No. 1

SOFIA CITY MUNICIPALITY
REPUBLIC OF BULGARIA

BASIC DESIGN STUDY REPORT
ON
THE PROJECT
FOR
CONSTRUCTION OF THE PURIFICATION PLANT FACILITIES
IN
SOFIA CITY MUNICIPALITY
IN
THE REPUBLIC OF BULGARIA

July 1998

JAPAN INTERNATIONAL COOPERATION AGENCY
PACIFIC CONSULTANTS INTERNATIONAL

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PREFACE

In response to the request from the Government of the Republic of Bulgaria, the Government of Japan decided to conduct a basic design study on the project for construction of the purification plant facilities in Sofia City Municipality in the Republic of Bulgaria and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Bulgaria a study team from 25 January to 20 February, 1998.

The team held discussions with the officials concerned of the Government of Bulgaria, and conducted field surveys at the study area. After the team returned to Japan, further studies were made. Then, a mission was sent to Bulgaria in order to discuss a draft basic design, and as this result, the present report was finalized.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Bulgaria for their close cooperation extended to the teams.

July 1998

Kimio Fujita
President
Japan International Cooperation Agency

July 1998

LETTER OF TRANSMITTAL

We are pleased to submit to you the basic design study report on the project for construction of the purification plant facilities in Sofia City Municipality in the Republic of Bulgaria.

This study was conducted by Pacific Consultants International, under a contract to JICA, during the period from 19 January, 1998 to 17 July, 1998. In conducting the study, we have examined the feasibility and rationale of the project with due consideration to the present situation of Bulgaria and formulated the most appropriate basic design for the project under Japan's grant aid scheme.

Finally, we hope that this report will contribute to further promotion of the project.

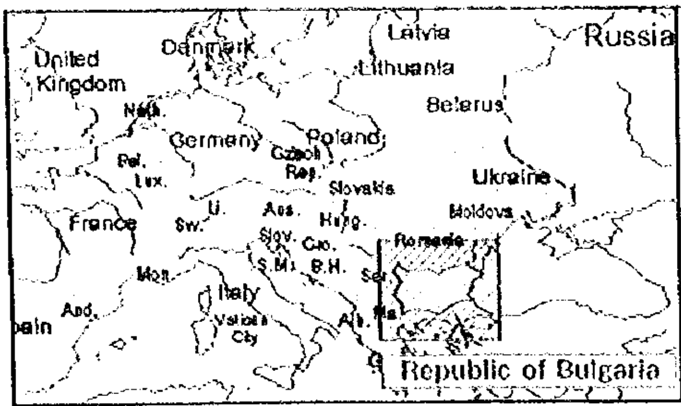
Very truly yours,

OKAGA Toshifumi

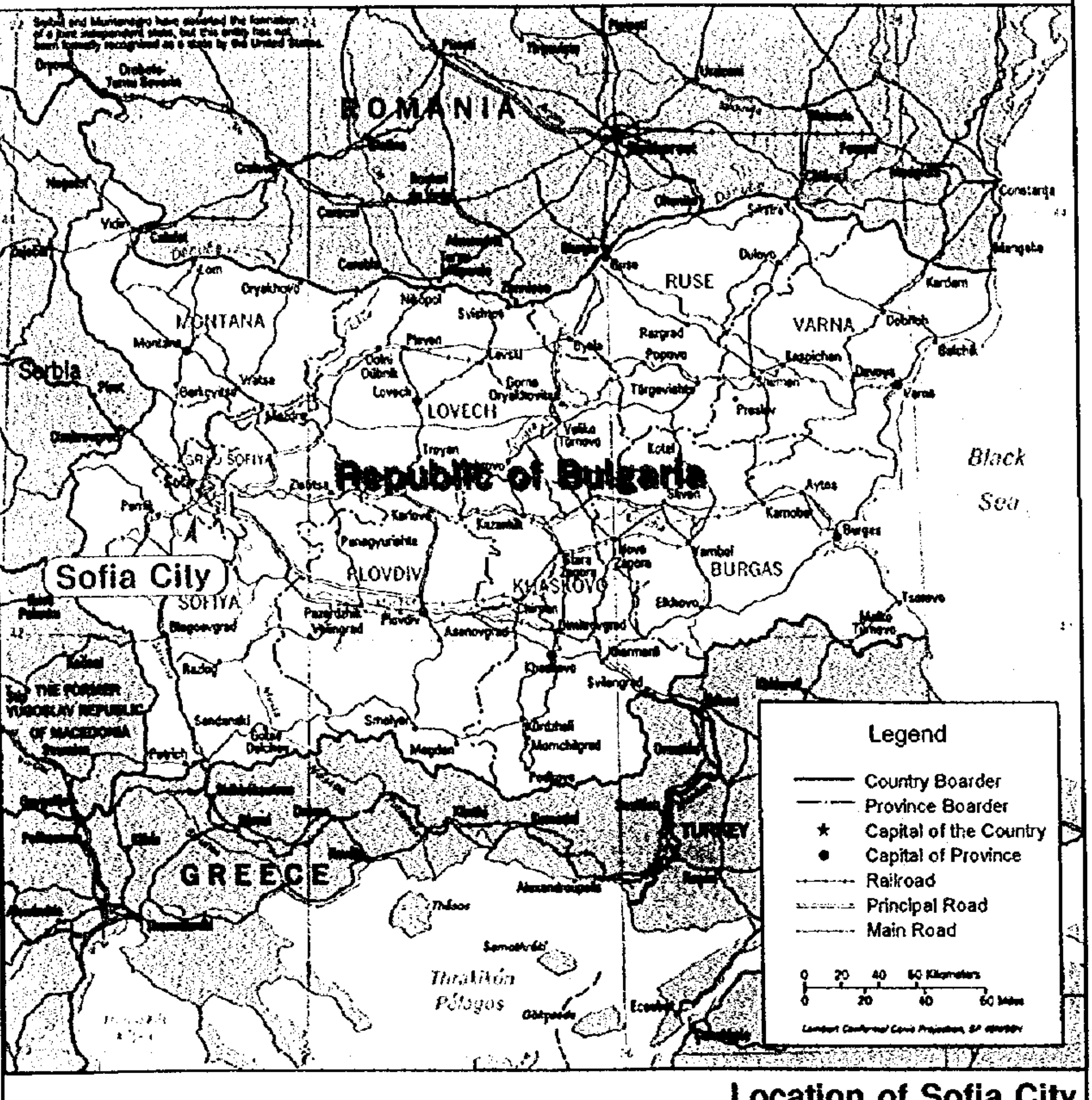
Project manager,

Basic design study team on
the project for construction of the
purification plant facilities
in Sofia City Municipality
in the Republic of Bulgaria

Pacific Consultants International

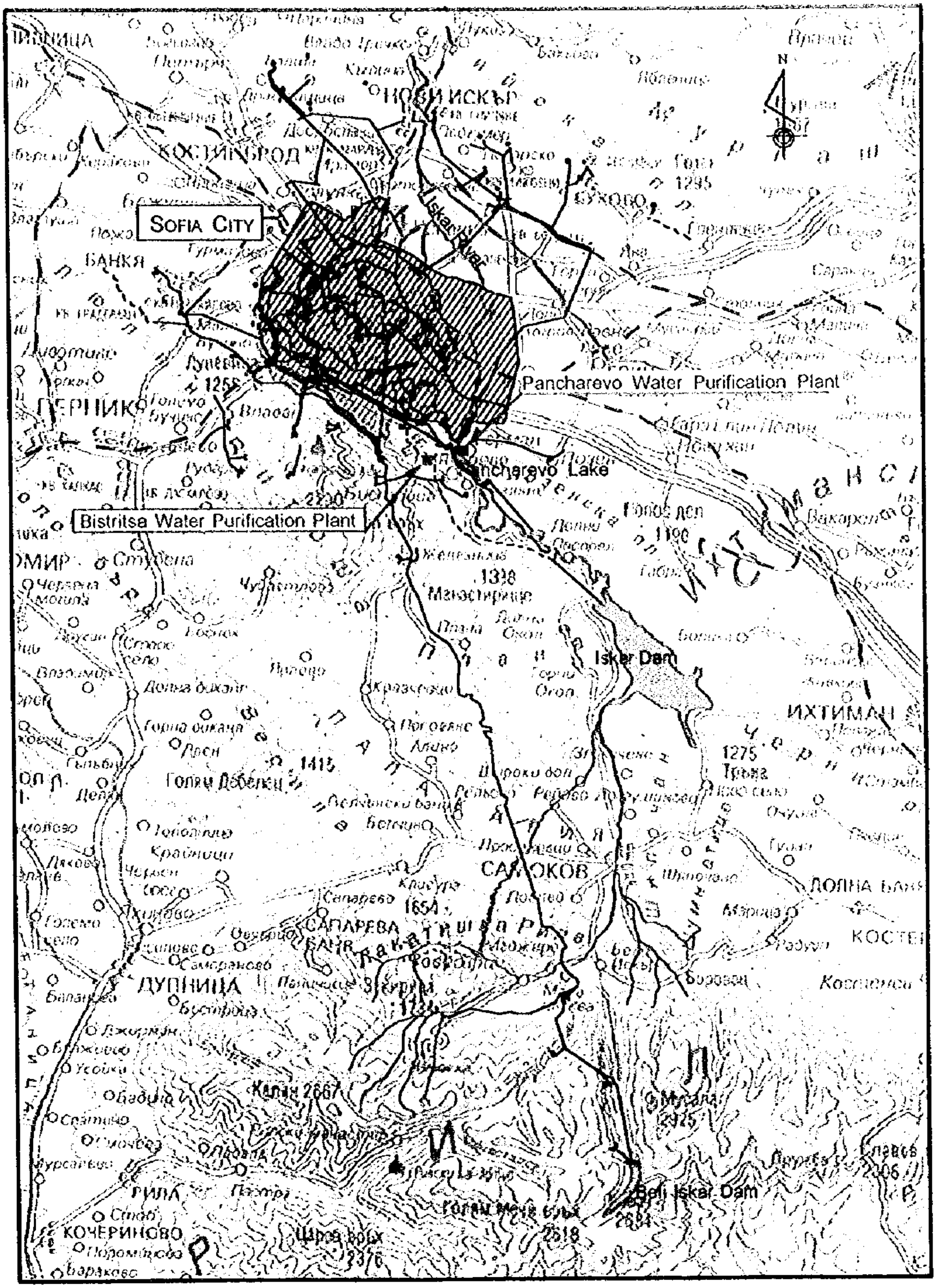


Location of Bulgaria

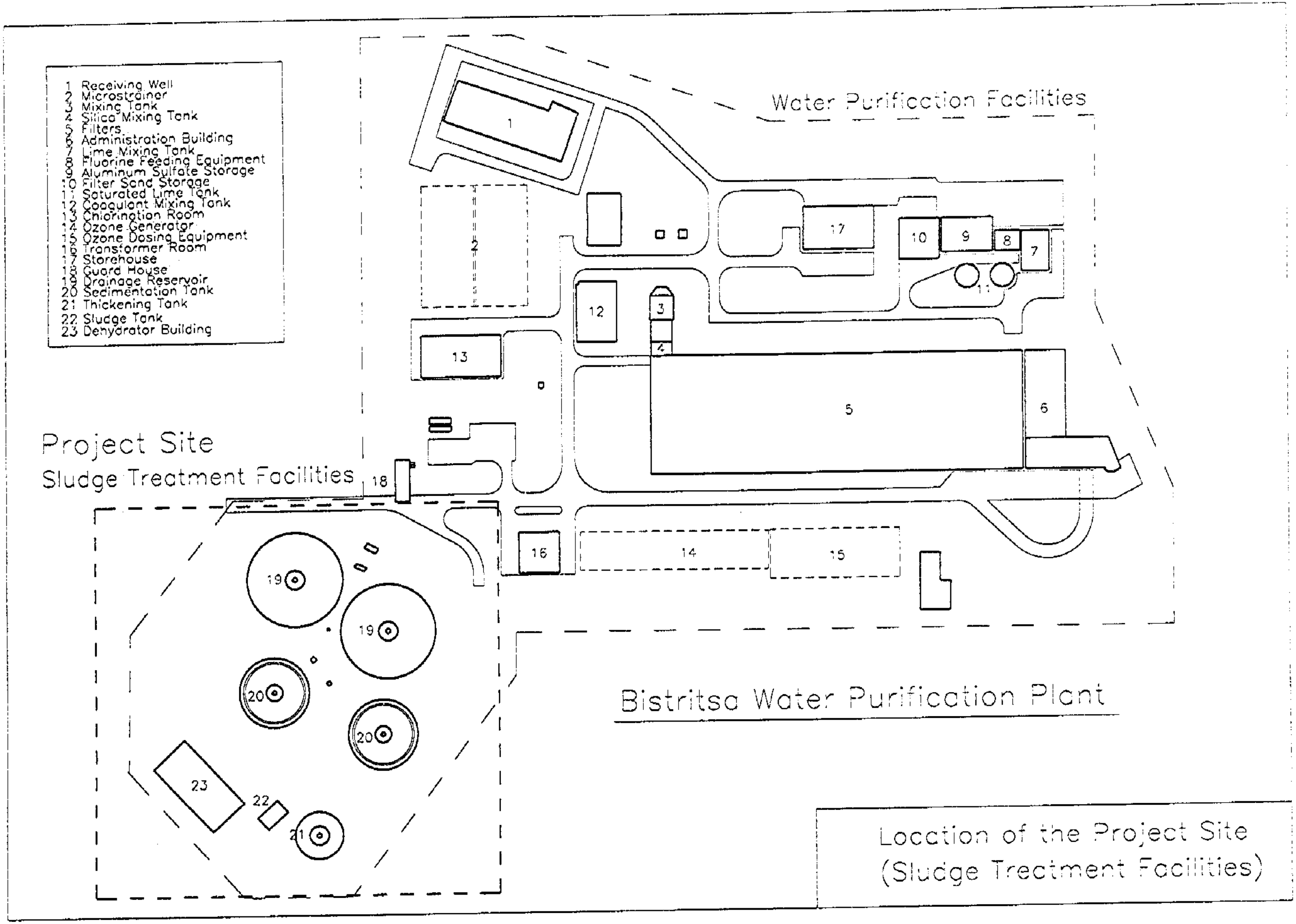


Location of Sofia City

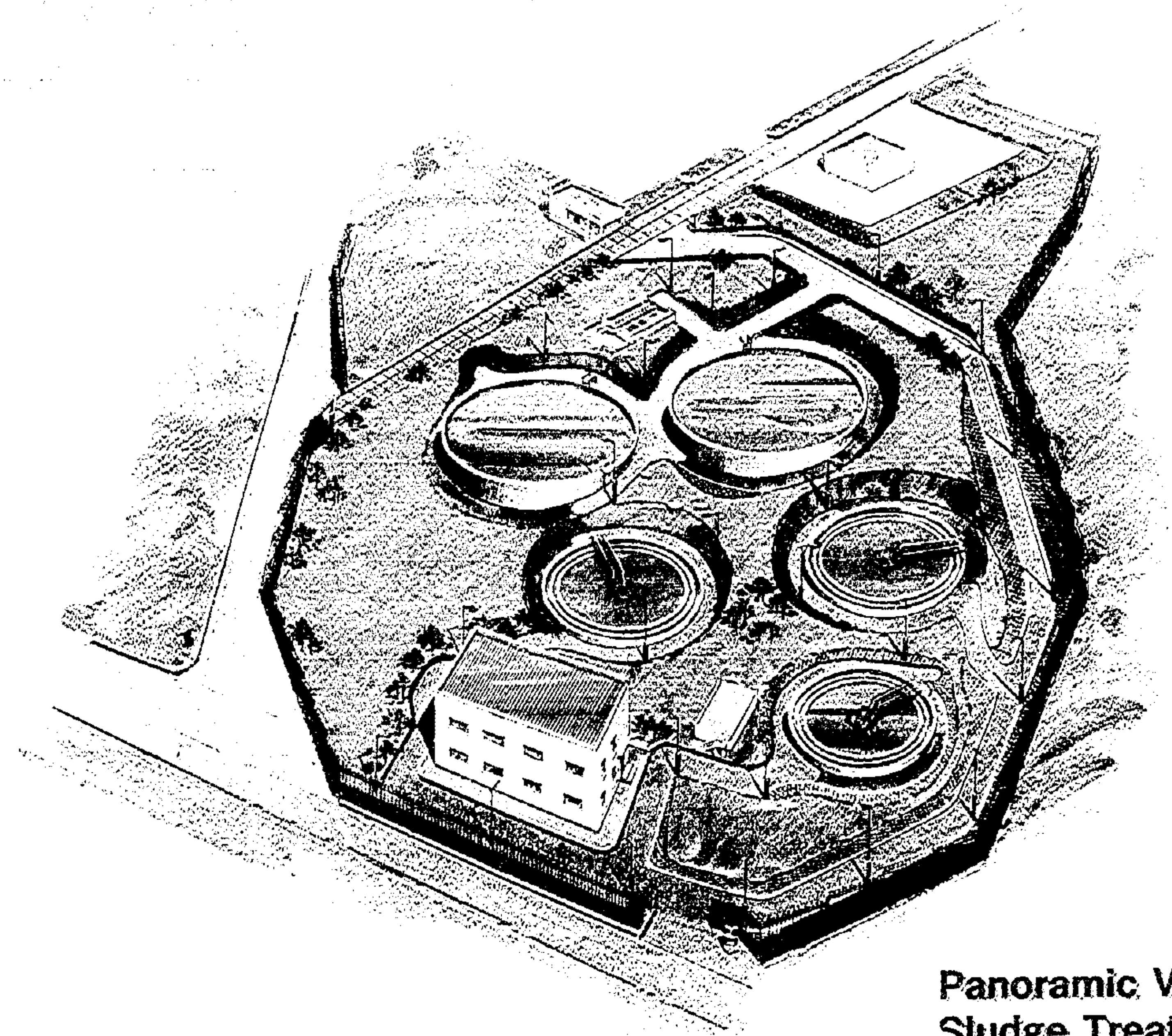
Location Map of the Project Site



Location Map of the Study Area
(Water Supply Systems of Sofia)



Location of the Project Site
(Sludge Treatment Facilities)



Panoramic View of the Sludge Treatment Facilities

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 2 CONTENTS OF THE PROJECT

LIST OF FIGURES

CHAPTER 2 CONTENTS OF THE PROJECT

CHAPTER 3 IMPLEMENTATION PLAN

BASIC DESIGN DRAWINGS

APPENDICES

CHAPTER 1 BACKGROUND OF THE PROJECT

CHAPTER 1 BACKGROUND OF THE PROJECT

Sofia City, the capital of the Republic of Bulgaria, has population of 1.19 million and area of 1,310 km^2. The city, located in western part of the country, is surrounded by Rodopi mountains in south and Balkan mountains in north.

The present rate of population served in Sofia City is 100%. But the existing water supply system suffers from the following problems:

- Insufficient capacity of water supply facilities for the growing water demand
- Decline in treatment capacity and product water quality of the existing water purification plant (hereinafter "WPP")
- Leakage from distribution network and scaling of distribution pipes

The existing water supply system is far from satisfactory in terms of both water quality and quantity. Improvement of the water supply facilities in Sofia City is an urgent subject at present.

In 1995, the Sofia City Municipality established a long-term water supply development plan in order to improve the existing facilities and to meet the projected future demand. Major projects under the development plan related to the requested project (hereinafter "the Project") are as follows:

- Construction of Bistritsa WPP with the capacity of 580,000 m^3/day will be completed to meet the future increase in the water demand. Rehabilitation works of the Pancharevo WPP will start after operation of this new plant begins, thereby ensuring stable supply of water during rehabilitation works.
- The Pancharevo WPP will be rehabilitated to improve the treated water quality.
- Leakage from the distribution network will be reduced to ensure the stable financial foundation of the Water Supply and Sewerage Company, Sofia through increase in accounted-for water, and to protect the water sources.

Construction of the Bistritsa WPP was started in 1980s and is currently scheduled to be completed by the end of 1998. In 1990, the Ministry of Environment ordered the purification plant to have sludge treatment facilities in compliance with the Environmental Protection Law. Their construction started in 1993 inside the Bistritsa

WPP. Because of constraints on budget, construction of the sludge treatment facilities comes to a halt when only 16% of their construction was completed. Full-scale operation of the Bistritsa WPP will start only when construction of the sludge treatment facilities is completed.

The Government of the Republic of Bulgaria requested the Government of Japan to extend grant aid to construction of the sludge treatment facilities for the Bistritsa WPP in 1997. In response to the above request, Japan International Cooperation Agency dispatched a preliminary study team to Sofia city to clarify the request and to examine the construction site in September 1997.

CHAPTER 2　CONTENTS OF THE PROJECT

CHAPTER 2 CONTENTS OF THE PROJECT

2-1 OBJECTIVES OF THE PROJECT

The objective of the Project is to enable operation of the Bistritsa WPP by completing the construction of the sludge treatment facilities of the Bistritsa WPP. This will ensure stable supply of safe and sufficient water to the residents of Sofia City.

2-2 BASIC CONCEPT OF THE PROJECT

2-2-1 Outline of Bistritsa Water Purification Plant

The Bistritsa WPP, which uses Iskar dam as solo raw water source, has water purification capacity of 6.75 m^3/s under normal operation (maximum: 8.8 m^3/s). The purification process consists of coagulation and filtration to remove suspended solids in a form of micro flocks. These micro flocks captured in filters are released through regular backwashing of filters. Process flow of the Bistritsa WPP is shown in Figure 2-1.

The water turbidity of Iskar dam is being low and stable throughout the year as shown in Table 2-1.

Table 2-1 Water quality of Iskar Dam (monthly average from 1990 to 1996)

	Unit	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug	Sep.	Oct.	Nov.	Dec.
Water Temperature	°C	4.2	4.2	5.3	7.6	9.9	11.2	12.7	13.3	14	13.6	10.2	6.2
Turbidity	mg/l	2.6	2.5	2.7	3.6	3.3	3.4	2.6	1.9	1.8	2.0	2.3	2.6
Dissolved oxygen	mg/l	1.84	1.96	2.1	2.15	2.16	2.12	1.9	1.86	1.8	1.91	1.86	1.77
Iron	mg/l	0.18	0.19	0.16	0.14	0.12	0.09	0.11	0.06	0.07	0.09	0.13	0.19
Manganese	mg/l	0.13	0.15	0.2	0.14	0.12	0.11	0.11	0.12	0.22	0.22	0.15	0.17
Ammonium	mg/l	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nitrous acid	mg/l	3.2	2.6	1.8	2.3	1.9	2.2	2.7	3.0	2.7	2.2	2.1	1.9
Nitric acid	mg/l	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
pH		7.2	7.2	7.2	7.2	7.1	7.0	6.9	6.9	6.9	7.0	7.2	7.1

(Source: Central Chemical and Biological Laboratory, Water Supply & Sewerage Company, Sofia)

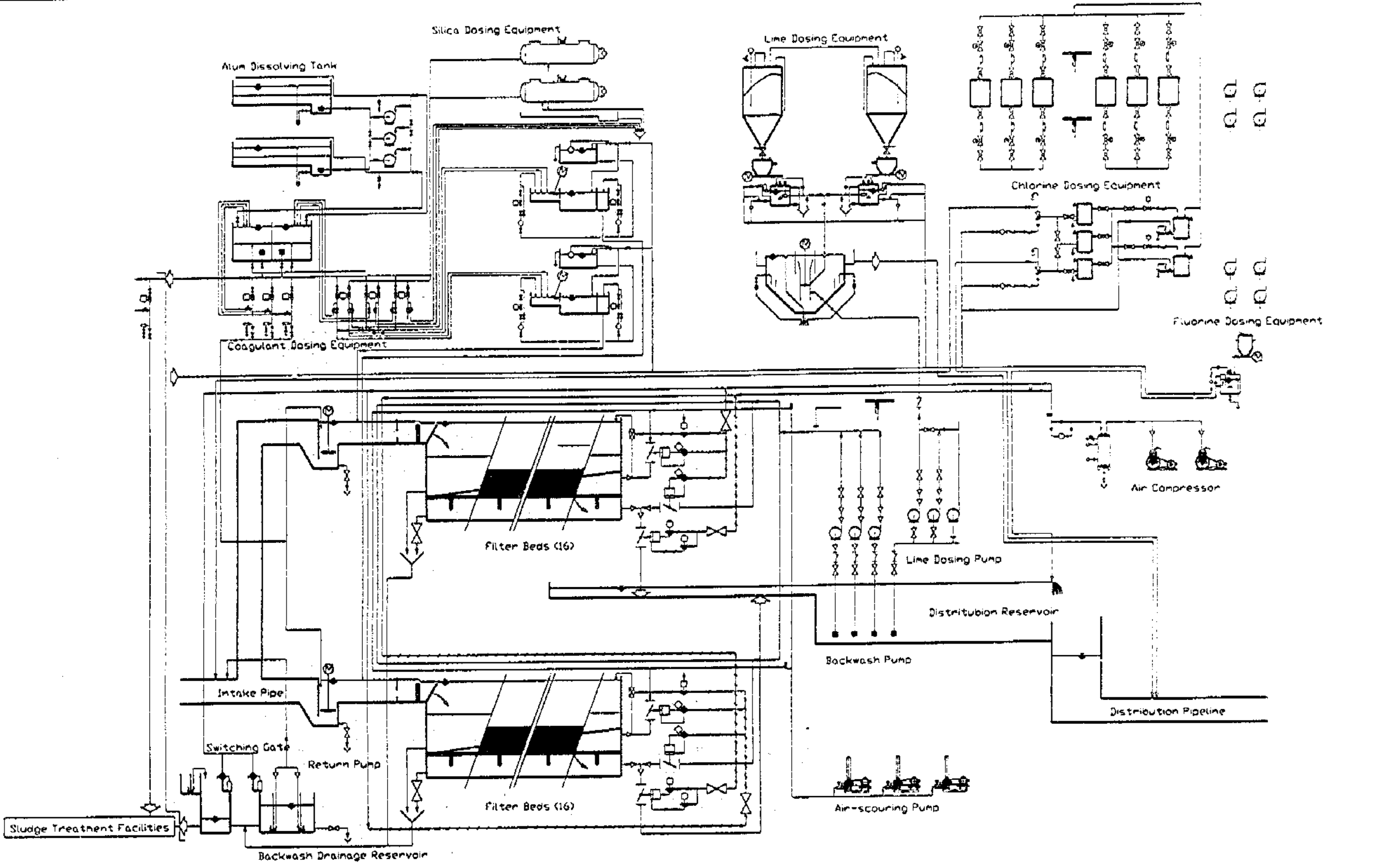


Figure 2-1
Process Flow of the Bistritsa Water Purification Plant

2-2-2 Basic Concept of the Project

The sludge treatment facilities separate the suspended solids, contained in backwash waste water of filters, from water by sedimentation and dehydration to enable disposed of the suspended solids in a form of sludge cake. Supernatant from sedimentation is discharged into the nearby river. The proposed sludge treatment process is shown in Figure 2-2.

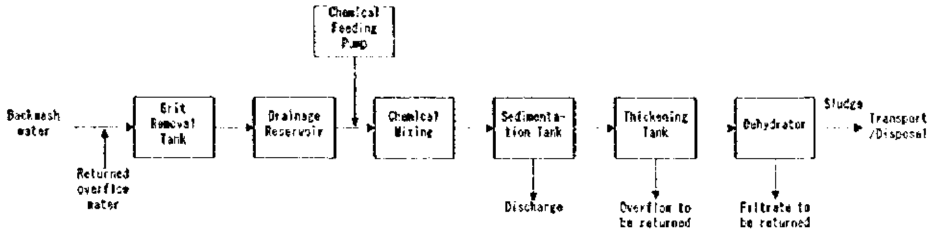


Figure 2-2 Proposed Sludge Treatment Process

Functions of major treatment facilities shown in Figure 2-2 are as follows.

- Grit removal chamber:	Remove grits from drainage (waste water)
- Drainage reservoirs:	Store drainage and supply the homogeneous drainage (sludge) at constant flow rate to sedimentation tanks.
- Sedimentation tanks:	Separate suspended solids in drainage from water. Coagulant is added to enhance sedimentation. Supernatant is discharged into river while settled sludge is sent to thickening tank.
- Thickening tank:	Thicken sludge. Supernatant is returned to grit removal chamber outlet while settled sludge is sent to dehydrators.
- Dehydrators:	Dehydrate thickened sludge. Dehydrated sludge is transported with trucks. Filtrate is returned to grit removal chamber outlet.

Treatment capacity of the facilities is determined, based on the design specifications of the existing water purification process, to treat filter backwash waste water under the maximum operation (water production = 8.8 m^3/s).

The Sofia City Municipality originally designed the facilities covered by the Project in 1991. A part of facilities are under construction. Concrete structures constructed and equipment procured by the Sofia City Municipality by now will be utilized for the Project as much as possible. Table 2-2 shows facilities that can be utilized in the Project.

Table 2-2 Existing facilities and equipment to be utilized

	Facility / Equipment	Specifications	Q'ty
Civil Structures	Drainage reservoir	Ø 40 m reinforced concrete	2 tanks
	Sedimentation tank	Ø 30 m reinforced concrete	1 tank
Mechanical Equipment	Sludge scraper	Ø 30 m steel made (including drive units)	3 units

Basic concept of the Project is to construct sludge treatment facilities to treat backwash waste water from filters in water purification process (water production: 6.75 m^3/day (normal operation), 8.8 m^3/day (maximum operation)) of Bistritsa WPP. The sludge treatment facilities enable discharge of clean supernatant, transport and disposal of dehydrated sludge cake for landfill an utilization for agriculture.

2-3 BASIC DESIGN

2-3-1 Design Concept

(1) Natural Conditions

Sofia City is located in a basin, which slopes from south (A.S.L.: 700m) towards north (A.S.L.: 500m). The Bistritsa WPP is located at approximately 740 m above sea level on the south slope of the basin. The area is colder and has more snowfalls than the city center.

The lowest ambient air temperature in winter is -15°C. Since the outdoor construction works are difficult in winter due to freezing and snowfalls, the outdoor works shall be completed by October.

Sofia city area is classified as IX region, which has potential of earthquake occurrence with magnitude 6.6 – 7. Civil and building structures of this project are designed to be earthquake resistant. The seismic coefficient of 0.27 will be used for structure design.

(2) Social Conditions

Bulgaria employs the rate schedule for electricity in order to suppress the power consumption at the peak hours. Considering the electricity rates, backwash operation of filters in the Bistritsa WPP will be done mainly in the night hours while the rate is the lowest. For the design of sludge treatment facilities, it is assumed that drainage from filters are generated only during the night hours.

(3) Operation and Maintenance Capacity of Implementation Agency

Sewerage department of Water Supply and Sewerage Company, Sofia operates a sewage treatment plant with 500,000 m^3/day treatment capacity constructed in 1984. The sewage treatment plant has sludge sedimentation, thickening and dehydration processes similar to those of the proposed sludge treatment plant, which have been operated and maintained properly. The operation of the above processes will give valuable information to operators of the proposed sludge treatment facilities.

The Pancharevo WPP will stop operating after the start of the Bistritsa WPP operation due to the required rehabilitation works. Most of the operators who presently work at the Pancharevo WPP will be transferred to the Bistritsa WPP. Therefore, the proposed sludge treatment plant will be operated by the experienced operators from the Pancharevo WPP. The experience of sludge treatment in the sewage treatment plant will help operators acquire necessary operation and maintenance techniques easily.

(4) Utilization of Local Contractors and Materials/Equipment

Most of the construction companies in Bulgaria are state-owned, while some of them are privatized after the fall of communism regime in 1989. In Sofia City, there is one state-owned enterprise in the field of waterworks, with around 1000 employees, and a few private enterprises with tens of employees. For the construction works of the Project, local construction companies will construct civil and building structures under supervision of experts from Japan.

In the history of the water supply sector of Sofia City, the local construction companies constructed Iskar Dam, the Pancharevo WPP and the water purification process of the Bistritsa WPP. With those experiences, the local construction companies have ability to construct civil and building structures in this project.

Most construction materials required for the Project are available locally. Local materials are utilized for the project as much as possible.

(5) The Scope of the Project and the Grade Setting

Grade of the Facilities and Materials

In principle, each equipment will be operated manually with a local control panel in order to be repaired and maintained easily by operators of Water Supply and Sewerage Company, Sofia. But, automatic controls will be installed for several equipment, such as flow controllers, of which operation is difficult without automatic controls. Water Supply and Drainage Company of Sofia has experience in operation of the large-scale water purification plant, the Pancharevo WPP, and is able to control and maintain partially automated systems judging from the operation records.

Procurement

Sludge scrapers to be procured within Bulgaria will be utilized to ensure quick supply of equipment and spare parts. These equipment has been used actually in water purification plants and wastewater treatment plants in Bulgaria with successful results. There are no Bulgaria-made dehydrators and they are not locally available. Feasibility of procuring dehydrators in the Western European countries (UK, Germany, or France) will be considered in view of ready supply of spare parts and technical support as well as the cost and time for transportation.

2-3-2 Basic Design

(1) Overall Plan

i) Capacity of sludge treatment facilities

Water purification process operation

The Bistritsa WPP has a capacity of 6.75 m^3/s for normal operation and 8.8 m^3/s for maximum operation. The water quality of Iskar Dam (to be used as raw water source) is good (Table 2-1), with the turbidity of 2.7 in annual average and its monthly average recorded maximum 3.6 in April (Table 2-3). The high monthly turbidity in April is due to inflow of snow melting water with high turbidity to the dam. But this dces not affect the raw water quality because Iskar dam has a large capacity.

Table 2-3 Raw water turbidity (monthly average from 1990 to 1996)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave.
Turbidity	2.6	2.5	2.7	3.6	3.3	3.4	2.8	2.0	1.8	2.1	2.4	2.8	2.7

Purification of the above raw water will be made by direct filtration method without sedimentation process. 5 mg/l of aluminum sulfate is added to enhance removal of suspended solids.

Filter operation method

The Sofia City Municipality has set the continuous filter operation (interval of backwash) to 48 hours for normal operation and 36 hours for maximum operation. The filter operation method is summarized in the table below.

Table 2-4 Filter operation methods

Mode of Operation	Water Production	Filtration Velocity	Backwash Interval	No. of Filters to be washed
Normal Operation	6.75 m^3/s	130 m/day	48 hours	16 filters/day
Maximum Operation	8.80 m^3/s	170 m/day	36 hours	21 filters/day

From operation data of same filters in the Pancharevo WPP which uses 20 - 50 % of its raw water directly from Iskar dam (the same raw water to be used by the Bistritsa WPP) and 50 - 75 % of its raw water from Iskar river. Turbidity of the raw water is generally low at 5 mg/l or less. Since no coagulant was added throughout 1997, raw water passed through sedimentation tanks for direct filtration. The filtration velocity is 130 m/day - 160 m/day, with the continuous filtration hours being 48 hours.

Filter Washing Method

Figure 2-3 shows the structure of filters in the Bistritsa WPP.

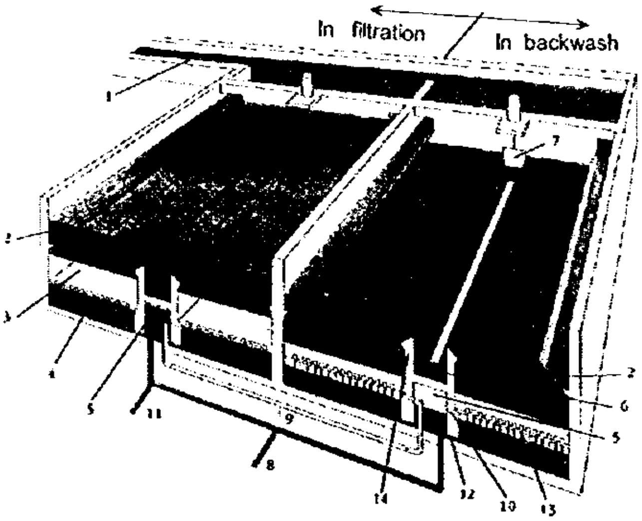


Figure 2-3 Structures of Filters in Bistritsa WPP

Filter washing consists of upflow water flushing and air scour from the bottom, causing re-suspension and discharge of suspended solids retained in filtration media. Table 2-5 shows the normal filter washing process.

Table 2-5 Filter washing process

	Process	Flow rate (flow velocity)	Time	Discharge per filter	Remarks
1	Discharge		3 – 4 min	–	Return to raw water inlet
2	Water washing	3.86 l/m²/s (14 m/hr)	5 min	245 m³ (Max.) 225 m³ (Nor.)	Inflow raw water:83 m³(Maximum) 63 m³(Normal)
	Air scour	15.0 l/m²/s (55 m/hr)			
3	Water washing	3.86 l/m²/s (14 m/hr)	10 min	489 m³ (Max.) 451 m³ (Nor.)	Inflow raw water:165 m³(Maximum) 126 m³(Normal)
4	Water recharge		5 min	–	Up to the operation water level
	Total		approx. 25min	734 m³ (Max.) 676 m³ (Nor.)	

These filters have no inlet valves, allowing raw water to flow into the filters even during washing. This water sweep filter surface to help washing.

Calculation of drainage (sludge) generation

The drainage generated from the above washing process is calculated for both normal and maximum operation. The parameters shown in the table below are used as design conditions for calculation of sludge contained in the drainage.

Table 2-6 Design conditions for calculation of sludge

	Design value	Remarks
Raw water turbidity	3.6 mg/l	Maximum value of monthly average (in April)
Coagulant dosage	5.0 mg/l	as aluminum sulfate (solid generation factor: 0.44)
Filtered water turbidity	0.5 mg/l	from experience of facilities in Japan

The calculation result is shown in Table 2-7. Details of calculations are shown in Appendix 5.

Table 2-7 Drainage generation

	Drainage Flow	Sludge amount*1
Normal Operation	10,816 m^3/day*2	3.1 t-DS/day
Maximum Operation	15,414 m^3/day*3	4.0 t-DS/day

*1 Dry weight (DS: dry sludge)
*2 (Drainage: 676 m^3/filter) x (No. of filters to be washed during normal operation: 16) = 10,816 m^3
*3 (Drainage: 734 m^3/filter) x (No. of filters to be washed during maximum operation: 21) = 15,414 m^3

Overall capacity of the sludge treatment facilities will be determined based on drainage generated under maximum operation because all the drainage generated must always be treated.

ii) Sludge treatment process flow

In "2-2 Basic Concept of the Project", sludge treatment process flow was shown in Fig. 2-1. Based on this flow, required facilities (equipment) and their basic roles were studied. The result is shown in Fig. 2-4 and Table 2-8. Capacities and specifications of these facilities will be examined later in "(2) Facility design".

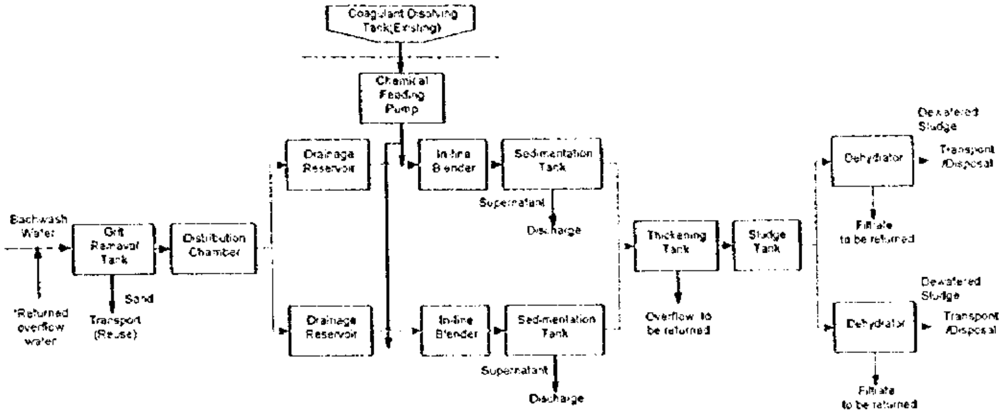


Figure 2-4 Sludge treatment process flow

Table 2-8 List of major facilities

Facility	Treatment Functions
Grit removal chamber	Removing grits (Ø > 0.6 mm) reusable for filters
Distribution chamber	Supplies equal drainage flow to two drainage reservoirs.
Drainage reservoirs	Store drainage and supply the homogeneous drainage (sludge) at constant flow rate to sedimentation tanks.
Coagulant feeder pumps	Feed coagulant (aluminum sulfate) from existing coagulant reservoirs (90 m^3 x 2) to the piping between drainage reservoirs and sedimentation tanks.
In-line blenders	Mix the coagulant with drainage to enhance coagulation.
Sedimentation tanks	Separate suspended solids in drainage from water through gravity sedimentation. The supernatant is discharged into river while settled sludge is sent to thickening tank.
Thickening tank	Thickens sludge further through gravity sedimentation to improve the efficiency of mechanical dehydration.
Sludge tank	Stores and mixes thickened sludge to supply homogeneous sludge to dehydrators.
Dehydrators	Dehydrate thickened sludge to facilitate transport with trucks for landfill and beneficial uses.

iii) Overall layout of facilities

Figure 2-5 shows the present layout of the Bistritsa WPP. In the proposed site for the sludge treatment facilities, two drainage reservoirs and one sedimentation tank are under construction. To examine horizontal position, level of the existing facilities and site topography, topographic survey was made. The result is shown in Figure 2-6. There is a ready-mixed concrete plant in the lower left corner C (shadowed).

At location D where thickening tank was initially planned, land has already been excavated to a certain degree. The thickening tank will be constructed in this location, while the proposed dehydrator building to its northwest at the lower end of the area C.

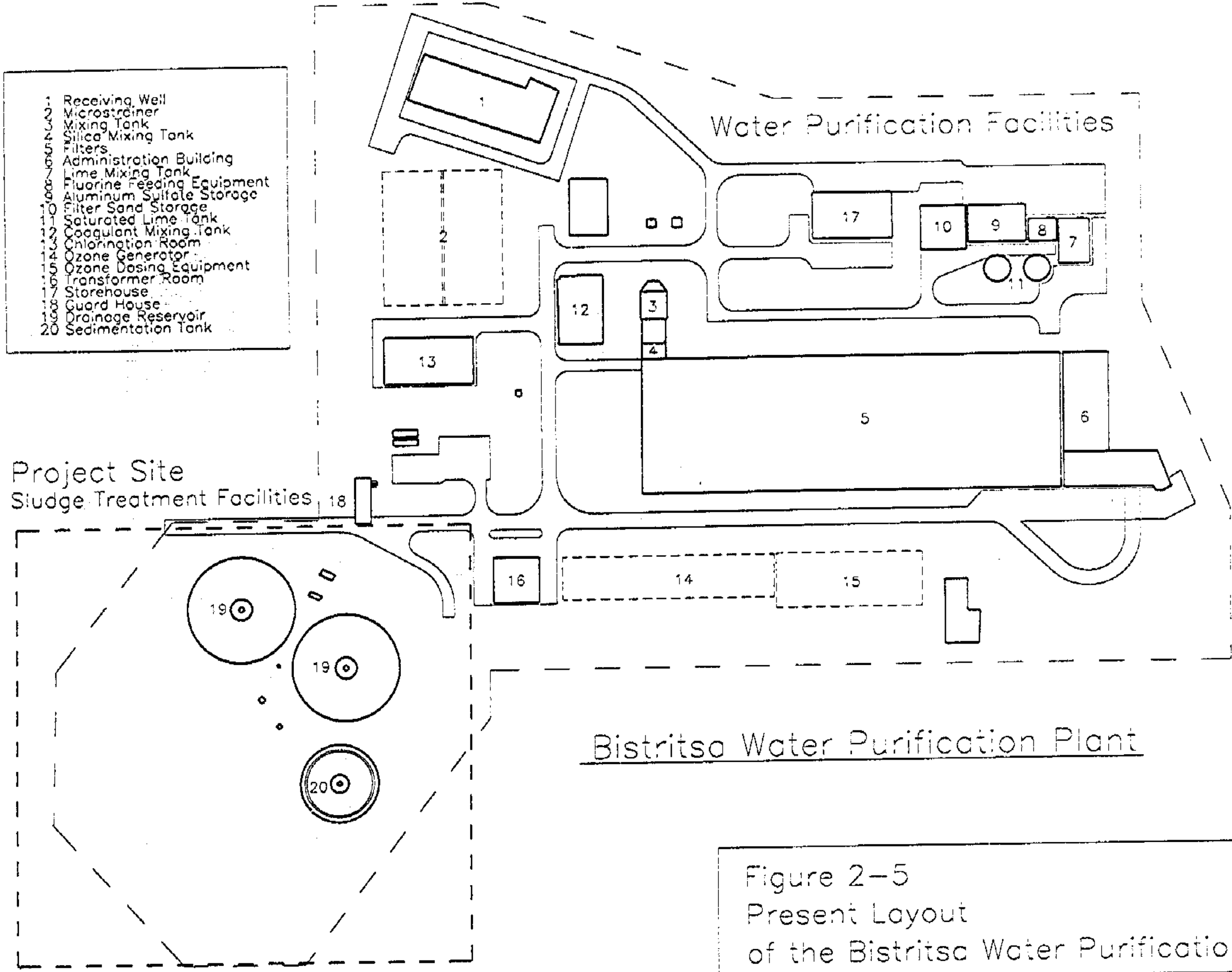


Figure 2–5
Present Layout
of the Bistritsa Water Purification Plant

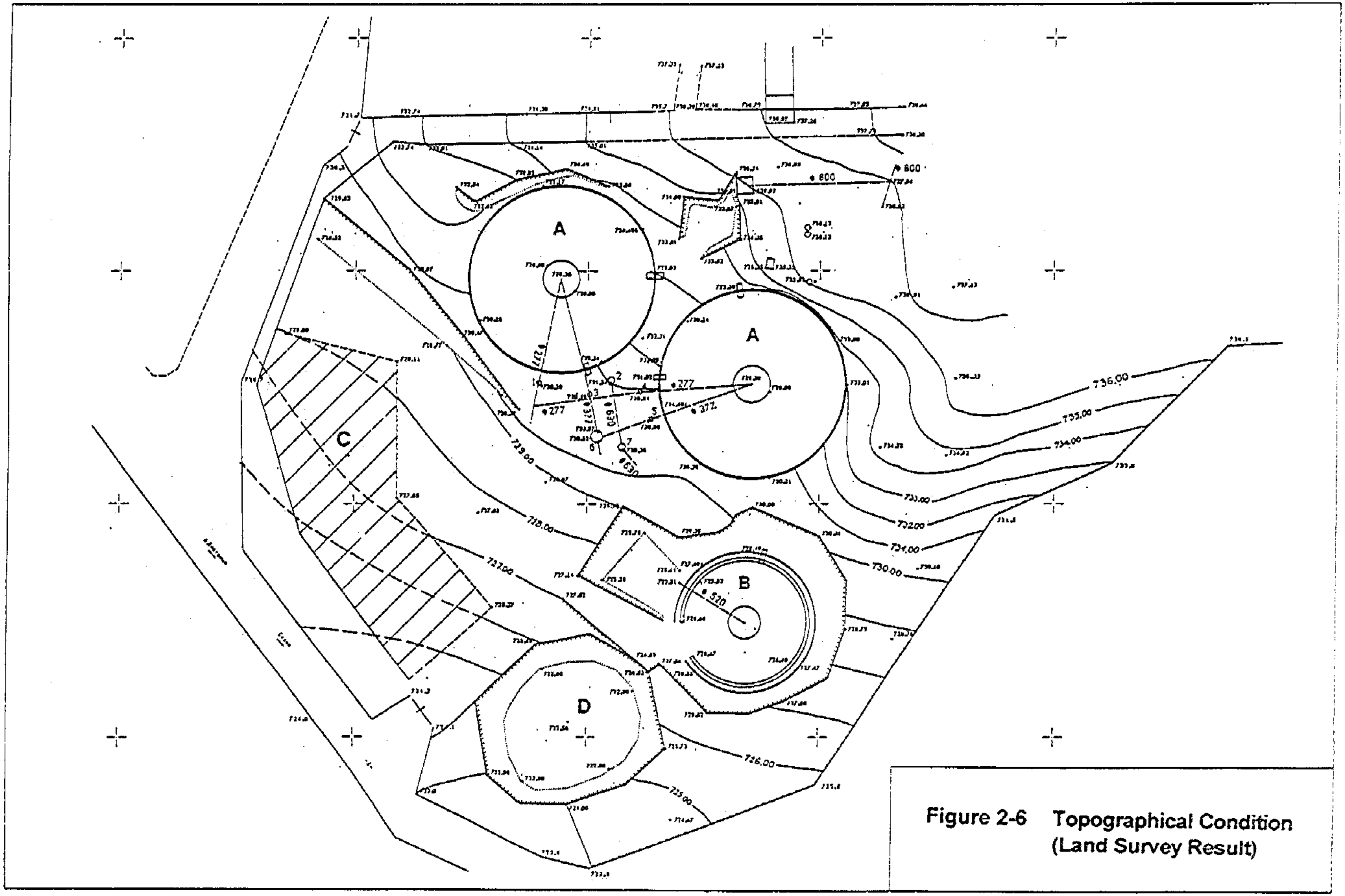


Figure 2-6 Topographical Condition (Land Survey Result)

iv) Sludge dehydration method

The most important element for selection of an appropriate dehydration method is to identify available dehydrated sludge disposal alternatives and their limitations stipulated in related laws and regulations (Environmental Protection Law, etc.). The available sludge disposal alternatives will be identified, then disposal limitations for selection of the dehydration method will be established.

There are two major alternatives to dehydrate thickened sludge, enabling transport with truck for disposal. They are drying beds and mechanical dehydration. Drying beds have advantages over mechanical dehydration in low construction, operation and maintenance costs. But they require large area. To dehydrate sludge from the Bistritsa WPP, about 4 ha will be necessary for drying beds. Drying beds can not be employed in this project because only about 0.5 ha of area is available. Therefore, the mechanical dehydration will be used for the Project.

Dehydrated sludge disposal alternatives

The Sofia City Municipality is currently considering landfill disposal for dehydrated sludge. Ministry of Environment and its subordinate agencies are engaged in monitoring of proper construction and operation of landfill sites according to the Environmental Protection Law and its regulations of Bulgaria. However, there are no clear stipulations concerning the quality of sludge disposed. Ministry of Environment is currently reviewing the Environmental Protection Laws adapting the EU's environmental law system. It is highly probable that the clearly defined stipulations are introduced concerning landfill of waste in the near future. Disposal limitations of sludge for landfilling to be introduced are examined based on national legislation in Europe, USA and Japan.

Dehydrated sludge generated from water purification plants has generally low contents of heavy metals except aluminum originating in the coagulant (aluminum sulfate) and does not contain other hazardous substances. pH value of sludge may rise to about 11 - 12 when lime is added in dehydration process. Leachate from such sludge with high pH value may have adverse effect on the environment. Without lime addition, sludge is considered inert without leaching of hazardous substances, so that the solid content of sludge, which is commonly employed as a limitation for landfill, is studied.

Acceptable sludge solids contents for landfilling in Europe and USA as well as in Japan are shown in Table 2-9.

Table 2-9 Acceptable sludge solids contents for landfill

Country	Solid Content	Remarks
Denmark	30% or more	
France	30% or more	
The Netherlands	35% or more	
USA	15% or more	co-disposal
	25% or more	mono-fill
Japan	15% or more	Law on Disposal and Cleaning of Wastes

In most of European countries, the acceptable solids contents are greater than 30 - 35%. In view of probable co-disposal with urban wastes, this project will employ the dehydration method which can achieve the solids content of 30% (target) of dehydrated sludge while ensuring 15% of solids content (guaranteed) at all time.

As the available sites for landfill will be scarce in the future, it is recommended to promote beneficial utilization of sludge for agriculture and other industries. It is known that the aluminum hydroxides in sludge adsorb phosphorous in soils. It may be necessary to add phosphorous fertilizer to the soil with low phosphorous content when alum sludge is incorporated into agricultural soils. Application of alum sludge at rate of 2.5% to the existing soil will not cause adverse effects on growth of plants (AWWA, 1995), may improve the physical properties of soil, thus suitable for agricultural use.

To promote beneficial uses, it is recommended to minimize the addition of chemical conditioners like lime and polymer in the course of dehydration. The minimization of chemical usage may lead to the reduction of operation costs.

Selection criteria for mechanical dehydration methods based on the study of sludge disposal alternatives are summarized as follows:

- 1 Alternative shall have the potential of achieving 30 % solids content of dehydrated sludge (target) while guaranteeing 15% or more solids content at all times.
- 2 Alternative shall use minimum chemical conditioners in the course of dehydration.

Selection of mechanical dehydration method

Mechanical dehydration methods for sludge generated in water purification plants, used in Japan, Europe and USA, include centrifuges, vacuum filters, pelletizers and filter presses (belt filter presses and filter presses). The principle mechanisms of these dehydration methods are summarized in Table 2-10.

Table 2-10 Principle mechanisms of mechanical dehydration methods

Method	Principle Mechanisms
Centrifuges	Separate, thicken and dehydrate solids using centrifugal force.
Vacuum filters	Vacuum cause solids adhere to a filter cloth. The liquid passes through the filter cloth and dehydrated sludge left on the filter cloth is removed with a scraper.
Pelletizers	Polymers and water glass are added to suspension. Turn it into pellets through rotation of sludge drum, separating thereby sludge and water. Dehydrated sludge has high water content, so that a drying process must be incorporated.
Pressure filters	
Belt filter presses	Sludge flocculated with polymers are passed and compacted between two belts for dehydration by filtration and compression.
Filter presses	Solids are pumped into filter chambers formed by filter clothes for dehydration by compression under water or oil pressure.

Table 2-11 shows comparison of these dehydration methods in terms of the necessity of chemical injection, nature of dehydrated sludge, costs, and environmental impacts.

Table 2-11 shows a generalized range of results which have been obtained for final solids concentrations from different dewatering devices for aluminum hydroxide sludges, which were generated through coagulation processes with aluminum sulfate or poly-aluminum chloride (PAC) used as coagulant. The only dehydration method that meets the above selection criterion 1 (solids content: 30% (target)) is filter press type. Filter presses are classified into three types depending on chemical conditioners to sludge. In consideration of the above selection criterion 2, filter presses without chemical conditioning are recommended. Although power consumption of filter presses is largest, the operation cost is smaller than the chemical conditioning types because no chemicals are needed.

Filter presses are typically divided into two categories: plate and frame presses and diaphragm presses according to dehydration mechanisms. Filter and frame presses use a series of rectangular frames which are brought together to form compartments with a filter cloth lining. While the sludge is being pumped into the compartments, the solids are retained and the water released from the filter press. The sludge pumping continues after compartments are full, thus pressuring the compartments, to further dehydrate the sludge.

Diaphragm filter is an enhanced version of the plate and frame press. After the fill and filter steps are completed, flexible diaphragms along the plates are expanded with compressed air or water to further compress solids in each compartment. This mechanism is shown in Figure 2-7. Diaphragm filters generally provide higher filter cake solids and decreased cycle times compared with the plate and frame press. On the basis of the above study results, this project will employ diaphragm filter presses without chemical conditioning.

Filter presses without chemical conditioning have been introduced in 100 or more locations in Japan. Filter presses are known to have high reliability in the dehydration efficiency and are relatively easy to operate.

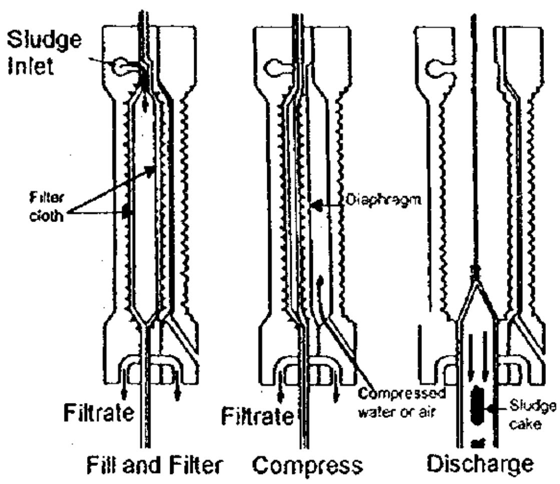


Figure 2-7 Dewatering mechanism of diaphragm filter press

Table 2-11 Comparison of mechanical dehydration methods for aluminum hydroxide sludge

Process	Chemical conditioning	Solids content of dehydrated sludge(%)	Toxicity of sludge	Sludge applicability for landfill disposal	Sludge potential for beneficial use	Land requirement	Construction cost	Operation cost[*5]		Maintenance cost[*5]	Environmental impacts					
								Chemicals	Power		Energy consumption	Noise	Vibration	Odor potential	Visual impact	Ground water contamination
Centrifuge	Polymer	10-15[*1]	Moderate	Low to Moderate	Low to Moderate	Small	Moderate	1	1	1	Moderate to High	Moderate to High	High	Low	None	None
Vacuum filter	Lime	10-17[*2]	High	Low	Low	Small	Moderate	1	2	1	High	Moderate	Low	Moderate	None	None
Pelletizer	Polymer + Water glass	10-15[*3]	Moderate	Low to Moderate	Low to Moderate	Small	Moderate	1.5	0.1	0.1	Low	Low	Low	High	Low	None
Pressure filter																
Belt filter press	Polymer	10-25[*1,4]	Moderate	Moderate	Moderate	Small	Moderate to High	1	0.5	0.3	Low to Moderate	Low	Low	Low	None	None
Filter press	Lime	35-45[*3]	High	Low to Moderate	Low to Moderate	Small	High	1	1	0.5	Moderate to High	Moderate	Low	Low	None	None
Filter press	Polymer	25-45[*2,3]	Moderate	Moderate	Moderate	Small	High	1	1.2	0.5	Moderate to High	Moderate	Low	Low	None	None
Filter press	None	25-35[*2,3]	Low	High	High	Small	High	0	1.4	0.5	Moderate to High	Moderate	Low	Low	None	None
Design target		≧ 30		Moderate to High	Moderate to High											

*1: AWWA/ASCS (1998), Water Treatment Plant Design
*2: Knock W.R. et al. (1993), Fundamental characteristics of water treatment plant sludge, Water Environmental Research, Vol. 65, No.6
*3: Operation data in Japan
*4: Kawamura (1991), Integrated Design of Water Treatment Facilities
*5: Value for centrifuge as 1.0

v) Drainage characteristics

Tests shown in the table below were made on drainage in order to obtain the basic data for the design of sludge treatment facilities. As the Bistritsa WPP has not been operating, samples were taken from filters while backwashing in the Pancharevo WPP which use similar raw water. Details of test methods and results are shown in Appendix 6. The results are summarized below.

Tests

Design	Parameter	Test method
Determination of coagulant dosage	Optimum coagulant dosage	Jar test
Determination of horizontal area of sedimentation and thickening tanks	Sedimentation characteristics (interface settling velocity)	Cylinder test
Study on supernatant disposal method	Water quality of effluent and recycle water	Supernatant quality test
Study on dehydrated sludge disposal method	Heavy metal contents	Settled sludge characteristics test

Results

Item	Test result	Remarks
Optimum chemical dosage	30 mg/l	Aluminum sulfate
Sludge settling velocity	10 mm/min	
Supernatant quality	Compliance with the water quality standards, Category II	For 15 measured items
Heavy metal contents of sludge	Compliance with the EU sludge in agriculture directive	Application of about 6.0 kg-dry sludge/m^2 possible per year (based on Cd and Zn contents)

The supernatant sample with the coagulant dosage of 30 mg/l and the sludge settling velocity of 10 mm/min, meets the Water Quality Environmental Standard, Category II for all measured parameters.

Agricultural utilization of sludge is under control of Ministry of Forestry, Bulgaria. EU Council Directive (86/278/EEC) for agricultural utilization of sewage sludge stipulates limits for heavy metal contents of sludge as shown in Table 2-12.

Table 2-12 Limit values on heavy metals stipulated in "Sludge in Agriculture" directive (CD 86/278/EEC)

Parameter	Concentrations in Soil (mg / kg)	Concentrations in Sludge (mg / kg-DS)	Annual average that may be put on soil (kg / ha / yr)
Cadmium	1-3	20-40	0.15
Copper	50-140	1000-1750	12
Nickel	30-75	300-400	3
Lead	50-300	750-1200	15
Zinc	150-300	2500-4000	30
Mercury	1-1.5	16-25	0.1
Chromium	-	-	-

Heavy metal contents of the sludge tested are low except for aluminum that was added as coagulant. Cadmium and Zinc contents meet the above directive for agricultural utilization of sludge. About 6 kg of sludge can be disposed annually per 1 m^2 of agricultural fields.

vi) Sludge dewaterbility

Bench-scale tests for dewatering could not be performed since test units were not available for the study team in Bulgaria. Operation data of filter presses in Japan are used to estimate dewaterbility (filtration velocity) of the sludge for this design.

Operation data of filter presses are shown in Table 2-13. Thickened sludge concentration is generally high in summer and low in winter. Filtration velocities of filter presses become higher as thickened sludge concentration increases. On the contrary, filtration velocity get lower as temperature of sludge goes down since viscosity of water increases. As a result, filtration velocity is lowest in winter. The average minimum filtration velocity of filter presses in winter shown in Table 2-13 is 1.44 kg-DS/m^2/hr. This value is used as a design value for equipment sizing of filter presses.

Table 2-13 Operation data of filter presses in Japan

No.	Location	Raw water (river/ lake)	Sludge generation (sedimentation/ filtration)	Chemical conditioning		Filter area of filter press (m^2)	Thickened Sludge solids content (%)		Filtration velocity ($kg\text{-}DS/m^2/hr$)		Remarks
				Yes/No	Type		Summer Maximum	Winter Minimum	Summer Maximum	Winter Minimum	
1	Tohoku	Lake	Sedimentation + Filtration	No	—	$408m^2 \times 1$	4.0	1.1	1.8	1.3	Water content: 76%
2	Tohoku	River	Sedimentation + Filtration	No	—	$460m^2 \times 1$	5.6	2.5	2.6	1.3	Water content: 68%
3	Hokkaido	River	Sedimentation + Filtration	No	—	$612m^2 \times 2$	16.0	1.2	4.2	1.7	Water content: 60%
4	Hokkaido	River	Sedimentation + Filtration	No	—	$850m^2 \times 2$	5.5	2.8	2.25	2.0	Water content: 67%
5	Hokkaido	River	Sedimentation + Filtration	Yes	Polymer	—	(average 2.7)		(average 2.0)		Water content: 75%
6	Shiga	Lake	Sedimentation	No	—	$256m^2$	1.5	0.6	2.0	0.9	$49500m^3/day$
7	Hyogo	Lake + River	Sedimentation	No	—	$640m^2$	(average 2.6)		(average 1.9)		$93000m^3/day$
	Average						6.5	1.6	2.57	1.44	

(2) Facility Design

i) Study on the capacity of each facility

Based on the sludge treatment process flow (Figure 2-4, Table 2-8) as studied in "(1) Overall Plan", the capacity of each facility was calculated based on the results of drainage characteristic tests and data of similar sludge. Details of the calculations are provided in Appendix 7. Capacities of major facilities are shown in Table 2-14 .

Table 2-14 Calculation results of capacities of major facilities

	Unit	Design capacity	Remarks
Grit removal Chamber			
Number		1	
Diameter	m	4.2	
Effective depth (average)	m	3	
Drainage reservoirs			
Number		2	
Diameter	m	40	
Effective depth	m	4	
Effective capacity	m^3	10,054	
Sedimentation tanks			
Number		2	
Diameter	m	30	
Effective depth	m	3.25	
Effective settling area	m^2	1,408	
Effective capacity	m^3	4,576	
Thickening tank			
Number		1	
Diameter	m	20	
Effective depth	m	3.5	
Effective capacity	m^3	1,100	
Dehydrators			
Number	unit	2	
Dehydration capacity	t/day	3.1	under normal operation
Operation hours	per day	10	under normal operation
Operation days	per week	7	
Filter area	m^2/unit	> 104 m^2	

ii) Specifications of facilities

Specifications for each facility determined by the above study are described below. Specifications for mechanical and electrical equipment used in the facilities are shown in Appendix 8.

Grit removal chamber

Grit removal chamber removes reusable grits (filter sand) with diameter greater than 0.6 mm contained in drainage, which are dried for removal by trucks. The proposed grit removal chamber is circular since only limited space is available between the existing inflow piping and drainage reservoirs. Incoming drainage is designed to circle the chamber once before being discharged. Settled grits are stored temporarily in the tank bottom and fed periodically to the drying bed by a submerged pump. The amount underflow is about 3 m^3 per discharge, with the sludge loading thickness over the drying bed of 30 cm and the drying area of approximately 10 m^2.

No. of tanks		1
Structure		Reinforced concrete
Dimensions	(Sedimentation section)	ϕ4.2 m×3.2 m
	(Sludge storage section)	ϕ1.5 m×2.3 m
Capacity	(Sedimentation section)	38.5 m^3
	(Sludge storage section)	3 m^3
Retention time		0.8 minutes
Mechanical and electrical equipment		Grit discharge pump x 1, Local control panel x 1

Distribution chamber

This chamber distributes equal quantity drainage to two drainage reservoirs. A baffle plate is provided at the inlet to prevent short-circuiting. Two overflow weirs of the same width are provided so that equal quantity of drainage overflows each weir. The weir width was set to obtain overflow depth of 0.25 m or less. Flashboards that adjust weir heights are provided. Drainage is directed to two reservoirs via pipes.

No. of tanks	1
Structure	Reinforced concrete
Overflow weir	2.2 m W x 2
Effluent pipe	Ø 800 mm x 2

Drainage reservoirs

Drainage reservoirs store incoming drainage, feed homogeneous drainage at a constant flow rate to the sedimentation tanks. Two existing reservoirs (Ø 40 m) have enough capacity to store drainage, thus can be used for this project. To keep drainage in the tank homogeneous, two submerged pumps are provided to each tank, which causes circular flow. Drainage is fed under gravity to the sedimentation tanks. Flow control devices are provided for the underflow pipes to keep drainage flow constant.

No. of tanks	2
Structure	Reinforced concrete
Dimensions	Ø40 m x effective water depth 4.0 m
Effective capacity	10,050 m^3
Drainage retention time	15.6 hours (under maximum operation)
Mechanical and electrical equipment	Mixer x 4, Flow control x 2, Local control panel x 1

Sedimentation tanks

Sedimentation tanks are used to settle suspended solids in the drainage to obtain clean supernatant. Settled sludge is thickened to about 0.5% and sent to the thickening tank. Coagulant (aluminum sulfate) is injected into inflow pipes and mixed with drainage by in-line blenders. Coagulant aid (polymers) is injected into the inflow pipes after the in-line blenders.

The sedimentation tanks are circular clarifiers, with sludge scrapers to scrape settled sludge to the center of the tanks for discharge. These scrapers use peripheral drive units. The power requirement for drive unit is 0.68 kW, therefore the existing drive units (power 0.75 kW) can be used. (Refer to 7.1 of Appendix 7) Trough to collect supernatant is installed along the inside of the wall. Settled sludge is sent by gravity to the thickening tank. The sludge flow is controlled with flow control valves and flow meters. Concerning civil engineering structures, one tank under construction (scheduled for completion by the Sofia City Municipality) will be used and another tank will be newly constructed.

No. of tanks	2
Structure	Reinforced concrete
Dimensions	Ø30 m x effective water depth 3.25 m
Effective capacity	4,590 m^3
Drainage retention time	7 hours (under maximum operation)
Sludge retention time	43 hours (under maximum operation)
Mechanical and electrical equipment	Pipe mixer x 2, Sludge scraper (drive units existing) x 2, Flow control x 2, Local control panel x 1

Thickening tank

Through gravity thickening, sludge is thickened to 3% solids content. Thickened sludge is discharged with sludge pumps to a sludge tank, then to mechanical dehydrators. The tank is provided with a sludge scraper to scrape thickened sludge to the center of the tank for discharge. This scraper has a peripheral drive unit. Since the required power of the drive unit is 0.46 kW, the existing drive unit (power 0.75 kW) can be used. (Refer to 7.1 of Appendix 7) The scraper is provided with a picket fence that consists of vertical bars to promote coagulation of sludge and to prevent anaerobic decomposition of sludge. Trough is installed along the inside of the wall.

No. of tanks	1
Structure	Reinforced concrete
Dimensions	Ø30 m x effective water depth 3.25 m
Effective capacity	2,470 m^3
Drainage retention time	1.4 days (under maximum operation)
Sludge retention time	3.5 days (under maximum operation)
Mechanical and electrical equipment	Sludge scraper (drive units existing) x 1, sludge discharge pump x 2, Local control panel x 1

Sludge tank

Sludge tank stores thickened sludge and keeps it homogeneous by mechanical mixing. Sludge is fed to dehydrators by pressure pumps. The tank will store an amount of sludge to be dehydrated by a half-day dehydration operation. The discharge pumps of thickening tank are controlled according to the sludge level of the tank in order to store the sludge sufficient for at least one cycle of dehydration for two dehydrators.

Coagulant aid feeding equipment to the sedimentation tanks can also provide polymers to this tank in order to improve dehydration efficiency.

No. of tanks	1
Structure	Reinforced concrete
Dimensions	W4.0 m x L6.0 m x effective water depth 3 m
Capacity	72 m^3
Sludge retention time	13 hours (under maximum operation)

Dehydrators and dehydrator building

The filter press dehydrators without chemical conditioning dehydrate the thickened sludge to the solid concentration of 30%. The number of dehydrators will be two considering the time required for repair in case of machine failures. Operation hours of dehydrators shall be less than 12 hours to allow one dehydrator dehydrate sludge generated per day in less than 24 hours. Considering time required for cleaning and daily maintenance of the dehydrators, operation hours are set to 10 hours. Dehydrators operate 7 days per week as same as the water purification process of the Bistritsa WPP by 4 teams of operators.

As auxiliary equipment to the dehydrators, filter-cloth cleaning equipment and belt conveyors for dehydrated sludge are provided. Dehydrated sludge is stored temporarily in sludge hoppers and loaded on trucks for disposal. The sludge hoppers can provide up to 1.5-days storage of sludge generated under normal operation.

Filtrate from dehydrators, together with the supernatant from the thickening tank is led to a supernatant tank, of which water is pumped back to the grit removal chamber outlet.

The dehydrator building is two-storied, with the dehydrators installed on the second story. There are a control room for the whole sludge treatment system and a toilet on the first story. Wastewater from the toilet etc. is pumped up to the central wastewater treatment facility in Bistritsa WPP.

Dehydrator

No. of dehydrators	2 units
Type	Filter press dehydrator without chemical conditioning
Operating hours	10 hours/day x 7 days a week (under normal operation)
Sludge dehydration rate	3.1 t-DS/day (under normal operation)
Filter area:	104 m^2 or more/unit
Auxiliary equipment	Hydraulic pump x 2, Filter washing device x 2, Compressor x 1, Belt conveyor x 2, Control panel x 2

Dehydrator building

No. of buildings	1 building
Structure	Reinforced concrete
Dimensions	W 16 m x L 25 m x H 10.8 m
Mechanical/electrical equipment	Traveling crane x 1, Sludge cake hopper x 2, Wastewater pump x 1

iii) Mass balance of the sludge treatment facilities

The mass balance diagrams of the sludge treatment facilities under normal and maximum operation are shown in Figures 2-8 and 2-9 respectively. The solids and water productions to be disposed are as shown in Table 2-15.

Table 2-15 Solids and water production to be disposed

		Normal operation	Maximum operation
Supernatant (from sedimentation tanks)		10,209 m^3/day	14,633 m^3/day
Dehydrated sludge	(70% water content)	13.4 t/day	10.4 t/day
	(as dry sludge)	3.1 t-DS/day	4.0 t-DS/day

iv) Horizontal Layout of the Facilities

On the basis of the discussions above, horizontal layout (Basic Design Drawings B-2) was prepared. The trucks transport dehydrated sludge through a gate installed near the existing temporary gate in the south-western corner of the site. A connection road (4 m wide) to the purification facilities of Bistritsa WPP will be constructed along the east end of the site. The service road (3 m wide) is constructed to provide access to each facility.

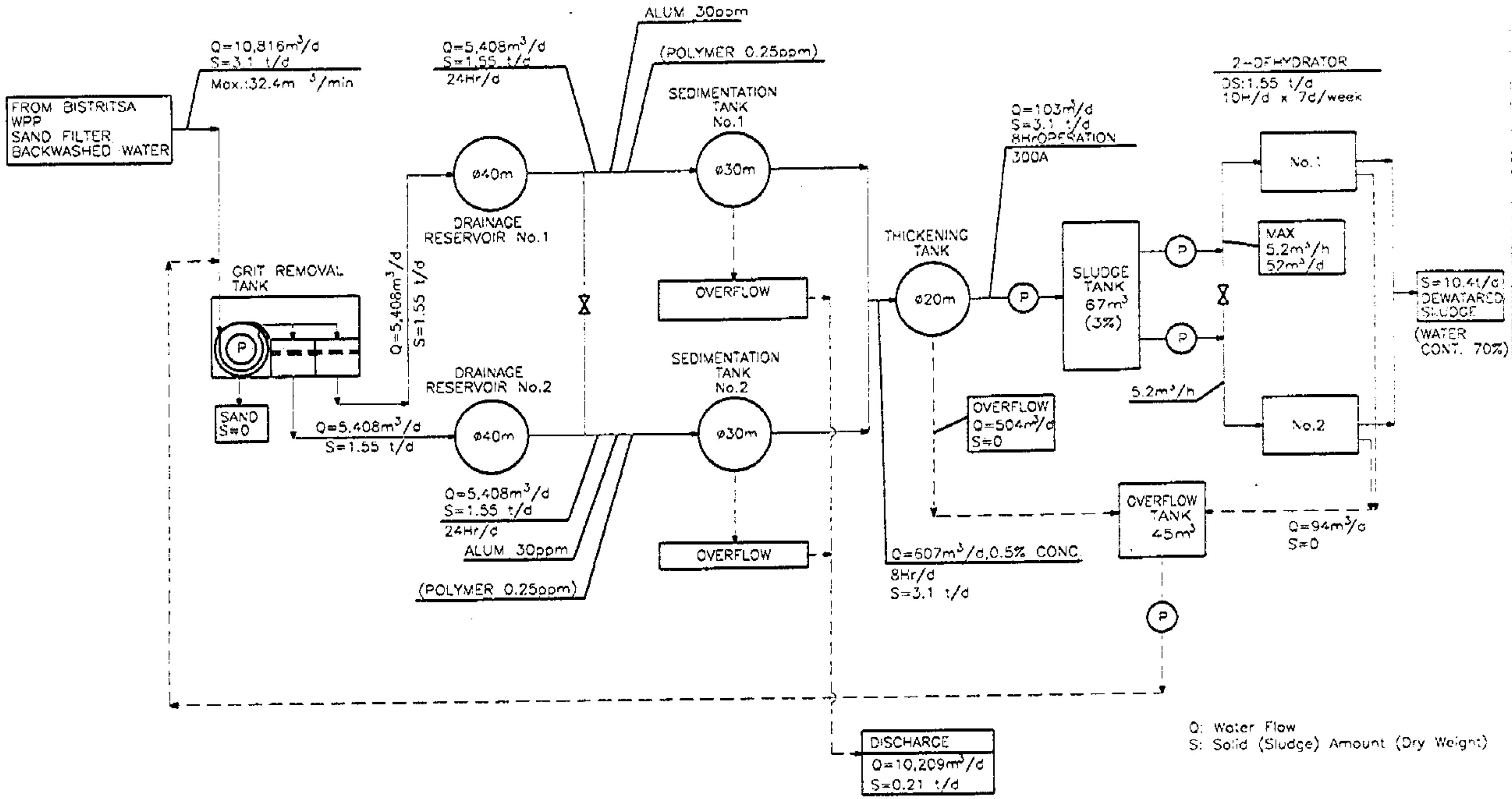


Figure 2-8
Mass Balance Sheet
of the Sludge Treatment Facilities
(Normal Operation)

Republic of Bulgaria Sofia City Municipality			
Basic Design Study on the Project for Construction of the Purification Plant Facilities			
Drawing Name	MASS BALANCE SHEET(1)		
Mar.1998	Scale : NON	No.	
JAPAN INTERNATIONAL COOPERATION AGENCY			

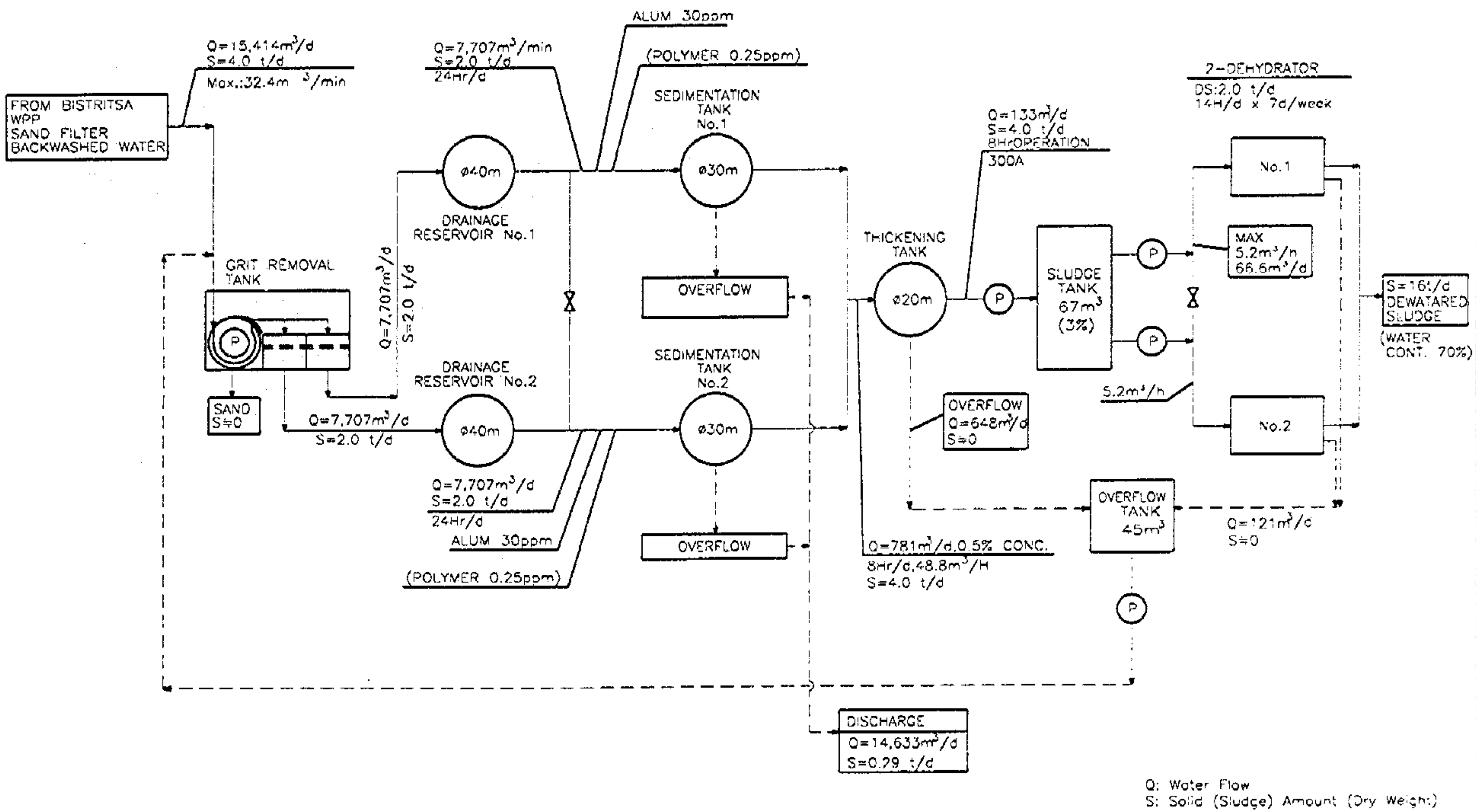


Figure 2-9
Mass Balance Sheet
of the Sludge Treatment Facilities
(Maximum Operation)

Republic of Bulgaria Sofia City Municipality			
Basic Design Study on the Project for Construction of the Purification Plant Facilities			
Drawing Name	MASS BALANCE SHEET (2)		
Mar.1998	Scale : NON	No.	
JAPAN INTERNATIONAL COOPERATION AGENCY			

v) Structure design

Results of structure analysis and foundation analysis for civil structures and buildings are described below.

The both analysis were made in compliance with the following design standards of both Bulgaria and Japan.

- Design Standard of Concrete and RC Concrete Structures, 1988, Bulgaria
- Recommendation for Design of Building Foundations, 1988, the Architectural Institute of Japan
- Design Criteria for Earthquake-resistant Technique in Water Facilities Design, Japan Water Works Association

Structure analysis

Structure analysis was made on existing and proposed structures to determine the sections and material strength. For the existing drainage reservoirs and sedimentation tank, it was examined that stress by water and earth pressure, which is calculated based on the design drawings by Sofia City Municipality, does not exceed the permissible stress of the materials.

The results of structure analysis of reinforced concrete tanks are summarized in Table 2-16 (see Appendix 9, Structural analysis for details). The existing drainage reservoirs and sedimentation tank have sufficient strength against water and earth pressure. For the thickening tank, distribution of steel bars was designed so that the structure has strength nearly equal to that of the existing tanks.

Table 2-16 Structure analysis results of reinforced concrete tanks

	Maximum tensile stress (kgf/cm^2)				Permissible tensile stress of steel (kgf/cm^2)
	Internal water pressure		External pressure (earth pressure)		
	Hoop tension	Vertical	Hoop tension	Vertical	
Drainage reservoirs	1,111	1,027	-*1	1,223	1,800
Sedimentation tank	911	634	-*1	691	1,800
Thickening tank	1,235	526	-*1	500	1,800

*1 Compressive stress applied

Foundation analysis

Foundation analysis was made based on boring and soil tests conducted by the Sofia City Municipality. The existing drainage reservoirs and sedimentation tank use mat foundation without piles. Bearing capacity of foundation was calculated for the thickening tank assuming mat foundation. The calculation results of bearing capacity of foundation for the above reinforced concrete tanks are shown in Table 2-17 (See Appendix 10 for details). For the reinforced concrete tanks, the footing loads do not exceed the permissible bearing capacity (long- and short-terms) of soil for all tanks, confirming that the bearing capacity of soil is sufficient.

Table 2-17 Calculation results of bearing capacity of foundation for reinforced concrete tanks

For walls

	Footing load (t/m^2)*1	Bearing capacity of soil (t/m^2)*2	
		Long-term	Short-term
Drainage reservoirs	8.6	32.6	38.3
Sedimentation tanks	6.1	51.5	57.2
Thickening tank	7.6	28.6	34.2

For center of the tank

	Footing load (t/m^2)*1	Bearing capacity of soil (t/m^2)*2	
		Long-term	Short-term
Drainage reservoirs	10.3	77.1	88.0
Sedimentation tanks	15.4	100.6	109.5
Thickening tank	12.1	51.7	63.0

*1 Second place below decimal point rounded up

*2 Second place below decimal point rounded down

Immediate settlements

Considering that the structures use mat foundation, immediate settlements were examined. Table 2-18 shows the calculation results for the reinforced concrete tanks (see Appendix 10 for details). The immediate settlements are less than the permissible settlements in all cases, indicating that the soil is rather stable. There are differential settlements between the wall and the center of the tank. Since all the tanks are circular, differential settlements do not affect the structures adversely.

Table 2-18 Calculation results of immediate settlements for reinforced concrete tanks

	Immediate settlements (cm)		Permissible settlement (cm)	
	Wall	Center of tank	Standard	Maximum
Drainage reservoirs	0.69	2.29	3.0 – (4.0)	6.0 – (8.0)
Sedimentation tanks	0.49	2.77		
Thickening tank	0.60	2.75		

(3) Equipment Schedule

Independent equipment to be required in this project is shown in the table below. Capacity of trucks are decided in order to transport sludge (10.4 ton / day) generated under normal operation by 2 trips of 2 trucks. Trucks are available in Bulgaria and to be procured locally.

Item	Specifications	Q'ty	Purpose
Dump truck	3 ton	2 units	to transport sludge accumulated in grit removal tank to transport dehydrated sludge for disposal

(4) Changes from the Request

Through the above study, the request from the Republic of Bulgaria was examined and optimum facilities have been designed. Major changes from the request are shown in Table 2-19.

Table 2-19 Changes from the Request

Item	Request	Change	Reason for change
Civil engineering (structures) and building works			
Grit removal chamber	1 unit	No change	
Chemical mixing	Chemical mixing tanks	In-line blenders	In-line blenders are employed because of space limitation and cost reduction.
Sedimentation tank	1 unit	2 units	The optimum tank surface area was selected based on the result of the sludge test. One existing tank is not enough to ensure the optimum tank surface area.
Thickening tank	2 units	1 unit	By installing two dehydrators, one thickening tank will be enough to offer the sufficient capacity. When one dehydrator is faulty, the operation time of the other one is doubled.
Dehydrator building	1 building	No change	
Auxiliary equipment for the proposed facilities	Electric and water supply. etc.	No change	

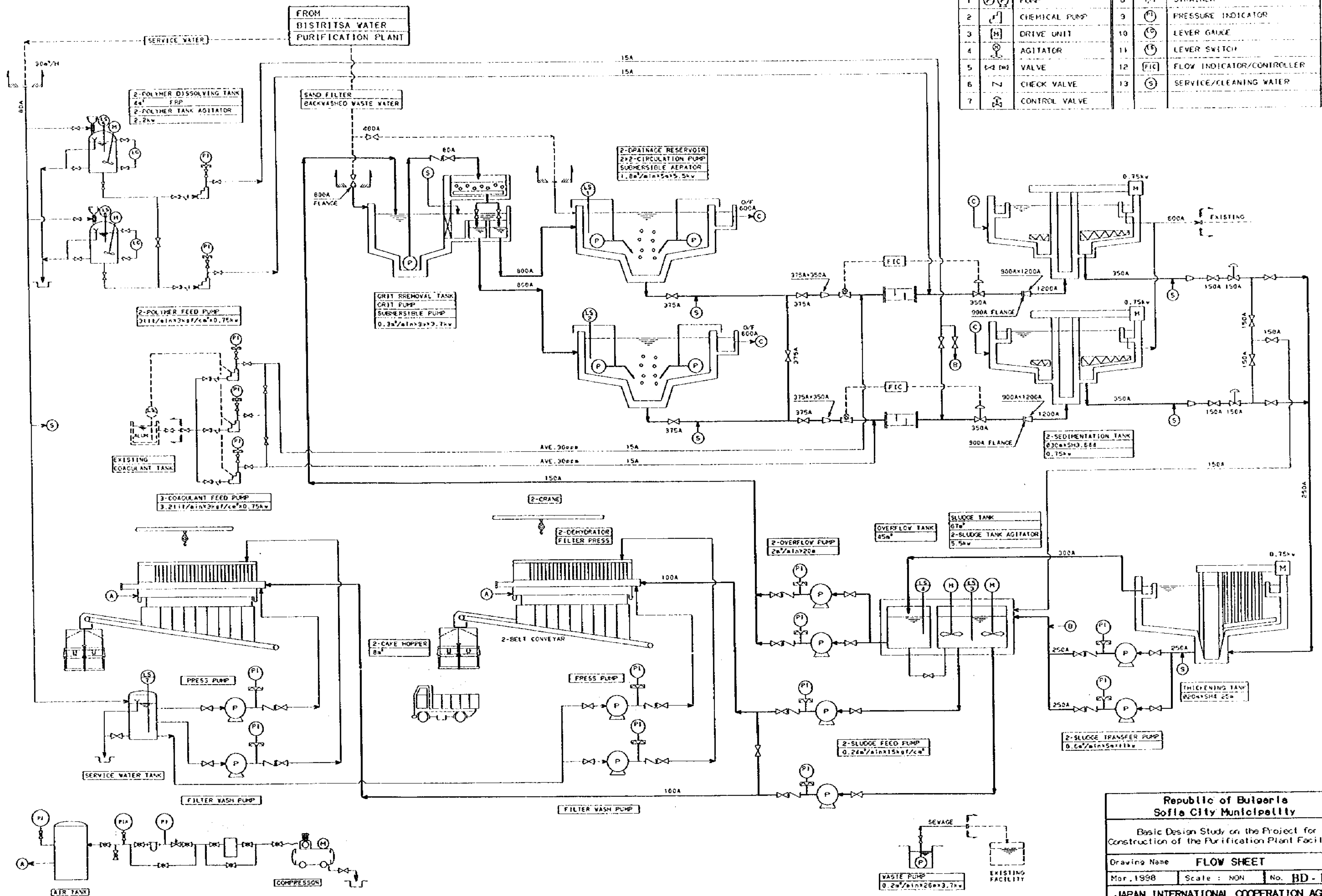
Table 2-19 Changes from the Request (continued)

Item	Request	Change	Reason for change
Equipment (mechanical and electrical)			
Grit removal chamber	1 set	No change	
Drainage reservoir	2 sets	No change	
Chemical mixing equipment	Mixing tanks	In-line blenders	See the above chemical mixing tank
Sedimentation tank	1 unit	2 units	One existing tank + one tank to be installed in this project
Thickening tank	2 units	1 unit	The number of thickening tanks was reduced to one.
Dehydrator	1 unit	2 units	The capacity was divided into two.
Other equipment			
Flow regulator	4 units	No change	
Aluminum sulfate injector	3 units	No change	
3-ton dump truck	2 units	No change	
Planting inside the site	1 set	None	Only time available for planting is in winter. It is not suitable for planting.

(5) Basic Design Drawings

List of basic design drawings prepared for this project is shown below.

No.	Name of Drawing	Scale	Page
BD-1	Flow Sheet	-	2-34
BD-2	General Arrangement	1/800	2-35
BD-3	Hydraulic Profile	-	2-36
BD-4	Grit Removal Tank	1/100	2-37
BD-5	Drainage Reservoir	1/400	2-38
BD-6	Sedimentation Tank	1/200	2-39
BD-7	Thickening Tank, Sludge Tank, Overflow Tank	1/200	2-40
BD-8	Dehydrator Building	1/200	2-41
BD-9	Piping Layout	1/800	2-42
BD-10	Single Line Diagram	-	2-43



LEGEND

1	Ⓟ	PUMP	8		STRAINER
2		CHEMICAL PUMP	9	(PI)	PRESSURE INDICATOR
3	[M]	DRIVE UNIT	10	(LG)	LEVER GAUGE
4		AGITATOR	11	(LS)	LEVER SWITCH
5		VALVE	12	[FIC]	FLOW INDICATOR/CONTROLLER
6		CHECK VALVE	13	(S)	SERVICE/CLEANING WATER
7		CONTROL VALVE			

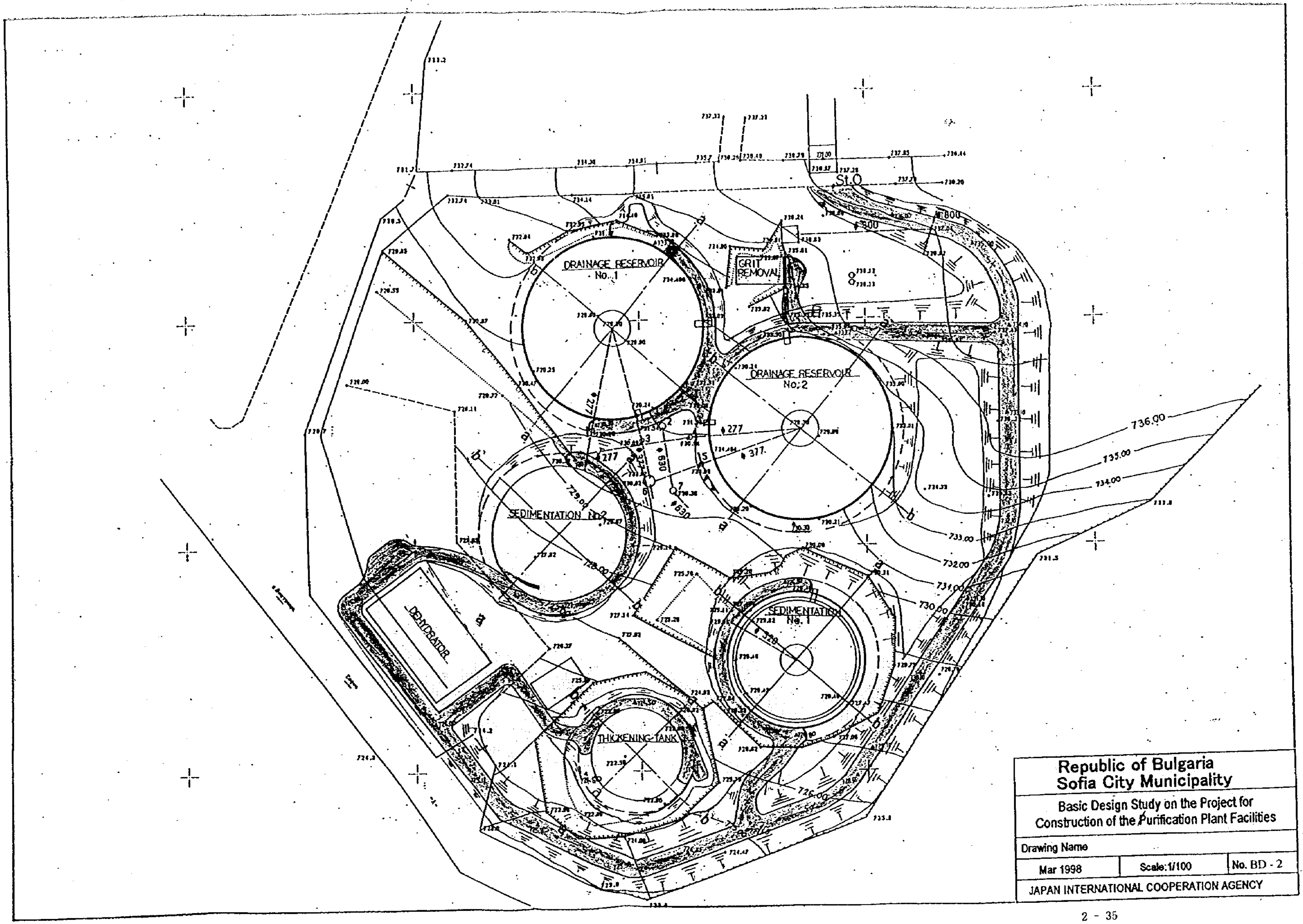
Republic of Bulgaria
Sofia City Municipality

Basic Design Study on the Project for
Construction of the Purification Plant Facilities

Drawing Name FLOW SHEET

Mar.1998 | Scale : NON | No. BD-1

JAPAN INTERNATIONAL COOPERATION AGENCY



Republic of Bulgaria
Sofia City Municipality

Basic Design Study on the Project for Construction of the Purification Plant Facilities

Drawing Name		
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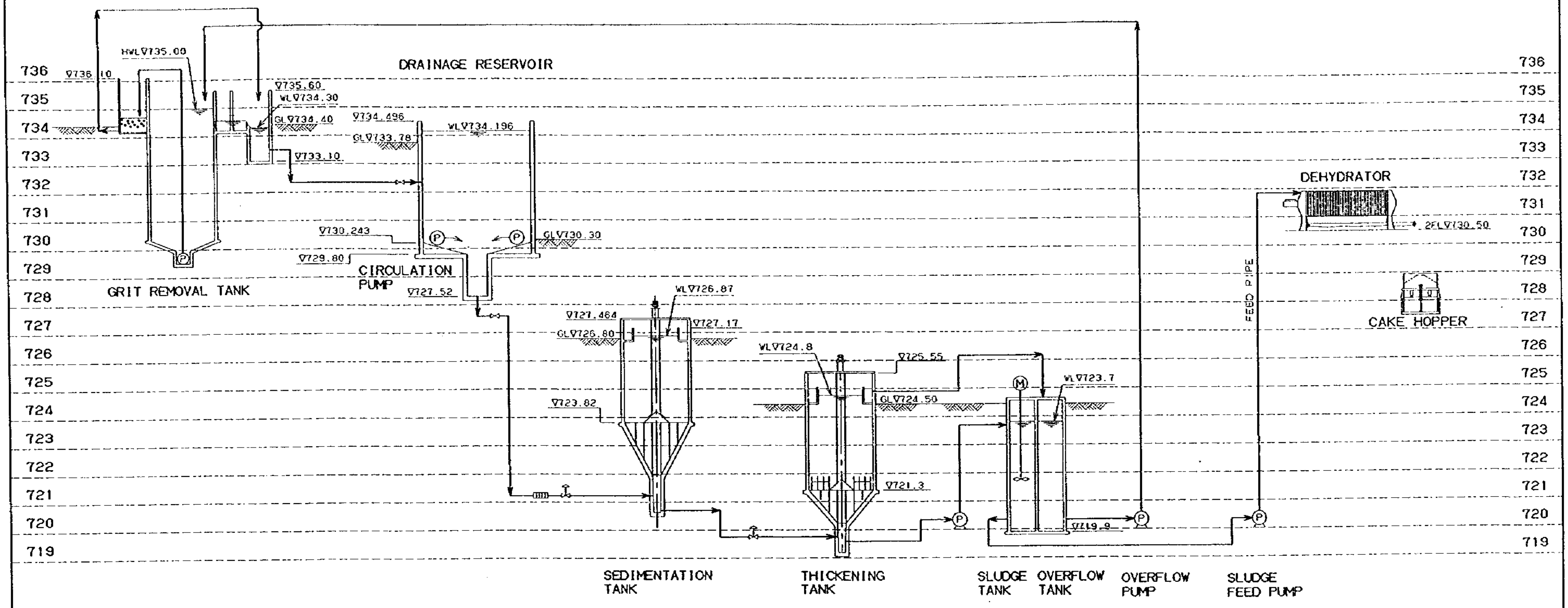

Republic of Bulgaria Sofia City Municipality	
Basic Design Study on the Project for Construction of the Purification Plant Facilities	
Drawing Name	HYDRAULIC PROFILE
Mar. 1998	Scale : NON — No. BD-3
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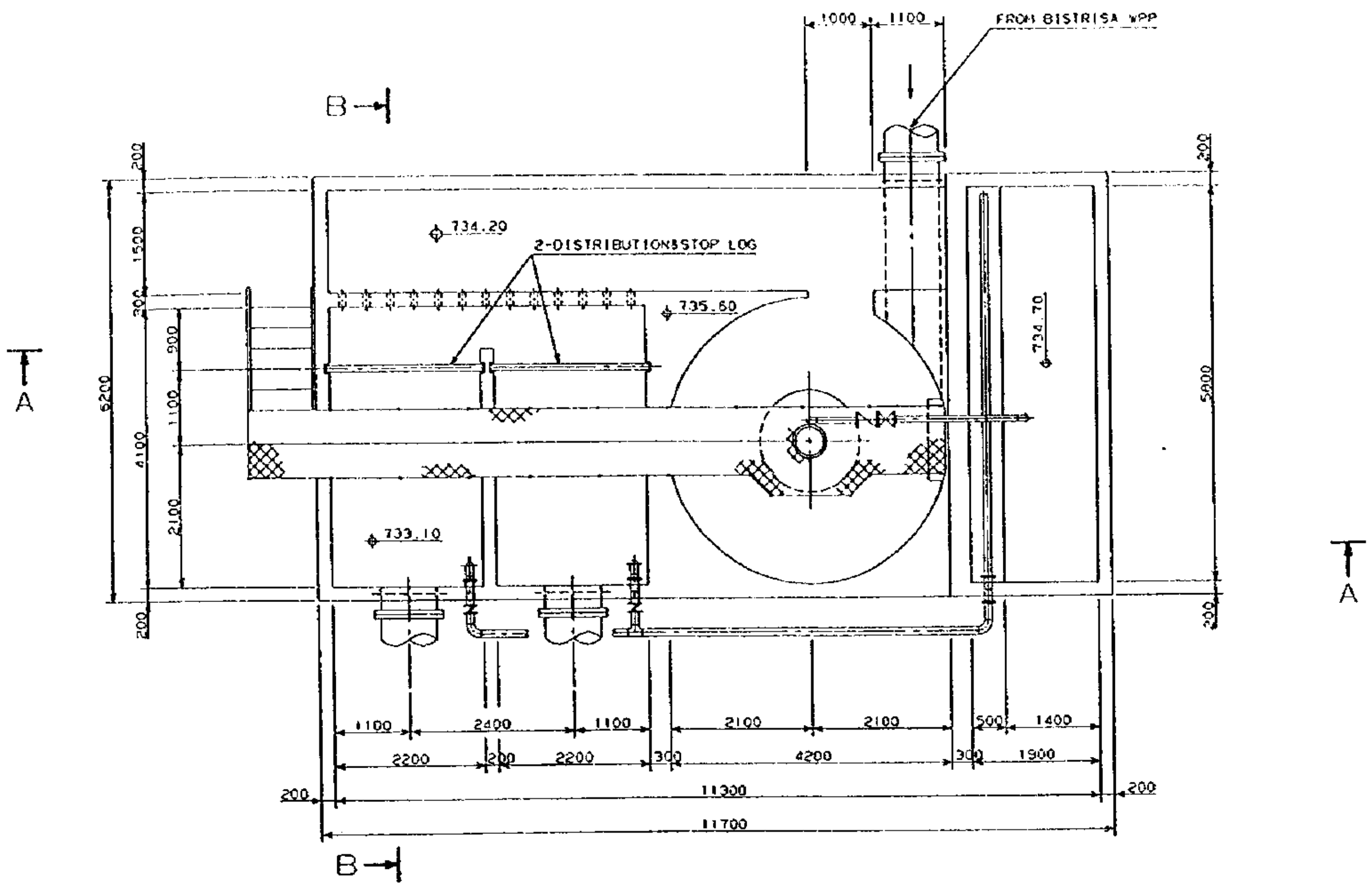
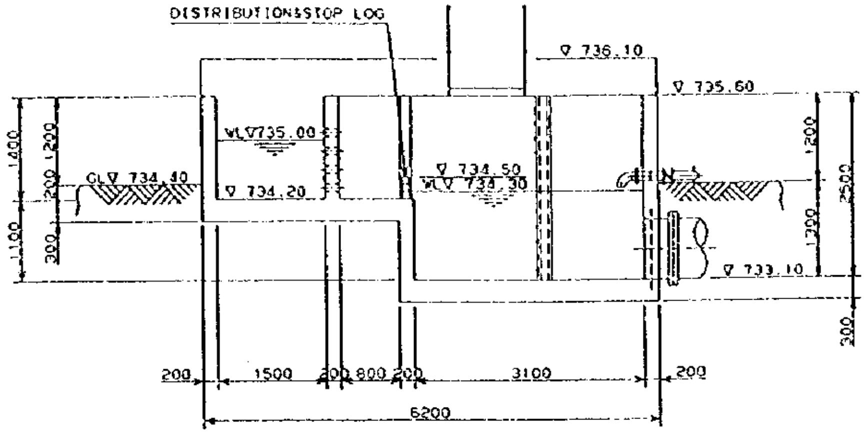
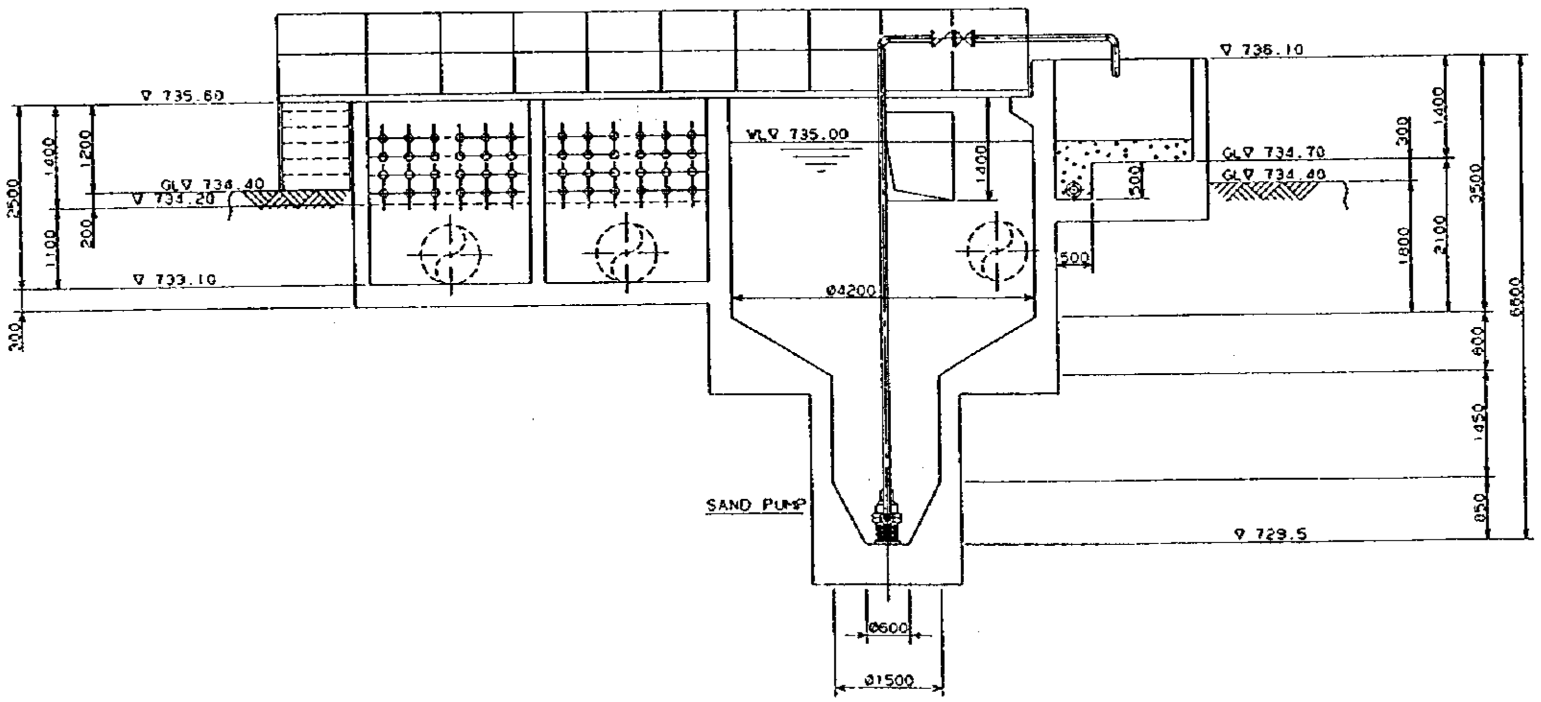




SECTION B~B



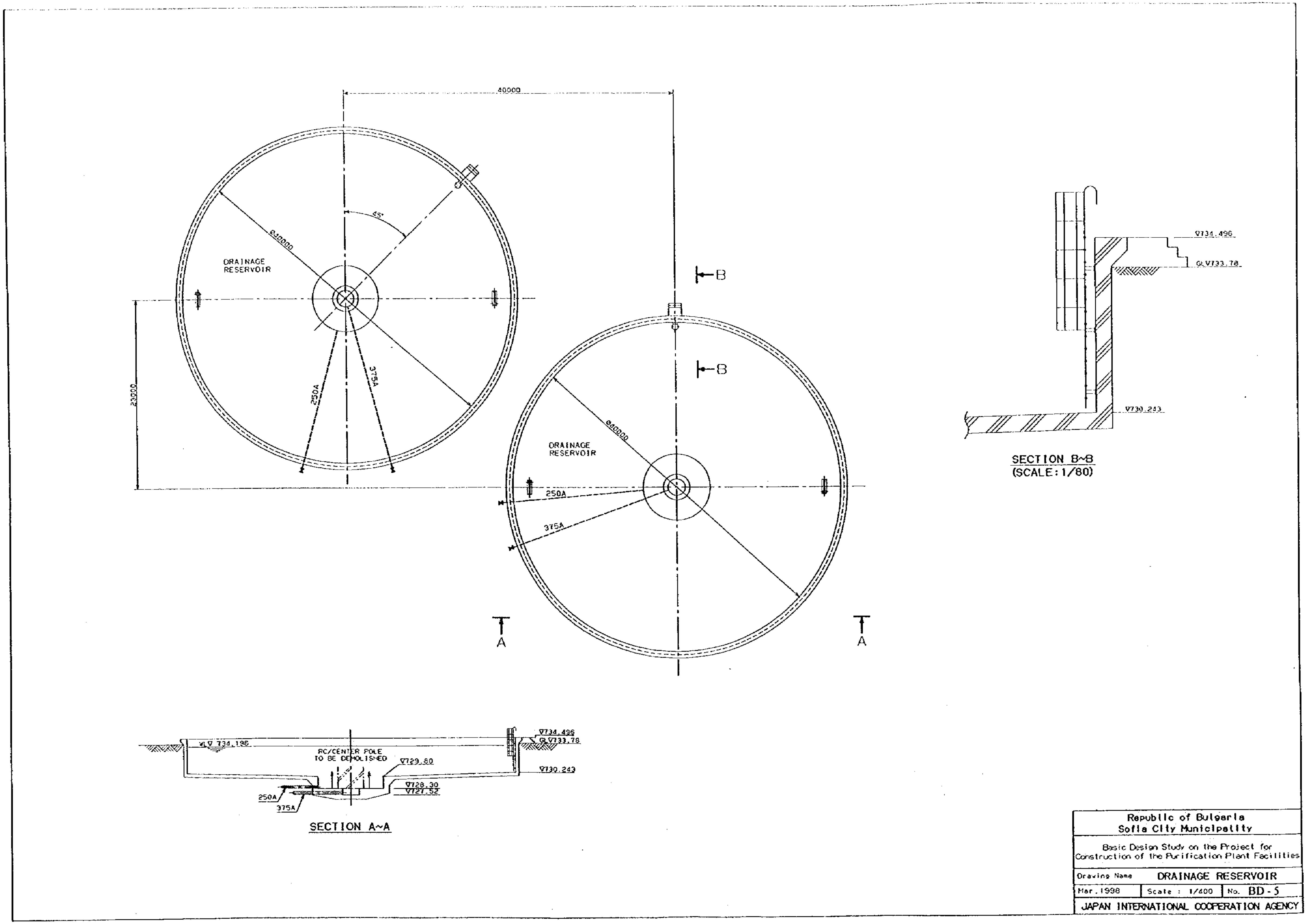
SECTION A~A

Republic of Bulgaria
Sofia City Municipality

Basic Design Study on the Project for Construction of the Purification Plant Facilities

Drawing Name	GRIT REMOVAL TANK	
Mar.1996	Scale : 1/100	No. BD-4

JAPAN INTERNATIONAL COOPERATION AGENCY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45°
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DRAINAGE
RESERVOIR
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375A
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B
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WLV 734.196
RC/CENTER POLE
TO BE DEMOLISHED
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∇728.30
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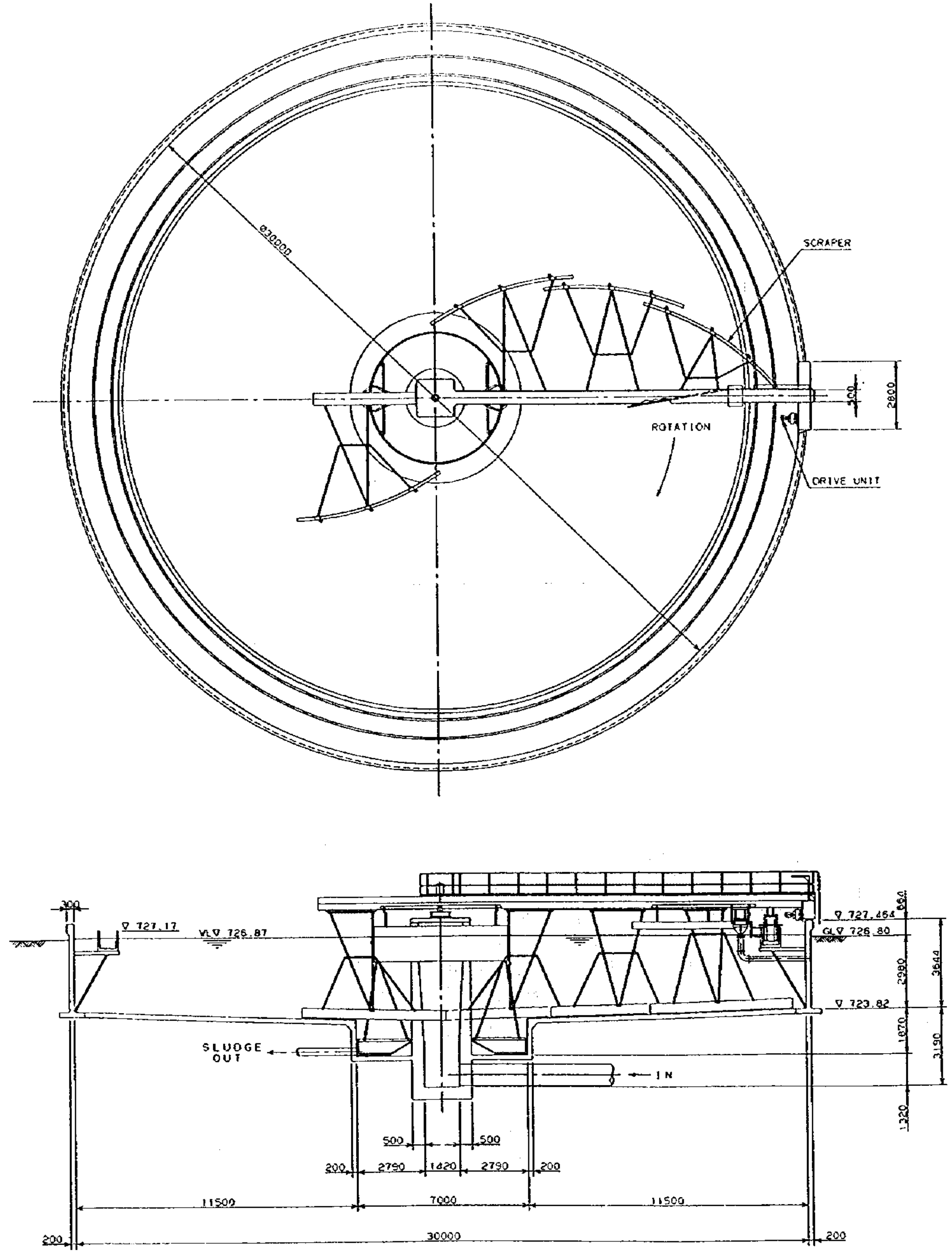
SECTION A~A
Republic of Bulgaria
Sofia City Municipality
Basic Design Study on the Project for
Construction of the Purification Plant Facilities
Drawing Name
DRAINAGE RESERVOIR
Mar. 1998
Scale : 1/400
No. BD-5
JAPAN INTERNATIONAL COOPERATION AGENCY

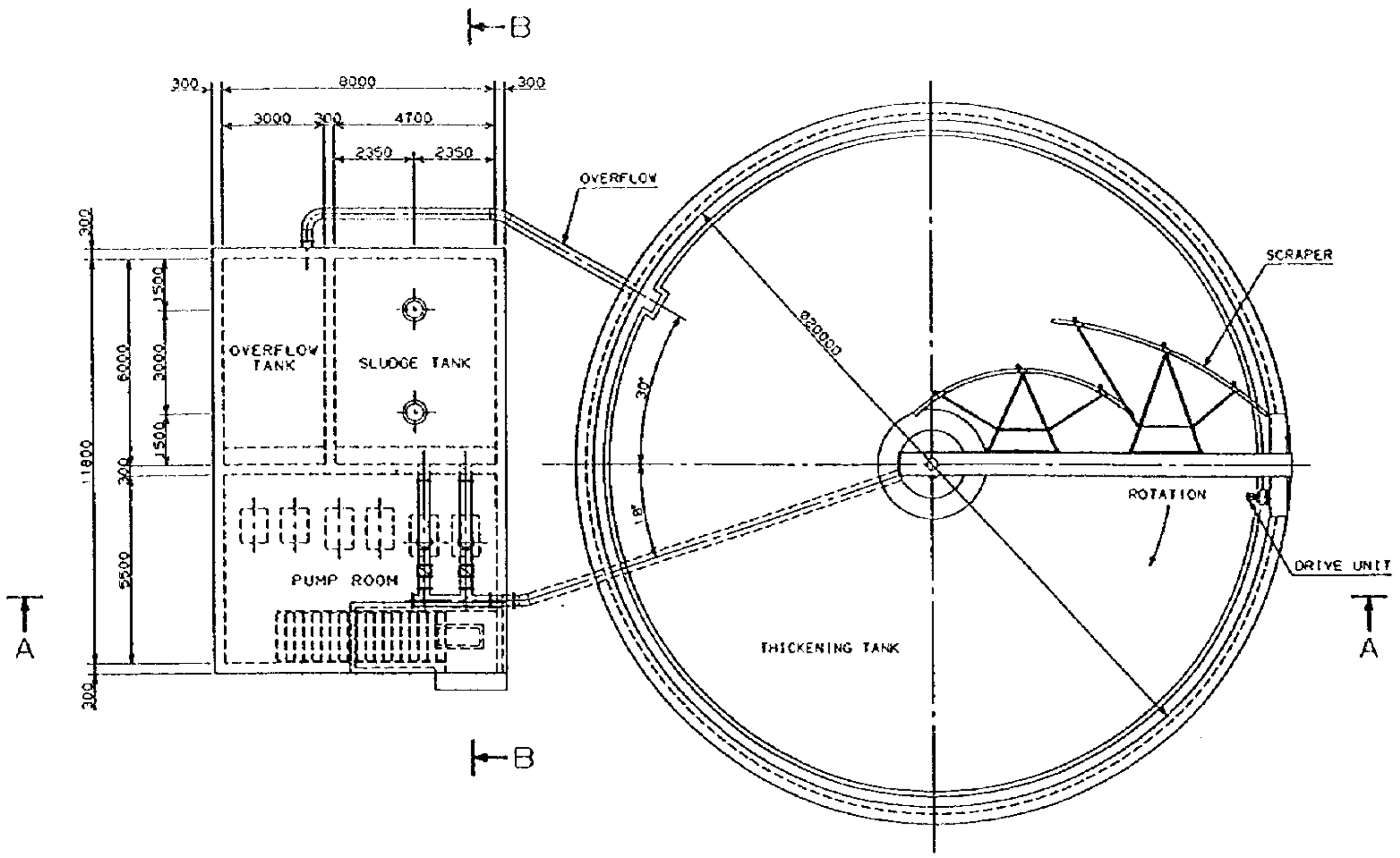


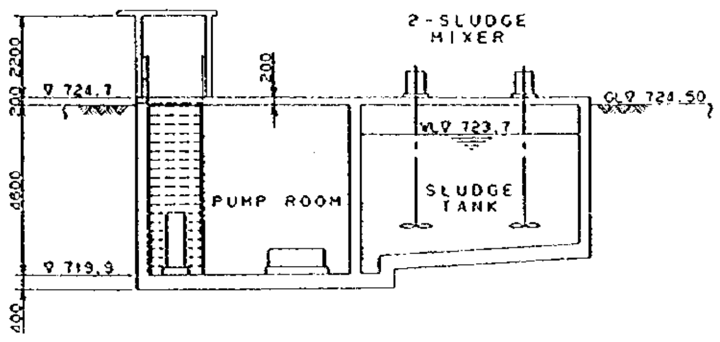
Republic of Bulgaria
Sofia City Municipality

Basic Design Study on the Project for Construction of the Purification Plant Facilities

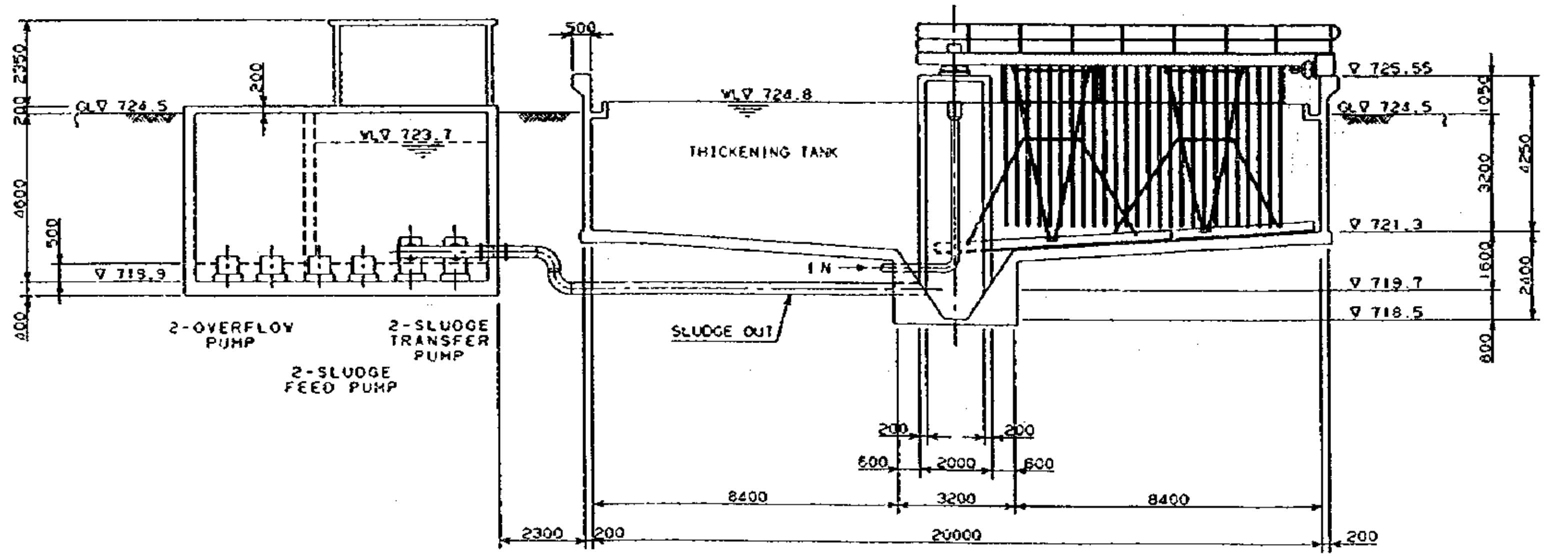
Drawing Name	SEDIMENTATION TANK	
Mar. 1998	Scale : 1/200	No. BD-6

JAPAN INTERNATIONAL COOPERATION AGENCY



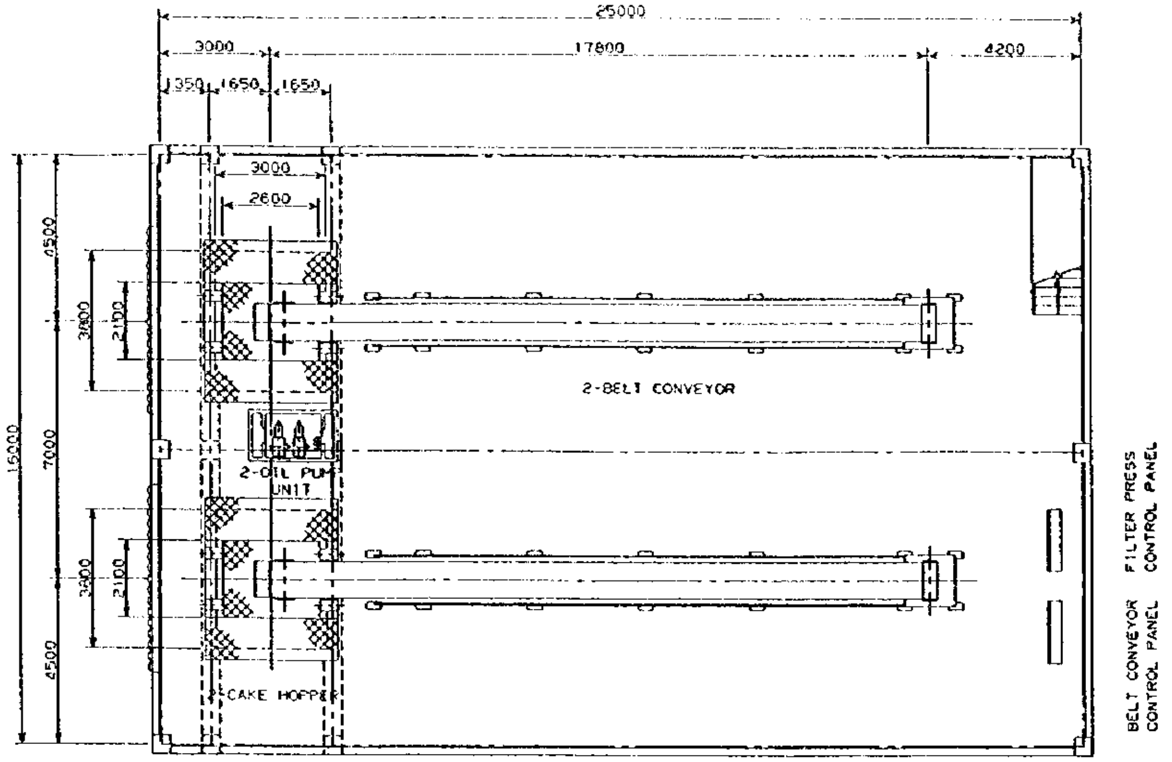


VIEW B~B

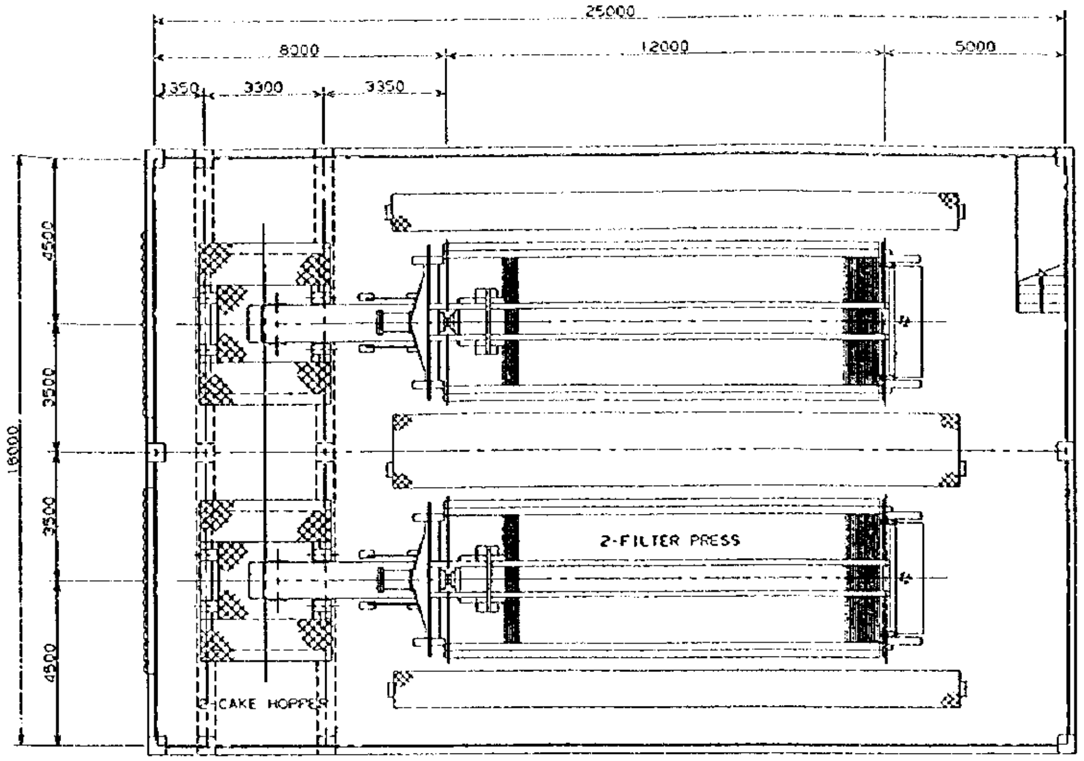


VIEW A~A

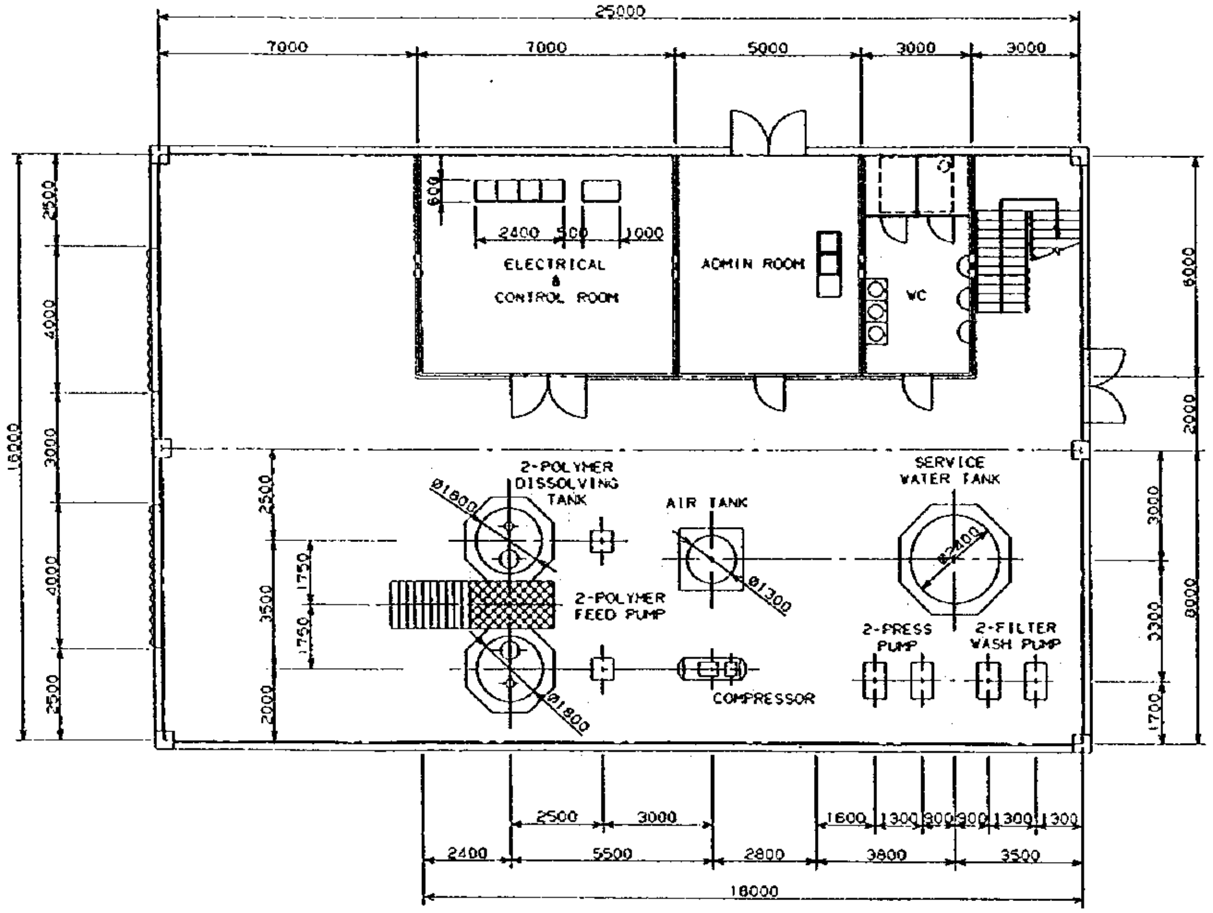
Republic of Bulgaria Sofia City Municipality		
Basic Design Study on the Project for Construction of the Purification Plant Facilities		
Drawing Name	THICKENING TANK	
Mar. 1998	Scale : 1/200	No. BD-7
JAPAN INTERNATIONAL COOPERATION AGENCY		



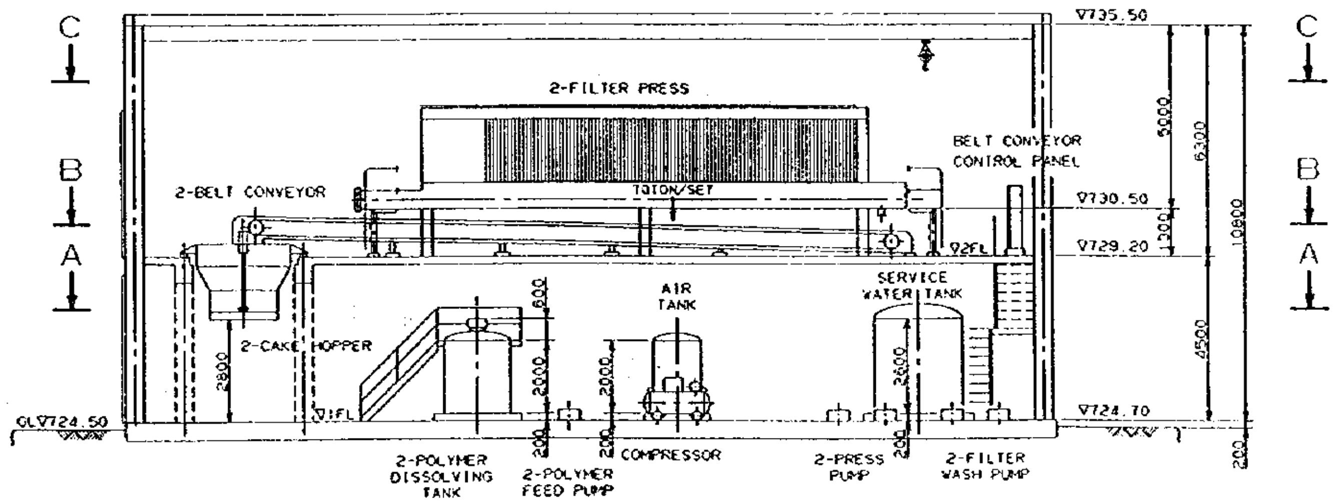
PLAN B-B



PLAN C-C

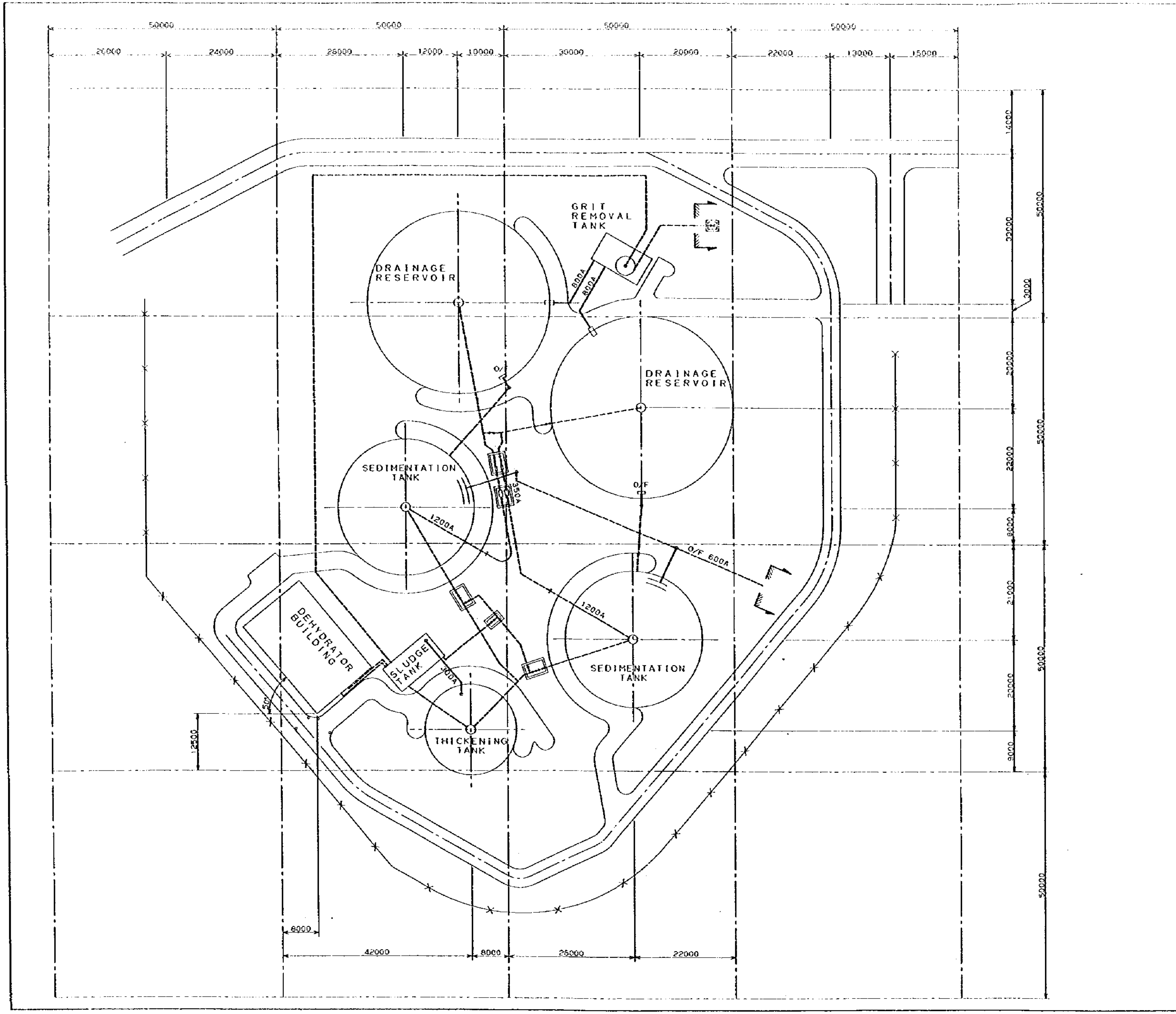


PLAN A-A



SECTION

Republic of Bulgaria Sofia City Municipality	
Basic Design Study on the Project for Construction of the Purification Plant Facilities	
Drawing Name	DEHYDRATOR BUILDING
Mar. 1998	Scale : 1/200 No. BD-8
JAPAN INTERNATIONAL COOPERATION AGENCY	

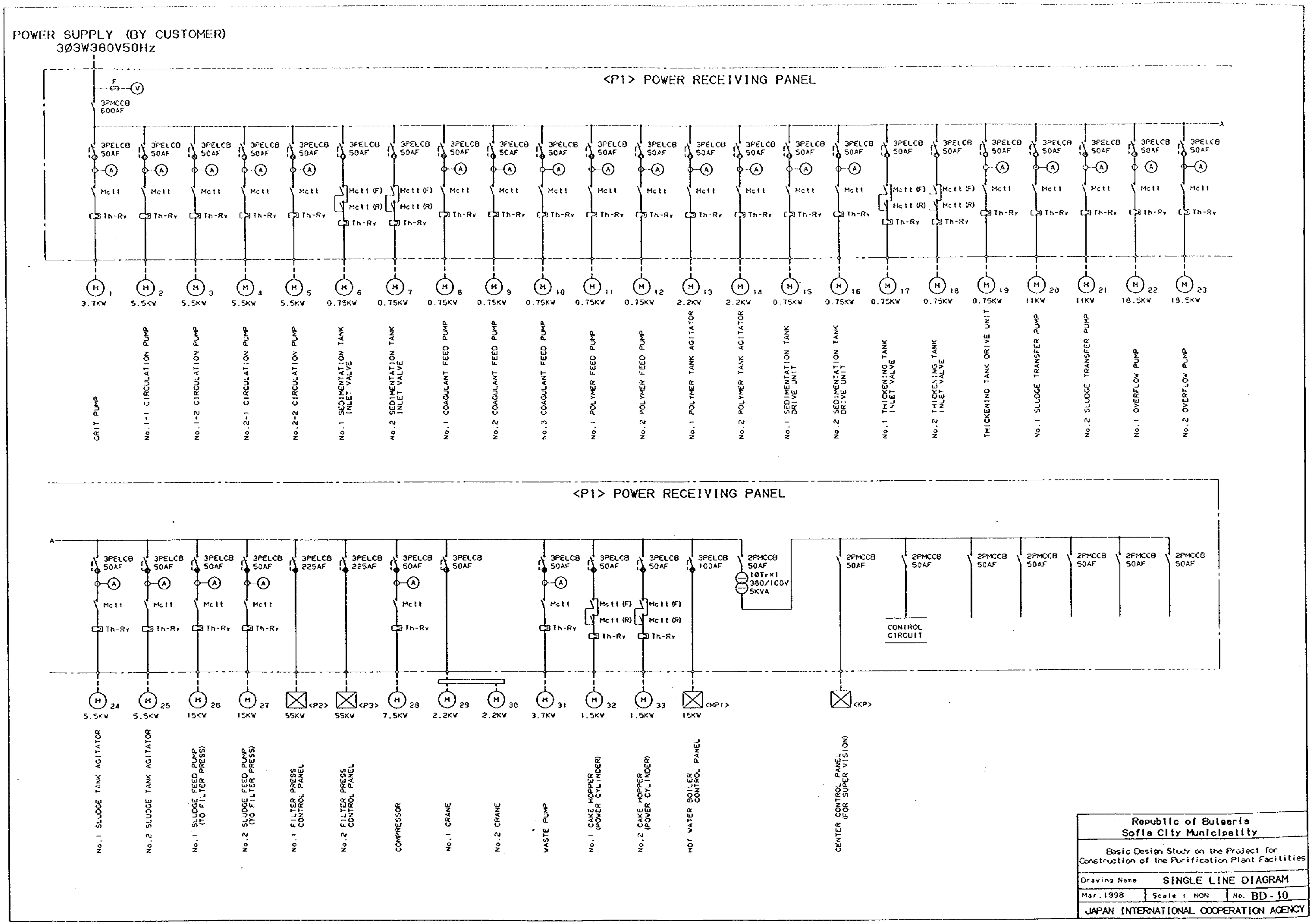


Republic of Bulgaria
Sofia City Municipality

Basic Design Study on the Project for Construction of the Purification Plant Facilities

Drawing Name	PIPING LAYOUT
Mar. 1998	Scale : 1/800
No.	BD-9

JAPAN INTERNATIONAL COOPERATION AGENCY



Republic of Bulgaria
Sofia City Municipality

Basic Design Study on the Project for Construction of the Purification Plant Facilities

Drawing Name	SINGLE LINE DIAGRAM
Mar. 1998	Scale : NON
No.	BD-10

JAPAN INTERNATIONAL COOPERATION AGENCY

CHAPTER 3 IMPLEMENTATION PLAN

CHAPTER 3 IMPLEMENTATION PLAN

3-1 IMPLEMENTATION PLAN

3-1-1 Conceptual Structure for Project Implementation

A part of facilities of the project has been designed and constructed by the Sofia City Municipality. In construction of the facilities to be provided, it is necessary to collect information from the design company and construction company that engaged in the construction works in order to confirm the original design concept.

The conceptual structure for the project implementation is illustrated in Figure 3-1.

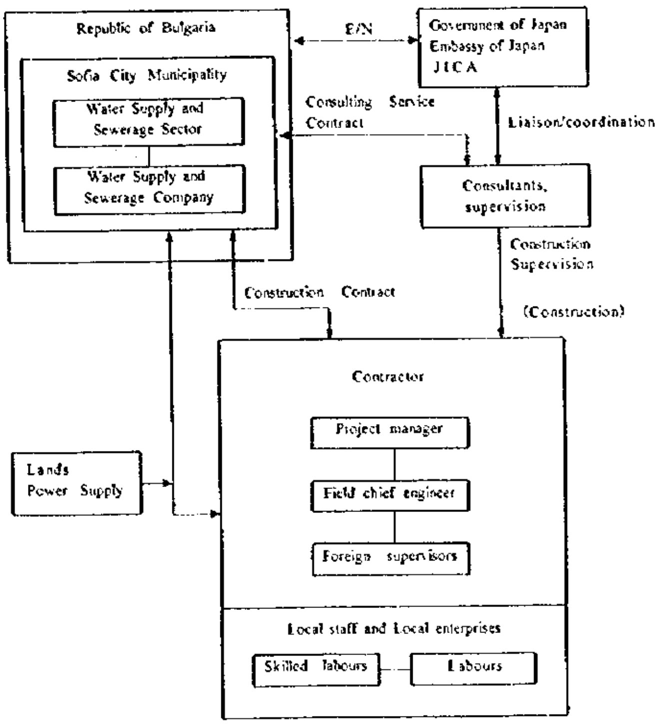


Figure 3-1 Conceptual structure for project implementation

3-1-2 Implementation Conditions

Most materials and equipment for construction are available in Bulgaria. Ready-mixed concrete plant and lands for soil taking/disposal are available within 10km from the Project site. As access roads to the site are all paved, it is easy to access the site in all seasons.

Since structures of the concrete tanks use pre-cast concrete panels, it should be necessary to take into account of Bulgarian construction techniques.

3-1-3 Responsibilities of Bulgaria and Japan

The scope of provisions from the Government of Japan will be limited to the inside boundary of the proposed site for sludge treatment facilities.

The Government of Japan will install the chemical feeder pumps in the existing chemical injection room of the water purification plant and lay PVC pipes up to the sedimentation tanks. One sedimentation tank is about to be completed and thus its civil structure will be completed by the Sofia City Municipality.

Primary power supply, hot water for heating, and telephone line will be supplied up to the connection points of equipment inside the proposed site by the Sofia City Municipality.

Responsibilities of the Government of the Republic of Bulgaria and the Government of Japan are summarized below.

Item	Bulgaria	Japan
Water for domestic use in the site and maintenance purpose for the facilities : Approx. 75 mm Dia., 3.5 L/sec	O	
Electric power supply : Approx. 200 KVA, 380 V, 4 W	O	
Inlet pipe to grit removal tank	O	
Outlet overflow pipe from sedimentation and thickening tanks	O	
Drain channel for rain water	O	
Hot water supply for room heating	O	
Telephone line	O	
Fencing	O	
Construction of grit removal tank structure (1 tank)		O
Improvement of existing waste water reservoirs (2 tanks)		O
Improvement of the existing sedimentation tank structure (1 tank)		O
Construction of sedimentation tank (1 tank)		O
Remodeling and installation of the existing sludge scrapers for sedimentation tanks (2 sets)		O
Construction of thickening tank (1tank)		O
Remodeling and installation of the existing sludge scraper for thickening tank (1 set)		O
Construction of dehydrator building (1 building)		O
Installation of dehydrators (2 sets)		O

3-1-4 Detail Design and Construction Supervision

(1) Detail Design

In order to formulate a detailed design, the basic design should be reviewed and the latest information to be obtained through field survey. The detailed design will include cost estimate by the consultants. Based on the approved detailed design, the contract documents will be prepared in accordance with the guidelines of JICA.

For selection of the contractor, the consultants will assist the Sofia City Municipality so that the tendering procedures would be conducted in accordance with the guidelines of JICA.

(2) Construction Supervision Services

Following the detail design, the construction supervision will be undertaken. Major items of the construction supervision services are summarized below.

- Close coordination with parties concerned for completing the construction as scheduled in the implementation program of the project
- Proper schedule and quality control giving precise and timely advises to the contractor and the executing agency
- Proper transfer of knowledge to the staff of the Sofia City Municipality on construction methods and techniques to maximize the expected effects of the grant aid project
- Adequate advice and guidance on operation and maintenance of the constructed facilities to facilitate the proper operation of the project

The above supervision works include the following duties and responsibilities.

- Supervision of construction program and quality such as approval and inspection of construction materials and works
- Inspection and approval of dimensions, numbers and shapes of the constructed works and facilities, and design changes as required with the approval of JICA and the Government of the Republic of Bulgaria
- Preparation of reports and papers required as specified by JICA
- Safety control
- Coordination among the agencies and organizations of the Government of the Republic Bulgaria during the implementation.

The above consulting services will be required from the commencement of the construction to the completion of the all construction works. Experts in several disciplines will be dispatched to the site in addition to the resident engineers for smooth implementation of the work. The resident engineer will be a civil engineer who coordinates the construction works.

3-1-5 Procurement Plan

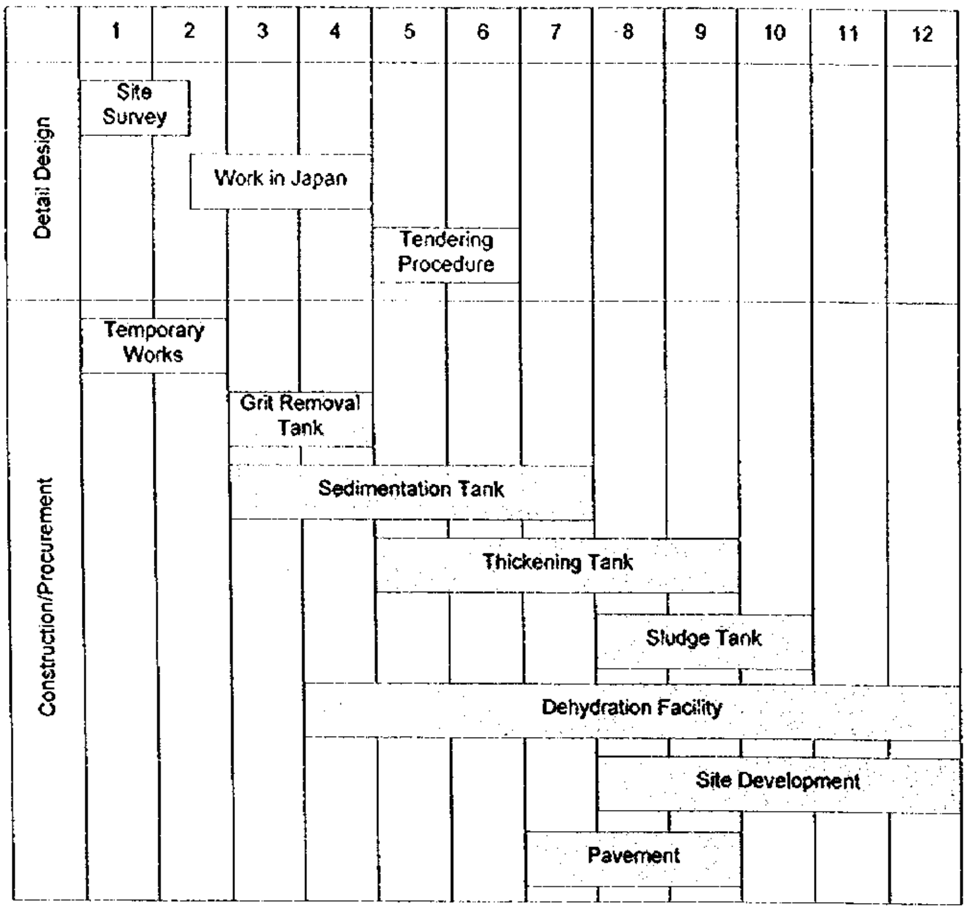
Most construction materials are available in Bulgaria. Equipment, such as dehydrators, pumps, values, and etc, are to be procured in European countries. The procurement plan is shown below.

Item	Specifications	Bulgaria	Japan	Others
Construction materials/equipment				
Cement		○		
Fine aggregate	Sand	○		
Coarse aggregate		○		
Admixture		○		
Crushed stone		○		
Sand		○		
Mortar	1:3	○		
Lumber		○		
Steel		○		
Plywood	t=12mm	○		
Pipe scaffolding		○		
Expansion joint	t=10mm	○		
Reinforcing bar		○		
Cut-off plate	B=20cm	○		
Asphalt	Elastic	○		
Flesh concrete		○		
PVC pipe	φ 150, L=5m	○		
Nail		○		
Hume pipe	φ 800、1000、1300	○		
U-gutter	U200x200	○		
Chemical feed pump				○
Screw pump				○
Submersible pump				○
Compressor	7.5kW			○
Sludge mixer	55kW			○
Dehydrator	Filter press, 15kW			○
Belt conveyor				○
Cake hopper				○
Equipment (independent)				
Truck	3 tons	○		

3-1-6 Implementation Schedule

Implementation schedule is shown below. 6 months for detail design and 12 months for construction are required respectively.

Implementation Schedule



3-1-7 Undertaking of the Recipient Country

Following necessary measures should be taken by the Sofia City Municipality on condition that Grant Aid of Japan be extended to the Project.

1.	To bear commissions to the Japanese foreign exchange bank for its banking services based upon the Banking Arrangement
2.	To ensure prompt unloading, tax exemption, customs clearance at the port of disembarkation in Bulgaria
3.	To accord Japanese nationals whose services may be required in connection with the supply of the products and the services under the verified contract such facilities as may be necessary for their entry into Bulgaria and stay therein for the performance of their work
4.	To obtain necessary permissions, licenses and other authorizations for implementing the Project, if necessary
5.	To assign appropriate budget and administrative staff members for proper and effective operation and maintenance of equipment and instruments provided under the Grant Aid scheme
6.	To secure land
7.	To clear, level and reclaim the Site
8.	To use and maintain properly and effectively all the facilities constructed and equipment provided under the Grant Aid scheme
9.	To provide facilities for distribution of electricity, water supply and other incidental facilities in and around the sites
10.	To bear all the expenses, other than those to be borne by the Japan's Grant Aid, which are necessary for construction of the facilities as well as transportation and installation of the equipment

3-2 OPERATION AND MAINTENANCE PLAN

(1) Institutional Plan

Organization

The facilities to be provided by the Project are managed by the Water Supply and Sewerage Company, Sofia. Operation and maintenance (O&M) are to be conducted by an organization belonging to Water Supply Department of the company. The personnel for the O & M of the Bistritsa WPP are to be present staff of the Pancharevo WPP that will be rehabilitated after start of the Bistritsa WPP operation.

Personnel Plan

Personnel plan for O&M of the sludge treatment facilities are proposed based on the present plan (4 teams, 1 shift = 12 hours) practiced in the Pancharevo WPP. One team is composed of three persons (one engineer and two operators). Four teams (twelve person) are to engage in O & M works. In addition to the above twelve, two drivers are to be assigned for sludge transportation.

(2) O & M Costs

O&M costs are to be composed of staff cost, chemical cost, electric power cost, fuel cost, repair cost and sludge disposal cost.

Tentative calculation of O&M costs is given below. The sludge disposal cost is not included in the calculation since disposal methods have not been finalized yet.

O&M Cost Calculation

(A) Amount of wastewater treatment (m^3/annum)	(B) Operation and Maintenance Cost ($\times 10^3$ Leva/annum)						
	(B1) Staff	(B2) Chemical	(B3) Electric	(B4) Fuel	(B5) Repair 1	(B6) Repair 2	Total
3,947,840	56,000	35,531	63,293	1,278	27,547	30,000	213,649
	26.2%	16.6%	29.6%	0.6%	12.9%	14.0%	100.0%

(A)	Amount of Waste Water Treatment	(Average daily backwash water) × 365 days = 10,816 m^3/day × 365 day = 3,947,840 m^3
(B1)	Staff Cost	(Number of staff) × (Annual staff cost per person[※1]) = 14 persons × 4,000,000 Leva/person = 56,000,000 Leva
(B2)	Chemical Cost	(Chemical dosage) × (A: amount of waste water treatment) × (Price of coagulation[※2]) = 30 mg/l × 3,947,840 m^3 × 300 Leva/kg = 35,530,560 Leva
(B3)	Electric Power Cost	(Daily electric power consumption[※3]) × (Average electric power charge[※4]) × 365days = 2091.48 kWh/day × 82.91 Leva/kWh × 365 days = 63,292,681 Leva
(B4)	Car Fuel	(Fuel consumption per day) × (Fuel price per liter) × 365 days = 5 lit/day × 700 Leva/lit × 365 days = 1,277,500 Leva
(B5)	Repair Cost 1[※5]	((B1)+(B2)+(B3)+(B4)) / (100 - 15%) × 15% = 156,100,741 Leva / 85% × 15% = 27,547,190 Leva
(B6)	Repair Cost 2 (Filter Replace)	(Estimated price of filter cloth) × (No. of filters to be replaced per annum) = 15,000,000 Leva/cloth × 2 units = 30,000,000 Leva

※1 Annual staff cost per person

Taking reference to data of Water Supply and Sewerage Co. as well as Pancharevo WPP, staff cost per person is assumed as below:

	Water Supply and Sewerage Co.	Pancharevo WPP
A. Total staff cost	6,634,212,000 Leva	130,806,000 Leva
B. Number of staff	1,850 persons	33 persons
C. Staff cost per staff (A/B)	3,586,061 Leva/persons	3,963,818 Leva/persons

For calculation purpose, 4,000,000 Leva is employed for staff cost per person.

※2 Price of Coagulation

In accordance with information of Water Supply and Sewerage Co., Sofia (May 1998), 300 Leva/kg is employed for unit price of aluminum sulfate.

※3 Daily Electric Power Consumption

Daily electric power consumption is calculated by the following formula.

(Electric power consumption) = Σ {(Power consumption of each equipment) × (Operation period per day)}

※4 Average Electric Power Charge

Since electric power tariff changes in accordance with season and hours in a day, expected average electric tariff through a year is calculated by weighted average of these tariff.

※5 Repair Cost 1

Determined by approx. 20% of total O&M cost for repairment that is actual record of Pancharevo WPP in 1995 and 1996, 15% of total O&M (exclude filter cloth replacement cost) is assumed as new facility.

(3) Financial Forecast

For operation of Bistritsa WPP, aforementioned O&M costs for sludge treatment are necessary in addition to the cost for water purification. The O&M costs for the sludge treatment facilities shall be covered by revenue from water rates since the facilities treats sludge generated in the water purification process.

This additionally required O&M costs should be born by income from water sales of Bistritsa WPP. The Bistritsa WPP itself is under construction at present, hence the following trial calculations are carried out on the basis of operation record of the Pancharevo WPP that is presently in operation at a capacity of approx. 388,000 m^3/day.

Profit and Loss (P/L) Statement of the Water Supply and Sewerage Company, Sofia

The P/L statement of the company in 1997 is summarized as below:

Income	14,776,047,000 Leva
Expense	14,031,459,000 Leva
Balance	744,588,000 Leva

(Refer to Appendix-11 for detail)

With start of operation of the Bistritsa WPP, rehabilitation of the Pancharevo WPP will begin. Income and expense of water supply sector may increase due to the difference in treatment capacities of the both WPPs.

The expected O&M costs for the sludge treatment facilities (213,649,000 Leva), that exclude sludge disposal cost, corresponds to 1.5% of the whole expense of the Water Supply and Sewerage Co. in 1997.

Examination by the Current Water Tariff

On condition that Bistritsa WPP begins its operation, O&M costs for sludge treatment per cubic meter of purified water are tentatively calculated.

A1	Annual water purification of Bistritsa WPP (Normal operation: 6.75 m^3/sec)	212,868,000 m^3/annual
A2	Annual accounted-for water of Bistritsa WPP (by using current rate of accounted for water: 43.7%)	93,023,000 m^3/annual
B	Annual O&M costs for sludge treatment	213,649,000 Leva/annual
C1	O&M costs for sludge treatment per cubic meter of purified water (C1 = B/A1)	1.00 Leva/m^3
C2	O&M costs for sludge treatment per cubic meter of accounted-for water (C2 = B/A2)	2.30 Leva/m^3

Compared with the current water rate for domestic use of 208 Leva (industrial/commercial use: 216 Leva), the above calculated cost (C2: 2.30 Leva/m^3) corresponds to about 1% of the rate. Therefore, it can be said that O&M costs for sludge treatment do not significantly affect the whole water rates.

CHAPTER 4 PROJECT EVALUATION AND RECOMMENDATION

CHAPTER 4 PROJECT EVALUATION AND RECOMMENDATION

4-1 PROJECT EFFECT

The Project will have the following favorable effects on the Republic of Bulgaria.

(1) Start of Bistritsa Water Purification Plant operation

The project, construction of sludge treatment facilities for the Bistritsa WPP, will enable the start of the Bistritsa WPP operation. The Bistritsa WPP will provide better quality drinking water than the Pancharevo WPP to Sofia City. The Bistritsa WPP will provide 583,200 m^3/day (6.75 m^3/s) of purified water under the normal operation, which is 90 % of the present total water supply (645,270 m^3/day) to Sofia City. Since purified water from the Bistritsa WPP will be blended with water from the other sources at reservoirs, most of all the 1,200,00 residents of Sofia City will enjoy the improved-quality drinking water from the Bistritsa WPP.

An alternative for the Project to improve the present situation of water supply in Sofia City is rehabilitation of the Pancharevo WPP. Even though the Pancharevo WPP is rehabilitated, the purification capacity of the WPP is 371,000 m^3/day (4.3 m^3/s). In order to meet the present demand of Sofia City, the Pancharevo WPP still has to provide 150,000 m^3/day of untreated water, only after chlorination, to Sofia City. The Environmental Protection Act of Bulgaria will obligate the Sofia City Municipality to construct a new sludge treatment facilities for the Pancharevo WPP at the same time of the rehabilitation of its purification process. Therefore, for the rehabilitation of the Pancarevo WPP, funding is required not only for rehabilitation cost of the existing process, which is estimated to be about 500 million Japanese Yen, but also for construction cost of its sludge treatment facilities, which amounts to be the cost of this Project.

(2) Contribution for environmental protection

10,816 m^3/day waste water that contains 3.1 ton dry sludge will be generated by the purification process of the Bistritsa WPP. The proposed sludge treatment facilities will remove 90 % of solids contained in the waste water to protect Iskar river from further pollution. The effluent from the proposed treatment plant will meet the water quality standards set by "Protection of Water and Soil against Pollution Act" of Bulgaria.

4-2 RECOMMENDATIONS

The basic design study team recommend the following measures to the Sofia City Municipality in order to maintain stable water supply service in terms of water quantity and quality, and to operate the proposed sludge treatment facilities appropriately.

(1) Reduction of unaccounted-for water

The unaccounted-for water consists of 55 % of the total water supply production in Sofia City. The estimated financial loss for Water Supply and Sewerage Company, Sofia caused by the above unaccounted-for water amounts to 500 million Leva in 1997 while total company's income of the same year was 1,140 million Leva. The following measures are recommended for the reduction of unaccounted-for water.

- Reduction of leakage that amounts to 28 % of the total water supply production: Replacement of distribution pipes older than 50 years (total length = 381 km) and asbestos cement pipes (total length = 752 km) with new pipes. The length of the those pipes is 48 % of the total length of the existing distribution pipes.

- Reduction of administrative loss that amounts to 32 % of the total water supply production: Replacement of malfunctioning old water meters and prevention of unauthorized connections whose water usage reaches 50 % of the administrative loss.

(2) Appropriate operation and maintenance of the sludge treatment facilities

- Acquisition of efficient and economical operation techniques: In Bulgaria, cost of treatment chemicals (chlorine, coagulant etc.) amounts to 50 % of the total operation expenses in water purification plants. Chemical dosage at the sludge treatment facilities shall be finely adjusted according to the waste water quality and quantity in order to minimize chemical cost.

- Improvement of operation and maintenance techniques of operators: In order to keep maintenance cost low, operators shall acquire proper operation and maintenance techniques to prevent equipment breakdowns.

- Acquisition of operation and maintenance techniques for sludge dehydrators: The proposed dehydrators use a dehydration method which is new for the Sofia City municipality. The Sofia City Municipality shall acquire proper operation and maintenance techniques of the dehydrators through installation and test run of the equipment. In order to obtain constant water contents of dehydrated sludge, dehydrator adjustment methods according to the feed sludge characteristics shall be acquired.