Table D.15 Survey Costs

(× 1,000 HUF)

KOFE Code	Name of River	Site Area (m^2)	Plane Survey (m^2)	Cross Sectioning (m)	Direct Survey Cost (HUF)	Total Survey Cost (HUF)
E-1	Cinege patak	2,880	9,690	1,080	91	118
E-2	Fuzfoi sed	8,640	15,960	1,790	149	194
E-3	Vorosberenyi sed	38,560	51,490	5,370	470	611
	Lovasi sed	2,720	9,500	1,070	89	116
E-4	Csopaki sed	1,840	8,455	1,015	81	106
	Aracsi sed	2,032	8,683	1,027	83	108
	Keki patak	18,720	27,930	2,990	257	334
	Szolosi sed	55,520	71,630	7,570	657	854
	Tavi(Aszofoi sed)	3,120	9,975	1,095	93	121
E-5	Orvenyesi sed	7,680	14,820	1,730	141	183
E-6	Csorszai patak	6,080	12,920	1,440	121	157
	Horogi sed	2,720	9,500	1,070	89	116
E-7	Burnot patak	51,520	66,880	6,940	609	792
E-8	Eger patak	36,640	49,210	5,250	453	589
E-9	Tapolca patak	25,600	36,100	3,990	336	437
E-10	Ketoles patak	2,720	9,500	1,070	89	116
	Vilagos patak	2,032	8,683	1,027	83	108
	Lesence patak	5,600	12,350	1,410	116	151
	Nemesvital ovarok	31,680	43,320	4,560	397	516
D-1	Endredi patak	8,640	15,960	1,790	149	194
D-2	Koroshegyi sed	12,640	20,710	2,230	191	249
D-3	Nagymetszes patak	51,520	66,880	7,130	615	800
D-4	Tetves patak	73,600	93,100	9,650	848	1,103
	A-B-Ccsatorna	3,120	9,975	1,285	98	128
D-5	Forro arok	2,320	9,025	1,045	86	111
	Jamai patak	15,200	23,750	2,580	220	286
D-6	Keleti-Nyugati-Focsatorna	14,720	23,180	2,550	216	280
	Keleti bozot	114,400	141,550	14,670	1,289	1,676
D-7	Nyugati ovcsatorna	102,400	127,300	13,160	1,159	1,506
Pumping Station	Balatonfenyves	86,560	108,490	11,220	988	1,284
	Balatonlelle	28,000	38,950	4,140	358	465
	Ordacsehi	37,600	50,350	5,310	461	600
	Beletelep	24,640	34,960	3,740	322	419
TOTAL						14,826

Note: Total survey costs include overhead costs of 30 % of the direct survey costs.

Table D.16 Breakdown of Project Cost (F/S)

(x 1,000 HUF)

Name of River	Design Flow Rate (m^3/sec)	Land Acquisition Cost	Direct Construction Costs				Survey Cost	Operation Cost
			L/C portion		F/C portion	Subtotal		
			(1st year)	(2nd year)				
Nyugati ovcsatorna (Vegetation purification method)	1.01	0	150,545	223,074	30,280	403,898	1,506	27,760
Keleti bozot (Vegetation purification method)	1.13	0	155,392	232,320	24,260	411,972	1,676	31,022
Keszthely Urban Runoff (Coagulation sedimentation method)	0.47	0	312,621	0	0	312,621	135	12,857
Total	–	0	618,558	455,394	54,540	1,128,491	3,317	71,639

Table D.17 Construction/Operation Costs by Year (Feasibility Study)

(× 1,000 HUF)

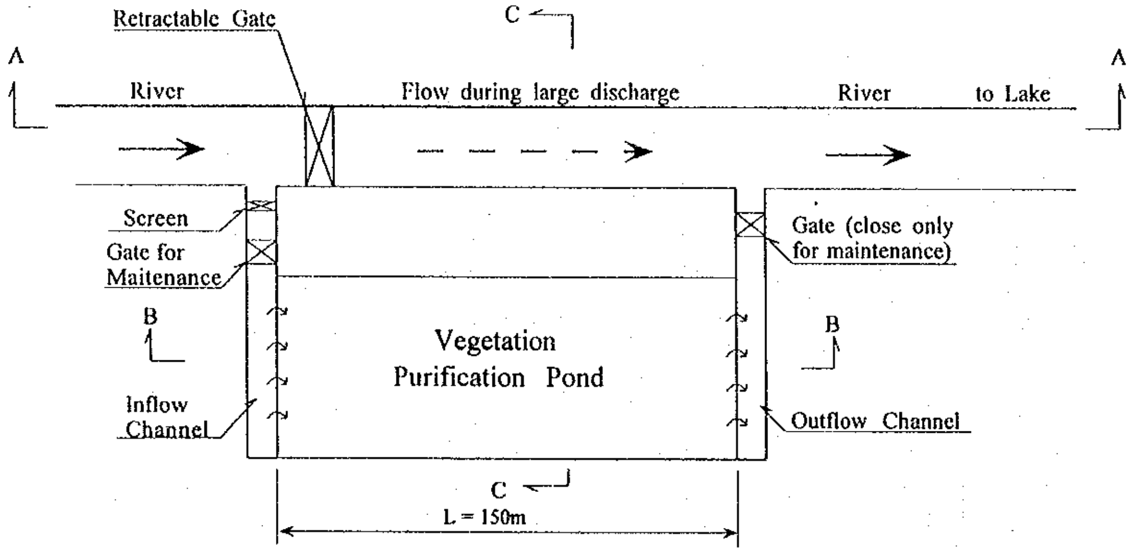
Name of River and Water Purification Facilities	2001 Construction Cost L/C	2001 Construction Cost F/C	2001 O/M Costs	2002 Construction Cost L/C	2002 Construction Cost F/C	2002 O/M Costs	2003 Construction Cost L/C	2003 Construction Cost F/C	2003 O/M Costs	2004 Construction Cost L/C	2004 Construction Cost F/C	2004 O/M Costs	2005 Construction Cost L/C	2005 Construction Cost F/C	2005 O/M Costs	2006 Construction Cost L/C	2006 Construction Cost F/C	2006 O/M Costs	2007 Construction Cost L/C	2007 Construction Cost F/C	2007 O/M Costs	Total Project Cost Construction Costs L/C	Total Project Cost Construction Costs F/C	Total Project Cost O/M (per year)
Nyugati ovcsatorna																								
1.Purification Facility				150,545			150,545															301,089	0	
2.Retractable Gate							29,278	30,280														29,278	30,280	
3.Gate and Screen							325															325	0	
4.Inflow,Outflow Channel							42,926															42,926	0	
5.Operation Costs												27,760			27,760			27,760			27,760			27,760
Keleti bozot																								
1.Purification Facility										155,392			155,392									310,784	0	
2.Retractable Gate													26,059	24,260								26,059	24,260	
3.Gate and Screen													325									325	0	
4.Inflow,Outflow Channel													50,544									50,544	0	
5.Operation Costs																		31,022			31,022			31,022
Keszthely urban runoff																								
1.Purification Facility																306,681						306,681	0	
2.Inflow,Outflow Channel																5,940						5,940	0	
3.Operation Costs																					12,857			12,857
Sub Total	0	0	0	150,545	0	0	223,074	30,280	0	155,392	0	27,760	232,320	24,260	27,760	312,621	0	58,782	0	0	71,639	1,073,951	54,540	71,639
Engineering service cost (5% of Construction Cost + Survey Cost)	57,015	2,727																				57,015	2,727	0
Contingency (5%)	2,851	136		7,527			11,154	1,514		7,770		1,388	11,616	1,213	1,388	15,631		2,939	0		3,582	56,548	2,863	3,582
Total	59,865	2,863	0	158,072	0	0	234,227	31,794	0	163,162	0	29,148	243,936	25,473	29,148	328,252	0	61,721	0	0	75,221	1,187,514	60,130	75,221

L/C : local currency portion
F/C : foreign currency portion
O/M : operation and maintenance

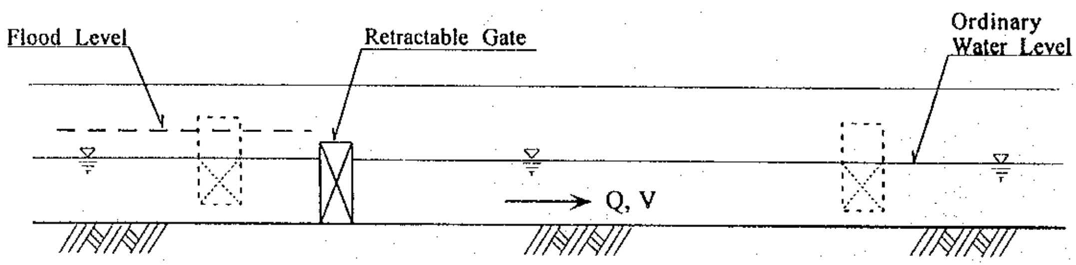
Table D.18 Implementation Schedule for Feasibility Study Projects

Name of River and Facilities	2001	2002	2003	2004	2005	2006	2007
Survey,Design	- - -						
Nyugati ovcsatorna							
1.Purification Facility		———	———				
2.Retractable Gate			———				
3.Gate and Screen			———				
4.Inflow,Outflow Channel			———				
5.Operation				- - -	- - -	- - -	- - -
Keleti bozot							
1.Purification Facility				———	———		
2.Retractable Gate					———		
3.Gate and Screen					———		
4.Inflow,Outflow Channel					———		
5.Operation						- - -	- - -
Keszthely urban runoff							
1.Purification Facility						———	
2.Inflow,Outflow Channel						———	
3.Operation							- - -

Vegetation Purification Method

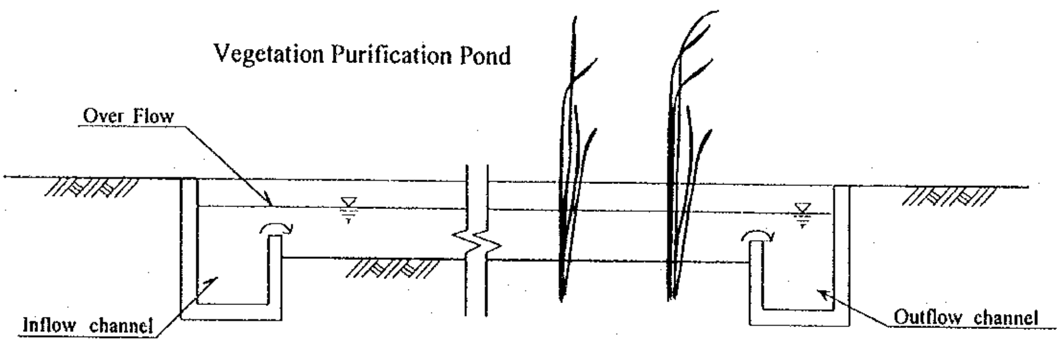


PLAN



SECTION A - A

Figure D.1 (1) Typical Layout and Profiles of Vegetation Purification Facility



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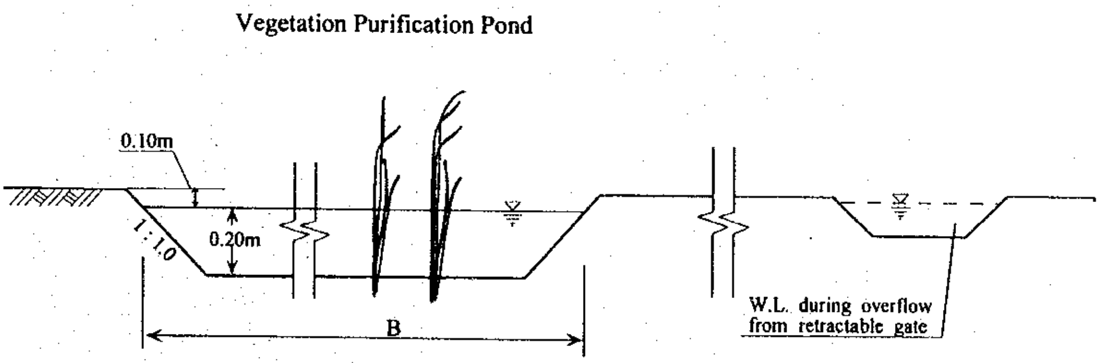


SECTION C - C

Figure D.1 (2) Typical Layout and Profiles of Vegetation Purification Facility

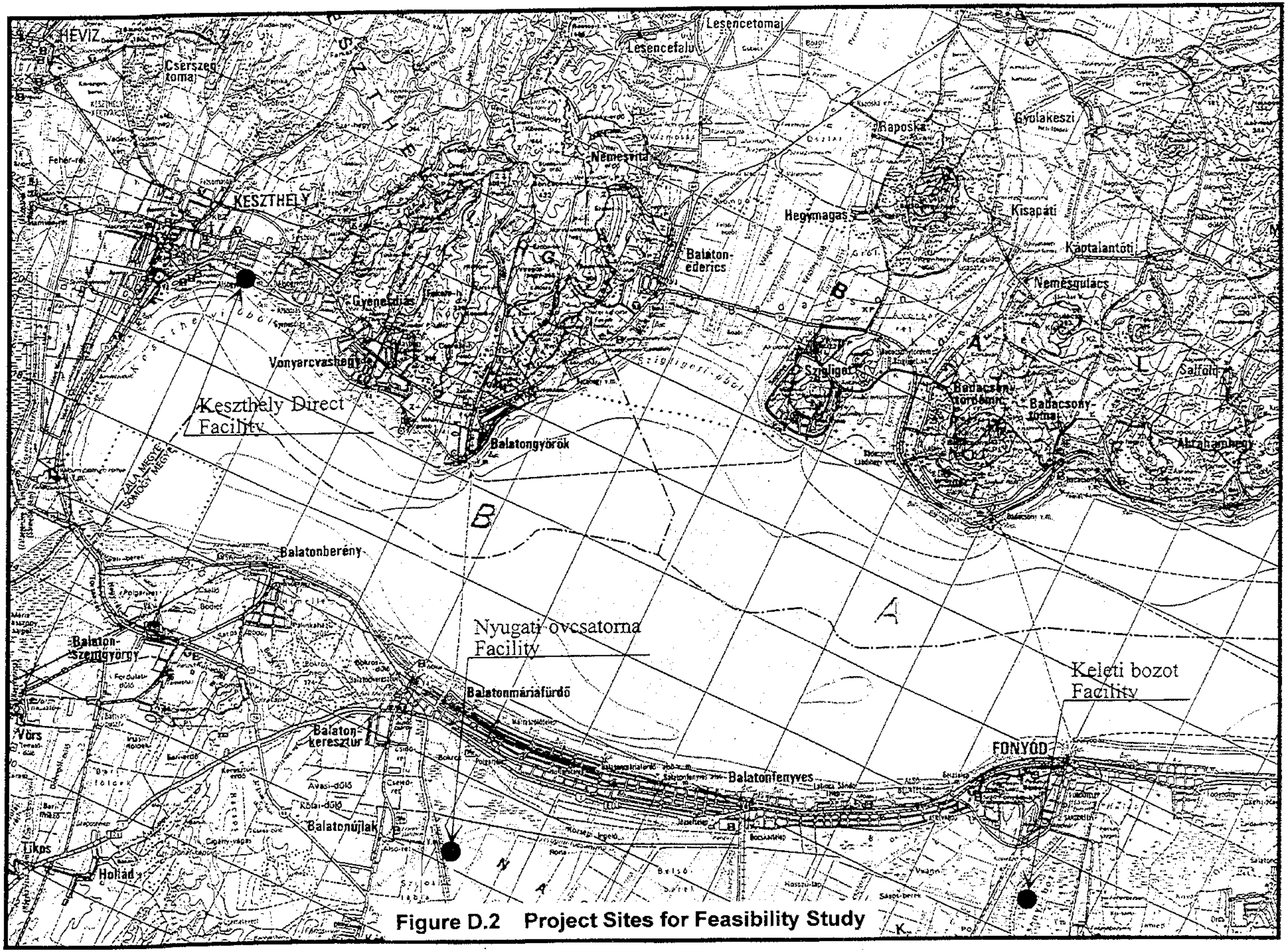


Figure D.2 Project Sites for Feasibility Study

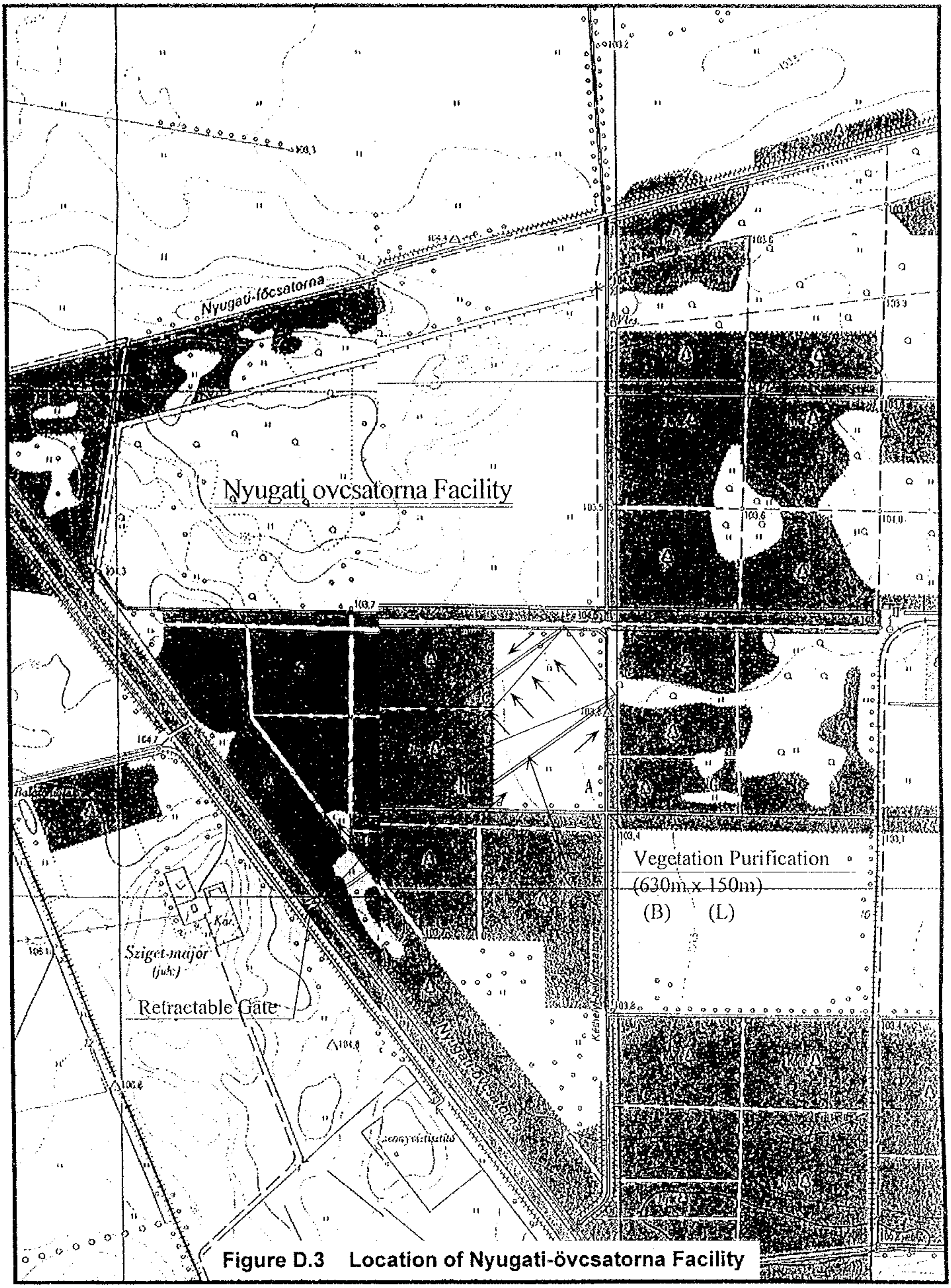


Figure D.3 Location of Nyugati-övcsatorna Facility

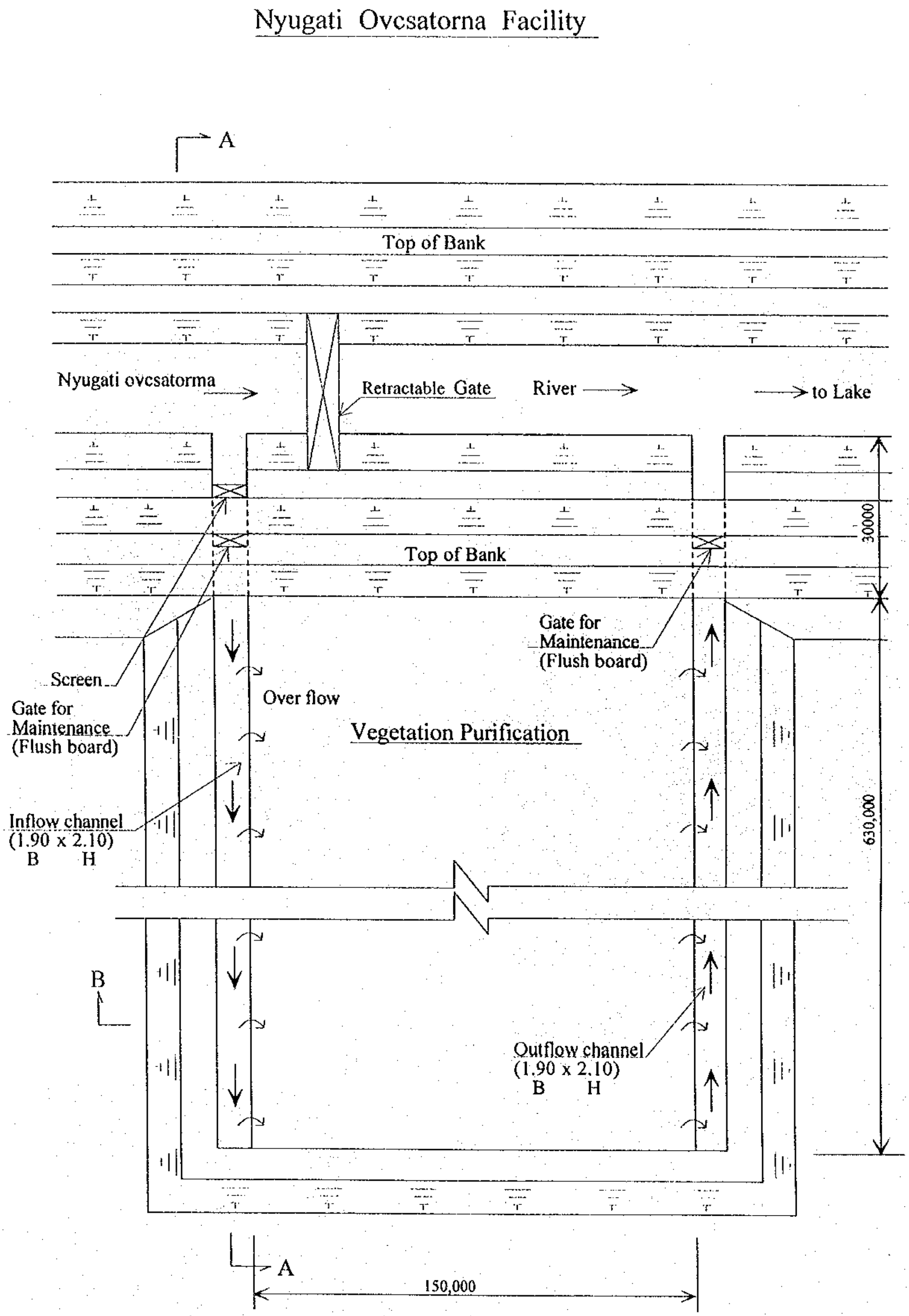


Figure D.4 General Layout of Nyugati-övcsatorna Facility

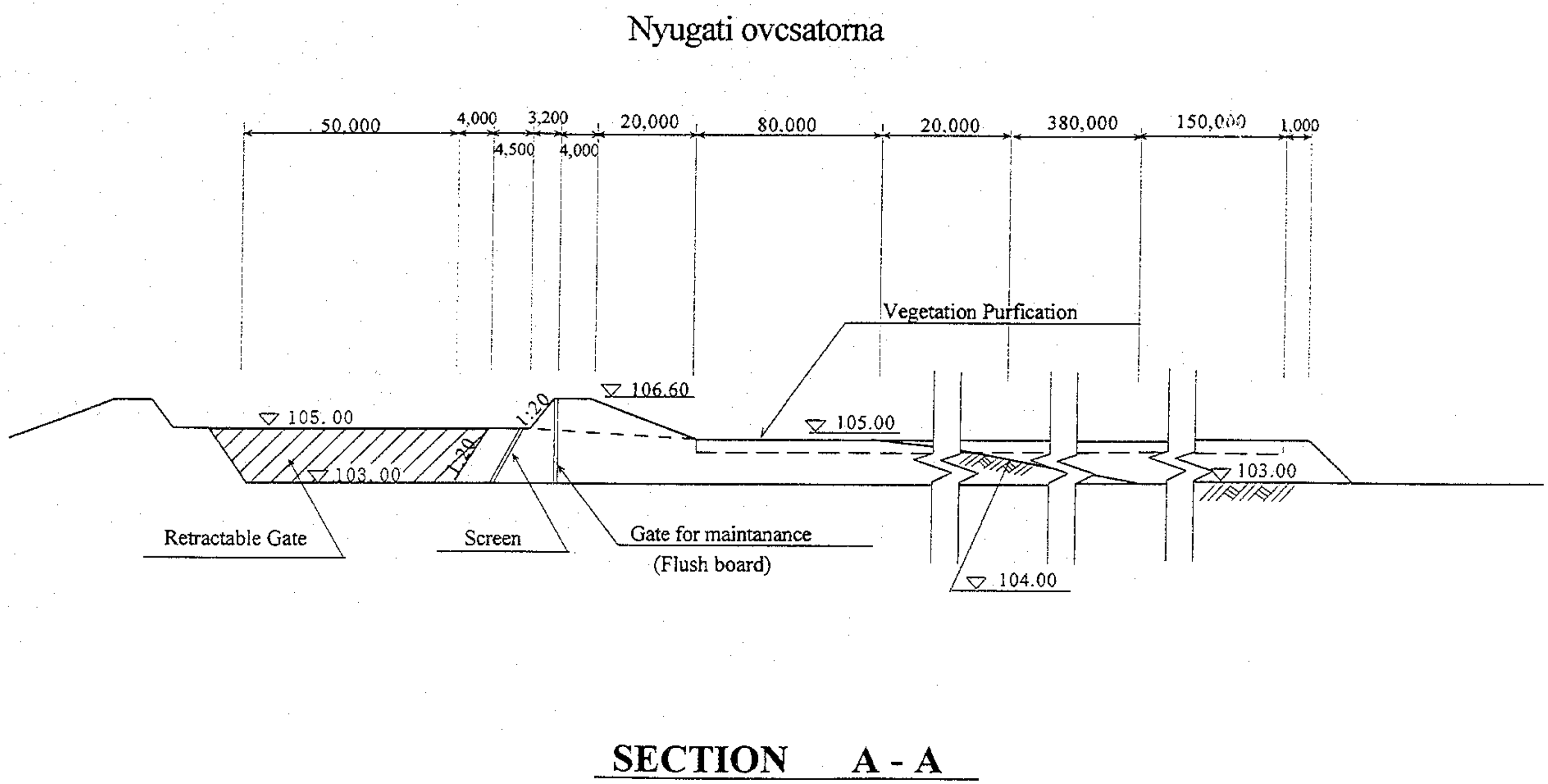
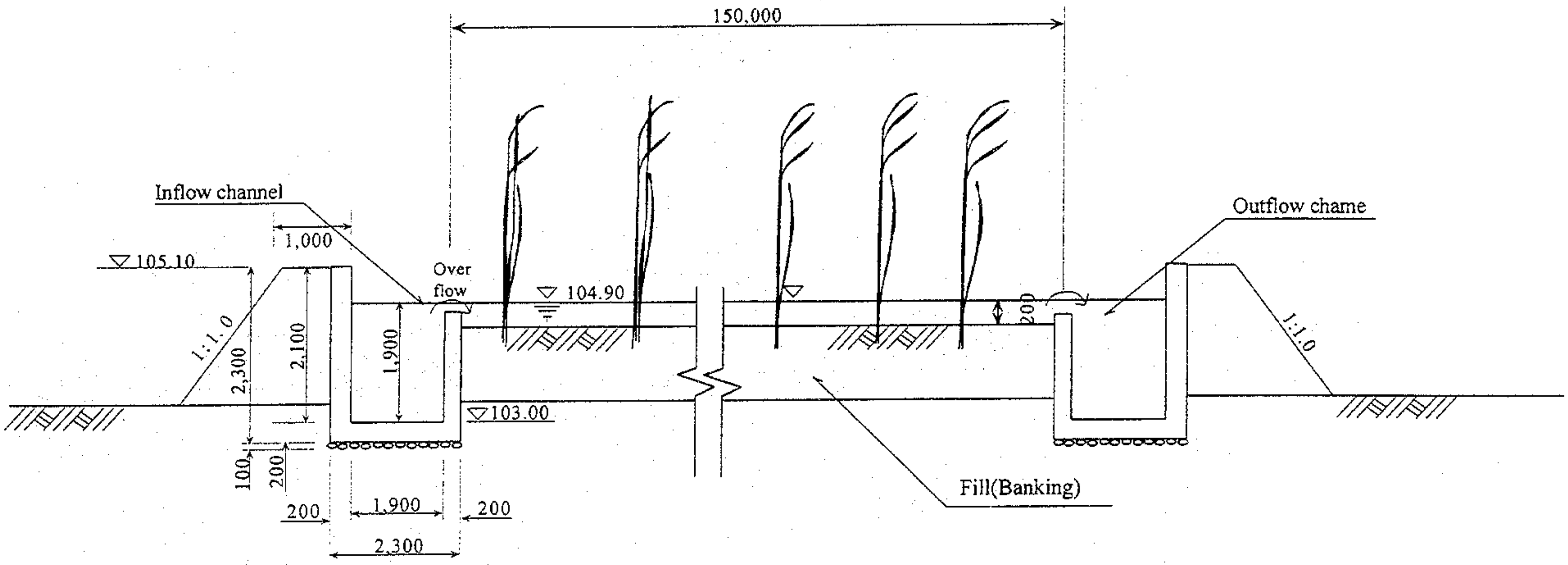


Figure D.5 (1) General Profiles of Nyugati-öovcsatorna Facility

Nyugati Ovcsatorna

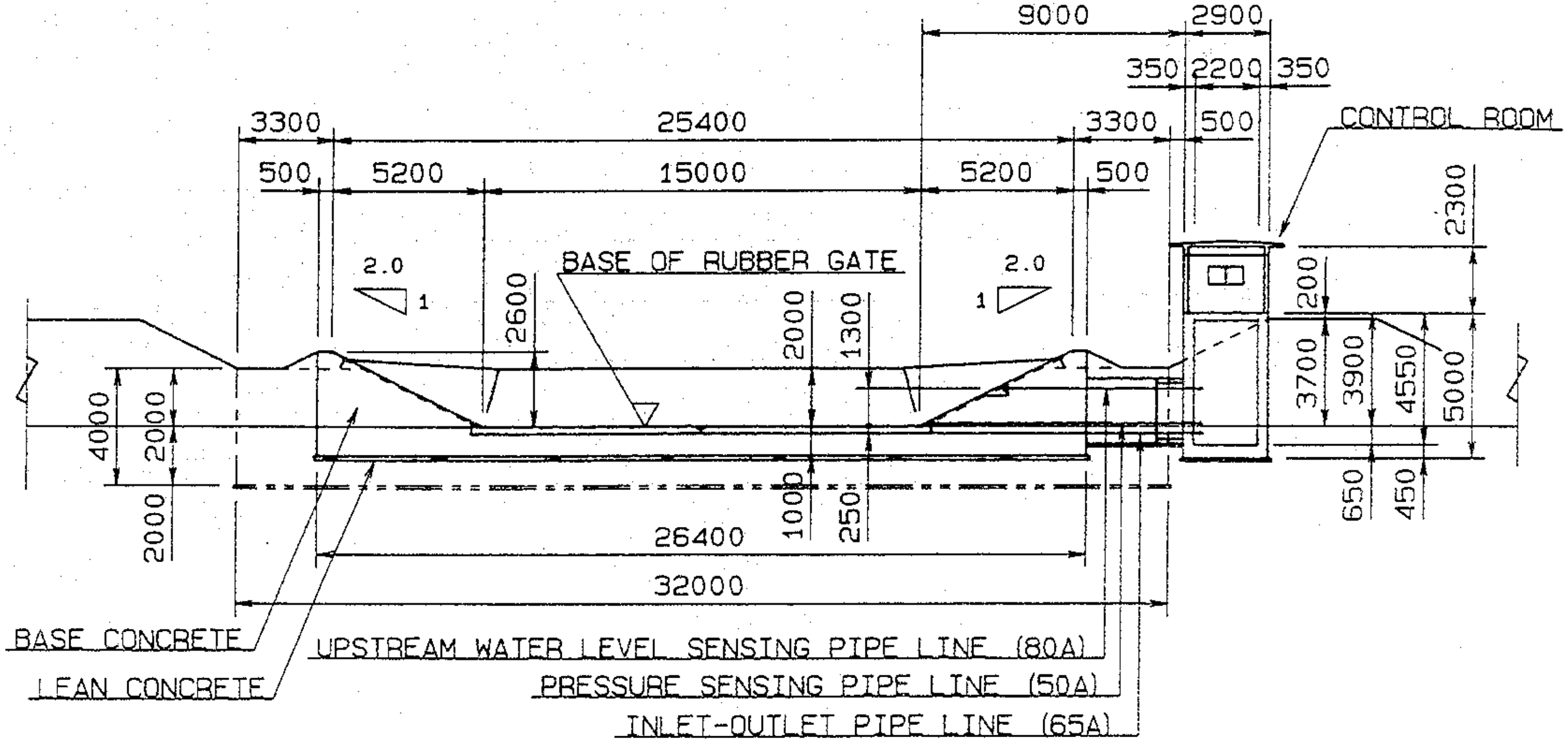


SECTION B - B

Figure D.5 (2) General Profiles of Nyugati-övcsatorna Facility

NYUGATI RUBBER GATE

ELEVATION S=1/200



DIMENSION : mm

Figure D.6 General Layout of Intake Gate (Nyugati-övcsatorna)

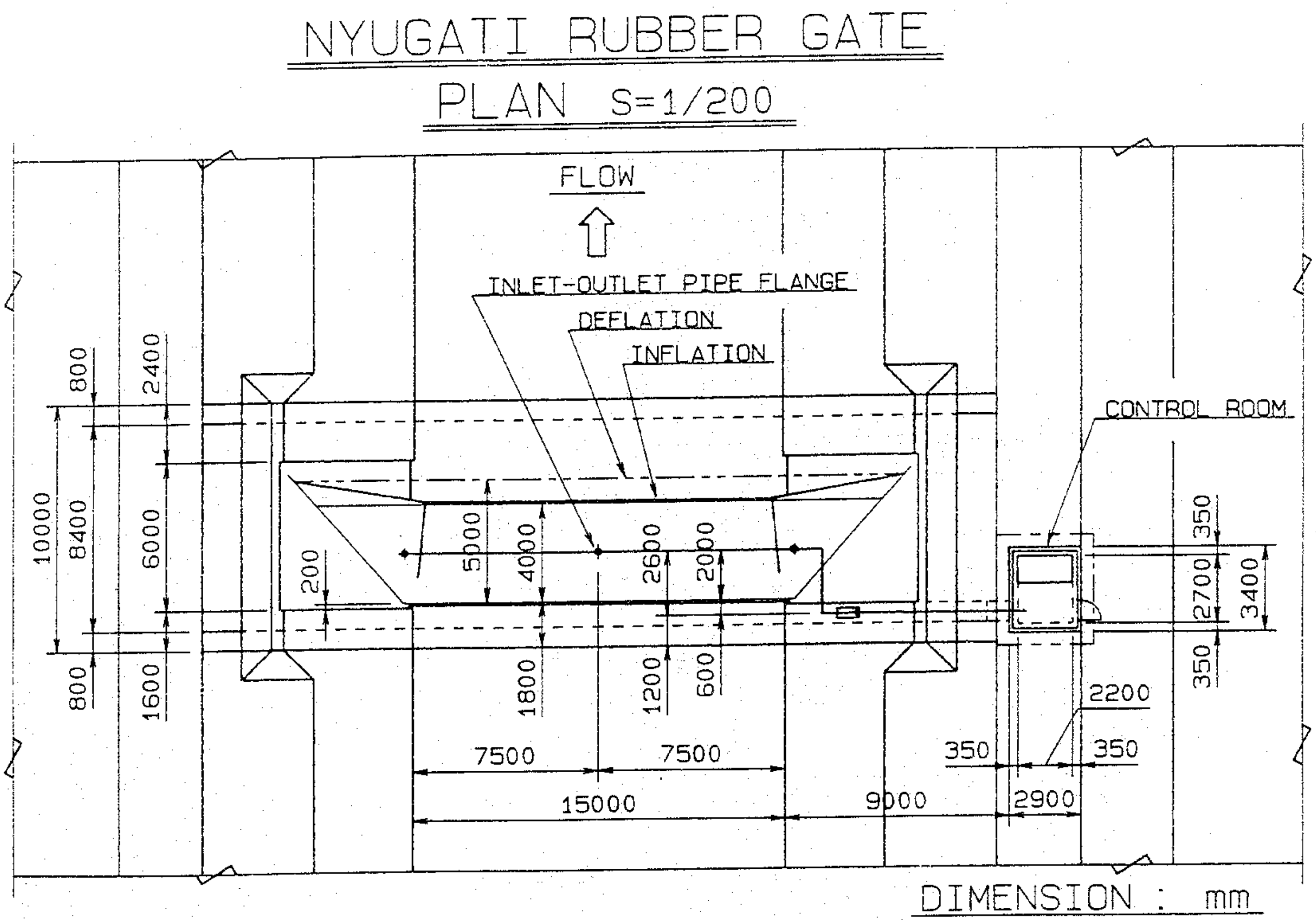
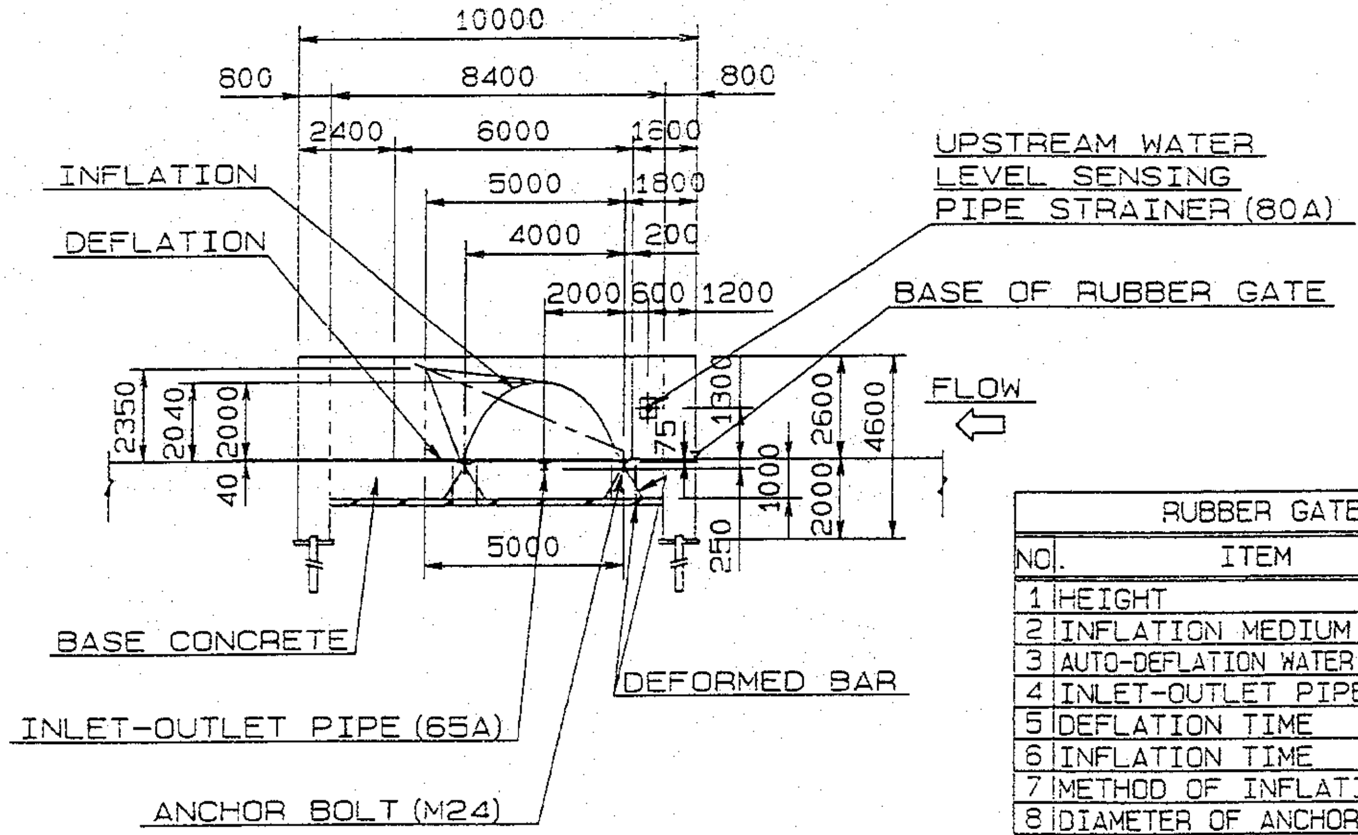


Figure D.7 (1) General Profiles of Intake Gate (Nyugati-övcsatorna)

NYUGATI RUBBER GATE
CROSS SECTION S=1/150



RUBBER GATE DIMENSIONS			
NO.	ITEM	DIMENSIONS	QUANTITY
1	HEIGHT	m	2.000
2	INFLATION MEDIUM		AIR
3	AUTO-DEFLATION WATER DEPTH	m	2.000
4	INLET-OUTLET PIPE		65A
5	DEFLATION TIME	min	30
6	INFLATION TIME	min	45
7	METHOD OF INFLATION		BLOWER
8	DIAMETER OF ANCHOR BOLT		M24
9	RIVER WIDTH	m	15.000
10	WALL SLOPE		1: 2.0
11	RIVER SLOPE		
12	ROCATION OF CONTROL ROOM		RIGHT
13	H.W.L	m	2.000
14	BACK WATER	m	2.000
15	CUSHION	mm	0

DIMENSION : mm

Figure D.7 (2) General Profiles of Intake Gate (Nyugati-övcsatorna)

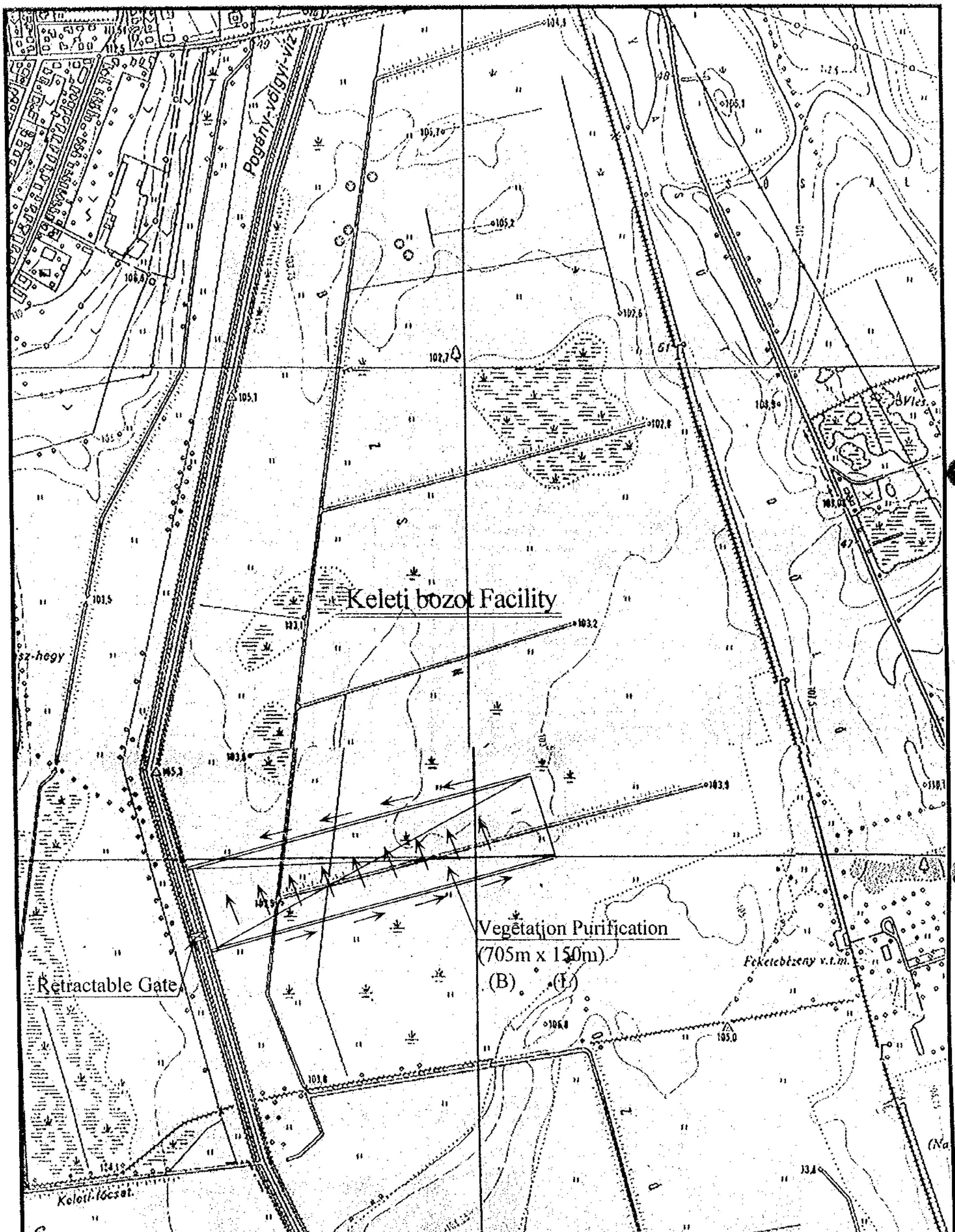


Figure D.8 Location of Keleti-bozot Facility

Keleti Bozot Facility

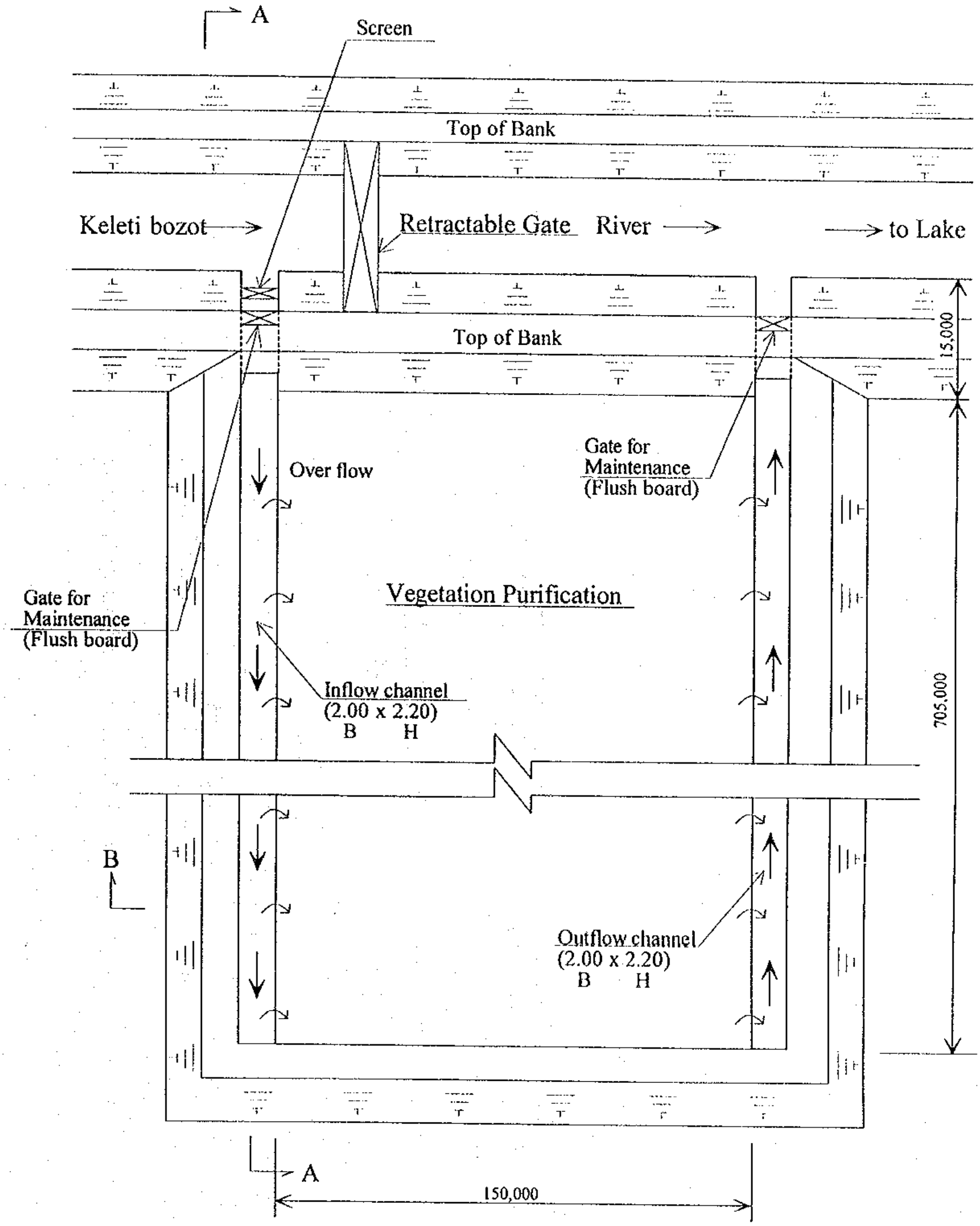


Figure D.9 General Layout of Keleti-bozot Facility

Keleti bozot

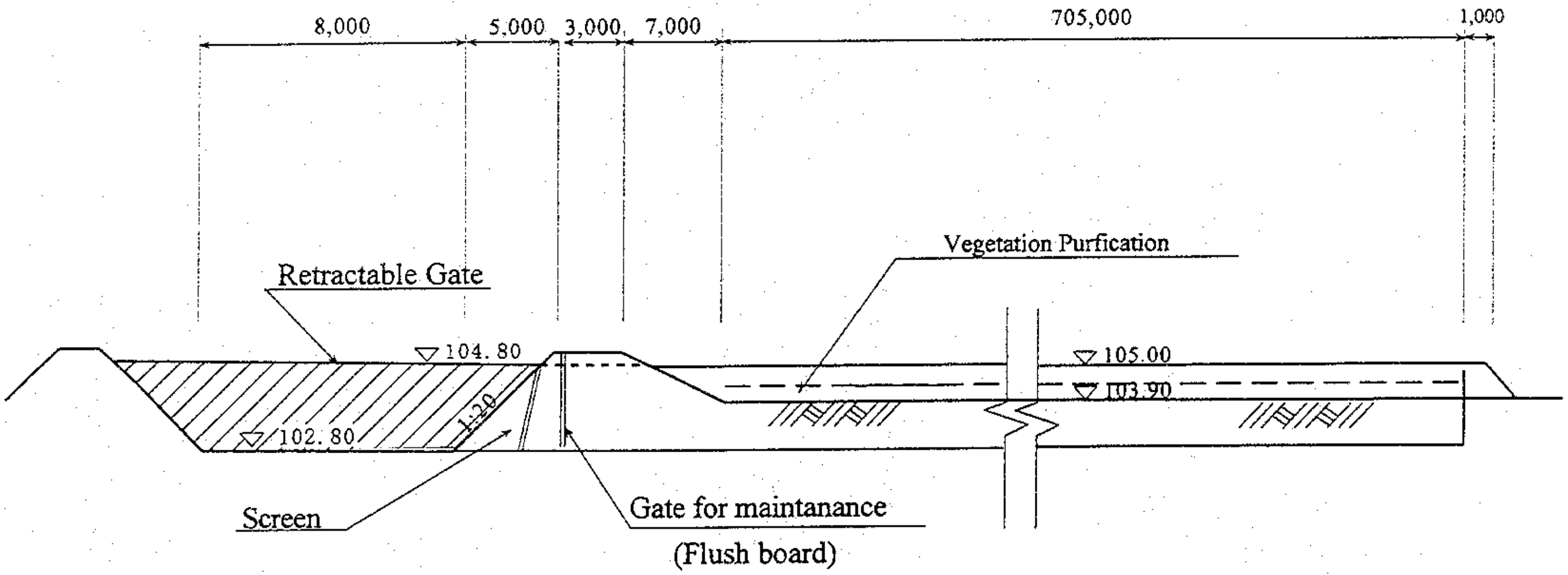


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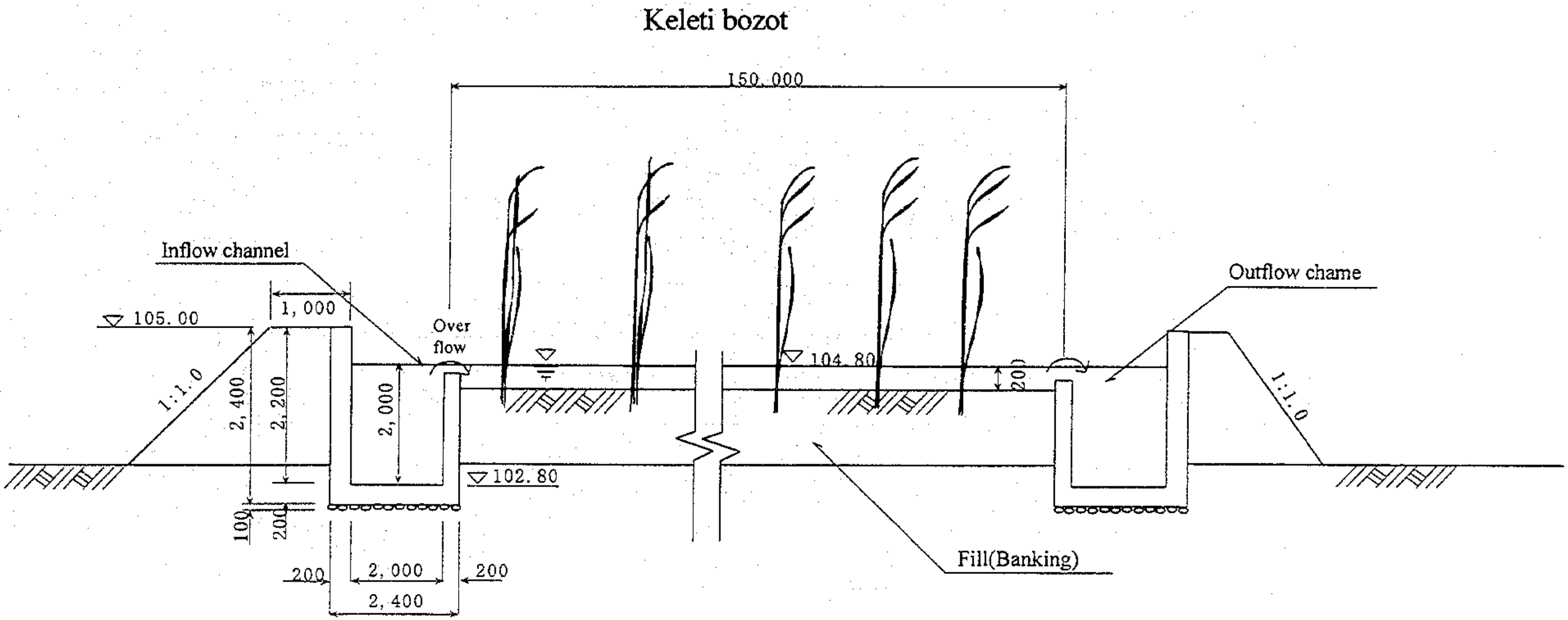
Figure D.10 (1) General Profiles of Keleti-bozot Facility



SECTION B - B

Figure D.10 (2) General Profiles of Keleti-bozot Facility

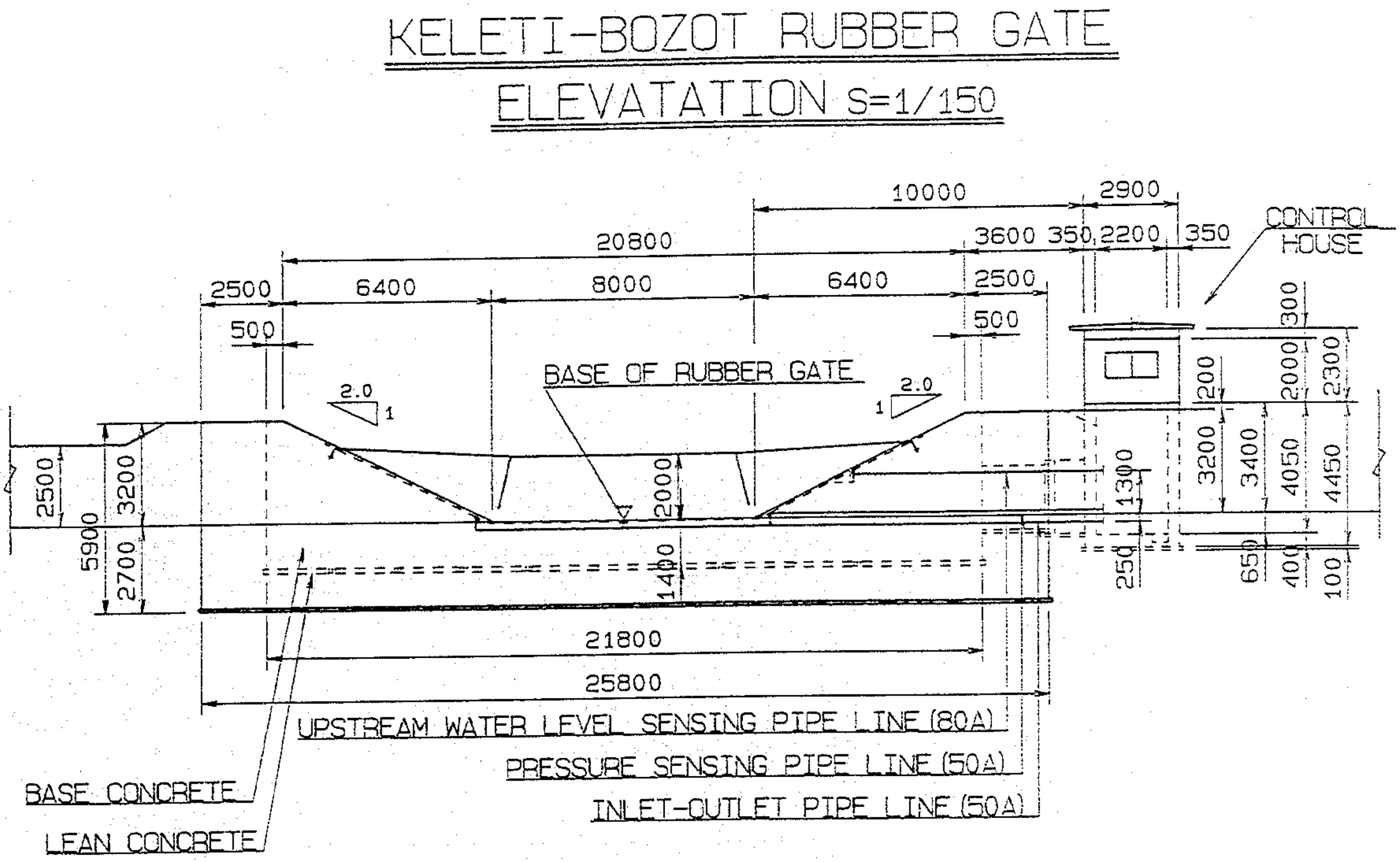


Figure D.11 General Layout of Intake Gate (Keleti-bozot)

KELETI-BOZOT RUBBER GATE

PLAN S=1/150

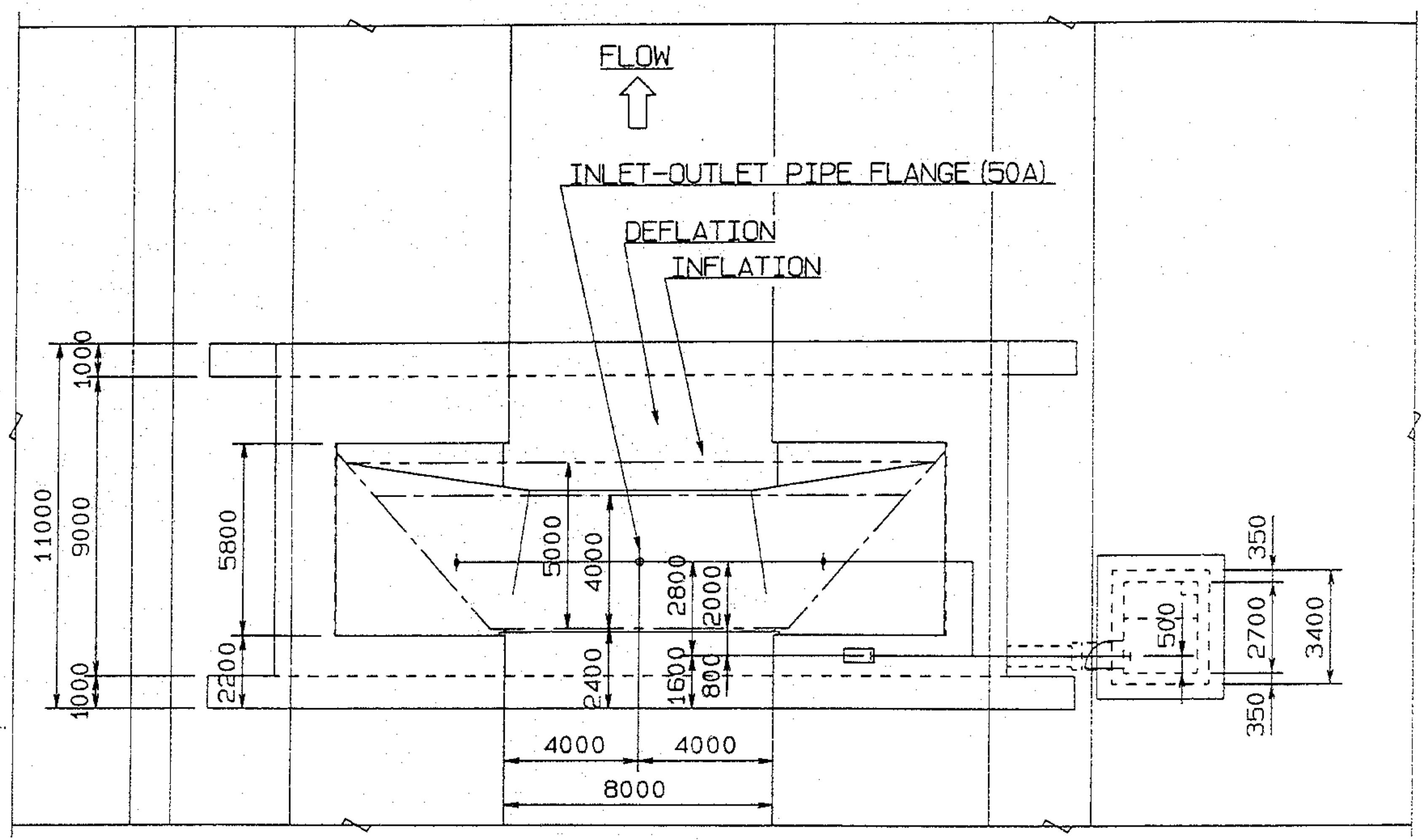
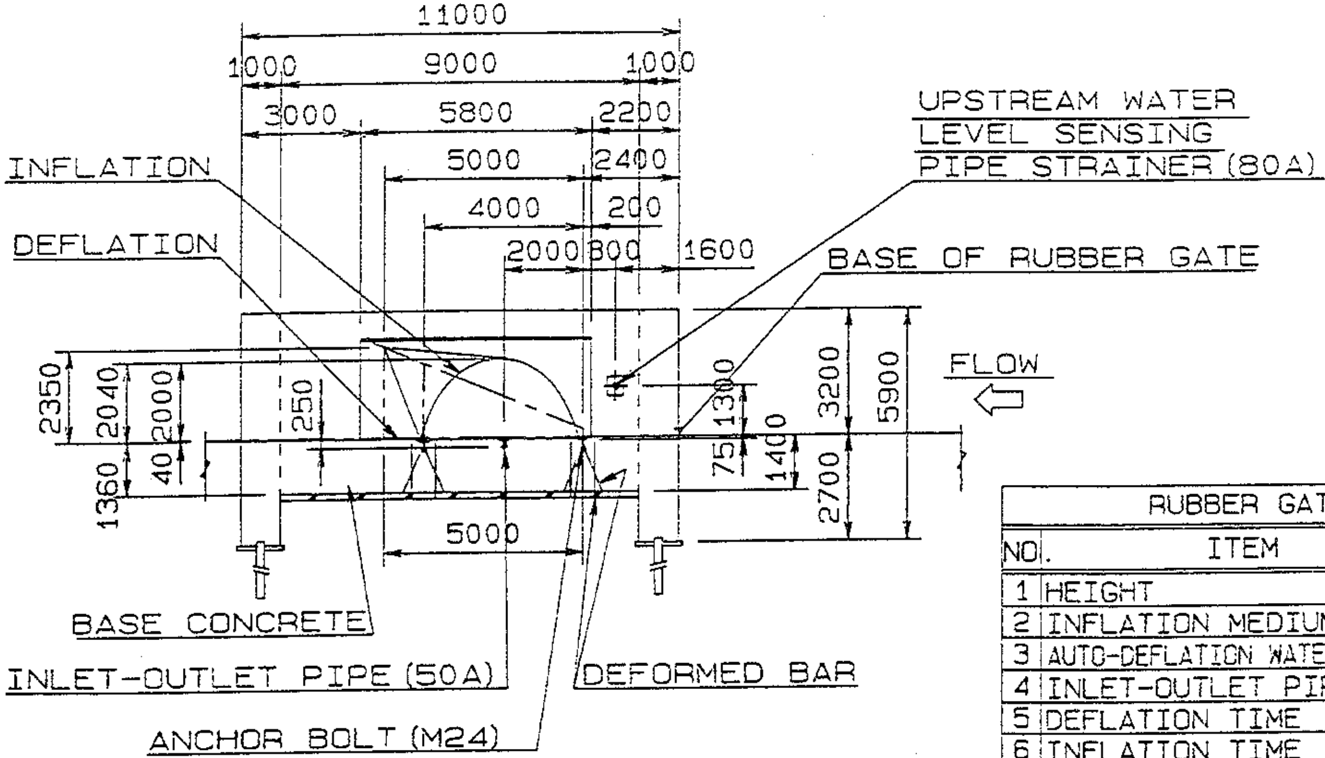


Figure D.12 (1) General Profiles of Intake Gate (Keleti-bozot)

KELERTI-BOZOT RUBBER GATE
CROSS SECTION S=1/150



DIMENSION : mm

RUBBER GATE DIMENSIONS			
NO.	ITEM	DIMENSIONS	QUANTITY
1	HEIGHT	m	2.000
2	INFLATION MEDIUM		AIR
3	AUTO-DEFLATION WATER DEPTH	m	2.000
4	INLET-OUTLET PIPE		50A
5	DEFLATION TIME	min	30
6	INFLATION TIME	min	30
7	METHOD OF INFLATION		BLOWER
8	DIAMETER OF ANCHOR BOLT		M24
9	RIVER WIDTH	m	8.000
10	WALL SLOPE		1:2.0
11	RIVER SLOPE		
12	ROCATION OF CONTROL ROOM		RIGHT
13	H.W.L	m	0
14	BACK WATER	m	2.000
15	CUSHION	mm	0

Figure D.12 (2) General Profiles of Intake Gate (Keleti-bozot)

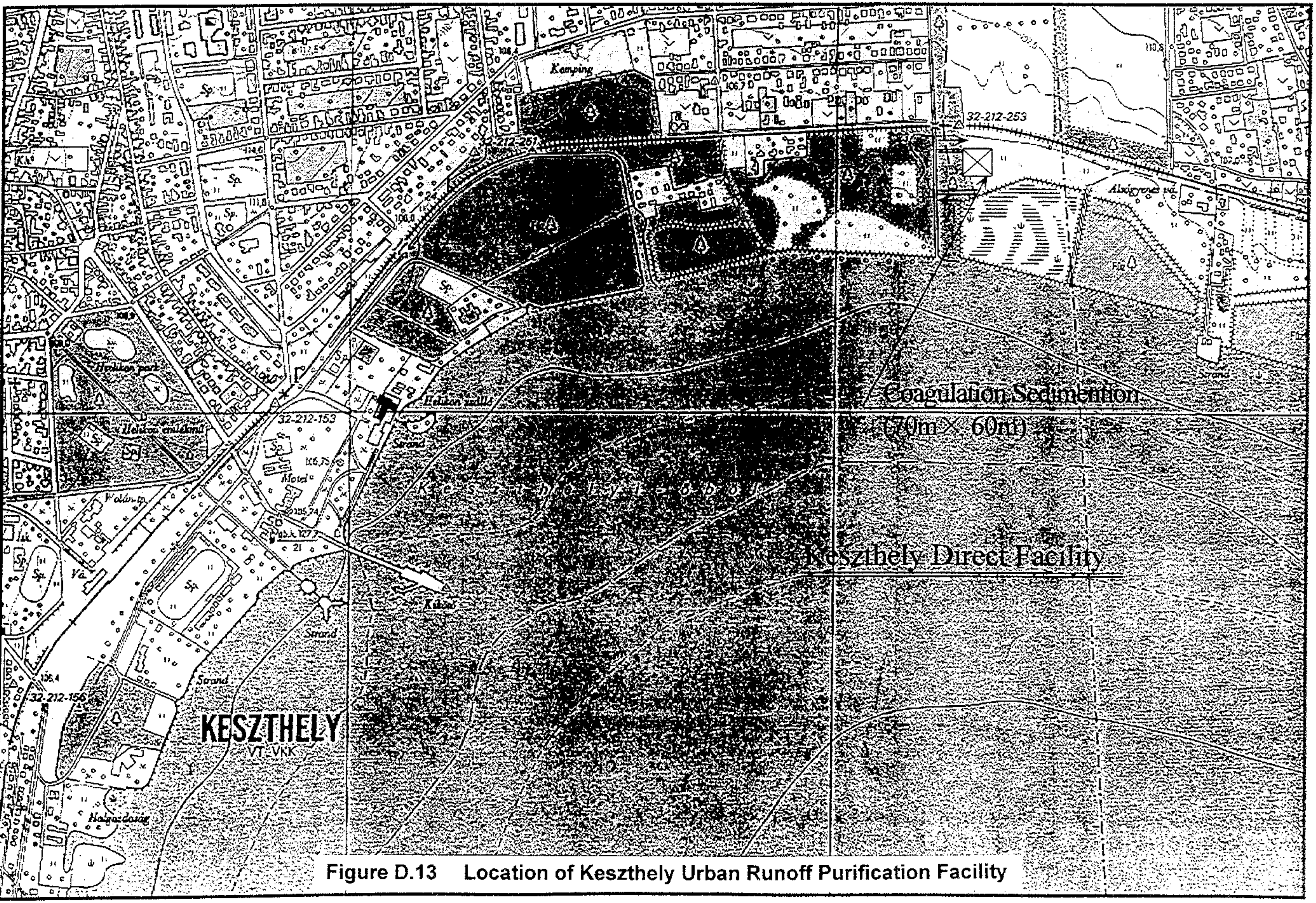


Figure D.13 Location of Keszthely Urban Runoff Purification Facility

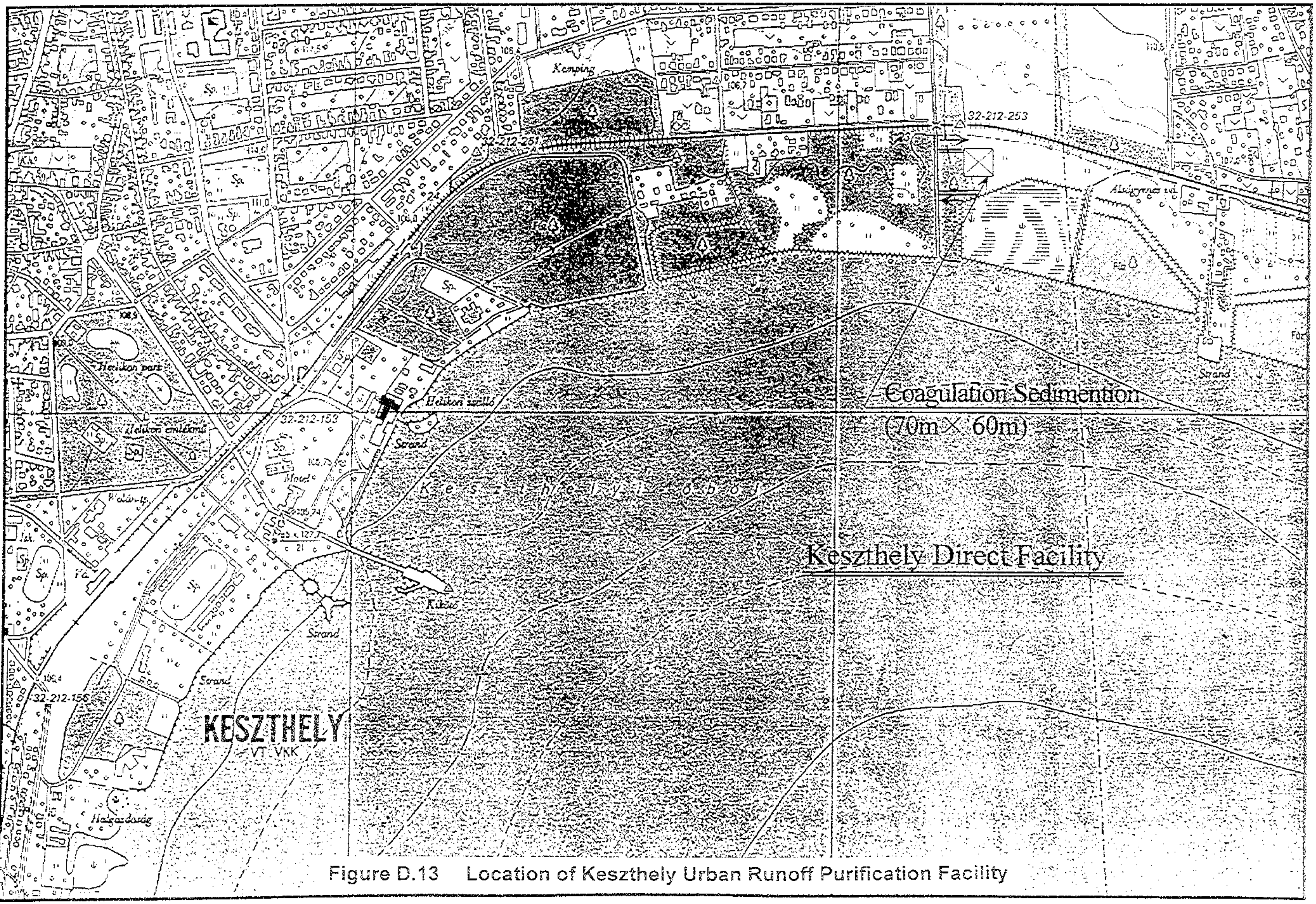
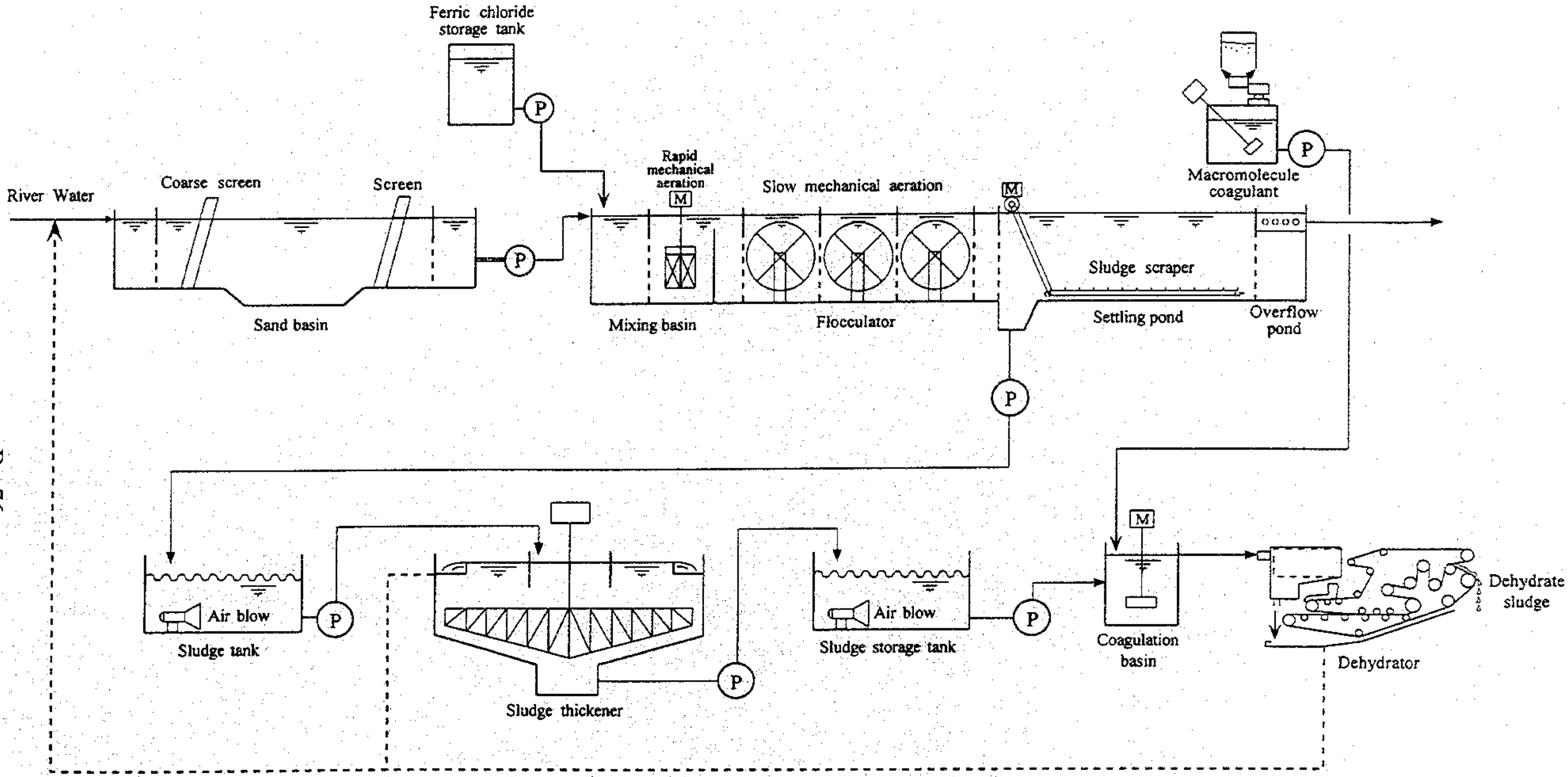


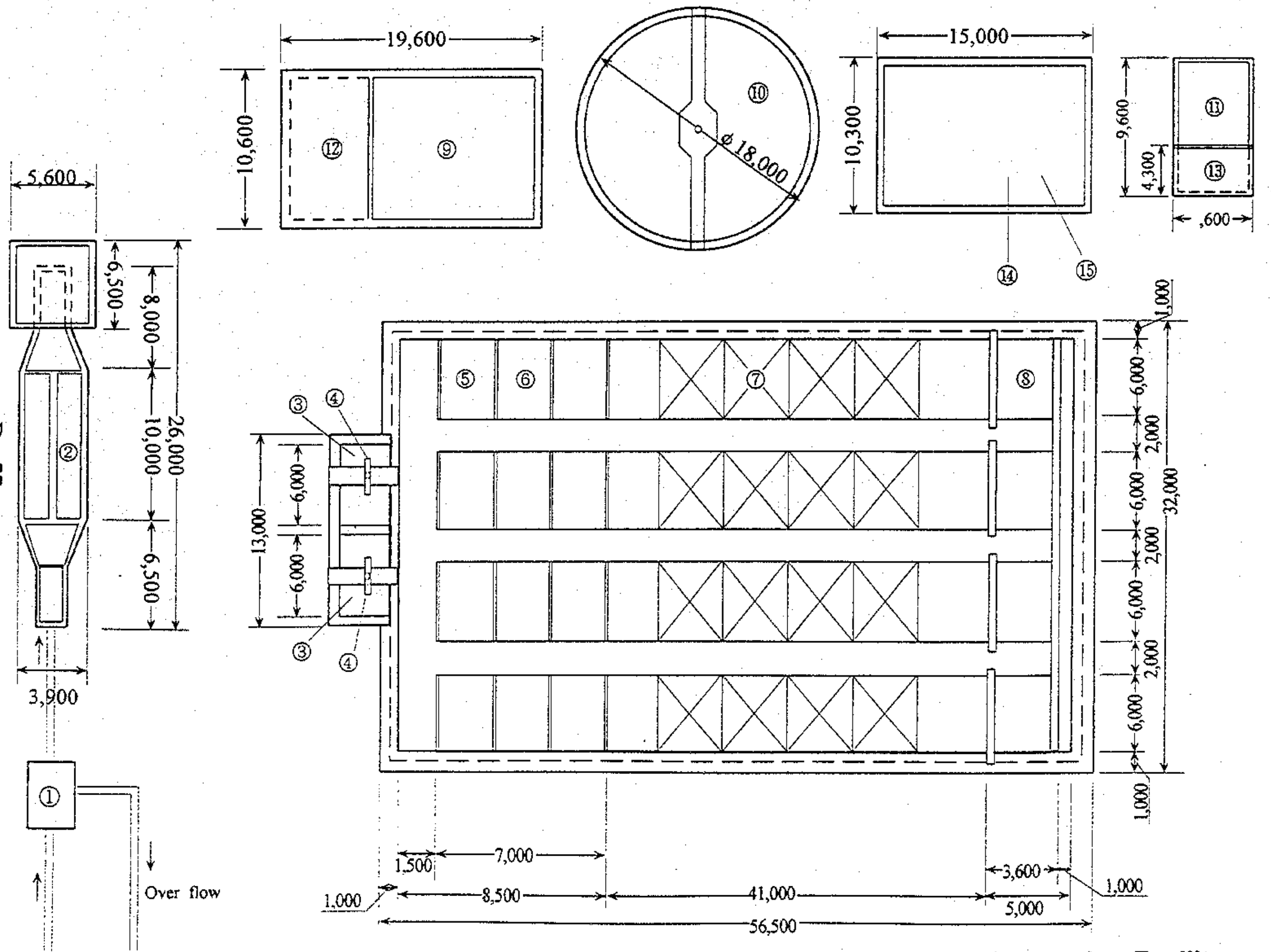
Figure D.13 Location of Keszthely Urban Runoff Purification Facility



Purification Flow

Figure D.14 System Flow of Coagulation Sedimentation Facility

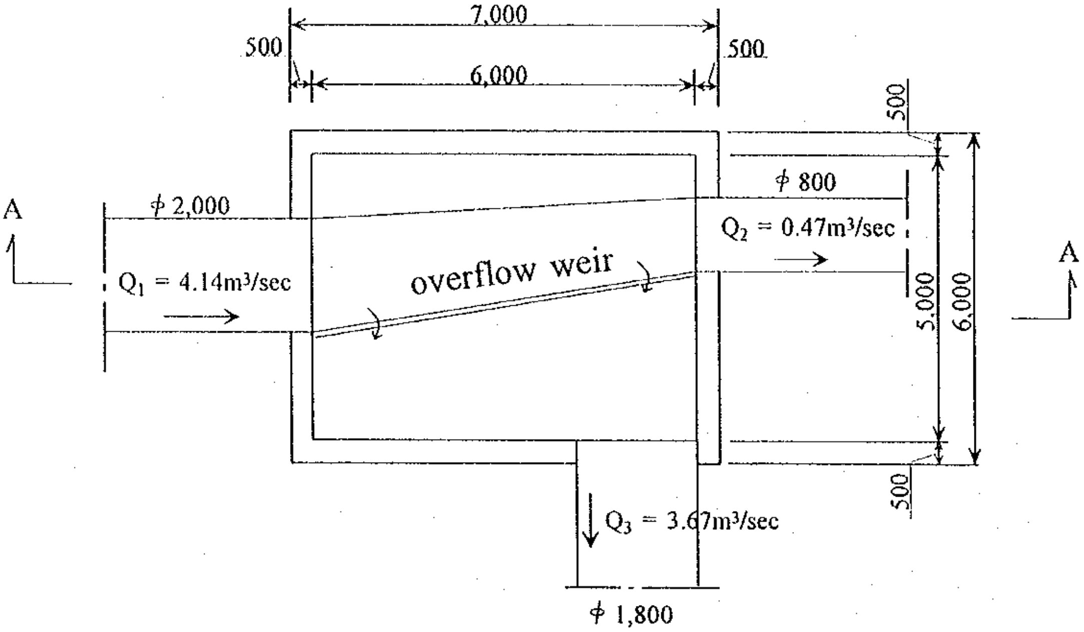
Coagulation Sedimentation Facility



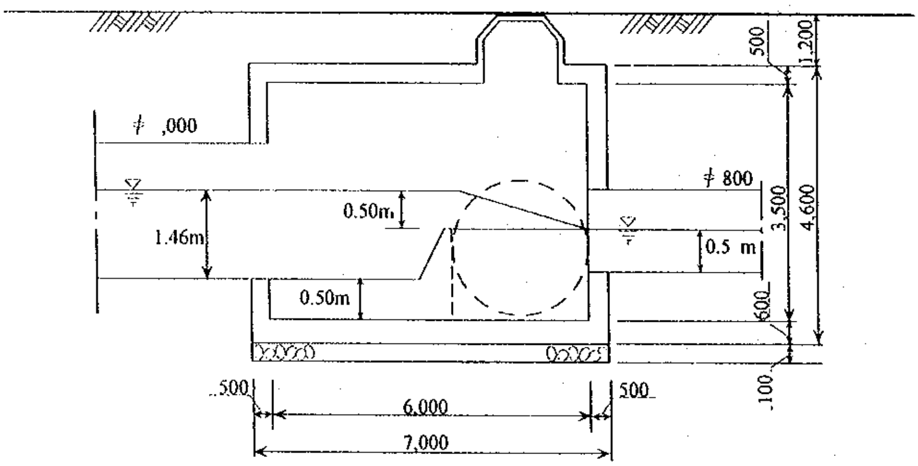
No	Name
1	Storm outfall
2	Sand basin
3	Mixing basin
4	Rapid mechanical aeration
5	Flocculator
6	Slow mechanical aeration
7	Settling pond
8	Overflow pond
9	Sludge tank
10	Sludge thickener
11	Sludge storage tank
12	Pumping station
13	Sludge pump
14	Coagulant storage tank
15	Dehydrator

Figure D.15 General Layout of Coagulation Sedimentation Facility

Figure **Storm Outfall**



PLAN



SECTION A - A

Figure D.16 Structure of Storm Outfall

APPENDIX - E

FACILITY PLAN (INTERNAL LOAD)

APPENDIX - E

FACILITY PLAN (INTERNAL LOAD)

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FACILITY PLAN (INTERNAL LOAD)

1 BRIEF HISTORY OF THIN LAYER DREDGING OF KESZTHELY BASIN

1.1 PREHISTORY

Dredging of Keszthely basin has considerably long history. The necessity of dredging to remove nutrient-rich lake bed sediments had been pointed out since early sixties by researchers. A wide range research program was launched in seventies to find out the reason why rapid degradation of water quality advanced. This research program made it clear that the phosphorus load, mainly responsible for algal production, accumulated in the sediment of lake bed.

First experimental dredging started in 1979 in the region of Balatongyörök. In the first period, the method of deep dredging was adopted and the layer dredging followed since 1981. Related to the deep dredging, on-site and laboratory surveys, experiments and measurements were made by many concerned organizations, and they concluded that significant quantity of bed sediment had accumulated in the trench and at the same time this solution of deep dredging was not effective in the case of suspended solids.

1.2 TEST DREDGING IN 1992

KDT-VIZIG built up a new dredging concept that directed to get dredger which are suitable for dredging of 24-25 km^2 up to 20cm deep (thin layer dredging) and disposing the sediment within the distance of 4 km. A test dredging by the use of a newly procured dredger was made from about beginning of May until the end of November in 1992.

Based on the estimation of the phosphorus content profile of the bed-sediment layer, the dredging depth was shown in a technical report of this test dredging[2)]. The sediment, highly polluted with phosphorus was a non-consolidated, settled layer formed in the past 2-3 decades, thickness of which could be estimated to be 15 to 20 cm on an average taking also into account the effect of bio-turbulence and internal migration.

The mobilizable P element to be included to total phosphorus(TP) was estimated high (20-30%) in the upper 15-30 cm sediment layer, whereas low (5-10%) in the lower layer. The TP content decreased significantly downward in the sediment.

In the above examination, the phosphorus in the form of mobilizable P and TP content was considered to play an decidedly important role. Other engineering evaluation was also performed on the basis of a large-scale experimental test dredging program including large number of field and laboratory measurements and observations on the conditions of sediment layer before and after dredging.

Above mentioned technical report also evaluated the effect of nutrient reduction by dredging as follows. The phosphorus in the upper 10 cm layer of the sediment was estimated that sediment-water interaction of this layer could be considered to be active. Before dredging, this layer contained 8,060 tons of dry material and 5.0 tons of TP content, 36 % of the TP content (1.84 tons) existed in mobile forms. Immediately after the dredging, the water content of the sediment decreased significantly, therefore upper 10 cm layer contained more dry material (10,400 tons) than before. Due to the higher dry material content, TP content of the layer also increased (5.46 tons). However the amount of the mobile phosphorus had decreased to 1.66 tons . In November, several months later, water content of the sediment was already higher than it had been immediately after dredging, although much lower than before dredging. There were 9,600 tons of dry material in the 10 cm layer, the amount of the TP did not change (5.47 tons), but the amount of the mobile forms decreased further (1.13 tons).

Focusing on the amount of mobile phosphorus, the effect of dredging in the above case, may be considered equal to the reduction of mobile phosphorus from 1.84 tons (before dredging) to 1.13 tons (several months later) ; namely the reduction ratio is estimated to be more than 38 % [(1.84 - 1.13) tons÷1.84 tons].

1.3 START OF FULL-SCALE THIN-LAYER DREDGING IN 1995

The result of the above-mentioned test dredging were favorable in respect of predicted phosphorus reduction level, namely many results were in favor of fulfillment of planned dredging program . Whereas, it was found that there might exist a danger of quick recontamination of the dredged area, that can be avoided only by the increased dredging speed. Related to this problem, the Government published the 1049/94 (VI.29) decision including the determination of the dredging capacity of 4 km^2 / year, which made it necessary to procure a second dredger. The procuring problem of the second dredger has not found an answer until today. This problem will be discussed in later section again.

The dredging plan with planned area of 2400 ha, planned depth of 20cm, and estimated dredging soil volume of 4,800,000 m^3 , and the disposing site plan adjacent to Keszthely were made and full-scale dredging work of thin layer based on this plan had been started in 1995, after a delay of two years, 1993 and 1994.

1.4 REEXAMINATION OF DREDGING AREA BY INTRODUCTION OF BAP IN 1997

It is stated by experts that the criteria for deepening the lake is relatively clear if the purpose is restoring the lake for sailing, power boating, and associated activities, while the deepening for control of the internal nutrient cycling and macrophyte growth has less clear criteria.

According to literatures in Lake Balaton, with regard to the deepening for the control of internal nutrient cycling, many researches including both on-site and laboratory surveys, engineering examinations have been executed by Hungarian experts of various specialists without satisfactory agreement. About the time when the full-scale thin-layer dredging was started, some kind of evidence according on the nutrient reduction effect of thin layer dredging, were gained from sediment transfer analysis, perhaps that is summarized below.

- If the test was made in a location where the dredger had removed a juvenile sediment layer and the test sample was taken immediately after dredging, then the result was very good in the case of 5 cm thick sample slices and it was still acceptable in the case of 15 cm thick sample slices.

- If the test was made outside the accumulation area of sediments and the test sampling was made one or two month after dredging, then that test sample usually had been contaminated already by the fresh sediment backfilled in the area, with P contents higher, in general, than that of the original surface layer. In such cases dredging was regarded to be harmful.

- If the hydro-biological activity of the bed sediment was high between the times when samples were taken before and after dredging for one reason or other, major changes were primary shown clearly in the BAP (Biologically Acceptable Phosphorus). As a result of dredging was evaluated very much preferred or very much unpreferred from time to time.

In other word, above phenomenon is explained as follow. Backfilling of the dredged areas and the increase of the easily available phosphorus (EAP) contents of the surface sediment are primarily caused by the settlement of the suspended matter. Hardly any contribution is made by the creeping mud and the activation of the strata which came to the surface as a result of dredging.

Very big change took place by reexamination executed in 1997 on the decision method of annual dredging areas. Before this reexamination, all dredging areas had been decided before the starting of dredging works on the basis of mainly total P value. In other words, annual dredging work was used to be executed in the partial area of the long term plan, one area by one area. After reexamination, annual dredging plan was decided every 2-3 years on the basis of BAP value, extremely, the decision might be made every year. According to the latter method, some areas may be dredged more than once during short time intervals.

In 1997 and 1998, the dredging work of Keszthely basin have been carried out in the water area, where the BAP parameter indicated high value.

2 PRESENT SITUATION OF THE DREDGING OF KESZTHELY BASIN

2.1 DREDGING OPERATION OF KESZTHELY BASIN

(1) Outline of Dredging System of the Lake Bed

The most common sediment removal technique involves the use of a dredger, especially the hydraulic cutter suction dredger or the mechanical dredger like the grab bucket dredger. In the case of the lake bed dredging project of Keszthely basin, a small-scale, but a highly efficient hydraulic suction dredger have been operating since 1992 . Sediment slurry loosened by the cutter head, moves to the pickup head, then generally, is discharged by pipeline to a remote disposal area. The sediment slurry in the form of soil-water mixture is discharged continuously through the pipeline by the hydraulic pressure. As the result, the quantity of the discharged slurry, in other words efficiency of dredging, is determined apparently in inverse proportion to the discharging distance.

Namely, the power of the available hydraulic cutter suction dredger decides directly theoretical and practical limitation of discharging distance . In the case of the dredger operating in Keszthely basin, the distance of practical limitation had been estimated about 5 km. If the distance between the dredging water area and the disposal area becomes longer than 5 km, the following three optional activities must be applied.

The first option is to introduce a more powerful dredger, the second is to attach a pressure boosting facility on the suitable position of the discharging pipeline to strengthen discharging ability. The third is to select another dredging system like as, for example, the system using two hydraulic cutter suction dredgers with some number of soil conveying-barges; namely one dredger excavates the lake-bed sediment and discharges to the soil-conveying barges and after the soil-conveying barge is transferred to water area near to the disposal area, another dredger discharges the sediment on the soil-conveying barge into the disposal area. The dredging system of the third option, which looks like the system to be adopted to a lake-beach nourishing project, has certain disadvantage that the dredging efficiency drops generally because of the discontinuous process .

(2) Examination on the Necessary Number of Dredger and Attached Vessels by KDT-VIZIG

1) Background of the examination

As was pointed out by the technical report, the planned area of 2400 ha to be dredged, includes the area which is out of limiting ability of discharging distance of the existing hydraulic cutter suction dredger. So, it may be necessary to introduce a new more powerful dredger and/or a pressure booster facility with the concerning attached facilities like as the pipelines to complete the dredging work of Keszthely basin by the scheduled target year.

The Balaton Branch Office of KDT-VIZIG (BVK) investigated in 1995 the existing dredging ability and the desirable combination of the dredging vessels to complete the dredging work of Keszthely basin during the period decided by the government. Its result is shown in the next section.

According to the term 1.4 of the 1049/1994 Governmental decision, the dredging work of the Keszthely basin must be made by the annual rate of 4 km^2. About this issue they examined the technical conditions and this possibilities.

2) Estimation of the present capacity

The existing dredger - according to the ship yard's prescription – guaranteed the 250-300 m^3 / h output with a NA-400 pipeline. Because of the inadequacy of the diameter of the existing pipeline, namely the adequate NA-400KPE pipeline only for 1230m and inadequate NA-300KPE pipeline for 2800m, the existing dredging capacity was estimated to be only 80 m^3/h, corresponding to the annual dredging area 1.5 km^2 and also the maximum transferring distance was limited to be 3800 m. Following additional facilities were necessary to operate the existing hydraulic cutter suction dredger with its nearly maximum efficiency.

- 4000 m long NA-KPE pipes
- 40 pontoons, in order to increase the distance
- 1 anchor barge
- 1 boat with engine

3) Necessary dredging ability

Necessary dredging ability was meant in two senses ; the dredging quantity and the discharging distance to increase the dredging ability.

Concern to the dredging quantity and the discharging distance

- 1 dredger
- 2 anchor barges
- 1 boat with engine
- 5000 m long NA-KPE pipes
- 40 pontoons

Concern to the discharging distance

- 1 booster facility
- 1 anchor barge
- 1 boat with engine

- 3000 m long NA-KPE pipes
- 20 pontoons

Common

- 1 NA-KPE pipes welding machine

2.2 DISPOSAL SITE MANAGEMENT

The dredging of 2400 ha planned in the thin layer dredging program, must be accompanied by the large quantity of bed sediment to be disposed. Regarding the disposal site, a technical report prescribes as follows.

One of the most important aspect on the arrangement of the existing disposal sites was the ownership of the located area, namely, the fact whether the advantage of sediment disposal belongs to the area of Balaton and whether disposal area is located inside coastal region in legal sense. Those areas were located inside this coastal region where the reed bushes were in bed condition. Reed bushes in front of the filled sites remained untouched at northern sites.

Outside of the legal lake shore, those areas were chosen in lower-productivity regions, where the level of soil water was high, which could not be used for agricultural purposes, in the region of Szigliget and mouth of Zala.

At present, 12 disposal sites are found in the various stage of development from stage of nearly completed to disposing to pre-planning ones. Existing 5 disposal sites designated as No 1-5, are on the northern coast of Keszthely basin, namely Gyenesdiás and Vonyarcvashegy from south-west to north-east (refer to *Figure E.1*). Here, a technical new idea is contemplated to utilize the defined existing disposal sites most effectively. Reutilization of existing disposal sites would proceed in the following way: dried material would be disposed to the hinterland at the level of railway filling and emptied disposal sites would be refilled either in more steps, after the appropriate consolidation.

At present, the re-utilizing work of the existing disposal sites has been already started in such a way that disposed and consolidated lake-bed sludge is being removed, by using earth-work machines and lorries, from disposal area to the hinterland area between the disposal area and the railway banking. This hinterland area will be used as an agricultural land, especially for gardening, after completion of the above mentioned work, which has been approved without any kind of compensation by the private section of its land owner.

The candidates of the future disposal sites are located along the coastal zone of Keszthely basin; the field near the crossing point of main road No 71 and Csóka-kö-patak creek (No 7), the forest located adjacent to No 7 on southern side (No 8), east side of the mouth of Zala (No 6), Halász field (No 10), east side of Balaton marshy pasture, north of the main road No 76 (No 11), forest, plough-land and field between Balatonszentgyörgy and Balatonberény (No9), reclaimed lands located in Balatonmáriafürdö (No 12), as shown *Figure E.1.*

There are great differences in their construction stage among these disposal sites, some disposal sites already have already existed, another sites are on planning stage and/or on adjusting stage . If all of these disposal sites are available, disposal sediment more than 4,800,000 m^3 can be filled under the condition of having enough ability of discharging distance.

2.3 CONCERN TO THE PARAMETER OF EFFECT ON NUTRIENT REDUCTION BY DREDGING

In Lake Balaton case, BAP had been introduced as the parameter which shows a level of nutrient characteristics of lake-bed sediments instead of EAP in recent year. The reason is mentioned already in section 1.4. The outline of BAP examination method is as follows.

Sampling of soil

The sampling were made with Eijkelkamp machine made in Holland that can take maximum 150 cm long undisturbed sediment soil sample in maximum 5 m deep water area.

Preparatory examination

- *Cylindrospermopsis raciborskii* that are multiplied a large numbers recently in the Lake Balaton was employed as a representative species to determine the multiplication of the chlorophyll-a.

- Test alga was multiplied in nutrient solution which is free from phosphorus for 7days to decrease the excess phosphorus accumulated in the cells to the minimal level.

- Phosphorus starved alga cultivated in 0, 20, 40, 60, 100, 120, 140 and 160 μg/l nutrient solution of PO_4-P content for an other 7 days . After this experiment, the chlorophyll-a concentration of the culture is measured and then chlorophyll –a concentration of each culture is plotted against PO_4-P concentration.

Examination

Phosphorus starved alga (*C. raciborskii*) is multiplied in sediment solution, the only phosphorus source being the Balaton bed-sediment. After 7 days, the chlorophyll-a concentration of the solution is measured. The BAP is evaluated by applying the result of the chlorophyll–a concentration of the solution to the above-mentioned calibration curve.

The evaluation method by using BAP may be an outstanding one, because of its parameter being correlated well to the alga growth. On the other side, at least until early this year, BAP is understood to be a subject requiring improvement further. Related to this items, for example, the necessity of simpler and more target-oriented analysis is pointed out. Apparently, this is one of the most difficult problem regarding the sediment removal project of Lake Balaton.

3 THE PROPOSAL ON THE DREDGING PROJECT OF LAKE BALATON IN 2000-2010

3.1 SOME FUNDAMENTAL SUBJECTS RELATED TO DREDGING PROJECT

Five subjects related to the dredging project of Lake Balaton are taken up in this section. The first subject is relating to soil characteristics of the lake bed sediments. The bed sediment, generally, consists of quartz, clay minerals, inorganic calcium, iron, aluminum and magnesium compounds, carbonates and organic matter. The relation between these elements depend very much on the origin of the sediment. In the case of Lake Balaton, proportion of limestone content shows remarkably high value. Suspended material contains more organic matter while material close to the bottom contains more quartz. The bed sediments of Lake Balaton look very soft as be seen in the followings.

- grain-size distribution clay , silt: 20%, fine sand: 70-80 %, sand: 0-20 %
- water content : 75-270 %
- density : 1.45-1.65 g/cm^3
- plasticity index : 47-58 %
- limestone content : 57-58 %

We can notice that the bed sediments of Lake Balaton has been formed mainly with the loose accumulated fine sand, mainly limestone. Therefore, water content shows a high value and density shows a relatively low value. High value of plasticity index like clay is the result of the carbonic content and not of the clay content. Another feature is a vertical distribution of consolidation rate of sediment, as shown in *Figure E.2*.

This feature as well as the softness of the bed sediment gives undoubtedly two notable technical information; one relates to the possibility of the large quantity of wave-driven suspended sediment in a stormy weather, another one relates to the easiness of dredging because of the softness of bed sediment.

The second subject is based on the difference between the nutrient content ratio of the lake-bed sediments of each lake basins as well as the difference between the water quality of each lake basins. A report by KDT-KÖFE in 1997 deals with the phosphorus content ratio of the sediment of Lake Balaton. According to the report, 1 m long undisturbed core samples of lake-bed sediment were obtained at 8 different lake points located in the 4 representative lake basin, and various kind of laboratory tests including TOC, organic phosphorus and BAP were performed at every 10 cm. The condition of the water quality and the nutrient content level of sediments of each lake-basins are shown in the form of some figures (refer to *Figure E.3*). The variation profiles of BAP values as well as the TP values shows not so clearly but sure tendency that the nutrient concentration becomes lesser from Keszthely points toward Balatonfüzfö point, which means less favorable to dredge.

The third subject is based on hydraulic character of Lake Balaton. In lake Balaton, lake water flows slowly in the direction of south-east, namely from Keszthely basin toward Siófok basin. This hydraulic character brings a clear answer that upstream area is superior to the downstream area as the dredging site for the improvement of water quality.

The last subject is relating to the assumption of dredging plan targeting financial year of 2010.

Methods to reduce releasing rate of nutrient from the bottom sediment are as follows.

The sediment cover and the phosphorus inactivation as well as the dredging were pointed out there. In Japanese case, the sediment cover methods, methods to cover a sea or a lake bottom with thin-layer sand mat, are used frequently, but all cases are executed in sea area. The reason that sediment cover method have not been used in lakes may be that sand mat decrease the water depth and volume of lake, as a result this will be unfavorable to water quality. Beach nourishment with poor nutritive sand is considered to be a kind of sediment cover which is favorable to the lake-water quality. Only the dredging method will be dealt with in the later section.

Unfortunately, as we have not sufficient technical information on the geographical and/or the vertical distribution of nutrient concentration and soil characteristics at present time, this proposal has to be composed with the insufficient materials. In such a situation, directly, we are forced to come to grips with the two very difficult technical problems in the consideration of the future dredging project to improve the water quality of Lake Balaton. The first problem is related to the dredging strategy, namely how to decide the annual dredging area. For example, we may choose from two deciding systems. One is a system tin which the annual dredging area is selected before the start of dredging from the whole dredging area that have been planned. The other is a system in which annual dredging area is selected from the point of view that it might be the most suitable dredging area at every a few years including every year. In other words, the former system resembles the one that had been adopted in the dredging work of 1995-1996 and the latter system are the one that have been selected in the dredging work of 1997-1998.

The second problem is related to the dredging depth. That is considered a more difficult problem to give a clear answer than the first one above mentioned.

As to the effectiveness of bottom deepening to control internal nutrient cycling, many researches on-site and laboratory survey, engineering examinations have been done in the case of Lake Balaton by the experts of various disciplines, perhaps, without effective agreement. Among researches, a distinguished and excellent on-site and laboratory survey had been accomplished by KDT KÖFE in 1997. *Figures E.4 and E.5* are drawn up by using reported numerical data in the above literature. These figures show the profile of TP value and BAP value of 8 points of Lake Balaton.

These figures make us to recognize, again, the complicated nature involved in the deciding problem of the depth of dredging. The figures show clearly that the concentration of nutrient, both TP and BAP generally decreases with the increasing depth of soil from the surface of the lake bed sediment. However, unfortunately, we must notice a remarkably irregular decreasing patterns, in an extreme case, the concentration of nutrient increases with the increasing sampling depth of soil.

Above mentioned feature of sediment is directly related to the determination of dredging depth and/or the number of repeated dredging; namely it may be required to dredge more than two times dredge because the removing of lake bed sediment of maximum depth from 15 to 20 cm, can be possible by one time of dredging with the usage of the existing dredger. An examination gives us a practical information, although the above mentioned two problems may not be taken in to account in our rough future dredging plan dealt within the latter section.

3.2 OUTPUT OF THE WATER QUALITY SIMULATION MODEL

Some results of the calculation based on the water quality simulation model related to the dredging project are as follows. The results of hindcasting of water quality of the whole area dated August,10,1994 (6 p.m.) and August,7, 1995 (4 p.m.) are shown in *Figures E.6* to *E.9*. In particular, the upper figures of *Figure E.6* and/or *Figure E.8* show the water quality distribution without dredging. The lower figures of *Figure E.6* and *Figure E.8* show the results of hindcasting with 40% reduced internal loads in Keszthely basin. *Figure E.7* and *Figure E.9* show the results of hindcasting with 40% reduced internal loads in all basins of Lake Balaton. The 40% reduction of internal loads after dredging assumed on the basis of measurement of reduction rate of mobile forms P after dredging. The levels of chlorophyll-a are significantly different between 1994 and 1995, but the general distribution patterns are similar, and well correlated with the depth of the basin. We can recognize the level of water quality improvement by comparing figures with or without dredging. The results of hindcasting of water quality of 4 basins in 1994 and 1995 are shown in 4 series of figures from *Figure E.10 to Figure E.17*. *Figures E.10, E.11, E14,* and *E.15* show the results of hindcasting in the case of 1994 and 1995 with 40% reduced internal loads in Keszthely basin. *Figures E.12, E.13, E.16* and *E.17* show the results of hindcasting in the case of 1994 and 1995 with 40% reduced internal loads in all basins of Lake Balaton. Two sets of values in each figures indicate water quality with 0% and 40% reduced internal loads. Namely, the difference between a set of higher value (0% reduced internal loads) and lower value (40% reduced internal loads) shows the expected effect of dredging.

We can recognize two notable points; the maximum of water quality improvement effect before and after dredging may be about 17 % and the effect of the dredging of upstream area, *i.d.* Keszthely basin, hardly extends to downstream area, *i.d.* Szigliget basin, suggesting the fact that the water quality improvement effect is locally determined.

3.3 DREDGING PROJECT IN 2000-2010

According to the calculation of the simulation model, the reduction of internal loading by dredging surface sediment has an significant effects on water quality of Lake Balaton. The most desirable selection from the standpoint of water quality improvement is to dredge all water area of the lake. The entire surface area of Lake Balaton come up to be 593 km^2. If the dredging of the entire surface area of Lake Balaton is planned to be completed during 10 years, about 30 sets of the dredging fleet will be necessary, since the dredging ability of one set of the dredging fleet is estimated to be 20 km^2/10 year. If the thickness of the dredging sediment layer is 20 cm and the dredged sediment is disposed to the disposal site 1m thickness, the area of disposal sites of about 119 km^2 will be necessary. This selection will be hard to rationalize from the wide ranging standpoints. Desirable dredging area in the years 2000-2010 is considered to be the south-eastern half area of the Szigliget basin as well as the yet not dredged area of the Keszthely basin by the following reasons. The first reason is related to the tendency of the water quality of Lake Balaton. The water quality of the south-eastern half area of the Szigliget basin as well as Keszthely basin appears to be worse comparing to another area. But, parameter indicating to the nutrient level of the lake bed sediment does not show such a remarkable difference between each basin, or each lake area (refer to *Figure E.3*).

The second reason is related to the considerably expensive cost accompanied to the dredging work . The outline of the proposed dredging plan in 2000-2010 is as follows.

(1) Procurement Plan

The procuring of three new dredgers and three booster vessels including necessary pipelines, pontoons, attached small boats, etc., are proposed. Existing one dredger and one booster vessel will be used for the dredging of Keszthely basin and two new dredgers and two booster vessels will be used for the dredging of Szigliget basin.

(2) Dredging Area

The dredging area will come up to about 14km^2 in Keszthely basin and 60km^2 in Szigliget basin shown in *Figure E.18.*

(3) Disposal Site Plan

It is very difficult to propose disposal sites because many problems will expect to be encountered directly depend on the ownership of the candidate land for the disposal sites. The preparatory candidate land for the disposal sites is shown in *Figures E.19 to E.21* which are draw up by using GIS (Geographical information systems). These figures shows the land area which satisfy the three conditions (present land use , land height, distance from the lake shore).

(4) Cost Estimation and Dredging Schedule

The outline of the dredging cost and dredging schedules is shown in *Table E.1* and *Table E.2.*

(5) Organization

The organization responsible for the dredging project is BVK (Balaton Branch Office) of KDT-VIZIG.

4 RECOMMENDATIONS

4.1 ELUCIDATION OF THE SEDIMENT DRIFT MECHANISM

Elucidating the sediment drift mechanism, or more exactly the mechanism regarding the sediment stirred up and settled down, may offer an important information to build up a reasonable dredging plan. The phenomena of sediment drift may happens mainly in the stormy weather. The source of the drift sediment may be the one of lake bed and/or beach stirred up by the wave. The suspended sediment stirred up by the wave may drift downstream by the lake flow which the wave may bring about directly and/or indirectly through water-level difference brought by strong wind. Field surveys such as wave height and water level observation, the observation of the quantity of drift sediment are necessary to elucidate the mechanism of sediment drift as well as the verification of simulation modeling.

4.2 DECISION METHOD OF THE DREDGING AREA AND/OR DREDGING DEPTH

A simple system comparing to the decision of the dredging area and the dredging depth might be used, if possible. In the case of the sediment removal projects in Japanese lakes considerably simple system are used, generally ,to decide both of the dredging area and dredging depth. Ignition loss plays an important role in a parameter related to solution rate of nutrient under the anaerobic condition.

(1) Shouge River in Hyogo Prefecture

The range of sediment soil to be removed are decided on the principle that more than one item of COD , ignition loss , sulfide content of the sediment soil are beyond each limiting value, namely 30mg/g, 15%, 1.2mg/g , respectively.

(2) Chukai Inland Sea in Tottori and Shimane Prefecture

The depth of sediment soil to be removed are decided to be 30cm, because the release rate of P hardly decreases in the layer deeper than the depth.

(3) Shibayama Lagoon in Ishikawa Prefecture

The range of sediment soil to be removed are decided on the principle that more than one item of COD, ignition loss , sulfide content, T-N, T-P of the sediment soil are beyond each limiting value.

(4) Otaru Canal in Hokkaido Prefecture

The range of sediment soil to be removed are decided on the principle that more than one item of COD , ignition loss , sulfide content of the sediment soil are beyond each limiting value, namely 30mg/g, 15%, 1mg/g.

(5) Suwa Lake in Nagano Prefecture

The depth of sediment soil to be removed are decided to be 50cm, because the release rates of T-P and T-N decreases to the level about one-third of the pre-dredging level.

5. REFERENCES

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