therefore, th t a gravity concrete dam with an overflow spillway would be the logical solution. Such a design was adopted for the purpose of this report. The spillway will be controlled by four tainter gates, each 16.25 m wide and 17 m high. The stilling basin will consist of a roller bucket flanked by training walls extending about 50 m downstream. The diversion facilities and the power plant will be located in Portugal. A power intake, located as far downstream as practicable, would connect with the diversion tunnel by means of an inclined shaft. The diversion tunnel would supply the power plant through branch tunnels leading to each unit. Upstream from the connection with the power intake and downstream from the branch tunnels, the diversion tunnel would be closed off. The power plant will be located immediately downstream from the stilling basin training wall and will be benched into the right bank sufficiently to be out of the way of the spillway discharge. The longitudinal axis of the plant will be almost parallel to the river, because of limited space. The head will be 59 m. If the plant were to be the first hydroelectric plant to be constructed, its installed capacity would be 76,000 kw. The dependable capacity would amount to 52,000 kw and the usable average annual energy would be 415,000,000 kwhr. The total cost of the project would be 393,000 contos. Its annual cost, including the transmission line, will be 52,500 contos. The benefit-cost ratio of the project will be 2.56 as compared with a new steam-electric plant at Pejao. It will produce usable energy at a cost of 0.124 escudos per kwhr delivered at the Ermesinde sub-station.

If it were built after Picote, in the economic sequence recommended, it would have an installed capacity of 65,500 kw. Its dependable capacity would be 42,000 kw. Its usable average annual energy output would increase from 405,000,000 kwhr two years after installation to 460,000,000 kwhr ten years after installation. The total cost of the project would be 368,100 contos. Its annual cost including transmission would be 50,300 contos. The benefit-cost ratio of the project would be 2.48 and the net cost of its energy would be 0.124 escudo per kwhr two years after installation. Ten years after installation the benefit-cost ratio would increase to 2.83 and the cost of its energy would fall to 0.109 escudos per kwhr.

B. Miranda Project - This project will be located on the International Douro River at km 43.5 measured upstream from the Tormes River. This **site** will develop nearly all the remaining head between the full pool elevation of the Picote project (471m) its full pool elevation of 527 m, which is determined by the necessity to avoid encroaching on the tailwater elevation of the Spanish Castro plant upstream. It will be about one (1) km from the village of Miranda. Access to river level will be difficult. However, the main road passes near the site, and there is a railroad station within 7 or 8 km.

The canyon is deeply incised between steep to vertical walls. The stream occupies the entire floor and no lateral ravine or bench affords space for accessory features needed at a power project. The gorge is cut predominantly in hard, coarse-grained to porphyritic granite. There are, however, on the upper levels adjoining the canyon, considerable masses and inliers of metamorphic rocks including zenoliths of mica and sericitic schist with gneiss.

Two patterns of regional joints, vertical to steeply inclined are seen in the walls of the canyon. These are fractures, NE-SW and NW-SE. The foundation rock is suitable for any type of dam. Rock is the only abundantly available construction material for the dam.

This site is about as narrow as can be adapted to the requirements for spillway width. There are no sites suitable for a rockfill dam with a saddle spillway anywhere in the Miranda reach. For the same reason, an arch dam with a chute spillway through the abutment would not be economical. Consequently, it appears that a gravity concrete dam with an overflow spillway will be the most economical alternative. The spillway will be controlled by four (4) tainter gates, each 16.25 m wide by 17 m high. The stilling basin will consist of a roller bucket flanked by training walls extending about 50 m downstream. The diversion facilities and the power plant will be located on Portuguese territory. The power plant will be benched into the right bank sufficiently to be out of the way of the spillway discharge. Because of limited space, its longitudinal axis will be parallel to the river. A power intake located as far downstream as practicable would connect with the diversion tunnel by means of an inclined shaft. The diversion tunnel would supply the power plant through branch tunnels leading to each unit. Upstream from the connection with the power intake and downstream from the branch tunnels, the diversion tunnel would be closed off. The head will be 55 m. If the project were the first to be constructed, the power plant would have a capacity of 72,000 kw. Its dependable capacity would be 50,000 kw and its usable energy output in the average year would amount to 385,000,000 kwhr. Its total cost would be 340,000 contos and its annual cost, including transmission, would be 47,500 contos. It would have a benefit-cost ratio of 2.58 as compared with a steam-electric plant at Pejao. It would produce usable energy at a cost of 0.124 escudos per kwhr delivered at the Ermesinde substation.

If it were built after Bemposta, in the economic sequence recommended, it would have an installed capacity of 60,600 kw.

Its dependable capacity would be 40,600 kw and its usable average annual energy output would increase from 360,000,000 kwhr two years after installation to 425,000,000 kwhr ten years after installation. The total cost of the project would be 316,500 contos. Its annual cost, including transmission, would be 42,500 contos. The benefit-cost ratio of the project would be 2.55 and its energy would cost 0.118 escudos per kwhr two years after installation. Ten years after installation, the benefit-cost ratio would increase to 3.04 and its energy cost would fall to 0.100 escudos per kwhr.

4. Projects on the National Douro River

A. General - The four projects on the National Douro River, namely the proposed Carrapatelo, Regua, Valeira and Pocinho Projects, would develop the head between elevation 10 and elevation 124 m. The lower elevation corresponds to the tailwater of the site farthest downstream, which would be suitable for a power dam; the higher elevation corresponds to the low water elevation at the mouth of the Huebra River, which is in the International reach of the river, but which was determined to be the usable upper limit of the National Douro by an agreement between Portugal and Spain dated August 11, 1927.

In general, the project sites are so disposed as to develop the total head in the minimum number of steps (four) without flooding the railroad which runs along the river. As this railroad is benched into steep slopes or canyon walls, or runs through tunnels, relocation of any appreciable length would be very costly. The pool of the Valeira dam, in addition would be limited by the elevation of the fertile Vilarica Valley, which would be flooded if the pool were raised much above elevation 104 m.

The Carrapatelo, Regua and Valeira Projects will be equipped with navigation locks. Together with two low navigation dams, between Porto and Carrapatelo, they will be adequate to pass existing river traffic. The Pocinho project proper would not have any provisions for navigation, since there seems to be little likelihood of any important traffic developing beyond that point.

The proposed projects would have comparatively little usable storage, only enough to furnish pondage regulation over a week-end or for a Spanish holiday. Essentially, therefore, they would be run-of-the river projects obtaining considerable low-flow regulation from the large Ricobayo Reservoir on the Esla River in Spain. Owing to their limited storage capacities, they would have a negligible effect on the Douro River floods.

No irrigation development is contemplated in connection with the projects on the National Douro although if the Pocinho project were built it might be desirable to divert water from its pool to the Vilarica Valley (see Chapter V).

In the future development of the National Douro, the logical sequence of construction would be to begin with the site farthest downstream and develop the sites in order, for the purpose of obtaining the benefits from navigation from the mouth, as early as possible.

For the purpose of evaluating the economics of the projects, they were, with the exception of Pocinho, designed with locks 11 m wide and 45 m long, which would be adequate to pass existing river traffic. As these would be required in any event, their cost was included as a part of the cost of power development. The economics of navigation were then based on the increase in cost of providing larger locks 17 m wide and 85.5 m long for the larger craft which would accompany a decided increase in commerce.

B. Carrapatelo Project - The Carrapatelo project, the most economical of those wholly in Portugal, would be a combined power and navigation project located on the Douro River at latitude 41° 5'.2 north and longitude 8° 7'.9 West of Greenwich at a locality named Carrapatelo.

At the dam site, the left (south) abutment rests on a projecting, fairly narrow ridge where the gaging station is located. The low-water discharge is now carried by two separate channels in rock, the deeper being on the left side. The slope of the right (north) abutment is uniform but rock is progressively more weathered and even covered by vegetation at higher levels.

Short access roads could connect to roads on either side of the river, and the railroad is at a distance of about 4 km. The site is relatively accessible for construction and operation of the dam. Due to width of valley, construction probably could be handled safely by cofferdamming the working areas and constructing the project in stages without resorting to diversion tunnels.

The area is contained within coarse-grained, somewhat porphyritic granite. Disintegration of rock on the valley sides is progressively greater with increased elevation but only sandy soil is found in the farmed land.

The river has formed deposits of sand and gravel in bars along the channel. It is understood that these materials have been sampled as aggregate and that they yielded acceptable results, tested in the laboratory. The bars apparently have material not larger than 3 inches in diameter.

Field and laboratory tests to establish adequacy and character of aggregate have been made.

No conspicuous fracture patterns are readily discerned. Careful study and investigation probably will establish structural features in bedrock of consequence to construction.

It is estimated that stripping at an average depth of 5 m would suffice for preparation of the foundation.

Five holes were drilled. Additional exploration by drilling will be needed for detailed design in view of the width of the canyon.

Relocations in the reservoir will include some sections of road, the raising of a few bridges, the elimination of two small villages totalling a few dozen dwellings, and the moving of the buildings of the thermal establishment of Aregos, whose hot springs will not be impaired.

For the purpose of this report, the same type of structure was assumed as shown in the 1948 report of the Portuguese Hydraulic Services. The dam will consist of a concrete gravity overflow section controlled by eight lift gates, each 22 m wide and 11 m high. Tainter gates will not be practicable at this site or at any of the other projects on the National Douro, because the tailwater would rise high above the spillway crest during a major flood. The spillway will have a capacity of 18,000 m3/sec at a head corresponding to full pool elevation of 46 m. A two-stage lock will be provided.

The power intake will be a continuation of the dam and will be integral with the power plant, the space for which will be excavated partly into the rock of the left abutment. The head developed will be 36 m. If Carrapatelo were to be the first hydroelectric plant to be constructed, its installed capacity would be 87,300 kw, of which 45,800 kw would be dependable. The usable average annual energy output would be 379,300,000 kwhr. The project would cost 552,000 contos. Its annual cost, including transmission cost and losses, would be 58,950 contos. Its overall benefit-cost ratio, including net navigation benefits, would be 2.12. It would produce usable energy at a net cost of 0.150 escudos per kwhr delivered at the Ermesinde sub-station.

If Carrapatelo were built after Miranda, in the economic sequence recommended, it would have an installed capacity of 69,000 kw. Its usable average annual energy output would increase from 310,000,000 kwhr two years after installation, to 415,000,000 kwhr ten years after installation. The total cost of the project would be 490,700 contos. Its annual cost, including transmission would be 51,000 contos. Taking benefits from navigation into account, the benefit-cost ratio of the project would be 1.84 and its energy cost would be 0.158 escudos per kwhr two years after installation. Ten years after installation, the benefit-cost ratio would increase to 2.53 and the energy cost would fall to 0.118 escudos per kwhr.

C. Regua Project - The Regua project would be a combined power and navigation project, located on the Douro River at latitude 41° 9' north and longitude 7° 44'.1 west of Greenwich, at km 107 on the railroad, which runs along the north side of the Douro River. In addition to the railroad on the north side, access will be furnished by a highway passing along the south bank at the site.

The dam will have a crest length of about 300 m (river width of about 200 m) so that stage construction without a diversion tunnel appears possible.

The valley is entrenched in metamorphic rocks, chiefly quartz-biotite schist and gneiss. Foliation is about at right angles to the river and with a dip of roughly 20°-30° downstream. Jointing is most apparent conformable to foliation, with downstream dip of 20°-30°. Rock is exposed extensively on the left (south) bank and in part of the valley bottom but not over much of the right bank. Soil covering on the slopes of the valley is thin. At higher elevations, talus is general.

A divergence in strike of schistosity on opposite sides of the valley has been considered by some observers as indicative of a possible fault. This zone is not readily apparent but may be demonstrated upon further investigation. Consideration should be given to possible sliding along schistosity and to variation in rock support.

A principal difficulty at this site is lack of construction materials in the vicinity. The gneiss and schist would not supply suitable crushed aggregate. Nor enough river deposits to produce the required volumes of sand and gravel. Aggregate could be hauled by railroad, however.

Detailed investigations, and field and laboratory studies coupled with suitable engineering analysis should be made to determine the suitability of this site.

Relocations in the reservoir will include a total of about 16 km of National Road No. 222 and the raising of one masonry bridge.

The dam would consist of a concrete gravity overflow section, with a crest length of about 300 m, controlled by eight lift gates, each 21 m wide and 11 m high. The spillway will have a capacity of 17,000 m3/sec a head corresponding to full pool elevation of 73 m. The power intake will be a continuation of the dam and will be integral with the power plant, which will be located on the right bank of the river. The head developed would be 27 m. If Regua were to be the first hydroelectric plant constructed, its installed capacity would be 70,000 kw, of which 37,000 kw would be dependable. The usable average annual energy output would be 250,000,000 kwhr. The project would cost 526,000 contos. Its annual cost, including transmission would be 56,580 contos. Its benefit-cost ratio, including navigation benefits would be 1.33. It would produce energy at a net cost of 0.218 escudos per kwhr delivered at the Ermesinde sub-station.

If the Regua Dam were built after Carrapatelo, in the economic sequence recommended, it would have an installed capacity of 30,400 kw. Its dependable capacity would be 23,600 kw. Its usable average annual energy would increase from

165,000,000 kwhr two years after installation to 215,000,000 kwhr ten years after installation. The total cost of the project would be 354,600 contos. Its annual cost, including transmission would be 35,700 contos. Taking navigation benefits into account, the benefit-cost ratio of the project would be 1.08 and the net cost of its energy would be 0.204 escudos per kwhr two years after installation. Ten years after installation the benefit-cost ratio would increase to 1.54 and the cost of its energy would fall to 0.157 escudos per kwhr.

D. Valeira Project - The Valeira project will be a combined power and navigation project located on the Douro River at latitude 41° 9'.6 north and longitude 7° 22'.7 west of Greenwich, at km 147 on the Douro River railroad. Access to the site will be easy from the railroad, which runs along the Douro River. An access road, two or three km long, could easily be built to connect with a highway south of the river. The relocations required in the reservoir would be insignificant.

The dam site is believed to lie in a schist formation. Rock appears to be about 1.5 m below streambed level. The valley at the site is wide enough so that the working areas could be cofferdammed and the project built in stages, without resorting to diversion tunnels.

The dam will consist of a concrete gravity overflow section controlled by seven lift gates, each 22 m wide and 11 m high. The spillway would have a capacity of 15,500 m3/sec at a head corresponding to full pool elevation of 104 m. A two-stage lock will be provided. The power intake will be a continuation of the dam and would be integral with the power plant, which will be located on the left bank of the river. The head developed will be 31 m. If Valeira were to be the first hydroelectric plant to be constructed, its installed capacity would be 77,000 kw, of which 41,000 kw would be dependable. The usable average annual energy output would be 316,100,000 kwhr. The project would cost 494,000 contos. Its annual cost, including transmission would be 57,360 contos. Its benefit-cost ratio, including navigation benefits would be 1.74. It would produce energy at a net cost of 0.175 escudos per kwhr delivered at the Ermesinde sub-station.

Although Valeira is a more economical project than Regua, it is recommended that it be built later, because Regua, being the next project downstream, would be required for continuity of navigation. If Valeira were constructed after Regua, in the sequence recommended, it would have an installed capacity of 35,000 kw. Its dependable capacity would be 25,200 kw. Its usable average annual energy output would increase from 185,000,000 kwhr two years after installation to 245,000,000 kwhr ten years after installation. The total cost of the project would be 329,500 contos. Its annual cost, including transmission would be 35,400 contos. Taking navigation benefits into account, the benefit-cost ratio of the project would be 1.30 and the net cost of its energy would be 0.180 escudos per kwhr two years after installation. Ten years after installation the benefit-cost ratio would increase to 1.86 and the cost of its energy would fall to 0.136 escudos per kwhr.

E. Pocinho Project - The Pocinho project would be a power project located on the Douro River at latitude 41° 8' north and longitude 7° 7'.6 west of Greenwich, just downstream from the bridge at Pocinho, the deck of which is well above the proposed full pool. Access would be available by the existing railroad and highway at the site.

Rock exposed in scattered outcrops in both abutments and in places on the valley floor is micaceous schist with dark slate. Foliation strikes obliquely across the river in an approximate east-west direction such that the dip is steeply downstream but towards the left (SE) abutment. Weathered rock and surface wash conceal the bedrock features over most of the valley's slopes. The limited outcrops near the highway bridge do not show any significant features in the bedrock. The strong tilt of foliation, if maintained, would eliminate cleavage as an important weakness of rock in the foundation. The rock seems sufficiently hard and sound to support any type of dam of the probable size needed at this site.

Downstream on the south (left) side of the river is an extensive terrace. This area may be underlain by river deposits which, if gravelly, would be useful for construction of the dam.

Availability of materials is unknown. The metamorphic rocks, schists and slate, in the bedrock series of the canyon are unsuited for crushed aggregate or as material for a rock-fill dam. Perhaps gravel deposits exist in the terrace south of the river or near the south of the Sabor River, 5 km downstream. This probably requires study in advance of design considerations.

The relocations required in the reservoir would be of little consequence.

The dam will be concrete gravity founded on rock with an overflow section flanked by abutment sections extending into the overburden material to intersection with sound rock. The full pool elevation will be 124 m. The spillway will be controlled by seven lift gates each 20 m wide and 11 m high, and would have a discharge capacity of 14,500 m3/sec. The power intake will be integral with the power plant. It will be located between the spillway and the left abutment section and will form part of the dam. The head developed will be 20 m. If Pocinho were to be the first hydroelectric plant to be constructed, its installed capacity would be 57,000 kw, of which 30,000 kw would be dependable. The usable average annual energy output would be 212,400,000 kwhr. The project would cost 420,000 contos. Its annual cost, including transmission, would be 48,090 contos. Its benefit-cost ratio would be 1.16. It would produce energy at a cost of 0.226 escudos per kwhr delivered at the Ermesinde sub-station.

If it were built after Valeira, in the economic sequence recommended, it would have an installed capacity of 22,300 kw, of which 16,200 kw would be dependable. Its usable average annual energy output would increase from 100,000,000 kwhr two years after installation to 155,000,000 kwhr ten years after installation. The total cost of the project would be 263,300 contos. Its annual cost, including transmission would be 27,400 contos. The benefit-cost ratio of the project would be 0.84 and the cost of its energy would be 0.274 escudos per kwhr two years after installation. Ten years after installation, the benefit-cost ratio would increase to 1.09 and the cost of its energy would fall to 0.177 escudos per kwhr.

5. Tributary Plants

A. General - The four power sites of greatest promise were investigated on four tributaries of the Douro River; namely, the Fragas da Torro project on the Paiva River, the Vilar-Tabuaco project on the Tavora River, the Laranjeiras project on the Sabor River, and the Vale de Madeira project on the Coa River. These projects would all have considerable reservoir storage, but owing to insufficient average rainfall, small drainage areas, or both, their energy output is comparatively modest. Their firm output was found to be smaller than had been shown in studies made by previous investigators who did not have available the streamflow records for the 1944-45 and 1949 periods of drought.

The firming-up capabilities of each plant would differ depending upon whether or not it was the first to be built. If it were the first, it would have to provide dependable capacity at a constant rate during the long dry period of 1944-45, in addition to the regulation already provided by the existing storage plants. The capacity contributed would then correspond to the firm output of the plant when considered in isolation, as the existing reservoir plants would leave a long flat trough in the load curve rather than a stepped valley, to be filled in by the new plant. As the studies indicated that the existing plants have sufficient peaking capacity to take care of system requirements for a long time to come, the new tributary plants would provide firm energy during drought periods in the base of the load duration curve. Because of all these factors, it was found that the tributary plants were not as attractive economically as the plants on the main river.

If the tributary plants were constructed after the main-river development was completed, they would benefit from a number of new circumstances.. The introduction of the comparatively large plants on the International Douro River has the effect of transferring the critical drought period for the system as a whole from 1944-45 to 1949. In this shorter drought period, the storage of the new tributary plants would be used to better advantage to increase their effective contribution of dependable capacity. The previously constructed plants on the National Douro River would benefit from the regulated flow of the tributary plants. The increase in dependable capacity from this source would be proportional to the sum of the heads at all the main river plants downstream from a given tributary plant. Although the dependable capacities contributed by the tributary plants would increase, and therefore more capacity would be installed, the additional energy available would be small, by no means proportional to the additional capacity. Consequently the cost of energy at the tributary plants would remain higher than at the main river plants. It is believed that when growth in load requires it, new studies should be made of the economics of the tributary plants in the light of new facts which may be apparent at that time. The following descriptions of the proposed plants are based on the assumption that each plant would be the first to be constructed.

B. <u>Fracas da Torre project</u> - The proposed Fragas da Torre project on the Paiva River appears to be the best of the tributary projects, chiefly because of its comparatively high runoff. The drainage area would be 663 km^2. The dam would be on the Paiva River about 0.25 km downstream from the Ponte de Alvarenga, at latitude 40° 57'.5 north and longitude 8° 10'.5 west of Greenwich. The plant, located about 1 km upstream from the mouth of the river, would be supplied by a concrete-lined tunnel 14,400 m long with a diameter of 2.97 m. The 85 meter-high concrete gravity dam with full pool at elevation 250 m would form a reservoir having a useful storage capacity of 258,000,000 m^3. The gross head developed would be 240 m. A surge tank excavated in rock would be located at the end of a tunnel from which a steel penstock would supply the plant. A regulated flow of 13.9 m3/sec combined with the average head, would result in a dependable capacity of 18,000 kw in the critical dry period. With this installed capacity, the average annual energy generated would be 157,900,000 kwhr of which it is assumed that 75%, or 118,400,000 kwhr would be usable. The capital cost of the project would be 346,000 contos. The annual cost, including transmission line costs and losses would be 31,870 contos. The benefit-cost ratio would be 0.84 as compared with a new steam plant at Pejao. The cost of energy at Ermesinde would be 0.270 escudos per kwhr.

C. Laranjeiras project - The proposed Laranjeiras project on the Sabor River appears to be the least economical of the tributary projects, because its available head would be small in comparison with that at the other tributary plants, and its high dam would be expensive. The runoff from its drainage area of 3460 km^2 average 22 m^3/sec, or 0.0064 $m^3/sec/km^2$, which is smaller than that from any of the other tributaries investigated. The project would be a combined power and irrigation project located at latitude 41° 13' north and longitude 7° 3'.5 west of Greenwich, about 6.5 km in a direct line from the mouth of the Sabor River. The 104 m high concrete gravity dam with full pool at elevation 207 m above mean sea level would form a reservoir having a useful storage capacity of 460,000,000 m^3. A morning glory spillway in the left abutment, with a shaft diameter of 12 m would make use of the downstream portion of the tunnel used for diversion during construction. An irrigation outlet through the right abutment would divert water into a tunnel approximately at right angles to the reservoir through a ridge into the Vilarica Valley. Inasmuch as this diversion for irrigation, which averages 0.77 m^3/sec (see Table XII-1) would be lost to power production, allowances were made for it in the power estimates. The power plant, located at the dam, would develop a gross head of 95 m. A regulated flow of 9.8 m^3/sec, combined with the average head, would result in a dependable capacity of 6400 kw during the critical dry period. With this installed capacity, the average annual energy generated would amount to 56,100,000 kwhr of which it is assumed that 75%, or 42,100,000 kwhr, would be usable. It is believed that the benefits from irrigation would be used to repay the expense of the irrigation project proper (irrigation outlet, tunnel, canals, laterals, pumps) without leaving very much in excess for the dam. However, an allowance of 2.5% of the cost of the dam and reservoir was deducted and assumed to be paid for out of the irrigation benefits. The capital cost of the power project, after this deduction, would be 427,000 contos. The annual cost, including transmission costs and losses, would be 37,800 contos. The benefit-cost ratio would be 0.25 as compared with a new steam plant at Pejao. The cost of energy at Ermesinde would be 0.90 escudos per kilowatt-hour.

TABLE XII-1

RECOMMENDED IRRIGATION RELEASES FOR

VILARICA VALLEY

Month	Irrigation release in cubic meters per second
January	0
February	0
March	0
April	0.41
May	0.64
June	0.78
July	1.03
August	1.03
September	0.77
October	0.46
November	0
December	0

D. Vale De Madeira project - The proposed Vale de Madeira Project on the Coa River is a storage project whose head would be developed by means of a dam, an underground power plant and a tailrace tunnel. The drainage area at the dam site would be 1150 km^2. The dam would be located at latitude 40° 48'.2 north and longitude 7° 0'.9 west of Greenwich, about 4.8 km northeast of the town of Pinhel. The dam, 105 m high would be an arch in its upper portion and a buttress dam in its lower portion, and would function as a combined arch and gravity structure. This design, which was developed by European consultants, was used to obtain the economies of the project. Before final approval for construction, however, it should receive extended study of a scope not possible in this report for a low priority project. The reservoir at full pool elevation 530 meters, would have a useful storage capacity of 311,000,000 m^3. The underground power plant located at the dam would operate under a gross head of 195 m, and would discharge into a tailrace tunnel 2160 m long emptying at a point downstream on the Coa River. A regulated flow of 5.92 m^3/sec, combined with the average head, would result in a dependable capacity of 8700 kw in the critical dry period. With this installed capacity, the average annual energy generated would be 76,200,000 kwhr, of which it is assumed that 75% or 57,200,000 kwhr would be usable. The capital cost of the project would be 225,000 contos. The annual cost, including transmission costs and losses, would be 22,180 contos. The benefit-cost ratio would be 0.57 as compared with a new steam plant at Pejao. The cost of energy at Ermesinde would be 0.388 escudos per kwhr.

E. <u>Vilar-Tabuaco project</u> - The proposed Vilar-Tabuaco project on the Tavora River is a storage project whose head would be developed principally by a canal, tunnel and penstock, having a combined length of 17,600 m. The drainage area at the dam site would be 362 km^2. The dam would be located at latitude 40° 58'.8 north and longitude 7° 32' west of Greenwich, about 1.5 km north-east of the village of Vilar. The Vilar plant would be located at the dam, and the Tabuaco plant would be located downstream, about 1 km east of the village of Tabuaco. The 49 m high gravity dam, with full pool at elevation 552 m, would form a reservoir having a useful storage capacity of 86,000,000 m^3. The small Vilar plant at the dam would be under a maximum gross head of 24.5 m^3. Its tailrace would discharge into a side-hill canal of trapezoidal cross-section about 8,300 m long interrupted by two tunnels, respectively 116 m and 160 m in length. The water would then enter a concrete-lined tunnel about 8500 m long, with a diameter of 2 m. A surge tank would be excavated in the rock at the end of the tunnel from which a steel penstock about 800 m long would connect with the Tabuaco power plant, which would operate under a maximum gross head of 386 m. A regulated flow of 2.27 m^3/sec, combined with the average head, would result in a dependable capacity of 7250 kw for the combined plants during the initial dry period. The installed capacity would be 350 kw at Vilar and 7250 kw at Tabuaco. With this installed capacity, the average annual energy output would be 64,100,000 kwhr, of which it is assumed that 75% or 48,100,000 kwhr would be usable. The capital cost of the project would be 169,000 contos. The annual cost, including transmission costs and losses, would be 17,610 contos.

The benefit-cost ratio would be 0.61 as compared with a new steam plant at Pejao. The cost of energy at Ermesinde would be 0.366 escudos per kwhr.

It is our understanding that the Portuguese Government has granted the concessions for the construction of this project under the policy that hydroelectric power should be used to decrease the consumption of costly imported coal at the existing steam-electric plants. The reservoir accordingly could be operated on an annual basis, being drawn down whenever necessary to reduce the requirements from the steam plants. As the storage would be nearly exhausted at the end of each season, the plant would furnish practically no support during drought periods, and could therefore be disregarded in estimates of system dependable capacity. The assumption is also made that the effect of the plant on the amount of energy which can be marketed by the proposed main-river plants would be negligible.

An economic investigation showed that the proposed Tavora plants would be economical for the purpose intended. Computations based on comparing an increment in investment in capacity with an increment in benefits from fuel replacement showed that it would be profitable to install up to 15,000 kw, assuming that all the energy produced could be sold. The installed capacity would amount to 700 kw at the Vilar plant and 14,300 kw at the Tabuaco plant. With this installed capacity, the average annual energy output would be 74,300,000 kwhr. The capital cost of the project would be 188,000 contos. The annual cost, including transmission costs and losses would be 21,370 contos. The benefits from savings in fuel would amount to 24,400 contos annually. The plant therefore would show a net saving of 3,030 contos annually and since it has already received official approval, it could begin to realize these benefits at a comparatively early date.

F. Pumped-storage project - A pumped-storage scheme was developed, combining the Carrapatelo project with the Sabor project whereby the Carrapatelo project with an installed capacity of 73,400 kw would be used during periods of abundant flow to supply energy for pumping water from the Douro River into the Laranjeiras Reservoir on the Sabor River by means of a concrete-lined tunnel 6500 m long and 4.4 m in diameter extending from the mouth of the Sabor River to the reservoir. A pumping plant with a capacity of 22,400 kw would share the same building with the Sabor power plant having a capacity of 25,800 kw and the same tunnel would be used for pumping and generating. The pumped water would be stored in the Laranjeiras reservoir having full pool elevation 207 m above mean sea level, and would be released during periods of drought to generate power at the Sabor power plant and at the Carrapatelo plant downstream. The flows of the Sabor River were included in the computations. The dependable capacity of the combination would total 51,000 kw. It would have a capital cost of 1,094,000 contos and an annual cost of 97,100 contos excluding transmission. No charge was made for the Carrapatelo energy used for pumping. Considering the project in isolation, it seemed at first as though the pumping feature would add about 7,500 kw above the dependable capacity of a project consisting of the Carrapatelo plant firmed up by the Sabor plant, without pumping. The additional annual cost of the pumping provisions would be about 26,000 contos which comes to about 3,500 escudos per kw of dependable capacity. This would make it more expensive than any project considered on the tributaries except the Laranjeiras project as much. However, even this estimate proved to be too optimistic. When the pumped-storage project was firmed up by the re-regulation of the Zezere reservoirs, it was found that the dependable capacity, about 52,000 kw, was exactly the same as the firmed-up dependable capacity of the two projects without pumping. Therefore, the pumped-storage element would contribute nothing, while its expense would be great. Consequently, it was eliminated from further consideration.

G. Diversion from the International Douro - We have investigated the economics of a diversion scheme from the International Douro into the Laranjeiras Reservoir on the Sabor River. As two Spanish power plants eventually would be located downstream from the diversion in the lower section of the International Douro, one under construction (Saucelle), and one proposed (Aldeadavila), we have assumed that only the excess over the maximum usable flow at these plants could be diverted. Investigation indicates that this figure would be 450 m^3/sec, corresponding to the full output of the Aldeadavila Project. Under these circumstances, the Laranjeiras Reservoir capacity would need to be very large, because there are long periods of time when no water could be diverted from the International Douro because of insufficient flows. For example, nothing could have been diverted in 1942, 1944, 1945 and from March 1948 through the end of 1950.

The intake of the diversion would be supplied from a pool at elevation 527 m above mean sea level formed by a low dam near a place called Coirellas at the upstream end of the International Douro. The diversion tunnel would be 24,700 m long and would discharge at elevation 502 m at Villa Cha, on one of the branches of the Angueira River, a tributary of the Sabor River. Diversion tunnel capacities from 75 to 865 m^3/sec were studied, involving increasing elevations of the Laranjeiras pool to furnish suitable storage for regulation. The flow of the Sabor River was included in the computations. Hydroelectric plant capacities varied from 25,000 to 75,000 kw and average annual energy outputs from 219,000,000 to 657,000,000 kwhr. The unit cost of the energy, including transmission charges, was found to vary between 0.69 and 0.79 escudos per kwhr, which is substantially higher than that at any of the tributary projects studied, except at the Laranjeiras project per se, and is even higher than the cost of energy at existing steam plants. At a future date, when the three main-river dams downstream from the mouth of the Sabor River would be in existence, the regulated flow would benefit their power plants and would render the diversion scheme more attractive.

The best of the schemes would be the one providing for a maximum diversion of 300 m^3/sec, for which the diameter of the unlined diversion tunnel would be 14.2 m. The diverted water would find its way along the river channel into the Laranjeiras Reservoir, which would require a full pool elevation of 310 m in order to provide the 4,100,000,000 m^3 required for regulation. The regulated flow would be 52 m^3/sec, which would yield a dependable capacity of 54,000 kw and an average annual energy generation of 474,000,000 kwhr at a plant located at the Laranjeiras Dam. The project would be very expensive chiefly because of the cost of the high gravity concrete dam needed for providing the storage, and the cost of the diversion tunnel. The total capital cost of the project would be 3,800,000 contos. The annual cost, including transmission, would be 325,000 contos, which would result in a unit cost of 0.69 escudos per kwhr. The diversion project would therefore have a very low priority, and would doubtless arouse opposition on the part of the Spanish interests. Therefore, it was dropped from further consideration.

CHAPTER XIII

GENERAL DISCUSSION OF FINDINGS

1. Power Requirements and Potentialities

The studies indicate that the existing thermal and hydroelectric power plants in Portugal, together with three hydro plants now under construction, namely, the Cabril, Salamonde, and Caniçada stations, will be able to meet the nation's power requirements until well into 1956, except for inability, should a particularly dry period be encountered in the latter part of 1956, to supply power for operating the two ammonium sulphate plants continuously at more than 90% of capacity. This conclusion, and subsequent estimates of system capacity, premise: (1) the complete integration of the numerous thermal and hydro plants composing the present system by means of a properly adjusted transmission network; (2) the development of rates under which producers are equitably compensated for standing by on orders of the load dispatcher as well as for delivery of energy; (3) the scheduling of production and transmission on the most advantageous and economical pattern by a national load dispatcher invested with full authority to accomplish the end sought; and (4) the full use of existing storage facilities to firm-up the energy generated at existing and future run-of-river plants.

By 1960 the aggregate dependable capacity of the thermal and hydroelectric plants now operative and now under construction will fall about 67,000 kw short of meeting the indicated demand. By 1965 the deficiency will be about 151,000 kw, and by 1970 about 263,000 kw.

The resources of the Douro basin can provide 25,000 kw of thermal capacity by use of local Pejao coals with a total cost per kwhr at Ermesinde of 22.9 centavos, and about ~~278,000~~ 285,000 kw of dependable hydroelectric capacity by development of seven sites on the Douro River and ~~three~~ four on its main Portuguese tributaries. The projects are listed in Table XIII-1 in order of apparent ecomomic priority. In each case the table shows the total cost per kwhr at Ermesinde based on the energy output of the first year during which full dependable capacity of the plant can be absorbed by the market - normally, the second year of the plant's life.

TABLE XIII-1

*ECONOMIC ORDER OF HYDROELECTRIC PLANTS

River		Site	Cost in Contos (exclusive of Transmission line)	Dependable Capacity kw	Total Cost per kwhr at Ermesinde (centavos)
Douro	(Int)	Picote	466,800	63,600	12.1
"	"	Bemposta	393,000	42,000	12.4
"	"	Miranda	316,500	40,600	12.8
"	(Portuguese)	Carrapatelo**	490,700	33,600	15.0
"	"	Valeira**	329,500	25,200	22.1
"	"	Regua**	354,600	23,600	17.7
"	"	Pocinho	263,300	16,200	23.4
Paiva		Fragas da Torre	346,000	18,000	27.0*
Coa		Vale de Madeira	225,000	8,700	38.8*
Tavora		Vilar-Tabuaco	169,000	7,250	36.6
Sabor		Laranjeiras	427,000	6,400	90.0*
Totals			3,781,400	285,150	

* Assuming 75% of final output usable second year after installation.

** Assuming that a lock for passage of barge tows drawing 2.7 m is provided; cost per kwhr makes allowance for navigation benefits.

For meeting the additional demand beyond the 303,000 kw of capacity which the Pejao thermal plant and the Douro hydroelectric plants can provide, additional hydroelectric plants upon the Douro tributaries, additional hydroelectric plants in other basins or additional thermal plants will be required. It is, of course, possible that certain plants in the latter two categories may be found to be sufficiently economical to interrupt instead of to follow the Douro hydroelectric series, particularly if increased coal reserves in sufficient volume to warrant additional thermal generation with domestic fuel should come to light.

The proper sequence of hydroelectric development would appear in general terms to be the order in which the plants are listed in Table XIII-1, although it may be found preferable to construct Regua before Valeira for the benefit of navigation. In selecting the installed capacities for these two projects, it has been assumed that Regua would precede Valeira.

2. Picote

Picote comes the closest of any of the projects considered to meeting the indicated need in 1960 for 67,000 kw of dependable capacity additional to that which existing hydroelectric plants and the existing thermal supplement of 100,000 kw can provide. It easily would take care of load growth to 1959. Its construction cost, 596,000 contos, including cost of transmission line to Ermesinde and cost of switchyard, is materially smaller than that of the best of the projects on the National Douro, namely, Carrapatelo, which is 585,300 contos for about 72% as much capacity. (See Table X-2). Its annual cost of 63,100 contos is but slightly greater than that of Carrapatelo's

57,060 contos (after giving effect to navigation benefits) with the result that cost of usable energy at Ermesinde (C$121 per kwhr) is but 81% of the cost of Carrapatelo energy. It thus appears that as between Picote and any plant on the national portion of the river, the choice must fall to Picote alike upon the grounds of first cost, capacity, and cost of energy; and it exhibits similar though not equal superiority over the other sites considered on the International Douro.

Construction of the Picote project would not impose any unprecedented or even unusual engineering problems unless the desirability of having all of the operating facilities upon the Portuguese side of the stream be considered in the latter category. It does not violate in any manner the existing accord with Spain, nor impose any undue or unusual hazard or any servitude, or inconvenience, upon Spanish plants downstream. In event of enemy action from the east it would be a few kilometers closer to hostilities than would the National Douro plants, but the difference seems inconsequential in terms of modern warfare, and, indeed, if the powerhouse were built underground, as the topography of the site well may show to be most advantageous, there probably would be less actual danger of damage at Picote than at some of the establishments farther from the border.

3. System Operation with the Picote Project Added

The dependable capacity of the Picote project, unassisted by Zezere storage or steam stand-by plants, would be about 22,000 kw. The re-regulation of Zezere would increase the capacity to 63,600 kw. Plates 21, 24 and 25 using the same scheme of presentation as Plates ~~26~~ 11 and ~~27~~ 12 respectively, illustrate the comparative effects, after Picote has been added to the system, of operating the Zezere plants to yield uniform output during the critical drought period and of re-regulating them to reduce drought period deficiency (with 1960 demand) to a uniform minimum.

Plate 22 illustrates how Picote would fit into the load duration curve under different conditions of stream flow. The diagram on the left shows the monthly load duration curve for January 1960, and the contributions of the various components of the system under the abundant stream flows of January 1944. The right hand diagram depicts the August 1960 load duration curve and the contributions of the component elements of the generating system under the unfavorable stream flow conditions of August 1949. Under these latter conditions, a slight deficiency (some 4,000 kw) would exist if Picote alone had been added to the "existing" system of hydroelectric and thermal units.

The use of the Zezere system to add about 45,000 kw of dependable capacity to Picote requires the maintenance of fairly high pool levels in the Zezere reservoirs during times of normal stream flow, to insure against being caught with a low pool by the critical dry spell, the time of occurrence of which can not be foreseen. Under present methods of operation it is understood that the Zezere reservoirs are drawn down to perhaps 30% or 40% of capacity in advance of the wet season. The rainy season flows, when they arrive, are used in part to refill the reservoirs and in part are passed through the turbines to produce power. With the reservoir entirely full when the rainy season flows arrive, the flows which exceeded the capacity of the turbines would have to be wasted over the spillways, since there would be no space for their storage; and to the degree that the pools are full, this condition would be approached. Even when inflow did not exceed turbine capacity a portion might have to be wasted over the spillway if the reservoir were full, because during the rainy season most of the other plants in the country would be producing at a high rate and demand probably would be less than the system output. Thus, there are two sources of potential waste of water when reservoirs are kept full without space to store inflow: (1) waste because volume of inflow may exceed turbine capacity; and (2) lack of market to absorb the energy from flows of lesser volume.

The Zezere reservoirs would not have to be kept entirely full to firm-up the Douro plants, but they need to be about 80% full, and so a portion of the normal year's wet season flow might be wasted over the spillways. This excess runoff could be stored and later released through the turbines to generate power, if it could be foreseen when the drought would come, or if there were a preference to do without power in time of drought. A carefully planned schedule of seasonal operation, both for the national system and for the Zezere system, and based on a rule curve, would eliminate excessive waste of water.

A further result of holding the pools high in normal years after the rate of flow has declined below that needed to produce power equaling demand, is the necessity to resort to the use of thermal power at times when, under present methods of operation, the demand could be, if not wholly, at least in part, supplied by hydroelectric power. The possible need for expensive thermal generation with the reservoirs 80% full suggests the possibility that a happier solution might be to continue to operate the reservoirs as at present, and provide steam stand-by capacity to which resort may be had in times of drought. The operating problems and procedures are beyond the scope of the present study, but it has seemed worthwhile to explore the economics of this suggested alternative by means of a very rough analysis.

Plate 25 shows graphically, for a repetition of the stream flows experienced between 1942 and 1950, to what extent the various components of a system comprised of "existing" hydroelectric and thermal installations plus Picote, severally would contribute to the output required to satisfy the 1960 estimated demand. The necessary use of thermal energy is shown at the base of the graph; then the usable Picote output, and next the usable output from "existing" hydroelectric plants. Above the demand line is shown the energy equivalent of the flow wasted by "existing" plants. Picote waste is not shown.

Approximate calculations indicate that in a year of normal stream flow, operation to conserve storage to firm-up the existing run-of-river plants and Picote would result in wasting at the Zezere dams of flows in excess of the turbine capacity, equivalent to 85,800,000 kwhr. Losses to all the dams comprising the Portuguese system from the spillway discharge of usable flows for which no power no demand exists, would amount to about 223,700,000 kwhr, corresponding (if the wastage is assumed to be distributed among the various plants of the nation proportionably to their respective outputs) to about 103,100,000 kwhr for the Zezere plants.

The sum of these two figures or 189,300,000 kwhr is the theoretical additional amount of power that could be recovered by drawing-down Zezere as compared with its output if it were operated to firm-up the run-of-river plants. It assumes perfect operation, based on foreknowledge, and disregards the decrease in power output due to the lower average head that would exist when the reservoirs were drawn down each year, as compared with the continuously high head that would be available if the reservoirs were kept about 80% full. This latter off-setting factor is significant. It would reduce indicated losses by about 60,000,000 kwhr. Thus the net amount of power which Zezere could recover by perfect operation, with foreknowledge, with drawdown of reservoirs each year, and assuming that no flood wave was of sufficient volume to cause any waste whatever, would be about 129,000,000 kwhr. Based upon the assumption that all other Portuguese storage installations were similarly operated to perfection, the figure of 129,000,000 kwhr might be doubled, becoming say, 258,000,000 kwhr.

In practice, since man is not in fact prescient, such operation would result in deficiencies during the critical dry periods. In 1945 and 1949, the reservoirs would have been emptied, an **interruption** of power supply would have occurred on a large scale and for extended periods of time (as in fact it did), so new steam standby plants would be needed to satisfy demand. Under the method of operation suggested in this report, the demand would be satisfied by output from Zezere storage conserved for such an emergency. The output from storage would have to meet demands of 80,000 kw anticipated under 1960 conditions - indicating that new steam standby capacity in that amount would have to be provided if the storage were dissipated instead of being conserved. This 80,000 kw capacity would be required in order to save 258,000,000 kwhr a year - a figure which corresponds to the annual output of a steam plant of about 30,000 kw capacity. Thus, almost three times as much steam capacity would be needed as would be required to generate the energy saved. Such a plant would cost, at 5030$00 a kilowatt, about 403,000 contos - almost as much as Picote. Including cost of transmission facilities, it would have

have fixed charges of about 45,000 contos a year, and as its purpose would be to permit the generation of 258,000,000 kwhr a year of additional energy by Zezere and the other storage plants, its fixed charges, disregarding fuel costs, would add 0.174 escudos per kwhr to whatever costs were entailed at the hydroelectric plants in the production of this extra energy. Even the 0.174 escudos cost is more than the cost per kwhr at Ermesinde for energy generated at any of the International Douro plants, and for that produced by all but one of the National Douro plants.

The situation would worsen with the passage of time. If all of the proposed run-of-river Douro River plants were built, the necessary steam standby capacity by 1970 would exceed 200,000 kw, and the resultant cost of saving steam energy by depleting storage in normal years would exceed the cost of generating it by the old (present day) thermal plants. Furthermore, the amount of steam energy that could be saved during years of abnormal runoff would grow less and less as more run-of-river plants were put into operation, so the economies of the new standby steam plants would deteriorate while the economies of the run-of-river hydro plants would steadily improve as more and more of their energy became marketable.

Admittedly, the foregoing calculations are quite approximate, but the implication is inescapable that the cheapest means of firming-up the power of the proposed run-of-river plants considering the over-all economy, is by the conservation of existing storage, regardless of the fact that to do so would sometimes entail the generation of thermal energy at times of normal stream flow when the reservoirs could furnish hydroelectric power if it were permissible to draw them down.

If the Pejao thermal plant is built it will, of course, relegate some of the present thermal capacity to stand-by status and this will permit more latitude in pulling down the reservoirs. If any appreciable portion of the existing thermal capacity is replaced by new hydroelectric capacity, it also will pass to stand-by status and will be available in time of drought, so the reservoirs safely could be drawn down still farther in normal years. An existing plant converted to standby status is in a different category from a new plant built for the purpose. These and similar operational problems deserve careful and continuing study. The big networks keep staffs of engineers busy solving them and constantly seeking to improve operation.

The question with which the preceding analysis has dealt is purely operational. The operational procedure assumed in the study, namely, the use of Zezere storage for firming up the Douro system output, is believed to be the most advantageous plan, but the comparative economic positions of the several projects probably would not be greatly affected by a decision to use thermal energy instead of the Zezere hydroelectric energy in part or in toto for firming-up purposes - or, indeed, by a decision not to strive for dependability. Certainly no such a decision could have the effect of displacing Picote as the most economical source of power.

4. Timing of Construction

It is apparent that with the high cost of existing thermal energy together with the demand for foreign exchange, it would be advantageous to construct new generating capacity to replace it as rapidly as funds and physical limitations permit. From the standpoint of time required for construction, the Pejao thermal plant appears to offer the best opportunity for early relief. Its construction must, however, be preceded by decision as to whether present methods of coal mining and processing at Pejao are to be retained or modified.

On the basis of cost per kwhr for the new projects studied, the Pejao steam plant would enter the sequence just ahead of Pocinho, but since physically it could be completed and go into operation at least two years ahead of the first hydroelectric plant, it would be economical to construct it immediately and concurrently with the initial hydro plant or plants. If hydro construction did not proceed fast enough both to keep abreast of the growing power demand and also to replace all existing thermal generation, as is likely to be the case, the Pejao plant could continue to operate advantageously throughout its entire economic life - first by replacement of existing thermal capacity and later as a necessary supplement. If existing thermal power were displaced completely by hydroelectric power, the Pejao plant would become inactive as soon as the more economical hydroelectric plants were able to carry the entire load unassisted by steam and theoretically would not resume operation until after all of the Portuguese Douro plants except Pocinho had been built. During the period of its inactivity, fixed charges would deplete prior savings, but under any set of conditions that rationally can be assumed, some savings would survive, and under any program likely to be adopted, they would be quite large.

The Picote plant should be started and completed as soon as possible and the succeeding hydroelectric installations should follow as rapidly as funds and reasonable economy in speed of construction will permit. Due consideration should be given to the savings usually inherent in the re-use of construction equipment on successive jobs as contrasted with the larger plant investment needed for concurrent initiation of a number of projects. But offsetting this saving would be the necessity for using more thermal power if the construction program were to be spread over a longer period of time. Nor can the possibility be ignored that some types of equipment virtually may be worn out on a single large job. In all likelihood, the rate of progress will be governed by the allocation of funds, as it usually is everywhere, so re-use of equipment probably will not be the determining factor. The foregoing remarks regarding timing ignore projects in areas other than the Douro Basin. If plants are built on other river systems before*, or concurrently with, those on the Douro, the dates by which successive Douro installations will be required will, of course, differ from those indicated by Plate 23. A comprehensive analysis embracing all watersheds probably would be useful, but it is beyond the scope of the present investigation.

* These deficiencies are based on the assumptions given above. Subsequent to the completion of the basic analyses, and too late for revisions, the Government of Portugal modified its Six-Year Plan to provide for the construction of the Bouca project in the Zezere system and the Paradela project in the Cavado system. These projects will add an appreciable amount of dependable capacity to the system and reduce the above deficiencies. The inclusion of these projects does not change the order of priority given herein, but merely permits more time in which to complete the program. A short description of the Bouca and Paradela projects can be found in the footnotes in Appendix D.

5. Coal, Iron Ore, and Iron

The estimates of coal and iron ore reserves presented in ChaptersIII and IV are believed to be conservative, and it would not be surprising if continuing exploration should prove greater tonnage in both cases. A conservative approach on the basis of present proven reserves plus half of probable reserves, indicates a 40-year supply of iron ore if exploited at the rate of 1,000,000 tons of beneficiated ore a year (corresponding to 2,000,000 tons a year mined), and a thermal plant of 25,000 kw burning Pejao coal.

The adoption of full seam mining at Pejao and the preparation of the output by air cleaning and washing would yield, in addition to the fuel needed by the 25,000 kw generating station, about 291,000 tons a year of marketable coal. Since the present market already absorbs 260,000 tons, the construction of the thermal plant would not leave much of the Pejao output available for steel production without restricting the consumption of present users. There might be available for such production about 30,000 tons a year above present market demands because the character of the processed coal would be superior to that of the average fuel produced by present methods. It seems probable that a steel industry, if one were established, would be set up near Porto rather than at the Moncorvo mines. As noted in Chapter III, expansion of present rate of Sao Pedro da Cova coal output, which is said to be fully absorbed by the market, would shorten the life of the mine below the present estimate of 25 years, based on certain plus half of probable reserves, and the present rate of output. The Pejao thermal plant would, however, probably displace the Massarelos thermal plant and thereby, on the basis of 1952 Massarelos energy output, release some 45,000 tons of Pejao and San Pedro da Cova fuel annually for use in the steel industry if desired, without harm to other coal consumers. If again on the basis of 1952 power production, all thermal generation by domestic coal at the Massarelos, Canicos, and Freixo plants were displaced, it would free about 47,000 tons a year. Thus, without restricting present consumption by existing users other than existing thermal power plants, it would be feasible to allocate about 47,000 tons of domestic coal a year to the production of iron and steel or to industry in general or to a second, smaller, new thermal plant. Since the domestic anthracite is too finely divided to use in a blast furnace, data are lacking to estimate just how much pig iron 47,000 tons would produce, and at what cost; and as pointed out in Chapter IV, a careful study not only of the roles of coal and ore, but also of the other ingredients, including labor supply and consideration of housing problems, will be required before definite conclusions can be reached regarding the desirability and details of processing a portion of the ore in Portugal. It is possible that pig iron production by means of a process employing a rotary kiln such as the Krupp-Renn process would be successful but it is not within the province of the present survey to explore the manufacturing process, problems, or economics, which latter may prove disappointing. Nor does it appear apposite to discuss the alternative possibilities of steel production by electrolytic processes, other than to remark that power load growth, exclusive of demand from a hypothetical steel industry, appears likely to absorb the output of firm energy almost as rapidly as the output can be increased by the construction of new plants. It seems questionable that steel production from secondary power could be worked out profitably.

The iron ore itself, after veneficiation at the mine, can be hauled by rail and marketed for export at prices yielding attractive profits. Such profits could be increased by 65 to 70 percent (less any waterway tolls which the government might levy) if water haul in barges could be substituted for rail haul below Pocinho by reason of improvement of the Douro River for 2.7 m navigation. The export of ore possibly could be usedas the basis for a trade agreement with a foreign steel producer or producers by which Portugal would obtain finished steel at prices below the costs from small-scale domestic production.

6. Navigation

Improvement to 2.7 m depth as far as Pocinho is shown in Chapter VII to be both practical and profitable, with a ratio of annual benefits to annual costs of 1.2. Of the total annual benefits of 42,173 contos indicated, 30,875 contos derive from iron ore traffic, 5,535 contos from wine traffic, 3,988 contos derive from coal traffic, and 1,775 contos from miscellaneous traffic. Total annual charges are indicated to be about 36,060 contos, on the assumptions that the Government will build and operate the navigation improvements and that, in general, the owners, producers, and/or marketers of the commodities moved will operate the tows and the loading and transfer facilities.

It may be of interest to examine the effects of navigation upon the revenues of Linha do Douro, and its feeder lines. At present they are probably hauling about 100,000 tons of iron ore a year from Carvalhal to Leixoes station for 70$00 a ton, which corresponds to 7,000 contos annual revenue. With the navigation project operating, they would haul 1,000,000 tons of ore a year from Carvalhal to Pocinho loading point at 20$66 a ton which would produce annual revenue of 20,660 contos.

Under the assumptions of Chapter VII, only 15% of the wine would move via Linha do Douro whereas at present that line carries about 84½%. The reduction would be about 70% in present volume. In Chapter VII it was found that if all the wine produced in the Douro were hauled by rail, the annual rail revenue (Linha do Douro only) would be 8,710 contos. (It might be noted parenthetically that the assumption was made in the absence of information on costs of haul by rabelo that barge haul would effect the same savings over haul by rabelo as it effected over haul by rail). On the basis of 84% being hauled by rail, the rail revenue would be 84½% of 8,710 contos or 7,360 contos. If only 15% were hauled by rail after the navigation project began to operate, the rail revenue would be only 1,310 contos, a reduction of 6,050 contos.

No means are available for determining what loss of revenue would result from diversion of miscellaneous commerce from rail to barge, but if revenue per ton be assumed to equal the mean between that derived from iron ore and wine, it would amount to 5,600 contos - probably an excessive figure.

In summary, then, if the navigation project were built and all of the iron ore and coal, 85% of the wine, and an additional 10,000 tons of miscellaneous cargo were hauled by water, the loss in revenue to the railroads, as compared with present revenues, could not exceed a total of 18,750 contos, while the increase in revenue from iron ore would be 20,660 contos, if the rail rates assumed in the study are retained. The railroads would, of course, be deprived of added revenues they otherwise would acquire, and if added revenue is essential to solvency, a question of policy arises.

These considerations do not apply to the case of coal movement where the savings computed are even depleted to compensate for elimination of the rabao fleet. Under certain assumptions, whose validity can not be definitely established at this time, the coal savings alone would pay the charges against the navigation improvement required to make them possible, and under most of the assumptions would leave an annual deficit of fairly small proportions whose absorption during the period anterior to construction of the Carrapatelo, Regua and Valeira power dams might be warranted by the value of the experience gained in planning future operations if the full navigation project is built.

The Ataes lock and dam is the initial navigation structure required, but if eventual movement of Moncorvo ore is contemplated, and is relied upon for economic justification of the navigation project, provision for exporting most of it should be considered, and the question of how to do so satisfactorily should be resolved before embarking upon construction at Ataes. The present indications are that improvement of the river's mouth by jetties and dredging would afford the best solution and at the same time would confer valuable collateral benefits by way of making Porto and Gaia harbors safer and more useful; but this conclusion should be verified or corrected by model experiments before being translated into works.

The most satisfactory structure to build at Ataes would be a lock with a dam whose movable crest was comprised of Sidney gates. The second choice would be one with its crest controlled by wickets and bear traps. A solid weir probably could be made to serve, but would be slightly higher than any in the United States built on sand-carrying rivers for navigation improvement. The question of bank protection against high velocities in the overfall area would need to be studied rather thoroughly. Sand probably would be carried over the dam by eddy action, but considerable dredging might be required following floods. The solid weir is by far the less certain as to results, of the three types considered, and its use would entail the most frequent suspension of commerce by reason of flooding of the lock. Under any plan considered the Ataes lock, the Entre-ós-Rios lock and the upper chambers of the power-dam locks would require sector gates at the upstream end, since they will have to be closed against current following the occurrence of floods high enough to overtop them.

7. Irrigation

There is only one proposed power project which would involve irrigation - the Laranjeiras project on the Sabor River. The irrigation releases would depend upon the agricultural requirements of the irrigated areas in the Vilarica valley. These questions were taken up in the 1945 report of the Junta Autonoma das Obras de Hidraulica

Agricola and the irrigation releases recommended therein have been used in the present study (see Table XII-1).

Since the Laranjeiras project has a low priority, the problem of irrigation was not pursued further.

8. Flood Control

No special flood control measures are anticipated at the proposed projects. The main river plants are expected to be operated with full reservoirs, in order to take advantage of the maximum head on the turbines. Ordinarily, therefore, they will provide little flood control storage. It may be found feasible to draw them down somewhat in anticipation of a storm, and thus provide a small amount of flood control storage. However, the total combined storage of this type for all the projects on the International and the Portuguese Douro would have a negligible effect on the great floods which have been experienced on the Douro River.

On the tributaries, incidental flood control benefits will be obtained if the reservoirs happen to be partially empty at the time of the flood. It is believed that flood control is of little importance except on the Sabor River, where it might be desirable to afford protection to the agricultural lands at its mouth. Flood control can be achieved by incorporating suitable provisions into the rule curve of the proposed Laranjeiras reservoir. Since the project has low priority, this question was not investigated further. It should be noted that any measures taken on the Sabor River will not provide protection against flooding by backwater from the Douro River. This could be guarded against by a system of levees, which would, however, be uneconomical.

9. Sedimentation

Sedimentation is not believed to be a serious problem. The tributaries of the Douro River which were investigated flow through rocky, mountainous country. Soil which could be washed down by the streams to fill up the reservoirs does not seem to exist in abundance. It is believed that the dead storage required to maintain a minimum head for power, or for other practical considerations, would be sufficient as a sedimentation allowance for a long period of years. On the International Douro, the topography is very rugged. The river, as far as could be observed, seemed to carry little alluvium. Almost all the bedload and suspended matter that would be brought down from the Spanish portion of the drainage area would be caught in the Ricobayo Reservoir on the Esla River, in reservoirs on the Spanish tributaries, and in the Castro Reservoir and other Spanish reservoirs on the Douro River just upstream from the International section. The Spanish utility company, Iberduero, has not found sediment an important problem in the western portion of the Douro basin and it is understood that no allowances for sediment storage are made in its existing or proposed reservoirs. On the Portuguese Douro, most of the alluvium would be contributed by the tributaries. Fortunately, the worst offender in this respect seems to be the Tamega River, which enters the Douro below the Carrapatelo project, the farthest downstream of the proposed main river power projects. None of the main river projects, either on the International or the Portuguese Douro are expected to develop any usable storage, except for daily or possibly week-end regulation. Consequently, even if a large proportion of their volume were to fill up with sediment, their function would continue unimpaired.

10. Degradation of the River Level

The question of degradation is closely related to that of sedimentation. In a river bed consisting of sand, gravel and bedrock, an equilibrium is established under natural conditions whereby any material moved downstream by the flow is replenished by deposited material carried by the water coming from upstream sources. If the upstream sediment supply is cut off by a reservoir, the clear water passing through will erode the alluvium downstream without replacing it with fresh material, and the river bed and tailwater elevation will be lowered. This process may have a number of unpleasant consequences. The ones of chief concern in this study are the possibilities that the effectiveness of the stilling facilities at the base of the spillways may be impaired by the lowered tailwater, and that the turbine runners may become subject to cavitation for the same reason. It is believed that the proposed plants are in little danger from that source. The proposed plants on the tributaries of the Douro River and on the International Douro are in locations where the river channel has been carved in rock, and is not subject to degradation. At the sites of proposed plants on the Portuguese Douro, rock is everywhere seen near the surface. However, there are also numerous sand bars. The proposed Carrapatelo project would be the most vulnerable, as it would not be protected from these effects by another large reservoir downstream. However, many circumstances would mitigate the effect of degradation. They are as follows: (1) the tailwater at Carrapatelo would be at an elevation only 10 meters above sea level and (2) possible navigation dams downstream would maintain the tailwater level at Carrapatelo and thus protect the turbines. As for stilling the spillway discharge, if a major flood occurred, such as that of 1909, the tailwater elevation and headwater elevation would only differ by a few meters, almost restoring open-river conditions. Under these circumstances, much suspended material would move through the reservoir, for the partial restoration of the sand-bars. The control for large discharges consists of the rocky sides of the valley, and would probably not be affected appreciably by changes in the river bed. For smaller discharges, the control may be located very far downstream,and may be subject to the effect of the sand and gravel brought down by the Tamega River.

CHAPTER XIV

CONCLUSIONS

1. Power

Continental Portugal has developed, is developing, or has specific plans for developing, most of the outstanding sites for generation of hydroelectric power on its river systems other than the Douro, and has six thermal generating stations, of over 10,000 kw capacity, the dependable capacity of which totals about 100,000 kw. All the important hydroelectric plants and most of the thermal plants, except those in the extreme southern part of the country, are interconnected by a transmission network which, following an A.C. calculating board or network analyzer study, can be so integrated and operated as to create a power pool capable of providing enough firm energy to meet all power demands, including those created by full time operation of the new ammonium sulphate plants, until 1956. By the end of the latter year, growth in demand will have been so great that the occurrence of a critical drought would reduce chemical plant operation to about 90% of full time if capacity other than that now being built were added to the system in the interim.

In addition to a network analyzer study, the attainment of successful power pool operation will require the establishment of a rate structure that will provide for the equitable reimbursement of all participants - producers, transmitters, and distributors - and will facilitate compliance with the directives of the National Load Dispatcher, whether his directive be to conserve storage in the interest of firming up run-of-river output in time of drought, or whether it be to produce and deliver energy currently. It follows that the National Load Dispatcher must have full authority to direct the operation of all units to the best advantage at all times, and must have the means for implementing his authority.

Because the existing rate structure compensates for energy alone instead of for both readiness to serve and service, successful power-pool operation involving the conservation of storage to provide firm capacity is not feasible at the present time; and because it is by that means alone that the existing system (including Cabril, Canicada, and Salamonde) can be made to meet power requirements into 1956 dependably, it is concluded that the most immediate need with respect to power is to revise the rate structure and to introduce power pool operation under the direction of a fully empowered National Load Dispatcher. The findings of the study regarding power are based throughout upon the assumption of firm energy and power pool operation.

No further development is needed in the Douro Basin to supply the immediate power requirements of the nation, but these are not static. By 1960, even with power pool operation, a deficiency of about 67,000 kw of dependable capacity is indicated unless new plants are built in the meantime. By 1965 the deficiency would be 151,000 kw and by 1970 about 263,000 kw. It requires several years to build a large hydroelectric project, hence of almost equal importance to the need to meet the present demand is the necessity to initiate planning and construction for future requirements.

The Douro is a large river. Its average flow can generate substantial quantities of energy. Its banks are steep and its valley narrow, so its plants can have very little storage. But elsewhere in the Zezere and Cavado River Systems nature has been generous in providing wide and deep valleys, and those charged with the development of those streams for hydroelectric power fortunately have taken such full advantage of the remarkable opportunities for storage which confronted them, that it now becomes possible through the judicious use of the great reservoirs they have provided, to make dependable the large outputs of the Douro run-of-river plants. The benefits to the national economy from the complementary functioning of the two types of project cannot be over-emphasized.

The study indicates that the most economical Douro plants will be those on the steeply sloping international portion of the river, upstream from the Tormes River, and that of the three projects planned to develop the full potential of that reach, the most favorable is the Picote project at km 22.4 above the mouth of the Tormes. The indications are clear that Picote should be the first of the new hydroelectric projects on the Douro River to be undertaken, and that the order of subsequent work on the Douro system should be to complete the development of the International Douro and then, beginning with Carrapatelo, to work upstream on the Portuguese Douro. The national plants do not require such long transmission lines as the international plants and the lower three of the national projects may be used to aid navigation and may yield benefits from navigation as well as from power production, but the natural advantages of narrowness of valley and steepness of slope of the international river are so pronounced that their effects conclusively outweigh the greater proximity to load center and the possible navigation benefits of the projects on the national portion of the stream.

In general, the immediate development of the Portuguese tributaries for power seems less profitable than development of the main river, because, while high heads are available on the tributaries, their flow, especially during dry periods, is quite small. A number of good storage sites exist, and after the dams on the Portuguese Douro have been built, the storage in tributary reservoirs would help to firm up the outputs of the main river plants. Until the International Douro plants have been built, however, the critical drought period would be that equivalent to the 1944-1945 period, which was of such long duration that the capacities of the tributary reservoirs would not be great enough to provide dependable capacity to the power system much in excess of the output of the tributary plants considered independently. After completion of the international plants, the critical drought would be one equivalent to that of 1949 - more severe, but of shorter duration - so that the tributary reservoirs would be more effective in firming up the Douro plants, particularly those through which the reservoir outflows would pass on their way to the sea. It is to be noted that the foregoing discussion seeks to establish the proper timing of construction upon the basis of providing the system with additional firm capacity. As a means merely of reducing thermal production requirements during periods of normal flow, the Vilar-Tabuaço project on the Tavora River appears to indicate justification if the installed capacity is carefully planned.

This study indicates that Pejao coal can be used profitably for the generation of power, and that reserves represented by those in the "certain" category plus one-half of those in the "probable" category are ample to support a 25,000 kw thermal plant - with the possibility that continuation of the far from complete exploration of the deposits may disclose considerably more coal than has hitherto been revealed. On the basis of the cost of power, at the Ermesinde substation, the hydroelectric plants of the International Douro and the lower three on the National Douro are more favorable than Pejao, but as Pejao can be built more quickly than any of the hydroelectric projects, and can effect large savings both in cash and foreign exchange by displacing an equivalent amount of generation by existing thermal plants, it is concluded that it could be built at once with profit.

The same conclusion applies with even greater force to the hydroelectric plants on the Douro. Although these plants will not be needed to meet differences between the demand and present system capabilities until some time in 1956, immediate construction to replace existing costly thermal generation would be most advantageous. Furthermore, from a study of indicated load growth, there does not appear to be any danger whatever that the program of immediate construction would provide output in excess of the combined requirements of thermal replacement and increase in demand.

2. Coal and Iron

As indicated in Chapter XIII, the reserves of Moncorvo iron ore and of Pejao coal have been estimated to be sufficient, respectively to permit the annual production of a million tons of concentrated ore and 383,000 tons of air-cleaned and washed coal, for a period of about 40 years. The methods and production rates outlined in Chapters III and IV are considered the most satisfactory. Full seam mining and cleaning of the Pejao coal will yield a better and more uniform product than is attainable by present methods; and as the iron ore must be beneficiated to become easily usable or marketable, it is clearly best to concentrate it at the mine rather than to haul the waste materials to some distant point for elimination. Definite and final conclusions on the best method to utilize the processed coal and dispose of the beneficiated ore, probably must await further study of the question of establishment of a domestic iron and steel industry. If it should be decided that all or even a large part of the national steel demand of some 150,000 tons a year should be supplied by local production, a considerable tonnage of the ore would remain in the country, and in all probability a volume of coal materially greater than that required for the proposed Pejao thermal plant would be allocated to the steel industry. It is believed, however, that such a decision would in all probability be based upon matters of national policy rather than solely upon economic grounds. It is the considered opinion of experts in iron ore exploitation in the United States that the most profitable courses probably would be to export the ore and to use the coal for the generation of electric power and other industrial and domestic uses. Obviously these conclusions cannot be considered unassailable in absence of full knowledge of the cost as well as the feasibility of Portuguese iron and steel production. The exploitation of the Guadramil iron ore deposits does not appear economically sound at the present time.

3. Navigation

The Douro valley produces, and will produce in much greater measure with an increase in the rate of exploitation of the Moncorvo ore reserves, several bulk commodities excellently suited to water transport. The steep slope of the river, its great range in volume of discharge, the high tides at its mouth, its sand movements, and shortness of haul interpose serious obstacles to its improvement for navigation and the establishment of a healthy and profitable river commerce. But despite these handicaps, analysis indicates that improvement to accommodate 2.7 m navigation from the mouth to Pocinho is feasible and would permit savings to shippers of about 42,190 contos a year if no tolls were charged by the Government, and a saving of 6,130 contos even if tolls totaling all charges for interest, amortization, maintenance and operation were assessed. In addition, the harbors of Porto and Gaia would be made more useful to ocean craft if improvement of the mouth of the river by means of jetties is the plan selected.

To carry navigation to Pocinho, the Carrapatelo, Regua, and Valeira power dams are necessary, and the navigation savings attributable to them are not large enough to overcome the natural superiority of the competitive International Douro sites and to warrant developing of the

Portuguese Douro in advance of the International Douro above the Tormes.

This poses a problem, because a long delay in building Carrapatelo, Regua, and Valeira, coupled with an immediate large increase in the production of Moncorvo iron ore, might result in the railroad making such extensive improvements to handle the increased ore traffic that there would be some hesitancy to embark upon a navigation project which would have the effect of abandoning whatever part of the railroad expenditure related to improvements below the Pocinho barge-loading point. And of course, if the delay were unduly prolonged, and in the interim the ore reserves had been so heavily depleted that there was not enough tonnage remaining to support a navigation project throughout a reasonable length of life, economic justification for river improvement would collapse.

The problem may not be as serious as it might at first appear. The expansion of the present modest rate of exploitation of Moncorvo ore into an enterprise vast enough to make serious inroads upon the great body of reserves, or to require major improvements to the broad gauge Linha do Douro will itself consume much time; and whereas it can easily afford to lag, the need for new hydroelectric power to meet load growth and replace expensive steam plant operation is immediate and compelling, and the rewards of speed are tangible and large. To take fullest advantage of the economies inherent in the hydroelectric developments and at the same time keep abreast of load growth, would require Pejao, all of the International Douro dams, and the lower three National Douro projects to be constructed over a period of about eight years, beginning in 1956. Such a program, of course, fails to take into account any new developments in other basins that may be assigned a priority ahead of the Douro.

The heavy tonnages, iron ore and coal, will reach the river at the extreme upper end of the navigation improvement and near its lower end, respectively. The coal movement together with such small tonnages of miscellaneous cargoes as the lowermost pool may attract, apparently, will not effect savings enough to equal annual charges against the Ataes lock and dam (the only structure needed to improve navigation to the Pejao mines), though the discrepancy should not be great if a solid weir on sound rock is found to be a practical solution. If the construction of the power dams is to be expedited, as the rewards of doing so would appear to justify, the construction within the next few years of Ataes lock and dam, even at costs which would produce annual charges in excess of annual benefits, would not seriously impair the economics of the navigation project as a whole when the deficits incurred during the predevelopment period were spread over the 40 year life of the enterprise; while the experience and knowledge gained would probably pay valuable dividends in better planning and operation of the subsequent elements of the navigation development. With 291,000 tons of coal and 20% of the miscellaneous tonnage assumed for the entire project, and an accompanying annual saving of 4,343 contos a year as indicated in Chapter VII, the annual deficit would range from 298.4 to 3,712.2 contos, depending upon type of structure and foundation at Ataes. If Ataes operated alone for 10 years before navigation to Pocinho became feasible, the accumulated losses would aggregate 2,984 to 37,122 contos - again depending upon type of structure and nature of foundation encountered. At 2.75% per annum, the interest charge on this development deficit would be 82 to 1,021 contos a year for the life of the full project, which then would have a benefit-cost ratio of from 1.27 to 1.13, the higher ratio pertaining to an Ataes lock and a solid weir on sound rock foundation, and the lower relating to a lock and movable dam controlled by Sidney gates founded on sand.

4. Irrigation and Flood Control

It is concluded from inspection and study of the areas under consideration that as a rule, everything damageable by flood is kept so well above the level attained by ordinary high waters that no losses of consequence attend their passage. The occurrence of floods of sufficient magnitude to cause serious damage is so infrequent that the annual returns from protection against them - where such protection is feasible and not objectionable to those protected - is not sufficient to cover the annual charges for interest, amortization, and maintenance. The agricultural lands along the lower Sabor and the Vilarica are subject to overflow by floods of fairly frequent experience, but there does not appear to be any way to protect them against inundation that would be at all commensurate in cost with the benefits which such protection would confer.

The only significant irrigable area in the basin is the land along the Vilarica, and the only means of providing it with irrigation at costs commensurable with benefits, involves construction of a dual purpose dam on the Sabor at Laranjeiras for power and irrigation, with most of the costs allocated to power. Since the economic standing of the

Laranjeiras dual purpose dam, compared to that of the other projects investigated on the Douro and its Portuguese tributaries, is last, it does not seem likely that its construction can be justified on economic grounds in the near future. It is accordingly concluded that irrigation should be postponed for the present, but that it need not be abandoned entirely. Ultimately the development of the Sabor for power will be needed. Irrigation by means of a reservoir can perhaps be undertaken profitably at that time. It is also possible that electric power will become cheap enough before Laranjeiras is built to make irrigation by means of pumping from ground water profitable.

CHAPTER XV

Recommendations

The most valuable resource of the Douro River Basin is its large hydroelectric power potential, the development of which to produce maximum return in the form of dependable energy is contingent upon the integration of its proposed plants with the other generating facilities of the nation, to form a national power pool. As the complete integration of existing plants together with those currently under construction, and their operation as a power pool would enable them to furnish an adequate supply of dependable power to all users until 1956, and as such integration is at the same time an indispensable prerequisite to full returns from the proposed investments on the Douro, it is recommended:

1. As the first move toward providing adequate and dependable power for Portugal, the necessary steps be taken to integrate present facilities fully, and to achieve power pool operation. These necessary steps, as has been pointed out previously, are: a network analysis with such corrective measures as it may indicate; the vesting of full authority in a National Load Dispatcher to control the operation of all generating and transmission facilities in the most economical and advantageous manner; and the establishment of a rate structure that will permit compliance with his directives without hardship to any of the participants in the pool operation.

2. Hydroelectric development of the International Douro above

the Tormes River by means of three peojects at Miranda, Picote, and Bemposta respectively, and the Portuguese Douro by four projects at Carrapatelo, Regua, Valeira, and Pocinho, be undertaken; to be followed, as load growth warrants, by projects on the Portuguese tributaries - at Fragas da Torre (Paiva River) Vale de Madeira (Coa River) Vilar-Tabuaco (Tavora River) and Quinta das Laranjeiras (Sabor River), the latter to be a dual purpose project for power and irrigation if at that time the irrigation feature still is needed and shows economic justification.

3. The Picote project be considered the hydroelectric project of first priority and it consist of a gravity concrete dam approximately 100 m high at a point about 22.4 km above the Tormes River, with full pool at elevation 471 m above sea level, a normal head of 74 m, the power house, tunnels and other operating features on the Portuguese side of the river, an initial power installation of 93,000 kw, and an estimated construction cost of about 426,000 contos.

4. The sequence of subsequent hydroelectric construction on the main Douro and its Portuguese tributaries be: Bemposta, Miranda, Carrapatelo, Regua, Valeira, Pocinho, and projects on the tributaries.

5. Construction be initiated as soon as practicable and prosecuted as rapidly as funds and other considerations permit, in order to displace as much existing thermal capacity as possible while still keeping abreast of load growth.

6. A 25,000 kw thermal generating plant be built at Germunde

to burn Pejao coal and that its design and construction be undertaken as soon as the grade of fuel to be used is decided.

7. Full seam mining be employed in the Pejao coal mines, and the output processed by separating the fines and washing the residue; and that production be increased to about 575,000 tons annually, in order to yield about 380,000 tons of marketable fuel a year.

8. Exploitation of iron ore deposits in the vicinity of Moncorvo be gradually stepped up to about 2,000,000 tons a year with beneficiation at the mines to produce about 1,000,000 tons a year of concentrated ore.

9. Exploratory borings to determine more definitely the volume of coal and iron ore reserves be continued.

10. Study be made of the feasibility and desirability of establishing a domestic iron and steel industry, for which, if recommendations 6 and 7 above are adopted, there would be available annually between 40,000 and 50,000 tons of Douro Basin coal.

11. A movable-bed model study of the Foz do Douro be made in order to verify conclusions as to feasibility and probable first cost and maintenance requirements, and lengths and alignments of structures required for its improvement to afford safe and dependable passage for ocean commerce using the harbors of Porto and Gaia.

12. Contingent upon a realistic program for the construction of hydroelectric power dams on the Douro River that will schedule completion of the Carrapatelo, Regua and Valeira projects before the coal and iron ore reserves are seriously depleted, or before

such extensive broad gauge railroad improvements made in the interest of ore movement, the navigation project outlined in Chapter VII be adopted, and a lock and movable crest dam at Ataes be built as soon as practicable, to serve as the first unit thereof.

13. Even if the comprehensive navigation project does not at the moment appear practicable because of the anticipated delay in the hydroelectric dam construction, or for other reasons, detailed study of foundation, bank conditions, and sand movements at Ataes be made, with a view to constructing the least expensive structure at that point for improving navigation to Entre-os-Rios or Germunde. Inasmuch as Carrapatelo, Regua and Valeira dams probably will be built before many years have elapsed, and will provide deep navigation pools, it does not seem advisable to plan a structure at Ataes that would permanently limit all navigation on the river to drafts of less than 2.7 meters.

NOTE: Detailed estimates for the construction of the recommended projects are contained in Appendix E.

ATHENS, GREECE OFFICE
17 PATRIARHOU IOAKIM ST.

CABLE ADDRESS
"PIERCE"
SCRANTON, PA.
ATHENS, GREECE
RANGOON, BURMA
WASHINGTON, D. C.

PIERCE MANAGEMENT
INCORPORATED

ENGINEERS AND MINE MANAGERS

COAL AND METAL MINING

SCRANTON ELECTRIC BUILDING
SCRANTON 3, PENNSYLVANIA

J. H. PIERCE, *Chairman*
J. S. MARSHALL, *President*
F. L. ROUSSELLE, *Exec. Vice-Pres.-Treas.*
F. G. KOPER, *Vice-President*
C. J. ADAMS, *Vice-President*
T. J. WELBY, *Secy. Asst. Treas.*
J. B. WARRINER, *Special Consultant*

WASHINGTON, D. C. REPRESENTATIVE:
PAUL F. SCHOLLA
1025 CONNECTICUT AVENUE, N.W.
TELEPHONE: REPUBLIC 3041

JUNE 10, 1952

MR. GERALD T. MCCARTHY
KNAPPEN TIPPETTS ABBETT ENGINEERING CO.
62 WEST 47TH STREET
NEW YORK, N.Y.

DEAR MR. MCCARTHY:

SUBMITTED HEREIN IS COAL REPORT IN CONNECTION WITH THE RIO DOURO PROJECT.

WE PARTICULARLY WISH TO COMMEND THE EXCELLENT HELP AND COOPERATION RECEIVED FROM BOTH THE OFFICIALS OF THE PORTUGUESE GOVERNMENT AND THOSE IN CHARGE OF THE MINES.

WE APPRECIATE HAVING HAD THE OPPORTUNITY OF WORKING WITH YOU ON THIS PROJECT AND WERE VERY PLEASED WITH THE FINE ASSISTANCE EXTENDED TO US BY ALL MEMBERS OF YOUR STAFF.

YOURS VERY TRULY,

PIERCE MANAGEMENT, INC.

F. L. ROUSSELLE
EXECUTIVE VICE-PRESIDENT

FLR:LR

APPENDIX A

COAL

INDEX

EXHIBITS	Following Page

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

1. Proved reserves at Pejao are 10,583,396 metric tons in place. Probable reserves are 20,068,747 metric tons in place. Based upon proposed increased production of 383,300 metric tons of washed coal per year, the safe life of these mines is 35 years. It is probable that the life of these mines may be extended to 45 years.
2. The S. Pedro da Cove Mine has certain and probable coal reserves of 10,782,662 metric tons in place. At the present rate of production the economic life of this mine is about 25 years.
3. S. Pedro da Cova Mine can supply 26% ash washed fines with 9900 B.T.U. per pound at a cost of 188$ per metric ton 4% moisture allowed F.O.B. power plant with 28$ allowed for transportation, storage and rehandling from the mine to the power plant.
4. Pejao Mines can supply 20% ash unwashed fines with 10,250 B.T.U. per pound at a cost of 200$ per metric ton 5% moisture allowed F.O.B. power plant with 25$ allowed for transportation, storage and rehandling from the mine to the power plant.
5. Pejao coal has a lower specific gravity than S. Pedro da Cova coal, 1.5 v.s. 1.7. The inherent ash in Pejao coal is lower than S. Pedro da Cova coal. These factors result in lower ash fines and make this coal, with fines removed, easier to clean than S. Pedro da Cova coal.
6. No allowance has been made in the cost of coal for profit to the mine operators.
7. Capital expenditures of 19,000,000$ and $500,000 are required at

Pejao Mines to increase production, install washing plant, aerial tramway and coal storage.

8. Capital expenditures required at S. Pedro da Cova Mine for track, transportation equipment, aerial tramway and coal storage are 9,940,000$ and $300,000.

9. S. Pedro da Cove Mine could either supply the power plant from its present production, therefore increasing the amount of coal imports required by Portugal, or from increased production, thereby shortening the life of the mine to about 17 years.

10. Location of the power station at Germunde, expansion of Germunde and Fojo Mines to produce 575,000 tons run-of-mine per year, washing all Pejao output except screenings furnished to the power plant are recommended from mining and over-all economic point of view.

CHAPTER NO. 1

ASSIGNMENT AND GENERAL DESCRIPTION

We were given the assignment of investigating and reporting on the reserves and facilities of the following coal mines, with respect to their ability to supply coal to the proposed new Rio Douro Thermal Power Plant:

1. Sao Pedro da Cova Mine

2. Pejao Mines (consisting of Germunde and Fojo Mines)

These mines are located in the carboniferous basin of the Douro which is the principal coal field of Portugal. Accompanying map, Exhibit No. 1, shows the location of these properties with relation to the surrounding territory.

Douro coal field is in the northeast part of Portugal. Following a general direction NW-SE, it extends from Apolia to a place near Gafanhao, passing through S. Pedro da Cova and Pejao. The approximate length of the basin is 90 kilometers and it is crossed by several rivers, the most important being the Douro. Width of carboniferous rock outcrop is very irregular, attaining one kilometer in the region of S. Pedro da Cova and disappearing in certain places.

—LEGENDA—

- Couto Mineiro de S. Pedro da Cova
- Couto Mineiro do Pejão

LOCATION OF COAL MINES		
PORTUGAL		
PIERCE MANAGEMENT, INC. MINING ENGINEERS, SCRANTON, PA.		
DATE June 1952	SCALE As Noted	EXHIBIT No. 1

SITUAÇÃO GERAL DA ZONA CARBONIFERA

GEOLOGICAL AGE AND OCCURRENCES

The carboniferous formation is overlaid with Pre-Cambric and Siluric period rocks.

Minable seams are of medium grade anthracite. The carboniferous zones of S. Pedro da Cova and Pejao are the only ones which up to the present time have shown any economic value.

That part of the basin which goes from the NW end of S. Pedro da Cova to the SE extremity of the concession of Pejao has been for some years subjected to systematic study and exploration.

Boreholes have been drilled in the S. Pedro da Cova area and also in the Germunde area, and a drilling program laid out for the Fojo area, where one borehole has been completed. The Fojo area has been developed to an approximate length of 6 kilometers.

TRANSPORTATION AND COMMUNICATIONS

S. PEDRO DA COVA MINE

This mine is connected with the Town of Porto by two roads, one of them going through Sondomer and the other through Velongo. The distances respectively are about 14 and 17 kilometers. There is also an electric railroad which transports passengers, merchandise and coal. This coal is transported to the power station of Transportas Colectivas do Porto. An aerial tramway, about 9,100 meters long is used to transport coal from the mine to storage yards. These storage yards are located at the railroad station in Porto, from where coal is distributed by railroad or trucks to consumers.

The aerial tramway is of a Bleichert type, with a capacity of 30 tons per hour.

PEJAO MINES

GERMUNDE MINE

This mine is located on the northeast end of the concession, on the left bank of the River Douro. It is connected with Castelo de Paiva and Entre-Os-Rios by National Highway No. 222, and also to Porto by another route about 40 kilometers long.

On the right bank of the Douro, in front of Germunde, is the village of Melres. A highway is being constructed which will connect Porto to Foz-do-Sousa, Melres and Entre-os-Rios.

All Germunde coal is transported on the Douro River.

FOJO MINE

This mine is located at the southeast end of the concession. The concession area is crossed at a place called Cascarvalhosa by National Highway No. 224 from Castelo de Paiva to Arouca.

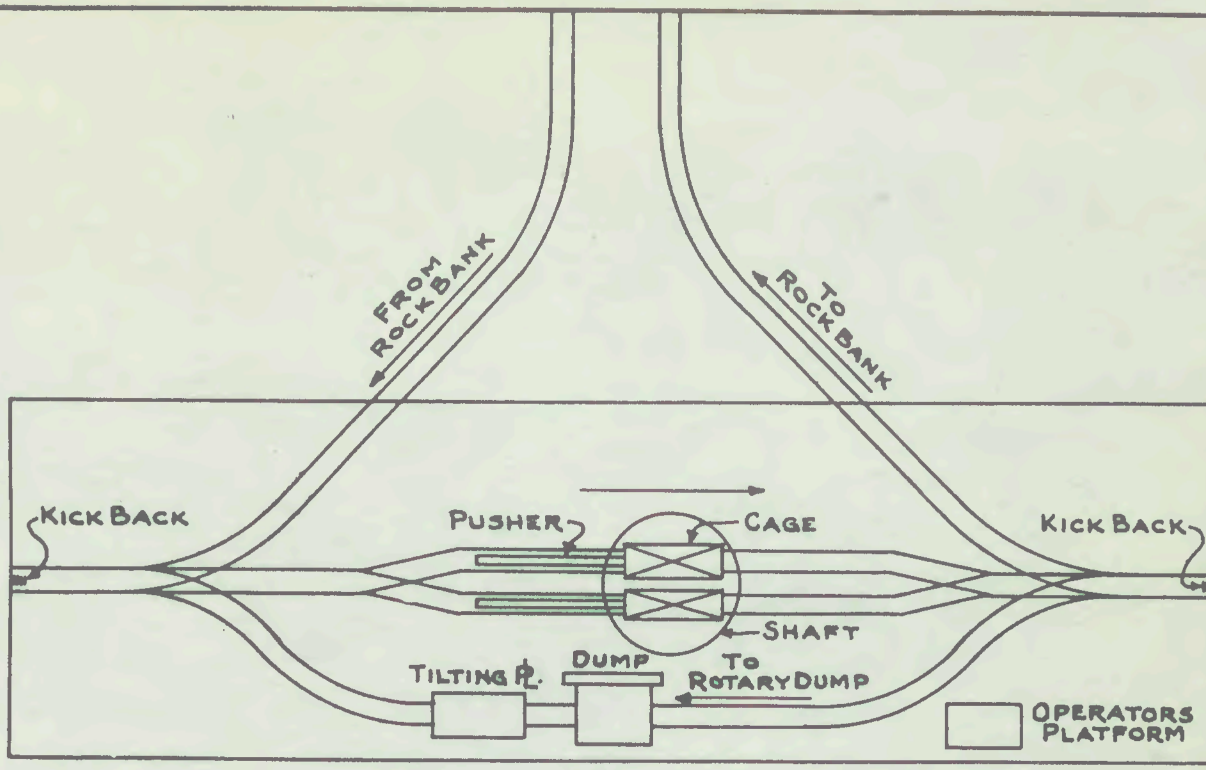
Fojo and Germunde Mines are connected by a narrow gauge (mine owned) railway for the transportation of coal. It has a length of about 10 kilometers, 60 cm gauge. A new mine shaft has been constructed at Fojo, and in the future, the entire production from Fojo mine will be hoisted through this shaft and loaded into cars for transfer to the Germunde picking plant.

The new Fojo Mine is modern in every respect and combines excellent technical design with good construction and modern equipment.

The caging and dumping arrangements at the shaft top are exceptionally well planned and are controlled and operated by only one operator.

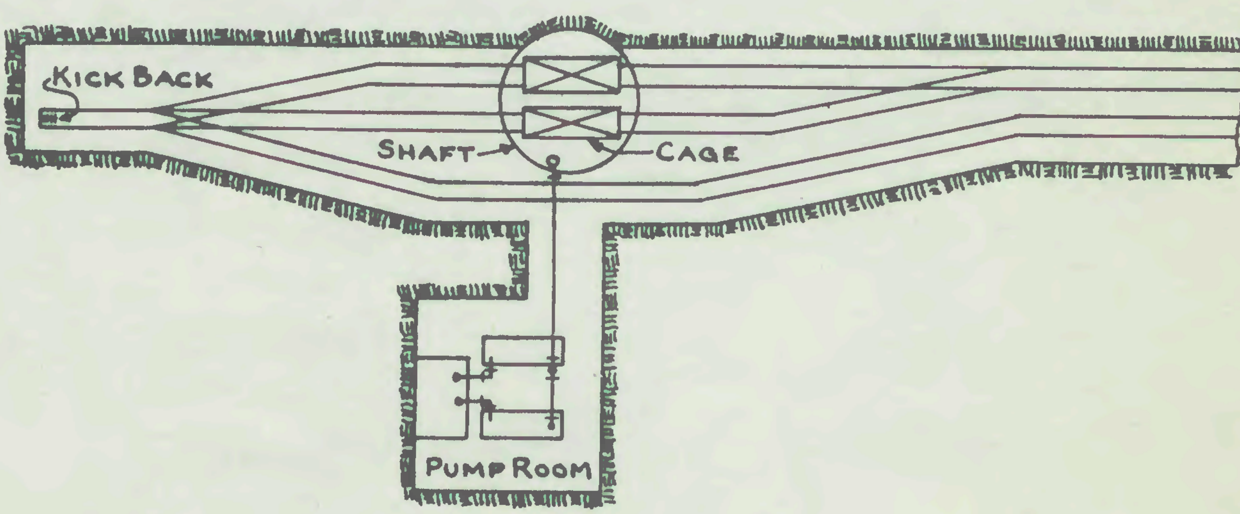
This arrangement which is shown in the accompanying picture, Exhibit No. 2, and in the sketch, Exhibit No. 3, shows how good design can result in shaft head structures with moderate capital outlay and low operating cost.

Exhibit No. 2
Fojo Mine Headframe



CAGING AND DUMPING ARRANGEMENT

TOP OF FOJO SHAFT



CAGING ARRANGEMENT

BOTTOM OF FOJO SHAFT

CAGING & DUMPING ARRANGEMENT FOJO SHAFT		
PORTUGAL		
PIERCE MANAGEMENT, INC. MINING ENGINEERS, SCRANTON, PA.		
DATE JUNE 1952	SCALE NONE	EXHIBIT NO. 3

CHAPTER NO. II

QUALITY AND ANALYSES OF COAL

Coal in the carboniferous basin of Douro is a medium grade anthracite and, as mined, has a specific gravity varying from 1.5 at Fojo Mine to 1.7 at S. Pedro da Cova.

It is very friable and is often mixed with clay, giving it a dull, greasy appearance with a plastic consistency. In other places the coal is more solidly massed but quite friable and when pressed between the fingers reduces to dust. It has a high percentage of ash and sulphur which decreases its heating and industrial value. However, this does not prevent its use in cement factories and for railroads and thermal power stations.

The "Chauffage" or heating anthracite is hard and bright, and when exposed to the atmosphere has irridescent even surfaces.

The following analyses by Instituto Portugues de Combustiveis show the quality of the coal and characteristics of the ash.

S. PEDRO DA COVA MINES

RUN-OF-MINE COAL (DRIED IN THE AIR)

Moisture	3.69%
Ash	36.29%
Volatile Matter	5.51%
Fixed Carbon	54.51%
Combustible Sulphur	0.79%
Sulphur in the Ash	0.07%
Upper heating value	4629 kg/cal
Lower heating value	4542 kg/cal

MARKET COAL

	Moisture	Ash	Volatile Matter	Fixed Carbon	Heating Value	Combustible Sulphur
	%	%	%	%	kg/cal	%
Chauffage	4.15	8.63	3.52	83.70	7170	0.62
2nd grade coal	3.24	35.00*	4.66	57.05	4820	0.63
Cribled pea coal	3.73	14.99	3.83	77.45	6610	----
Cribled washed coal	3.59	26.22*	4.63	65.56	5600	0.83
0 to 8 mm. washed coal	3.89	26.98*	4.36	64.77	5500	0.81
Normal mixture	4.09	40.81*	5.90	49.20	4210	----
Special dust	3.23	24.46	----	----	----	----
Schlamms	4.70	32.60	5.36	47.44	4720	----

Remarks: The percentage of ash marked * is definitely greater than the average values furnished by the Concessionnaire.

ANALYSIS OF ASH FROM RUN-OF-MINE COAL

SiO_2	55.05%
Fe_2O_3	7.75%
Al_2O_3	33.64%
CaO	1.58%
MnO	0.04%
MgO	1.02%
Na_2O	0.24%
K_2O	3.54%
CO_2	0.33%
P_2O_5	0.22%
SO_3	0.29%
TiO_2	Traces
Initial Deformation	1500° C

PEJAO MINES

RUN-OF-MINE COAL

Tests on Fojo and Germunde run-of-mine as furnished are not representative of the product of the mines, but are the result of selective mining.

The introduction of full seam mining, which will follow the construction of a cleaning plant, will result in an ash content in the run-of-mine at least equal to that at S. Pedro da Cova or about 37.5%. Samples of run-of-mine submitted for independent analysis to combustion equipment manufacturers support this percentage of ash in the run-of-mine at Pejao.

MARKET COAL

	Moisture	Ash	Volatile Matter	Fixed Carbon	Heating Value	Combustible Sulphur
	%	%	%	%	Kg/Cal.	%
Compact Anthracite	3.64	17.73	3.11	75.52	6160	1.82
Cribled Industrial	4.16	18.85	3.10	73.89	6020	0.98
Industrial Mixture	4.48	21.07	4.02	70.43	5800	1.91
Chauffage Briquette	3.24	27.71	5.29	62.77	5340	0.91

ANALYSIS OF ASH FROM RUN-OF-MINE COAL

SiO_2	51.00%
Fe_2O_3	17.20%
Al_2O_3	27.07%
CaO	Traces
MnO	0.11%
MgO	2.43%
Na_2O	0.28%
N_2O	3.10%
CO_2	0.10%
P_2O_5	0.60%
SO_3	0.46%
Initial Deformation	1365° C
Softening Temperature	1395° C
Fluid Temperature	1415° C

The combustion characteristics of Pejao coal will be discussed more fully in another part of the report. However, we have studied the reports of Babcock & Wilcox on this coal and note that it is their belief that under forced draught, run-of-mine coal containing up to 46% ash can be burned.

It is our considered judgment that the new thermal station should be tied to the Pejao coal reserve rather than the S. Pedro da Cova reserve, and for that reason we will discuss the Pejao facilities at considerable length later in this report.

S. Pedro da Cova coal reserve, of course, always can be considered as reinforcement reserves to Pejao reserves in a long-range thermal plant installation.

CHAPTER NO. III

CALCULATIONS OF RESERVE COAL AND LIFE OF MINES

PEJAO MINES

PERCENTAGE OF REJECTS

The mining loss at the Pejao Mines is estimated at 15%. This includes mine pillars, mine losses and rejects in the mine.

It is proposed to construct a modern washing plant at Pejao (Germunde). Losses of recoverable coal in the washing plant and rejects from the run-of-mine will be about 15%, thus, the total recovery from the coal in place will be about 70%.

GERMUNDE RESERVES

The method employed in calculating the reserves is shown in the following example of computations in connection with the accompanying map, Exhibit No. 4. The thickness of the seams is the total of all seams. The specific gravity is taken at 1.5.


DIRECÇÃO GERAL DE MINAS E SERVIÇOS GEOLÓGICOS
SERVIÇO DE FOMENTO MINEIRO
ZONA CARBONÍFERA DO PEJÃO
AVALIAÇÃO DAS RESERVAS DE CARVÃO DO COMPARTIMENTO GERMUNDE-ARDA
PERFIL LONGITUDINAL
ESCALA
10 0 50 100 150 200M.
explorado
carvão à vista
reservas certas
reservas prováveis
Rio Douro
Nivel do Mar
Rio Arda
Limite da Concessão
Sond. No. 1
Sond. No. 2
Sond. No. 8
Sond. No. 4
Sond. No. 3
Sond. No. 5
Sond. No. 6
explorado
galeria do piso 35m.
galeria do piso 85m.
gal. da Xeira ou Pedorido
al.00 gal. da Abelheira
veios
P=8.50
P=5.50
P=1.50
P=7.00
P=7.50
P=8.00
P=1.00
LONGITUDINAL SECTION THRU
GERMUNDE RESERVES
PORTUGAL
PIERCE MANAGEMENT, INC.
MINING ENGINEERS, SCRANTON, PA.
DATE
JUNE 1952
SCALE
AS NOTED
EXHIBIT
NO. 4

GERMUNDE RESERVES ESTIMATED FROM MAP

Section Number			Metric Tons In Place
1	$\frac{25 + 86}{2} \times 166 \times 11 \times 1.5$	=	152,014
2	$\frac{86 + 112}{2} \times 75 \times 2.4 \times 1.5$	=	26,730
3	$\frac{112 + 134}{2} \times 59 \times 1.3 \times 1.5$	=	14,150
4	$\frac{184 + 216}{2} \times 89 \times 5.3 \times 1.5$	=	141,510
5	$\frac{216 + 240}{2} \times 68 \times 12.5 \times 1.5$	=	290,700
6	$\frac{136}{2} \times 42 \times 2.5 \times 1.5$	=	10,710
7	$\frac{333 + 371}{2} \times 59 \times 13.4 \times 1.5$	=	417,436
8	$\frac{370 + 398}{2} \times 73 \times 5.7 \times 1.5$	=	239,675
9	$\frac{398 + 434}{2} \times 100 \times 5 \times 1.5$	=	312,000
10	$\frac{434 + 510}{2} \times 210 \times 1.5 \times 1.5$	=	223,020
11	$196 \times 203 \times 13 \times 1.5$	=	775,866
12	$\frac{313 + 343}{2} \times 82 \times 7.5 \times 1.5$	=	302,580
13	$\frac{343 + 271}{2} \times 121 \times 7.5 \times 1.5$	=	417,904
14	$\frac{467 + 313}{2} \times 256 \times 5.8 \times 1.5$	=	868,608
15	$\frac{329 + 285}{2} \times 73 \times 3.5 \times 1.5$	=	117,658
16	$\frac{285 + 271}{2} \times 95 \times 3.5 \times 1.5$	=	138,652
17	$\frac{292 + 234}{2} \times 368 \times 1 \times 1.5$	=	145,176
18	$234 \times 87 \times 1 \times 1.5$	=	30,537

Total Carried Forward 4,624,926

ADDITIONAL RESERVES ESTIMATED FROM BOREHOLES NOS. 1 to 8

			Metric Tons In Place	
Section ABCD	=	$\frac{132 + 240}{2}$ x 686 x 8.5 x 1.5 =	1,626,849	
Section CDEF	=	$\frac{86 + 132}{2}$ x 292 x 1.5 x 1.5 =	71,613	
Section EFGH	=	$\frac{86 + 58}{2}$ x 213 x 1.5 x 1.5 =	34,506	
Section GHILK	=	$\frac{58 + 24}{2}$ x 237 x 6 x 1.5 =	87,453	
			1,820,421	1,820,421
		GRAND TOTAL		6,445,347

Germunde Total Reserves Certain 6,445,347 M. tons, which less 1951 production of 61,951 M. tons gives a net reserve of 6,383,396 M. tons. In this total is included 395,632 M. tons found in mine in Sections A,B,C,D,F,G, as shown on Exhibit No. 4.

PROBABLE RESERVES (GERMUNDE)

				Metric Tons In Place
Section NOPQ	=	$\frac{418 + 488}{2}$ x 686 x 5.5 x 1.5	=	2,563,753
Section PQRS	=	$\frac{488 + 514}{2}$ x 292 x 5 x 1.5	=	1,097,190
Section RSTV	=	$\frac{514 + 450}{2}$ x 121 x 5 x 1.5	=	437,415
Section LMTK	=	$\frac{538 + 294}{2}$ x 329 x 1.5 x 1.5	=	307,944
Section TTKV	=	$\frac{188 + 124}{2}$ x 329 x 5 x 1.5	=	384,930
Section LLII	=	$\frac{285 + 271}{2}$ x 95 x 2 x 1.5	=	79,230
Section IIVV	=	$\frac{176 + 212}{2}$ x 95 x 5 x 1.5	=	138,225
Section IVZ	=	176 x 455 x 1 x 1.5	=	60,060
		TOTAL		5,068,747

SUMMARY

Germunde Mine total coal reserves will then be as follows:

	Metric Tons In Place
Certain	6,383,396
Probable	5,068,747
Total	11,452,143

FOJO AREA RESERVES

Fojo reserves are estimated from information obtained from mining and from one borehole. The drilling of more boreholes in this area is under way and the results are expected to increase the reserves in the "certain" class. The specific gravity of Fojo coal is also 1.5.

Fojo reserves are estimated at:

	Metric Tons In Place
Certain	4,200,000
Probable	15,000,000
Total	19,200,000

LIFE OF PEJAO MINES AT PROPOSED FUTURE OUTPUT

The mine life calculation is projected on the basis of a **forecast** by the present operator of Fojo and Germunde Mines of the annual production through a proposed cleaning plant.

	PRESENT PRODUCTION	PROPOSED PRODUCTION
	Metric Tons Hand Picked	Metric Tons Washed Coal
Fojo	200,000	230,000
Germunde	60,000	153,300
Total	260,000	383,300

From the preceding reserve calculations we have:

Reserves in Place - Metric Tons

	Certain Reserves	Probable Reserves	Probable Total
Germunde	6,383,396	5,068,747	11,452,143
Fojo	4,200,000	15,000,000	19,200,000
Total	10,583,396	20,068,747	30,652,143

Allowing for 15% mining loss and 15% cleaning plant loss will reduce the recoverable reserves to 70% of the reserve in place.

FUTURE LIFE BASED ON TOTAL CERTAIN RESERVES

70% of 10,583,396 ÷ 383,300 tons = 20 years approximately

FUTURE LIFE BASED ON CERTAIN AND PROBABLE RESERVES

70% of 30,652,143 ÷ 383,300 tons = 56 years approximately

MOST PROBABLE RESERVE LIFE

Certain	10,583,396 metric tons
One-half or Probable	10,034,373 metric tons
	20,617,769 metic tons

70% of 20,617,769 ÷ 383,300 tons = 38 years approximately

The foregoing is based on the fact that these mines will produce 383,300 metric tons per year of market coal, of which 100,000 tons yearly may be diverted to the power plant, and 283,300 tons for other markets.

In case the probable reserve should prove deficient, more coal could be diverted from the industry total of 283,300 tons. It seems, therefore, that it is safe to assume that the power plant can be assured of a 35-year supply of coal exclusive of S. Pedro da Cova reserve of 10,782,665 metric tons in place.

CHAPTER NO. IV

GENERAL DESCRIPTION OF PEJAO MINES

GERMUNDE MINE

There are four seams of coal in this mine, three of which are being mined at present by means of drifts. It is proposed to sink a new shaft near the River Douro to operate the lower levels.

The present workings have access drifts on the + 137.4 meter level; the + 87.4 meter level and the + 35.71 meter level, and have natural drainage and ventilation.

There are no locomotives in this mine, the mine cars being pushed by hand.

Two 12 H.P. diesel locomotives are being rebuilt at Fojo and will be used at the Germunde Mine in the near future. There are 100 mine cars in use. These cars have a capacity of 0.9 metric ton.

Mine cars are pushed by hand from the loading points to the preparation plant. The preparation plant handles the coal from Fojo mine in addition to the coal from Germunde mine. Coal is hand picked only.

A new modern washing plant is proposed to handle the output of Fojo and Germunde mines. It will be located near the Douro River at Germunde Mine. We understand that the tentative site of the proposed new Thermal Power Plant, on the right hand bank of the Douro River, will be about 500 meters from the Germunde preparation plant, and of this distance, 200 meters will be a river span.

AIR COMPRESSORS

The compressed air station is located on the surface and contains three compressors, one of 25 H.P., one of 80 H.P., and one of 50 H.P. Pneumatic wet drills are used for driving entries, chutes, and crosscuts in the bottom rock.

ENTRIES

Double track entries are 3 meters wide by 2.2 meters high. Single track entries are 1.5 meters wide by 2.2 meters high. The return (ventilation) entries are about 1 meter wide by 2 meters high. Raises and chutes are 1.2 meters by 1 meter and run in height up to 50 meters. Ladders are installed in the raises. The rails are 12 to 14 kilograms per meter with a track gauge of 60 c.m.

The entries are well timbered with eight to ten inch timber sets. Reinforced concrete mine sets have been tried since 1948 and most of these sets are still in use.

METHOD OF WORK

There are four seams, three of which are being worked in the Germunde Mine. The pitch of the seams is 40° to vertical. Strike entries are driven in the bottom rock, and cross entries are driven on about 50 meter centers to cut the three seams. The method of mining is the slicing system with backfill. Each slice is about 2.2 meters high.

Generally, the collars of the timber sets are recovered. Coal is transported in wheelbarrows from the working face to the coal chutes. Raises and coal chutes are carried up with the backfill. The amount of timber used is about 75 kg per ton of coal mined.

Exhibit No. 5 shows a section through the Germunde Mine.

For the purpose of estimating traffic for the Douro River Navigation Project, and on the assumption that the thermal plant is

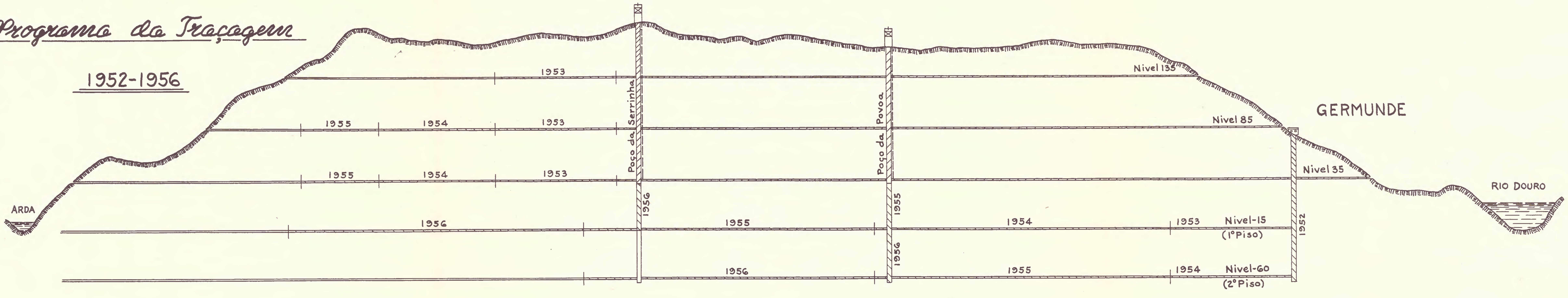
CAMPO DE LAVRA "Germunde-Arda"

12/G-MINA DE GERMUNDE

ESCALAS { Compr.- 1/5000 ; Alturas 1/2500 }

Programa da Traçagem

1952-1956



LEGENDA

Galerias e Poços realizados até 1952
Galerias e Poços a realizar em 1952-1956
Poços a revestir em 1952

SECTION THRU GERMUNDE MINE		
PORTUGAL		
PIERCE MANAGEMENT, INC. MINING ENGINEERS, SCRANTON, PA.		
DATE JUNE 1952	SCALE AS NOTED	EXHIBIT NO. 5

located so as to use coal from Fojo and Germunde mines, the river traffic of commercial coal from these properties would be 283,300 tons per year, exclusive of the coal used in the thermal plant.

FOJO MINE

There is one seam in the property 4 meters to 40 meters thick with an average thickness of 11 to 13 meters. The pitch of the seam ranges from 50^{o} to 80^{o}. The reserves as shown previously have been estimated from mine workings and one borehole. The length along the strike is about 3.5 km. A new shaft has been constructed and in a few months, it will handle all of the coal produced at Fojo. The headframe is constructed of reinforced concrete and the surface and bottom landings are equipped with fully automatic installations.

The shaft is 4.5 meters in diameter, 80 meters deep and concrete lined. The cages are single deck and hold two cars and are equipped with safety dogs on rigid guides. Hoisting arrangement has a designed capacity of 1200 metric tons a day. The mine cars have a capacity of 0.7 tons and run on 60 c.m. gauge track.

At present there are 160 mine cars in use and 200 new mine cars on order.

The distance from the new shaft to the Germunde picking plant and loading dock is 10 kilometers. Fojo Mine has four diesel locomotives underground, 2 - 30 H.P. and 2 - 20 H.P.

Six steam locomotives are used on the surface 2 - 45 H.P. and 4 - 20 to 25 H.P.

There are 102 surface railroad cars to transport the coal to the picking plant. The running gear on these cars consist of 2 trucks to each car, to enable them to take sharp curves.

Surface railroad cars have the following capacities:

10 - 5000 Kg. capacity
58 - 6000 Kg. capacity
34 - 7500 Kg. capacity

In addition to this transportation equipment, the company owns 45 - 50 river barges and hires an average of 40 barges. The barges have a capacity of 40 to 60 tons. The whole output from Fojo and Germunde is transported to market on the River Douro.

Electric power is taken from the general network power system. There is one substation which contains:

7 transformers -	1,162.0 K.V.A.
1 transformer -	29.3 K.V.A.
Total	1,191.3 K.V.A.

Voltage 1500 - 380 - 220
Cycle 50

PUMPING STATION AT FOOT OF NEW SHAFT

There are no priming pumps. The equipment consists of the following:

1 - 37 K.W centrifugal pump working
1 - 37 K.W. centrifugal pump spare

These pumps are good for 75 meter head and are fitted with check and gate valves in a 6" diameter discharge line..

During March, 1952 this pump worked five minutes per hour. It is proposed to construct sumps with 24 hour capacity.

AIR COMPRESSORS

The compressed air station is located on the surface and contains:

1 - 175 H.P. Ingersoll-Rand Air Compressor
1 - 25 H.P. Ingersoll-Rand Air Compressor

They are complete with intermediate and after-coolers and air receivers.

DRILLS

Compressed air drills are used underground for driving entries in the bottom rock. There are 13 wet and 3 dry drills, of which 8 are stopehammers. There is also one jumbo with column and two mounts. The drill bits have carbon inserts.

EXPLOSIVES

Explosive storage is located underground at Germunde mine and has a capacity of five tons. The explosives are transported to the various mines in small quantities by auto cars.

ENTRIES

Double track entries are 3 M. wide inside the timber at rail level and 2.2 meters high from top of rail to underside of timber collar.

Single track entries are 1.5 meters wide by 2.2 meters high.

Raises and chutes are 1.2 meters by 1.0 meter and range in height up to 50 meters. Raises are equipped with ladders.

Fojo mine has natural ventilation and return air exhausts to the atmosphere at Choupelo Shaft.

We have recited this equipment in some detail so as to emphasize that the mine is well equipped for long range operation.

METHOD OF WORK

There is one coal seam in Fojo mine having an average thickness of 11-13 meters with a pitch of 50° to 80°.

Strike entries are driven in the bottom rock, and cross entries are driven on about 50 meter centers to cut the seam.

Method of mining is the slicing system with backfill, working up the raise on the backfill. Each slice is about 2.2 meters high.

Some timber is recovered when the backfill is put in. Usually the collars of the timber sets are recovered. Coal from working faces is transported in wheelbarrows over the backfill to the coal chutes. Raises and coal chutes are carried up with the backfill. Coal is won by the use of hand picks, and miners produce about 6 tons per shift. The amount of timber used is about 75 Kg. per ton. Where the seam is thick they turn off the room entry (which is along the strike and at the footwall) and drive to the hanging wall taking all the coal in that slice and backfilling before starting a new slice. The height of the slice is 2.2 meters.

Exhibit No. 6 shows a section through Fojo Mine with projections of future work.


CAMPO DE LAVRA "Fojo-Paraduça"
ESCALAS - Compr. - 1/5000
ALturas 1/2500
PARADUÇA
CHOUPELO
ERVEDAL
VALE DA CANA
FOJO
Poço da Paraduça
1952
1956
Poço do Choupelo
1952
1954
0 Fojo
1956
1955
1954
1953
1952
1º Piso (Nivel-75)
1953
1956
1955
1954
2º Piso (Nivel-150)
12/F - MINA DO FOJO
Programa da Traçagem
1952-1956
LEGENDA
Galerias e Poços realizados até 1952
Galerias e Poços a realizar em 1952-1956
Revestimento de Poços a realizar em 1952
SECTION THRU FOJO MINE FUTURE WORK
PORTUGAL
PIERCE MANAGEMENT, INC.
MINING ENGINEERS, SCRANTON, PA.
DATE JUNE 1952
SCALE AS NOTED
EXHIBIT NO. 6

CHANGE HOUSES

Present capacity of the change house is 50 men. A new change house is being constructed at Fojo with capacity for 100 men.

GENERAL COMMENTS - PEJAO MINES

Empreza Carbonifera do Douro, Lda., operates the Germunde and Fojo mines.

The owner of these mines is Mr. Jean Tyssen and the operation is conducted by Jacques Tyssen, his son. He is a young man of progressive ideas and has capable assistants well versed in the technical and administrative problems of coal mining.

Office records are complete and mining and geologic mapping and borehole recordings are excellent. Administration buildings, storehouses, shops and mine buildings are of excellent design and substantial construction.

The new Fojo mine which has just been completed shows excellent engineering design and construction, and careful selection of equipment.

Staff personnel is excellently housed in homes of modern construction and with modern facilities. Sixteen houses for technical workers are being erected at Santa Barbara near Fojo mine. These houses are attractive in appearance, and consist of kitchen, living room, three to four bedrooms, shower bath and toilet facilities, electric lights, storage space and ample ground for gardening. Picture marked Exhibit No. 7, shows some of this housing.

In addition, the Company has built an excellent store in which commissary supplies and other items necessary for those living in isolated localities are for sale. This store is run on a cooperative basis for the benefit of the workers. Its affairs are conducted by a committee of workers who are elected periodically by the workers. Ample provision has been made for recreational facilities for staff, technicians and workers. These facilities consist of tennis courts, football fields, bowling alleys and competitive sports events are conducted.

Social and medical services form an important part of the conduct of this operation. The Company maintains an excellent hospital, and now has near completion an unusually modern dispensary for workers and their families. In this dispensary will be installed the most modern equipment such as x-ray machines, infared and ultraviolet machines, dental equipment and minor surgical equipment.

The Company employs five doctors, six male nurses, three women nurses and two women who visit the homes of workers to discuss health and social welfare with the families.

We have recited these activities in considerable detail because they are evidences of sound management and good labor relations which are essential elements in maintaining a labor force on a stable basis.

It gives us assurance that a power plant, which may depend upon this Company's ability to maintain a steady and uniform supply of coal, can safely rely on its source of supply.

Exhibit No. 7
Housing at Pejao Mines

CHAPTER NO. V

PEJAO MINES - OPERATING ANALYSIS,

PRODUCTION, COSTS, LABOR AND EFFICIENCIES

The following information was furnished to us by Mr. Jacques Tyssen, Operating Manager:

COST OF COAL

Items of Cost	Cost Per Metric Ton Present Production - Hand Picked Fojo Mine	 Germunde Mine
Mining Cost	70$	82$
Railroad	6$5	--
Screening and Pick-up	3	6
Repairs and Maintenance	5	5
General Expense at Mines	15	15
Medical Services	3	3
Social Services	10	10
Amortization	15	15
Administration (Ports)	10	10
Government Taxes for Housing and Social Purposes	8	8
	145$5	154$

PRODUCTION

Tonnages produced from these mines for the past five years are as follows:

	Hand Picked Run-of-Mine Metric Tons		
	Germunde	Fojo	Total
1947	43,426	161,512	204,938
1948	47,781	163,760	211,541
1949	57,401	206,355	263,756
1950	63,501	194,950	258,451
1951	61,951	196,618	258,569

ANALYSIS OF PRODUCTION AND COSTS

It will be noted from the foregoing that there has been a progressive increase in the production trend over the past five years despite many serious problems which tend to retard production such as:

1. Lack of constant supply of electric power
2. Difficulty of securing supplies and equipment
3. Difficulty of securing timber
4. Insufficient labor
5. Poor river transportation

Most of these problems are susceptible to improvement. The current house building program will ease the labor shortage, and the power situation should materially improve. Beneficial regulations by the Portugese Government could eliminate much of the difficulties mentioned in 2 and 3 above. Assuming the Douro River Navigation Program is approved, No. 5 would be solved by the construction and use of much larger boats to convey coal to Porto or Leixoes.

As Germunde is a new mine, it is possible to increase production to 200,000 metric tons hand picked coal per year over a maximum period of five years. The rate of increase is dependent upon market demand for coal and capital available for mine development. We are of the opinion that this mine can obtain a production of 150,000 tons per year by the time the power plant can be completed.

At Fojo Mine, production can be increased to 300,000 metric tons hand picked per year during the year 1953. It is safe to assume that by the time a power plant is built, the combined tonnage from these mines can be 450,000 metric tons hand picked coal per year.

The coal requirements of the power plant at the date of this study had not definitely been determined but are assumed for the purpose of this report to be a maximum of 100,000 tons of low heating value fuel per year.

Thus, it willbe seen that production increases at Germunde and Fojo can easily supply this demand. We estimate that Germunde Mine on a conservative basis, after allowing for mining losses and washery reject losses, can produce 8,000,000 tons of cleaned coal.

It is possible that the life of Germunde Mine will be greatly increased as further exploration develops new reserve areas not included in our calculations. Our analysis is predicted on the fact that a new washing plant will be erected on the left bank of the Douro River at Germunde with a capacity of 1200 tons raw coal per shift.

The total production of run-of-mine coal from both Germunde and Fojo amounting to 575,000 metric tons run-of-mine per year (equivalent to 500,000 metric tons per year hand picked) will be sent to the plant.

The requirements of the power plant up to 120,000 tons per year of 1/64" x 0" unwashed fines containing about 20% ash can be dry separated and sent to the power plant. The balance of the product, or plus 1/64" size, will be higher in ash and will be cleaned in the washing plant to produce an 18% ash product. It is anticipated that the recovery from this plant will be two-thirds of the total input, or 383,300 metric tons of shipped coal per year. If the power plant requirements are 100,000 tons per year, the balance, or 283,300 metric tons, will be available for other markets. In the event the power plant requirements are in excess of 120,000 metric tons per year, additional washed coal can be sent to the power plant. Coal washability curves submitted by the operator, the tests of Babcock and Wilcox, screen and ash tests on fine coal, are the basis for our recommendation that the power plant burn 1/64" x 0" fines.

We must consider the proposed increased production schedule at this point in our cost of coal analysis because obviously the cost of producing coal is dependent upon annual production volume.

We were advised by Mr. Jacques Tyssen that the price of coal to the power plant would be between 115 to 120 Escudos per ton.

The cost of coal, as shown in the foregoing table, averages 147 Escudos per metric ton of hand picked coal at the mine, when the cost is spread over both mines. Considering the low wage scale in effect which spread over all categories of men equals 25.90 Escudos per man including bonuses, the cost of coal is unusually high due to low efficiency.

The management furnished us on April 18th, 1952 a list of workers at the two mines as shown below:

	Germunde	Fojo	Total
Face and Backfill Men	208	556	764
Preparation and Development	31	46	77
Total Mining Workmen	239	602	841
Transportation and Maintenance	45	249	294
Total Underground	284	851	1135
Outside Employees	66	84	150
Railroad, Picking Tables, Repairs and Office	95	319	414*
Total Employees	445	1254	1699

*Distributed in proportion to respective production of each mine.

Using 1951 results, we can calculate present efficiency as follows:

	Yearly Production	Days Worked	Number of Men	Man-Days	PRODUCTION Per Man-Day
Germunde	61,951	296	445	131,720	.470 tons
Fojo	196,618	296	1254	371,184	.536
Total	258,569	296	1699	502,904	.50 ton per day

The over-all efficiency of 0.5 ton per man-day is unusally low, and is approximately one-half of European average productivity.

This low efficiency is caused by:

a. Low state of transport mechanization

b. Complete back-filling of seams

c. Low total production in relation to facilities for increased production.

As the production of Germunde and Fojo increases, the efficiency will rise rapidly through the mechanization of Germunde transportation and the fact that workers in the office, river transport, washery and pickers, technical workers and general service workers will not increase in proportion to tonnage increase. It is a fair assumption that workers on mining and back-filling and development will increase in direct proportion to tonnage increases. If Germunde increases from 60,000 tons per year to 200,000 metric tons of hand picked coal, this represents an increase of 233%. If Fojo increases from 200,000 tons to 300,000 metric tons of hand picked coal yearly, this represents an increase of 50%.

It is our opinion, based on experience, that face workers will increase roughly in proportion to tonnage increases and all other workers probably 25%. On this basis we can project a new labor force for each mine as follows:

	GERMUNDE		FOJO		TOTAL
	Present	Future	Present	Future	Future
Face and Back-fill Men	208	485	556	834	1319
Preparation and Development	31	72	46	84	156
Total Mining Workers	239	557	602	918	1475
Transport and Maintenance	45	56	249	311	367
	284	613	851	1229	1842
Outside Employees	66	82	84	105	187
Railroad Pickers, Repairs and Office Men	95	119	319	400	519
Total Employees	445	814	1254	1734	2548

FOJO

Based on a yearly production of 300,000 tons, 300 work days and 1734 men, the efficiency will be .577 tons as against .536 tons or an increase of about 8%in efficiency. Based on this efficiency, the proforma cost sheet would be as follows:

	Per Metric Ton Hand Picked	
	Present	Future
Mining Cost	70$	70$
Railroad	6$5	6$
Screening	3$	2$76
Repairs	5$	4$60
General Expenses at Mine	15$	13$80
Medical Services	3$	2$76
Social Services	10$	9$20
Amortization	15$	15$
Porto Administration	10$	9$20
Government Taxes	8$	8$
	145$5	141$32*

*This does not take into account any added efficiency due to greater mechanization in the future.

GERMUNDE

Based on a yearly production of 200,000 tons, 300 work days and 814 men, the efficiency would be .82 tons per man day as against .47 tons per man-day or an increased efficiency of 75%.

Based on the 75% increased efficiency projected for Germunde Mine, the proforma or projected cost of production at Germunde should be approximately as follows:

	Per Metric Ton Hand Picked	
	Present	Future
Mining Cost	82$	82$
Railroad	--	--
Screening and Picking	6	1$50
Repairs and Maintenance	5	1$25
General Expense at Mine	15	3$75
Medical Services	3	.75
Social Services	10	2$50
Amortization	15	15$
Porto Administration	10	2$50
Government Taxes	8	8$
	154$	117$25

The combined efficiency of both mines should increase to .65 to .70 tons per man-day as against .5 tons at present or approximately 34%.

Average future cost of both mines would be determined as follows:

Fojo	300,000 tons at 141$00	=	42,300,000$
Germunde	200,000 tons at 117$25	=	23,450,000$
TOTAL	500,000 tons at 131$5	=	65,750,000$ *

*Undoubtedly management will adjust the distribution of these costs as between each mine as Germunde's tonnage increases.

As the power plant will probably be located across the river from the Germunde loading point, and an aerial tramway built across the river, both capital cost and operating cost of the facilities necessary from the mine to the power plant may be considered as part of the power plant installation. The cost price at the mine should govern the sale price to the power plant.

CHAPTER NO. VI

COST OF COAL DELIVERED TO POWER PLANT

The Ministry of Economy, through the General Director of Fuel, has furnished certain data relative to the sales price of different sizes and grades of anthracite as follows:

Types of Fuel	Price per ton at Porto	MM Size Grading	Price Adjusted From Porto to Mine
Heating	445$	35-/36	420$ *
Forge	375$	5-/15	350$
Normal	305$	35-/70	280$
Industrial Coal			
Run-of-Mine	200$	------	175$
Sifted	200$	0/20	175$
Sifted	200$	0/10	175$

* After deducting 25$ for transportation from mine to Porto.

The sales distribution of the coal produced by this company in 1951 shows the following:

	Metric Tons	Sizing
Cement Industry	106,813	0 x 10 M.M.
Power Stations	11,557	10 M.M.x 30 M.M.
Railroads	4,914	10 M.M.x 30 M.M.
Industrial Clients	58,884	10 M.M.x 30 M.M.
Railroad Briquettes	30,035	--------
Industrial Briquettes	7,617	--------
Domestic Briquettes	24,706	--------

It is not possible to say at this time with great accuracy what the price of power plant coal should be, because this price can only be accurately determined after the washery is in operation, and careful screen analyses are made to determine the percentages of coal sold at various price levels.

An approximate computation of the costs of the washed coal and screenings sent to the power plant would be as follows:

Annual Amount - 500,000 tons hand picked at 131$5 -	65,750,000$
Less Screening and Picking 500,000 tons at 6$	3,000,000
	62,750,000$
Plus Cleaning Plant Costs 575,000 Run-of-Mine at 8$	4,600,000
TOTAL ANNUAL AMOUNT	67,350,000$
Cost Per Market Ton - 383,300 tons	175$

The heating value per pound of the 20% ash screenings, 5% moisture allowed, will be 10,250 B.T.U. and the 18% ash washed coal, 5% moisture allowed, 10,526 B.T.U.

In addition to the above costs at the mine, the cost to the power plant will have to include the cost of delivering the coal from the cleaning plant to the power plant.

If the cleaning plant is built on the left bank of the Douro River at Germunde, and the power plant and storage yards are built on the opposite bank of the river, and using capital cost data from Chapter No. VII, the cost of delivering the coal from the cleaning plant to the power plant is estimated as follows:

AERIAL TRAMWAY

Capital Cost $200,000 plus 500,000$ = 6,500,000$

Average Interest Rate over Amortizing Life at 6% = 3%

Amortizing Life - 30 years

	Per Year	Per Ton
Maintenance & Power Costs	200,000$	2$00
Interest 3% on 6,500,000$	195,000$	1$95
Amortization of Capital (30 years)	217,000$	2$17
Total Fixed Charges	612,000$	6$12

STORAGE YARD

Capital Cost $300,000 plus 500,000$ = 9,500,000$

	Per Year	Per Ton
Maintenance and Power Costs	300,000$	3$00
Interest 3% on 9,500,000$	285,000$	2$85
Amortization of Capital (30 years)	317,000$	3$17
Distributing and Reloading Storage Coal		7$00
Total Storage Cost		16$02

The above charges represent 22$ per ton to be added to mine cost, and if we add a safety factor of 3$ per ton, it requires that 25$ be added to the mine cost of coal, making a total cost to the Power Plant of 200$ per metric ton.

The sale price of coal to the Power Plant will have to be negotiated on the basis of conditions prevailing at the time the Power Plant is put into operation.

CHAPTER NO. VII

CAPITAL EXPENDITURE BREAKDOWN

The following estimates are for the capital cost of increasing the Pejao Mines production to 575,000 metric tons run-of-mine per year, coal cleaning plant required and facilities for delivering and storing coal.

PEJAO MINES CAPITAL EXPENDITURES

Local Currency	Amount
Cleaning Plant	9,000,000$
New Shaft completely equipped	5,000,000
Compressor and Transformers	1,000,000
Drift and Crosscuts	3,000,000
Houses and Roads	1,000,000
TOTAL	19,000,000$

POWER PLANT CAPITAL EXPENDITURES

AERIAL TRAMWAY AND STORAGE YARD EQUIPMENT

Local Currency	Amount
Erecting Aerial Tramway	500,000$
Preparing Storage Site	500,000$
TOTAL	1,000,000$
Foreign Currency	
Aerial Tramway 500 Meters 50 tons per hour	$200,000
Storage Yard Equipment	300,000
TOTAL	$500,000

CHAPTER NO. VIII

S. PEDRO DA COVA MINE

GENERAL DESCRIPTION OF MINE

The coal reserves in place, certain and probable, are estimated at 10,782,662 metric tons, which are proved by ten boreholes and information gained from mine workings. The mine workings are extensive since the mine has been operated since about 1820.

There are six seams of coal of which four are being worked. Their thickness varies from 0 to 10 meters with an average of about 2 1/2 meters.

Coal is of the Silurian Age and is highly folded and faulted. The pitch of the seams is 60 to 90°; the strike is N50W.

Footwall is schist and the hanging is partly altered sandstone.

Main hoisting shaft, named S. Vicente, handles the coal from three levels, namely the 48, 94 and 148 meter levels. Level 188 to be opened in the future will also use the S. Vicente shaft.

Four active openings to the surface are used. They are: hoisting shaft; manway shaft; material and supply shaft, and ventilation shaft.

The hoisting shaft is vertical, 4 meters in diameter and 148 meters deep. It is equipped with a 230 H.P. double drum hoist, rope 32 mm diameter.

Hoist capacity at a depth of 200 meters is 100 metric tons per hour.

Ventilation shaft is rectangular in section, 3.8 x 2.3 meters inclined, and has a 60 H.P. ventilating fan installed on the surface. In order to improve the ventilation, one 16 H.P. fan and one 8 H.P. fan are installed inside the mine. The water gauge is 80 mm.

PERCENTAGE OF REJECTS

Mining recovery is estimated at 90% and this includes mine pillars, mine losses, and rejects in the mine.

The percentage of rejects from hand picking is 12 to 13% and the percentage of rejects from washery is 10%. Some of the rejects come from dilution, a reasonable estimate of the recovery marketable coal is 75% of the reserves.

COAL RESERVES IN PLACE - S. PEDRO DA COVA MINE

Specific Gravity 1.7 - Data taken from maps and reports dated 1945.

Metric Tons

Seams	Coal in Sight	Reserves Certain	Reserves Probable	Total
1	545,045	1,858,083	779,229	3,182,357
2	206,227	1,299,082	479,972	1,985,281
3	925,985	1,315,375	881,280	3,122,640
4	627,300	750,125	1,159,675	2,537,100
5	797,512	----	450,075	1,247,587
Passal Seam	----	412,794	244,800	657,594
TOTALS	3,102,069	5,635,459	3,995,031	12,732,559

PRODUCTION 1946 - 1951

[illegible]	Metric Tons
1946	254,812
1947	211,662
1948	227,544
1949	254,293
1950	255,512
1951	258,600
TOTAL	1,462,423

Reserves exhausted 1946 - 1951

$$\frac{1,462,423}{.75} = 1,949,897 \text{ Metric Tons}$$

Coal reserves remaining January 1, 1952 - Metric Tons.

January 1, 1946	12,732,559
Exhausted 1946 - 1951	1,949,897
Balance - January 1, 1952	10,782,662

At the present rate of production, S. Pedro da Cova Mine has on indicated economic life of about twenty-five years.

COMPRESSED AIR STATION

Compressed air station is located on the surface and consists of:

1 - 180 H.P. Ingersoll-Rand Air Compressor - water cooled

3 - 40 H.P. Ingersoll-Rand Air Compressors - air cooled

Compressors operate at 100 pounds per square inch working pressure.

Entries are driven in the bottom rock and jackhammers are used for the drilling. There are about 10 wet drills in use and 10 spare.

Mine is free from gas and workmen use open lights. Gangways and cross-cuts are well illuminated using the 220 volt electric circuit.

ENTRIES

Double track entries are 3.5 meters wide at rail level and 2 meters high.

Single track entries are 2.5 meters wide and 2 meters high. They are well timbered, using timber from 20 to 25 cm diameter.

TRANSPORTATION

Mine car tracks are 60 cm gauge with rails weighing 8 to 14 Kg. per meter. There are about 300 mine cars in use fitted with plain bearings and the capacity of the car is 0.50 cubic meter.

Mine cars are taken to the foot of the shaft by means of two diesel locomotives of 10 H.P. each.

The company proposes to purchase two diesel locomotives, one 30 H.P. and one 10 H.P., and to relay the mine car tracks with 24 Kg. per meter rails. There are two inclined shafts inside the mine located on the second level in the 1st seam. These shafts handle the coal from the lower levels. Where the pitch is not great the mine cars are hoisted up on the 60 c.m. mine car track. Where the pitch is great, an inclined shaft cage of two mine car capacity is used.

PUMPING PLANT

Pump room is located at the foot of the shaft and contains:

1 -	Pump	110 H.P.	working
1 -	Pump	50 H.P.	spare

There are no priming pumps. The discharge line is 6 1/4" diameter. In March, 1952 pump worked two hours out of eight. During the winter, the pump works about 4 hours in eight hours.

FIRST AID

First Aid Station is under the supervision of a doctor. No hospital is provided because S. Pedro da Cova is located near Porto where all hospital cases are taken.

CHANGE HOUSE

The main change house has a capacity for 100 men, plus a change house for the foremen and staff. Rest rooms are provided for the women workers.

EXPLOSIVES

Explosive magazine has a capacity of 2 metric tons.

GENERAL

Surface buildings are kept in good repair with generally good housekeeping.

The standard of living and education is about equal to that in Porto.

METHOD OF WORK

Several methods of work are employed depending on the conditions, such as the pitch of the seam, thickness and nature of the coal, roof, floor, etc.

Generally, the seam is blocked off in about 25 x 25 meter blocks, and the coal is won by attacking the working faces with two to six men.

As the coal is worked out and the face advanced, the exhausted area is backfilled with rock from the development work.

Where the pitch of the seam is not great, cuts are carried along the strike of the seam and the advance carried down the pitch of the seam, backfilling being done to the raise and held in place by timber.

In fairly steep pitching seams the face is advanced along the strike with access roads through the backfill. In other places the coal is worked advancing down the pitch.

The amount of timber used is about 60 Kg. per ton of coal.

Face men produce about six to eight tons of coal per shift. The average output for inside men is two tons per shift.

Engineer Augusto Farinas de Almeida, the General Manager, states that S. Pedro da Cova mine could increase its production and supply 120,000 tons of coal to the Power Plant by the use of the proposed two new locomotives and 24 Kg. rails.

PREPARATION

Lump sizes of coal are hand picked while the fine sizes are screened and washed in a Rheolaveur fine-coal cleaning plant. Respect total rejects by test from the picking plant and the washery were found to be 22.4% of the run-of-mine production.

Water used at the preparation plant is pumped from a stream called the Little River.

COAL SIZING AND ANALYSES

The sizes, percentage of ash, and the heating value of coal produced at S. Pedro da Cova are:

SIZE OF COAL	ASH CONTENT PERCENT	HEATING VALUE CAL/KG.
Heating	10	7100
Motor	15	6600
Motor Second Class	35	4800
Foundry	15	6600
Motor (Size about Pea)	25	5700
Washed Motor	25	5700
Screened and Washed	25	5700
0/8 Washed	27	5500
Dust Washed	26	5600
Sludge	37	4600
Screened Normal Not Washed	47	3700
Mixed Normal	34	4900
Dust	37	4600

CAPITAL COST NECESSARY TO MEET POWER PLANT REQUIREMENTS

If S. Pedro da Cova production is expanded to meet power plant requirements, then the owner will have to make certain expenditures to expand production. These expenditures are as follows:

1	Aerial tram to Douro River Loading station 7 1/2 km at 1,200,000$ per km	9,000,000$
1	30 H.P. Diesel Locomotive	160,000$
1	10 H.P. Diesel Locomotive	120,000$
3.5	km of track (28 Kg. per meter)	160,000$
	Total Capital Cost	9,440,000$

If S. Pedro da Cova coal is supplied to a power plant located about 5 km. east of Porto on the right bank of the Douro River, there would be additional capital charges against the power plant for storage and reclaiming equipment of:

Storage Yard Equipment $300,000 plus 500,000$

Charges of 16$ per ton to cover amortization, maintenance and distribution would have to be added to the mine price.

COST OF COAL AT S. PEDRO DA COVA

The cost of coal at S. Pedro da Cova is approximately as follows:

	Per Ton
Labor	83$
Materials	26$
Social Charges	24$
Royalties and Taxes	5$
General Expenses	9$
Washing	4$
Porto Administration	9$
Estimated Mine Price	160$
Added Cost of Storage and Rehandling	16$
Estimated Amortization	12$
Expected Cost Delivered at Power Plant	188$

The heating value of this coal, assuming washed dust of 26% ash grade is furnished, will be 9900 B.T.U., based on a moisture content of 4%.

This mine is well equipped to produce coal for the Power Plant and has excellent top works, but has a shorter life and its location in respeft to the proposed location of the Power Plant would add additional costs for transporting this coal up the Douro River.

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COAL AND METAL MINING

SCRANTON ELECTRIC BUILDING
SCRANTON 3, PENNSYLVANIA

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J. B. WARRINER, *Special Consultant*

WASHINGTON, D. C. REPRESENTATIVE:
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1025 CONNECTICUT AVENUE, N.W.
TELEPHONE: REPUBLIC 3041

JULY 8, 1952

MR. GERALD T. MCCARTHY
KNAPPEN-TIPPETTS-ABBETT-MCCARTHY, ENGINEERS
62 WEST FORTY-SEVENTH STREET
NEW YORK, NEW YORK

DEAR MR. MCCARTHY:

SUBMITTED HEREIN IS REPORT IN CONNECTION WITH THE IRON ORE DEPOSITS OF NORTHERN PORTUGAL. WE WISH TO CALL YOUR PARTICULAR ATTENTION TO THE STATEMENT CONTAINED IN THE PREFACE OF THIS REPORT, WHICH WE ARE REPEATING HEREWITH FOR EMPHASIS.

> "IT SHOULD BE RECOGNIZED THAT THIS IS STRICTLY A PRELIMINARY REPORT WHICH EVALUATES THE POSSIBILITIES OF THREE IRON ORE DISTRICTS WHICH HAVE NOT HAD THE BENEFIT OF SUFFICIENT DRILLING AND EXPLORATION TO DETERMINE THEIR FULL VALUE. OBVIOUSLY, THEIR ECONOMIC VALUE DEPENDS UPON THE ABILITY TO FIND A MARKET OF SUFFICIENT VOLUME TO JUSTIFY LARGE CAPITAL EXPENDITURES. BECAUSE THE ORES ARE LOW GRADE, FURTHER ECONOMIC AND ENGINEERING STUDIES OF A DETAILED NATURE MUST BE MADE, NOT ONLY OF THE ORE-BODIES, BUT ALSO OF THE PROBLEM OF ORE CONCENTRATION TO A DEGREE THAT INSURES MINIMUM TRAFFIC CHARGES TO COMPETITIVE MARKETS, AND OF A QUALITY THAT FINDS READY ACCEPTANCE IN THESE MARKETS.
>
> THE CONCLUSIONS ARE THAT THE MONCORVO REGION IN PARTICULAR, DESERVES A COMPLETE AND DETAILED GEOLOGICAL, ENGINEERING AND ECONOMIC STUDY TO PROVE QUANTITIES AND COST ESTIMATES, AND TO PROVIDE MINING AND BENEFICATION PLANS TO THE POINT WHERE CAPITAL COST ESTIMATES CAN BE MADE WITH ASSURANCE.
>
> MOREOVER, THE ECONOMICS OF CREATING A SMALL STEEL INDUSTRY REQUIRES CAREFUL EVALUATION OF THE RAW PRODUCTS THAT ENTER INTO STEEL PRODUCTION AND THE DETERMINATION OF THE ECONOMIC LOCATION FOR A STEEL MILL.

THE ABSENCE OF COKING COAL REQUIRES RESEARCH WORK TO DETERMINE THE BEST TYPE OF FURNACE TO USE IN REDUCING HIGH SILICA ORES WITH NON-COKING COALS."

WE PARTICULARLY WISH TO COMMEND THE EXCELLENT HELP AND COOPERATION EXTENDED BY OFFICIALS OF THE PORTUGUESE GOVERNMENT, AND ALSO THE ASSISTANCE EXTENDED BY MEMBERS OF YOUR STAFF.

VERY TRULY YOURS,

PIERCE MANAGEMENT, INC.

F. L. Rousselle

F. L. ROUSSELLE
EXECUTIVE VICE-PRESIDENT

FLR:MD

APPENDIX B

IRON

INDEX

PREFACE

We were given the assignment by the Portuguese Government, through Knappen-Tippetts-Abbett-McCarthy, of making a preliminary examination of the iron ore deposits of northern Portugal, and of determining their competitive position and economic importance.

Under date of June fourth, Mr. Lucien Eaton of this firm, was sent to Portugal for the purpose of making this study.

The districts visited were the following:

1. Vila Cova
2. Guadramil
3. Moncorvo

Members of the Servico de Fomento Mineiro of the Portuguese Government accompanied Mr. Eaton on the trip, and furnished him with transportation, maps and reports, arranged for hotel accommodations and were of the greatest assistance in every way.

It should be recognized that this is strictly a preliminary report which evaluates the possibilities of three iron ore districts which have not had the benefit of sufficient drilling and exploration to determine their full value. Obviously, their economic value depends upon the ability to find a market of sufficient volume to justify large capital expenditures. Because the ores are low grade, further economic and engineering studies of a detailed nature must be made, not only of the ore bodies, but also of the problem of ore concentration to a degree that insures minimum traffic charges to competitive markets, and of a quality that finds ready acceptance in these markets.

The conclusions are that the Moncorvo Region in particular deserves a complete and detailed geological, engineering and economic study to prove quantities and cost estimates, and to provide mining and benefication plans to the point where capital cost estimates can be made with assurance.

Moreover, the economics of creating a small steel industry requires careful evaluation of the raw products that enter into steel production and the determination of the economic location for a steel mill.

The absence of coking coal requires research work to determine the best type of furnace to use in reducing high silica ores with non-coking coals. Recent developments in South Africa using the German Krupp-Renn Process may point the way for similar development in Portugal.

ASSIGNMENT

The purpose of the examination was to make a preliminary study of the iron ore deposits and to write a report, which will state:

1. The probable amount of ore which can be expected.
2. The probable average analysis of the ore, and its suitability for the production of iron, using Portuguese coal.
3. The probable cost of production.
4. The probable market for the ore both present and future.
5. The best location for a steel plant in Portugal using Portuguese coal and ore.

A basic reason for the examination was also to determine whether or not enough freight can be expected from these mines to warrant preparations for shipping the ore down the Douro River in barges to Porto and Leixoes rather than by rail.

CHAPTER NO. I

ESTIMATE OF ORE RESERVES

The reserves of positive and probable ore, that is to say, the total ore which is reasonably assured, we have estimated as follows:

	Tons
Vila Cova	50,000
Guadramil	2,000,000
Moncorvo	78,000,000
TOTAL	80,050,000

Additional ore may be inferred from geological structure, but more development will have to be done to prove its reasonable assurance.

Figures will be given in greater detail later in this report, when the deposits are being described.

CHAPTER NO. II

AVERAGE ANALYSIS

All of the ore is low-grade. By hand-sorting and mixing, the analysis of a limited amount of ore in each district could be improved to such an extent that it could be sold, but the proportion of such ore to the total is relatively small. All, or nearly all, of the ore appears to be amenable to concentration. The Vila Cova ore can be concentrated magnetically. The carbonate ore at Guadramil can be concentrated by roasting. The Moncorvo ore can be cleaned by heavy media separation, and can probably be concentrated by fine grinding and washing, possibly with flotation. The ore is richer in iron by 10 percent than the taconites of Lake Superior in the United States, and should therefore have a better concentrating ratio, not more than 2 to 1. Most of the Moncorvo ore can be mined cheaply in open pits, and the cost of the concentrated ore should be low enough to place it in a strong competitive position.

The average analysis, calculated from published figures, and those shown on maps and sections, is as follows:

DISTRICT	ORE	FE %	SiO_2 %	PHOS. %	S %
Vila Cova	Magnetite	35	33		
Guadramil	Limonite	50	8	1.3	.15
Guadramil	Siderite	40	6	.7	.15
Moncorvo	Martite	43.6	28.8		

Except for some of the Guadramil ore, the silica content of the raw ore is too high to permit its use as the only feed for a blast furnace. If mixed with basic ores, such as are found in England, it should work very well. Furnace men do not like to use ore which contains more than 18% silica, except under unusual conditions and then in limited quantities only. The average silica content of the furnace charge should be 8%. Most of the ore at Moncorvo contains more than 20% SiO_2, and will therefore be unacceptable. At the Minas de Moncorvo, a satisfactory analysis is being maintained by careful mixing of two grades of ore and by discarding the fines, but a large proportion of the ore cannot be used at all.

CHAPTER NO. III

PROBABLE COST OF PRODUCTION

VILA COVA

The cost of production at Vila Cova will be relatively high, and will vary with the degree of concentration. The quantity produced will be so small that it may be disregarded.

GUADRAMIL

Three fourths of the ore at Guadramil will have to be mined underground, and conditions are unfavorable for cheap mining. The ore is narrow and hard. Above water level the walls are soft and weak. Timber is scarce and expensive. Mining by horizontal cut-and-fill is almost compulsory, and this method of mining is expensive.

Possibly one fourth of the ore can be mined in open pits by stripping both walls, but the cost per ton for stripping will be high, because the ore is narrow, and the ore would have to be cleaned by heavy media separation or by hand-sorting before shipment.

If the railroad is not extended to the ore deposits, the cost of trucking to Braganca, 37 kms., will be prohibitive, and the amount of ore indicated is barely enough to justify the capital expense of building the railroad.

The distance by rail from Guadramil to Leixoes would be approximately 320 kms., and the freight rate would be about 106$.

The siderite ore should be roasted, either at or near Leixoes or at the mines, using low-grade coal from the Porto district. Whether roasting should be done at the mines or the port will depend on the difference between the freight on the coal and the saving in freight on the roasted ore. A favorable freight rate on the coal should be obtained, because it would make a payload for the cars both going up and coming down.

The cost of ore delivered at Leixoes is estimated as follows:

COST OF MINING GUADRAMIL ORE

Mining	50$
Trucking to Railroad	5
General Expense	10
Roasting	15
TOTAL	80$
Freight to Leixoes	106
Dock charges at Leixoes	18
Government Tax	2
TOTAL	206
Probable selling price of roasted ore at Leixoes	209
PROFIT	3$

MONCORVO

Most of the ore can be mined in large open pits, the ore being drilled with churn drills and loaded into trucks by power shovels. It will be hauled to a crushing plant at the head of a wire-rope tramway, which will lower it to a concentrating plant at the bottom of the hill near the railroad, where it will be screened, cleaned by heavy-media (sink float), ground fine enough to release the silica, and be concentrated to 60% iron and less than 10% silica. These results should be possible on a ratio of two tons of crude ore to one ton of concentrates. If the concentrates are "pelletized", that is, made into round pellets, 1 cm. to 2 cm. in diameter, they will be an ideal feed for a blast furnace. "Pelletizing" costs only half as much as sintering.

The cost of ore delivered on shipboard at Leixoes is conservatively estimated as follows:

	Per Ton
Mining (2tons)	45$
Aerial Tramway	5
Crushing and Screening	5
Sink-float Cleaning	5
Grinding and Flotation (1.8 tons)	25
General Expense	10
Pelletizing (1 ton)	15
TOTAL	110$
Government Royalty Tax	4
Transport to Leixoes	72
Dock Charges at Leixoes	18
Cost on Shipboard	204$
Sales Price	244$
PROFIT	40$

It should be possible to reduce these cost figures by 20%, especially those on the railroad and docks.

CHAPTER NO. IV

PROBABLE MARKET

The present price of iron ore is exceptionally high, but it is unlikely to decline much, except in periods of industrial depression.

Following the Civil War in the United States, the price paid for ore of approximately the same grade as the Portuguese ores was the same as that paid now for Portuguese ore; but, when large deposits of higher grade ore were found, the demand for the high-silica ores disappeared, and the price of all ore declined.

The ore situation now, however, is quite different from what it was then--eighty years ago. The high-grade ores of England are exhausted, and so are those of Northern Spain. The Riff ores of Spanish Morocco are said to be increasing rapidly in sulphur content and to be approaching exhaustion. There is some good ore left in Southern Spain, but the end is said to be in sight. The French ores in Normandy and Brittany are similar to those in Portugal, although the silica content is less. In the Erzberg deposits in Austria the oxidized ore has been exhausted, and only siderite remains. The Lorraine ore deposits remain virtually unchanged, although the ore close to the surface has been mined. The only place in Europe west of the Iron Curtain, where more high-grade ore is available now than in the past is Norway and Sweden.

High-grade ore must be brought long distances by water to reach the iron furnaces of Western Europe. It comes from Bell Island, Newfoundlan Newfoundland, and will soon be coming from Labrador. It comes from the West Coast of Africa and from Brazil. The long distances that these ores must be shipped makes the competitive position of the Portuguese ores much better that it was in the past. Moreover, the recent experiments in concentrating iron ore that is high in silica in the United States have pointed the way for reducing the silica content of the Portuguese ores.

If the silica content of Portuguese ores is reduced and the iron content increased, it should be possible to sell a million tons of Portuguese ore a year for use abroad or to use it for making iron in Portugal.

CHAPTER NO. V

SITE FOR A STEEL PLANT

The principal raw materials for making iron are iron ore, coal or charcoal, and limestone. The location of these materials has an important bearing on the choice of a site for the plant, but the most important factor is the market for steel products. Unless all three of the raw materials are close together, it is usually best to build the plant near the market, because the freight rates on raw materials are much lower than those on finished products. Other important considerations are proximity to an adequate source of electric power and to a plentiful supply of clean, fresh water and good transportation facilities.

In Portugal all of these items, except the ore, are near Porto, and a site near Leixoes is indicated.

There may be other considerations, however, which will affect the choice of a site for a plant. In order to prevent too great a concentration of population in the Porto district with its consequent increase in the cost of living and higher wage-scale, and in order to give employment to the people in or near the mining district, it may be better to locate the plant near the mines.

The question has arisen as to whether or not the Portuguese coal, which is anthracite, can be used for making iron. This coal does not coke well, although some sort of coke could probably be made by mixing the coal with high-volatile from abroad or with petroleum distillation residues. However, anthracite coal was used for making iron long before coke came into use. Until 1840 the state of Massachusetts was the largest producer of iron in the United States, and all of this iron was made with charcoal. Then it was found that anthracite coal could be used instead of charcoal, and the iron business moved to Eastern Pennsylvania. Then the Pittsburgh seam of bituminous coal was found to make excellent coke, and the iron business moved to the Pittsburgh district.

CHAPTER NO. VI

DESCRIPTIONS OF THE ORE DEPOSITS

VILA COVE DO MARAO

REFERENCES

The iron ore deposits now being worked are described in detail in Volume 11, Fasc. 3 and 4 of Estudos, Notas e Trabalhos do Servico de Fomento Mineiro, published in 1946. Most of the maps used in this report on Vila Cova are taken from that volume.

HISTORY

The Vila Cova deposits were worked very many years ago, possibly by the Romans; but the old workings indicate that only the softer ore, found at the tops of steep anticlines, was mined. The ore was probably smelted in forges, using charcoal for fuel.

In recent years an attempt was made to find the downward extention of these lodes by driving tunnels and crosscuts under them, but only partial success was achieved.

The known deposits are now being worked by the Sociedad das Minas de Vila Cova with headquarters in Porto.

SITUATION AND EXTENT

The deposits are situated on the southeastern slope of the Alto do Siao less than 1 km. north of the village of Vila Cova. Vila Cova is 9 kms. west by north from Vila Real, which is the nearest shipping point on the railroad. The distance by road from Vila Cova to Vila Real is 22 kms., but a new road is now being built jointly by the mining company and the government, which will reduce the distance to 14.5 kms.

The altitude of the deposits varies from 870 m. to 1,000 m. above sea-level.

There are six mining concessions in the district, of which only one, Monte das Rosarias, has any known ore. This concession is held by the

Sociedad das Minas de Vila Cova.

The deposits extend northwest for 500 m. from the portal of a tunnel, which is 600 m. north of the village of Vila Cova. Farther to the north on the north flank of the Alto do Siao there are small outcrops of iron formation, but they do not appear to be of commercial importance.

A magnetic survey of the mineralized area has been made, and shows some other magnetic zones besides those mentioned, but the indications on surface and the size of the positive abnormalities in magnetism do not indicate ore-bodies of commercial size. An estimate of ore based on the magnetic survey was made, and a large tonnage was estimated, but the figures are quite unreliable, and have little basis in fact.

TRANSPORTATION

At present the ore is hauled 22 kms. by truck to Vila Real, where it is loaded by hand into small gondola cars on a narrow gauge (1 m.) track. The narrow gauge track joins the wide-gauge (1.665 m.) track on the Rio Douro near the town of Peso de Regua, 16 kms. in a straight line, 29 kms. by rail, south of Vila Real.

From Regua to Leixoes is 119 kms. on the wide-gauge track.

We were told that ore had been hauled directly to Porto by truck at a cost of $2 U. S. per ton, a distance of 113 kms. (70 miles) by road. This is 3¢ per ton-mile, and is less than actual cost. The trucks must have had loads both to and from Porto.

It has been proposed to build a wire-rope tramway from the mine to Regua, a distance of 22 kms., but, unless new development shows up a lot of new ore, the ore reserves are much too small to justify such an investment.

An alternative plan, which would eliminate the transfer of ore from narrow-gauge to wide-gauge tract at Regua, would be to haul directly by truck to Regua. The distance by road is now 50 kms., but it could be shortened to 40 kms. by a little new construction.

Freight rates are at present about 1 1/2 ¢ U. S. per ton-mile, which is considerably more than is charged for long hauls of Lake Superior ore.

MODE OF OCCURRENCE OF THE ORE

The ore occurs as magnetite disseminated through bands of rock that are interstratified with quartzite. The bands of magnetite are narrow, usually only a few cms. wide, but the total width of the vein may be 4 m. or even more.

The rocks in which the magnetite occurs are closely folded, and the best ore appears to be along the sides and near the tops of the anticlines. The general strike of the anticlines is northwest. In many ways the structure is similar to that of the gold reefs at Bendigo in Australia, but the anticlines are smaller, sharper and not so persistent.

The ore mined by the "ancients" was that found at the tops of the anticlines, and presumably was softer and probably richer than that in the sides, or legs, of the anticlines. The ore mined at present is in the legs of the anticlines, and is generally wider in the southwest leg.

ANALYSIS

Samples were taken as follows:

1. Run-of-mine from floors and walls of drifts on the bottom level, No. 4, in the Galeria de Tecto and the Galeria de Muro.
2. Hand-sorted Ore.
3. Unsorted Ore.
4. Unsorted Ore from No. 3.

At the time of typing results of analyses had not been received.

From previous sampling the average ore mined contains about 35% Fe and 33% SiO_2.

DEVELOPMENT AND EXPLORATION

The ore is found on both sides of a steep valley, in which flows a small stream, known as Ribeira de Sobugueira. On the east side of this valley are two old openings on the apices of two sharp anticlines. The lower of these is known as Esperanca, and was opened at an elevation of 935 m. above sea level. The anticline pitched gently downward to the northwest, and was followed for a total of 75 m. The lower openings are filled with rock, and cannot be seen. They are known as Pesquisa Teotonio Pereira.

20 m. east of Esperanca and 5 m. higher is an old opening known as Salazar. Little can be seen here, although the ore was followed for nearly 30 m. The opening follows the crest of a small anticline, and the lower part of the workings is filled with waste.

On the west side of the valley there are three old openings, which are apparently on the same anticline. The highest of these openings is called Carvalho, or No. 1. It is an open-cut, and was opened at an elevation of 1010 m. above sea level. It is in ore which dips steeply to the south and which at one place is 13 m. wide, although the ore is not all of good grade for the full width. Drifts along foot wall and hanging wall have followed the ore northwest for 65 m. The ore apparently pitches downwards towards the northwest.

Next lower down is another open-cut, called Sala de Jantar. It was opened at an elevation of 970 m., and was driven southwest into the hillside for 20 m. in ore 6 m. wide. It is called No. 2.

No. 3 was a small open-cut in the hillside at an elevation of 930 m. above sea level, 90 m. southeast of Jantar. There are now two gangs of men working at No. 3, following the ore to the northwest. The appearance of the workings resembled that of No. 1. From No. 3 a long incline was driven downwards at an inclination of -15^0 to the northwest for a distance of 75 m. It followed a vein of ore 4 m. wide. This incline is called the Poco Angelo.

At a place near the stream at an elevation of 895 m. a tunnel, called the Galeria Principal, or No. 4, was driven 70 m. a little west of north to reach a point under Esperanca, and a short branch was driven northeast in an endeavor to find the downward extension of Pesquiza Salazar. No ore was found in either place.

A long crosscut, called Antiga Traversa, was then driven nearly 100 m. southwest and from it a drift, known as Galeria Angelo, was driven northwest and west until it reached the ore at the bottom of the Poco Angelo. Two drifts were driven northwest in this ore, the northern drift, Galeria de Muro, following a vein 2 m. wide, and the southern drift, Galeria de Tecto, following a vein 4 m. wide. A cross-cut was also driven north under the Sala de Jantar, or No. 2, but found only a narrow seam of ore.

With the exception of the Poco Angelo and the tunnel at No. 4 the openings were made for the extraction of ore and not for exploration, and do not show much ore.

There are other old workings on the line of the lode Northwest of Carvalho, or No. 1, at Angelo IV on the map, and above, but the vein appears to be very narrow and uncertain.

RESERVES

Estimate of the known ore is as follows:

Positive Ore	25,000 tons
Probable Ore	25,000 tons
Total...............	50,000 tons
Inferred Ore	50,000 tons
Total...............	100,000 tons

MINING METHODS

Most of the ore will have to be mined underground with the use of little timber and the percentage of extraction is unlikely to be higher than 75%.

CONCENTRATION

At present the only form of concentration in use is picking out the lean material by hand, but the ore should be amenable to magnetic concentration. The best practice appears to be to crush the ore to about 3 in. (75 mm.) and then put it over a Dings Magnetic Drum with a strong-field. This will discard only the clean rock that contains little iron.

The concentrates should then be put over a Dings Magnetic Drum with a weak field. This will remove the pure ore. The reject should then be put over a magnetic drum with a strong field, the fines being fed to a crocket wet magnetic concentrator.

By proper adjustment this treatment should be able to turn out a product containing 65% Fe or better. By fine grinding, a product containing 69% Fe can probably be obtained.

By concentration before shipment much of the cost of freight will be eliminated.

PRODUCTION

Production will be relatively small, and will probably be not more than 30,000 tons a year, not enough to affect the traffic problem on the Douro River.

The competitive position of Vila Cova ore will depend on the degree of concentration. If the ore is concentrated into a high-grade product, containing 65% Fe or better, it should find a ready market in England, France and Belgium, but the quantity will be small.

CHAPTER NO. VII

DESCRIPTION OF ORE DEPOSITS
GUADRAMIL

REFERENCES

The iron deposits at Guadramil are described in detail in Volume VI Fasc. 1-4 of Estudos Notas e Trabalhos do Servico de Fomento Mineiro, published in 1952. The map and sections used in this report were taken from this volume.

HISTORY

The soft parts of the outcrops of the Guadramil ore-deposits were mined long ago by the Romans. They had no explosives and could not mine the harder ore. During the Middle Ages some ore was probably mined for local consumption, but the amount was insignificant.

SITUATION AND EXTENT

The deposits are near the top of a low range of bare, rounded hills, called Barreiras Brancas, on the high plateau 37 kms. by road northeast of the town of Braganca, District of Braganca, in the province of Tras-os-Montes. The ore bed crosses the Spanish border, but soon pinches out.

The road from Braganca to Guadramil consists of 20 kms. of graded, water-bound macadam, 10 kms. of graded highway with earth or gravel surface and 7 kms. of ungraded, single track dirt road, 37 kms. in all. One bridge will have to be built.

There are seven concessions on the ore deposits, covering 325 hectares (811 acres). One of the concessions, No. 834, has been abandoned, and one, No.1081, is for gold.

TRANSPORTATION

The distance by road from the mines to Braganca is 37 kms. Braganca is the end of a narrow-gauge railroad, which starts at Tua on the Rio Douro, and follows the Rio Tua Valley up to Mirandela, and then turns northeast across the plateau. From Tua to Braganca is 135 kms. Ore would be transferred to the wide-gauge railroad at Tua, the haul from Tua to Leixoes being 157 kms. If the railroad is extended to the mine, the total haul from the mines to Leixoes will be between 320 and 330 kms. and on the present basis the freight rate would be 106$ per ton.

MODE OF OCCURRENCE OF THE ORE

The ore occurs as three beds, two of which, Barreiras Brancas, and Barreiras Brancas No. 1, stand nearly vertical. The third bed, which lies between the other two, dips north about 35°. The beds strike northwest-southeast. All three beds may be parts of one bed, which has been cut up by faults.

The footwall and hanging wall are quartizite and schist. Both walls are weak and badly weathered as far down as water level.

The outcrop ore, where it has been left, is almost typical "Brown Ore". Only the harder ore has been left, the softer ore having been mined by the Romans.

Below water level the ore is siderite. It is hard and gray and unoxidized, when first mined, but soon changes color to reddish brown.

Above water level the ore is limonite and hydrous-hematite, and is a mixture of hard and soft. The Romans mined much of the soft ore.

ANALYSIS

Samples of oxidized "Brown Ore" were taken from two crosscuts, T_1 and U_1.

Another sample was taken from a typical exposure of partly altered ore.

A fourth sample was taken from unaltered siderite in the Ganderas shaft near the Spanish border.

From data published the analyses of the two average grades of ore appear to be:

	Fe	SiO_2	Phos.%	S.%
Limonite	50	8	1.3	.15
Siderite	40	6	.7	.15

The silica content is lower and the phosphorus content much higher than in Vila Cova or Moncorvo.

Roasting the siderite, which contains 40% Fe will raise the iron content to 48% and the silica to 7%.

DEVELOPMENT AND EXPLORATION

The Servico de Fomento Mineiro has done a large amount of exploratory work in the district in the past few years.

Shafts have been sunk to depths as follows:

Name	Depth M.
Poco Casona	49
Casteloes	50
Barreiras Brancas Norte	16
Gandeiras	65
Pena de Ferro	16
Buracote	52

A large number of trenches has been dug both to explore the beds and to determine the geological structure.

Several small inclines and tunnels have also been driven.

These shafts, trenches, inclines and tunnels are shown on Map No. 6.

From the information given by this work the outcrop has been mapped and the lengths and thickness of the three beds have been shown to be as follows:

Bed	Length	Average Thickness	Dip
Serra das Barreiras Brancas	1800	5.2	78° SW
Monte da Gandeira	400	3.0	18° SE
Serra das Barreiras No. 1	800	4.1	73° SE

RESERVES

We estimate the known ore, positive and probable, as follows:

	Tons
Barreiras Brancas	1,000,000
Monte da Gandeira	500,000
Barreiras Brancas No. 1	500,000
TOTAL	2,000,000

MINING METHODS

No ore is now being mined. The ore nearest the surface can be mined in open pits by stripping off the weathered footwall and hanging wall rocks to a depth of about 12 m., leaving the sides sloping 35°.

In the steeper ore both sides must be stripped, but some of the ore, particularly that in the Monte de Gandeira, has to be stripped only on the hanging wall side.

The ore below the stripped portion will have to be mined underground.

Reasonably strong ore with weak walls must be mined by a stoping method which either uses a large amount of timber or uses rock or sand filling. Timber is scarce and expensive, and so only a filling method is left. Horizontal cut-and-fill is indicated. This is not a cheap method of mining, but it is well adapted to mining much of the ore above the water level.

Below water level, the walls are stronger and the ore is harder. It can probably be mined by shrinkage stoping, which is cheaper than cut-and-fill.

The percentage of extraction by underground mining will be between 60% and 75%.

CONCENTRATION

The limonite ore is not amenable to concentration. The siderite ore contains only 8% to 10% of impurities other than CO_2. The CO_2 can be driven off by heat, using low-grade fuel. The resulting improvement in iron content and in structure will make the ore more readily marketable, and, if roasted at the mines, will reduce the cost of transportation.

It may be cheaper however to do the roasting near Porto, using fines from local coal mines. Whichever location gives the lower cost should be used. The weight of the ore will be reduced about 20%, and this saving in freight must be matched with the cost of freight on the coal before a decision is reached.

PRODUCTION

Considering the size of the reserves and the capital expense, the mines should have a life of at least ten years. This means 800 to 1,000 tons a day, which is about all that the railroad can handle.

COMPETITIVE POSITION

The long haul by rail, especially on the narrow-gauge track, makes the competitive position of the Guadramil ore very weak. Estimated costs, as shown previously show too small a profit to justify the risks involved.

CHAPTER NO. VIII

DESCRIPTION OF THE ORE DEPOSITS
MONCORVO

REFERENCES

Most of the information in regard to the ore deposits at Moncorvo was obtained in the field, but was supplemented by a report furnished by the Servico de Fomento Mineiro, written in 1948, and by maps and cross-sections from the same source. Ferrominas, Lda., also furnished maps and cross-sections of its own operations, which were very helpful.

HISTORY

The Moncorvo ore deposits must have been known by the Romans, but the ore was too hard to mine, and too silicious for them to smelt. The Romans preferred the soft limonitic ores that they found at Guadramil and in the Burgos District in Spain.

Some years ago the deposits attracted the attention of the Germans, and the more prominent deposits were filed on in concessions, Proc. No. 267-275 and 277 and 278, and were held until the last world war. These concessions are now in the name of the Companhia Mineiro de Moncorvo and are in litigation.

The French Company of Schneider and Compagnie also acquired 23 concessions. Most of them have float ore only.

In the current year a company called Ferrominas Lda., has begun operations on the Concession Fragas da Carvalhosa, No. 290, and has shipped between 30,000 and 40,000 tons of ore to England.

SITUATION AND EXTENT

The Moncorvo iron ore deposits are the largest in Portugal. They are situated on the hills east of the City of Torre de Moncorvo. In the Braganca District of the Province of Tras-os-Montes. They are 8 kms. in a direct line northeast of the Rio Douro, and are 20 kms. By road and 22 kms by narrow-gauge railroad from Pocinho on the south side of the river. The ore deposits are at elevations of 800 to 900 M. above sea level and 200 to 300 M. above the railroad, which in turn has a drop of 300 M. to the Rio Douro at Pocinho.

The ore is found on the tops of the hills, forming hard caps, which have resisted erosion. On the flanks of the hills there are widespread deposits of "Float" ore, which on the lower slopes consist of rounded pebbles and small boulders.

The hills on which the iron ore is found form a curve like a giant fish hook, 3 kms to 4 kms. long, of which the Cabeco da Mua forms the point and the Alto do Mendel and Fragas de Cotavia the shank. The Alto do Mendel is 2 kms. southeast of the city of Torre de Moncorvo.

There are 35 concessions of 50 hectares each covering the ore in place and the float ore on the flanks of the hills.

TRANSPORTATION

The ore can be easily lowered from the hilltop by wire rope tramways to the narrow-gauge railroad 2 kms. to 3 kms. east of Torre de Moncorvo. From the loading point it is 22 kms. down grade to Pocinho on the south side of the Rio Douro, where the ore is transferred by hand to cars on the wide-gauge track. From Pocinho to Leixoes is 202 kms.

MODE OF OCCURRENCE OF THE ORE

The ore occurs as a thick bed which has been folded and faulted extensively. The ore is interstratified with quartsite and schist, thin bands of rock cutting the ore into many layers.

The ore was apparently originally siderite, (iron carbonate), of sedimentary origin, and has been oxidized to martite, an oxide of iron of the same chemical composition as hematite, FE_2O_3.

Because of its hardness the ore bed has resisted erosion and is now found on the tops of the hills. The principal ore deposits are on the following concessions:

1. Cabeco da Mua
2. Fragas da Cotovia and Alto do Mendel
3. Fragas da Carvalhosa
4. Santa Maria

The Cabeco da Mua deposit is a syncline, which has a wide fault zone running through it.

On Fragas da Cotovia and Alto do Mendel the formation stands on end, and the width of the deposit perhaps may be accounted for by repetitive folding.

On Fragas da Carvalhosa there are three beds, possibly four, which are displaced by faults and dip south at 20° to 40°.

At Santa Maria the beds stand at a steep angle, and apparently are displaced by faults, which may make them appear to be wider than they are.

ANALYSIS

By averaging the analyses given on cross-sections and maps of the deposits, the average analysis of the ore has been calculated.

		Fe	SiO_2
1.	Cabeco da Mua	45.05	26.86
2.	Cotovia	41.76	30.46
3.	Alto do Mendel	41.00	33.76
4.	Fragas de Carvalho (estimated)	45.00	25.00
5.	Weighted average of 4 principal deposits	43.6	28.8

DEVELOPMENT AND EXPLORATION

On surface a very large number of trenches were dug and several pits were sunk by the Companhia Mineira de Moncorvo, and underground a large amount of tunneling, cross-cutting and shaft sinking was done. Most of these openings can now be seen, and there are very good maps and records. This exploration work is shown in part on Map No. 8. Most of the underground work was inspected but little can be seen now in the trenches.

Little work has been done on development of float ore, and an accurate estimate is impossible.

RESERVES

Reserves of positive and probable ore are estimated as follows:

	Tons
Cabeco da Mua	40,000,000
Fragas de Cotovia and Creto de Mendel	25,000,000
Santa Maria	5,000,000
Fragas da Carvalhosa	5,000,000
Float Ore	3,000,000
TOTAL	78,000,000

MINING METHODS

The ore must be stripped clean first, and the stripped material dumped off the ore formation, where it will not interfere with later operations.

The ore will then be mined in open pits in benches 10 M. to 15 M. high. Drilling will be done with churn drills, loading with power shovels, and hauling with large trucks.

Ore will be sent down to the railroad by aerial tramway. It will have to be crushed before it is loaded on the tramway, and the crusher will be on the hill at the head of the tramway.

The ore will need cleaning and concentrating. The mill will be beside the railway. If the mill is located in a central position, it will serve for all of the deposits, and they can be mined one at a time, the mining equipment and aerial tramway being moved from one site to the next in succession.

At a production of 2,000,000 tons of crude ore per year, the deposits will last about 40 years.

CONCENTRATION

If it is to be of commercial value, the ore must be concentrated. This can be accomplished by cleaning it first by heavy-media separation or by cyclone separators, followed by fine grinding and flotation. The best practice appears to be to float off the silica.

By a concentration ratio of not more than 2:1 it should be possible to obtain a product containing 60% iron and less than 10% SiO_2.

PRODUCTION

It should be possible to sell 1,000,000 tons a year of ore containing 60% iron and less than 10% silica. This would require a production of 2,000,000 tons of crude ore a year; about 7,000 tons a day.

Some of the waste material should be good for concrete aggregate, road metal and railway ballast.

At 2,000,000 tons a year the deposits should last a minimum of forty years.

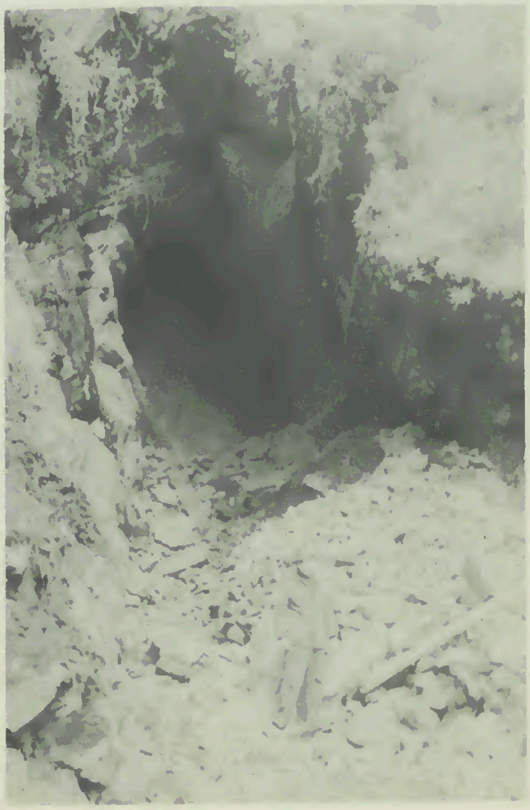
COMPETITIVE POSITION

If the ore is concentrated to 60% Fe and less than 10% SiO_2, it should command a ready market at nearly all times, and its competitive position should be very good.

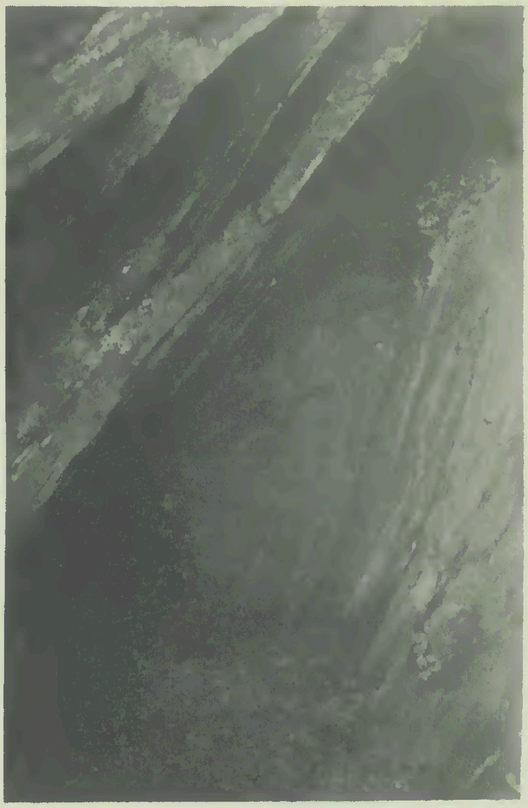
PICTURES AND MAPS

B-40-B-45

No. 4 Tunnel



No. 1 Carvalho



Teotonio Pereira

Esperanca

GUADRAMIL

Barreiras Brancas

VILA COVA

Jantar

Trench and Shaft

Outcrop of Ore

Fragas da Carvalhosa

Lower Bed

Lower Bed - North End

Fragas da Carvalhosa

Mining Upper Bed

Bed Prepared for Mining

Cotovia and Alto de Mendel

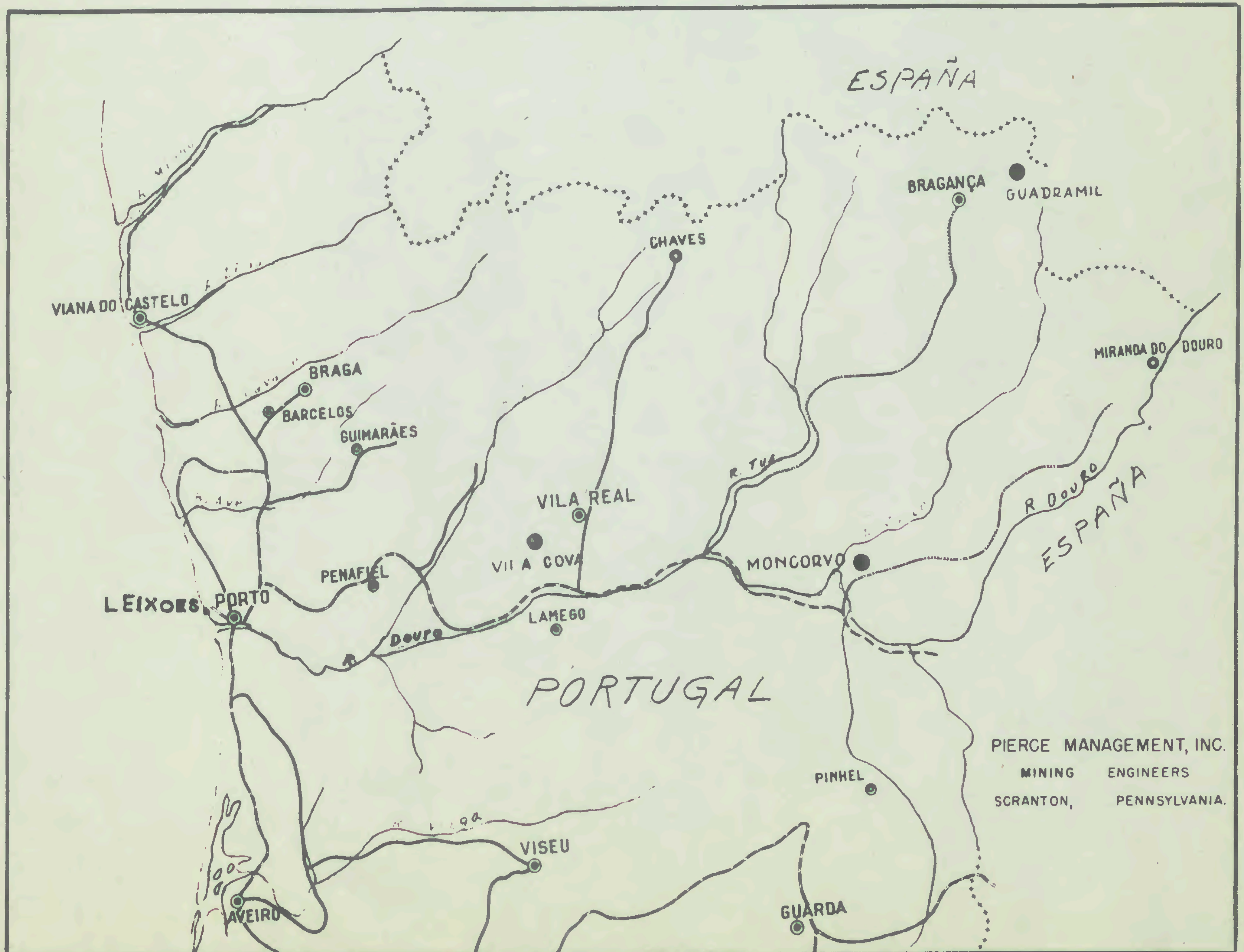
Cotovia Outcrop

MONCORVO

Cabeco de Mua

LEIXOES

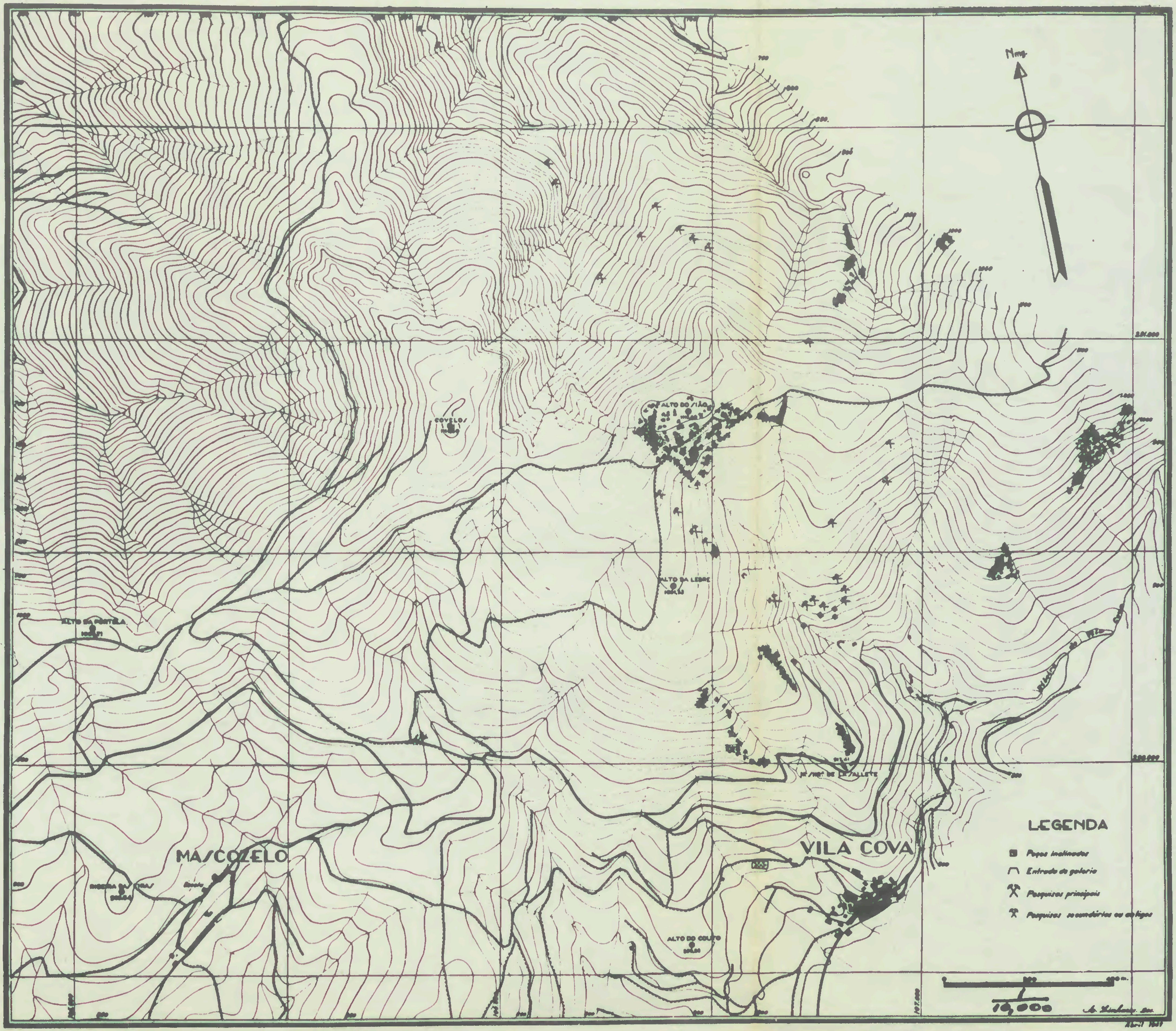
Unloading Ore From Cars

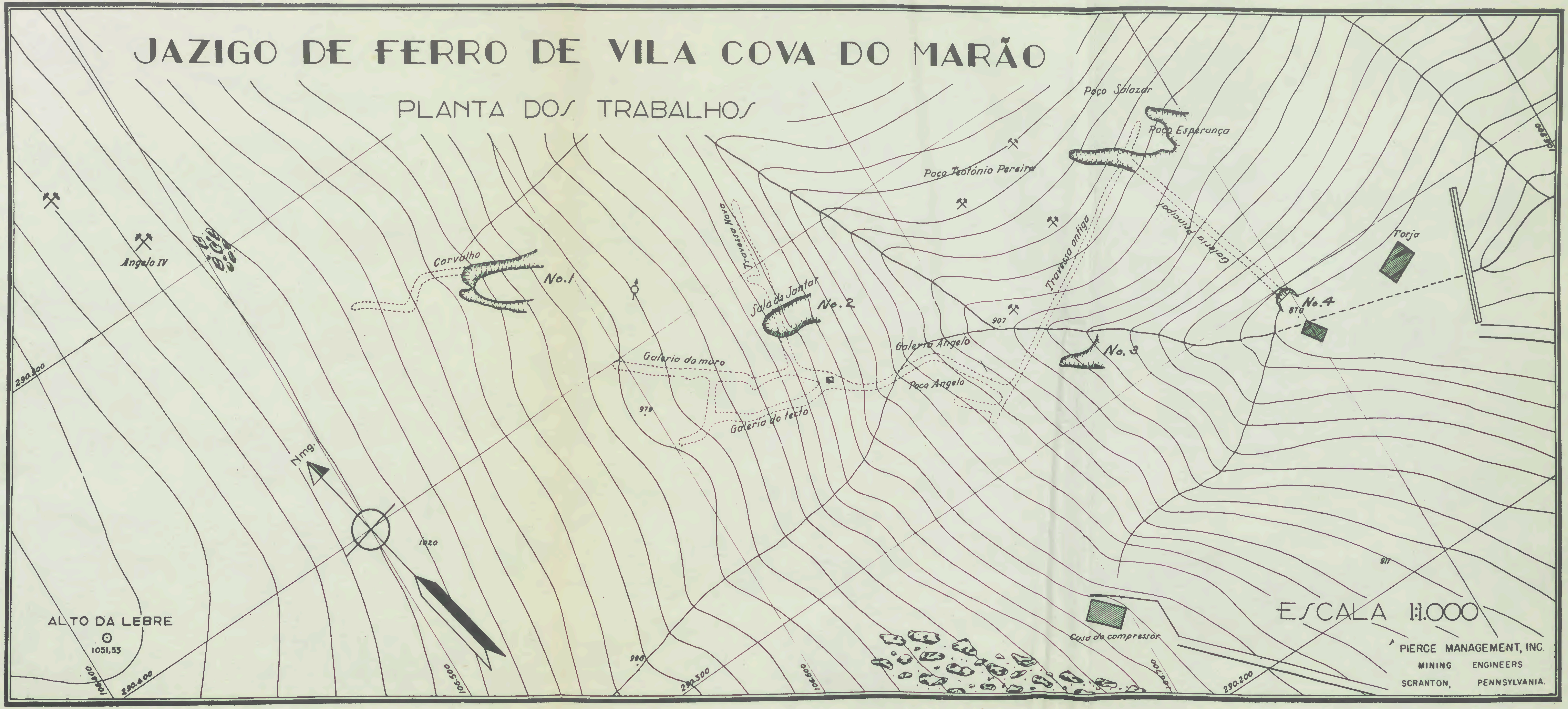

ESPAÑA
BRAGANÇA
GUADRAMIL
CHAVES
VIANA DO CASTELO
MIRANDA DO DOURO
BRAGA
BARCELOS
GUIMARÃES
R. TUA
VILA REAL
R DOURO
ESPAÑA
VII A COVA
MONCORVO
PENAFIEL
LEIXOES
PORTO
LAMEGO
Douro
PORTUGAL
PIERCE MANAGEMENT, INC.
MINING ENGINEERS
SCRANTON, PENNSYLVANIA.
PINHEL
VISEU
GUARDA
AVEIRO

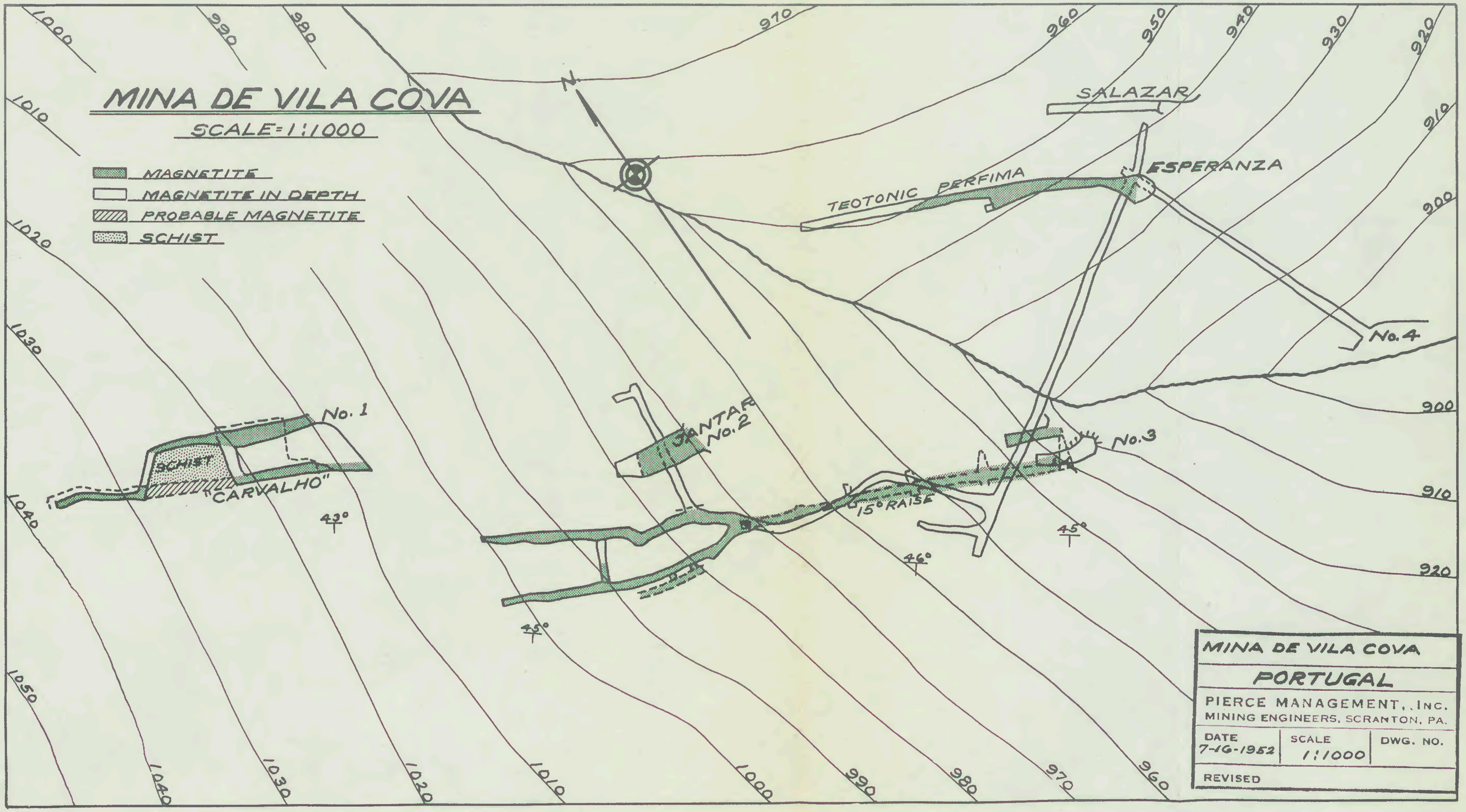
JAZIGO DE FERRO DE VILA COVA DO MARÃO

PLANTA TOPOGRAFICA

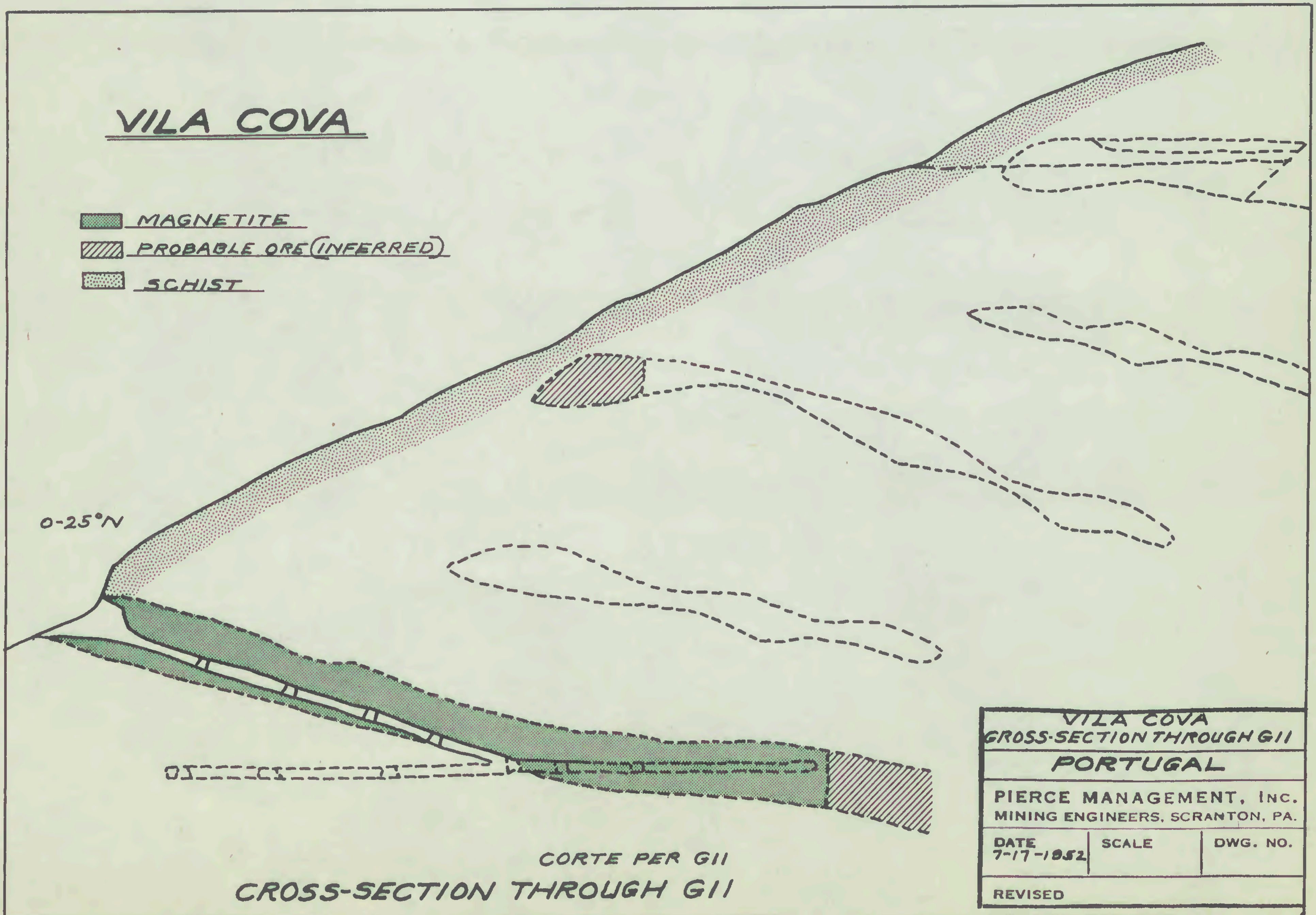
PIERCE MANAGEMENT, INC.
MINING ENGINEERS
SCRANTON, PENNSYLVANIA.




JAZIGO DE FERRO DE VILA COVA DO MARÃO
PLANTA DOS TRABALHOS
Poço Salazar
Poço Esperança
Poço Teotónio Pereira
Galeria principal
Travessa Nova
Travessa antiga
Torja
Angelo IV
Carvalho
No. 1
Sala de Jantar
No. 2
907
No. 4
870
Galeria Angelo
No. 3
Galeria do muro
Poço Angelo
978
Galeria do tecto
290.300
Nmg.
1020
911
ESCALA 1:1.000
ALTO DA LEBRE
1051,53
Casa do compressor
PIERCE MANAGEMENT, INC.
MINING ENGINEERS
SCRANTON, PENNSYLVANIA.
106.400
290.400
106.500
290.500
106.600
106.700
290.200
106.800



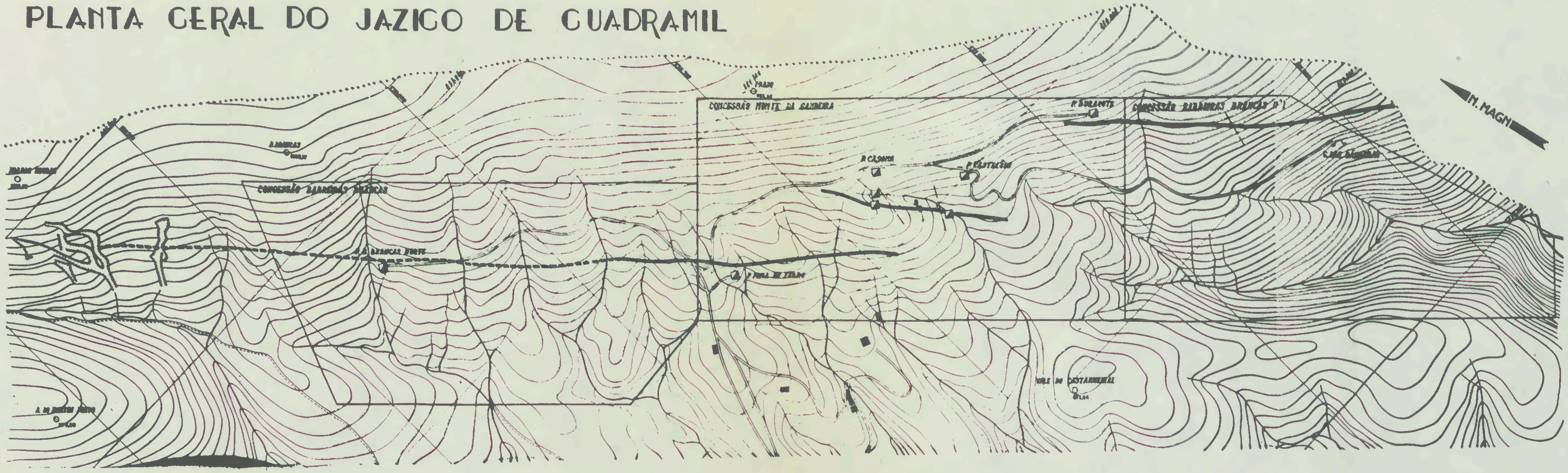
MINA DE VILA COVA
SCALE=1:1000
MAGNETITE
MAGNETITE IN DEPTH
PROBABLE MAGNETITE
SCHIST
1000
990
980
970
960
950
940
930
920
910
900
1010
1020
1030
1040
1050
N
SALAZAR
ESPERANZA
TEOTONIC PERFIMA
No. 4
No. 1
SCHIST
"CARVALHO"
JANTAR
No. 2
No. 3
15° RAISE
43°
45°
46°
45°
MINA DE VILA COVA
PORTUGAL
PIERCE MANAGEMENT, INC.
MINING ENGINEERS, SCRANTON, PA.
DATE
7-16-1952
SCALE
1:1000
DWG. NO.
REVISED


VILA COVA
MAGNETITE
PROBABLE ORE (INFERRED)
SCHIST
0-25°N
CORTE PER G11
CROSS-SECTION THROUGH G11
VILA COVA
GROSS-SECTION THROUGH G11
PORTUGAL
PIERCE MANAGEMENT, INC.
MINING ENGINEERS, SCRANTON, PA.
DATE
7-17-1952
SCALE
DWG. NO.
REVISED

PLANTA GERAL DO JAZIGO DE GUADRAMIL

PIERCE MANAGEMENT, INC.
MINING ENGINEERS
SCRANTON, PENNSYLVANIA.

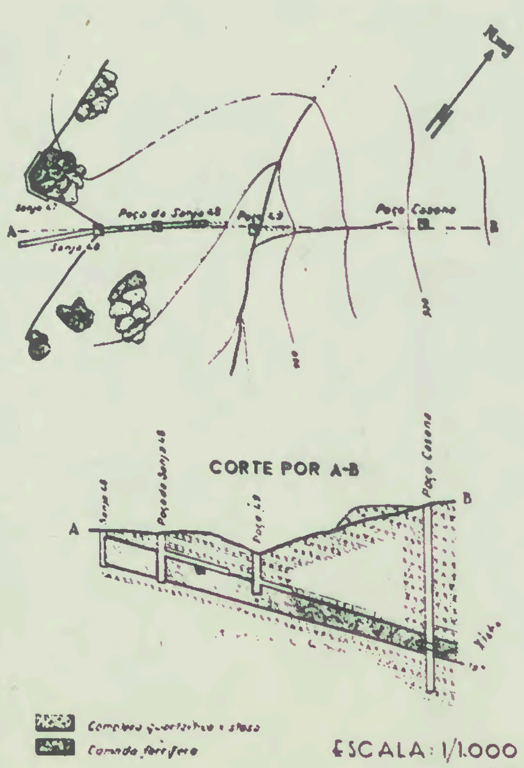
Escala 1:5.000



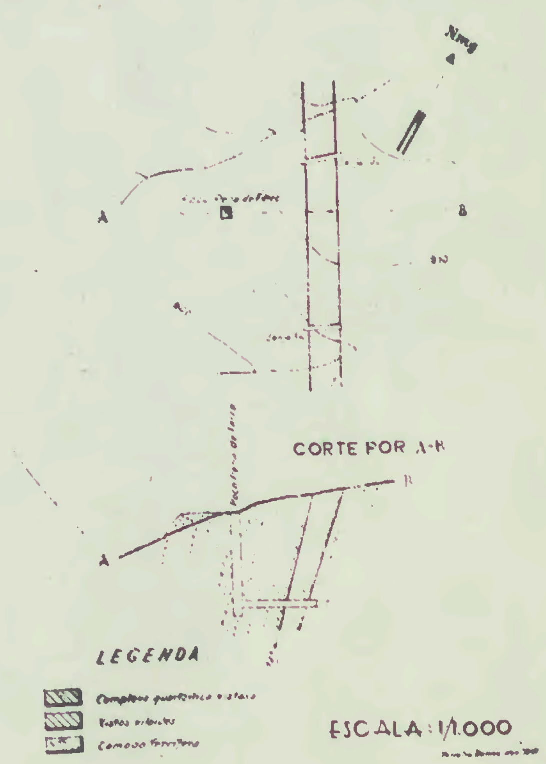
LEGENDA

- Corte contínuo de trabalhos antigos
- Construções executadas pelo Serviço
- Caminhos abertos ou reparados pelo Serviço
- Falhas
- Poços
- Boca de galeria
- Linha de fronteira

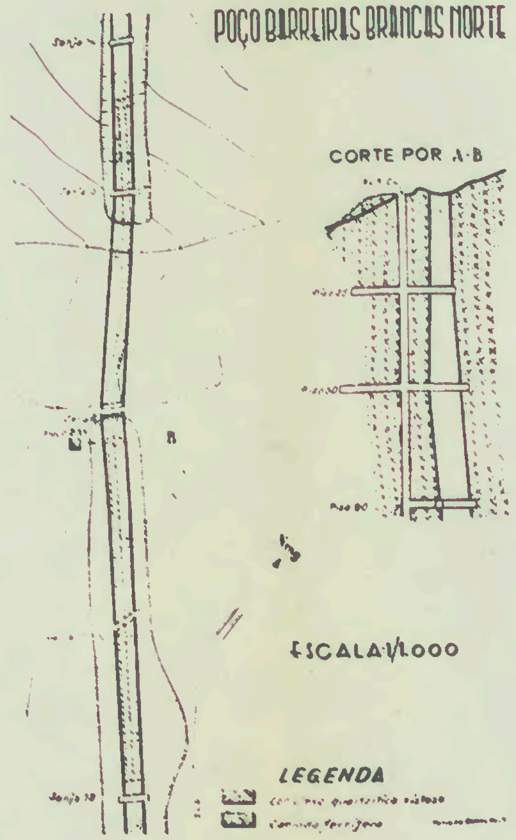
TRABALHOS DO 3º CAMPO DE RECONHECIMENTO



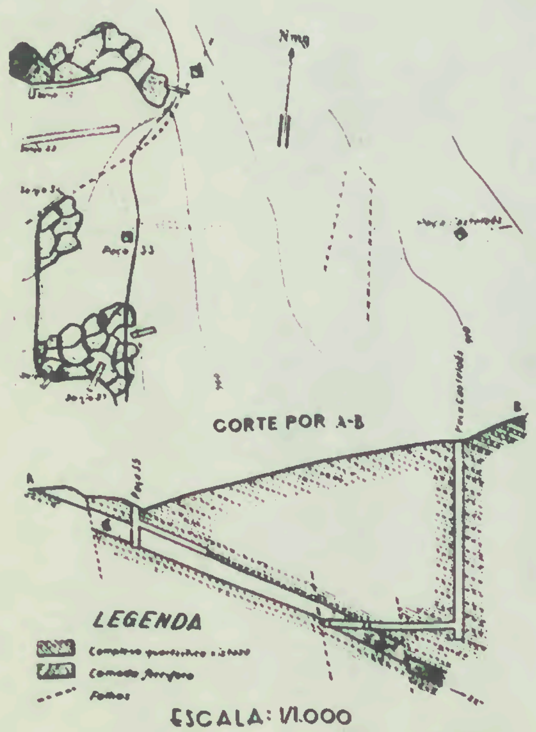
TRABALHOS DO 2º CAMPO DE RECONHECIMENTO



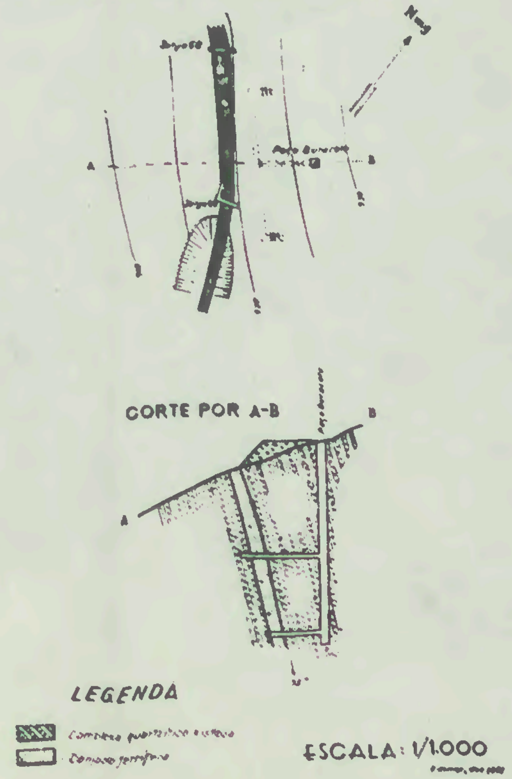
POÇO BARREIRAS BRANCAS NORTE



TRABALHOS DO 4º CAMPO DE RECONHECIMENTO



TRABALHOS DO 5º CAMPO DE RECONHECIMENTO



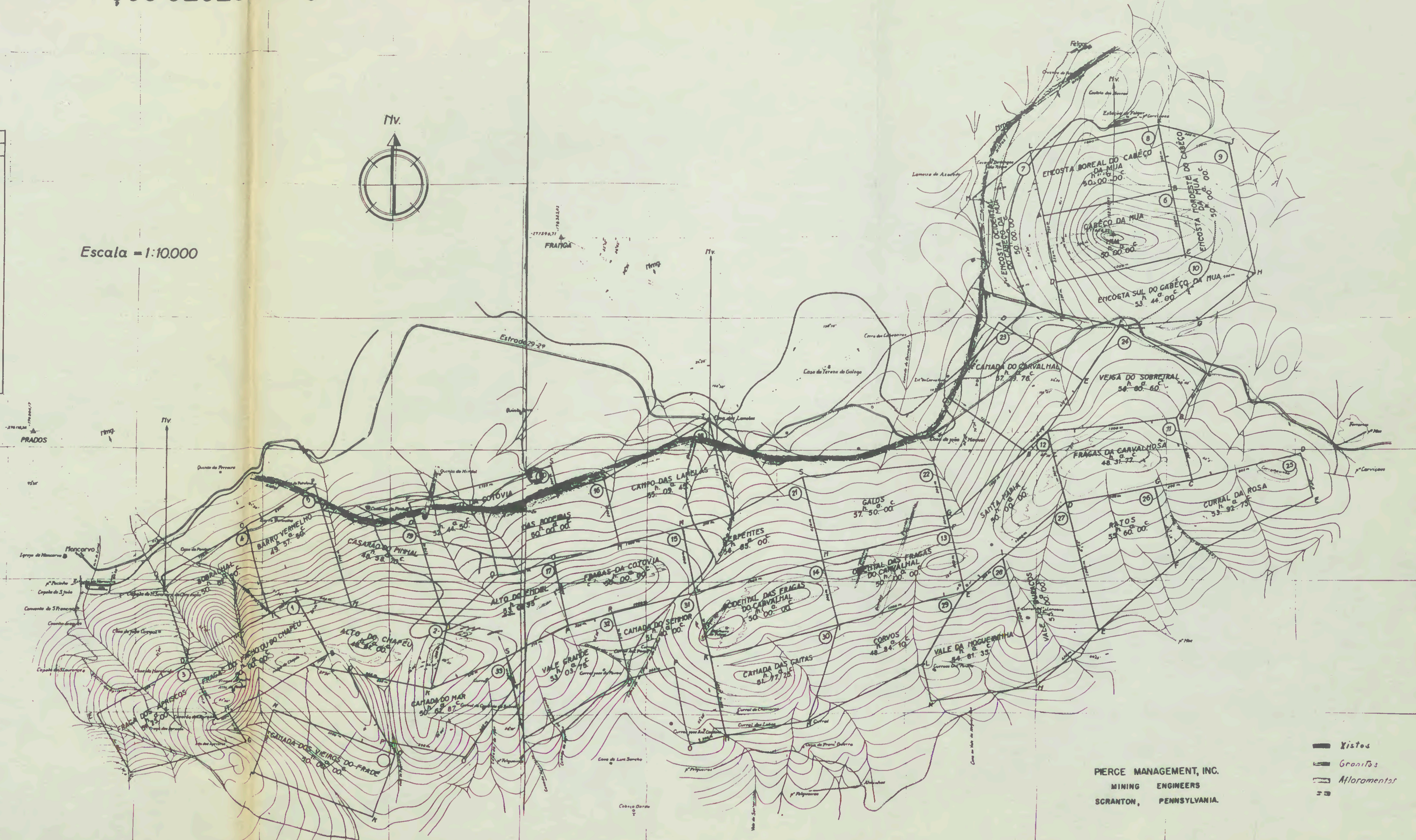
TRABALHOS DO 6º CAMPO DE RECONHECIMENTO

DIRECÇÃO GERAL DE MINAS E SERVIÇOS GEOLOGICOS
SERVIÇO DE FOMENTO MINEIRO

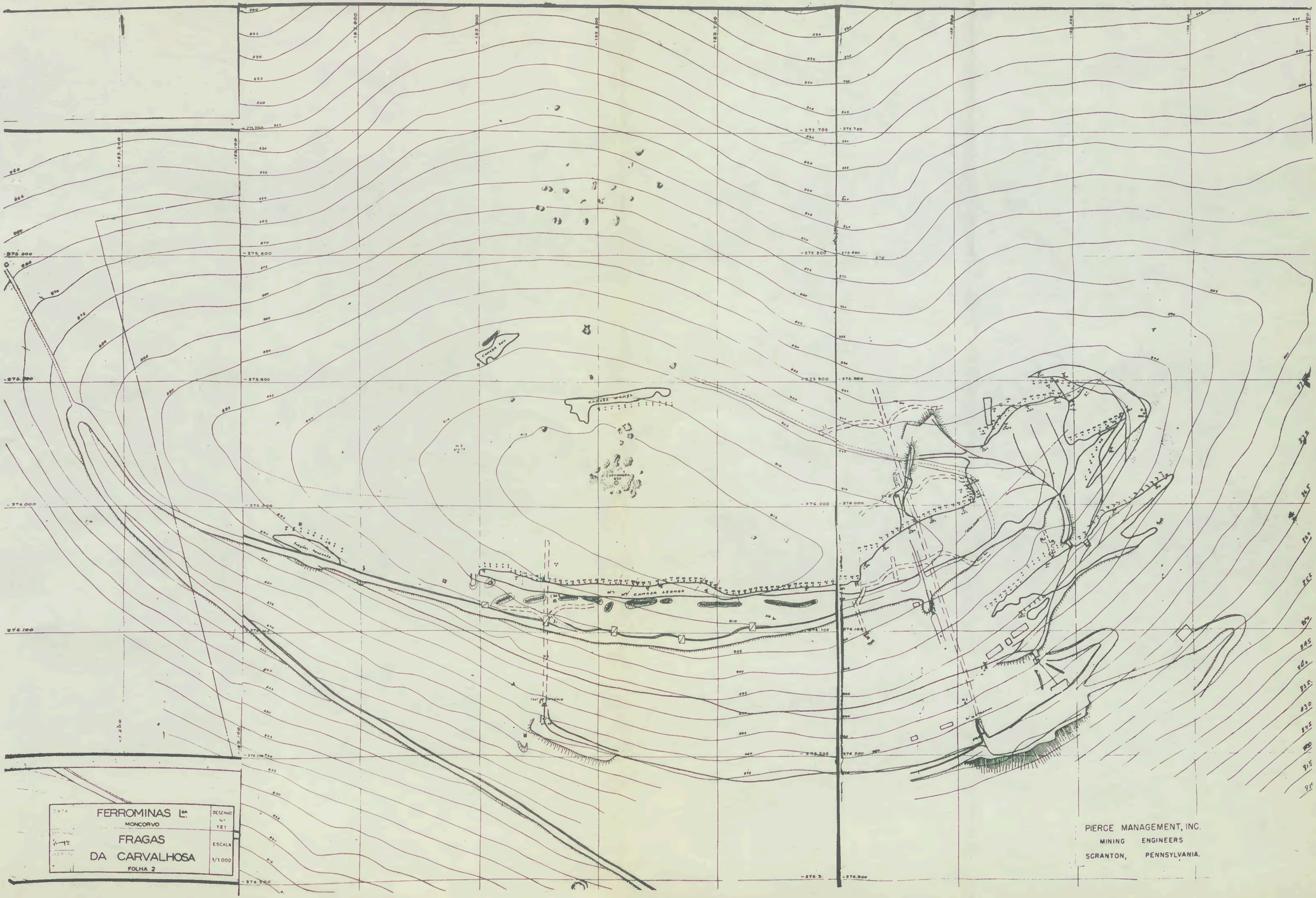
MINAS DE FERRO DE MONCORVO
ÁREA TOTAL = 1.710 Hect. - 54 Ar. - 79 Cent.

Nº	Nomes das Minas	Nº	Nomes das Minas
	JÁ RECONHECIDAS		RECONHECIDAS NESTA DATA
1	Fragas do Facho	17	Alto do Mindel
2	Alto do Chapéu	18	Campo de Lamelas
3	Fragas dos Apriscos	19	Casarão do Pinhal
4	Sobralhal	20	Poço da Cotovia
5	Barro Vermelho	21	Serpentes
6	Cabêço da Mua	22	Galos
7	Encosta Ocidental do Cabêço da Mua	23	Canada do Carvalhal
8	Encosta Boreal do Cabêço da Mua	24	Veigas do Sobreiral
9	Encosta Nordeste do Cabêço da Mua	25	Curral da Rosa
10	Encosta Sul do Cabêço da Mua	26	Ratos
11	Fragas da Carvalhosa	27	Vale de Buracos
12	Santa Maria	28	Vale da Nogueirinha
13	Oriental das Fragas do Carvalhal	29	Corvos
14	Ocidental das Fragas do Carvalhal	30	Canada das Gaitas
15	Fragas da Cotovia	31	Canada do Senhor
16	Duas Rodeiras	32	Vale Grande
		33	Canada do Mar

Moncorvo, 18 de Setembro de 1875



Encosta Boreal do Cabeço da Mua.
Encosta Ocidental do Cabeço da Mua.
E.ª Nordeste do Cabeço da Mua.
Cabeço da Mua.
Encosta Sul do Cabeço da Mua.
Estação de Carvalhal
Canada do Carvalhal.
Veigas do Sobreiral.
Sobralhal.
Barro Vermelho.
Poça da Coloria.
Duas Rodeiras.
Campo de Lamelas.
Fragas do Facho.
Alto da Mendel.
Fragas da Coloria.
Fragas dos Apriscos.
Alto do Chapéu.
Serpentes.
Oulos.
Santa Maria.
Fragas da Carvalhosa.
Oriental das Fragas do Carvalhal.
Ocidental das Fragas do Carvalhal.
Canada do Senhor.
Vale Grande.
Canada do Mar.
Canada dos Gaitas.
Corvos.
Vale da Nogueirinha.
Vale de Buracos.
Ratos.
Curral da Rosa.
PIERCE MANAGEMENT INC.
MINING ENGINEERS
SCRANTON, PENNSYLVANIA
Explicação:
Concessão Companhia Mineira de Moncorvo.
Trabalho antigo
Sanja.
Galeria
Mineral de ferro
Quartzite
Xisto
Falhas
MINAS DE FERRO DE MONCORVO
1: 5000


FERROMINAS Lda
MONCORVO
FRAGAS
DA CARVALHOSA
FOLHA 2
DESENHO Nº 121
ESCALA 1/1.000
PIERCE MANAGEMENT, INC.
MINING ENGINEERS
SCRANTON, PENNSYLVANIA.

APPENDIX C

HYDROLOGY

APPENDIX C - HYDROLOGY

TABLES

APPENDIX C

HYDROLOGY

1. Runoff Data in Portugal

A. Flood history - The great floods on the Douro River are not remarkable from the point of view of high discharge per unit of drainage area. Below the confluence of the Esla River, at the beginning of the International Douro, where the drainage area is 63,000 km^2, or about the same as at the proposed Picote project, the maximum discharge of record in 1909 attained 0.11 $m^3/sec/km^2$. As compared with American rivers of about the same drainage area, it is less than one-third the discharge reached by the record floods on the Susquehanna River on the north atlantic region and by the Ohio River in the north central region, less than one-half the maximum runoff of the Tennessee River in the south central part, and Sacramento River in California, and about half that of the Colorado River in Texas. However, it is about 50 percent greater than the maximum attained by the Republican River in Kansas, in the western plains area.

The Douro River flood records are outstanding from the point of view of their antiquity. It is fairly well established from extensive research by Spanish hydraulic engineers that, for the reach just downstream from the confluence with the Esla River, the flood of 1909, which attained 7000 $m^3/sec.$, was the greatest ever experienced from the XIIIth century onward, although on the Douro River upstream from the confluence with the Esla River, the flood of 1860, with discharge of 3000 m^3/sec., seems to have exceeded that of 1909. Downstream on the Portuguese Douro near the Bitetos gage, the flood of 1739 may have exceeded the 1909 flood by a slight margin, but the evidence is not conclusive on this point.

Before its regulation by the Ricobayo Reservoir, the Esla River was the greatest flood-producing tributary in the Douro Basin. The peak floods from this area were greater than from the entire area of the Douro River above the junction with the Esla. One reason for this difference is the large amount of valley storage in the flat reach between the Esla River and Valladolid. Since the completion of the reservoir on the Esla, there has been a great flood on January 19, 1939, with a peak inflow greater than 6000 m^3/sec which was regulated in the reservoir and modified to a peak outflow of 3500 m^3/sec. The spillway capacity at the Ricobayo Reservoir is 5000 m^3/sec. The spillway capacities at the Spanish Villalcampo and Castro projects on the main river upstream from the proposed Picote project are 11,000 m^3/sec. The drainage areas at these projects are substantially the same as at Picote. The Spanish Saucelle project on the downstream Spanish section of the International Douro will have a spillway capacity of 12,500 m^3/sec. The drainage area at Saucelle exceeds that at Picote by 15% as it includes the drainage basin of the Tormes River and some minor tributaries.

B. Available records - Records of flow were needed to compute the output of the existing hydroelectric plants, and to determine the performance of proposed projects. The gaging stations selected for the studies were either at the plant sites, as close as possible to these sites, or on drainage areas as nearly similar as could be found to those under consideration. A list of gaging stations with their periods of record is given in Table C-1.

Tables C-2 to C-15 inclusive show the average monthly flow and average annual flows for the various gaging stations. Tables C-16 and C-17 show the averages and extremes, both for the period of record and the period of study 1942-1950, for various rivers not in the Douro Basin, for rivers in the Douro Basin and for the proposed Douro River projects.

C. Period of record selected for study - The period 1942-1950 was selected for investigation because it was desired to assure dependable operation of the proposed projects under critical conditions. Since this period contains the two severe droughts of 1944-1945 and 1949 it was well adapted to this particular purpose. An important advantage of this recent period is that records of flow covering it are available. On the Zezere River the Cabril record began in 1942 and the Castelo do Bode record in 1938-1939. The Cavado River records began in 1939-1940. Since these records are used to compute the major part of the hydroelectric output, an attempt to go very much further back than 1942 would place the whole study on a foundation of increasingly uncertain extrapolation. It is also possible that this period may mark the initial stage of a long term dry cycle in Europe although we do not know enough of the cyclical aspect of hydrology to be able to affirm this with certainty.

The data in Tables C-16 and C-17 indicate that the average runoff of Portuguese rivers for the 1942-1950 period was markedly lower than that for a longer period of record. However, the Douro River record in Table C-17 shows that the period included several years of average runoff and one year (1946-1947) with runoff notably greater than the average.

D. Computations of flow at existing hydroelectric plants - Flows were available at the plant sites at the following locations: Lima River at Lindoso (See Table C-15), Zezere River at Castelo do Bode (See Table C-15), Zezere River at Cabril (See Table C-13, and Ocreza River at Pracana See Table C-12). The Tejo River at Belver can be included in this list since the drainage area at the plant does not differ by more than 2 percent from that at the gaging station at Vila Velha do Rodao. (See Plate 27).

In a number of instances, the gaging station is close to the plant site on the same stream or nearby in the same basin where the rainfall and other characteristics are similar. At several places the flows were estimated to be proportional to the respective drainage areas at the gaging station and at the plants. For example, the flow of the Rabagao River at the Vila Nova plant (Table C-21) was computed from the Cavado River record at Paradela, and the Cavado River flow at the Salamonde, Canicada and Penide plants (see Table C-22 to C-24, respectively) were obtained from the Cavado River record below Rio Caldo.

For the remaining plants, the flows were found by proportioning according to drainage areas, using a gaging station with a tributary area where the precipitation was believed to be similar to that at the plant under consideration.* In addition, at those plants listed subsequently which are identified by an asterisk, the estimated flows for the years 1943 through 1945 were taken from a report entitled "Estudo da Conjugacao Entre As Producoes de Energia Hidraulica e Termica em Portugal" by Sr. Moniz Pereira, published in February 1952 by the Associacao Industrial Portuguesa. Flows at the Santa Luzia (see Table C-18) plant on the Pampilhosa River whose tributary area includes a diversion from the Ceira River were obtained by proportion from the Zezere River at Cabril. Flows at the four plants of the Serra da Estrela* system on the Alva River (Sabugueiro I*, Senhora do Desterro*, Ponte de Jugais* and Vila Cova*, see Table C-25 to C-28) were obtained by proportion from the Cavado River at Paradela, as were the flows at the four plants of the Ave River* system (Guilhofrei*, Ermal*, Ponte da Esperanca* and Senhora do Porto* see Table C-29 to C-30), the four plants of the Alforfa River system (Cova da Nave, Pedra da Figuaira, Alforfa and Estrela - see Table C-41 to C-44), the Covas plant (see Table 34) on the Minho River, the Mesa do Galo plant (see Table C-33) on the Borralha River, and the Corvete plant on the Bugio River.

Flows at the Chocalho* plant (see Table C-31) on the Varosa River, and the Freigil plant (see Table C-32) on the Cabrum River

* See Table 17a.

were obtained by proportion from the Tavora River records at Ponte Nova. The Sabor River records at Laranjeiras were used to compute the flows of the four plants of the Niza River system (Povoa, Poio-Bruceira, Velada and Foz - Tables C-37 to C-40) as well as the flows at four irrigation projects developing incidental power, namely, the Cabeco Monteiro plant (See Table C-46) on the Ponsul River, the Pego do Altar plant (See Table C-47) on the Santa Catarina River, the Vale do Gaio plant (See Table C-48) on the Xarrama River, and the Pego Longo (See Table C-49) plant on the Campilhas River. The flows of a fifth irrigation and power project, the Maranhao plant (See Table C-45) on the Seda River were obtained by proportion from the Tejo River records at Vila Velha de Rodao.

E. Extension of records - Some records of insufficient length were extended by plotting a correlation curve between the available flows and concurrent flows at another gaging station and then extrapolating from the curve. For example, the record of the Zezere River at Cabril was thus extended to cover the earlier part of 1942, from a correlation with the Zezere River at Castelo do Bode. This method was also used in extending records in the Douro Basin, as indicated below.

2. Runoff Data in the Douro Basin

A. Analysis of records on International and National Douro - On the main Douro River, from the beginning of the International Douro to the mouth of the river, a total of 17 gage-height records have been maintained at various points and for intermittent periods of time. The longest records are at Puente Pino in Spain, and at Regua and Escamarao - Bitetos in Portugal. The Spanish record is available for 20 years and the two Portuguese records have been collected for about 30 years. Intermittent current - meter measurements of discharge have been made in the last 10 years in the vicinity of 10 of the gaging stages. (See Plate 21).

The stream - gaging data on the main Douro River were carefully examined with a view for making revisions if necessary. A study of the Bitetos record indicated that the discharge measurements plotted over a wide range and could not be depended upon to give a reliable rating curve. Apparently the slope of the river varied with rising and falling stages and with changes in the great sand bar at Bitetos. Attempts were made to correlate the discharge with both stage and slope. The slope was measured by taking the difference between gage readings at Mourilhe (Carrapatelo) and Bitetos. The results were not satisfactory, although some correlation between discharge and slope was indicated.

A study then was made of the long gage-height record obtained at Regua, at the quai gage opposite the town, at the old bridge above the town and at Begauste, a short distance above the bridge. Satisfactory gage relations were established between the gage readings at the three points and verified by readings in the summer of 1952. A consistent stage-discharge relation was established for the bridge gage and daily discharges were computed for the period June 1923 to date. There were short periods of missing record prior to 1932. A comparison between the new record at Regua and the previously computed record at Bitetos, indicated that the latter record gave consistently smaller discharges than Regua. The difference was sometimes as much as 30%. It should be noted that the first power estimates for the Carrapatelo dam site, made by the Hydraulic Services on the basis of the Bitetos record, yielded very conservative results.

The runoff record for the Puente Pino record on the International Douro was obtained from the office of the Spanish Hydrographic Service in Valladolid. The derivation of the record from the basic data was not examined, but correlation studies were made between the average monthly flows at Puente Pino and the corresponding flows in periods of concurrent record at Sendim on the International Douro and at Pocinho and Regua on the National Douro. The studies indicated that the Spanish record was reasonably consistent with all available data on the main river.

B. Computation of flows at proposed projects on the Douro River - For the proposed Bemposta, Picote and Miranda projects on the International Douro, the Spanish record at Puente Pino just upstream from the International section was used without adjustment as the difference in drainage areas between the gaging station and the dam sites is less than one percent.

For the proposed Carrapatelo project, the flow was computed from the Regua runoff record, with a small adjustment for difference on drainage area. For the proposed Regua project, of course, the records for the Regua gage were used directly. The flows at the proposed Valeira project were found by subtracting the discharge of the Tavora River from the Regua flows and proportioning the remainder according to the ratio of the net drainage areas. The flows at the proposed Pocinho project were obtained from the Valeira discharge as found above by subtracting the flow of the

Sabor River and then proportioning the remainder according to the ratio of the net drainage areas.

C. Computations of flows at proposed projects on tributaries of the Douro River - In the case of the proposed Laranjeiras project on the Sabor River, the proposed Vale de Madeira project on the Coa River, and the proposed Fragas da Torre project on the Paiva River, the gaging stations are at the project sites. For the proposed Vilar-Tabuaco project on the Tavora River, the flows were found by proportion from the Tavora River gaging station at Ponte Nova. The Tavora River record was extrapolated for the period prior to October 1947 by means of a correlation with the Paiva River at Castro Daire. The Sabor River record at Laranjeiras was extrapolated after September 1949 by means of a correlation with the Tavora River at Ponte Nova. The Coa River record at Vale do Areal was extrapolated for the period prior to October 1946 by means of a correlation with the Sabor River at Laranjeiras.

3. Evaporation from Reservoir Surfaces

No evaporation records were available in Portugal, except those from a "Piche" instrument at the Observatorio da Serra do Pilar, which do not represent evaporation from a free water surface. In the United States a value sometimes used in the southeast for annual evaporation is 45 inches (114 cm). Reservoir evaporation in the southwestern states may reach 90 inches (228 cm) or more. In Portugal the climate is drier than that in the southeastern United States, but not as hot as in the southwestern states. Records of a similar type of mediterranean climate in Greece and Turkey indicate average annual reservoir evaporation varying between 100 and 120 cm. Weighing all the factors, and considering particularly the prevalence of high winds for long periods in Portugal, an estimated average annual evaporation of 150 cm is considered to be reasonable and conservative. The distribution for each month of the year was computed from the ratio that the monthly evaporation from the Piche instrument bears to its annual total. The adopted figures for monthly evaporation are shown in Table C-51. The reservoir surface from which evaporation takes place was assumed to be that corresponding to the average head at the power plant.

PLATES

TABLE C-1

LIST OF GAGING STATIONS

BASIN	RIVER	STATION	PERIOD OF RECORD
Douro	Douro	Regua	1922-23 To 1951-52 (Inc.)
Douro	Douro	Puento Pino	1930-31 To 1950-51 (Inc.)
Douro	Pai Va	Castro Daire	1917-18 To 1950-51 (Inc.)
Douro	Pai Va	Fragas da Torre	1934-35 To 1950-51
Douro	Tavora	Ponte Nova	1947-48 To 1951-52
Douro	Sabor	Laranjeiras	1937-38 To 1948-49 (Inc.)
Douro	Coa	Vale do Areal	1946-47 To 1951-52
Cavado	Cavado	Paradela	1939-40 To 1951-52
Cavado	Cavado	Rio Caldo	1939-40 To 1951-52
Tejo	Tejo	V.V. do Rodao	1902-03 To 1949-50
Tejo	Ocreza	Pracana	1932-33 To 1949-50
Tejo	Zezere	Ponte do Cabril	1941-42 To 1950-51
Tejo	Zezere	Castelo do Bode	1938-39 To 1950-51
Lima	Lima	Lindoso	1920-21 To 1951-52

TABLE C-2

DOURO RIVER AT PUENTE PINO

OBSERVED AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 63,300 km^2)

WATER YEAR	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	AVERAGE ANNUAL FLOW
1930-1931	135	264	424	559	392	1,009	553	328	129	58	38	49	328
1931-1932	135	488	290	268	199	281	284	338	200	146	60	80	231
1932-1933	143	247	905	506	612	967	426	337	174	69	40	45	373
1933-1934	93	142	209	445	294	566	769	593	303	278	100	39	319
1934-1935	43	68	436	324	401	744	287	345	340	82	80	79	269
1935-1936	92	130	569	1,630	1,785	1,303	1,618	798	411	257	84	96	731
1936-1937	143	196	166	341	1,045	1,041	836	383	213	125	98	142	394
1937-1938	207	432	818	642	416	242	175	201	183	127	86	73	300
1938-1939	61	207	407	1,258	512	320	709	244	194	134	99	148	358
1939-1940	260	501	349	739	1,351	813	226	421	196	120	93	131	433
1940-1941	191	393	342	876	1,221	1,174	762	898	620	212	140	161	582
1941-1942	181	200	242	268	340	374	400	396	124	140	171	163	250
1942-1943	226	251	362	978	532	358	306	280	155	135	124	123	319
1943-1944	213	398	388	290	295	316	266	179	164	168	98	86	238
1944-1945	120	216	313	261	379	263	195	158	92	86	56	66	184
1945-1946	63	126	337	346	313	279	459	858	410	133	195	185	309
1946-1947	141	151	228	290	840	1,315	702	418	231	145	105	137	392
1947-1948	198	143	197	686	791	361	241	315	173	159	121	116	292
1948-1949	101	92	176	183	139	55	78	80	82	66	37	48	95
1949-1950	105	93	220	231	197	197	126	129	281	111	123	145	163
1950-1951	100	89	223	303	761	1,051	462	332	227	131	89	121	324

Average for the period: 328

TABLE C-3

DOURO RIVER AT CARRAPATELO

AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 93,475 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	308	333	874	777	787	225	113	142	142	201	354	727	415
1943	1,642	1,032	718	561	409	134	131	126	111	386	474	606	528
1944	390	294	372	527	227	157	135	96	82	99	209	377	247
1945	347	487	286	197	148	109	90	55	65	50	223	879	245
1946	603	515	606	1,018	1,482	648	156	197	186	143	184	419	513
1947	494	1,588	2,320	1,237	662	312	183	145	189	246	202	313	658
1948	1,416	1,242	631	465	608	329	173	158	124	109	112	339	476
1949	447	275	127	156	128	100	98	51	63	134	154	344	173
1950	332	559	401	228	287	456	179	141	160	137	140	312	278

Average for the period: 392

Note: Flows derived from Douro River at Regua.

TABLE C-3a

DOURO RIVER AT REGUA

OBSERVED AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 92,225 km^2)

WATER YEAR	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	AVERAGE ANNUAL FLOW
1922 - 1923										87	70	60	
1923 - 1924	80	366	770	896	1,015	1,713	1,517	661	215	69	50	129	623
1924 - 1925	117	-	978	656	717	888	995	828	594	212	72	-	-
1925 - 1926	188	939	-	188	2,451	-	1,114	-	-	-	-	-	-
1926 - 1927	51	2,055	1,828	833	786	1,395	990	645	404	117	63	53	768
1927 - 1928	211	579	1,356	1,538	1,088	1,590	1,497	779	271	88	-	-	-
1928 - 1929	254	178	578	939	1,098	765	-	515	517	-	-	-	-
1929 - 1930	-	-	-	-	-	-	-	-	-	-	-	-	-
1930 - 1931	-	-	-	-	-	-	763	392	158	48	-	-	-
1931 - 1932	180	898	299	355	242	533	402	464	271	164	93	128	336
1932 - 1933	295	377	1,477	1,078	872	1,351	621	480	245	141	73	54	589
1933 - 1934	163	303	425	613	368	858	1,176	934	411	278	170	119	485
1934 - 1935	49	168	1,019	646	514	1,036	480	527	532	271	203	174	468
1935 - 1936	215	323	1,266	3,149	3,148	2,266	2,488	1,115	590	384	115	115	1,264
1936 - 1937	188	330	336	1,004	1,789	1,933	1,275	589	369	150	108	132	684
1937 - 1938	239	1,023	1,596	954	614	354	262	268	142	129	126	106	484
1938 - 1939	85	186	554	1,954	893	422	875	327	307	150	113	118	499
1939 - 1940	443	729	499	1,378	2,056	1,453	508	661	312	131	101	105	698
1940 - 1941	196	604	461	1,659	2,228	1,703	1,109	1,289	867	251	136	138	887
1941 - 1942	146	246	262	304	329	863	767	777	222	112	140	140	359
1942 - 1943	199	349	718	1,621	1,020	709	554	404	132	129	124	110	506
1943 - 1944	381	468	598	385	290	367	520	224	155	133	95*	81	308
1944 - 1945	98	206	372	343*	481	283	195	146	108	89	54	64	203
1945 - 1946	49	220	867	595	508	599	1,004	1,462	640	154	195	184	540
1946 - 1947	141	182	414	487	1,567	2,290	1,221	654	308	181	143	187	648
1947 - 1948	243	198	309	1,398	1,227	623	460	600	326	171	156	122	486
1948 - 1949	108	111	335	442	272	126	154	126	99	96	50	62	165
1949 - 1950	132	152	339	327	552	396	225	283	450	177	139	158	278
1950 - 1951	135	138	308	523	1,137	1,750	719	542	388	151	142	176	509
1951 - 1952	227	1,039	546	501	526	508	1,060	651	-	-	-	-	

Average for the period: 536

* Estimated from partial record and comparison with Bitetos.

TABLE C-3b

DOURO RIVER AT VALEIRA

AVERAGE MONTHLY FLOW IN m^3/s
(DRAINAGE AREA = 87,775 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	288.0	312.5	810.0	722.5	730.0	208.5	106.4	133.7	133.7	189.5	332.0	673.0	386.6
1943	1,507.0	963.0	672.5	526.0	385.0	125.8	123.1	118.5	104.6	349.5	442.0	563.0	490.0
1944	363.0	275.5	347.0	491.0	212.0	147.8	126.8	90.7	77.3	93.4	196.0	349.0	230.8
1945	323.0	455.0	268.2	185.3	139.0	102.8	85.0	51.5	61.1	46.7	208.5	794.0	226.7
1946	560.0	480.0	560.0	952.0	1,384.0	601.0	145.9	186.0	175.6	133.9	170.7	386.0	477.9
1947	456.0	1,454.0	2,150.0	1,150.0	619.0	292.5	172.6	136.5	178.6	232.2	189.0	292.3	610.2
1948	1,299.0	1,160.0	589.0	435.5	570.0	309.5	163.0	149.0	116.4	103.0	105.8	317.0	443.1
1949	417.0	257.5	118.9	145.7	119.3	94.0	91.6	47.7	59.2	125.9	144.0	321.8	161.9
1950	311.0	520.0	373.5	212.8	268.0	428.0	168.4	132.8	151.0	129.0	131.4	292.7	259.9

Average for the period: 365.2

Note: Flows derived from Douro River at Regua.

TABLE C-3c

DOURO RIVER AT POCINHO

Average MONTHLY FLOW IN m^3/s
(DRAINAGE AREA = 82,775 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	275.0	300.0	713.0	655.0	664.0	190.2	102.0	130.7	129.8	180.7	314.5	592.5	354.0
1943	1,309.0	865.0	626.0	495.5	371.5	122.1	120.1	116.1	100.0	314.0	420.0	532.5	449.3
1944	343.5	262.0	331.5	469.0	203.0	144.0	123.8	88.4	75.1	90.8	190.8	337.2	221.6
1945	311.0	440.0	260.5	180.1	134.8	99.8	82.9	50.6	60.0	45.5	199.5	681.5	212.2
1946	533.0	452.0	507.5	879.0	1,263.0	562.5	140.1	182.0	171.1	128.6	161.3	361.5	445.1
1947	420.0	1,223.0	1,900.0	1,044.0	587.0	282.0	168.5	133.8	174.0	223.5	182.0	270.0	550.6
1948	1,095.0	1,066.0	547.0	401.0	533.0	292.5	158.5	145.0	114.1	100.5	101.2	290.0	403.6
1949	381.0	244.7	112.0	139.7	115.4	90.8	88.5	46.7	57.1	122.1	136.8	304.5	153.3
1950	296.3	470.5	337.3	196.1	248.7	408.0	161.0	129.8	147.7	126.0	126.3	279.8	244.0

Average for the period: 337.1

Note: Flows derived from the Douro River at Regua.

TABLE C-3d

DOURO RIVER AT MIRANDA, BEMPOSTA AND PICOTE

AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREAS = 63,500, 63,750 and 63,850 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	268	340	374	400	396	124	140	171	163	226	251	362	268
1943	978	532	358	306	280	155	135	124	123	213	398	388	332
1944	290	295	316	266	179	164	168	98	86	120	216	313	209
1945	261	379	263	195	158	92	86	56	66	63	126	337	174
1946	346	313	279	459	858	410	133	195	185	141	151	228	308
1947	290	840	1,315	702	418	231	145	105	137	198	143	197	393
1948	686	791	361	241	315	173	159	121	116	101	92	176	278
1949	183	139	55	78	80	82	66	37	48	105	93	220	99
1950	231	197	197	126	129	281	111	123	145	100	89	223	163
											Average for the period:		247

Note: Flows assumed to be the same as for the Douro River at Puente Pino since the drainage areas are substantially the same.

TABLE C-4

PAIVA RIVER AT CASTRO DAIRE

OBSERVED AVERAGE MONTHLY FLOW IN m³/s

(DRAINAGE AREA = 293 km²)

WATER YEAR	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	AVERAGE ANNUAL FLOW
1917 - 1918	0.3	0.4	0.3	4.8	3.1	2.5	12.4	3.4	0.9	0.5	0.1	0.6	2.4
1918 - 1919	0.4	7.4	6.4	24.4	73.0	24.5	13.9	4.3	1.6	0.7	0.2	0.2	13.1
1919 - 1920	0.3	3.2	8.5	15.9	6.0	8.5	21.1	7.1	3.9	1.3	0.4	0.3	6.4
1920 - 1921	8.0	7.3	14.7	11.0	12.2	4.2	1.9	1.3	0.7	0.2	0.1	0.2	5.2
1921 - 1922	0.4	0.7	3.3	22.3	15.8	18.3	28.6	6.3	4.1	1.0	0.4	0.5	8.5
1922 - 1923	6.5	13.6	10.9	12.3	26.9	12.8	12.4	6.5	2.4	0.7	0.3	0.2	8.8
1923 - 1924	0.8	6.4	9.6	17.1	21.6	45.0	15.6	7.5	3.5	0.7	0.3	4.4	11.0
1924 - 1925	2.4	10.8	17.7	12.6	16.5	10.9	11.5	6.8	5.6	2.2	0.7	0.5	8.2
1925 - 1926	2.2	11.6	44.8	14.0	64.0	13.7	17.1	6.7	2.9	0.6	0.2	0.2	14.8
1926 - 1927	0.7	34.2	9.0	10.8	14.9	26.2	8.7	4.0	1.7	1.3	0.3	0.4	9.4
1927 - 1928	0.5	2.3	28.3	9.8	7.3	19.3	31.6	14.7	8.0	1.3	0.4	0.5	10.3
1928 - 1929	1.0	2.1	4.4	5.7	16.8	8.8	3.6	2.6	0.9	0.6	0.1	0.3	3.9
1929 - 1930	0.9	7.9	38.6	23.9	20.9	19.0	18.4	7.1	2.8	1.2	0.4	0.4	11.8
1930 - 1931	0.3	2.5	5.1	17.9	4.3	17.5	9.2	7.3	4.1	1.0	0.5	0.4	5.8
1931 - 1932	1.6	17.3	4.8	7.6	4.7	5.5	8.1	6.4	3.8	1.2	0.3	1.7	5.2
1932 - 1933	3.4	3.7	20.9	14.8	8.6	20.8	5.8	4.2	1.1	0.3	0.1	0.2	7.0
1933 - 1934	0.3	0.5	2.7	7.4	3.5	19.7	13.1	5.2	1.4	0.3	0.2	0.2	4.5
1934 - 1935	0.2	0.6	32.4	7.6	14.9	10.4	4.4	3.8	2.5	0.6	0.2	0.2	6.5
1935 - 1936	0.2	6.6	47.8	73.4	55.4	38.2	29.1	6.4	2.4	1.0	0.2	0.2	21.7
1936 - 1937	0.4	1.4	2.0	3.5	30.8	41.1	16.2	4.8	1.6	0.3	0.1	0.3	8.5
1937 - 1938	1.2	15.6	23.4	11.8	5.1	2.7	1.2	1.5	0.3	0.2	0.1	0.1	5.3
1938 - 1939	0.2	0.4	8.3	37.6	12.0	5.8	14.5	4.3	2.2	0.6	0.3	0.1	7.2
1939 - 1940	7.3	8.6	6.9	24.2	38.4	22.4	8.2	7.0	2.5	0.7	0.2	0.2	10.6
1940 - 1941	0.7	9.5	5.0	39.2	38.4	21.0	16.8	13.4	7.3	2.2	0.5	0.3	12.9
1941 - 1942	0.3	4.0	2.2	2.9	2.7	15.9	11.3	13.5	4.5	1.0	0.3	0.3	4.9
1942 - 1943	1.1	2.4	13.6	39.7	13.7	5.9	4.3	2.3	0.6	0.4	0.2	0.9	7.1
1943 - 1944	15.1	6.5	9.1	5.3	2.7	4.6	7.0	2.8	0.9	0.6	0.3	0.3	4.6
1944 - 1945	0.4	1.4	7.6	5.7	6.2	2.9	1.4	1.1	0.5	0.2	0.1	0.2	2.3
1945 - 1946	0.3	2.4	32.2	9.1	7.1	13.2	9.6	14.8	11.2	1.9	0.6	0.7	8.6
1946 - 1947	1.3	4.2	10.3	10.4	44.9	34.4	17.5	6.6	2.6	0.7	0.3	0.3	11.1
1947 - 1948	0.4	0.6	4.7	38.9	12.2	5.9	5.0	4.6	3.0	0.7	0.4	0.2	6.4
1948 - 1949	0.4	0.8	6.4	8.1	3.3	2.1	1.5	1.4	0.7	0.5	0.1	0.2	2.1
1949 - 1950	0.53	2.51	3.83	2.96	13.17	8.73	4.11	4.69	4.26	1.60	0.44	0.31	3.9
1950 - 1951	0.52	3.04	5.07	12.14	33.72	36.72	6.78	7.45	5.68	1.83	0.56	0.53	9.5

Average for the period: 7.9

TABLE C-5

PAIVA RIVER AT FRAGAS DA TORRE

OBSERVED AVERAGE MONTHLY FLOW IN m^3/s
(DRAINAGE AREA = 663 km^2)

WATER YEAR	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	AVERAGE ANNUAL FLOW
1934 - 1935	-	-	-	-	32.3	27.7	10.8	11.0	8.4	2.4	1.1	1.0	-
1935 - 1936	1.2	37.1	155.2	177.5	141.5	107.8	71.6	17.2	7.6	4.4	1.9	1.7	60.4
1936 - 1937	2.8	6.0	5.9	100.5	79.3	106.3	48.4	14.0	6.3	2.1	1.4	2.3	31.3
1937 - 1938	5.7	41.0	70.6	32.7	11.7	7.6	5.1	7.0	2.0	1.2	0.8	1.6	15.6
1938 - 1939	2.3	6.5	37.7	110.3	35.4	16.6	38.3	12.9	7.8	3.7	2.4	4.7	23.2
1939 - 1940	21.6	24.8	17.7	61.8	106.0	54.3	21.6	21.6	7.4	3.2	1.7	2.0	28.6
1940 - 1941	4.4	30.4	12.6	107.1	113.0	60.8	49.0	38.1	21.8	7.3	2.6	2.0	37.4
1941 - 1942	2.2	12.2	6.6	10.6	9.5	43.1	30.2	38.7	13.3	3.6	0.7	2.0	14.4
1942 - 1943	4.0	7.6	42.3	101.4	34.7	16.1	10.4	6.0	2.2	1.8	1.0	4.2	19.3
1943 - 1944	49.4	15.4	26.7	12.8	7.3	10.9	25.7	7.5	3.3	2.3	1.3	1.7	13.7
1944 - 1945	2.0	6.2	23.9	16.4	16.5	6.9	4.7	4.6	2.7	0.7	0.6	1.0	7.2
1945 - 1946	2.5	11.9	78.4	20.8	17.4	31.5	21.6	38.2	24.1	4.2	1.7	2.2	21.2
1946 - 1947	5.0	14.7	35.8	32.0	138.2	98.0	50.3	16.3	5.9	1.8	1.0	1.2	33.4
1947 - 1948	1.6	3.4	20.6	112.3	29.4	14.1	12.9	12.0	6.9	1.6	1.4	0.9	18.1
1948 - 1949	2.4	3.0	24.7	22.7	7.4	4.7	3.3	2.9	1.6	0.6	0.2	1.4	6.2
1949 - 1950	2.27	13.42	11.95	8.09	49.32	23.07	9.21	15.70	11.83	4.15	1.18	1.02	12.6
1950 - 1951	1.66	14.00	16.70	40.76	94.44	102.11	16.50	20.90	13.71	5.16	1.95	1.88	27.5

Average for the period: 23.1

TABLE C-6

TAVORA RIVER AT PONTE NOVA

OBSERVED AVERAGE MONTHLY FLOW IN m^3/s
(DRAINAGE AREA = 444 km^2)

WATER YEAR	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	AVERAGE ANNUAL FLOW
1947 - 1948	0.24	0.33	3.06	39.79	13.37	6.84	4.27	4.23	2.45	0.35	0.18	0.12	6.27
1948 - 1949	0.12	0.33	3.29	5.65	2.60	1.68	1.68	1.22	0.59	0.21	0.09	0.08	1.46
1949 - 1950	0.37	1.09	2.66	2.09	8.99	6.72	2.97	3.30	2.84	1.01	0.14	0.12	2.69
1950 - 1951	0.16	0.62	1.79	6.17	20.96	33.26	5.79	4.76	3.27	1.89	0.22	0.22	6.59
1951 - 1952	0.35	15.97	5.01	4.12	-	-	-	-	-	-	-	-	-

Average for the period: 4.25

TABLE C-7

SABOR RIVER AT LARANJEIRAS

OBSERVED AVERAGE MONTHLY FLOW IN m^3/s
(DRAINAGE AREA = 3,460.3 km^2)

WATER YEAR	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	AVERAGE ANNUAL FLOW
1937 - 1938	-	63.45	244.91	33.81	14.93	9.14	4.34	4.25	1.01	0.22	0.02	0.01	-
1938 - 1939	0.25	1.72	11.12	131.81	35.03	13.32	30.20	8.77	5.71	1.43	0.39	1.00	20.06
1939 - 1940	0.00	17.33	14.19	79.57	135.37	69.32	20.46	17.44	5.74	1.35	0.94	0.37	30.17
1940 - 1941	3.27	40.52	13.63	173.61	207.17	110.18	73.03	63.66	29.27	6.60	2.82	0.87	60.39
1941 - 1942	1.55	9.54	8.27	7.99	6.98	83.34	56.22	54.14	14.59	2.50	0.58	1.61	20.61
1942 - 1943	5.48	11.58	68.78	174.53	81.70	35.33	21.05	6.95	1.52	0.82	0.29	2.77	34.23
1943 - 1944	28.97	14.46	20.85	13.03	8.70	9.28	13.17	5.60	1.31	0.75	0.61	0.77	9.79
1944 - 1945	0.75	1.77	5.42	5.90	6.95	2.70	1.81	1.55	1.16	-	0.00	0.00	-
1945 - 1946	-	5.29	99.38	17.14	19.46	42.89	56.77	97.68	27.82	3.30	0.81	1.29	-
1946 - 1947	2.89	6.40	17.71	28.28	208.02	215.52	86.84	21.38	5.31	1.02	0.34	1.44	49.60
1947 - 1948	4.37	3.52	17.27	183.99	74.67	31.83	26.93	26.68	11.53	1.46	1.28	0.44	32.00
1948 - 1949	0.72	2.76	21.74	28.98	8.30	4.91	3.53	1.77	1.46	1.42	0.10	1.00	6.39

Average for the period (excluding 1937 - 1938 and 1944 - 1946): 29.25

TABLE C-8

COA RIVER AT VALE DO AREAL

OBSERVED AVERAGE MONTHLY FLOW IN m^3/s
(DRAINAGE AREA = 1,100 km^2)

WATER YEAR	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	AVERAGE ANNUAL FLOW
1946 - 1947	-	2.10	3.40	7.60	63.30	77.00	65.00	11.90	4.10	0.80	0.00	0.00	-
1947 - 1948	0.70	4.30	9.00	53.00	32.70	20.40	10.30	22.00	4.03	0.73	0.29	0.00	13.12
1948 - 1949	0.23	1.37	10.84	18.83	3.95	1.78	2.85	2.50	2.35	0.77	0.00	0.18	3.80
1949 - 1950	4.34	4.82	12.23	11.76	25.45	13.23	6.72	21.61	14.63	3.62	0.94	0.53	9.99
1950 - 1951	2.05	4.00	5.10	13.20	30.10	58.10	11.80	8.70	5.30	3.00	0.41	0.50	11.87
1951 - 1952	2.80	48.20	13.00	8.00	6.00	-	-	-	-	-	-	-	-

Average for the period: 9.70

TABLE C-9

CAVADO RIVER AT PARADELA

OBSERVED AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 221 km^2)

WATER YEAR	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	AVERAGE ANNUAL FLOW
1939 - 1940	12.6	16.5	10.6	33.5	44.3	20.1	14.5	11.8	4.2	1.1	0.57	0.47	14.2
1940 - 1941	2.0	27.5	5.4	43.1	43.9	27.4	24.2	21.1	11.2	2.1	0.66	0.35	17.4
1941 - 1942	0.12	6.2	2.8	5.2	3.3	24.1	18.5	21.5	7.1	1.4	0.31	0.67	7.6
1942 - 1943	2.8	7.0	31.6	49.6	16.4	7.2	4.3	2.1	0.41	0.61	0.08	0.85	10.2
1943 - 1944	18.0	6.9	7.5	4.4	2.4	4.6	14.3	3.9	1.5	2.3	0.7	0.68	5.6
1944 - 1945	0.55	2.2	7.7	8.1	7.0	2.6	2.4	3.2	1.5	0.48	0.44	0.42	3.0
1945 - 1946	1.0	6.5	27.4	10.3	8.5	15.6	10.1	17.2	11.6	1.7	0.59	1.2	9.3
1946 - 1947	4.7	11.4	16.6	14.3	54.3	52.3	21.8	7.4	1.3	0.48	0.39	0.47	15.5
1947 - 1948	1.4	1.7	11.5	51.7	11.2	6.3	5.4	8.5	4.0	0.9	1.3	0.45	8.7
1948 - 1949	0.45	5.9	21.1	10.0	4.4	3.7	2.6	1.5	1.1	0.42	0.15	2.0	4.4
1949 - 1950	4.8	11.8	9.7	5.6	36.2	11.5	4.0	11.0	6.4	1.6	0.45	0.52	8.6
1950 - 1951	0.83	15.5	11.5	17.7	42.6	31.9	6.5	9.4	5.0	1.6	0.63	0.69	12.0
1951 - 1952	1.86	27.4	8.9	-	-	-	-	-	-	-	-	-	-

Average for the period: 9.7

TABLE C-10

CAVADO RIVER BELOW MOUTH OF RIO CALDO

OBSERVED AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 760 km^2)

WATER YEAR	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	AVERAGE ANNUAL FLOW
1939 - 1940	85.5	92.5	47.7	147.1	207.1	93.2	51.1	42.5	17.7	8.1	3.57	2.94	66.5
1940 - 1941	12.4	117.4	27.2	180.5	176.5	165.3	73.3	78.5	53.9	13.5	6.0	4.0	75.7
1941 - 1942	4.4	33.7	14.4	26.8	16.8	109.3	70.1	72.9	40.4	10.8	5.2	7.9	34.4
1942 - 1943	10.4	32.5	100.5	164.5	62.3	24.7	16.1	11.2	5.1	12.4	3.2	10.6	37.8
1943 - 1944	90.9	30.2	41.1	23.3	14.0	31.2	68.1	17.5	10.3	12.3	7.0	7.6	29.5
1944 - 1945	6.2	14.1	52.7	27.2	40.8	14.0	13.2	12.7	6.3	2.4	3.7	5.4	16.6
1945 - 1946	16.4	13.7	136.4	40.4	37.2	66.2	37.7	72.7	56.2	5.6	2.7	9.4	41.2
1946 - 1947	27.2	50.2	74.8	60.1	255.8	229.1	82.6	33.2	8.0	3.9	2.3	3.1	69.2
1947 - 1948	6.7	10.1	65.6	227.8	47.9	23.7	21.9	31.8	13.4	3.9	7.9	2.4	38.6
1948 - 1949	4.1	24.3	86.1	40.8	22.5	12.1	9.3	5.6	5.1	1.8	0.88	11.4	18.7
1949 - 1950	23.7	61.0	35.7	19.8	136.1	45.6	16.3	38.6	22.8	7.4	3.2	3.1	34.4
1950 - 1951	4.7	72.7	46.2	74.5	188.2	138.2	25.3	39.2	21.6	6.6	3.5	4.1	52.1
1951 - 1952	11.6	121.0	39.7	-	-	-	-	-	-	-	-	-	-

Average for the period: 42.9

TABLE C-11

TEJO RIVER AT RODAO

OBSERVED AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 59,167 km^2)

WATER YEAR	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	AVERAGE ANNUAL FLOW
1902 - 1903	188	570	502	348	221	148	116	255	233	84	30	70	230
1903 - 1904	98	97	300	424	1,720	895	333	140	101	50	15	35	351
1904 - 1905	64	123	236	214	136	184	167	106	158	80	29	40	128
1905 - 1906	56	362	347	763	203	185	308	306	193	76	27	129	246
1906 - 1907	224	427	150	111	165	85	134	167	86	24	14	52	137
1907 - 1908	582	1,304	901	1,080	271	183	188	146	146	60	24	49	411
1908 - 1909	61	157	207	146	109	213	178	143	128	36	8	21	117
1909 - 1910	31	429	1,890	409	338	367	310	234	157	49	18	31	355
1910 - 1911	149	346	2,640	332	299	308	629	304	353	109	56	60	465
1911 - 1912	226	321	1,060	669	3,760	1,010	373	266	130	53	30	38	661
1912 - 1913	98	71	71	456	302	245	268	115	80	31	10	29	148
1913 - 1914	1,070	1,660	264	178	1,050	563	310	209	110	76	19	19	461
1914 - 1915	33	121	889	1,300	883	1,240	617	429	231	80	44	43	492
1915 - 1916	49	183	1,230	503	484	2,760	621	452	164	66	29	30	548
1916 - 1917	50	243	1,920	841	2,490	1,060	466	389	218	84	38	69	656
1917 - 1918	61	62	62	509	149	130	337	141	72	25	8	30	132
1918 - 1919	37	118	133	314	2,380	1,046	1,164	253	195	63	26	25	480
1919 - 1920	152	593	285	272	470	494	402	223	123	50	19	24	259
1920 - 1921	125	197	238	271	368	218	124	-	173	143	185	50	-
1921 - 1922	173	124	161	488	544	352	371	163	144	31	49	27	219
1922 - 1923	289	261	231	252	432	357	516	202	94	44	17	24	227
1923 - 1924	36	368	432	525	783	1,455	1,312	246	94	36	19	75	448
1924 - 1925	63	336	569	197	281	261	219	146	246	73	19	14	202
1925 - 1926	32	177	1,403	307	2,175	636	635	419	134	51	19	24	501
1926 - 1927	79	1,043	428	264	544	558	286	159	89	41	17	17	294
1927 - 1928	53	278	1,529	-	328	1,097	827	858	284	80	37	121	-
1928 - 1929	138	178	128	136	511	535	128	146	87	51	11	50	175
1929 - 1930	37	121	573	544	687	564	538	409	415	120	40	28	340
1930 - 1931	86	66	125	334	97	867	240	103	61	25	10	21	170
1931 - 1932	260	381	121	147	166	442	153	153	77	33	13	71	168
1932 - 1933	123	221	1,574	1,049	643	1,073	255	167	90	38	33	25	441
1933 - 1934	91	110	169	201	108	210	701	197	75	21	15	18	160
1934 - 1935	22	62	681	223	127	277	111	176	166	40	18	13	160
1935 - 1936	26	121	1,111	2,914	3,462	2,388	1,994	732	451	258	174	163	1,150
1936 - 1937	189	178	190	1,245	1,864	1,828	714	303	185	87	37	41	572
1937 - 1938	280	2,367	1,085	449	239	169	124	233	68	29	17	61	427
1938 - 1939	54	88	414	1,467	694	213	706	157	132	45	27	49	337
1939 - 1940	481	835	720	2,316	1,926	1,007	371	290	182	92	38	40	692
1940 - 1941	139	151	200	2,521	2,170	1,374	748	814	296	145	62	46	722
1941 - 1942	71	273	159	151	154	928	638	447	127	42	16	48	254
1942 - 1943	137	459	987	1,210	903	1,075	599	384	84	42	23	90	499
1943 - 1944	145	247	220	168	94	91	363	153	81	38	16	58	140
1944 - 1945	68	163	209	197	226	126	103	37	27	11	5	3	98
1945 - 1946	16	24	2,455	622	249	981	1,912	3,329	498	103	43	55	857
1946 - 1947	6	98	146	236	5,166	7,915	2,155	743	358	209	142	217	1,449
1947 - 1948	154	113	172	750	677	295	244	449	180	47	34	34	262
1948 - 1949	44	66	141	138	68	55	71	42	33	14	8	84	64
1949 - 1950	92	83	279	165	276	121	59	117	89	24	11	12	111

Average flow for period: 379

TABLE C-12

OCREZA RIVER AT PRACANA

OBSERVED AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 1,410 km^2)

WATER YEAR	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	AVERAGE ANNUAL FLOW
1932 - 1933	8.6	14.1	61.1	53.8	27.8	40.3	13.9	15.4	4.5	2.2	1.6	2.0	20.4
1933 - 1934	6.8	7.5	12.3	20.2	6.7	34.0	47.1	12.2	4.3	2.1	2.1	2.1	13.1
1934 - 1935	2.0	5.0	61.1	15.9	7.0	19.6	7.5	6.8	4.4	2.8	1.8	1.8	11.3
1935 - 1936	2.2	17.9	59.3	108.2	113.5	106.5	74.6	21.4	10.4	4.4	2.6	2.6	43.6
1936 - 1937	4.4	6.6	6.1	61.8	57.2	85.0	39.7	11.0	11.7	2.9	2.4	3.2	24.3
1937 - 1938	7.5	55.1	77.9	30.6	13.0	12.4	9.7	12.6	5.2	2.9	2.3	3.1	19.4
1938 - 1939	3.5	7.5	21.7	82.4	28.2	12.4	30.4	13.8	10.8	3.1	1.6	3.3	18.2
1939 - 1940	22.0	27.8	34.2	102.0	107.6	91.7	20.2	19.1	5.8	1.8	0.4	0.4	36.1
1940 - 1941	4.3	24.3	8.0	84.9	114.0	66.2	42.2	39.0	10.6	4.7	0.7	0.7	33.3
1941 - 1942	1.8	11.6	4.8	7.5	8.5	113.0	33.5	18.4	5.1	1.8	0.8	3.6	17.5
1942 - 1943	14.7	49.3	67.8	132.7	25.2	47.0	18.8	7.3	2.9	1.8	0.6	3.7	31.0
1943 - 1944	7.4	8.4	10.4	4.4	2.6	4.7	20.3	4.3	2.0	1.2	0.5	1.2	5.6
1944 - 1945	1.4	10.3	11.4	6.6	4.6	3.0	4.5	3.6	2.6	1.2	0.0	0.0	4.1
1945 - 1946	13.1	11.4	80.1	24.2	13.1	29.7	20.0	67.0	13.4	2.0	0.8	1.5	23.0
1946 - 1947	2.2	3.7	5.2	18.3	132.4	98.1	35.7	10.1	3.1	0.6	0.1	1.7	25.9
1947 - 1948	10.0	3.7	17.5	80.7	33.0	21.6	9.4	15.7	7.2	1.3	0.8	1.0	16.8
1948 - 1949	1.4	1.8	18.4	19.9	6.6	4.1	3.9	2.6	2.3	1.3	0.0	15.3	6.5
1949 - 1950	7.9	10.6	81.4	23.7	34.2	14.8	8.0	31.4	18.9	5.5	0.9	1.6	19.9

Average for the period: 20.6

All flows converted to m^3/s from recorded data in cu. m. X 10^3

TABLE C-13

ZEZERE RIVER AT PONTE DO CABRIL

OBSERVED AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 2,340 km^2)

WATER YEAR	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	AVERAGE ANNUAL FLOW
1941 - 1942	-	-	-	-	12.30	185.43	87.75	228.26	14.63	2.52	0.82	1.94	-
1942 - 1943	37.88	92.37	140.55	314.01	115.90	118.09	64.00	25.14	4.79	3.22	2.12	23.54	78.47
1943 - 1944	24.90	30.83	55.56	24.57	8.54	11.68	73.09	11.59	6.06	3.58	2.68	3.45	21.38
1944 - 1945	3.39	23.15	30.10	17.75	16.39	7.52	7.95	5.67	2.77	1.02	1.74	1.07	9.88
1945 - 1946	13.16	45.84	189.91	53.73	32.80	78.15	86.03	189.76	47.62	8.43	7.08	5.21	63.14
1946 - 1947	7.27	13.36	23.26	41.44	285.38	230.31	122.26	2.87	8.59	4.68	4.81	6.16	62.53
1947 - 1948	8.54	4.49	40.92	177.24	92.57	55.87	30.47	46.19	21.00	4.25	2.88	4.10	40.71
1948 - 1949	4.54	4.33	52.20	52.79	12.05	8.02	6.31	4.08	2.16	0.85	0.18	8.40	12.99
1949 - 1950	11.58	20.42	80.38	31.84	99.10	45.90	20.06	81.00	37.98	9.08	3.09	4.41	37.07
1950 - 1951	8.09	23.15	24.72	79.73	173.68	202.97	-	-	-	-	-	-	-

Average for the period: 40.77

TABLE C-14

ZEZERE AT CASTELO DO BODE

OBSERVED AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 3,950 km^2)

WATER YEAR	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	AVERAGE ANNUAL FLOW
1938 - 1939	-	-	-	-	-	-	131.20	58.80	46.70	12.70	5.50	13.90	-
1939 - 1940	81.20	90.20	125.40	369.70	388.30	338.30	72.80	70.40	22.50	3.50	0.16	0.06	130.21
1940 - 1941	14.20	93.50	25.80	317.42	419.59	247.00	158.48	142.54	38.30	18.12	2.59	1.64	123.27
1941 - 1942	2.27	28.87	12.21	26.00	22.00	295.36	143.80	108.60	23.00	2.90	0.50	2.00	55.63
1942 - 1943	44.60	104.70	184.50	438.00	164.00	186.90	90.90	40.40	6.30	3.30	1.10	39.00	108.64
1943 - 1944	39.10	44.40	102.20	33.00	14.40	23.34	95.20	22.74	7.70	2.80	1.66	3.05	32.47
1944 - 1945	3.13	32.96	43.70	29.70	27.04	11.25	11.33	7.00	1.55	0.20	0.30	0.20	14.03
1945 - 1946	16.10	52.30	261.20	80.71	52.88	113.59	93.93	221.75	68.50	9.90	5.98	3.89	81.73
1946 - 1947	9.80	19.42	34.00	66.00	433.00	320.00	157.00	42.00	13.00	6.00	6.00	7.00	92.77
1947 - 1948	14.13	5.70	66.10	261.10	124.40	86.90	50.10	71.80	32.10	0.73	0.26	0.00	59.44
1948 - 1949	0.47	1.27	55.00	61.00	6.00	4.00	2.00	0.50	0.00	0.00	0.00	13.90	12.01
1949 - 1950	12.00	28.86	128.16	47.22	139.20	63.79	28.02	92.40	45.20	13.40	2.00	6.00	50.52
1950 - 1951	10.00	27.00	33.00	-	-	-	-	-	-	-	-	-	-

Average for the period: 69.16

TABLE C-15

LIMA RIVER AT LINDOSO

OBSERVED AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 1,514 km^2)

WATER YEAR	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	AVERAGE ANNUAL FLOW
1920 - 1921	68.72	45.25	47.17	52.46	50.20	29.99	19.78	27.22	16.39	5.07	1.86	4.14	30.69
1921 - 1922	12.66	25.25	36.33	64.19	85.30	119.67	124.39	41.22	23.13	6.33	2.07	2.52	45.26
1922 - 1923	32.06	68.50	66.55	68.43	112.08	84.79	87.22	40.00	17.55	2.93	1.17	1.23	48.54
1923 - 1924	30.72	51.60	50.71	91.49	89.44	112.67	100.16	57.26	26.06	5.41	1.73	12.75	52.50
1924 - 1925	10.44	67.20	147.47	99.91	121.52	95.52	114.57	79.78	42.67	14.94	5.52	5.39	67.08
1925 - 1926	76.79	171.66	118.68	118.07	127.59	58.65	106.94	48.61	32.43	7.39	2.08	1.17	72.51
1926 - 1927	22.05	112.53	42.40	59.50	103.94	164.37	41.94	23.98	12.92	18.87	6.24	10.72	51.62
1927 - 1928	11.11	37.25	95.25	48.75	38.90	120.87	143.03	81.57	54.91	10.47	2.50	7.01	54.30
1928 - 1929	20.93	33.23	38.26	33.68	81.36	39.76	18.14	25.76	12.62	15.19	2.11	2.86	26.99
1929 - 1930	8.62	93.57	150.52	119.18	95.89	66.61	95.91	88.68	82.64	73.96	64.98	58.16	58.16
1930 - 1931	52.76	50.29	54.49	95.89	37.34	154.52	66.97	58.48	30.58	11.11	10.40	9.58	52.70
1931 - 1932	28.04	96.54	41.56	84.41	111.36	88.87	99.08	83.68	75.17	64.49	3.19	23.46	66.65
1932 - 1933	73.28	54.19	151.88	111.36	66.39	119.49	37.51	41.11	10.90	5.08	0.97	1.73	56.16
1933 - 1934	30.32	29.64	59.22	67.02	26.04	106.23	89.24	34.61	13.61	4.90	2.14	2.98	38.83
1934 - 1935	2.57	16.34	164.65	39.35	53.18	73.70	50.42	38.33	7.13	13.06	3.44	2.64	38.73
1935 - 1936	3.35	79.62	121.91	229.48	227.28	189.06	127.72	32.56	23.50	13.27	3.38	2.29	87.79
1936 - 1937	6.63	30.71	22.73	143.22	166.68	237.25	121.01	32.40	13.43	3.32	0.98	1.49	64.99
1937 - 1938	9.14	88.40	127.26	82.79	25.54	16.48	8.92	11.05	4.45	1.08	0.41	5.13	31.72
1938 - 1939	4.36	33.11	84.97	242.72	56.61	28.68	85.59	24.88	21.30	10.80	42.82	11.59	53.95
1939 - 1940	66.91	71.33	46.73	125.97	217.86	98.58	56.90	69.79	24.80	7.25	2.11	1.44	65.81
1940 - 1941	10.85	69.93	33.49	172.02	247.13	158.76	113.74	110.31	61.98	11.40	4.12	2.14	82.99
1941 - 1942	2.42	30.75	16.30	35.07	18.93	121.19	64.24	87.70	35.40	7.23	2.90	4.57	35.56
1942 - 1943	19.69	25.75	89.45	200.73	87.61	31.12	15.80	8.85	2.95	2.19	0.78	5.97	40.91
1943 - 1944	58.73	26.07	29.66	16.12	11.55	18.48	66.59	12.41	5.58	7.08	2.74	3.35	21.53
1944 - 1945	5.22	14.54	58.18	49.62	16.06	10.73	11.11	13.72	7.20	1.58	1.57	2.00	15.96
1945 - 1946	14.81	40.34	134.67	50.24	35.52	63.03	44.42	77.29	48.89	6.69	2.80	6.56	43.77
1946 - 1947	8.82	48.63	78.58	68.31	259.57	230.59	113.09	44.29	11.91	2.90	1.41	2.85	72.58
1947 - 1948	3.31	10.29	77.22	194.06	63.54	27.08	19.64	34.78	15.35	2.93	6.36	5.83	38.37
1948 - 1949	7.72	12.47	58.80	47.31	16.06	13.36	9.91	7.89	6.85	6.13	4.48	6.50	16.46
1949 - 1950	14.02	53.09	29.52	21.30	121.40	59.94	19.83	43.37	28.46	10.06	9.62	11.14	35.15
1950 - 1951	10.82	65.85	56.13	110.36	162.32	163.97	36.11	49.00	20.53	8.36	8.34	11.12	58.58
1951 - 1952	14.29	111.80	47.29	38.67	33.48	49.58	64.68	-	-	-	-	-	-

Average flow for period: 49.25

TABLE C-16

GAGING STATIONS IN DOURO RIVER BASIN

AVERAGE FLOWS AND EXTREMES IN m^3/s

River	Station	Drainage Area km^2	Period of Record	FOR THE PERIOD OF RECORD: Average Flow m^3/s	Minimum Flow: Minimum Month	Minimum Flow: Minimum Day	Maximum Flow: Maximum Month	Maximum Flow: Maximum Day	Date of Occurrence	FOR THE PERIOD 1942 - 1950: Average Flow m^3/s	Minimum Flow: Minimum Month	Minimum Flow: Minimum Day	Maximum Flow: Maximum Month	Maximum Flow: Maximum Day	Date of Occurrence
Douro	Regua	92,225	1931-32 to	519.8	48.0	-	-	-	July '31	388.1	49.0	-	-	-	Oct. '45
			1950-51		-	-	3,149	-	Jan. '36		-	-	2,290	-	Mar. '47
Douro	Puente Pino	63.300	1930-31 to	328.0	37.0	-	-	-	Aug. '49	249.0	37.0	-	-	-	Aug. '49
			1950-51		-	-	1,785	-	Feb. '36		-	-	1,315	-	Mar. '47
Paiva	Castro Daire	293	1917-18 to	7.9	0.1	-	-	-	Aug. '38&'49 Sept. '39	5.7	0.1	-	-	-	Aug. '49
			1950-51		-	-	73.4	-	Jan. '36		-	-	44.9	-	Feb. '47
Paiva	Fragas da Torre	663	1935-36 to	23.1	0.2	-	-	-	Aug. '49	16.3	0.2	-	-	-	Aug. '49
			1950-51		-	-	177.5		Jan. '36		-	-	138.2	-	Feb. '47
Tavora	Moinho da Ponte Nova	444	1947-48 to 1950-51	4.3	0.08	0.06	-	-	Sept. '49 Sept.4-13,49 Aug.11-18,49	4.33					
					-	-	39.79	-	Jan. '48						
					-	-	-	111.89	Mar.16,51						
Sabor	Laranjeiras	3,460	1938-39 to	26.97	0.0	0.0	-	-	Oct. '39 Aug.& Sept.45	22.0					
			1948-49		-	-	215.52	-	Mar. '47						
					-	-	-	1,200.54	Jan.29,'48						
Coa	Vale do Areal	1,100	1946-47 to	11.70	0.0	-	-	-	Aug.& Sept.47 Sept.48&Aug.49	10.0					
			1950-51		-	-	77.0	-	Mar. '47						

TABLE C-17

GAGING STATIONS IN BASINS OTHER THAN THE DOURO

AVERAGE FLOWS AND EXTREMES IN m^3/s

River	Station	Drainage Area km2	FOR THE PERIOD OF RECORD: Period of Record	Average Flow m3/s	Minimum Flow: Minimum Month	Minimum Flow: Minimum Day	Maximum Flow: Maximum Month	Maximum Flow: Maximum Day	Date of Occurrence	FOR THE PERIOD 1942 - 1950: Average Flow m3/s	Minimum Flow: Minimum Month	Minimum Flow: Mimimum Day	Maximum Flow: Maximum Month	Maximum Flow: Maximum Day	Date of Occurrence
Cavado	Paradela	221	1939-40 to	9.7	0.08	-	-	-	Aug. '43	8.1	0.08	-	-	-	Aug. '43
			1950-51		-	-	54.3	-	Feb. '47		-	-	54.3	-	Feb. '47
Cavado	Below Mouth of Caldo River	760	1939-40 to	42.9	0.88	-	-	-	Aug. '49	35.6	0.88	-	-	-	Aug. '49
			1950-51		-	-	255.8	-	Feb. '47		-	-	255.8	-	Feb. '47
Tejo	Vila Velha de Rodao	59,167	1902-03 to	378.6	3.0	-	-	-	Sept. '45	415.0	3.0	-	-	-	Sept. '45
			1949-50		-	-	7,915	-	Mar. '47		-	-	7,915	-	Mar. '47
Ocreza	Pracana	1,410	1932-33 to	20.6	0.0	-	-	-	Aug. and Sept. '45 Aug. '49	16.7	0.0	-	-	-	Aug. and Sept. '45 Aug. '49
			1949-50		-	-	130.2	-	Jan. '43		-	-	130.2	-	Jan. '43
Zezere	Ponte do Cabril	2,340	1942-43 to	40.77	0.18	0.15	-	-	Aug. 30&31, 1949*						
			1949-50		-	-	314.01	2,669.0	Jan. 20,43						
Zezere	Castelo do Bode	3,950	1939-40 to	69.16	0.0	0.0	-	-	Sep.48; June, July&Aug.49*	56.36	0.0	0.0	-	-	Sep.48; June, July&Aug.49*
			1949-50		-	-	438.0	-	Jan. '43		-	-	438.0	2,039.0	Jan.21,43
					-	-	-	2,044.8	Jan.24,41						
Lima	Lindoso	1,514	1920-21 to	50.06	0.41	-	-	-	Aug. '38	35.59	0.78	-	-	-	Aug. '43
			1950-51		-	-	259.57	-	Feb. '47		-	-	259.57	-	Feb. '47

*There are other dates during which the minimum daily flow occurred.

TABLE C-17a

PROPOSED DOURO RIVER PROJECTS

AVERAGE FLOWS AND EXTREMES IN m^3/s

Station	Drainage Area km2	Period of Record	Average Flow m^3/s	FOR THE PERIOD OF RECORD					FOR THE PERIOD 1942 - 1950					
				Minimum Flow		Maximum Flow		Date of Record	Average Flow m^3/s	Minimum Flow		Maximum Flow		Date of Record
				Minimum Month	Minimum Day	Maximum Month	Maximum Day			Minimum Month	Minimum Day	Maximum Month	Maximum Day	
Carrapatelo*	93,475	1931-51	524.9	48.5	-	3,180	-	July '31 Jan. '36	392.0	49.5	-	2,313	-	Oct. '45 Mar. '47
Regua	92,225	1931-51	519.8	48.0	-	3,149	-	July '31 Jan. '36	388.1	49.0	-	2,290	-	Oct. '45 Mar. '47
Valeira*	87.775	1931-51	497.0	45.9	-	3,010	-	July '31 Jan. '36	371.0	46.8	-	2,190	-	Oct. '45 Mar. '47
Pocinho*	82.775	1931-51	488.0	45.0	-	2,956	-	July '31 Jan. '36	364.0	46.0	-	2,150	-	Oct. '45 Mar. '47
Bemposta	63.850	1930-51	328.0	37.0	-	1,785	-	Aug. '49 Feb. '36	247.0	37.0	-	1.315	-	Aug. '49 Mar. '47
Picote**	63.750	1930-51	328.0	37.0	-	1,785	-	Aug. '49 Feb. '36	247.0	37.0	-	1,315	-	Aug. '49 Mar. '47
Miranda**	63.500	1930-51	328.0	37.0	-	1.785	-	Aug. '49 Feb. '36	247.0	37.0	-	1.315	-	Aug. '49 Mar. '47

* Flow computed from Regua record.
** Flow computed from Bemposta record.

TABLE C-18

PAMPILHOSA AND CEIRA RIVERS AT SANTA LUZIA

AVERAGE MONTHLY FLOW IN m^3/s
(DRAINAGE AREA = 90km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	0.6	0.6	7.7	3.6	2.7	0.6	0.1	0.1	0.1	1.5	3.6	5.4	2.2
1943	15.2*	1.1*	6.5*	1.8*	0.1*	0.0*	0.2*	0.0*	1.7*	2.7*	0.7*	7.1*	3.1
1944	0.0*	0.6*	1.1*	5.3*	0.4*	0.1*	0.1*	0.0*	0.2*	0.5*	4.4*	4.4*	1.4
1945	2.6*	0.0*	0.2*	0.5*	1.0*	0.0*	0.0*	0.0*	0.0*	0.7*	4.5*	14.4*	2.0
1946	2.1	1.3	3.0	3.3	7.3	1.8	0.3	0.3	0.2	0.3	0.5	0.9	1.8
1947	1.6	11.0	8.9	4.7	0.1	0.3	0.2	0.2	0.2	0.3	0.2	1.6	2.4
1948	6.8	3.6	2.1	1.2	1.8	0.8	0.2	0.1	0.2	0.2	0.2	2.0	1.6
1949	2.0	0.5	0.3	0.2	0.2	0.1	0.0	0.0	0.3	0.4	0.8	3.1	0.7
1950	1.2	3.8	1.8	0.8	3.1	1.5	0.3	0.1	0.2	0.3	0.9	1.0	1.2

Average for the period: 1.8

Notes:
1.) *Flows from "ESTUDO DA CONJUGACAO ENTRE AS PRODUCOES DE ENERGIA HIDRAULICA E TERMICA EM PORTUGAL" by Moniz Pereira.

2.) All other flows derived from Zezere River flows at Porte do Cabril.

TABLE C-19

ZEZERE RIVER AT PONTE DO CABRIL

AVERAGE MONTHLY FLOW IN m^3/s
(DRAINAGE AREA = 2,340 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	16.9*	14.5*	200.0*	94.0*	69.0*	15.0*	3.2*	1.5*	2.7*	37.9	92.4	140.6	57.3
1943	314.0	115.9	118.1	64.0	25.1	4.8	3.2	2.1	23.5	24.9	30.8	55.6	65.2
1944	24.6	8.5	11.7	73.1	11.6	6.1	3.6	2.7	3.4	3.4	23.2	30.1	16.8
1945	17.8	16.4	7.5	8.0	5.7	2.8	1.0	1.7	1.1	13.2	45.8	189.9	25.9
1946	53.7	32.8	78.2	86.0	189.8	47.6	8.4	7.1	5.2	7.3	13.4	23.3	46.1
1947	41.4	285.4	230.3	122.3	2.9	8.6	4.7	4.8	6.2	8.5	4.5	40.9	63.4
1948	177.2	92.6	55.9	30.5	46.2	21.0	4.2	2.9	4.1	4.5	4.3	52.2	41.3
1949	52.8	12.0	8.0	6.3	4.1	2.2	0.8	0.2	8.4	11.6	20.4	80.4	17.3
1950	31.8	99.1	45.9	20.1	81.0	38.0	9.1	3.1	4.4	8.1	23.2	24.7	32.4

Average for the period: 40.6

Note: *Flows extrapolated from Zezere River at Castelo do Bode.
See Table C-13, page C-24, for actual record of Ponte do Cabril by water-years.

TABLE C-20

ZEZERE RIVER AT CASTELO DO BODE

OBSERVED AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 3,950 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	26.0	22.0	295.4	143.8	108.6	23.0	2.9	0.5	2.0	44.6	104.7	184.5	79.8
1943	438.0	164.0	186.9	90.9	40.4	6.3	3.3	1.1	39.0	39.1	44.4	102.2	96.3
1944	33.0	14.4	23.3	95.2	22.7	7.7	2.8	1.7	3.0	3.1	33.0	43.7	23.6
1945	29.7	27.0	11.2	11.3	7.0	1.6	0.2	0.3	0.2	16.1	52.3	261.2	34.8
1946	80.7	52.9	113.6	93.9	221.8	68.5	9.9	6.0	3.9	9.8	19.4	34.0	59.5
1947	66.0	433.0	320.0	157.0	42.0	13.0	6.0	6.0	7.0	14.1	5.7	66.1	94.7
1948	261.1	124.4	86.9	50.1	71.8	32.1	0.7	0.3	0.0	0.5	1.3	55.0	57.0
1949	61.0	6.0	4.0	2.0	0.5	0.0	0.0	0.0	13.9	12.0	28.9	128.2	21.4
1950	47.2	139.2	63.8	28.0	92.4	45.2	13.4	2.0	6.0	10.0	27.0	33.0	42.3
											Average for the period:		56.6

Note: For 1938-1951 record by water-years, see Table C-14, page C-24.

TABLE C-21

RABAGAO RIVER AT VENDA NOVA

AVERAGE MONTHLY FLOW IN m^3/S

(DRAINAGE AREA = 240 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	5.6	3.6	26.2	20.1	23.4	7.7	1.5	0.3	0.7	3.0	7.6	34.3	11.2
1943	50.0	7.6*	7.6*	4.6*	1.9*	1.1*	0.4*	1.1*	0.8*	16.8*	7.2*	8.4*	9.0
1944	5.7*	2.7*	6.5*	9.5*	3.8*	1.5*	1.9*	0.8*	0.8*	0.4*	1.5*	8.8*	3.7
1945	6.8*	7.6*	1.5*	3.1*	2.3*	1.1*	0.4*	0.4*	0.4*	0.8*	6.9*	30.1*	5.1
1946	11.2	9.2	16.9	11.0	18.7	12.6	1.8	0.6	1.3	5.1	12.4	18.0	9.9
1947	15.5	58.9	56.8	23.7	8.0	1.4	0.5	0.4	0.5	1.5	1.8	12.5	15.1
1948	56.2	12.2	6.8	5.9	9.2	4.3	1.0	1.4	0.5	0.5	6.4	22.9	10.6
1949	10.8	4.8	4.0	2.8	1.6	1.2	0.5	0.2	2.2	5.2	12.8	10.5	4.7
1950	6.1	39.3	12.5	4.3	11.9	7.0	1.7	0.5	0.6	0.9	16.8	12.5	9.5
											Average for the period:		8.8

Notes:

1.) * Flows from "ESTUDO DA CONJUGACAO ENTRE AS PRODUCOES DE ENERGIA HIDRAULICA E TERMICA EM PORTUGAL" by Moniz Pereira

2.) All other flows derived from Cavado River at Paradela.

TABLE C-22

CAVADO RIVER AT SALAMONDE

AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 623 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	22.0	13.8	89.7	57.5	59.8	33.2	8.9	4.3	6.5	8.5	26.7	82.5	34.5
1943	135.0	51.2	20.2	13.2	9.2	4.2	10.2	2.6	8.7	74.5	24.8	33.7	32.3
1944	19.1	11.5	25.6	55.9	14.5	8.4	10.1	5.7	6.2	5.1	11.6	43.2	18.1
1945	22.3	33.5	11.5	10.8	10.4	5.2	2.0	3.0	4.43	13.4	11.2	112.0	23.3
1946	33.1	30.5	54.3	30.9	59.7	46.1	4.6	2.2	7.7	22.3	41.2	61.4	32.8
1947	49.3	209.7	188.0	67.8	27.2	6.6	3.2	1.9	2.5	5.5	8.3	53.8	52.0
1948	186.7	39.3	19.4	18.0	26.1	11.0	3.2	6.5	2.0	3.4	19.9	70.6	33.9
1949	33.5	18.4	9.9	7.6	4.6	4.2	1.5	0.7	8.5	19.4	50.0	29.3	15.6
1950	16.2	111.8	37.4	13.4	31.7	18.7	6.1	2.6	2.5	3.8	59.7	37.9	28.5
											Average for the period:		30.1

Note: Flows derived from Cavado River at Rio Caldo.

TABLE C-23

CAVADO RIVER AT CANICADA

AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 783 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	27.6	17.3	112.7	72.3	75.2	41.6	11.1	5.4	8.1	10.7	33.5	103.5	43.2
1943	169.5	64.2	25.4	16.6	11.5	5.3	12.8	3.3	10.9	93.6	31.1	42.4	40.6
1944	24.0	14.4	32.2	70.2	18.0	10.6	12.7	7.2	7.8	6.4	14.5	54.3	22.7
1945	28.0	42.1	14.4	13.6	13.1	6.5	2.5	3.8	5.6	16.9	14.1	140.7	25.1
1946	41.7	38.3	68.2	38.8	74.9	57.9	5.8	2.8	9.7	28.0	51.7	77.1	41.2
1947	62.0	263.5	236.0	85.2	34.2	8.2	4.0	2.4	3.2	6.9	10.4	67.6	65.3
1948	234.5	49.4	24.4	22.6	32.8	13.8	4.0	8.1	2.5	4.2	25.1	88.8	42.5
1949	42.2	23.2	12.5	9.6	5.8	5.3	1.9	0.9	11.8	24.4	62.8	36.8	19.8
1950	20.4	140.5	47.0	16.8	39.8	23.5	7.6	3.3	3.2	4.8	75.0	47.6	35.8
											Average for the period:		37.4

Note: Flows derived from Cavado River at Rio Caldo.

TABLE C-24

CAVADO RIVER AT PENIDE

AVERAGE MONTHLY FLOW IN m^3/s
(DRAINAGE AREA = 1,321 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	46.6	29.2	190.5	122.0	126.8	70.4	18.8	90.4	13.7	18.1	56.5	175.0	79.8
1943	286.5	108.5	43.0	28.0	19.5	8.9	21.6	5.6	18.4	158.0	52.5	71.5	68.5
1944	40.5	24.4	54.3	118.5	30.5	17.9	21.4	12.2	13.2	10.8	24.6	91.6	38.3
1945	47.3	71.2	24.4	23.0	22.1	11.0	4.2	6.4	9.4	28.6	23.8	227.5	41.6
1946	70.3	64.8	115.3	65.6	126.6	97.8	9.8	4.7	16.4	47.4	87.4	130.1	69.7
1947	104.7	445.0	398.0	143.8	57.8	13.9	6.8	4.0	5.4	11.6	17.6	114.2	110.2
1948	396.0	83.4	41.2	38.1	55.3	23.3	6.8	13.8	4.2	7.1	42.3	150.0	71.8
1949	71.1	39.2	21.1	16.2	9.8	8.9	3.1	1.5	19.8	41.3	106.2	62.2	33.4
1950	34.5	237.0	79.4	28.4	67.2	39.7	12.9	5.6	5.4	8.2	126.5	80.4	60.4
											Average for the period		63.7

Note: Flows derived from Cavado River at Rio Caldo.

TABLE C-25

CANICADA AND LORIGA RIVERS AT SABUGUEIRO I

AVERAGE MONTHLY FLOW IN m^3/s
(DRAINAGE AREA = 11 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	0.3	0.2	1.2	0.9	1.1	0.4	0.1	0.0	0.0	0.1	0.4	1.6	0.5
1943	1.6*	0.0*	0.9*	0.6*	0.1*	0.0*	0.4*	0.0*	1.6*	1.1*	0.5*	0.8*	0.6
1944	0.1*	0.0*	0.5*	0.7*	1.3*	0.5*	0.3*	0.3*	0.1*	0.2*	0.6*	0.6*	0.4
1945	0.4*	0.1*	0.1*	0.3*	0.3*	0.2*	0.1*	0.2*	0.0*	0.6*	1.1*	1.8*	0.4
1946	0.5	0.4	0.8	0.5	0.9	0.6	0.1	0.0	0.1	0.2	0.6	0.8	0.5
1947	0.7	2.7	2.6	1.1	0.4	0.1	0.0	0.0	0.0	0.1	0.1	0.6	0.7
1948	2.6	0.6	0.3	0.3	0.4	0.2	0.0	0.1	0.0	0.0	0.2	1.0	0.5
1949	0.5	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.1	0.2	0.6	0.5	0.2
1950	0.3	1.8	0.6	0.2	0.6	0.3	0.1	0.0	0.0	0.0	0.8	0.6	0.4
											Average for the period:		0.5

Notes:

1.) * Flows from "ESTUDO DA CONJUGACAO ENTRE AS PRODUCOES DE ENERGIA HIDRAULICA E TERMICA EM PORTUGAL" by Moniz Pereira

2.) All other flows derived from Cavado River at Paradela.

TABLE C-26

ALVA RIVER AT SENHORA DO DESTERRO

AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 50 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	1.2	0.8	5.4	4.2	4.9	1.6	0.3	0.1	0.2	0.6	1.6	7.2	2.3
1943	5.6*	0.1*	3.5*	2.1*	0.5*	0.0*	1.5*	0.1*	3.3*	4.1*	1.6*	3.1*	2.1
1944	0.2*	0.1*	1.7*	2.5*	1.8*	1.7*	0.9*	1.1*	0.4*	0.8*	2.3*	2.6*	1.3
1945	1.3*	0.2*	0.2*	1.0*	1.1*	0.7*	0.2*	0.5*	0.1*	1.7*	3.9*	6.5*	1.4
1946	2.3	1.9	3.5	2.3	3.9	2.6	0.4	0.1	0.3	1.1	2.6	3.8	2.1
1947	3.2	12.3	11.8	4.9	1.7	0.3	0.1	0.1	0.1	0.3	0.4	2.6	3.2
1948	11.7	2.5	1.4	1.2	1.9	0.9	0.2	0.3	0.1	0.1	1.3	4.8	2.2
1949	2.3	1.0	0.8	0.6	0.3	0.2	0.1	0.0	0.4	1.1	2.7	2.2	1.0
1950	1.3	8.2	2.6	0.9	2.5	1.4	0.4	0.1	0.1	0.2	3.5	2.6	2.0

Average for the period: 2.0

Notes:

1) *Flows from "ESTUDO DA CONJUGACAO ENTRE AS PRODUCOES DE ENERGIA HIDRAULICA E TERMICA EM PORTUGAL" by Moniz Pereira

2) All other flows derived from Cavado River at Paradela.

TABLE C-27

ALVA RIVER AT PONTE DE JUGAIS

AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 67 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	1.6	1.0	7.3	5.6	6.5	2.2	0.4	0.1	0.2	0.8	2.1	9.6	3.1
1943	7.4*	0.2*	4.6*	2.8*	0.7*	0.0*	2.0*	0.2*	4.2*	5.4*	2.2*	4.1*	2.8
1944	0.3*	0.1*	2.2*	3.4*	2.2*	2.2*	1.2*	1.4*	0.7*	1.3*	3.2*	3.8*	1.8
1945	1.8*	0.3*	0.5*	1.3*	1.6*	1.0*	0.3*	0.8*	0.2*	2.0*	5.2*	8.8*	2.0
1946	3.1	2.6	4.7	3.1	5.2	3.5	0.5	0.2	0.4	1.4	3.4	5.0	2.8
1947	4.3	16.4	15.8	6.6	2.2	0.4	0.2	0.1	0.1	0.4	0.5	3.5	4.2
1948	15.7	3.4	1.9	1.6	2.6	1.2	0.2	0.4	0.1	0.1	1.8	6.4	3.0
1949	3.0	1.3	1.1	0.8	0.4	0.3	0.1	0.1	0.6	1.4	3.6	2.9	1.3
1950	1.7	11.0	3.5	1.2	3.3	1.9	0.5	0.1	0.2	0.2	4.7	3.5	2.6

Average for the period: 2.6

Notes:

1) *Flows from "ESTUDO DA CONJUGACAO ENTRE AS PRODUCOES DE ENERGIA HIDRAULICA E TERMICA EM PORTUGAL" by Moniz Pereira

2) All other flows derived from Cavado at Paradela.

TABLE C-28

ALVA RIVER AT VILA COVA

AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 71 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	1.6	1.0	7.6	5.9	6.8	2.2	0.4	0.1	0.2	0.9	2.2	10.0	3.2
1943	7.6*	0.2*	4.8*	2.9*	0.7*	0.1*	2.1*	0.2*	4.4*	5.6*	2.2*	4.2*	2.9
1944	0.3*	0.2*	2.2*	3.5*	2.2*	2.3*	1.2*	1.5*	0.7*	1.4*	3.3*	3.9*	1.9
1945	1.8*	0.3*	0.5*	1.3*	1.6*	1.0*	0.3*	0.8*	0.2*	2.1*	5.2*	9.1*	2.0
1946	3.3	2.7	5.0	3.2	5.4	3.7	0.5	0.2	0.4	1.5	3.6	5.3	2.9
1947	4.5	17.2	16.6	6.9	2.4	0.4	0.2	0.1	0.2	0.4	0.5	3.6	4.4
1948	16.4	3.6	2.0	1.7	2.7	1.3	0.3	0.4	0.1	0.1	1.9	6.7	3.1
1949	3.2	1.4	1.2	0.8	0.5	0.4	0.1	0.1	0.6	1.5	3.7	3.1	1.4
1950	1.8	11.5	3.6	1.3	3.5	2.0	0.5	0.1	0.2	0.3	4.9	3.6	2.8

Average for the period: 2.7

Notes:

1) *Flows from "ESTUDO DA CONJUGACAO ENTRE AS PRODUCOES DE ENERGIA HIDRAULICA E TERMICA EM PORTUGAL" by Moniz Pereira

2) All other flows derived from Cavado River at Paradela.

TABLE C-29

AVE RIVER AT GUILHOFREI

AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 122 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	2.9	1.8	13.3	10.2	11.8	3.9	0.8	0.2	0.4	1.6	3.9	17.4	5.7
1943	27.4	9.0	4.0	2.4	1.2	0.2	0.3	0.0	0.5	9.9	3.8	4.1	5.2
1944	2.4	1.3	2.5	7.9	2.2	0.8	1.3	0.4	0.4	0.3	1.2	4.2	2.1
1945	4.5	3.9	1.4	1.3	1.8	0.8	0.3	0.2	0.2	0.6	3.6	15.1	2.8
1946	5.7	4.7	8.6	5.6	9.5	6.4	0.9	0.3	0.7	2.5	6.3	9.2	5.0
1947	7.9	29.9	28.8	12.0	4.1	0.7	0.3	0.2	0.3	0.8	0.9	6.3	7.7
1948	28.5	6.2	3.5	3.0	4.7	2.2	0.5	0.7	0.2	0.2	3.2	11.6	5.4
1949	5.5	2.4	2.0	1.4	0.8	0.6	0.2	0.1	1.1	2.6	6.5	5.3	2.4
1950	3.1	20.0	6.3	2.2	6.1	3.5	0.9	0.2	0.3	0.5	8.5	6.3	4.8

Average for the period: 4.6

Notes:

1) Flows derived from Cavado River at Paradela.

2) Flows of Ave River at Erinal and at Ponte da Esperanca assumed the same as those at Guilhofrei.

TABLE C-30

AVE RIVER AT SENHORA DO PORTO

AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 150 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	3.5	2.2	16.4	12.6	14.6	4.8	1.0	0.2	0.4	1.9	4.8	21.4	7.0
1943	33.6	11.1	4.9	2.9	1.4	0.3	0.4	0.1	0.6	12.2	4.7	5.1	6.4
1944	3.0	1.6	3.1	9.7	2.6	1.0	1.6	0.5	0.5	0.4	1.5	5.2	2.6
1945	5.5	4.8	1.8	1.6	2.2	1.0	0.3	0.3	0.3	0.7	4.4	18.6	3.4
1946	7.0	5.8	10.6	6.8	11.7	7.9	1.2	0.4	0.8	3.2	7.7	11.2	6.2
1947	9.7	36.8	35.5	14.8	5.0	0.9	0.3	0.3	0.3	1.0	1.2	7.8	9.5
1948	35.1	7.6	4.3	3.7	5.8	2.7	0.6	0.9	0.3	0.3	4.0	14.3	6.6
1949	6.8	3.0	2.5	1.8	1.0	0.8	0.3	0.1	1.4	3.3	8.0	6.6	3.0
1950	3.8	24.6	7.8	2.7	7.5	4.3	1.1	0.3	0.4	0.6	10.5	7.8	5.9

Average for the period: 5.6

Note: Flows derived from Cavado River at Paradela.

TABLE C-31

VAROSA RIVER AT CHOCALHO

AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 305 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	1.7	1.3	11.2	7.4	9.3	2.6	0.5	0.1	0.1	0.6	1.3	9.3	3.8
1943	16.2*	15.1*	4.1*	3.5*	1.8*	0.4*	0.3*	0.0*	0.3*	19.2*	4.3*	5.0*	5.8
1944	2.7*	1.9*	2.7*	5.2*	2.4*	0.6*	0.3*	0.0*	0.1*	0.2*	0.9*	4.2*	1.8
1945	4.1*	3.8*	1.8*	1.4*	1.1*	0.5*	0.1*	0.0*	0.0*	0.0*	1.5*	6.9*	1.8
1946	6.0	4.0	9.0	6.1	10.3	7.2	1.0	0.3	0.3	0.6	2.4	6.9	4.5
1947	6.9	31.6	26.8	12.0	4.1	1.4	0.3	0.1	0.1	0.2	0.2	2.1	7.2
1948	27.3	9.2	4.7	2.9	2.9	1.7	0.2	0.1	0.1	0.1	0.2	2.3	4.3
1949	3.9	1.8	1.2	1.2	8.4	0.4	0.1	0.1	0.1	0.3	0.7	1.8	1.7
1950	1.4	6.2	4.6	2.0	2.3	2.0	0.7	0.1	0.1	0.1	0.4	1.2	1.8

Average for the period: 3.6

Notes:

1) *From "ESTUDO DA CONJUGACAO ENTRE AS PRODUCOES DE ENERGIA HIDRAULICA E TERMICA EM PORTUGAL" by Moniz Pereira.

2) All other flows derived from Tavora River at Ponte Nova.

TABLE C-32

CABRUM RIVER AT FREIGIL

AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 66 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	0.4	0.3	2.4	1.6	2.0	0.6	0.1	0.0	0.0	0.1	0.3	2.0	0.8
1943	6.8	1.8	0.8	0.5	0.3	0.1	0.0	0.0	0.1	2.3	0.8	1.3	1.2
1944	0.7	0.3	0.6	0.9	0.3	0.1	0.1	0.0	0.0	0.0	0.1	1.0	0.3
1945	0.8	0.8	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.3	5.4	0.7
1946	1.3	0.9	1.9	1.3	2.2	1.6	0.2	0.1	0.1	0.1	0.5	1.5	1.0
1947	1.5	6.8	5.8	2.6	0.9	0.3	0.1	0.0	0.0	0.0	0.0	0.5	1.5
1948	5.9	2.0	1.0	0.6	0.6	0.4	1.0	0.0	0.0	0.0	0.0	0.5	1.0
1949	0.8	0.4	0.2	0.2	0.2	0.1	0.0	0.0	0.0	0.1	0.2	0.4	0.2
1950	0.3	1.3	1.0	0.4	0.5	0.4	0.1	0.0	0.0	0.0	0.1	0.3	0.4

Average for the period: 0.8

Note: Flows derived from Tavora River at Ponte Nova.

TABLE C-33

BORRALHA RIVER AT MESA DO GALO

AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 70 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	1.6	1.0	7.6	5.9	6.8	2.2	0.4	0.1	0.2	0.9	2.2	10.0	3.3
1943	15.7	5.2	2.3	1.4	0.7	0.1	0.2	0.0	0.3	5.7	2.2	2.4	3.0
1944	1.4	0.8	1.5	4.5	1.2	0.5	0.7	0.2	0.2	0.2	0.7	2.4	1.2
1945	2.6	2.2	0.8	0.8	1.0	0.5	0.2	0.1	0.1	0.3	2.1	8.7	1.6
1946	3.3	2.7	5.0	3.2	5.4	3.7	0.5	0.2	0.4	1.5	3.6	5.3	2.9
1947	4.5	17.2	16.6	6.9	2.4	0.4	0.2	0.1	0.2	0.4	0.5	3.6	4.4
1948	16.4	3.6	2.0	1.7	2.7	1.3	0.3	0.4	0.1	0.1	1.9	6.7	3.1
1949	3.2	1.4	1.2	0.8	0.5	0.4	0.1	0.1	0.6	1.5	3.7	3.1	1.4
1950	1.8	11.5	3.6	1.3	3.5	2.0	0.5	0.1	0.2	0.3	4.9	3.6	2.8

Average for the period: 2.6

Note: Flows derived from Cavado River at Paradela.

TABLE C-34

MINHO RIVER AT COVAS

AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 170 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	4.0	2.5	18.6	14.2	16.6	5.5	1.1	0.2	0.5	2.2	5.4	24.3	7.9
1943	38.2	12.6	5.5	3.3	1.6	3.2	0.5	0.1	0.6	13.8	5.3	5.8	7.5
1944	3.4	1.8	3.5	11.0	3.0	1.2	1.8	0.5	0.5	0.4	1.7	5.9	2.9
1945	6.2	5.4	2.0	1.8	2.5	1.2	0.4	0.3	0.3	0.8	5.0	21.1	3.9
1946	7.9	6.5	12.0	7.8	13.2	8.9	1.3	0.4	0.9	3.6	8.8	12.8	7.0
1947	11.0	41.8	40.2	16.8	5.7	1.0	0.4	0.3	0.4	1.1	1.3	8.8	10.7
1948	39.8	8.6	4.8	4.2	6.5	3.1	0.7	1.0	0.4	0.4	4.5	16.2	7.5
1949	7.7	3.4	2.8	2.0	1.2	0.8	0.3	0.1	1.5	3.7	9.1	7.5	3.3
1950	4.3	27.9	8.8	3.1	8.5	4.9	1.2	0.4	0.4	0.6	11.9	8.8	6.7

Average for the period: 6.4

Note: Flows derived from Cavado River at Paradela.

TABLE C-35

TEJO RIVER AT BELVER

AVERAGF MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 61,000 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	149.0	156.0	914.5	622.5	441.8	126.2	41.4	18.9	47.6	132.1	455.0	992.1	341.4
1943	1,290.9	880.4	1,089.0	595.5	380.9	88.4	41.4	23.6	89.4	132.0	240.0	221.8	422.5
1944	169.2	94.1	97.4	359.4	152.3	82.0	38.6	17.4	59.2	26.8	63.9	82.0	103.4
1945	77.3	88.6	49.4	40.6	14.7	10.8	4.3	2.0	1.1	6.3	9.4	964.6	105.9
1946	244.0	97.8	384.5	749.5	1,304.5	195.7	40.4	16.9	21.6	2.4	38.6	57.3	262.8
1947	92.7	2,024.0	3,100.0	845.0	291.6	140.8	82.1	55.8	85.2	159.1	115.9	177.8	597.5
1948	773.5	697.5	304.0	250.6	462.2	185.8	48.1	35.2	35.4	23.7*	22.6*	108.2*	245.7
1949	164.8*	70.7*	23.7*	30.4*	22.6*	14.0*	12.6*	1.5*	1.6*	20.6*	34.6*	99.9*	41.4
1950	82.4*	242.0*	136.0*	52.1*	73.2*	143.8*	28.8*	21.1*	24.9*	21.4*	24.0*	81.9*	77.6

Average for the period: 244.2

Notes:

1) Flows derived from Tejo River at Rodao.

2) *Flows for these months extrapolated from Douro River flows at Bitetos.

TABLE C-36

OCREZA RIVER AT PRACANA

AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 1,410 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	7.5	8.5	113.0	33.5	18.4	5.1	1.8	0.8	3.6	14.7	49.3	67.8	27.0
1943	132.7	25.2	47.0	18.8	7.3	2.9	1.8	0.6	3.7	7.4	8.4	10.4	22.2
1944	4.4	2.6	4.7	20.3	4.3	2.0	1.2	0.5	1.2	1.4	10.3	11.4	5.4
1945	6.6	4.6	3.0	4.5	3.6	2.6	1.2	0.0	0.0	13.1	11.4	80.1	10.9
1946	24.2	13.1	29.7	20.0	67.0	13.4	2.0	0.8	1.5	2.2	3.7	5.2	15.2
1947	18.3	132.4	98.1	35.7	10.1	3.1	0.6	0.1	1.7	10.0	3.7	17.5	27.6
1948	80.7	33.0	21.6	9.4	15.7	7.2	1.3	0.8	1.0	1.4	1.8	18.4	16.0
1949	19.9	6.6	4.1	3.9	2.6	2.3	1.3	0.0	15.3	7.9	10.6	81.4	13.0
1950	23.7	34.2	14.8	8.0	31.4	18.9	5.5	0.9	1.6	0.5*	2.0*	5.7*	12.3

Average for the period: 16.6

Note: *Flows derived from Tavora River at Ponte Nova.

See Table C-12, page C-23, for actual record by water-years.

TABLE C-37

NIZA RIVER AT POVOA

AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 155 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	0.4	0.3	3.7	2.5	2.4	0.7	0.1	0.0	0.1	0.2	0.5	3.1	1.2
1943	7.8	3.7	1.6	0.9	0.3	0.1	0.0	0.0	0.1	1.3	0.6	0.9	1.4
1944	0.6	0.4	0.4	0.6	0.3	0.1	0.0	0.0	0.0	0.0	0.1	0.2	0.2
1945	0.3	0.3	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.2	4.5	0.5
1946	0.8	0.9	1.9	2.5	4.4	1.2	0.1	0.0	0.1	0.1	0.3	0.8	1.1
1947	1.3	9.3	9.7	3.9	1.0	0.2	0.0	0.0	0.1	0.2	0.2	0.8	2.2
1948	8.2	3.3	1.4	1.2	1.2	0.5	0.1	0.1	0.0	0.0	0.1	1.0	1.4
1949	1.3	0.4	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.1	0.2	0.5	0.3
1950	0.4	1.8	1.3	0.6	0.6	0.6	0.2	0.0	0.0	0.0	0.1	0.3	0.5

Average for the period: 1.0

Note: Flows derived from Sabor River at Laranjeiras.

TABLE C-38

NIZA RIVER AT POIO BRUCEIRA

AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 158 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	0.4	0.3	3.8	2.6	2.5	0.7	0.1	0.0	0.1	0.3	0.5	3.1	1.2
1943	8.0	3.7	1.6	1.0	0.3	0.1	0.0	0.0	0.1	1.3	0.7	1.0	1.5
1944	0.6	0.4	0.4	0.6	0.3	0.1	0.0	0.0	0.0	0.0	0.1	0.2	0.2
1945	0.3	0.3	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.2	4.5	0.5
1946	0.8	0.9	2.0	2.6	4.5	1.3	0.2	0.0	0.1	0.1	0.3	0.8	1.1
1947	1.3	9.5	9.8	4.0	1.0	0.2	0.0	0.0	0.1	0.2	0.2	0.8	2.3
1948	8.4	3.4	1.5	1.2	1.2	0.5	0.1	0.1	0.0	0.0	0.1	1.0	1.5
1949	1.3	0.4	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.1	0.2	0.5	0.3
1950	0.4	1.9	1.4	0.6	0.7	0.6	0.2	0.0	0.0	0.0	0.1	0.4	0.5

Average for the period: 1.0

Note: Flows derived from Sabor River at Laranjeiras.

TABLE C-39

NIZA RIVER AT VELADA

AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 209 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	0.5	0.4	5.0	3.4	3.3	0.9	0.2	0.0	0.1	0.3	0.7	4.2	1.6
1943	10.5	4.9	2.1	1.3	0.4	0.1	0.0	0.0	0.2	1.7	0.9	1.3	2.0
1944	0.8	0.5	0.6	0.8	0.3	0.1	0.0	0.0	0.0	0.0	0.1	0.3	0.3
1945	0.4	0.4	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.3	6.0	0.6
1946	1.0	1.2	2.6	3.4	5.9	1.7	0.2	0.0	0.1	0.2	0.4	1.1	1.5
1947	1.7	12.6	13.0	5.2	1.3	0.3	0.1	0.0	0.1	0.3	0.2	1.0	3.0
1948	11.1	4.5	1.9	1.6	1.6	0.7	0.1	0.1	0.0	0.0	0.2	1.3	1.9
1949	1.8	0.5	0.3	0.2	0.1	0.1	0.1	0.0	0.1	0.1	0.3	0.7	0.4
1950	0.6	2.4	1.8	0.8	0.9	0.8	0.3	0.0	0.0	0.0	0.2	0.5	0.7

Average for the period: 1.3

Note: Flows derived from Sabor River at Laranjeiras.

TABLE C-40

NIZA RIVER AT FOZ

AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 272 Km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	0.6	0.5	6.6	4.4	4.3	1.1	0.2	0.0	0.1	0.4	0.9	5.4	2.0
1943	13.7	6.4	2.8	1.7	0.5	0.1	0.1	0.0	0.2	2.3	1.1	1.6	2.5
1944	1.0	0.7	0.7	1.0	0.4	0.1	0.1	0.0	0.1	0.1	0.1	0.4	0.4
1945	0.5	0.5	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.4	7.8	0.8
1946	1.3	1.5	3.4	4.5	7.7	2.2	0.3	0.1	0.1	0.2	0.5	1.4	1.9
1947	2.2	16.4	16.9	6.8	1.7	0.4	0.1	0.0	0.1	0.3	0.3	1.4	3.9
1948	14.5	5.9	2.5	2.1	2.1	0.9	0.1	0.1	0.0	0.1	0.2	1.7	2.5
1949	2.3	0.7	0.4	0.3	0.1	0.1	0.1	0.0	0.1	0.1	0.4	0.9	0.5
1950	0.7	3.2	2.4	1.0	1.1	1.0	0.3	0.0	0.0	0.1	0.2	0.6	0.9

Average for the period: 1.7

Note: Flows derived from Sabor River at Laranjeiras.

TABLE C-41

ALFORFA RIVER AT COVAO DA NAVE

AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 1 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	0.02	0.02	0.11	0.08	0.10	0.03	0.01	0.00	0.00	0.01	0.03	0.14	0.05
1943	0.22	0.07	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.08	0.03	0.03	0.04
1944	0.02	0.01	0.02	0.06	0.02	0.01	0.01	0.00	0.00	0.00	0.01	0.04	0.02
1945	0.04	0.03	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.03	0.12	0.02
1946	0.05	0.04	0.07	0.05	0.08	0.05	0.01	0.00	0.01	0.02	0.05	0.08	0.04
1947	0.06	0.25	0.24	0.10	0.03	0.01	0.00	0.00	0.00	0.01	0.01	0.05	0.06
1948	0.23	0.05	0.03	0.02	0.04	0.02	0.00	0.01	0.00	0.00	0.03	0.10	0.04
1949	0.04	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.01	0.02	0.05	0.04	0.02
1950	0.02	0.16	0.05	0.02	0.05	0.03	0.01	0.00	0.00	0.00	0.07	0.05	0.04

Average for the period: 0.04

Note: Flows derived from records of Cavado River at Paradela.

TABLE C-42

ALFORFA RIVER AT PEDRA DA FIGUEIRA

AVERAGE MONTHLY FLOW IN m^3/s
(DRAINAGE AREA = 5 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	0.1	0.1	0.6	0.4	0.5	0.2	0.0	0.0	0.0	0.1	0.2	0.7	0.2
1943	1.1	0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.4	0.2	0.2	0.2
1944	0.1	0.1	0.1	0.3	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.2	0.1
1945	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.6	0.1
1946	0.2	0.2	0.4	0.2	0.4	0.3	0.0	0.0	0.0	0.1	0.3	0.4	0.2
1947	0.3	1.2	1.2	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3
1948	1.2	0.2	0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.1	0.5	0.2
1949	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.2	0.1
1950	0.1	0.8	0.3	0.1	0.2	0.2	0.0	0.0	0.0	0.0	0.4	0.3	0.2
											Average for the period:		0.2

Note: Flows derived from records of Cavado River at Paradela.

TABLE C-43

ALFORFA RIVER AT ALFORFA

AVERAGE MONTHLY FLOW IN m^3/s
(DRAINAGE AREA = 9 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	0.2	0.1	1.0	0.8	0.9	0.3	0.1	0.0	0.0	0.1	0.3	1.3	0.4
1943	2.0	0.7	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.7	0.3	0.3	0.4
1944	0.2	0.1	0.2	0.6	0.2	0.1	0.1	0.0	0.0	0.0	0.1	0.3	0.2
1945	0.3	0.3	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.3	1.1	0.2
1946	0.4	0.3	0.6	0.4	0.7	0.5	0.1	0.0	0.0	0.2	0.5	0.7	0.4
1947	0.6	2.2	2.1	0.9	0.3	0.1	0.0	0.0	0.0	0.1	0.1	0.5	0.6
1948	2.1	0.5	0.3	0.2	0.3	0.2	0.0	0.1	0.0	0.0	0.2	0.9	0.4
1949	0.4	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.1	0.2	0.5	0.4	0.2
1950	0.2	1.5	0.5	0.2	0.5	0.3	0.1	0.0	0.0	0.0	0.6	0.5	0.4
											Average for the period:		0.4

Note: Flows derived from records of Cavado River at Paradela.

TABLE C-44

ALFORFA RIVER AT ESTRELA

OBSER AVERAGE MONTHLY FLOW IN m^3/s .M.S.

(DRAINAGE AREA = 12 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	0.3	0.2	1.3	1.0	1.2	0.4	0.1	0.0	0.0	0.2	0.4	1.7	0.6
1943	2.7	0.9	0.4	0.2	0.1	0.0	0.0	0.0	0.0	1.0	0.4	0.4	0.5
1944	0.2	0.1	0.2	0.8	0.2	0.1	0.1	0.0	0.0	0.0	0.1	0.4	0.2
1945	0.4	0.4	0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.1	0.4	1.5	0.3
1946	0.6	0.5	0.8	0.5	0.9	0.6	0.1	0.1	0.1	0.3	0.6	0.9	0.5
1947	0.8	3.0	2.8	1.2	0.4	0.1	0.0	0.0	0.0	0.1	0.1	0.6	0.8
1948	2.8	0.6	0.3	0.3	0.5	0.2	0.0	0.1	0.0	0.0	0.3	1.1	0.5
1949	0.5	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.1	0.3	0.6	0.5	0.2
1950	0.3	2.0	0.6	0.2	0.6	0.3	0.1	0.0	0.0	0.0	0.8	0.6	0.5
												Average for the period:	0.5

Note: Flows derived from records of Cavado River at Paradela.

TABLE C-45

SEDA RIVER AT MARANHAO

AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 2,282 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	5.5*	4.6*	38.5*	16.4*	5.5*	0.6*	0.1*	0.0*	0.0*	0.4*	4.2*	29.2*	8.8
1943	40.2*	48.2*	39.8*	8.8*	5.0*	0.4*	0.1*	0.0*	0.4*	0.4*	0.6*	2.4*	12.2
1944	1.0*	0.5*	0.7*	1.2*	0.2*	0.3*	0.0*	0.0*	0.0*	0.0	0.1	0.1	0.3
1945	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	3.0
1946	1.6	0.2	4.2	26.3	48.8	1.0	0.0	0.0	0.0	0.0	0.0	0.1	6.8
1947	0.2	75.9	116.7	31.7	2.3	0.5	0.1	0.1	0.1	0.7	0.3	0.8	19.1
1948	17.4	14.0	2.5	1.7	6.2	0.9	0.0	0.0	0.0	0.0**	0.0**	0.3**	3.6
1949	.7**	0.1**	0.0**	0.0**	1.4**	0.0**	0.0**	0.0**	0.0**	0.0**	0.0**	0.2**	0.2
1950	0.1**	1.6**	0.5**	0.0**	0.1**	0.5**	0.0**	0.0**	0.0**	0.0**	0.0**	0.1**	0.2
												Average for the period:	6.0

Notes:

1) *From "JUNTA AUTONOMA DAS OBRAS DE HIDRAULICA AGRICOLA - RELATORIO DE 1941/44" pg. (between) 248-249.
2) Other flows derived from Tejo River at Vila Velha de Rodao, from "Anuario das Servicas Hidraulicos" Vol. 2 (1944-45 pg. 13 & 1946-47 p. 9)
3)**Vila Valha de Rodao flows for these months extrapolated from Douro River flows at Bitetos.

TABLE C-46

PONSUL RIVER AT CABECO MONTEIRO

AVERAGE MONTHLY FLOW IN m^3/s
(DRAINAGE AREA = 358 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	1.2*	0.8*	16.4*	5.2*	2.8*	0.3*	0.0*	0.0*	0.0*	1.2*	6.8*	16.2*	4.2
1943	16.3*	4.6*	12.6*	3.7*	0.8*	0.1*	0.0*	0.0*	0.2*	3.0	1.5	2.2	3.5
1944	1.3	0.9	1.0	1.4	0.6	0.1	0.1	0.1	0.1	0.1	0.2	0.6	0.5
1945	0.6	0.7	0.3	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.5	10.3	1.1
1946	1.8	2.0	4.4	5.9	10.1	2.9	0.3	0.1	0.1	0.3	0.7	1.8	2.5
1947	2.9	21.6	22.3	9.0	2.2	0.5	0.1	0.0	0.1	0.5	0.4	1.8	5.1
1948	19.0	7.7	3.3	2.8	2.8	1.2	0.2	0.1	0.0	0.1	0.3	2.2	3.3
1949	3.0	0.9	0.5	0.4	0.2	0.2	0.1	0.0	0.1	0.2	0.5	1.2	0.6
1950	0.9	4.2	3.1	1.4	1.5	1.3	0.5	0.1	0.1	0.1	0.3	0.8	1.2

Average for the period: 2.4

Notes:

1) *Flows from "JUNTA AUTONOMA DAS OBRAS DE HIDRAULICA AGRICOLA, RELATORIO DE 1941/44", pp. 188-189.

2) Other flows derived from Sabor River at Laranjeiras.

TABLE C-47

SANTA CATARINA RIVER AT PEGO DO ALTAR

AVERAGE MONTHLY FLOW IN m^3/s
(DRAINAGE AREA = 746 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	1.7	1.5	18.0	12.1	11.7	3.1	0.5	0.1	0.3	1.2	2.5	14.8	5.6
1943	37.6	17.6	7.6	4.5	1.5	0.3	0.2	0.1	0.6	6.2	3.1	4.5	7.0
1944	2.8	1.9	2.0	2.8	1.2	0.3	0.2	0.1	0.2	0.2	0.4	1.2	1.1
1945	1.3	1.5	0.6	0.4	0.3	0.3	0.1	0.0	0.0	0.1	1.1	21.4	2.3
1946	3.7	4.2	9.2	12.2	21.1	6.0	0.7	0.2	0.3	0.6	1.4	3.8	5.3
1947	6.1	45.0	46.5	18.7	4.6	1.1	0.2	0.1	0.3	0.9	0.8	3.7	10.7
1948	39.6	16.1	6.9	5.8	5.8	2.5	0.3	0.3	0.1	0.2	0.6	4.7	6.9
1949	6.2	1.8	1.1	0.8	0.4	0.3	0.3	0.0	0.2	0.3	1.0	2.5	1.2
1950	2.0	8.7	6.5	2.8	3.1	2.7	0.9	0.1	0.1	0.1	0.6	1.7	2.4

Average for the period: 4.7

Note: Flows derived from Sabor River at Laranjeiras.

TABLE C-48

XARRAMA RIVER AT VALE DO GAIO

AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 509 km2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	1.2	1.0	12.3	8.3	8.0	2.1	0.4	0.1	0.2	0.8	1.7	10.1	3.8
1943	25.7	12.0	5.2	3.1	1.0	0.2	0.1	0.0	0.4	4.3	2.1	3.1	4.8
1944	1.9	1.3	1.4	1.9	0.8	0.2	0.1	0.1	0.1	0.1	0.3	0.8	0.8
1945	0.9	1.0	0.4	0.3	0.2	0.2	0.1	0.0	0.0	0.1	0.8	14.6	1.6
1946	2.5	2.9	6.3	8.4	14.4	4.1	0.5	0.1	0.2	0.4	0.9	2.6	3.6
1947	4.2	30.6	31.7	12.8	3.1	0.8	0.2	0.1	0.2	0.6	0.5	2.5	7.3
1948	27.1	11.0	4.7	4.0	3.9	1.7	0.2	0.2	0.1	0.1	0.4	3.2	4.7
1949	4.3	1.2	0.7	0.5	0.3	0.2	0.2	0.0	0.1	0.2	0.7	1.7	0.8
1950	1.3	6.0	4.4	1.9	2.1	1.8	0.6	0.1	0.1	0.1	0.4	1.1	1.7

Average for the period: 3.2

Note: Flows derived from Sabor River at Laranjeiras.

TABLE C-49

CAMPILHAS RIVER AT PEGO LONGO

AVERAGE MONTHLY FLOW IN m^3/s

(DRAINAGE AREA = 109 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	0.3	0.2	2.6	1.8	1.7	0.5	0.1	0.0	0.1	0.2	0.4	2.2	0.8
1943	5.5	2.6	1.1	0.7	0.2	0.1	0.0	0.0	0.1	0.9	0.5	0.7	1.0
1944	0.4	0.3	0.3	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2
1945	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.2	3.1	0.3
1946	0.5	0.6	1.4	1.8	3.1	0.9	0.1	0.0	0.0	0.1	0.2	0.6	0.8
1947	0.9	6.6	6.8	2.7	0.7	0.2	0.0	0.0	0.1	0.1	0.1	0.5	1.6
1948	5.8	2.4	1.0	0.8	0.8	0.4	0.1	0.0	0.0	0.0	0.1	0.7	1.0
1949	0.9	0.3	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.2	0.4	0.2
1950	0.3	1.3	1.0	0.4	0.5	0.4	0.1	0.0	0.0	0.0	0.1	0.2	0.4

Average for the period: 0.7

Note: Flows derived from Sabor River at Laranjeiras.

TABLE C-50

LIMA RIVER AT LINDOSO

OBSERVED AVERAGE MONTHLY FLOW IN m^3/s
(DRAINAGE AREA = 1,514 km^2)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE ANNUAL FLOW
1942	35.1	18.9	121.2	64.2	87.7	35.4	7.2	2.9	4.6	19.7	25.8	89.4	42.7
1943	200.7	87.6	31.1	15.8	8.8	3.0	2.2	0.8	6.0	58.7	26.1	29.7	39.2
1944	16.1	11.6	18.5	66.6	12.4	5.6	7.1	2.7	3.4	5.2	14.5	58.2	18.5
1945	49.6	16.1	10.7	11.1	13.7	7.2	1.6	1.6	2.0	14.8	40.3	134.7	25.3
1946	50.2	35.5	63.0	44.4	77.3	48.9	6.7	2.8	6.6	8.8	48.6	78.6	39.3
1947	68.3	259.6	230.6	113.1	44.3	11.9	2.9	1.4	2.8	3.3	10.3	77.2	68.8
1948	194.1	63.5	27.1	19.6	34.8	15.4	2.9	6.4	5.8	7.7	12.5	58.8	37.4
1949	47.3	16.1	13.4	9.9	7.9	6.8	6.1	4.5	6.5	14.0	53.1	29.5	17.9
1950	21.3	121.4	59.9	19.8	43.4	28.5	10.1	9.6	11.1	10.8	65.8	56.1	38.2

Average for the period: 36.4

TABLE C-52

ASSUMED MONTHLY EVAPORATION FROM RESERVOIR

IN METERS OF DEPTH

MONTH		DEPTH IN METERS
January	–	0.07
February	–	0.09
March	–	0.12
April	–	0.15
May	–	0.15
June	–	0.15
July	–	0.15
August	–	0.18
September	–	0.15
October	–	0.12
November	–	0.09
December	–	0.08
Total Annual Evaporation in Meters of Depth	–	1.50

APPENDIX D

POWER COMPUTATIONS

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POWER COMPUTATIONS

1. Routing of Flows Through Existing Plants

A. Basic procedure - Using the flows determined as described above it was possible to assume an operation of the hydroelectric plants, both existing and proposed, which would develop the greatest amount of dependable energy and best meet existing or anticipated demand. As the problem involved fitting the proposed Douro plants into the national system, many plants had to be investigated and their most advantageous operation studied, which required a long time and a large volume of computations.

In routing the flow through existing plants, the various hydroelectric systems presented problems of varying complexity. The largest share of the work was spent in developing the output of the more important systems and plants. The basic considerations given below apply generally. The upper limit of the output, obviously, is the installed capacity of the plant. In the case of comparatively low-head plants, corrections were made for reduction in plant capacity due to decreased head during periods of high tailwater resulting from high flows. These corrections were found later to be of very little practical importance in the overall system operation. In the case of the reservoir plants, loss in plant capacity had to be allowed for where the drawdown decreased the head to the point where it was insufficient to force enough water through the turbines to develop their rated capacity. No loss in output would be involved here, but there would be a reduction in peaking capacity which had to be checked against system demand as shown by the monthly load duration curves. Because of the large existing installed capacity in the Portuguese power system, it was found always possible to satisfy the peak demand, in spite of the loss in peaking capacity which would occur at some plants during drought periods.

In the discussion which follows, dependable capacities during the dry period are established for the various existing systems and individual plants. These are not to be interpreted as evaluations of these projects, or estimates of what they actually contribute to the Portuguese power system. They simply represent one of the steps in the analysis the object of which was to find the capability of the entire system during the critical dry period in order to determine the requirements of proposed future projects.

B. <u>Zezere River system</u>*-

(1) <u>General</u> - The Zezere River system is the most important group of hydroelectric plants in Portugal and because of its large storage and great installed capacity it has the most promising possibilities for acting as a kind of "hydraulic flywheel" to supplement new major run-of-river projects and stabilize the entire growing Portuguese power system for a long time to come, if it is operated with that end in view. Proceeding downstream, the system would consist of four reservoirs and their associated plants in series, the existing Santa Luzia project, the Cabril project now under construction, the Bouca project, scheduled for construction, and the existing Castelo do Bode project.

*See note on Bouca project at end of this Appendix.

(2) The Santa Luzia project, the smallest plant of the group, is located on the Pampilhosa River, a tributary of the Zezere River. The drainage area at the site initially was 50 km^2, but a diversion by means of a tunnel has added a drainage area of 40 km^2 from the neighboring Ceira River Basin, so that the total area tributary to the plant is 90 km^2. The Santa Luzia Reservoir has a useful storage of 50,000,000 m^3. The head is developed by means of a steel pipeline 4469 m long with a diameter varying from 1.80 to 1.45 m in diameter. The average net head after deducting the friction losses in the pipeline is 297 m. The minimum net head would be 257 m. The installed capacity of the plant is 17,000 kw. At maximum drawdown, the capacity would drop to 11,000 kw.

(3) The Cabril project when completed will be the second largest plant in Portugal. It is located on the main Zezere River. The drainage area at the site is 2340 km^2. The reservoir would have a useful storage capacity of 500,000,000 m^3. The head would be developed by a plant at the dam. The maximum head will be 115 m, the average head - 96 m, and the minimum head - 65 m. The installed capacity of the plant will be 107,000 kw. At maximum drawdown, the capacity will drop to 61,000 kw.

(4) The Castelo do Bode plant is the largest in Portugal. It is also located on the main Zezere River. The drainage area at the site is 3947 km^2. The reservoir has a useful storage capacity of 875,000,000 m^3. The head is developed by a plant at the dam. The maximum head is 95 m, the average - 83 m, and the minimum - 53 m. The installed capacity of the plant is 135,000 kw. At maximum dra-

drawdown, the capacity would fall to 73,000 kw.

(5) System capability - The total installed capacity of the Zezere River system will be therefore 259,000 kw, while the total peaking capacity at lowest drawdown will be 145,000 kw.

The effectiveness of a given amount of storage is determined by the total average head through which the stored waters would be used to generate energy. The average head below the Castelo do Bode Reservoir is the head at the plant, 83 m, and the stored energy in the full reservoir would amount to 225,000 kw-mos. (A kilowatt-month represents the energy in one kilowatt of power operating during one average month.) The average head below the Cabril reservoir would amount to the sum of the heads at Cabril and Castelo do Bode, or 179 m, and the stored energy in the full Cabril Reservoir would amount to 276,500 kw-mos. The average head below the Santa Luzia Reservoir would amount to the sum of the heads at the plants at Santa Luzia, Cabril and Castelo do Bode, or 476 m, and the stored energy in the full Santa Luzia Reservoir would amount to 73,700 kw-mos. The stored energy in the three reservoirs would total 575,200 kw-mos.

The first approximation to determining the output of the system was obtained by using a method of routing energy, rather than flows, which is analogous to the conventional method of routing for a single plant. The output of the natural flow at each plant is computed, month by month, and the monthly totals found for the system. The energy in storage is then added to or subtracted from the output from natural flows to determine the total regulated output of the system. Since this method is based on assuming an average net head for the power plants, another routing was then made, this time a conventional one, in which the heads were varied in accordance with the drawdowns. The system was regulated to maintain continuous output during the critical dry periods of 1944-1945 and 1949, and the dependable capacity was found to be 44,000 kw (at 100% load factor).

A rule curve indicating the total energy storage in the system was developed to control the operation to yield the minimum continuous output of 44,000 kw and at the same time draw down the reservoir to yield as much energy as possible. This rule curve indicates a safe drawdown of only 20 percent of the total. Beyond this point, drawing for additional energy would endanger the continued operation of the Portuguese power system during a severe drought, unless, of course, surplus steam capacity were available to make up the deficiency. As explained in Chapter VIII of the report, the method of regulation of the Zezere River system was further modified to supplement the output of the proposed new run-of-river plants. No rule curve was derived for the re-regulated operation.

C. Cavado River system* - (1) General - The Cavado River system comes next in importance to the Zezere River system, and because of its large storage (40 percent that of Zezere in terms of energy) and its great installed capacity, it can be of considerable assistance in stabilizing the operation of the Portuguese power system. Proceeding downstream, the system would consist of three reservoirs and four plants in series, the existing Venda Nova-Vila Nova project, the Salamonde project now under construction, the Canicada project now under

*See note on Paradela project at end of this Appendix.

construction and the existing Penide project. This last project has no storage of its own.

(2) The Venda Nova-Vila Nova project, the most important of the group, consists of a dam and reservoir on the Rabagao River, a tributary of the Cavado River, from which waterways 3.5 km long divert the water to a power plant located on the Cavado River. The drainage area at the dam site is 240 km^2. The useful reservoir storage is 92,000,000 m^3. The head is developed by a tunnel and gallery 2650 m long with a diameter varying from 3.2 to 2.4 meters and a penstock 817 m long with a diameter varying from 2.4 to 1.8 m. After deducting the friction losses in the waterways, the maximum net head is 403 m, the average net head - 378 m, and the minimum net head - 349 m. The installed capacity of the plant is 76,800 kw. At maximum drawdown, the capacity is reduced to 67,600 kw.

(3) The Salamonde project is located on the Cavado River. The drainage area at the site is 623 km^2. The useful reservoir storage will be 55,000,000 m^3. The plant will be located underground near the dam,and the head will be developed by means of a horseshoe tailrace tunnel about 1900 m long with an equivalent diameter of 6.2 m. After deducting the friction loss in the waterways, the maximum net head will be 122 m, the average net head will be 111 m, and the minimum net head will be 81 m. The installed capacity of the plant will be 38,000 kw. The capacity at maximum drawdown will be reduced to 25,800 kw.

(4) The Canacada project is located on the Cavado River. The drainage area at the site is 783 km^2. The useful reservoir storage will be 115,000,000 m^3. The plant will be located underground near the dam and the head will be developed by means of a tailrace tunnel with a length of 7600 m. After deducting the friction loss in the waterways, the maximum net head will be 96 m, the average net head will be 85 m, and the minimum net head will be 58.5 m. The installed capacity of the plant will be 45,000 kw. At maximum drawdown, the capacity will be reduced to 25,200 kw.

(5) The Penide plant is located on the Cavado River at a site where the drainage area is 1321 km^2. There is no storage at the plant. The head is 6 m and the installed capacity of the plant is 1840 kw.

(6) System capability - The total installed capacity of the system is therefore 161,640 kw, while its total peaking capacity at lowest drawdown would be 120,400 kw.

The average head below the Canicada Reservoir would be equal to the sum of the heads at Canicada and Penide, or 91 m, and the stored energy in the full Canicada reservoir would be 32,400 kilowatt-months. The average head below the Salamonde reservoir would be the sum of the heads at Salamonde, Canicada and Penide, or 202 m, and the stored energy in the full Salamonde reservoir would 34,400 kilowatt-months. The average head below the Venda Nova reservoir would be the sum of the heads at Venda Nova-Vila Nova, Salamonde, Canicada and Penide, or 580 meters and the stored energy in the full Venda Nova reservoir would be 165,500 kilowatt-months. The stored energy in the three reservoirs would total 232,300 kilowatt-months.

The routing for the Cavado system was done in the same manner as the one for the Zezere system, and the same comments apply as were made in the discussion of that system. The Cavado system was found to have a dependable capacity of 38,000 kw (at 100 percent load factor) during the critical drought period.

D. Lindoso project - The existing Lindoso project is located on the Lima River just a few km from the Spanish frontier, at a site where the drainage area is 1514 km^2. The project proper has negligible storage but regulation is furnished by two reservoirs in Spain, each having 80,000,000 m^3 of useful storage. One is the Conchas Reservoir on the Lima River, and the other is the newly constructed Salas Reservoir on the Salas River. The head at the Lindoso plant is developed by a canal and tunnel which divert the water from an up-stream site on the river to a pond with a capacity of 180,000 m^3 from which a tunnel and penstocks lead to the plant. The average net head, which can with little error be regarded as constant, is 184 m. The installed capacity at the plant is 60,000 kw, but its effective peaking capacity over any protracted period can be considered to be only 40,000 kw, owing to the limited hydraulic capacity of the water-ways. The natural flows at the Lindoso site were assumed to be regulated by operating the two Spanish reservoirs in such a manner as to yield the maximum dependable capacity at Lindoso during the critical drought period. This continuous capacity was found to be 19,400 kw (at 100 percent load factor).

E. Tejo River system - The Tejo River system consists of two existing plants, Pracana and Belver.

(1) The Pracana project is located on the Ocreza River, a tributary of the Tejo River, at a site where the drainage area is 1410 km^2. The reservoir has a useful storage capacity of 90,000,000 m^3. The head is developed by a plant at the dam, and varies between a maximum of 54.5 m and a minimum of 22 m, with an average of 42 m. The installed capacity at the plant is 12,800 kw. At maximum reservoir drawdown the plant capacity falls to 4,900 kw.

(2) The Belver project is located on the Tejo River, downstream from the mouth of the Ocreza River, at a site where the drainage area is 61,000 km^2. The reservoir storage is negligible. The head is developed by a plant at the dam. It is constant at 15 m, except at high flows of the Tejo River, when the head (and capacity of the plant) are reduced. Corrections were made for this condition. The installed capacity of the plant is 32,000 kw, but during major floods the capacity drops to 8300 kw or even less.

(3) System capability - The two plants were assumed to operate to obtain the maximum continuous capacity during the critical dry period. This continuous capacity was found to be 5,100 kw (at 100 percent load factor). The minimum peaking capacity of the system would occur during floods on the Tejo River, and was found to amount to about 21,100 kw, compared with a combined installed capacity of 44,800 kw.

F. Serra da Estrela system - (1) General - The Serra da Estrela system consists of four high-head plants in series. Proceeding downstream, they are the Sabugueiro I, Senhora do Desterro, Ponte de Jugais, and Vila Cova plants. None of these has any storage of its own. Most of the storage, 15,000,000 m^3, is located upstream from Sabugueiro in the Lagoa Comprida and Cavoes de Lariga reservoirs which have a total drainage area of 11 km^2. Then there is another 6,000,000 M^3 of storage in two reservoirs having a total drainage area of 10 km^2 on streams which enter between the Sabugueiro and the Senhora do Desterro plants.

(2) The Sabugueiro project is located on the Alva River, a tributary of the Mondego River, at a point where the drainage area is 12 km^2. The constant net head of 580 m at the plant is developed by a system of long canals and pipe lines. The capacity of the plant is 12,800 kw.

(3) The Senhora do Desterro plant is located on the Alva River at a site where the drainage area is 50 km^2. A low dam diverts the water into a canal and penstock to create a constant net head of 171 m. The capacity of the plant when it is reconstructed will be 8300 kw.

(4) The Ponte de Jugais plant is located on the Alva River at a site where the drainage area is 67 km^2. A canal leading from the tailrace of the Senhora do Desterro plant is joined by another canal leading from a diversion dam on the Canica River, and the combined flow is taken by a penstock which develops a constant net head of 225 m. The capacity of the plant is 12,000 kw.

(5) The Vila Cova plant is located on the Alva River at a site where the drainage area is 71 km^2. A low dam diverts the water into a canal and penstock to develop a constant net head of 205 m. The capacity of the plant is 11,000 kw.

(6) System capability - The installed capacity of the system is 44,100 kw, and all of it is always available for peaking purposes.

Flows were routed in such a manner as to obtain the maximum continuous output at the Senhora do Desterro plant during the critical dry period. Using this criterion, the dependable capacity for the system was found to be about 7200 kw (at 100% load factor).

G. Ave River system - (1) General - The Ave River system (also called the Ermal system) consists of four plants in series on the Ave River. Proceeding downstream, they are the Guilofrei plant, which is the only one having storage, the Ermal plant, the Ponte da Esperanca plant, and the Senhora do Porto plant.

(2) The Guilofrei project is located at a site with a drainage area of 122 km^2. The reservoir has a useful storage of 21,000,000 m^3. The head is developed by a plant at the dam. It varies between a maximum of 35.6 m and a minimum of 11 m. The average head is 26 m. The installed capacity of the plant is 1920 kw. The capacity becomes negligible at the lowest reservoir drawdown.

(3) The Ermal project has a tributary drainage area of 122 km^2, the same as Guilofrei. A canal from the tailrace of the Guilofrei plant and penstocks are used to develop the constant net head of 82 m. The installed capacity of the plant is 10,400 kw.

(4) The Ponte da Esperanca plant has a tributary drainage area of 124 km^2. A low dam on the Ave River diverts the water into a canal and penstock to develop a constant net head of 26 m. The installed capacity of the plant is 2720 kw.

(5) The Senhora do Porto plant has a tributary drainage area of 150 km^2. It is supplied from a diversion dam on the Ave River from which a canal and concrete penstock lead to the plant and develop a constant net head of 50 m. The installed capacity of the plant is 5240 kw.

(6) System capability - The installed capacity of the system is 20,280 kw. The peaking capacity would be reduced to 18,360 kw at maximum drawdown of the Guilofrei Reservoir.

Flows were routed in such a manner as to obtain the maximum continuous output at the Ermal plant during the critical dry period. Using this criterion, the dependable capacity of the system was found to be about 2700 kw (100% load factor).

H. Niza River system - (1) General - The Niza River system consists of four plants in series on the Niza River, a tributary of the Tejo River. Proceeding downstream, they are the Povoa, Poio-Bruceira, Velada and Foz plants.

(2) The Povoa project is located at a site where the drainage area is 155 km^2. The reservoir has a useful storage of 22,000,000 m^3. The average head of 27 m is developed by a plant at the dam. The installed capacity of the plant is 736 kw.

(3) The Poio-Bruceira project has a tributary area of 158 km^2. It consists of a dam and reservoir having a useful storage of 6,000,000 m^3, from which a canal, gallery and penstock lead to the plant, developing a constant net head of 62 m. The installed capacity of the plant is 1712 kw.

(4) The Velada plant has a tributary area of 209 km^2. A low dam diverts the water into a canal, gallery and penstock to develop a constant net head of 108 m. The installed capacity of the plant is 4480 kw.

(5) The Foz plant has a tributary area of 272 km^2. The constant net head of 13 m is developed by a plant at the dam. The installed capacity of the plant is 560 kw.

(6) System capability - The total installed capacity of the system is 7488 kw, almost all of which would always be available for peaking purposes.

Flows were routed to obtain the maximum continuous output at the Velada plant during the critical dry period. Using this criterion, the dependable capacity of the system was found to be about 1000 kw (at 100% load factor).

I. Alforfa River system - (1) General - The Alforfa River system consists of four plants in series on the Alforfa River, a tributary of the Zezere River, which is in turn a tributary of the Tejo River. Proceeding downstream, they are the Covao da Nave, Pedra Da Figueira, Alforfa and Estrela plants.

(2) The Covao da Nave project, which is the only one having storage, is located at a site where the drainage area is 1 km^2. The

reservoir has a useful storage capacity of 2,000,000 m^3. A penstock leading from the dam develops an average net head of 218 m. The installed capacity of the plant is 1000 kw.

(3) <u>The Pedra da Figueira plant</u> is located at a site where the drainage area is 5 km^2. A canal and penstock develop a constant net head of 316 m. The installed capacity of the plant is 1616 kw.

(4) The Alforfa plant is located at a site where the drainage area is 9 km^2. A canal and penstock develop a constant net head of 208 m. The installed capacity of the plant is 2600 kw.

(5) <u>The Estrela plant</u> is located at a site where the drainage area is 12 km^2. A canal and penstock develop a constant net head of 46 m. The installed capacity of the plant is 1100 kw.

(6) <u>System capability</u> - The installed capacity of the system is 6316 kw, and all of it is always available for peaking purposes.

Flows were routed to obtain the maximum continuous output at the Pedra da Figueira plant during the critical dry period. Using this criterion, the dependable capacity of the system was found to be about 450 kw (at 100% load factor).

J. <u>Run-of-river plants</u> - For the run-of-river plants the estimated flows were routed through the plants at constant head. Pertinent data on the run-of-river plants are given in Table D-1.

TABLE D-1

RUN-OF-RIVER PLANTS

Plant	River	Drainage Area (km^2)	Head (m)	Plant Capacity (kw)
Chocalho	Varosa	305	161	10,240
Freigil	Cabrum	66	120	2,500
Mesa do Galo	Borralha	70	68	1,470
Covas	Coura	170	22	648
Corvete	Bugio	Unknown	100	1,000

K. Irrigation projects - (1) General - The irrigation projects were assumed to be operated during the irrigation season as nearly as possible according to the schedules outlined in the Portuguese irrigation report dated 1945 "Hidraulica Agricola". The power output is available whenever water is released for irrigation purposes or when water is otherwise wasted over the spillway, in which event it is used to generate power up to the limit of the plant capacity.

(2) The Maranhao project, now under construction, is located on the Seda River at a site where the drainage area is 2282 km^2. The reservoir will have a useful capacity of 127,000,000 m^3. The maximum head will be 40 m. The average effective head will be 37 m and the installed capacity will be 5000 kw. The assumed schedule of irrigation releases in m^3/sec is as follows: April, 7.6; May, 9.0;

June, 9.0; July, 9.8; August, 9.6; September, 8.2; and during the other months of the year, zero.

(3) The Cabeco Monteiro project is located on the Ponsul River at a site where the drainage area is 358 km^2. The reservoir has a useful capacity of 77,000,000 m^3. The maximum head is 34 m. The average head will be 27 m. The installed capacity is 2080 kw. The assumed schedule of irrigation releases in m^3/sec is as follows: April, 3.3; May, 5.6; June, 8.0; July, 10.5; August, 10.5; September, 5.6; October 3.9; and during the other months of the year, zero.

(4) The Pego do Altar project is located on the Santa Catarina River at a site where the drainage area is 746 km^2. The reservoir has a useful capacity of 80,000,000 m^3. The average head is 34 meters. The installed capacity is 2000 kw. The assumed schedule of irrigation releases is 5.1 m^3/sec uniformly from April to September inclusive, and zero during the other months of the year.

(5) The Vale do Gaio project is located on the Xarrama River at a site where the drainage area is 509 km^2. The reservoir has a useful capacity of 60,000,000 m^3. The average head is 20 m and the installed capacity is 1030 kw. The assumed schedule of irrigation releases is 3.8 m^3/sec uniformly from April to September inclusive, and zero during the other months of the year.

(6) The Pego Longo project, now under construction, is located on the Campilhas River at a site where the drainage area is 109 km^2. The reservoir will have a useful capacity of 20,000,000 m^3. The average head will be 16 m and the installed capacity will be 440 kw. The assumed schedule of irrigation releases is 1.3 m^3/sec uniformly from April to September inclusive, and zero during the other months of the year.

2. Routing of Flows Through Proposed Projects

A. Projects on the tributaries of the Douro River - On the tributaries of the Douro River, four projects having storage for regulation were studied. They are described in Chapter XII. For each project, the flows were routed through the reservoir, and the storage used to produce a uniform power output during the critical dry periods. Allowance was made for evaporation as explained in paragraph 3., above. It is believed that leakage through the concrete structures and the rocky abutments would not constitute a serious problem if the foundations were properly grouted. For the Sabor Project a deduction was made in the power estimates for the irrigation diversions which would flow through a tunnel into the adjacent Vilarica Valley, and would not pass through the turbines. The effect of varying heads was included in all the pertinent computations.

The average annual energy production was determined by routing the flow through the assumed power installation. The method of obtaining the usable energy is described in Chapter X of this report. The results are shown in Table X-4.

B. Projects on the International Douro - On the International Douro, the three proposed projects Bemposta, Picote and Mirando will be operated with their reservoirs full, except for possible drawdown for daily or week-end pondage. This may become necessary if the upstream Spanish power plants at Castro and Villalcampo are operated as peaking plants, but it is understood that present Spanish plans call for their use chiefly as base load plants. In view of the high average flow of the river, it is estimated that the effective head would be very nearly equal to the maximum head. However, a drawdown of about 10 m is anticipated at the proposed Picote project which would provide 11,000,000 m^3 of pondage corresponding to about 80% of the plant's daily requirements. Under normal conditions of full pool elevation and rated output of 93,000 kw, the discharge of the plant will be 155 m^3/sec.

As shown on the hydrograph of average monthly flow on Plate 28, the river flow has marked seasonal variations, being abundant in the winter and spring, and decreasing to relatively small values in the summer and fall. Since operation of the Ricobayo Reservoir began on the Esla River, the summer flows on the International Douro have been more dependable. In the future, they will be still further improved, as this reservoir will supply flow for a number of Spanish-owned power plants, the Villalcampo and Castro plants upstream from the proposed projects, and downstream, the Saucelle plant and ultimately the proposed Aldeadavila plant. The operation of the Ricabayo Reservoir would of course tend to equalize the daily flows during the month as well as the monthly averages.

Variations in flow and in output are to be expected in the operation of the proposed plants on the International Douro. Their firm capacities do not depend on the minimum regulated flow but have been determined in accordance with the firming-up effect of the existing large Portuguese reservoir systems, as explained in Chapter VIII of this report. For this reason the proposed International Douro plants, as well as those on the Portuguese Douro, would be in a position to benefit from a general improvement in low-flow regulation, even though there might be occasions when the discharge became unusually small. No credit was taken for future increases in the low flow in assigning the installed capacities, but it is recommended that provisions be made during initial construction for the future expansion of the proposed plants to take care of this and other possibilities.

C. Projects on the Portuguese Douro - On the Portuguese Douro, the four proposed projects, Carrapatelo Regua, Valeira and Pocinho would be operated in a manner similar to the projects on the International Douro, that is, at full pool, except for daily or weekly pondage. All the projects except Pocinho would be equipped with navigation locks. In making the routings, an allowance of 2 m^3/sec was deducted from the flows at these projects, to allow for the water used in lockages and for leakage through the lock gates. As may be seen from Table C-16 and C-17, the average flows are appreciably higher on the Portuguese Douro than on the International Douro, while the dry season flows do not differ as much, because the regulation is accomplished in the Spanish portion of the basin. The effect of flood conditions on the power output of the proposed projects is discussed in Chapter XIII.

3. Spanish Projects in the Douro Basin

A number of existing and proposed Spanish projects will affect the future runoff and power production of the International and National Douro.

A. Irrigation projects - As may be seen from the map of the Douro Basin in Plate 3, there are a large number of small reservoirs in the basin, distributed around the rim. These are almost all irrigation reservoirs. According to the report on the Douro River by the Portuguese Hydraulic Services, dated 1948, the drainage area controlled by the existing irrigation reservoirs is about 3000 km^2, while future irrigation reservoirs will control an additional 8000 km^2 of area. The rainfall and runoff in the controlled areas are more than the average for the Spanish basin. The proposed reservoirs will have an aggregate storage capacity somewhat less than 2,000,000,000 m^3, and will control, to a varying degree, more than 12% of the drainage area contributing to the International Douro, and a still greater proportion of the runoff. They will operate to reduce the high winter flows and to increase somewhat the flow in the months when the tributaries are normally dry under natural conditions. The contribution to summer runoff will depend on the amount of "return flow" from agricultural areas, and on the reuse of the return flows in downstream areas. There may be some contribution to dependable capacity of the power plants downstream. In general, the net result will be to decrease the average annual flows owing to the consumptive use of water on the irrigated areas. The overall effect on the proposed International Douro and Portuguese Douro projects is not easy to forecast, but it will tend to be beneficial rather than adverse.

B. Power projects - The most important of the Spanish developments is the existing Ricobayo Reservoir on the Esla River, with a usable storage of more than 1,100,000,000 m^3 which began operation in 1934. It controls a drainage area of 17,000 km^2 and is operated for power regulation by the Spanish Iberduero Power Company. The plant at the site has a gross head of 85 m and an installed capacity of 148,000 kva.

On the Douro River in Spain upstream from the confluence with the Esla River, there is the small San Roman project with an installed capacity of 4950 kva. Downstream from the mouth of the Esla there is the Villalcampo project which has a useful storage of 53,000,000 m^3, a head of 37 m and an installed capacity of 96,000 kva. Further downstream, precisely at the head of the International Douro, is the almost-completed Castro project, with a useful storage of 20,000,000 m^3, a head of 40 m and an installed capacity of 84,000 kva. Still further downstream on the Spanish portion of the International Douro, which is below the portion allotted to Portugal, is the Saucelle project, now under construction, with a useful storage of 56,000,000 m^3, a head of 62 m and an installed capacity of 180,000 kva. A big project is proposed for construction at Aldeadavila, immediately upstream from Saucelle in the Spanish portion of the International Douro. It will have a useful storage of 82,000,000 m^3, a head of 139 m and an installed capacity of about 480,000 kva.

There are plans for three reservoirs on the Tera River above the Ricobayo Reservoir with a total storage capacity of 120,000,000 m^3. A reservoir on the Tormes River is under study, having a storage capacity of 600,000,000 m^3 with a plant developing a head of 300 m. A dam and diversion tunnel are being studied on the Huebra River, which would develop a head of 740 m. The proposed reservoir storage capacity is believed to be about 100,000,000 m^3. The effect of the two last-named reservoirs would of course not be felt at the proposed

Portuguese plants on the International Douro, but would improve the low flows on the Portuguese Douro.

The effect of the Ricobayo Reservoir in the past has been appreciable in increasing the low flows and modifying flood flows. It can be seen that the prospects in the future are for an increasing amelioration of the low flows on the Douro River, particularly within Portugal. However, it is difficult to estimate this effect numerically. The reason for this is that the Spanish plants on the Douro River form part of a power system which may have somewhat different operating requirements from the Portuguese system. No rule curve of operation has ever been devised for the Ricobayo Reservoir. The plan of operation is expected to be that which will give the greatest economic return to the Iberduero system, which includes steam plants and hydroelectric plants in the Pyrenees,and it will not necessarily parallel the requirements of Portugal. However, in order to obtain the optimum return on its investment, Iberduero will have to make greater efforts than in the past to sustain the dry season flows at its big Douro plants. When the Aldeadavila project comes into existence, there will exist below the Ricobayo Reservoir no less than four major Spanish plants with an installed capacity aggregating 840,000 kva, namely, the Villalcampo, Castro, Aldesdavila and Saucelle projects, having a cumulative head of 278 m. With the inclusion of the plant at the Ricobayo Reservoir, the total capacity would rise to 988,000 kva. and the total head to 363 m. As Spain is building additional steam and hydroelectric plants, it is anticipated that operation in future years will permit better regulations on the Douro

River. The Iberduero Company has supplied the following information on its proposed plan of operation: (1) The ultimate plan of operation of the Douro system will be to use the Ricobayo Reservoir to regulate summer flows and to close its gates all winter; (2) water will be withdrawn from storage beginning June 10 to 15 and the draft will continue until November 15 to 20; (3) a minimum flow of 120 m^3/sec can be maintained in the Douro, without the proposed reservoirs on the Tormes and other tributaries in all known dry periods except two, 1923 and 1929; (4) minimum runoff would drop to 80 m^3/sec in a period equivalent to 1923 and lower in a recurrence of 1949, but not as low as actually occurred in that year; and (5) any plant in the Portuguese Douro must have sufficient pondage to regulate flows over the week-end and Spanish holidays, as it is anticipated that the Sunday discharge leaving the Saucelle plant will be reduced to 60 m^3/sec.

NOTE

As indicated previously, after completion of the basic analyses, and too late for revisions, the Government of Portugal modified its Six-Year Plan to provide for the construction of the Bouca project in the Zezere system and the Paradela project in the Cavado system. A short description of these projects follows.

The Bouca project is scheduled for construction. It will be located on the Zezere River between the Castelo do Bode and Cabril plants and will develop the head remaining between them. The installed capacity of the plant will be about 65,000 kw operating at a constant head of 54 meters. The project will have no useful storage of its own but will benefit from the large volume of storage in the reservoirs upstream and will add appreciably to the dependable capacity of the Zezere system.

<u>The Paradela project</u> is scheduled for construction. The dam will be located on the Cavado River, upstream from the junction with the Rabagao River, at a point where the drainage area is 228 km^2. The gross head of 415 m will be developed by a tunnel and a pipeline 11.8 km long. Space has been provided in the Vila Nova powerhouse for its installed capacity of 40,000 kw. A usable reservoir storage capacity of 90,000,000 m^3, together with the additional installed capacity, will augment appreciably the firm output of the Cavado system, since the water released from its reservoir will pass through all the plants of the system, with the exception of the Venda Nova-Vila Nova development.

APPENDIX E

COST ESTIMATES

INDEX

TABLES

APPENDIX E

COST ESTIMATES

1. Scope

The estimates of cost of the Douro River Development consist of two parts: The capital cost, including direct construction costs and indirect costs of each project; the annual cost of administration, operation, maintenance, insurance and amortization of capital cost of each project.

2. Capital Costs

A. Direct cost - Detailed estimates of cost were prepared for each project on the basis of in-place cost of all materials. This cost includes: Purchase price, delivery to site, labor, apportionate part of construction plant, insurance, overhead, and profit of the constructor, and all other incidental costs incurred in the process of erection and installation. Some items, such as turbines and certain construction plant equipment, include an extra cost for freight to Porto from point of manufacture. Based upon a quantity survey from preliminary designs, the cost for each project was computed using unit prices equivalent to a constructor's bid price. These unit prices were based on current bidding practice in and near the Douro River Basin, in particular, on construction costs for Salamonde Dam and estimates for Vale de Madeira Dam. Where information about a particular item was lacking, its cost was obtained from U.S. manufacturers and converted into Portuguese currency at the legal rate of exchange.

Miscellaneous items include minor items, such as grout and water stops, drainage and weephole piping, elevators and utilities, etc.

For a more precise estimate of the Picote project, the cost of construction plant was obtained separately, and the unit price of material reduced by the value of plant apportioned to it. The Picote estimate includes the provisions for eventual expansion, as described in Paragraph 11 of Chapter XI.

Table E-1 lists the unit prices used in the estimates.

B. Indirect cost - For the Picote project, it was determined that 10% would cover contingencies, 6% the interest on capital investment during construction, 3.5% the cost of issuing bonds and of procurement of capital, and 9% the cost of studies, engineering and supervision. The total indirect cost of 28.5% was added to the capital cost to determine the total cost. For other plants, estimated in less detail, an additional 5% to 7% was allowed for contingencies and residences for operating personnel, making a total indirect cost of 33.5% to 35.5%.

C. Tables of capital costs - Tables E-2 through E-17 detail, by projects, preliminary estimates for the various hydroelectric, steam and navigation projects. The estimates for projects on the tributary plants, proposed several years in the future, are not given in as great detail as those for earlier plants.

3. Annual Costs

The annual cost of any hydroelectric project is based upon the assumption that all structures and other installations would have a useful life of 70 years, while equipment, such as generators, gates, hoists and cranes, would last 35 years. The percentage breakdown for total annual cost follows:

Item	Installation	Equipment
Interest	5.75%	5.75%
Taxes, insurance, misc.	0.40	0.40
Depreciation	1.43	2.86
Total Annual Cost	7.58%	9.01%

These percentages are applied to the total project costs, excluding transmission and switchyard costs, as detailed in Tables E-2 to E-12.

Maintenance costs are derived from the experience of hydroelectric projects in the United States, adjusted by information available from Portuguese plants. The useful life of the diversion works at Bemposta was assumed to be 70 years. The cost of maintaining the canals in the Vilar Tabuaco scheme is included in the maintenance item (see Table E-18).

The annual cost of transmission of power is based on the experience of the United States Federal Power Commission. The form used in Table E-18 includes the expense of operating the transmission system and the losses of power in transmission. The line loss factor is a function of the length of the transmission line.

The annual costs of the navigation projects are detailed in Chapter VII and of the Pejao Thermal Plant, in Chapter IX.

TABLE E-1

UNIT PRICES

Item		Unit	Unit Cost Picote *	Unit Cost Other Projects
			(Escudos)	(Escudos)
Land -	purchase	ha	10,000	10,000
	clearing	ha	-	5,000
Excavation -	earth	m^3	-	11
	rock, open cut	m^3	43	70
	dam and spillway	m^3	68	110
	tunnel, large chamber	m^3	-	145
	tunnel, large diameter	m^3	157	190
	tunnel, vent access shaft	m^3	-	210
	tunnel, small diameter	m^3	-	265
	tunnel, supports (add'l.)	m^3	-	11
	smoothing of platforms	m^2	-	20
	smoothing of berms and slopes	m^2	-	40
Dredging -	sand	m^3	-	5
	rock	m^3	-	330
Drilling		m^3	90	120
Masonry -	rock 20 to 2500 kg	m^3	-	90
	rock, 2500 to 7500 kg	m^3	-	100
	concrete block in superstructure	m^3	-	420
	concrete block, berm and slope	m^3	-	450
Concrete -	mass, for jetties	m^3	-	350
	mass 180 kg cement/m^3	m^3	291	380
	foundation 250 kg/m^3	m^3	-	420
	structural 250 kg/m^3	m^3	402	500
	beam and slab 300 kg/m^3	m^3	740	830
	tunnel lining 300 kg/m^3	m^3	455	550
	grouting (incl. equipment)	m^3	705	1,050
Steel -	reinforcing, mass	kg	4.5	4.5
	reinforcing, structural	kg	5	5
	structural	kg	10	10
	gates	kg	26	26
	hoists and operating equip.	kg	41.4	41.4
Timber -		m^3		1,000
Rock fill		m^3	50	50
Rock fill (crib)		m^3	-	40
Filter material		m^3	-	60
Riprap		m^3	-	240
Articulated mattress		m^2	-	195
Foundation treatment		m	-	2,200
Anchors, incl. holes, steel and grout		ea	-	200
Sheet steel piles (purchase)		kg	-	6
Steel piling (in place)		m^2	-	105
Wood piling		m	-	30

* Not including apportionate cost of construction plant.

TABLE E-2

DETAILED COST ESTIMATE OF THE PICOTE PROJECT

Item	Quantity	Unit	Unit Cost (Escudos)	Total Cost (Contos)
CONSTRUCTION PLANT				
Construction Buildings and Shops				2,400
Coarse and Fine Aggregate Plants				3,600
Cement Handling Equipment				1,800
Concrete Manufacturing Equipment				5,300
Concrete Transfer Train System				1,200
Cableway Plant				5,800
Stationary and Portable Compressors				3,200
Grout Pumps and Mixers				100
Pumps (Dewatering)				1,600
Trucks (Assorted)				2,900
Tractors and Graders				1,300
Shovels (4-Electric and Gas)				4,500
Cranes (3-with misc. hoists)				2,400
Automobiles (10)				700
Electrical Generating and Lighting (1500 kw total)				4,200
Utilities				900
Personnel Accommodations				1,800
Miscellaneous				5,300
SUB-TOTAL				49,000
DEDUCT FOR SALVAGE				15,000
SUB-TOTAL - CONSTRUCTION PLANT				34,000
PERMANENT HOUSING				5,000
RESERVOIR LAND				
Outright Purchase	240	ha	10,000	2,400
Easements				200
SUB-TOTAL - RESERVOIR LAND				2,600
RIVER DIVERSION				
Excavation - Tunnel	50,000	m3	157	7,850
Concrete - Mass	2,800	m3	291	700
- Structural	1,140	m3	402	450
Rock Fill	4,000	m3	50	200
Steel - Reinforcing - Dam	24,000	kg.	4.5	100
Dewatering and Pumping				500
Miscellaneous				1,100
SUB-TOTAL - RIVER DIVERSION				10,900
ACCESS ROADS				
From Picote Village to Dam	3	km	133,000	400
Vicinity of Dam (6m width-in rock)	5	km	1,260,000	6,300
SUB-TOTAL - ACCESS ROADS				6,700
DAM				
Excavation - Dam & Spillway	187,000	m3	68	12,720
Concrete - Mass	206,000	m3	291	59,950
- Structural	12,400	m3	402	4,980
- Beam and Slab	500	m3	740	370
Steel - Reinforcing - Mass	615,000	kg	4.5	2,760
- Structural	85,000	kg	10	850
Drilling	20,000	m	90	1,800
Grouting	900	m3	705	640
Spillway Tainter Gates	643,000	kg	26	16,720
Spillway Gate Hoists	200,000	kg	41.4	8,280
Spillway Gantry Crane			L.S.	5,000
Lighting System				700
Miscellaneous				1,730
SUB-TOTAL - DAM				116,500
INTAKE				
Excavation - Rock, Open Cut	26,000	m3	43	1,120
Concrete - Structural	10,200	m3	402	4,100
- Beam and Slab	1,400	m3	740	1,040
Steel - Reinforcing - Structural	620,000	kg	5	3,100
- Structural	265,000	kg	10	2,650
Intake Gates, Frames and Guides	200,000	kg	26	5,200
Intake Gate Hoists	42,000	kg	41.4	1,740
Intake Crane	18,000	kg	41.4	750
SUB-TOTAL - INTAKE				19,700
WATERWAYS				
Excavation - Rock, Open Cut	105,000	m3	43	4,510
- Tunnel	7,000	m3	157	1,100
Concrete - Mass	500	m3	291	150
- Tunnel Lining	1,300	m3	455	590
Steel - Reinforcing, Mass	5,000	kg	4.5	20
- Structural	1,063,000	kg	10	10,630
SUB-TOTAL - WATERWAYS				17,000
POWERHOUSE				
Excavation - Rock, Open Cut	143,000	m3	43	6,150
Concrete - Structural	22,300	m3	402	8,960
Steel - Reinforcing, Structural	860,000	kg	5	4,300
- Structural	160,000	kg	10	1,600
Drilling	7,000	m	90	630
Grouting	200	m3	705	140
Miscellaneous				2,420
SUB-TOTAL - POWERHOUSE				24,200
POWER PLANT EQUIPMENT				
Turbines and Governors (each 44,000 h.p. and 166.7 r.p.m.)	3	ea	10,000,000	30,000
Generators with Exciters and coolers (31,000 kw)	3	ea	18,000,000	54,000
Low Tension Electrical Equipment for Station				16,000
Auxiliary Station Equipment				3,000
Draft Tube Bulkhead Gates				500
Gantry Crane (250-ton)				5,000
Elevator				400
Utilities				1,700
Freight to Ports				3,000
Erection				10,000
Miscellaneous				3,100
SUB-TOTAL - POWER PLANT EQUIPMENT				126,700
SUB-TOTAL - DIRECT COST				363,300
Contingencies		10.0%		36,330
Interest during Construction		6.0%		21,780
Finance Charges		3.5%		12,700
Studies, Engineering, Supervision		9.0%		32,690
TOTAL COST (Excluding Switchyard and Transmission Line)				466,800
SWITCHYARD				
Transformers - 40,000 kva, 3 phase, 13.8/150 kv	3	ea	3,300,000	9,900
Switchgear				10,000
Structures and Improvements				1,600
SUB-TOTAL - DIRECT COST				21,500
Indirect Costs - 28.5%				6,100
TOTAL COST OF SWITCHYARD				27,600
TRANSMISSION SYSTEM (195.5 km of Double Circuit 150 kv)				
Towers, Including Painting and Grounds				36,675
Insulators				7,620
Hardware				3,165
Wires (Conductors and Grounds)				33,025
Miscellaneous				1,970
Labor				18,190
Engineering and Overhead				955
TOTAL COST OF TRANSMISSION SYSTEM				101,600
GRAND TOTAL - (Including Switchyard and Transmission Line)				596,000

TABLE E-3

COST ESTIMATE OF THE BEMPOSTA PROJECT

Item	Quantity	Unit	Unit Cost (Escudos)	Total Cost (Contos)
RESERVOIR LAND				
Outright Purchase	256	ha	10,000	2,560
Easements				240
SUBTOTAL - RESERVOIR LAND				2,800
RIVER DIVERSION				
Excavation - Tunnel	53,000	m^3	190	10,070
Concrete - Mass	2,800	m^3	380	1,060
- Structural	1,160	m^3	500	580
Rock Fill	4,000	m^3	50	200
Steel - Reinforcing, Dam	14,000	kg	4.5	60
- Reinforcing, Structural	34,000	kg	5	170
Dewatering & Pumping				980
Miscellaneous				880
SUBTOTAL - RIVER DIVERSION				14,000
ACCESS ROADS				2,000
DAM AND INTAKE				
Excavation - Dam & Spillway	91,000	m^3	110	10,010
Concrete - Mass	229,000	m^3	380	87,020
Steel - Reinforcing, Dam	695,000	m^3	4.5	3,120
Foundation	220	m	2,200	490
Gates	643,000	kg	26	16,720
Hoists	200,000	kg	41.4	8,280
Gantry Crane				5,000
Miscellaneous				3,260
SUBTOTAL - DAM AND INTAKE				133,900
POWERHOUSE				
Excavation - Rock, Open Cut	97,000	m^3	70	6,790
Concrete - Structural	19,300	m^3	500	9,650
Steel - Reinforcing, Structural	750,000	kg	5	3,750
Miscellaneous				5,210
SUBTOTAL - POWERHOUSE				25,400
POWER PLANT EQUIPMENT				
Turbines				28,000
Generators				49,000
Low Tension				13,000
Auxiliary				2,500
Crane				5,000
Freight				3,000
Erection				10,000
Miscellaneous				5,500
SUBTOTAL - POWER PLANT				116,000
TOTAL DIRECT COST				294,100
INDIRECT COST				98,900
TOTAL COST (Exclusive of Switchyard & Transmission System)				393,000
SWITCHYARD				18,000
TRANSMISSION SYSTEM				
Towers, Including Painting and Land				14,200
Insulators				3,500
Hardware				1,500
Wires, Conductors and Grounds				21,600
Miscellaneous				8,200
Labor				8,800
Engineering and Overhead				1,200
TOTAL COST OF TRANSMISSION SYSTEM				59,000
GRAND TOTAL				470,000

TABLE E-4

COST ESTIMATE OF THE MIRANDA PROJECT

Item	Quantity	Unit	Unit Cost (Escudos)	Total Cost (Contos)
RESERVOIR LAND				
Outright Purchase	214	ha	10,000	2,140
Easements				260
SUBTOTAL - RESERVOIR LAND				2,400
RIVER DIVERSION				
Excavation - Tunnel	43,000	m^3	190	8,170
Concrete - Mass	2,800	m^3	380	1,060
- Structural	1,160	m^3	500	580
Steel - Reinforcing, Dam	13,400	kg	4.5	60
- Reinforcing, Structural	34,000	kg	5	170
Rock Fill	4,000	m^3	50	200
Dewatering & Pumping				980
Miscellaneous				780
SUBTOTAL - RIVER DIVERSION				12,000
ACCESS ROADS				5,000
DAM AND INTAKE				
Excavation - Dam & Spillway	67,000	m^3	110	7,370
Concrete - Mass	167,000	m^3	380	63,760
Steel - Reinforcing, Dam	495,000	kg	4.5	2,230
Foundation	200	m	2,200	440
Gates	643,000	kg	26	16,720
Hoists	200,000	kg	41.4	8,280
Gantry Crane				5,000
Miscellaneous				2,500
SUBTOTAL - DAM AND INTAKE				106,300
POWERHOUSE				
Excavation - Rock, Open Cut	53,000	m^3	70	3,710
Concrete - Structural	18,400	m^3	500	9,200
Steel - Reinforcing, Structural	720,000	kg	5	3,600
Miscellaneous				3,690
SUBTOTAL - POWERHOUSE				20,200
POWER PLANT EQUIPMENT				
Turbines				26,000
Generators				47,000
Low Tension				12,000
Auxiliary				2,400
Crane				5,000
Freight				3,000
Erection				9,600
Miscellaneous				3,800
SUBTOTAL - POWER PLANT EQUIPMENT				108,800
TOTAL DIRECT COST				254,700
INDIRECT COST				85,300
TOTAL COST (Exclusive of Switchyard & Transmission)				340,000
SWITCHYARD (Including Indirect Costs)				17,000
TRANSMISSION SYSTEM				
Towers, Including Painting and Land				19,000
Insulators				4,700
Hardware				2,000
Wires, Conductors and Grounds				28,800
Miscellaneous				11,100
Labor				11,800
Engineering and Overhead				1,600
TOTAL COST OF TRANSMISSION SYSTEM				79,000
GRAND TOTAL				436,000

TABLE E-5

COST ESTIMATE OF THE CARRAPATELO PROJECT

Item	Quantity	Unit	Unit Cost (Escudos)	Total Cost (Contos)
RESERVOIR LAND				9,500
DIVERSION - Coffer Dam				6,000
ACCESS ROADS				500
DAM				
Excavation - Dam & Spillway	46,000	m^3	110	5,060
Concrete - Mass	143,000	m^3	380	54,340
- Structural	14,700	m^3	500	7,350
- Beam & Slab	3,000	m^3	830	2,490
Steel - Reinforcing, Dam	72,000	kg	4.5	320
- Reinforcing, Structural	620,000	kg	5	3,100
Foundation	234	m	2,200	520
Gates	1,345,000	kg	26	34,970
Hoists	277,000	kg	41.4	11,470
Gantry Crane				5,000
Miscellaneous				3,480
SUBTOTAL - DAM				128,100
POWERHOUSE				
Excavation - Dam & Spillway	139,000	m^3	110	15,290
Concrete - Foundation	105,000	m^3	420	44,100
- Beam & Slab	4,000	m^3	830	3,320
Steel - Reinforcing, Structural	1,580,000	kg	5	7,900
Miscellaneous				3,370
SUBTOTAL - POWERHOUSE				73,980
POWER PLANT EQUIPMENT				
Turbines				37,000
Generators				69,000
Low Tension				20,000
Auxiliary				4,000
Crane				5,000
Freight				3,000
Erection				10,000
Miscellaneous				5,000
SUBTOTAL - POWER PLANT EQUIPMENT				153,000
LOCK				
Excavation - Rock, Open Cut	186,000	m^3	70	13,020
- Tunnels	1,170	m^3	265	310
- Shaft	200	m^3	210	40
Concrete - Mass	17,800	m^3	420	7,480
- Structural	2,700	m^3	500	1,350
- Beam & Slab	300	m^3	830	250
Steel - Reinforcing, Structural	54,000	kg	5	270
- Structural	7,000	kg	10	70
Anchorage	1,100	ea	200	220
Gates	598,000	kg	26	15,550
Hoists	78,000	kg	41.4	3,230
Bridge				630
SUBTOTAL - LOCK				44,420
TOTAL DIRECT COST				413,500
Indirect Cost				138,500
TOTAL COST (Exclusive of Switchyard & Transmission)				552,000
SWITCHYARD (Including indirect Costs)				21,000
TRANSMISSION SYSTEM				
Towers, Including Painting & Land				2,900
Insulators				700
Hardware				300
Wires, Conductors and Grounds				4,400
Miscellaneous				1,700
Labor				1,800
Engineering and Overhead				200
TOTAL COST OF TRANSMISSION SYSTEM				12,000
GRAND TOTAL				585,000

TABLE E-6

COST ESTIMATE OF THE REGUA PROJECT

Item	Quantity	Unit	Unit Cost (Escudos)	Total Cost (Contos)
RESERVOIR				
Purchase	820	ha	10,000	8,200
Easement				400
SUBTOTAL - RESERVOIR				8,600
DIVERSION - Coffer Dam				6,000
ACCESS ROADS				500
DAM AND INTAKE				
Excavation - Dam & Spillway	64,000	m^3	110	7,040
Concrete - Mass	180,000	m^3	380	68,400
- Structural	13,900	m^3	500	6,950
- Beam & Slab	2,800	m^3	830	2,320
Steel - Reinforcing, Dam	90,000	kg	4.5	400
- Reinforcing, Structural	586,000	kg	5	2,930
Foundation	380	m	2,200	840
Gates	1,410,000	kg	26	36,660
Hoists	270,000	kg	41.4	11,180
Crane				5,000
Miscellaneous				5,780
SUBTOTAL - DAM AND INTAKE				147,500
POWERHOUSE				
Excavation - Dam & Spillway	44,000	m^3	110	4,840
Concrete - Foundation	73,400	m^3	420	30,830
- Beam & Slab	3,800	m^3	830	3,150
Steel - Reinforcing, Structural	1,450,000	kg	5	7,240
Miscellaneous				4,680
SUBTOTAL - POWERHOUSE				50,740
POWER PLANT EQUIPMENT				
Turbines				36,000
Generators				69,000
Low Tension				16,000
Auxiliary				4,000
Crane				5,000
Freight to Porto				3,000
Erection				10,000
Miscellaneous				6,000
SUBTOTAL - POWER PLANT EQUIPMENT				149,000
LOCK				
Excavation - Rock Open Cut	176,000	m^3	70	12,320
Concrete - Foundation	12,300	m^3	420	5,170
- Structural	1,700	m^3	500	850
- Beam and Slab	200	m^3	830	170
Steel - Reinforcing, Structural	40,000	kg	5	200
- Structural	11,000	kg	10	110
Anchors	800	ea	200	160
Gates	328,000	kg	26	8,530
Hoists	80,000	kg	41.4	3,310
Bridge				300
Miscellaneous				540
SUBTOTAL - LOCK				31,660
TOTAL DIRECT COST				394,000
INDIRECT COST				132,000
TOTAL COST (Exclusive of Switchyard & Transmission System)				526,000
SWITCHYARD (Including Indirect Cost)				17,000
TRANSMISSION SYSTEM				
Towers, Painting and Land				5,500
Insulators				1,400
Hardware				600
Wires, Conductors and Grounds				8,400
Miscellaneous				3,200
Labor				3,400
Engineering and Overhead				500
TOTAL COST OF TRANSMISSION SYSTEM				23,000
GRAND TOTAL				566,000

TABLE E-7

COST ESTIMATE OF THE VALEIRA PROJECT

Item	Quantity	Unit	Unit Cost (Escudos)	Total Cost (Contos)
RESERVOIR				
Purchase	772	ha	10,000	7,720
Easement				380
SUBTOTAL - RESERVOIR				8,100
DIVERSION				6,000
ACCESS ROADS				3,000
DAM AND INTAKE				
Excavation - Dam & Spillway	39,000	m^3	110	4,290
Concrete - Mass	121,500	m^3	380	46,170
- Structural	12,900	m^3	500	6,450
- Beam & Slab	2,600	m^3	830	2,320
Steel - Reinforcing, Dam	61,000	kg	4.5	270
- Reinforcing, Structural	540,000	kg	5	2,700
Foundation	270	m	2,200	590
Gates	1,335,000	kg	26	34,710
Hoists	270,000	kg	41.4	11,180
Crane				5,000
Miscellaneous				5,920
SUBTOTAL - DAM AND INTAKE				119,600
POWER HOUSE				
Excavation - Dam and Spillway	132,000	m^3	110	14,520
Concrete - Foundation	93,000	m^3	420	39,060
- Structural	3,500	m^3	830	2,910
Steel - Reinforcing, Structural	1,400,000	kg	5	7,000
Miscellaneous				3,550
SUBTOTAL - POWER HOUSE				67,040
POWER PLANT EQUIPMENT				
Turbines				35,000
Generators				65,000
Low Tension				14,000
Auxiliary				3,000
Crane				5,000
Freight				3,000
Erection				10,000
Miscellaneous				4,000
SUBTOTAL - POWER PLANT EQUIPMENT				139,000
LOCK				
Excavation - Rock, Open Cut	42,000	m^3	70	2,940
Concrete - Foundation	17,600	m^3	420	7,390
- Structural	3,600	m^3	500	1,800
- Beam & Slab	300	m^3	830	250
Steel - Reinforcing, Structural	50,000	kg	5	250
- Structural	13,000	kg	10	130
Anchors	1,100	ea	200	220
Gates	309,000	kg	26	8,030
Hoists	125,000	kg	41.4	5,180
Bridge				540
Miscellaneous				570
SUBTOTAL - LOCK				27,260
TOTAL DIRECT COST				370,000
INDIRECT COST				124,000
TOTAL COST (Exclusive of Switchyard & Transmission)				494,000
SWITCHYARD (Including Indirect Costs)				18,000
TRANSMISSION SYSTEM				
Towers, Painting and Land				7,900
Insulators				2,000
Hardware				800
Wires, Conductors and Grounds				12,000
Miscellaneous				4,600
Labor				5,000
Engineering and Overhead				700
TOTAL COST OF TRANSMISSION SYSTEM				33,000
GRAND TOTAL				545,000

TABLE E-8

COST ESTIMATE OF THE POCINHO PROJECT

Item	Quantity	Unit	Unit Cost (Escudos)	Total Cost (Contos)
RESERVOIR				
Purchase	740	ha	10,000	7,400
Easement				300
SUBTOTAL - RESERVOIR				7,700
DIVERSION				6,000
ACCESS ROADS				300
DAM AND INTAKE				
Excavation - Dam & Spillway	67,000	m^3	110	7,370
Concrete - Mass	131,800	m^3	380	50,080
- Structural	11,800	m^3	500	5,900
- Beam & Slab	2,400	m^3	830	1,990
Steel - Reinforcing, Dam	66,000	kg	4.5	300
- Reinforcing, Structural	498,000	kg	5	2,490
Foundation	500	m	2,200	1,100
Gates	1,207,000	kg	26	31,380
Hoists	233,000	kg	41.4	9,650
Crane				5,000
Miscellaneous				6,340
SUBTOTAL - DAM AND INTAKE				121,600
POWER HOUSE				
Excavation, Dam and Spillway	15,000	m^3	110	1,650
Concrete - Foundation	46,700	m^3	420	19,610
- Structural	2,600	m^3	830	2,320
Steel - Reinforcing, Structural	1,040,000	kg	5	5,200
Miscellaneous				3,220
SUBTOTAL - POWER HOUSE				32,000
POWER PLANT EQUIPMENT				
Turbines				31,000
Generators				66,000
Low Tension				25,000
Auxiliary				3,000
Crane				5,000
Freight				3,000
Erection				10,000
Miscellaneous				4,000
SUBTOTAL - POWER PLANT EQUIPMENT				147,000
TOTAL DIRECT COST				341,600
INDIRECT COST				105,400
TOTAL COST (Exclusive of Switchyard & Transmission)				420,000
SWITCHYARD (Including Indirect Costs)				14,000
TRANSMISSION SYSTEM				
Towers, Painting and Land				9,600
Insulators				2,400
Hardware				1,000
Wires, Conductors & Grounds				14,600
Miscellaneous				5,600
Labor				6,000
Engineering & Overhead				800
TOTAL COST OF TRANSMISSION SYSTEM				40,000
GRAND TOTAL				474,000

TABLE E-9

COST ESTIMATE OF VILAR TABUACO PROJECT

Item	Total Cost (Contos)
VILAR	
Expropriations	8,800
Access	1,500
Diversion	1,600
Dam	51,500
Powerhouse	900
Equipment	1,900
SUBTOTAL AT VILAR	65,700
WATERWAYS	
Canal	8,500
Tunnel	37,500
Surge tank	200
Penstock	3,900
Gate house	300
SUBTOTAL OF WATERWAYS	50,400
TABUACO	
Powerhouse	700
Equipment	9,800
SUBTOTAL AT TABUACO	10,500
TOTAL DIRECT COST	126,600
Indirect Cost	42,400
TOTAL COST (Exclusive of switchyard and transmission)	169,000
Switchyard (including indirect costs)	1,800
Transmission system (including indirect costs)	2,200
GRAND TOTAL	173,000

TABLE E-10

COST ESTIMATE OF FRAGAS DA TORRE PROJECT

Item	Total Cost (Contos)
Expropriations	9,600
Access	1,800
Diversion	9,200
Dam and Intake	101,700
Waterways	111,800
Powerhouse	4,200
Equipment	20,900
TOTAL DIRECT COST	259,200
Indirect Cost	86,800
TOTAL COST (Exclusive of switchyard and transmission)	346,000
Switchyard (including indirect costs)	4,200
Transmission system (including indirect costs)	1,800
GRAND TOTAL	352,000

TABLE E-11

COST ESTIMATE OF VALE DE MADEIRA PROJECT

Item	Total Cost (Contos)
IMPOUNDING WORKS	
Expropriations	8,000
Access	1,500
Diversion	800
Dams	
Principal	136,000
Lateral	3,000
Auxiliary buildings	3,700
SUBTOTAL-IMPOUNDING WORKS	153,000
GENERATING WORKS	
Tunnel	4,200
Penstock	1,500
Galleries	2,100
Powerhouse	700
Equipment	7,000
SUBTOTAL-GENERATING WORKS	15,500
TOTAL DIRECT COST	168,500
Indirect Cost	56,500
TOTAL COST (Excluding switchyard and transmission)	225,000
Switchyard (including indirect costs)	2,000
Transmission system (including indirect cost)	6,000
GRAND TOTAL	233,000

TABLE E-12

COST ESTIMATE OF LARANJEIRAS PROJECT

Item	Total Cost (Contos)
Expropriations	20,000
Access	1,000
Diversion	12,800
Dam	248,000
Spillway	22,600
Intake and waterways	7,600
Flood control	6,500
Powerhouse	1,500
Equipment	7,800
TOTAL DIRECT COST	327,800
Indirect Cost	109,800
TOTAL COST	437,600
Irrigation allowance	10,600
NET COST (Excluding switchyard and Transmission)	427,000
Switchyard (including indirect cost)	1,700
Transmission system (including indirect cost)	3,300
GRAND TOTAL	432,000

TABLE E-13

DETAILED ESTIMATES OF COST OF CONSTRUCTION - 25,000 KW PEJAO STEAM PLANT

Item	Design 1 45% Ash (Contos)	Design 2 20% Ash (Contos)	Design 3 18% Ash (Contos)
LAND	14	14	14
STRUCTURES & IMPROVEMENTS			
Station Building	23,400	13,286	13,286
Circulating Water Intake House	1,000	1,000	1,000
Coal Handling & Miscellaneous Structures	1,100	2,543	842
Yard Improvements	1,600	1,286	1,286
BOILER PLANT			
Boiler - complete	28,733	28,022	28,022
Coal Handling Equipment	3,629	1,837	3,326
Ash Handling Equipment	714	429	429
Feed Water System	908	908	908
Water Supply & Purification System	671	671	671
Boiler Plant Piping	5,692	4,554	4,554
TURBO-GENERATOR			
Turbo-generator Unit - complete	22,108	22,108	22,108
Circulating Water Pumps	922	922	922
ACCESSORY ELECTRICAL EQUIPMENT (Generator Main Connections, Station Control System, Station Auxiliary Power System, etc.)	6,108	6,108	6,108
MISCELLANEOUS POWER PLANT EQUIPMENT	4,000	2,857	2,857
SUB-TOTAL	100,599	86,559	86,333
FREIGHT	5,714	4,286	4,286
SUB-TOTAL	106,313	90,845	90,619
Indirect costs - 35.5%*	37,741	32,250	32,170
TOTAL COST OF POWER PLANT (Exclusive of Step-up Substation)	144,054	123,095	122,789
STEP-UP SUBSTATION - 12 KV/60 KV			
Transformer - 31,250 kva, 3ø, 50 Cycle - 12 kv/60 kv.	2,472	2,472	2,472
60 kv - Outdoor Air Blast Circuit Breaker - Complete	431	431	431
Disconnects	57	57	57
Potential Transformers	150	150	150
Current Transformers	95	95	95
Steel	287	287	287
Miscellaneous	294	294	294
Freight	431	431	431
SUB-TOTAL	4,217	4,217	4,217
Indirect costs - 35.5%*	1,497	1,497	1,497
TOTAL COST OF STEP-UP SUBSTATION	5,714	5,714	5,714
60 KV TRANSMISSION LINE - PEJAO TO ERMESINDE (24 km)			
Towers, Including Painting and Grounds	1,152	1,152	1,152
Insulators	288	288	288
Hardware	120	120	120
Wires (Conductors and Grounds)	1,752	1,752	1,752
Miscellaneous	672	672	672
Labor	720	720	720
Engineering and Overhead	96	96	96
TOTAL COST OF TRANSMISSION LINE**	4,800	4,800	4,800
GRAND TOTALS	154,568	133,609	133,303

* Interest During Construction	6.0%
Finance Charges	3.5%
Studies, Supervision, etc.	9.0%
Residences for Personnel	2.0%
Contingencies	15.0%
Total	35.5%

**This estimate covers installation and all pertinent charges itemized under*.

TABLE E-14

ATAES NAVIGATION DAM
MOVABLE CREST WEIR (SIDNEY GATES) ON SAND

Item	Quantity	Unit	Unit Cost (Escudos)	Total Cost (Contos)
COFFERDAM				
Rock Fill (Cribs)	207,000	m^3	40	8,280
Timber	4,360	m^3	1,000	4,360
Steel Sheet Piling - Purchase	445,000	kg	6	2,670
Placement and Removal of Cribs & Piling All Stages				2,690
Unwatering and Pumping				600
Miscellaneous				500
				19,100
Salvage Savings				1,800
SUBTOTAL - COFFERDAM				17,300
UPSTREAM PROTECTION				
Riprap	3,300	m^3	240	790
Concrete - Mass	8,400	m^3	380	3,190
Steel - Reinforcing Dam	42,000	kg	4.5	190
Steel Sheet Piling	25,000	m^2	105	2,620
Miscellaneous				310
SUBTOTAL - UPSTREAM PROTECTION				7,100
DAM				
Excavation - Dam & Spillway	5,000	m^3	110	550
Wood Piling	9,400	m	30	280
Concrete - Mass	18,000	m^3	380	6,840
- Structural	7,500	m^3	500	3,750
- Beam & Slab	8,000	m^3	830	6,640
Steel - Reinforcing, Dam	90,000	kg	4.5	400
- Reinforcing, Structural	705,000	kg	5	3,520
Gates	910,000	kg	26	23,660
Miscellaneous				1,360
SUBTOTAL - DAM				47,000
STILLING BASIN				
Wood Piling	18,400	m^3	30	550
Filter Material	3,700	m^3	60	220
Concrete - Structural	5,600	m^3	500	2,800
Steel - Reinforcing, Structural	168,000	kg	5	840
Riprap	1,200	m^3	240	290
Articulated Mattress	17,200	m^2	195	3,350
Miscellaneous				250
SUBTOTAL - STILLING BASIN				8,300
LOCK				
Excavation - Rock, Open Cut	40,000	m^3	70	2,800
- Sand	28,500	m^3	11	310
Wood Piling	3,360	m	30	100
Concrete - Structural	33,000	m^3	500	16,500
Steel - Reinforcing, Structural	990,000	kg	5	4,950
Anchors	1,900	ea	200	380
Gates	460,000	kg	26	12,000
Operating Equipment	208,500	kg	41.4	8,630
Poiree Dam				300
Miscellaneous				830
SUBTOTAL - LOCK				46,800
TOTAL DIRECT COST				126,500
INDIRECT COST				45,500
TOTAL COST				172,000

TABLE E-15

ATAES NAVIGATION DAM

SUMMARY ESTIMATE OF VARIOUS SCHEMES

Type of Structure	High weir		Bear trap gates		Sidney gates	
Foundation	Rock	Sand	Rock	Sand	Rock	Sand
Cofferdam	18,100	18,100	17,300	17,300	17,300	17,300
Upstream protection	–	7,100	–	7,100	–	7,100
Dam	13,800	16,400	31,100	37,500	41,600	47,000
Stilling basin	–	8,300	–	8,300	–	8,300
Lock	44,500	47,200	44,100	46,800	44,100	46,800
Total Direct Cost	76,400	97,100	92,500	117,000	104,800	126,500
Indirect Cost	25,600	36,900	32,500	41,000	35,200	45,500
Total Cost	102,000	134,000	125,000	158,000	140,000	172,000

TABLE E-16

ENTRE-OS-RIOS NAVIGATION DAM

Item	Quantity	Unit	Unit Cost (Escudos)	Total Cost (Contos)
COFFERDAM				
Rock fill (crib)	149,000	m^3	40	5,960
Timber	3,040	m^3	1,000	3,040
Steel sheet piling - purchase	316,000	kg	6	1,900
Placements removal of cribs and piling all stages			L.S.	1,700
Unwatering and pumping			L.S.	400
Miscellaneous				500
				13,500
Salvage savings				1,500
SUBTOTAL-COFFERDAM				12,000
DAM				
Excavation, dam and spillway	11,000	m^3	110	1,210
Foundation	204	m	2,200	450
Concrete, mass	10,500	m^3	380	3,990
Concrete, structural	5,000	m^3	500	2,500
Concrete, beam and slab	4,300	m^3	830	3,570
Steel reinforcing, dam	53,000	kg	4.5	240
Steel reinforcing, struct.	408,000	kg	5	2,040
Gates	392,000	kg	26	10,200
Miscellaneous				800
SUBTOTAL-DAM				25,000
LOCK				
Excavation, dam and spillway	11,000	m^3	110	1,210
Concrete, structural	17,200	m^3	500	8,600
Steel, reinforcing, struct.	516,000	kg	5	2,580
Anchors	1,400	ea	200	280
Gates	250,000	kg	26	6,500
Operating equipment	107,000	kg	41.4	4,430
Miscellaneous				1,000
SUBTOTAL-LOCK				24,600
TOTAL DIRECT COST				61,600
Indirect Costs				21,400
TOTAL COST				83,000

TABLE E-17

PORT OF FOZ DO DOURO JETTY PLAN

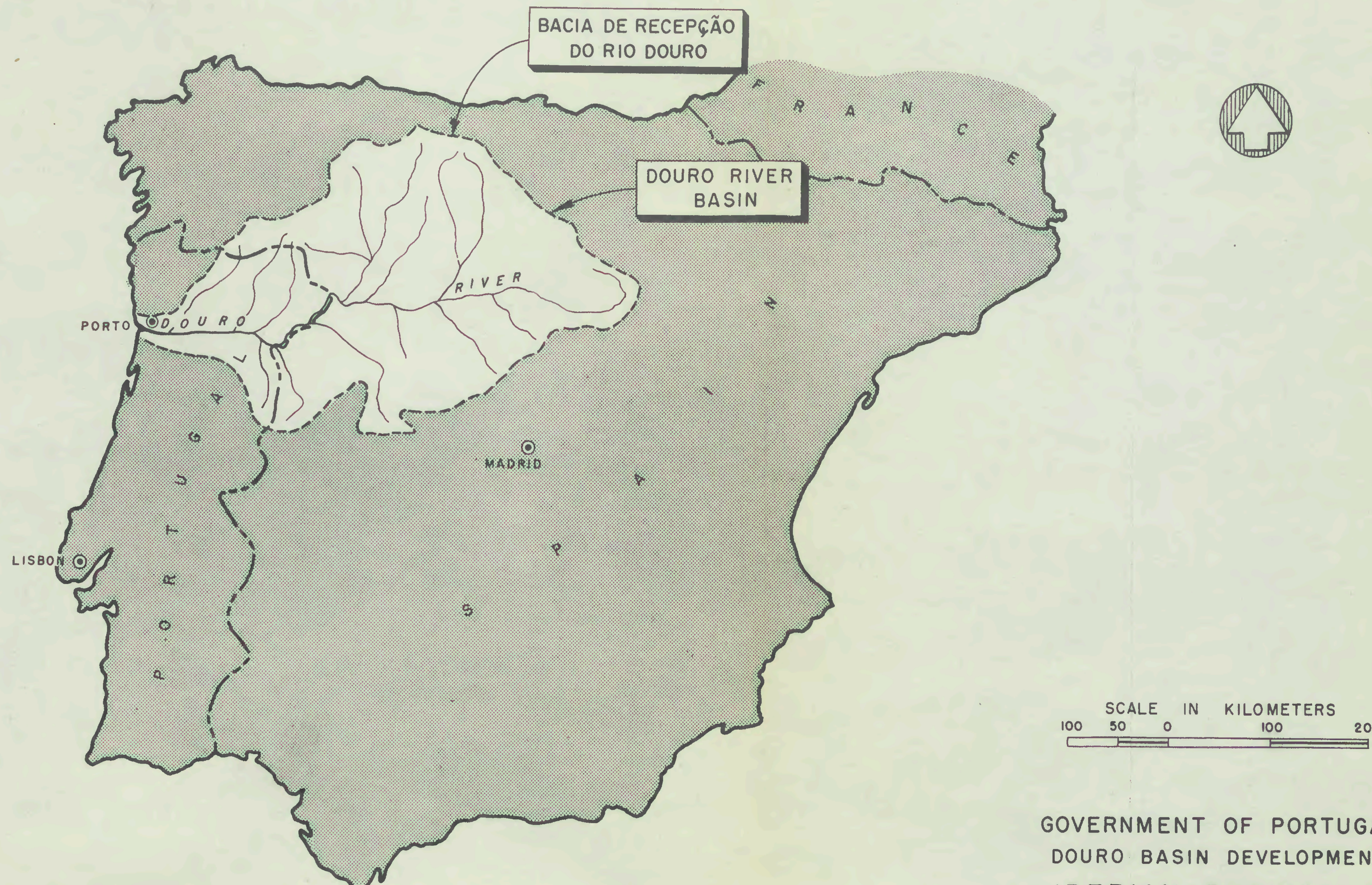
Item	Quantity	Unit	Unit Costs (Escudos)	Total Costs (Contos)
DREDGING				
Dredging in Sand	1,568,000	m^3	5	7,840
Dredging in Rock	70,000	m^3	330	23,100
SUBTOTAL-DREDGING				30,940
NORTH JETTY				
Rock 20 to 2,500 kg	124,000	m^3	90	11,200
Rock 2.5 to 7.5 Tons	56,000	m^3	100	5,600
Smoothing the platforms	9,500	m^2	20	190
Smoothing berms and slopes	35,000	m^2	40	1,400
Concrete blocks in superstructure	20,500	m^3	420	8,600
Concrete blocks in berm and slopes	5,700	m^3	450	25,600
Concrete in place in the superstructure	32,400	m^3	350	11,310
SUBTOTAL-NORTH JETTY				63,900
SOUTH JETTY				
Rock 20 to 2,500 kg	135,000	m^3	90	12,150
Rock 2.5 to 7.5 Tons	62,000	m^3	100	6,200
Smoothing the platforms	10,500	m^2	20	210
Smoothing berms and slopes	38,300	m^2	40	1,530
Concrete blocks in superstructure	23,000	m^3	420	9,650
Concrete blocks in berms and slopes	64,000	m^3	450	28,800
Concrete in place in the superstructure	36,000	m^3	350	12,590
SUBTOTAL-SOUTH JETTY				71,130
TRAINING WALLS	115,200	m^3	100	11,520
TOTAL DIRECT COST				177,490
Indirect Cost				62,510
TOTAL COST				240,000

TABLE E-18

ANNUAL COSTS OF HYDROELECTRIC PROJECTS

ITEM	UNIT	PICOTE	BEMPOSTA	MIRANDA	CARRAPATELO	REGUA	VALEIRA	POCINHO	VILAR TABUACO	FRAGAS DA TORRE	VALE DA MADEIRA	LARANJEIRAS
Installed Capacity	kw	93,000	76,000	72,000	87,300	70,000	77,000	57,000	7,600	18,000	8,700	6,400
Capital Cost - Installations	10^3 contos	273	204	140	202	213	179	140	99	325	200	408
Capital Cost - Equipment	10^3 contos	194	189	200	350	313	315	280	70	21	25	19
Capital Cost - Project	10^3 contos	467	393	340	552	526	494	420	169	346	225	427
Annual Cost - Installations 7.58%	10^3 contos	20.7	15.5	10.6	15.3	16.1	13.6	10.6	7.5	24.6	15.2	30.9
Annual Cost - Equipment 9.01%	10^3 contos	17.5	17.0	18.0	31.5	28.2	28.3	25.2	6.3	1.9	2.2	1.7
Annual Cost - Maintenance	10^3 contos	5.6	5.0	4.8	5.2	4.7	5.1	4.2	2.1	2.3	1.6	1.4
Annual Cost - Diversion	10^3 contos		0.6									
Annual Cost - Project	10^3 contos	43.8	38.1	33.4	52.0	49.0	47.0	40.0	15.9	28.8	19.0	34.0
A Cost of Output at Busbar	esc/kw	471	501	464	595	700	622	701	2,090	1,637	2,206	5,312
B Annual Cost of Step-Up Sub-Station	esc/kw	29	29	29	29	29	29	29	29	29	29	29
Step-Up Losses - 0.011 (A + B)	esc/kw	5	6	5	7	8	7	8	23	18	25	59
C Cost of Output at High Tension Terminal, Sending	esc/kw	505	536	498	631	737	658	738	2,142	1,684	2,260	5,400
D Annual Cost of Transmission Lines	esc/kw	107	91	109	14	33	43	70	30	10	71	46
Line Loss Factor		0.108	0.102	0.113	0.048	0.061	0.072	0.080	0.066	0.045	0.094	0.084
Line Losses - Line Loss Factor (C + D)	esc/kw	66	64	69	31	47	51	65	143	76	219	457
E Cost of Output at High Tension Terminal, Receiving	esc/kw	678	691	676	676	817	752	873	2,315	1,770	2,550	5,903
TOTAL ANNUAL COST	10^3 contos	63.1	52.5	48.8	59.1	57.2	58.0	49.8	17.6	31.9	22.2	37.8

PLATES



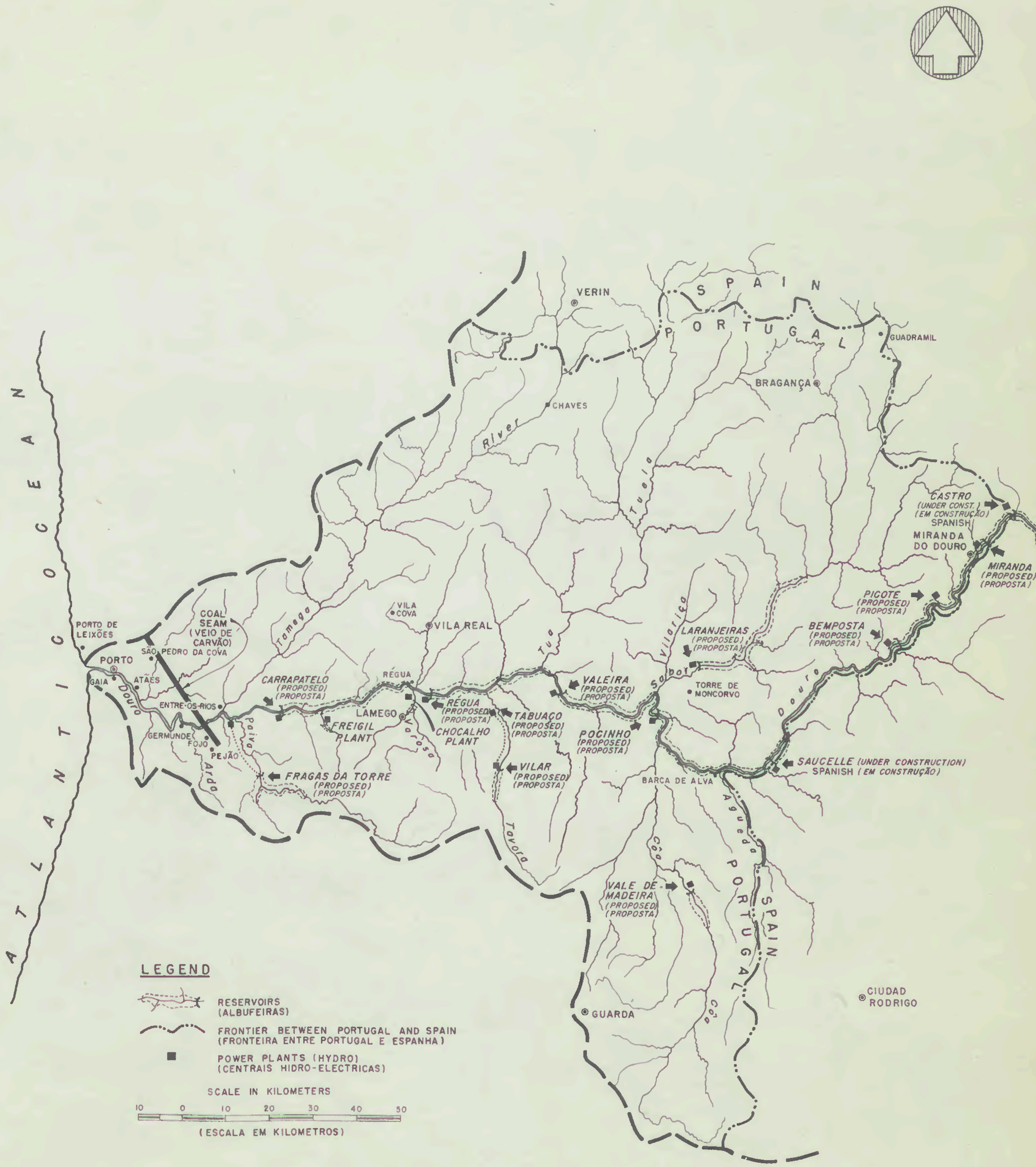
GOVERNMENT OF PORTUGAL
DOURO BASIN DEVELOPMENT

IBERIAN PENINSULA
DOURO RIVER BASIN

KNAPPEN · TIPPETTS · ABBETT · McCARTHY
ENGINEERS
NEW YORK, N.Y.

MARCH 1953

PLATE 1



GOVERNMENT OF PORTUGAL
DOURO BASIN DEVELOPMENT

DOURO RIVER BASIN

LOCATION OF EXISTING AND PROPOSED PROJECTS IN PORTUGAL

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MARCH 1953 PLATE 2

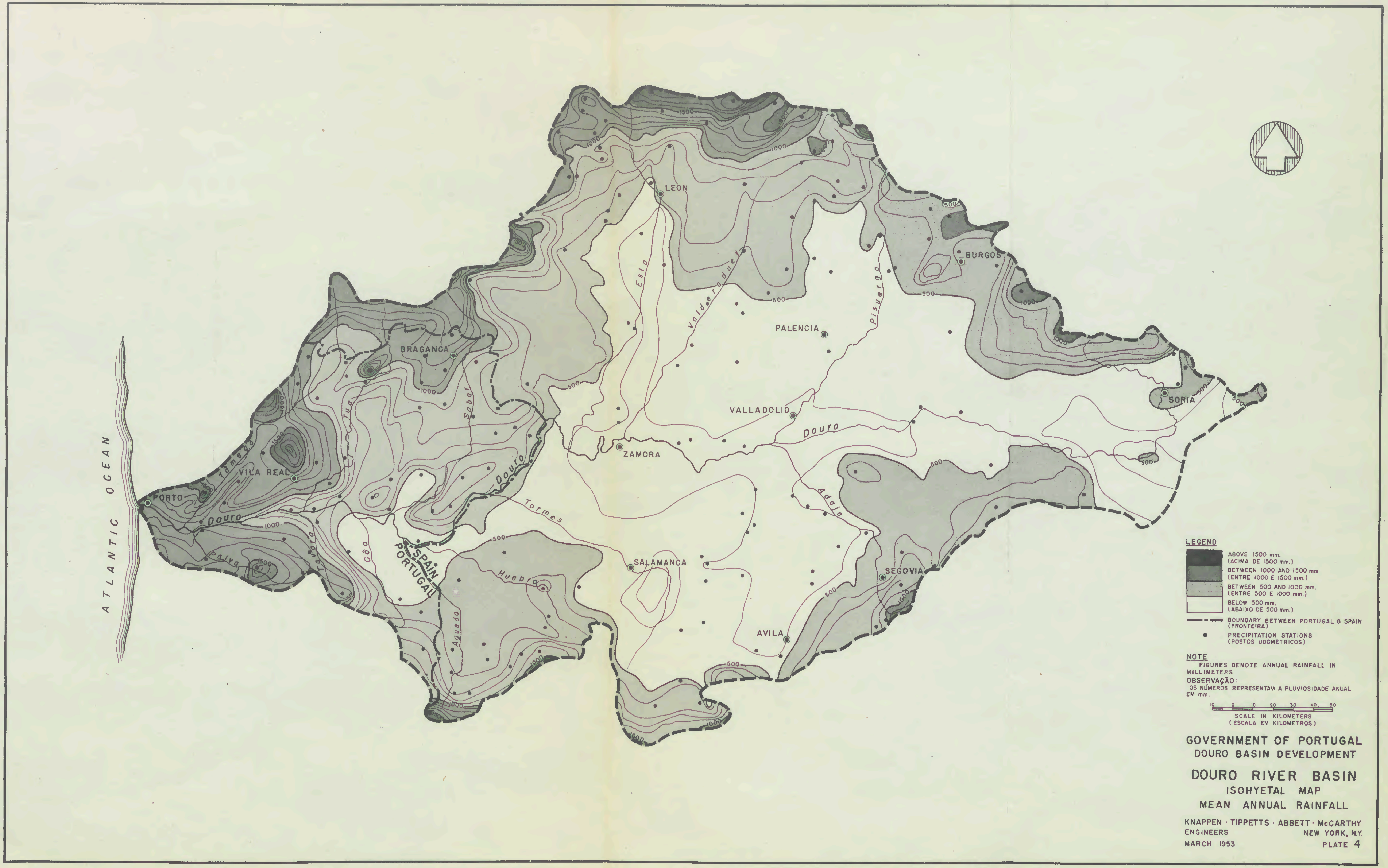
GOVERNMENT OF PORTUGAL
DOURO BASIN DEVELOPMENT

DOURO RIVER BASIN

LOCATION OF EXISTING AND PROPOSED PROJECTS IN PORTUGAL AND SPAIN

KNAPPEN · TIPPETTS · ABBETT · McCARTHY ENGINEERS — NEW YORK, N.Y.

MARCH 1953 — PLATE 3


ATLANTIC OCEAN
PORTO
VILA REAL
BRAGANCA
LEON
PALENCIA
BURGOS
VALLADOLID
ZAMORA
SORIA
SALAMANCA
SEGOVIA
AVILA
SPAIN
PORTUGAL
Douro
Tâmega
Tua
Sabor
Paiva
Côa
Agueda
Huebra
Tormes
Esla
Valderaduey
Pisuerga
Adaja
LEGEND
ABOVE 1500 mm.
(ACIMA DE 1500 mm.)
BETWEEN 1000 AND 1500 mm.
(ENTRE 1000 E 1500 mm.)
BETWEEN 500 AND 1000 mm.
(ENTRE 500 E 1000 mm.)
BELOW 500 mm.
(ABAIXO DE 500 mm.)
BOUNDARY BETWEEN PORTUGAL & SPAIN
(FRONTEIRA)
PRECIPITATION STATIONS
(POSTOS UDOMETRICOS)
NOTE
FIGURES DENOTE ANNUAL RAINFALL IN MILLIMETERS
OBSERVAÇÃO:
OS NÚMEROS REPRESENTAM A PLUVIOSIDADE ANUAL EM mm.
SCALE IN KILOMETERS
(ESCALA EM KILOMETROS)
GOVERNMENT OF PORTUGAL
DOURO BASIN DEVELOPMENT
DOURO RIVER BASIN
ISOHYETAL MAP
MEAN ANNUAL RAINFALL
KNAPPEN · TIPPETTS · ABBETT · McCARTHY
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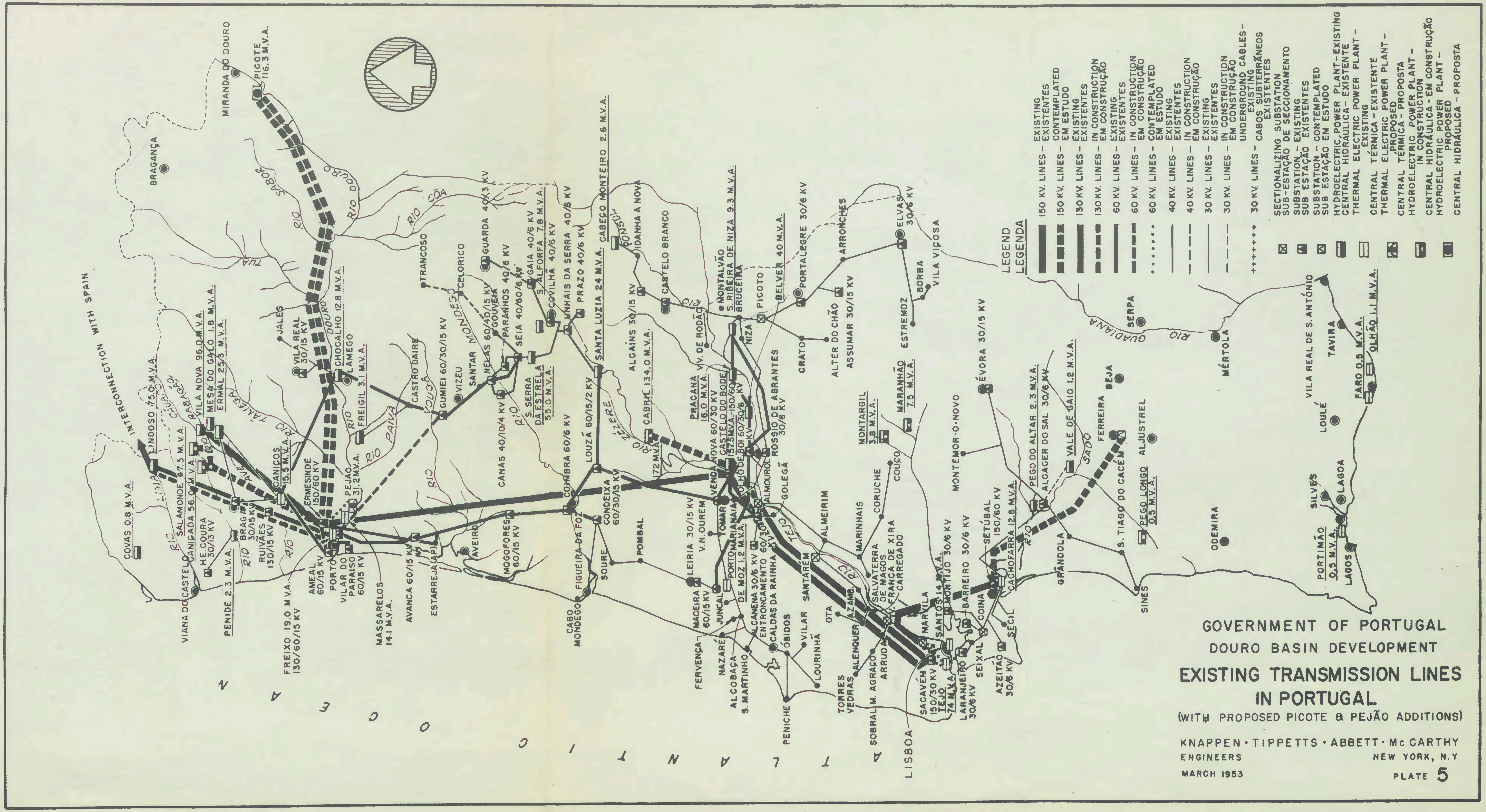
NEW YORK, N.Y.
MARCH 1953
PLATE 4



GOVERNMENT OF PORTUGAL

DOURO BASIN DEVELOPMENT

EXISTING TRANSMISSION LINES IN PORTUGAL

(WITH PROPOSED PICOTE & PEJÃO ADDITIONS)

KNAPPEN · TIPPETTS · ABBETT · McCARTHY
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MARCH 1953

PLATE 5

TYPICAL TRAFFIC ON THE DOURO RIVER
TRÁFEGO NO RIO DOURO

COAL LOADING AT GERMUNDE
CARREGANDO CARVÃO EM GERMUNDE

RABAOS FULLY LOADED
RABÕES COMPLETAMENTE CARREGADOS

RABAO SHOWING STEERING OAR
RABÃO MOSTRANDO O REMO-LEME

RABAO RETURNING UPSTREAM UNDER SAIL
RABÃO À VELA DE VOLTA PARA MONTANTE

CHANNEL IMPROVEMENT
MELHORAMENTO DO CANAL

GOVERNMENT OF PORTUGAL
DOURO BASIN DEVELOPMENT

COAL TRAFFIC,
DOURO RIVER

KNAPPEN TIPPETTS ABBETT McCARTHY
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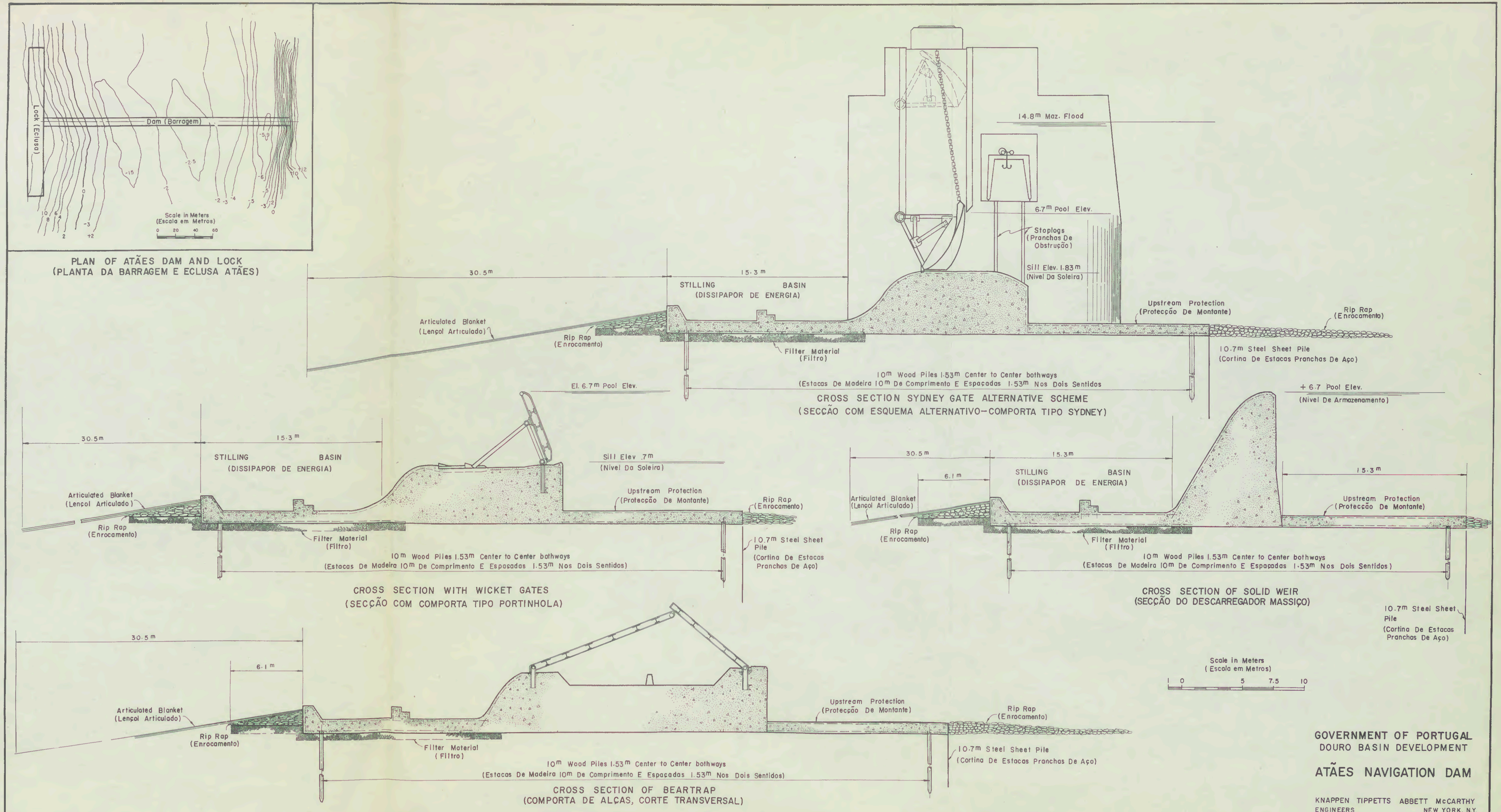
MARCH 1953 — PLATE 5a

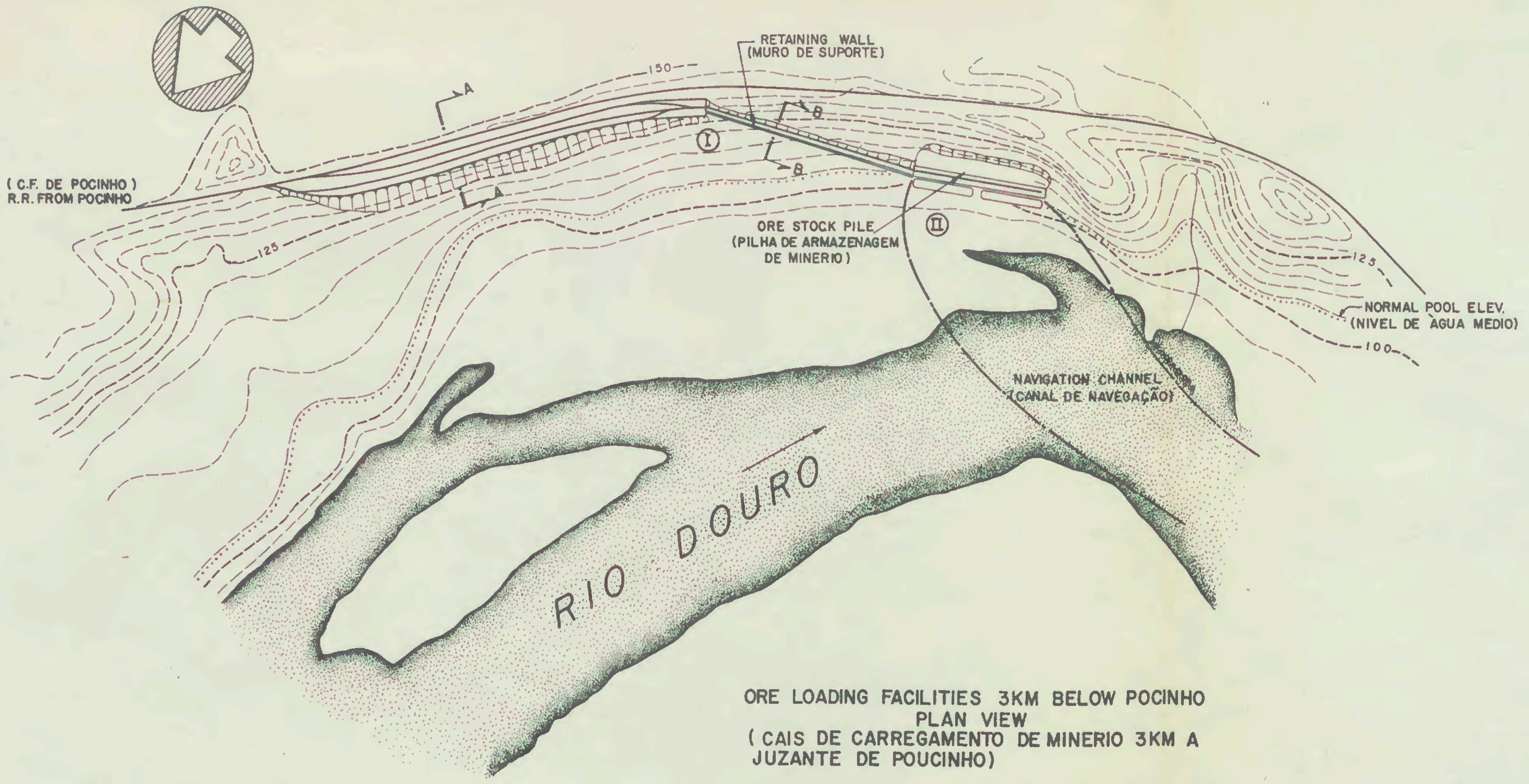
HARBOR OF LEIXÕES
(PORTO DE LEIXÕES)
(DUQUES DE ALBA)
DOLPHINES
ZERO HIDROGRAFICO
HYDROGRAPHIC ZERO
EL.+ 8.00
SECTION C-C
CROSS SECTION OF CANAL AND BREAKWATERS
(CORTE DO CANAL E QUEBRA-AGUAS)
(TÚNEL)
TUNNEL
(ECLUSA)
LOCK
(CANAL PROPOSTO DE 6m)
PROPOSED 6m CHANNEL
THALWEG
CANTAREIRA
(ZONA DE CARREGA MENTO)
LOADING FACILITIES
(PILHA DE MINÉRIO)
ORE STOCKPILE
ELEVATIONS REFER TO HYDROGRAPHIC ZERO, WHICH IS 1.93 METERS BELOW MEAN SEA LEVEL.
(COTAS REFERIDAS AO ZERO HIDROGRÁFICO, 1.93m ABAIXO DO NIVEL MEDIO DO MAR.)
(PONTE DE ACESSO À PRAIA)
ACCESS BRIDGE TO BEACH
(BATELÕES DE MINÉRIO)
ORE BARGES
EL.-4.0
SECTION B-B
CROSS SECTION OF CANAL
(CORTE DO CANAL)
(NIVEL MAXIMO)
EL.+ 8
MAX. FLOW
EL.+ 4
MAX. TIDE
(MARÉ MAXIMA)
6m
17m
6m
(PILHA DE MINÉRIO)
STOCKPILE OF ORE
BACK FILL
(ATERRO)
SECTION D-D
CROSS SECTION OF ORE DOCK
(CORTE DA DOCA MINÉRIO)
USE LINING FOR SECTIONS OF FAULTY ROCK
(REVESTIMENTO NAS SECÇOES DE ROCHA DEFEITUOSA.)
TOP OF EMPTY BARGE
(TOPO DO BATELÃO VAZIO)
(ZERO HIDROGRAFICO)
HYDROGRAPHIC ZERO
WALKWAY
(PASSEIO)
70# RAIL
(CARRIL DE 70 LIBRAS)
BOTTOM OF LOADED BARGE
(FUNDO DO BATELÃO CARREGADO)
CROSS SECTION OF PROPOSED NAVIGATION TUNNEL
FROM DOURO RIVER TO THE PORT OF LEIXÕES
SECÇÃO DO TUNEL DE NAVIGAÇÃO PROPOSTO
DESDE O DOURO ATÉ AO PORTO DE LEIXÕES
EL.+ 6.00
(CUBOS DE BETÃO DE 50 TON)
50 TON CONCRETE BLOCKS
(ZERO HIDROGRAFICO)
HYDROGRAPHIC ZERO
(PEDRAS)
STONES
20 TO 2500KG
2.5 TO 7.5 TON STONE
SECTION A-A
CROSS SECTION OF JETTY
(CORTE DO MOLHE)
SADDLE TO BE PREPARED FOR FLOOD RELIEF
CANAL DE ALIVIO DE CHEIAS PROPOSTO
DOURO
SCALE IN METERS
500
0
500
GOVERNMENT OF PORTUGAL
DOURO BASIN DEVELOPMENT
LEIXÕES HARBOR TO FOZ DOURO AND ORE DOCK
KNAPPEN - TIPPETTS - ABBETT - McCARTHY
ENGINEERS
NEW YORK, N.Y.
MARCH 1953
PLATE 6



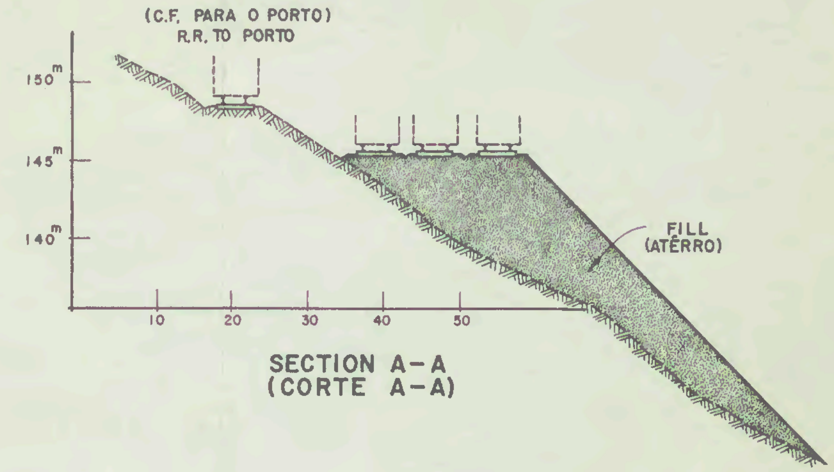
GOVERNMENT OF PORTUGAL
DOURO BASIN DEVELOPMENT

ATÃES NAVIGATION DAM

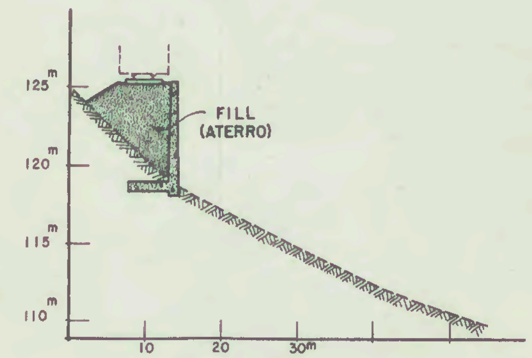
KNAPPEN TIPPETTS ABBETT McCARTHY
ENGINEERS NEW YORK, N.Y.
MARCH 1953 PLATE 7



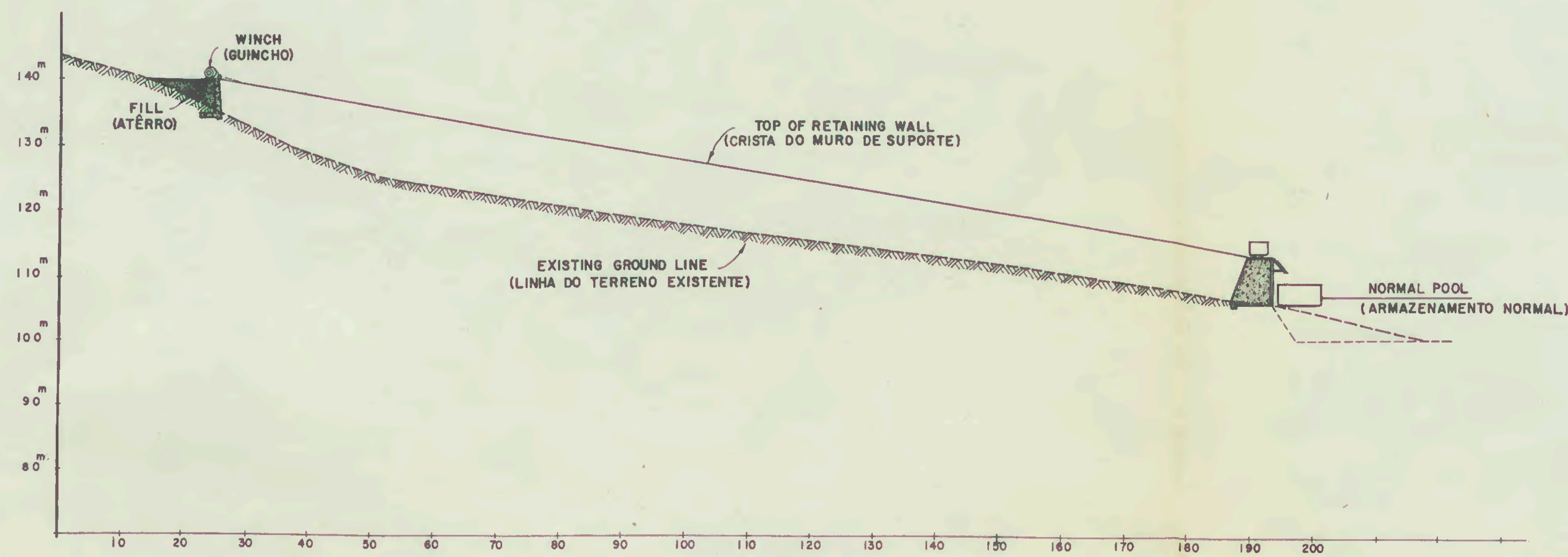
ORE LOADING FACILITIES 3KM BELOW POCINHO
PLAN VIEW
(CAIS DE CARREGAMENTO DE MINERIO 3KM A
JUZANTE DE POUCINHO)



SECTION A–A
(CORTE A–A)



SECTION B–B
(CORTE B–B)



PROFILE I-II
(PERFIL I-II)

GOVERNMENT OF PORTUGAL
DOURO BASIN DEVELOPMENT

ORE LOADING FACILITIES BELOW POCINHO

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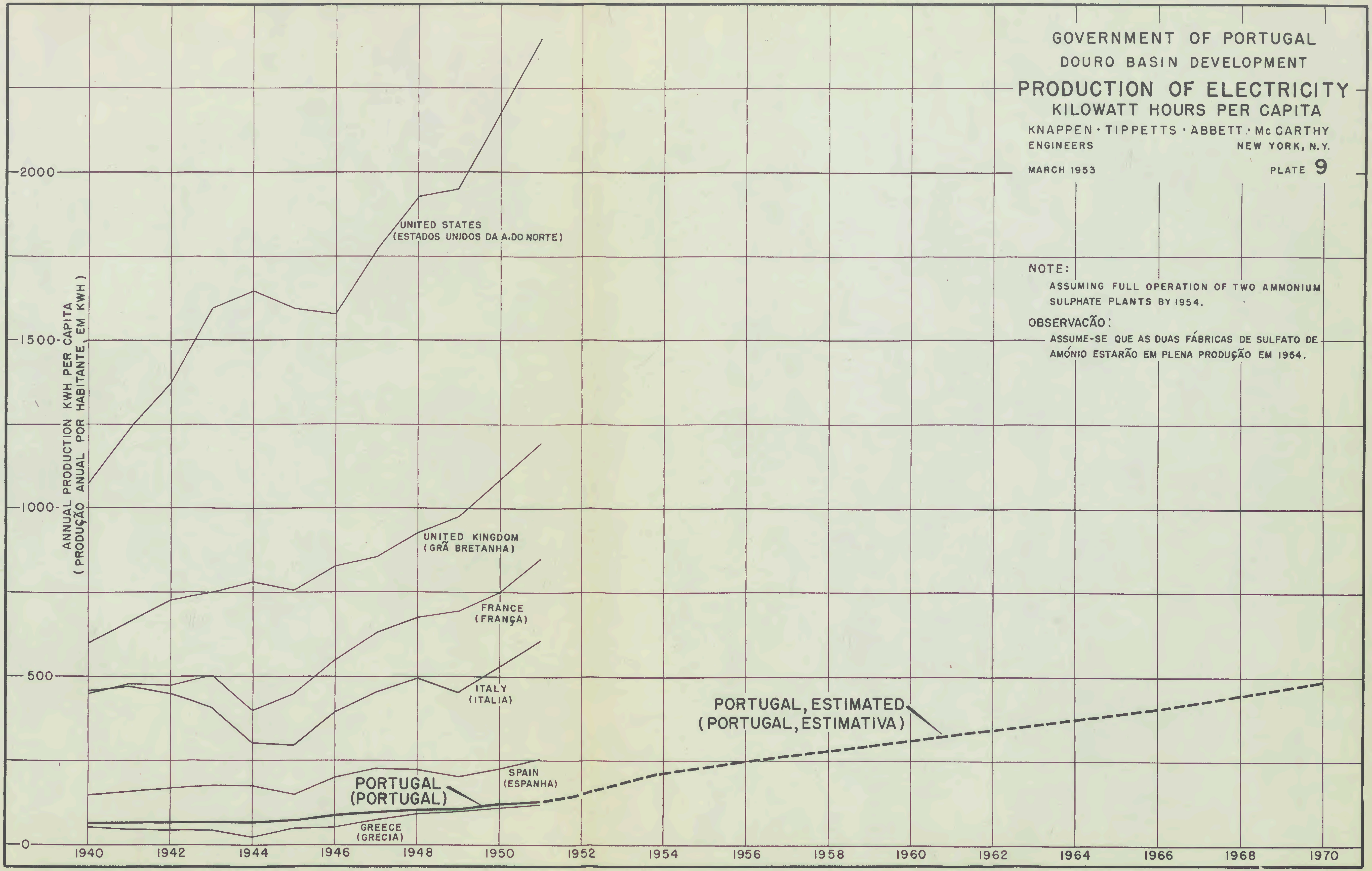
MARCH 1953 PLATE 8

PLATE 8a

LOW-WATER CONDITIONS AT MOUTH OF DOURO RIVER NOVEMBER-DECEMBER 1951

DISPOSIÇÃO DA BAIXA-MAR NA FOZ DO DOURO NOVEMBRO-DEZEMBRO, 1951



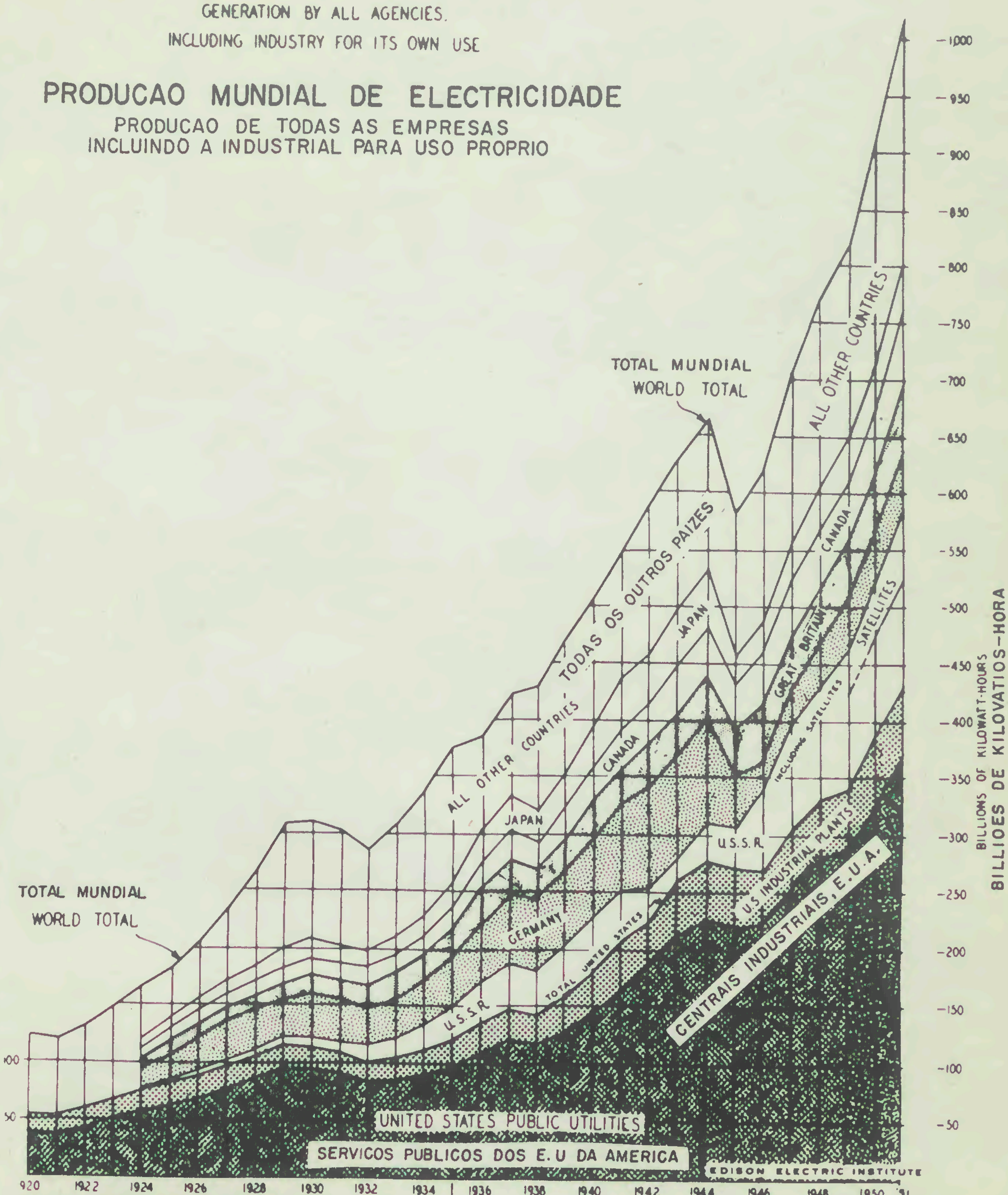
SOURCE: U.N. STATISTICAL BULLETIN (FONTE DE INFORMAÇÃO: BULETIM ESTATISTICO DA O.N.U.)

WORLD PRODUCTION OF ELECTRICITY

GENERATION BY ALL AGENCIES.
INCLUDING INDUSTRY FOR ITS OWN USE

PRODUCAO MUNDIAL DE ELECTRICIDADE

PRODUCAO DE TODAS AS EMPRESAS
INCLUINDO A INDUSTRIAL PARA USO PROPRIO



(AS ESTIMATED IN STATISTISCHER BERICHT DER ELEKROINDUSTRIE INTERNATIONAL)

ESTIMATIVA EXTRAIDA DO RELATORIO ESTATISTICO. DA "ELECTROINDUSTRIE INTERNATIONAL."

ESTIMATED AND INTERPOLATED FROM MONTHLY BULLETIN OF THE UNITED NATIONS.

ESTIMATIVA E INTERPOLAÇÃO EXTRAIDOS DO BULETIM MENSAL DAS NAÇÕES UNIDAS

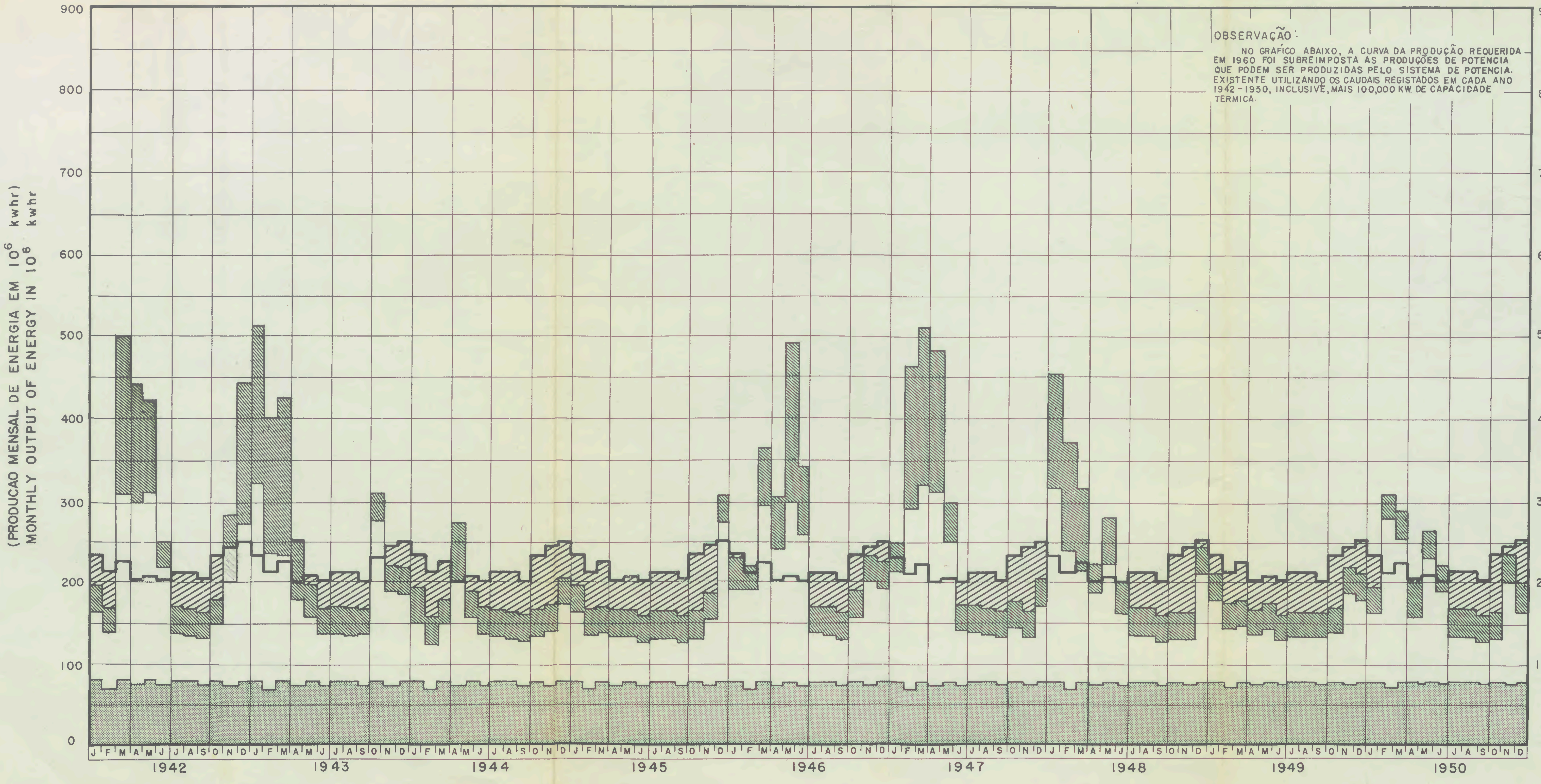
KNAPPEN TIPPETTS ABBETT McCARTHY

ENGINEERS

GOVERNMENT OF PORTUGAL — DOURO BASIN DEVELOPMENT

DATE: MARCH 1953

PLATE 10



LEGEND

- ZÉZERE OUTPUT (PRODUÇÃO DO ZEZERE)
- DEFICIT
- STEAM OUTPUT * (PRODUÇÃO TÉRMICA)
- OUTPUT FROM EXISTING HYDROELECTRIC PLANTS EXCLUDING ZEZERE (PRODUÇÃO DAS CENTRAIS HIDRAULICAS EXISTENTES EXCLUINDO ZEZERE)
- 1960 REQUIREMENT** (DEMANDA EM 1960)

* 100,000 KW INSTALLED (INSTALADOS)

** INCLUDING AMMONIUM SULPHATE PLANTS (INCLUINDO FÁBRICAS DE SULFATO DE AMONIO)

NOTE: IN THE FOREGOING GRAPH, THE CURVE OF THE 1960 POWER REQUIREMENT IS SUPERIMPOSED IN TURN UPON THE POWER OUTPUTS THAT COULD BE PRODUCED BY THE EXISTING POWER SYSTEM, UTILIZING THE STREAM FLOWS EXPERIENCED IN EACH OF THE YEARS, 1942-1950 INCLUSIVE, PLUS 100,000 KW OF THERMAL CAPACITY.

GOVERNMENT OF PORTUGAL
DOURO BASIN DEVELOPMENT

OUTPUT OF EXISTING SYSTEM
BEFORE ZEZERE REREGULATION

KNAPPEN TIPPETTS ABBETT McCARTHY
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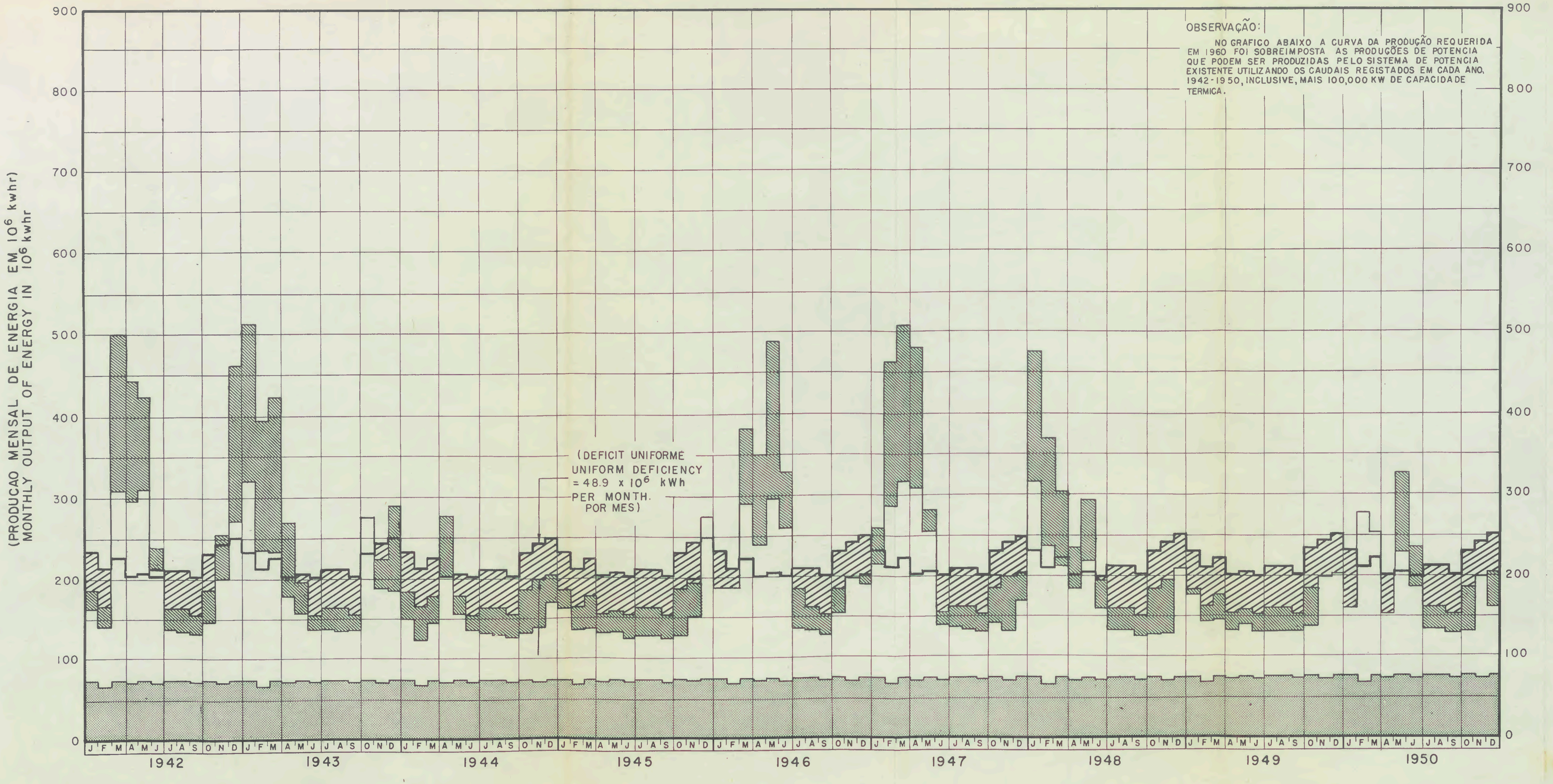
NEW YORK, N.Y.

MARCH 1953

PLATE 11



LEGEND

- ZEZERE OUTPUT (PRODUÇÃO DO ZEZERE)
- DEFICIT
- STEAM OUTPUT * (PRODUÇÃO TERMICA)
- OUTPUT FROM EXISTING HYDROELECTRIC PLANTS EXCLUDING ZEZERE (PRODUÇÃO DAS CENTRAIS HIDRÁULICAS EXISTENTES EXCLUINDO ZEZERE)
- 1960 REQUIREMENT ** (DEMANDA EM 1960)

* 100,000 kW INSTALLED (INSTALADOS)

** INCLUDING AMMONIUM SULPHATE PLANTS (INCLUINDO FÁBRICAS DE SULFATO DE AMÓNIO)

NOTE: IN THE FOREGOING GRAPH, THE CURVE OF THE 1960 POWER REQUIREMENT IS SUPERIMPOSED IN TURN UPON THE POWER OUTPUTS THAT COULD BE PRODUCED BY THE EXISTING POWER SYSTEM, UTILIZING THE STREAM FLOWS EXPERIENCED IN EACH OF THE YEARS, 1942-1950 INCLUSIVE, PLUS 100,000 KW OF THERMAL CAPACITY.

GOVERNMENT OF PORTUGAL

DOURO BASIN DEVELOPMENT

OUTPUT OF EXISTING SYSTEM AFTER ZEZERE REREGULATION

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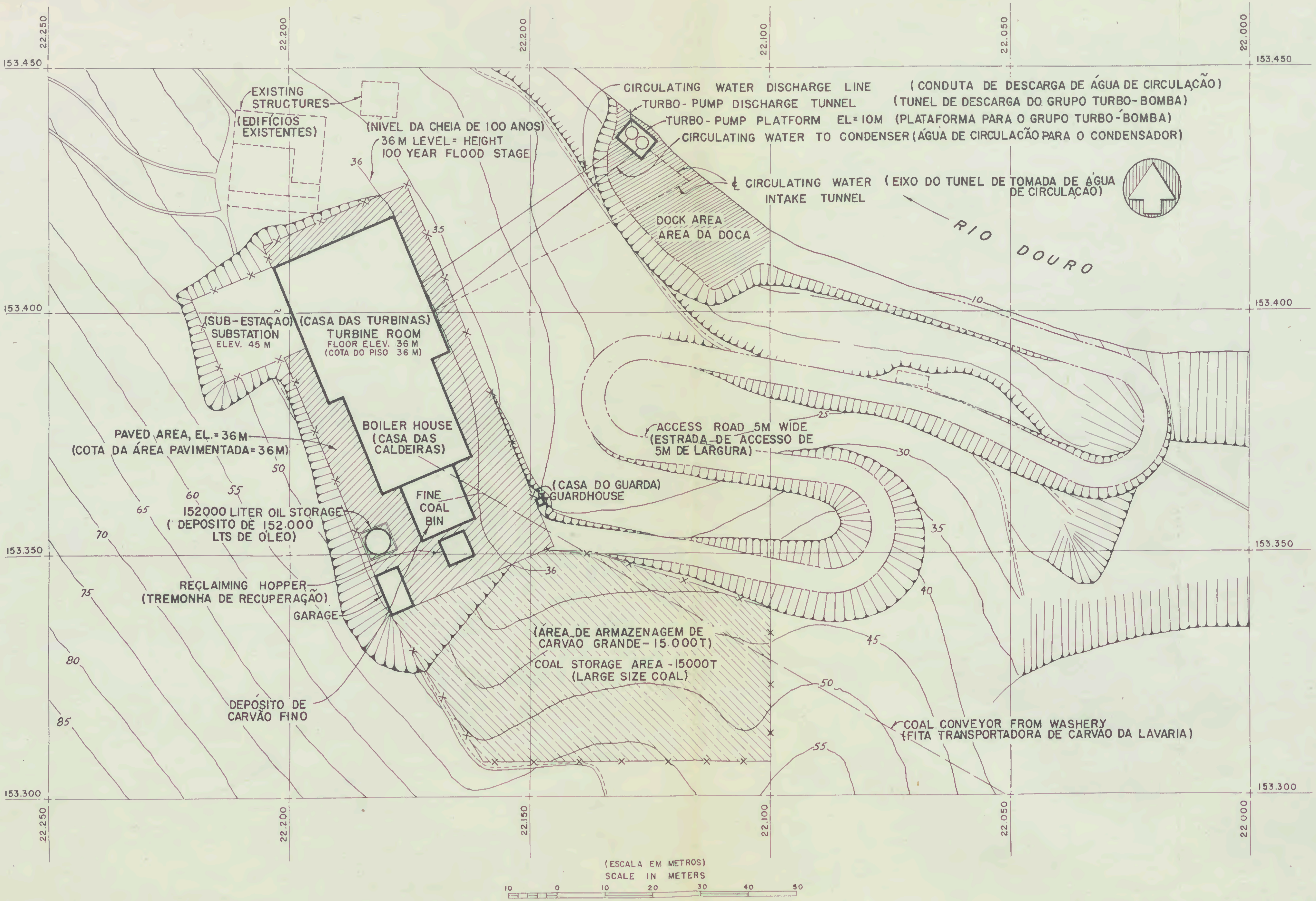
MARCH 1953

PLATE 12



NOTE:
CONTOURS SHOWN ARE EXISTING.

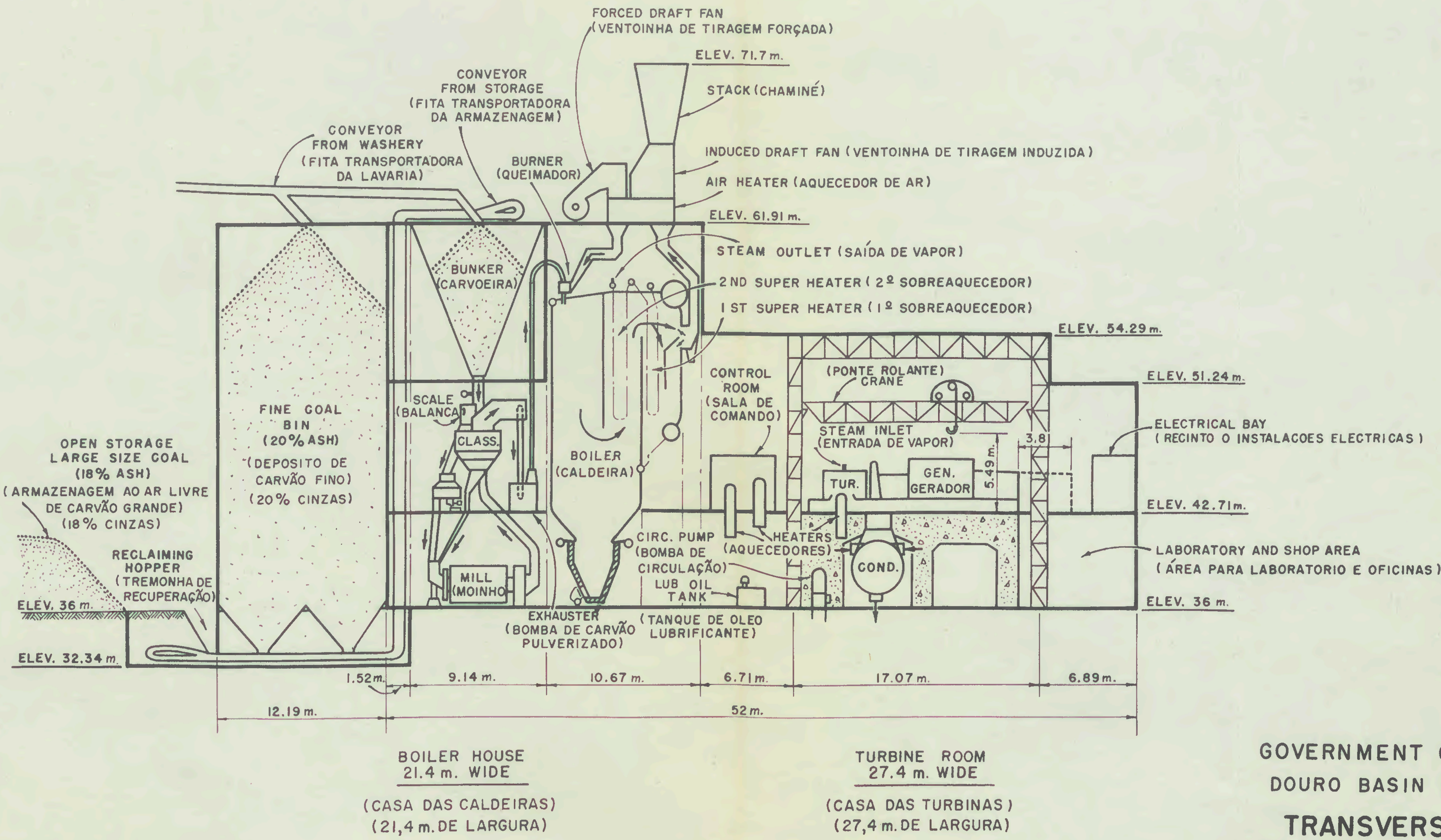
OBSERVAÇÃO:
AS CURVAS DE NÍVEL REPRESENTAM O TERRENO EXISTENTE

GOVERNMENT OF PORTUGAL
DOURO BASIN DEVELOPMENT

PROPOSED SITE LAYOUT
PEJÃO THERMAL PLANT UTILIZING UNWASHED MINE FINES (20 % ASH)

KNAPPEN TIPPETTS ABBETT McCARTHY
ENGINEERS NEW YORK, N.Y.

MARCH 1953 PLATE 13



GOVERNMENT OF PORTUGAL
DOURO BASIN DEVELOPMENT

TRANSVERSE VIEW

PEJÃO THERMAL PLANT UTILIZING UNWASHED MINE FINES (20% ASH)

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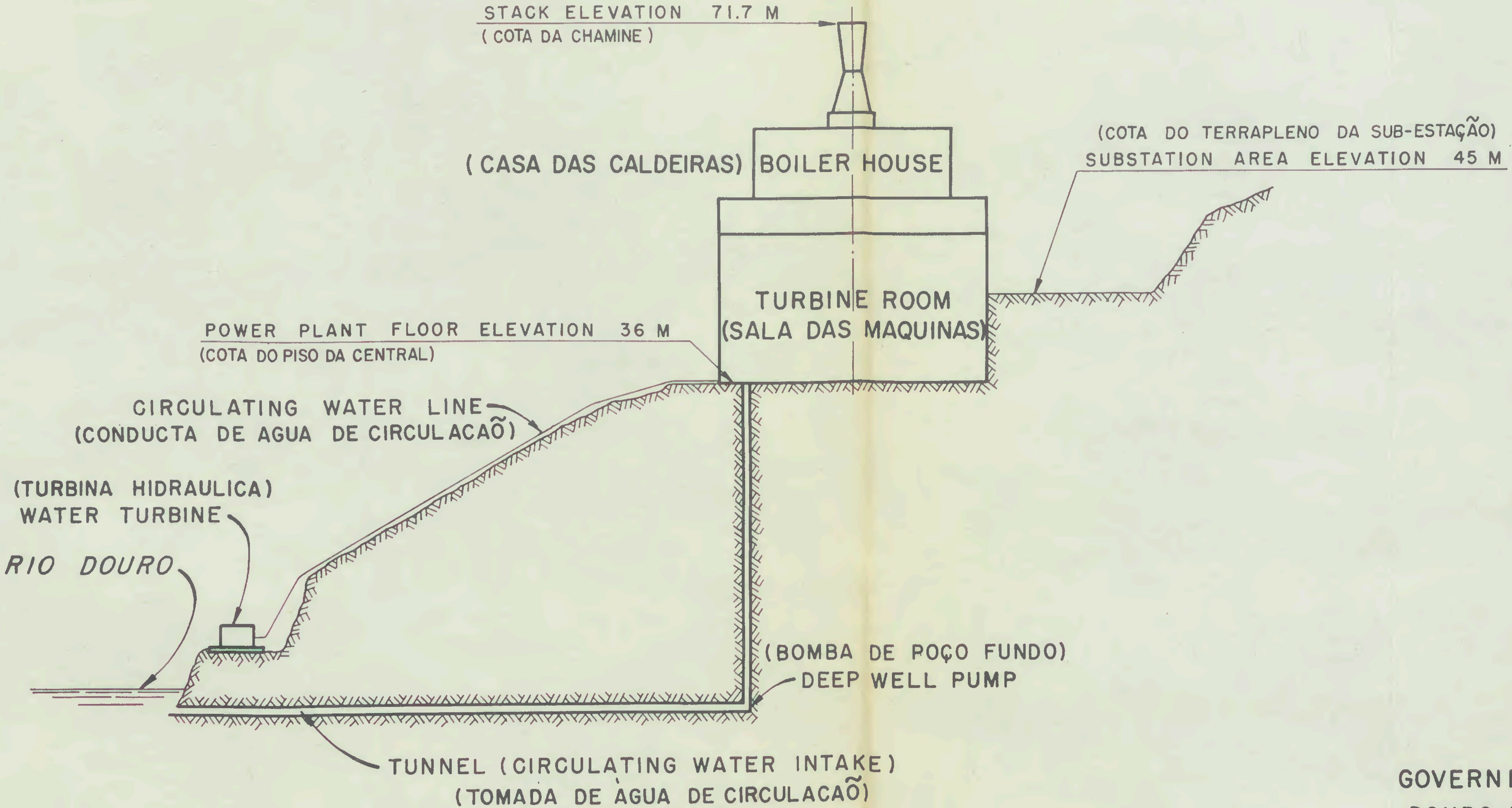
MARCH 1953 — PLATE 14



PROFILE

ALONG CIRCULATING WATER INTAKE LOOKING SOUTH

(PERFIL)

(SEGUNDO A TOMADA DE AGUA DE CIRCULACÃO, OLHANDO PARA SUL)

GOVERNMENT OF PORTUGAL

DOURO BASIN DEVELOPMENT

SECTIONAL PROFILE

PEJAO THERMAL PLANT UTILIZING UNWASHED MINE FINES (20% ASH)

KNAPPEN TIPPETTS ABBETT McCARTHY
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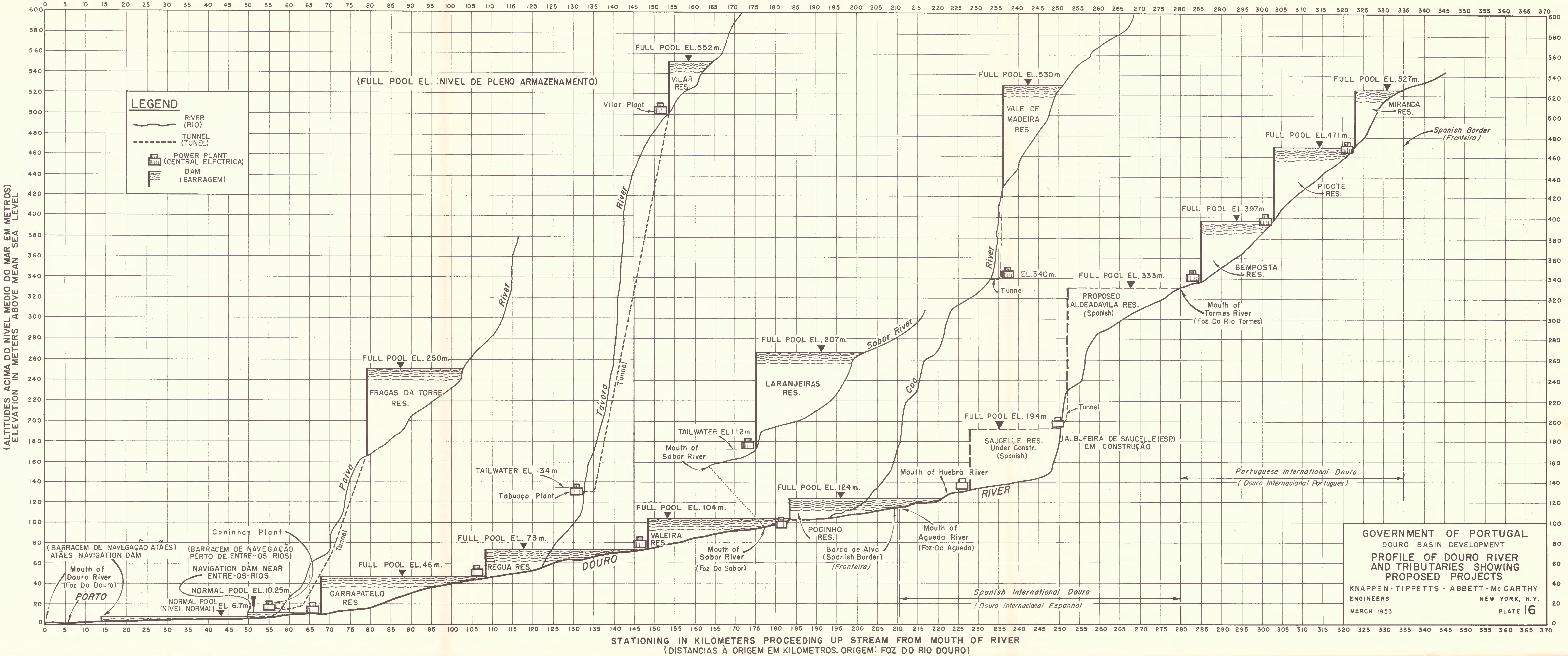
MARCH 1953

PLATE 15



(FULL POOL EL.: NIVEL DE PLENO ARMAZENAMENTO)
LEGEND
RIVER (RIO)
TUNNEL (TUNEL)
POWER PLANT (CENTRAL ELECTRICA)
DAM (BARRAGEM)
(ALTITUDES ACIMA DO NIVEL MEDIO DO MAR EM METROS)
ELEVATION IN METERS ABOVE MEAN SEA LEVEL
FULL POOL EL. 552m.
VILAR RES.
Vilar Plant
River
Tavora
Tunnel
FULL POOL EL. 250m.
FRAGAS DA TORRE RES.
River
Paiva
Tunnel
TAILWATER EL. 134m.
Tabuaço Plant
FULL POOL EL. 207m.
Sabor River
LARANJEIRAS RES.
TAILWATER EL. 112m.
Mouth of Sabor River
FULL POOL EL. 530m
VALE DE MADEIRA RES.
River
Coa
EL. 340m.
Tunnel
FULL POOL EL. 333m.
PROPOSED ALDEADAVILA RES. (Spanish)
Mouth of Tormes River (Foz Do Rio Tormes)
FULL POOL EL. 194m.
SAUCELLE RES. Under Constr. (Spanish)
Tunnel
(ALBUFEIRA DE SAUCELLE (ESP.) EM CONSTRUÇÃO
FULL POOL EL. 527m.
MIRANDA RES.
Spanish Border (Fronteira)
FULL POOL EL. 471m.
PICOTE RES.
FULL POOL EL. 397m
BEMPOSTA RES.
Portuguese International Douro (Douro Internacional Portugues)
Mouth of Huebra River
RIVER
FULL POOL EL. 124m.
POCINHO RES.
Barca de Alva (Spanish Border) (Fronteira)
Mouth of Agueda River (Foz Do Agueda)
Spanish International Douro (Douro Internacional Espanhol)
FULL POOL EL. 104m.
VALEIRA RES.
Mouth of Sabor River (Foz Do Sabor)
FULL POOL EL. 73m.
REGUA RES.
DOURO
FULL POOL EL. 46m.
CARRAPATELO RES.
Caninhas Plant
(BARRACEM DE NAVEGAÇÃO PERTO DE ENTRE-OS-RIOS)
NAVIGATION DAM NEAR ENTRE-OS-RIOS
NORMAL POOL EL. 10.25m.
NORMAL POOL (NIVEL NORMAL) EL. 6.7m.
(BARRACEM DE NAVEGAÇÃO ATÃES)
ATÃES NAVIGATION DAM
Mouth of Douro River (Foz Do Douro)
PORTO
STATIONING IN KILOMETERS PROCEEDING UP STREAM FROM MOUTH OF RIVER
(DISTANCIAS À ORIGEM EM KILOMETROS. ORIGEM: FOZ DO RIO DOURO)
GOVERNMENT OF PORTUGAL
DOURO BASIN DEVELOPMENT
PROFILE OF DOURO RIVER AND TRIBUTARIES SHOWING PROPOSED PROJECTS
KNAPPEN · TIPPETTS · ABBETT · McCARTHY
ENGINEERS
NEW YORK, N.Y.
MARCH 1953
PLATE 16


PLAN OF RESERVOIR
(PLANTA DA ALBUFEIRA)
PICOTE PROJECT
WATER SURFACE AREA IN SQUARE KILOMETERS
(AREAS INUNDADAS EM KM²)
4
3
2
1
510
490
470
450
430
410
390
370
WATER SURFACE ELEVATION IN METERS
(NIVEL DE AGUA EM METROS)
AREA
(AREA)
CAPACITY
(CAPACIDADE)
0
20
40
60
80
100
120
140
160
180
200
220
240
CAPACITY IN MILLION CUBIC METERS
(VOLUMES ARMAZENADOS EM M³)
RESERVOIR AREA AND CAPACITY CURVES
(CURVAS DAS AREAS INUNDADAS E CAPACIDADES DA ALBUFEIRA)
FULL POOL ELEVATION 471 m
(NIVEL DE PLENO ARMAZENAMENTO 471 m)
FULL POOL ELEVATION 471 m
(NIVEL DE PLENO ARMAZENAMENTO 471 m)
FULL POOL ELEVATION 471 m
(NIVEL DE PLENO ARMAZENAMENTO 471 m)
FULL POOL ELEVATION 471 m
(NIVEL DE PLENO ARMAZENAMENTO 471 m.
MATCH LINE
(LINHA DE COINCIDÊNCIA)
MATCH LINE
(LINHA DE COINCIDÊNCIA)
SCALE IN METERS
100
0
500
1000
KNAPPEN · TIPPETTS · ABBETT · McCARTHY
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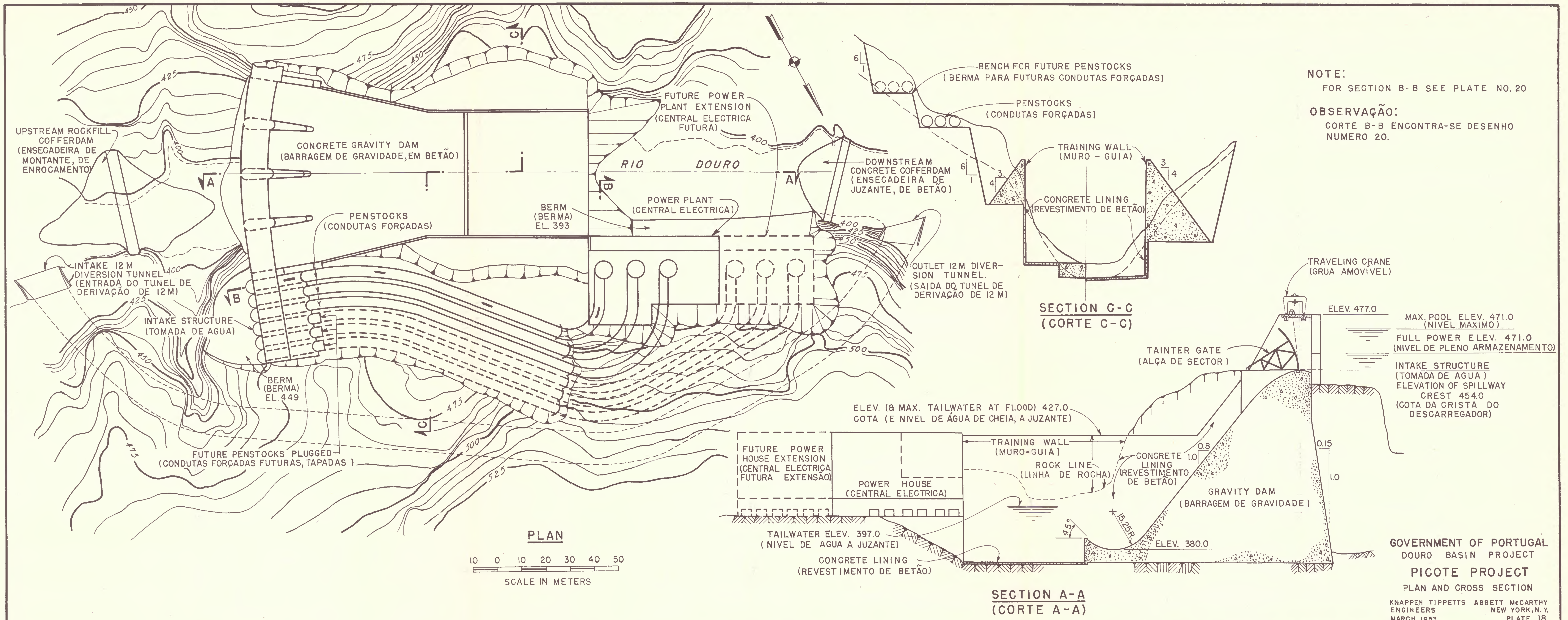
NEW YORK, N.Y.
MARCH 1953
PLATE 17

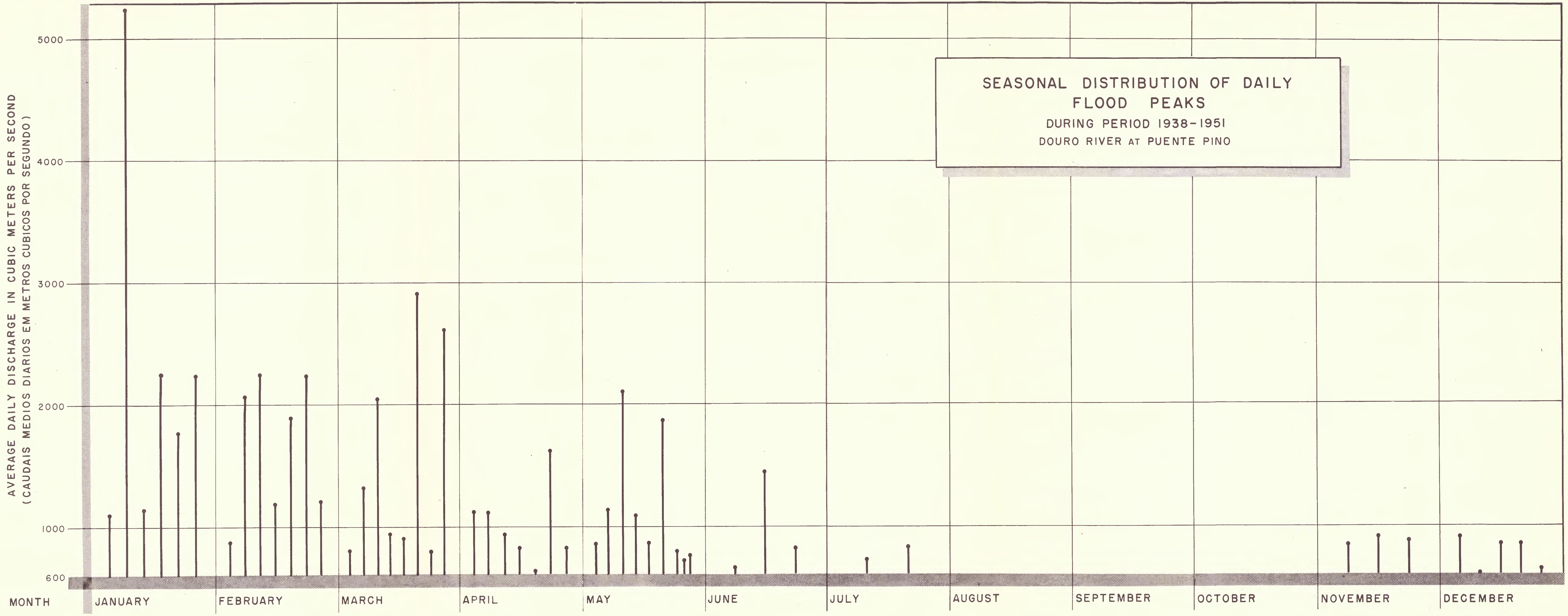


GOVERNMENT OF PORTUGAL
DOURO BASIN PROJECT

PICOTE PROJECT

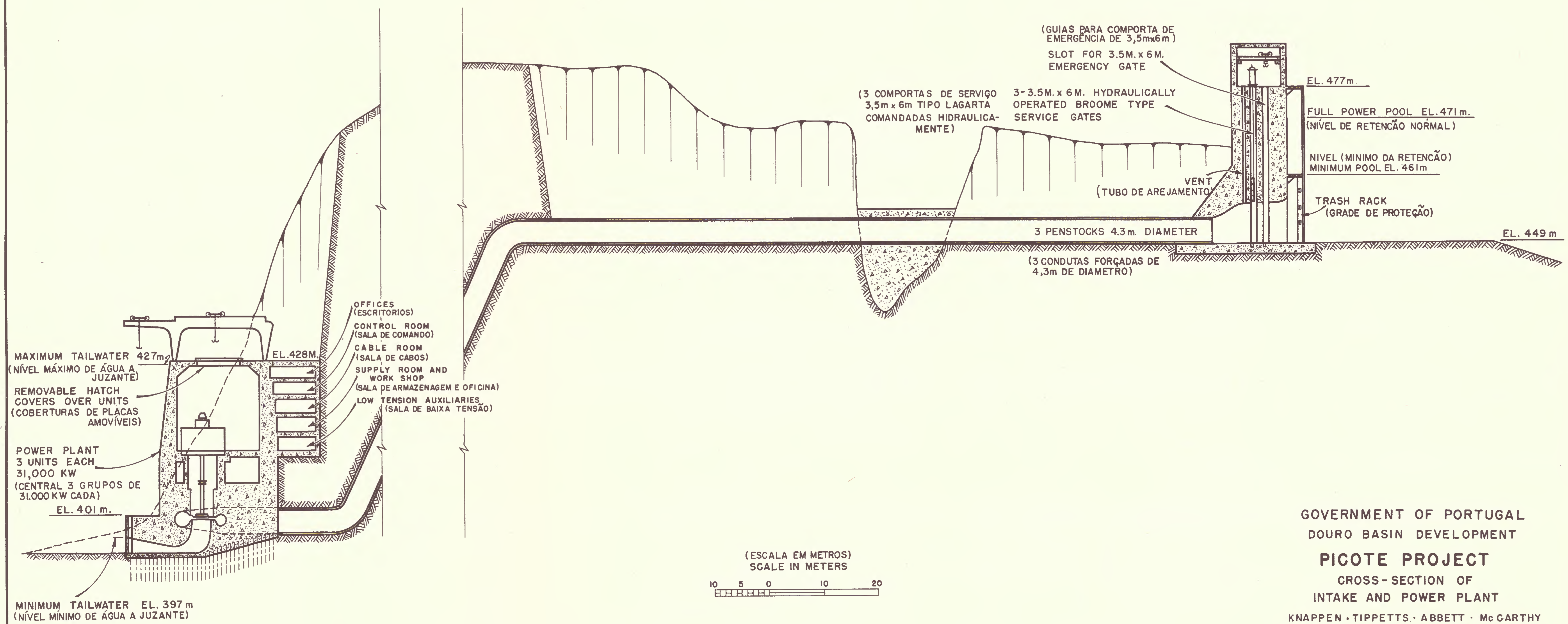
PLAN AND CROSS SECTION

KNAPPEN TIPPETTS ABBETT McCARTHY ENGINEERS NEW YORK, N.Y.
MARCH 1953 PLATE 18



NOTE: DRAINAGE AREA 63,300 KM²
OBSERVAÇÃO: ÀREA DA BACIA HIDROGRAFICA 63,300 KM²

KNAPPEN TIPPETTS ABBETT McCARTHY
ENGINEERS
NEW YORK, N.Y.
MARCH 1953



GOVERNMENT OF PORTUGAL

DOURO BASIN DEVELOPMENT

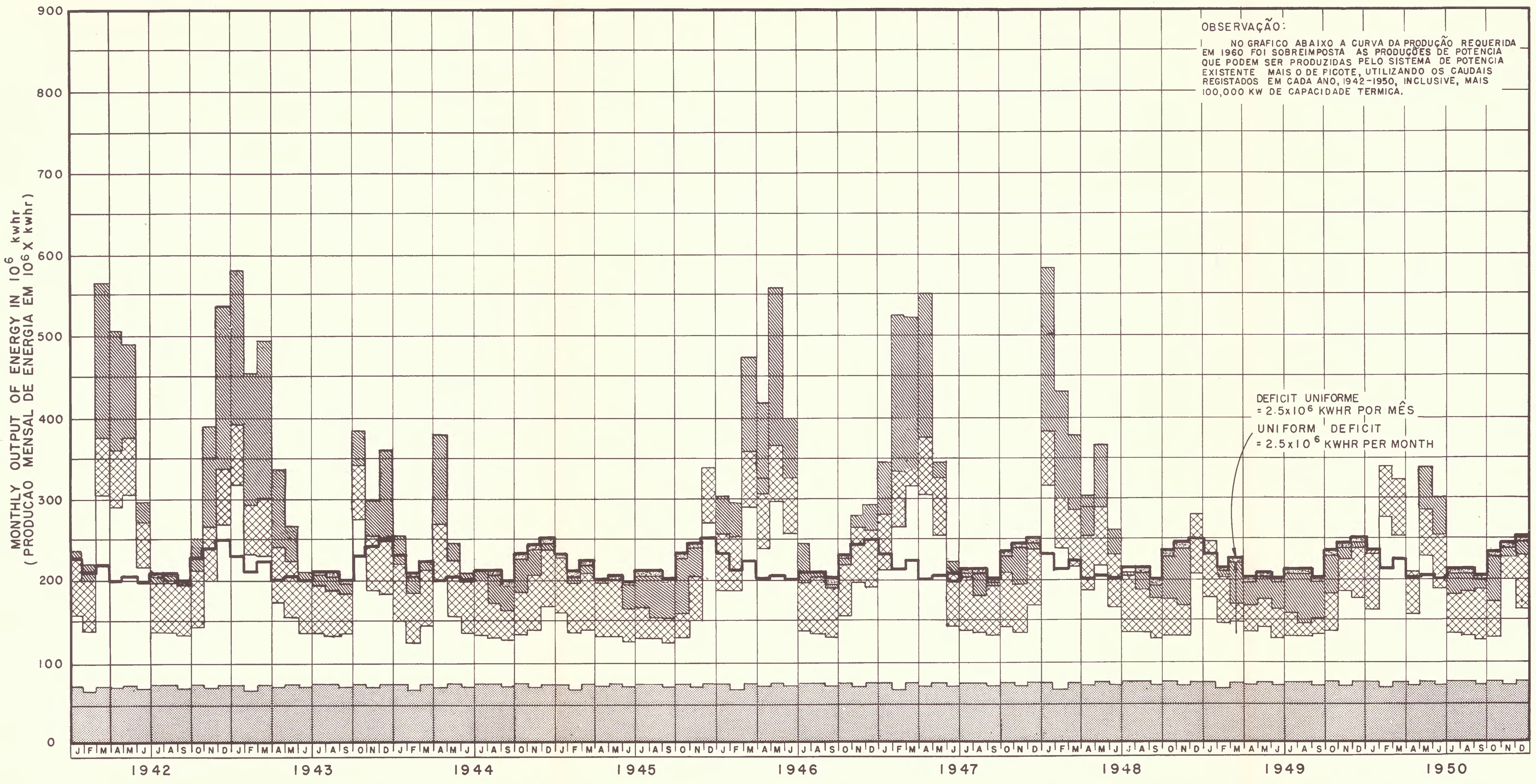
PICOTE PROJECT

CROSS-SECTION OF INTAKE AND POWER PLANT

KNAPPEN · TIPPETTS · ABBETT · McCARTHY

ENGINEERS NEW YORK, N.Y.

MARCH 1953 PLATE 20



LEGEND

ZEZERE OUTPUT
(PRODUÇÃO DO ZEZERE)

DEFICIT

PICOTE OUTPUT *
(PRODUÇÃO DE PICOTE)

STEAM OUTPUT, * *
(PRODUÇÃO TERMICA)

OUTPUT FROM EXISTING HYDROELECTRIC PLANTS EXCLUDING ZEZERE
(PRODUÇÃO DAS CENTRAIS HIDRAULICAS EXISTENTES EXCLUINDO ZEZERE)

1960 REQUIREMENT * * *
(DEMANDA EM 1960)

* PLANT WITH INSTALLED CAPACITY OF 93,000 KW AT 74 METER HEAD.
(CENTRAL COM 93,000 KW CAPACIDADE INSTALADA, 74 METROS DE QUEDA)

* * 100,000 KW INSTALLED
(INSTALADOS)

* * * INCLUDING AMMONIUM SULPHATE PLANTS,
(INCLUINDO FÁBRICAS DE SULFATO DE AMÓNIO)

NOTE: IN THE FOREGOING GRAPH, THE CURVE OF THE 1960 POWER REQUIREMENT IS SUPERIMPOSED IN TURN UPON THE POWER OUTPUTS THAT COULD BE PRODUCED BY THE EXISTING POWER SYSTEM, PLUS PICOTE, UTILIZING THE STREAM FLOWS EXPERIENCED IN EACH OF THE YEARS, 1942-1950 INCLUSIVE, PLUS 100,000 KW. OF THERMAL CAPACITY.

GOVERNMENT OF PORTUGAL
DOURO BASIN DEVELOPMENT

OUTPUT OF SYSTEM INCLUDING PICOTE
AFTER ZEZERE REREGULATION

KNAPPEN TIPPETTS ABBETT McCARTHY
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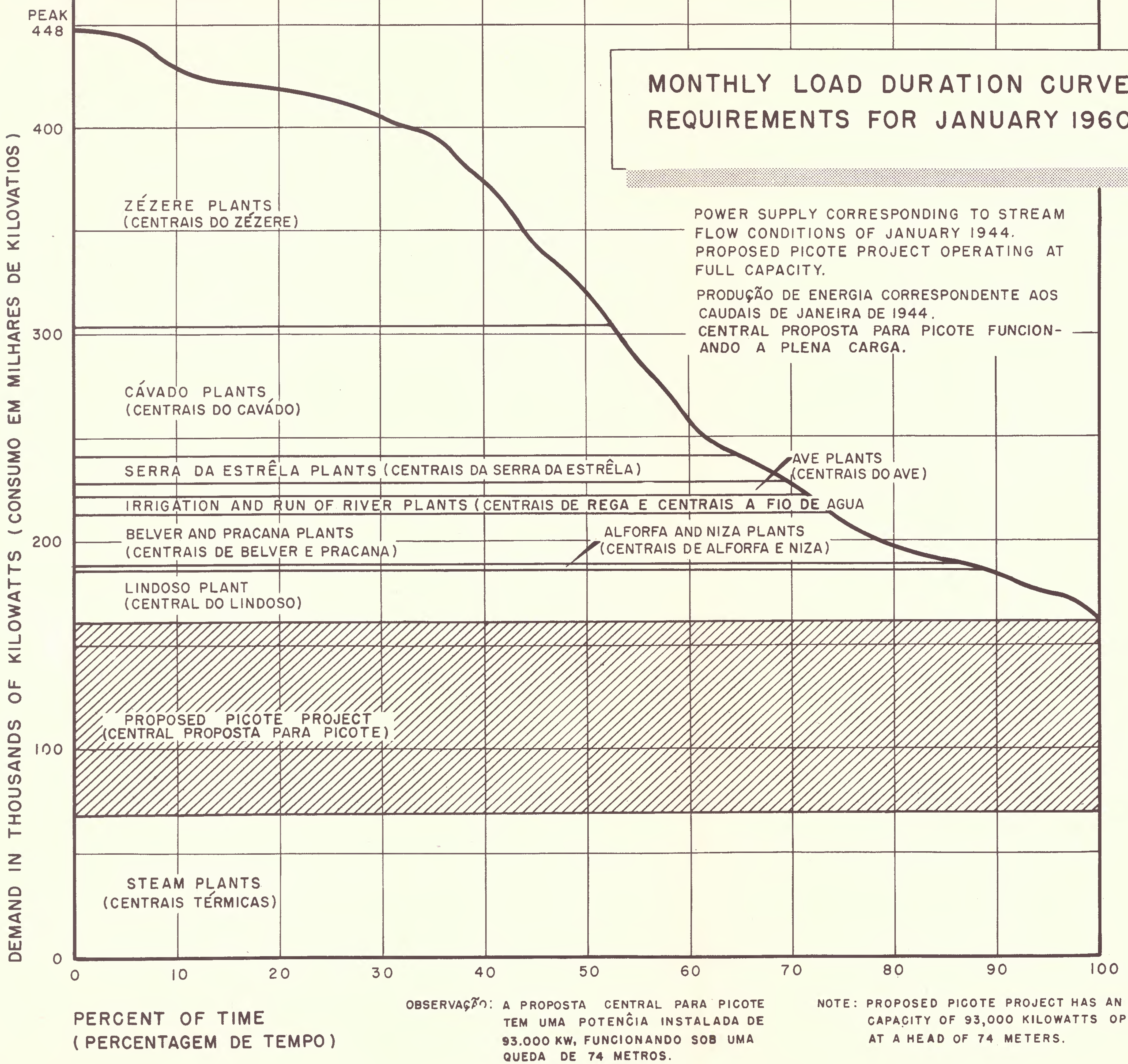
NEW YORK, N.Y.

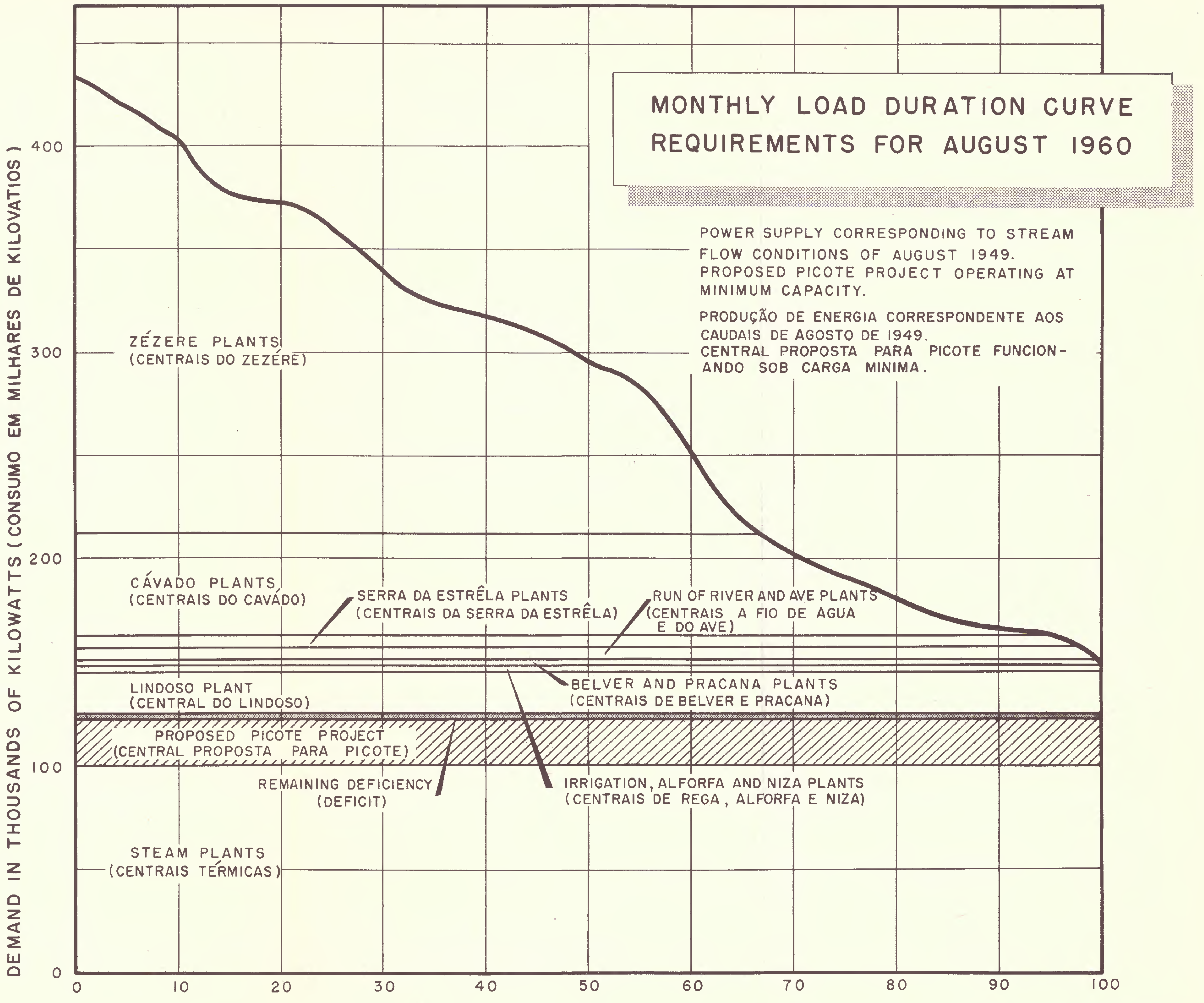
MARCH 1953

PLATE 21



OBSERVAÇÃO: A PROPOSTA CENTRAL PARA PICOTE TEM UMA POTENCIA INSTALADA DE 93.000 KW, FUNCIONANDO SOB UMA QUEDA DE 74 METROS.

NOTE: PROPOSED PICOTE PROJECT HAS AN INSTALLED CAPACITY OF 93,000 KILOWATTS OPERATING AT A HEAD OF 74 METERS.



PERCENT OF TIME
(PERCENTAGEM DE TEMPO)

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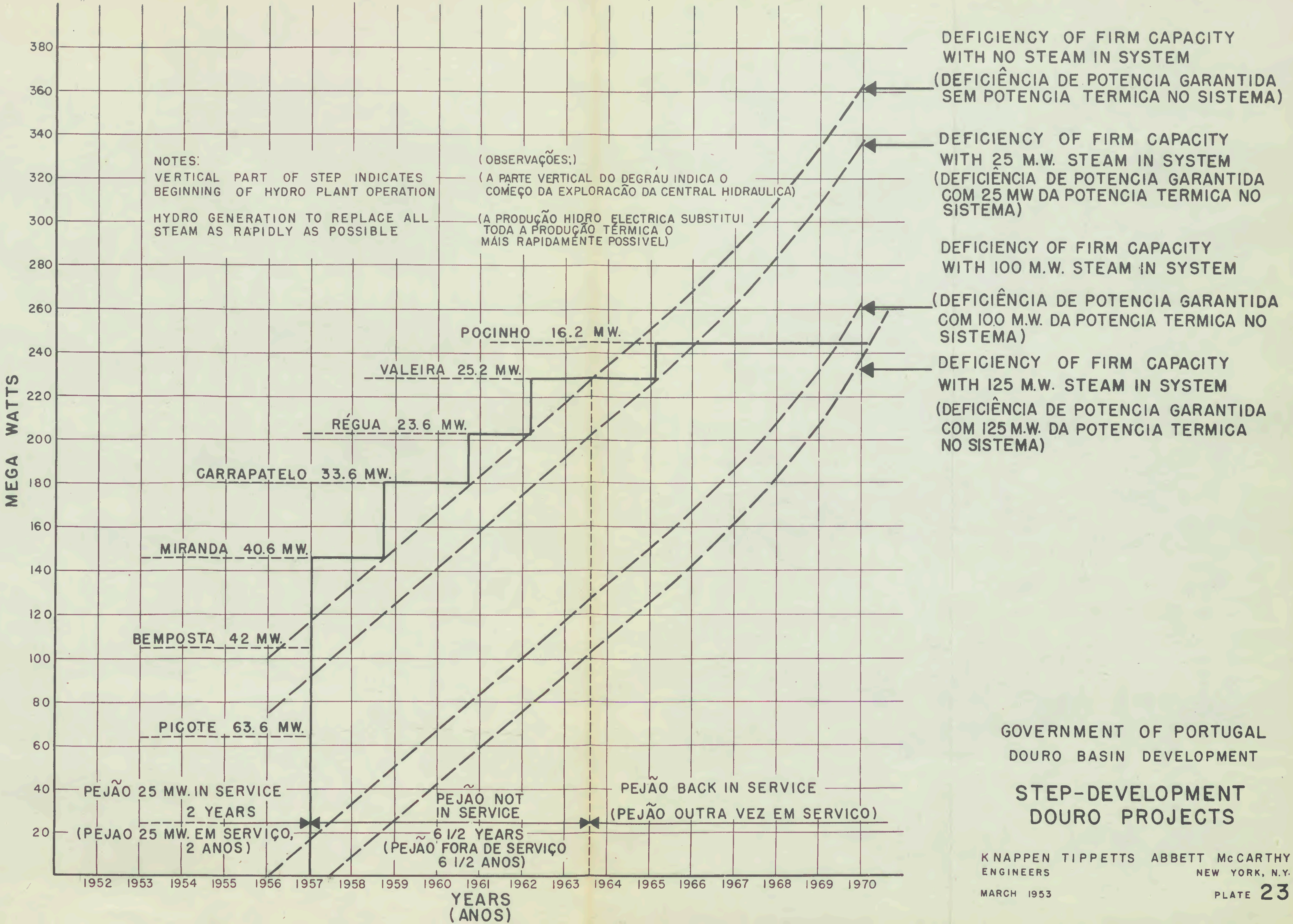
MARCH 1953



GOVERNMENT OF PORTUGAL

DOURO BASIN DEVELOPMENT

STEP-DEVELOPMENT DOURO PROJECTS

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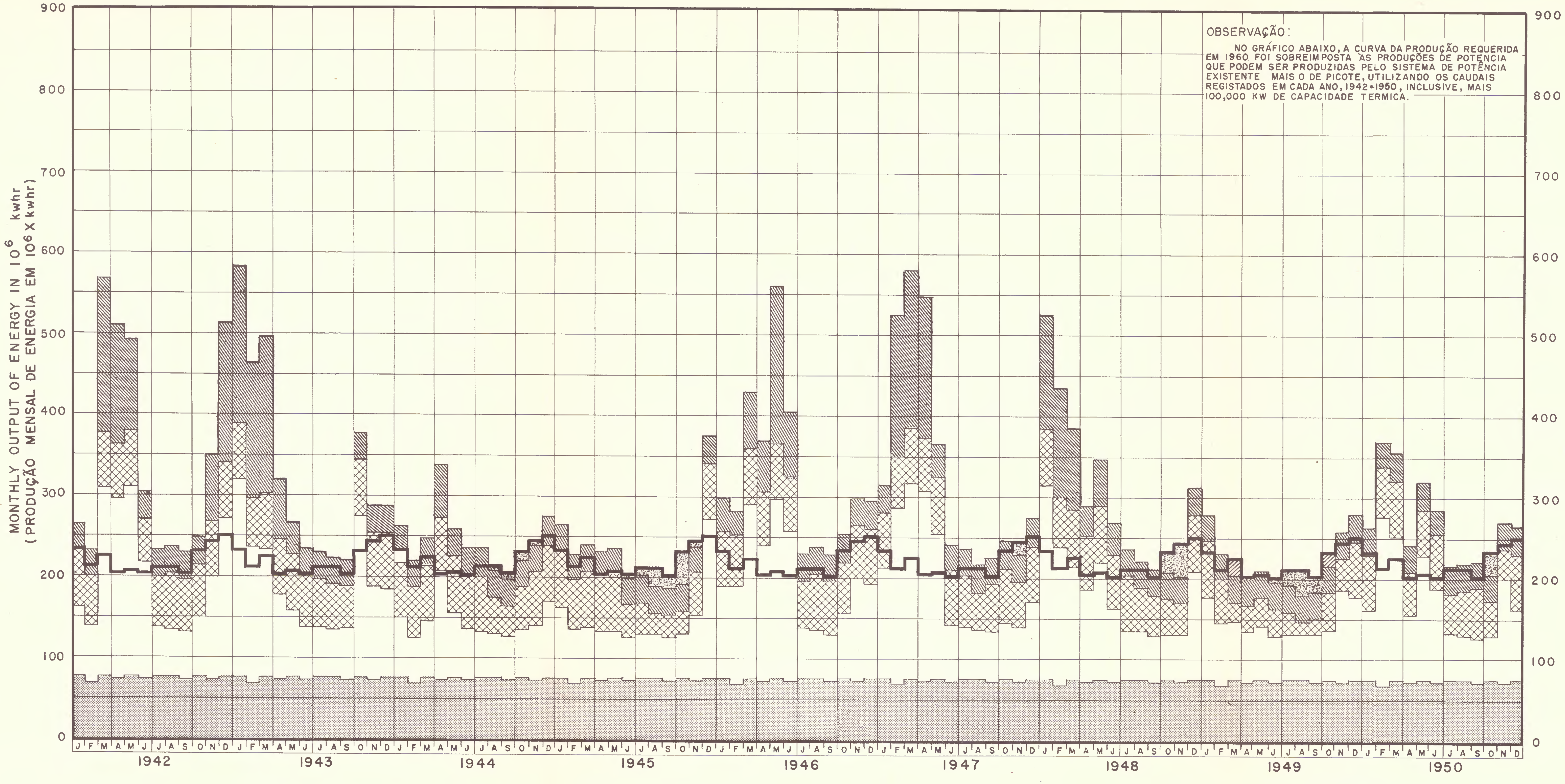
NEW YORK, N.Y.

MARCH 1953

PLATE 23



LEGEND

ZÉZERE OUTPUT
(PRODUÇÃO DO ZÉZERE)

DEFICIT

PICOTE OUTPUT *
(PRODUÇÃO DE PICOTE)

STEAM OUTPUT * *
(PRODUÇÃO TÉRMICA)

OUTPUT FROM EXISTING HYDROELECTRIC PLANTS EXCLUDING ZÉZERE
(PRODUÇÃO DAS CENTRAIS HIDRÁULICAS EXISTENTES EXCLUINDO ZÉZERE)

1960 REQUIREMENT * * *
(DEMANDA EM 1960)

* PLANT WITH INSTALLED CAPACITY OF 93,000 KW AT 74 METER HEAD
(CENTRAL COM 93,000 KW CAPACIDADE INSTALADA, 74 METROS DE QUEDA)

* * 100,000 KW INSTALLED
(INSTALADOS)

* * * INCLUDING AMMONIUM SULPHATE PLANTS
(INCLUINDO FÁBRICAS DE SULFATO DE AMÓNIO)

NOTE: IN THE FOREGOING GRAPH, THE CURVE OF THE 1960 POWER REQUIREMENT IS SUPERIMPOSED IN TURN UPON THE POWER OUTPUTS THAT COULD BE PRODUCED BY THE EXISTING POWER SYSTEM, PLUS PICOTE, UTILIZING THE STREAM FLOWS EXPERIENCED IN EACH OF THE YEARS, 1942-1950 (INCLUSIVE), PLUS 100,000 KW OF THERMAL CAPACITY

GOVERNMENT OF PORTUGAL
DOURO BASIN DEVELOPMENT

OUTPUT OF SYSTEM INCLUDING PICOTE
BEFORE ZEZERE REREGULATION

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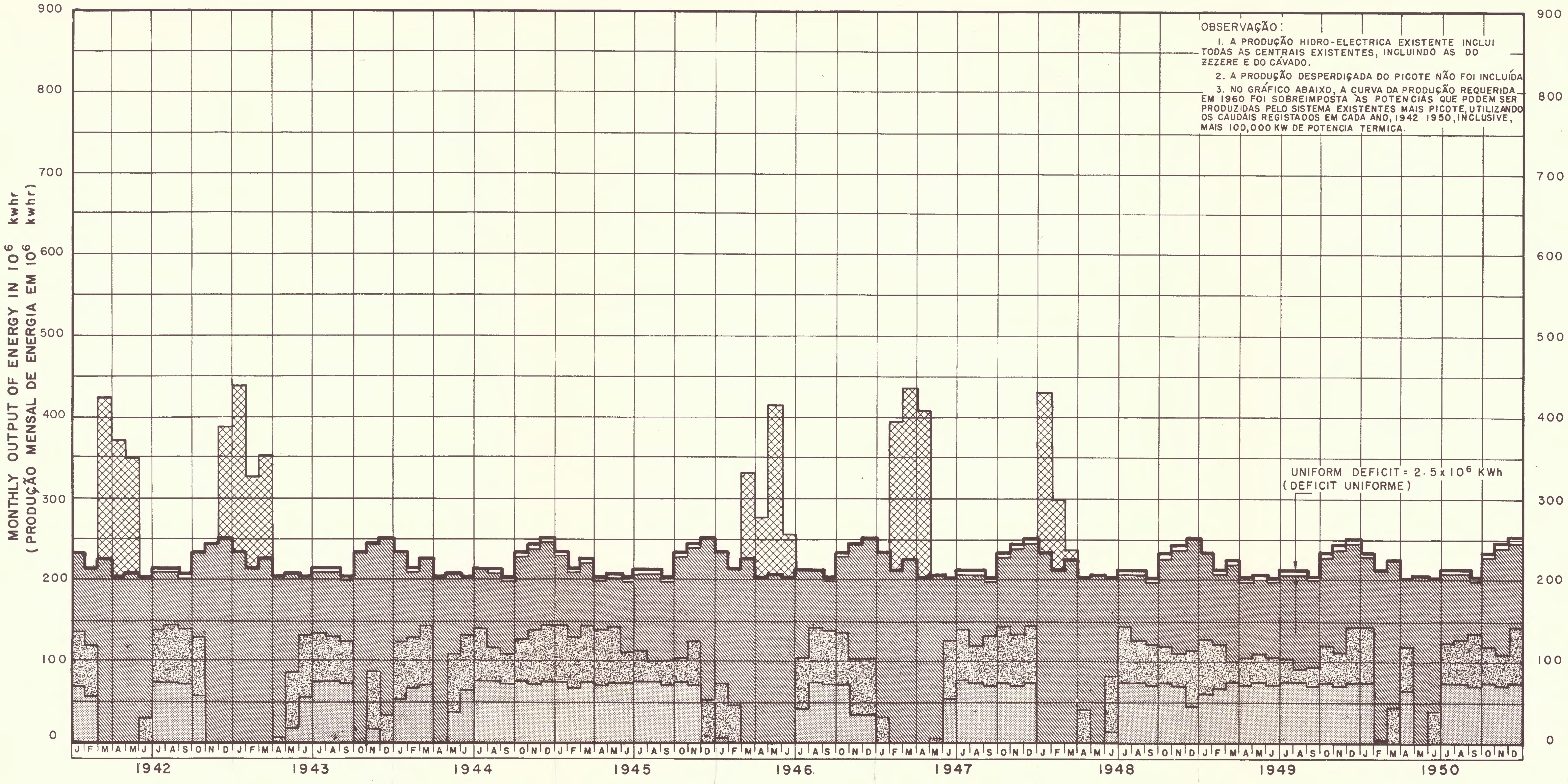
MARCH 1953 PLATE 24



LEGEND

DEFICIT
(DEFICIT)

WASTED OUTPUT FROM EXISTING HYDROELECTRIC PLANTS
(PRODUÇÃO DESPERDIÇADA DAS CENTRAIS HIDRO-ELECTRICAS EXISTENTES)

USABLE OUTPUT FROM EXISTING HYDROELECTRIC PLANTS
(PRODUÇÃO UTILIZÁVEL DAS CENTRAIS HIDRO-ELECTRICAS EXISTENTES)

USABLE PICOTE OUTPUT *
(PRODUÇÃO UTILIZÁVEL DE PICOTE)

REQUIRED STEAM OUTPUT **
(PRODUÇÃO TERMICA EXIGIDA)

1960 REQUIREMENT ***
(PRODUÇÃO EXIGIDA EM 1960)

* PLANT WITH INSTALLED CAPACITY OF 93,000 KW AT 74 METER HEAD
(CENTRAL COM 93,000 KW DE POTENCIA INSTALADA SOB 74 METROS DE QUEDA)

** 100,000 KW INSTALLED
(100,000 KW INSTALADOS)

*** INCLUDING AMMONIUM SULPHATE PLANTS
(INCLUINDO AS FÁBRICAS DE SULFATO DE AMÓNIO)

NOTE:

1. THE EXISTING HYDROELECTRIC OUTPUT INCLUDES ALL EXISTING PLANTS, INCLUDING ZEZERE AND CAVADO.
2. THE WASTED PICOTE OUTPUT IS NOT SHOWN.
3. IN THE FOREGOING GRAPH, THE CURVE OF THE 1960 POWER REQUIREMENT IS SUPERIMPOSED IN TURN UPON THE POWER OUTPUTS THAT COULD BE PRODUCED BY THE EXISTING POWER SYSTEM PLUS PICOTE, UTILIZING THE STREAM FLOWS EXPERIENCED IN EACH OF THE YEARS, 1942–1950 INCLUSIVE, PLUS 100,000 KW OF THERMAL CAPACITY.

GOVERNMENT OF PORTUGAL
DOURO BASIN DEVELOPMENT

USABLE OUTPUT OF SYSTEM INCLUDING PICOTE
AFTER ZEZERE REREGULATION

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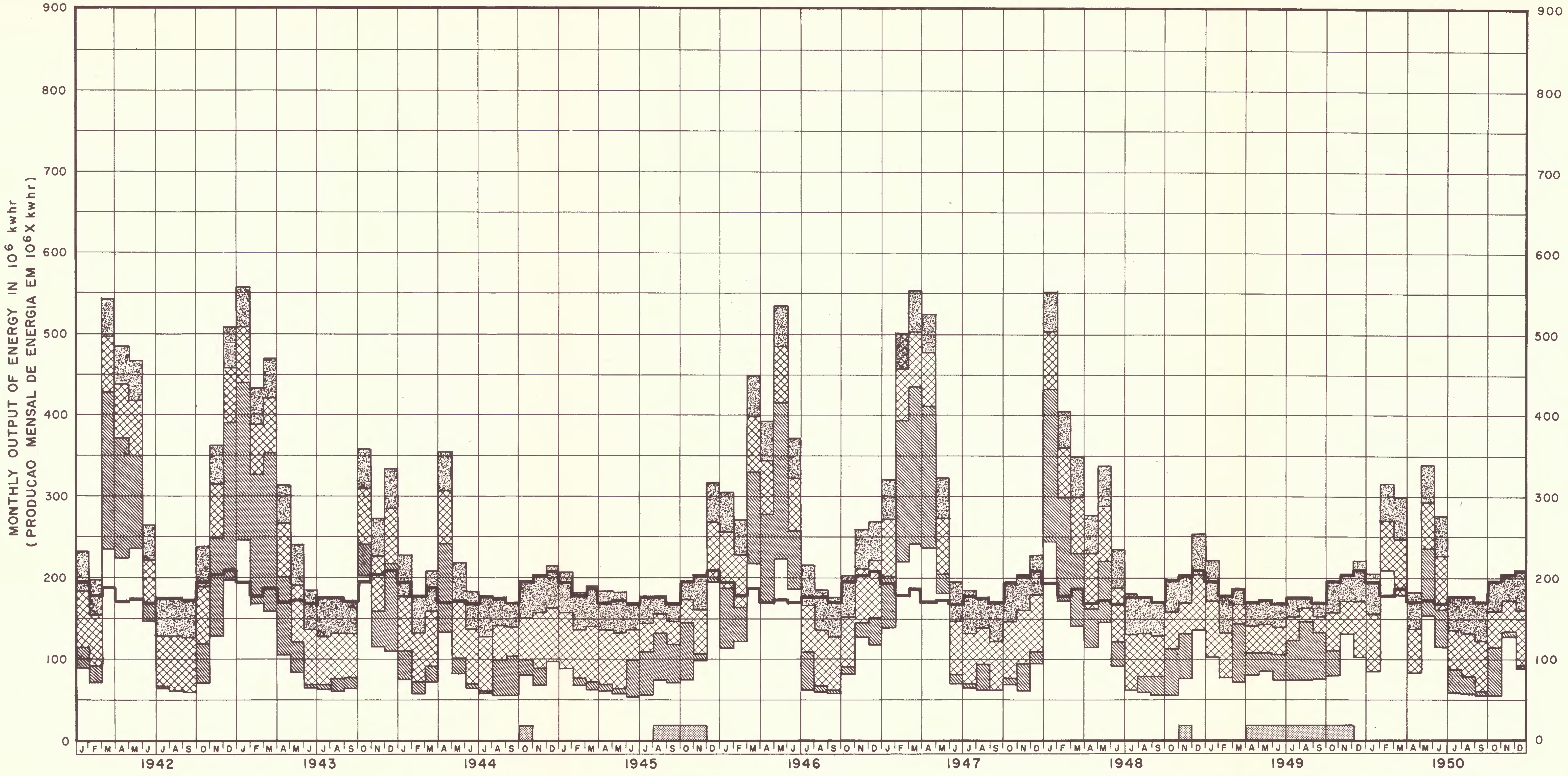
MARCH 1953

PLATE 25



LEGEND

BEMPOSTA OUTPUT (PRODUÇÃO DA BEMPOSTA)

PICOTE OUTPUT (PRODUÇÃO DO PICOTE)

ZEZERE OUTPUT (PRODUÇÃO DO ZÉZERE)

OUTPUT FROM EXISTING HYDROELECTRIC PLANTS (PRODUÇÃO DAS CENTRAIS HIDRAULICAS EXISTENTES)

OUTPUT FROM PEJAO STEAM PLANT (PRODUÇÃO DA CENTRAL TERMICA DO PEJÃO)

1957 REQUIREMENT * (PRODUÇÃO REQUERIDA EM 1957)

* INCLUDING AMMONIUM SULPHATE PLANTS (INCLUINDO AS FÁBRICAS DE SULFATO DE AMÓNIO)

NOTE:

IN THE FOREGOING GRAPH, THE CURVE OF THE 1957 POWER REQUIREMENT IS SUPERIMPOSED IN TURN UPON THE POWER OUTPUTS THAT COULD BE PRODUCED BY THE EXISTING POWER SYSTEM PLUS PICOTE AND BEMPOSTA, UTILIZING THE STREAM FLOWS EXPERIENCED IN EACH OF THE YEARS, 1942 - 1950 INCLUSIVE, PLUS THE 25,000 KW PEJAO THERMAL PLANT, WHICH IS USED ONLY WHEN NEEDED TO SATISFY THE REQUIREMENTS.

OBSERVAÇÃO:

NO GRÁFICO ABAIXO, A CURVA DA PRODUÇÃO REQUERIDA EM 1957 FOI SOBREIMPOSTA ÀS PRODUÇÕES DE POTENCIA QUE PODEM SER PRODUZIDAS PELO SISTEMA DE POTENCIA EXISTENTE ACRESCIDO DE PICOTE E BEMPOSTA UTILIZANDO OS CAUDAIS REGISTADOS EM CADA ANO, 1942 a 1950, INCLUSIVE, MAIS 25,000 KW DA CENTRAL TÉRMICA DO PEJÃO QUE SERÃO UTILIZADOS APENAS QUANDO NECESSÁRIOS PARA SATISFAZER OS REQUERIMENTOS.

GOVERNMENT OF PORTUGAL
DOURO BASIN DEVELOPMENT

OUTPUT OF SYSTEM INCLUDING PICOTE, BEMPOSTA AND PEJÃO THERMAL PLANT
BUT EXCLUDING EXISTING THERMAL CAPACITY AFTER ZEZERE REREGULATION

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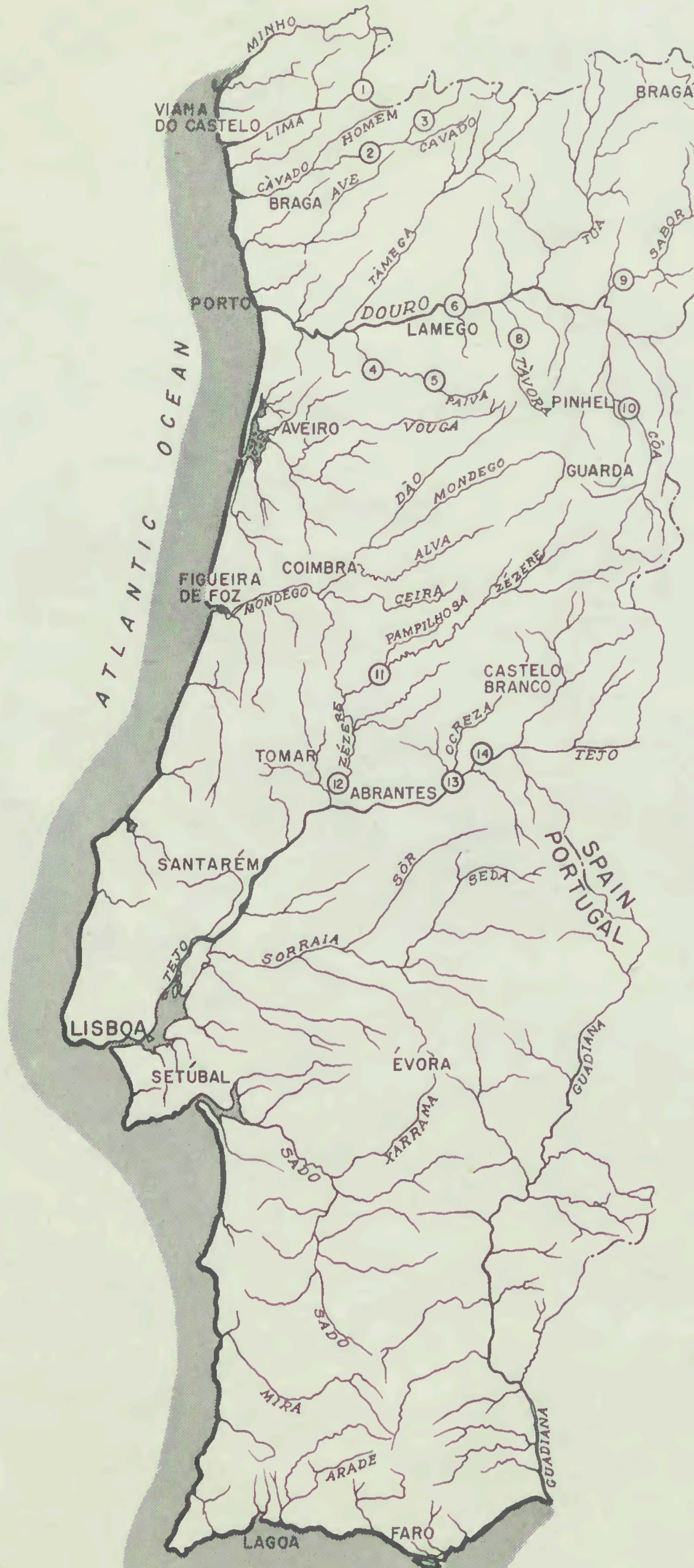
MARCH 1953

PLATE 26



LEGEND

1. LIMA RIVER AT LINDOSO
2. CÀVADO RIVER BELOW RIO CALDO
3. CÀVADO RIVER AT PARADELA
4. PAIVA RIVER AT FRAGAS DA TORRE
5. PAIVA RIVER AT CASTRO DAIRE
6. DOURO RIVER AT RÉGUA
7. DOURO RIVER AT PUENTE PINO
8. TÀVORA RIVER AT PONTE NOVA
9. SABOR RIVER AT LARANJEIRAS
10. CÔA RIVER AT VALE DO AREAL
11. ZÉZERE RIVER AT PONTE DO CABRIL
12. ZÉZERE RIVER AT CASTELO DO BODE
13. OCREZA RIVER AT PRACANA
14. TEJO RIVER AT VILA VELHA DE RODÃO

SCALE IN KILOMETERS
20 0 20 40 60 80 100

GOVERNMENT OF PORTUGAL
DOURO BASIN DEVELOPMENT

SELECTED RIVER GAGING STATIONS IN PORTUGAL AND SPAIN

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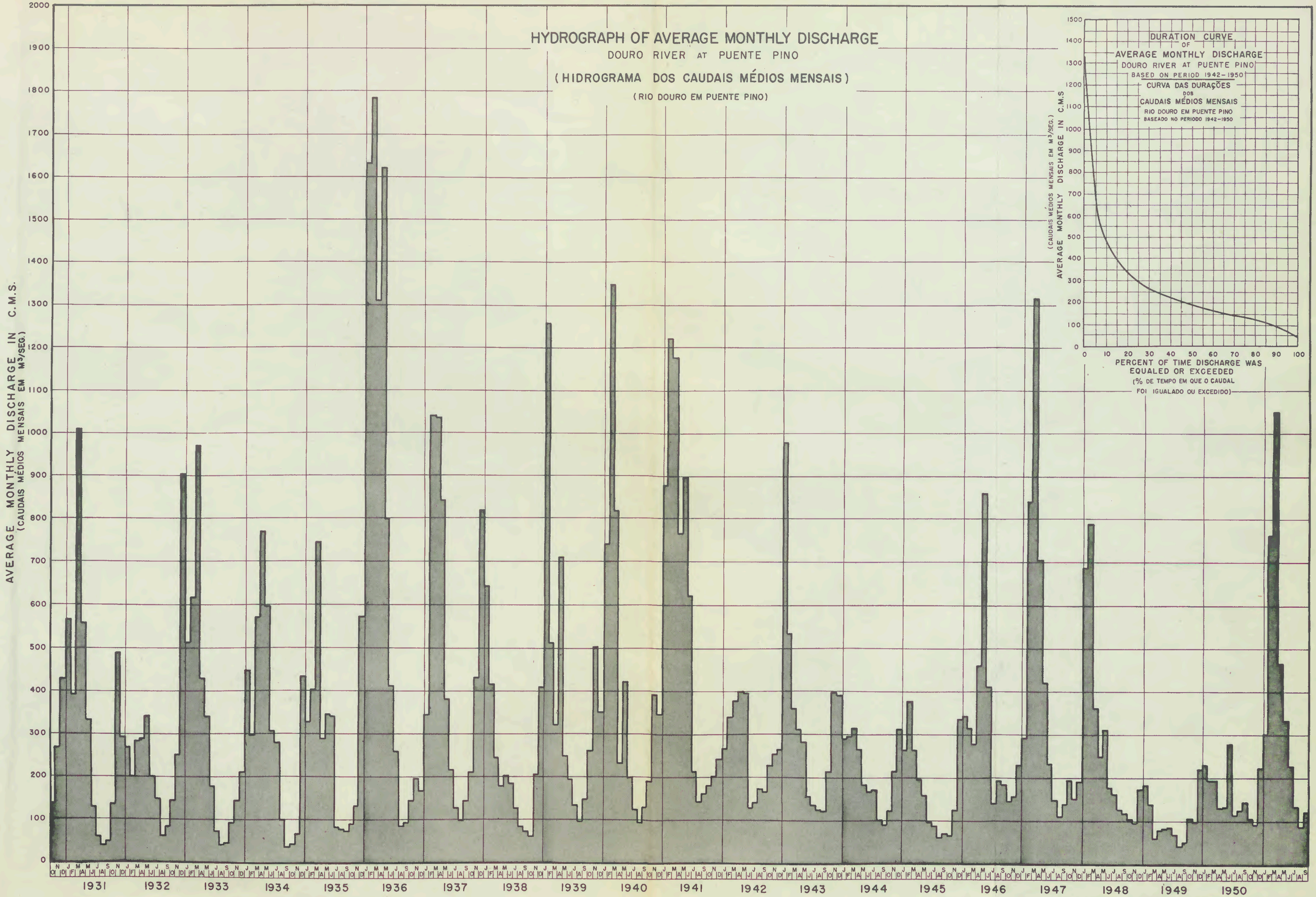
MARCH 1953 PLATE 27



NOTE: DRAINAGE AREA 63,300 KM²
(OBSERVAÇÃO: AREA DA BACIA HIDROGRÁFICA 63,300 KM²)

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ENGINEERS
NEW YORK, N.Y.
MARCH 1953
PLATE 28