APPENDICES

Appendix 1 Member List

Member List of the Basic Design Study Team

1.	Team Leader	Mr. Taro Kikuchi Bureau of Economic Cooperation, Ministry of Foreign Affairs
2.	Technical Advisor	Mr. Masayuki Matsuda Engineering Division, Osaka Municipal Waterworks Bureau
3.	Coordinator	Mr. Yuichi Sugano Grant Aid Project Study Department, JICA
4.	Water Supply Planner	Mr. Toshifumi Okaga Pacific Consultants International
5.	Water Purification Plant Engineer	Mr. Shunichi Nakatake Pacific Consultants International
6.	Mechanical and Electrical Facilities Planner	Mr. Ryohei Kawanishi Pacific Consultants International
7.	Civil Engineer	Mr. Koji Yoshina Pacific Consultants International
8.	Procurement / Cost Estimator	Mr. Naoto Tohda Pacific Consultants International

Member of the Explanation Team for the Draft Basic Design

1.	Team Leader	Ms. Keiko Yamamoto Development Specialist (Water Supply), Institute for International Cooperation, Japan International Cooperation Agency
2.	Water Supply Planner	Mr. Toshifumi Okaga Pacific Consultants International
3.	Water Purification Plant Engineer	Mr. Shunichi Nakatake Pacific Consultants International

Appendix 2 Itinerary

Itinerary for the Basic Design Study

(1/2)

Date	Official Mission	Consultant Member
1/24	Travel (Tokyo→[JL407/LH715]→Frankfurt)	
1/25	Travel (Frankfurt→[LH3378]→Sofia)	
1/26	Courtesy Call to Embassy of Japan / JICA Office / Ministry of Foreign Affairs / Sofia City Municipality、Explanation and Discussion of IC/R	
1/27	Site Survey (Iskar Dam、Pancharevo WPP、Distribution Reservoir、Bistritsa WPP)	
1/28	Discussion on the Survey Result	
1/29	Discussion on M/D、Courtesy Call to Water Supply and Sewerage Company	
1/30	Signing of M/D、Report to Embassy of Japan / JICA Office	
	Travel (Sofia→[LH3385]→Frankfurt→[JL408]→)	Further Study
1/31	Travel (→[JL408]→Tokyo)	Inner Meeting
2/1		Holiday
2/2		Meeting on Study Schedule (Sofiacity Municipality)
2/3		Data Collection (Original Design of the Facilities)
2/4		Courtesy Call to MORDPW、Kawanishi/Yoshina (Frankfurt→Sofia)
2/5		Data Collection (Design Calculation)、Water Quality/Sludge Test (Pancharevo
2/6		Ministry of Environment and Waters、Water Supply and Sewerage Company
2/7		Data Analysis
2/8		Holiday
2/9		Report of Study Progress to Sofia City Water Quality/Sludge Test(Pancharevo WPP)
2/10		Data Collection (Procurement Schedule) Water Quality/Sludge Test(Pancharevo WPP)
2/11		Sewerage Water Treatment Plant Water Quality/Sludge Test(Pancharevo WPP)
2/12		Meeting on Land Survey
2/13		Regional Inspection Office, MOEW Land Survey (Bistritsa WPP)
2/14		Data Analysis

Date	Official Mission	Consultant Members
2/15		Holiday
2/16		Land Survey (Bistritsa WPP) Water Quality Data (MOE)
2/17		Discussion on Technical Notes Water Quality Data (Meteorological St.)
2/18		Discussion on Technical Notes
2/19		Signing of Technical Notes Water Quality/Sludge Test (Pancharevo
2/20		Report to Embassy of Japan、JICA Office Travel (Sofia→[LH3445]→Frankfurt)
2/21		Travel (Frankfurt→[LH715]→)
2/22		Travel (→[LH715]→Tokyo)

Itinerary for Explanation for the Draft Basic Design

Date	Official Mission	Consultant Member
5/19	Travel (Tokyo→[LH711]→Frankfurt)	
5/20	Travel (Frankfurt→[LH3406]→Sofia)	
5/21	Courtesy Call to Embassy of Japan / JICA Office / Sofia City Municipality、Explanation and Discussion of IC/R	
5/22	Discussion on DF/R	
5/23	Site Survey	
5/24	Discussion on the Survey Result	
5/25	Discussion on M/D	
5/26	Discussion on M/D、Signing of M/D、Report to JICA Office	
5/27	Report to Embassy of Japan Travel (Sofia→[LZ437]→Frankfurt→[JL408]→)	
5/28	Travel (→Tokyo)	

Appendix 3 List of Party Concerned in the Republic of Bulgaria

1.	**Sofia City Municipality**	
	Mr. Stefan Sofianski	Mayor
	Mr. Ivan Gechev	Deputy Mayor
	Mr. Petar Stoylov	Infrastructure Department
	Mr. Svetozar Stoyanov	Water Supply, Sewerage and Treatment Plant
	Mr. Stanislav Minkov	Water Supply and Sewerage Sector
2.	**Ministry of Foreign Affairs**	
	Mr. Boyko Mirchev	Deputy Minister
	Mr. Ivan Simitrov	Counselor, Desk Officer of Japan, Asia, Australia and Oceania Department
	Mr. Stanislav Baev	Head of Asia, Australia and Oceania Department
	Mr. Nikolay Mariv	Deputy Head of Asia, Australia and Oceania Department
3.	**Water Supply and Sewerage Company, Sofia**	
	Mr. Nikolai Berov	Chairman of the Managing Board
	Mr. Rossen Petkov	Director, Financial Department
	Dr. Liliana Vassileva	Head of Department, Marketing and Business Analysis Department
	Mr. Stefan Zahariev	Director, Bistritsa Purification Plant
	Mr. Alexandr Saishkov	Deputy Head, Pancharevo Purification Plant
	Mr. Nikolai Mihailov	Chief Electrical Engineer, Bistritsa Purification Plant
4.	**Sofian Invest**	
	Mr. Hristo ZamLizov	Director of Treatment Plant Department
5.	**Ministry of Regional Development and Public Works**	
	Mr. Plamen Nikiforov	Head of Water Sector, Main Division
6.	**Ministry of Environment and Waters**	
	Mr. Constantin Papazov	Chief Expert, Water Sector
7.	**Eco-Grant (Design Company)**	
	Mr. Lubomir Stefanov	Director of Design
8.	**Hydrostroy (Construction Company)**	
	Ms. Radka Kuleva	Chief, Financial Department
9.	**University of Architecture, Civil Engineering and Geodesy, Sofia (Technical Advisor)**	
	Prof. Todor D. Guirguinov	Department of "Water Supply, Sewerage, Water and Wastewater Treatment"

Appendix 4 Minutes of Discussions

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

Based on the result of the Preliminary Study, 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 (hereinafter referred to as "the Project") and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent to Bulgaria the Basic Design Study Team (hereinafter referred to as "the Team"), headed by Mr. Taro Kikuchi, Grant Aid Division, Bureau of Economic Cooperation, Ministry of Foreign Affairs, from 25th January to 20th February 1998. The team had a series of discussions with the officials and conducted field surveys. As a result of discussions and the field surveys, both sides confirmed the main items described in the attachment.

Sofia, 30 January 1998

Mr. Taro Kikuchi
Leader,
Basic Design Study Team,
JICA

Mr. Stefan Sofianski
Mayor,
Sofia Municipality,
Republic of Bulgaria

30.1.98

ATTACHMENT

1. Objective

The objective of the proposed project is:

(1) to operate the Bistritsa Purification Plant by installing the sludge treatment facility in conformity to the environmental law of Bulgaria.(short-term)

(2) to assist provision of safe quality and stable amount of water to Sofia citizen as well as environmental protection.(long-term)

2. Project Site of Japan's Grant Aid (hereinafter referred as to "the Site")

The project site is located in Bistritsa Purification Plant in Sofia. The location of the project site is shown in Annex I.

3. Responsible and Executing Agency on Bulgarian Side

Responsible Agency:	Sofia City Municipality
Executing Agency:	Sofia City Municipality

4. Items requested for Japan's Grant Aid by the Government of Sofia City Municipality

In the course of discussions with the Team, the Government of Sofia City Municipality requested components listed in Annex II. However, final components for the Project will be determined on the Japanese side through further study in Japan and in Sofia.

5. Japan's Grant Aid System

1) The Government of Sofia City Municipality has understood the system of Japan's Grant Aid on Annex III as explained by the Team.

2) The Government of Sofia City Municipality will take necessary measures, as described in Annex IV for the smooth implementation of the Project on condition that the Japan's Grant Aid is extended to the Project.

6. **Schedule of the Study**

1) The Team will proceed to further study in Bulgaria until 20 February 1998.

2) JICA will prepare the draft report in English and dispatch a mission in order to explain its contents in May 1998.

3) In case that the content of the draft report is accepted in principle by the Government of Sofia Municipality, JICA will complete the final report and send it to Sofia City Municipality in August 1998.

7. **Other Relevant Issues**

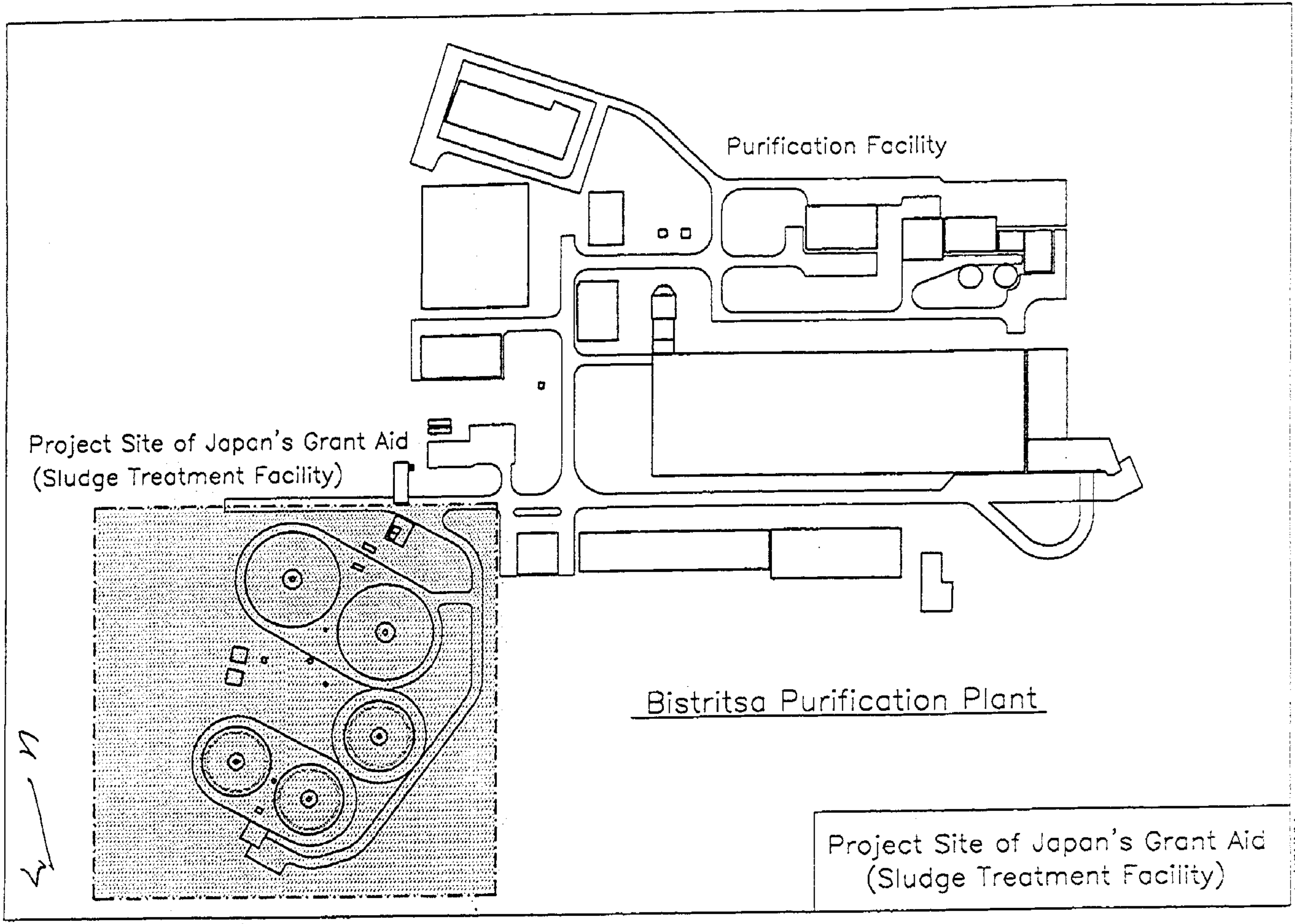
1) The Team stated the Project would be examined technically in accordance with the original capacity of the Bistritsa Purification Plant designed on Bulgarian side.

2) Both sides confirmed the Project would be implemented within the Site for sludge treatment facility.

3) The Team insisted repeatedly that the judgement on the utilization of the existing two drainage reservoirs and one sedimentation tank would be made based upon the result of the Basic Design Study after analysis in Japan.

4) The Team confirmed necessity to discuss about making it clear what will be completed in the Site on Bulgarian side for handover during the Basic Design Study.

5) The Team underlined the importance on how Bulgarian side operates and maintains facilities and equipment which might be constructed and provided under Japan's Grant Aid scheme, especially on budget allocated for maintenance.



Project Site of Japan's Grant Aid
(Sludge Treatment Facility)

ANNEX II

CONSTRUCTION OF THE FACILITIES

NO.	ITEMS	QT.
1	Grit Removal Chamber	1
2	Chemical Mixing Tanks	2
3	Thickening Tanks	2
4	Dehydration House	1
5	Infrastructure within the Site related to the waste water plant such as electricity, water supply and sewage	l.s.

INSTALLATION OF THE EQUIPMENT

NO.	ITEMS	QT.
1	Grit Removal Chamber	1
2	Drainage Reservoirs	2
3	Chemical Mixing Tanks	2
4	Sedimentation Tank	1
5	Thickening Tank	2
6	Dehydration Facility	1
7	Other Mechanical Facilities ・ Flow Regulator ×2 ・ Alum Measuring Pump ×3 ・ Dump Truck (3ton) for dehydrated Cake ×2	

ANNEX III

JAPAN'S GRANT AID PROGRAM

1. Japan's Grant Aid Procedures

(1) The Japan's Grant Aid Program is executed by the following procedures:

- Application (request made by a recipient county)
- Study (Preliminary Study / Basic Design Study conducted by JICA)
- Appraisal & Approval (Appraisal by the Government of Japan and Approval by the Cabinet of Japanese Government)
- Determination (Exchange of Notes between the both Governments)
- Implementation (Implementation of the Project)

(2) Firstly, an application or a request for a project made by the recipient country is examined by the Government of Japan (the Ministry of Foreign Affairs) to see whether or not it suitable for Japan's Grant Aid. If the request is deemed suitable, the Government of Japan entrusts a study on the request to JICA (Japan International Cooperation Agency)

Secondly, JICA conducts the Study (Basic Design Study), using a Japanese consulting firm. If the background and objective of the requested project are not clear, a Preliminary Study is conducted prior to a Basic Design Study.

Thirdly, the Government of Japan Appraises to see whether or not the Project is suitable for Japan's Grant Aid program, based on the Basic Design Study report prepared by JICA and the results are then submitted to the Cabinet for approval.

Fourthly, the Project approved by the Cabinet becomes official when pledged by the Exchange of Notes signed by the both Governments.

Finally, for the implementation of the Project, JICA assists the recipient country in preparing contracts and so on.

2. Contents of the Study

(1) Contents of the Study

The purpose of the Study (Preliminary Study / Basic Design Study) conducted on the Project requested by JICA is to provide a basic document necessary for appraisal of the Project by the Japanese Government. The contents of the Study are as follows:

a) to confirm background, objectives, benefits of the Project and also institutional capacity of agencies concerned of the recipient country necessary for the Project implementation,

b) to evaluate appropriateness of the Project for the Grant Aid Scheme from a technical, social and economical point of view,

c) to confirm items agreed on by the both parties concerning a basic concept of the Project

d) to prepare a basic design of the Project,

e) to estimate cost involved in the Project.

Final Project components are subject to approval by the Government of Japan and therefore may differ from an original Request.

Implementing the Project, the Government of Japan requests the recipient country to take necessary measures involved which are itemized on Exchange of Notes.

(2) Selecting (a) Consulting Firm(s)

For smooth implementation of the study, JICA uses (a) consulting firm(s) registered. JICA selects (a) firm(s) through proposals submitted by firms which are interested. The firm(s) selected carry(ies) out a Basic Design Study and write(s) a report, based upon terms of reference made by JICA.

The consulting firm(s) used for the study is(are) recommended by the JICA to a recipient country after Exchange of Notes, in order to maintain technical consistency.

(3) Status of a Preliminary Study in the Grant Aid Program

A Preliminary Study is conducted during the second step of a project formulation & preparation as mentioned above.

A result of the study will be utilized in Japan to decide if the Project is to be suitable for a Basic Design Study.

Based on the result of the Basic Design Study, the Government would proceed to the stage of decision making process (appraisal and approval).

It should be noted that at the stage of Preliminary Study, neither the Government of Japan, nor JICA, nor the Study Team make any commitment concerning the realization of the Project in the scheme of Grant Aid Program.

3. Japan's Grant Aid Scheme

(1) What is Grant Aid?

The Grant Aid Program provides a recipient country with non reimbursable funds needed to procure facilities, equipment and services for economic and social development of the country under the following principles in accordance with relevant laws and regulations if Japan. The Grant Aid is not in a form of donation or such.

(2) Exchange of Notes (E/N)

The Japan's Grant Aid is extended in accordance with the Exchange of Notes by both Governments, in which the objectives of the Project, period of execution, conditions and amount of the Grant etc. are confirmed.

(3) "The period of the Grant Aid" means one Japanese fiscal year which the Cabinet approves the Project for. All procedure such as Exchange of Notes, concluding a contract with (a) consulting firm(s) and (a) contractor(s) and making final payment to them must be completed within a single fiscal year or, when unavoidable, the next year at the latest.

(4) Under the Grant, in Principle, products and services to be purchased should be of origins of Japan or the recipient country.

When the two Government deem it necessary, the Grant may be used for the purchase of products, services, or both from (a) third country(ies).

However the prime contractors, namely, consulting, contractor and procurement firms, are limited to "Japanese nationals".(The term "Japanese nationals" means Japanese physical persons or Japanese juridical controlled by Japanese physical persons.)

(5) Necessity of the "Verification"

The Government of the recipient country or its designated authority will conclude into contracts in Japanese yen with Japanese nationals. Those contracts shall be verified by the Government of Japan. The "Verification" is deemed necessary to secure accountability to Japanese taxpayers.

(6) Undertakings required to the government of the recipient country

In the implementation of the Grant Aid, the recipient country is required to undertake necessary measures such as the following:

i) to secure land necessary for the Sites of the Project and to clear and level the land prior to commencement of the construction work,

ii) to provide facilities for distribution of electricity, water supply and drainage and other incidental facilities in and around the Sites,

iii) to secure buildings prior to the installation work in case the Project is providing equipment,

iv) to ensure all the expenses and prompt execution for unloading, customs clearance at the port of disembarkation and inland transportation of the products purchased under the Grant Aid,

v) to exempt Japanese nationals form customs duties, internal taxes and other fiscal levies which will be imposed in the recipient country with respect to the supply of the products and services under the Verified Contracts,

vi) to accord Japanese nationals whose services may be required in connection with the supply of the products and services under the Verified Contracts, such facilities as may be necessary for their entry into the recipient country and stay therein for the performance of their work.

(7) Proper Use

The recipient country is required to maintain and use facilities constructed and equipment purchased under the Grant Aid properly and effectively and to assign staff necessary for their operation and maintenance as well as to bear all expenses other than those to be borne by the Grant Aid.

(8) Re-export

The products purchased under the Grant Aid shall not be re-exported from the recipient country.

(9) Banking Arrangement (B/A)

a) The Government of the recipient country or its designated authority shall open an account in the name of the Government of the recipient country in an authorized foreign exchange bank in Japan (hereinafter referred to as "the Bank"). The Government of Japan will execute the Grant Aid by making payments in Japanese yen to cover the obligations incurred by Government of the recipient country or its designated authority under the contracts verified.

b) The payments will be made when payment requests are presented by the Bank to the Government of Japan under an Authorization to Pay issued by the Government of the recipient country or its designated authority.

ANNEX IV

Necessary measures to be taken by the Government of Sofia City Municipality

Following necessary measures should be taken by the Government of Sofia City Municipality on condition that the Government 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 provide 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;

6. To secure the Site for the Project;

7. To clear, level and reclaim the Site prior to commencement of the construction;

8. To use and maintain properly and effectively all the facilities constructed and equipment provided under the Grant;

9. To provide facilities for distribution of electricity, water supply and other incidental facilities in and around the Sites; and

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.

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

Based on the Minutes of Discussions signed on 30th January 1998 between the Basic Design Study Team (hereinafter referred to as "the Team") of Japan International Cooperation Agency (JICA) and Sofia City Municipality in the Republic of Bulgaria, the consultant members of the Team had a series of discussions and conducted field surveys from 25th January to 19th February 1998.

As a result of the discussions and the surveys, both sides confirmed the technical conditions described in the attachment.

Sofia, 19th February 1998

Mr. Toshifumi Okaga
Pacific Consultants International
Tokyo, Japan

Mr. Ivan Gechev
Deputy Mayor,
Sofia Municipality,
Republic of Bulgaria

ATTACHMENT

1. Capacity of the Sludge Treatment Facility

Based on the original design of the filtration system, the capacity of the sludge treatment facility is to be approx. 15,400 m^3/day, that is calculated on the basis of washing water capacity for 21 filter beds in a day. The sludge volume contained in the above flow is estimated to be approx. 3-4 tons dry sludge per day. The detail calculations are shown in ANNEX I.

2. Treatment Process

The sludge treatment process is to be made taking into consideration of the raw water quality and the water quality standard for river water to be discharged. The design conditions for treatment process are as follows:

(1) Design raw water quality
Maximum turbidity in the past five years of monthly average turbidity: 3.6 mg/L

(2) Chemical dosage
Alum dosing rate: 5 mg/L
Silica dosing rate: 2 mg/L

(3) Water quality standard of the receiving water : Category II

The flow diagram for the treatment process is shown in ANNEX II.

3. Number of Equipment

The number of equipment would be modified from the Application Form to Japan's Grant Aid in terms of the following items as a result of the determination of the facilities' outline.

Equipment	Number of Equipment		Note
	Application Form	Proposed Design	
Sedimentation Tank	1 no.	2 nos.	Slower settling speed is proposed
Thickening Tank	2 nos.	1 no.	Two dehydrators are to be equipped
Chemical Mixing Tank	2 nos.	Not required	Alternative system is proposed
Dehydrator	1 no.	2 nos.	For maintenance purpose

6 u

4. Utilization of the Existing Structures / Equipment

The Team has surveyed the existing structures / equipment such as two drainage reservoirs, one sedimentation tank, the scraper equipment and connecting pipes to each tank. In principal, these structures would be utilized on condition that the followings are provided by the Sofia City Municipality prior to the implementation of the construction of the sludge treatment facility.

Structures	Conditions
Drainage reservoirs	To clean up the reservoirs; and To carry out leakage test for 72 hrs.
Sedimentation tank (One under construction)	To complete the structure of the one tank now under construction; and To clean up the tank; and To carry out leakage test for 72 hrs.
Scraper equipment for three tanks (30 m dia.)	To provide the 3(three) complete sets of equipment; and To provide technical specifications and drawings of the equipment
Others	To construct temporary drainage system around tanks to avoid sudden inflow of rain water

5. Provision of Utility and Equipment

The following items are to be provided by the Sofia City Municipality for operation of the sludge treatment facility.

(1) Water for domestic use in the site and maintenance purpose for the facilities : Approx. 75 mm Dia., 3.5 L/sec
(2) Electric power supply : Approx. 200 KVA, 380 V, 4 W
(3) Inlet pipe to grit removal tank
(4) Outlet overflow pipe from sedimentation and thickening tanks
(5) Drain channel for rain water
(6) Hot water supply for room heating
(7) Telephone line
(8) Fencing

6. Necessary Measures for Approvals

Sofia City Municipality will take necessary measures to obtain approvals for design, construction and commission of the Project without causing the delay for project schedule. The following approval processes are expected for the Project.

(1) Approval for design by the Technical Committee organized by Sofia City Municipality

(2) Approval for EIA (Environmental Impact Assessment) by Ministry of Environment and Waters including permissions for discharge of effluent and dumping of dehydrated sludge from the sludge treatment facility

(3) Approval for commissioning of the facility by National Inspectrate for Regional Construction Control.

ANNEX I

(1) Water production of Bistritsa Water Purification Plant (Phase I)

Water production

Under normal operation: $Q = 6.75\ m^3/sec.$ ⇒ Filter backwash interval = 48 hrs
Under maximum operation: $Q = 8.8\ m^3/sec.$ ⇒ Filter backwash interval = 36 hrs

Water quality

Raw water turbidity (monthly average between 1990 to 1996)

Month	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

Design raw water turbidity = 3.6 mg/l (maximum monthly average value)

(2) Filter backwash water discharge (incoming flow to the sludge treatment plant)

Filter backwash water discharge is calculated assuming that the purification plant operates under the maximum mode (production = $8.8\ m^3/sec.$) since the discharge from the filters should be received by the sludge treatment facility under all circumstances.

Design conditions

Under maximum operation: $Q = 8.8\ m^3/sec.$ ⇒ Filter backwash interval = 36 hrs
⇒ Number of filters backwashed per day = 21

Filtration area per filter = $140\ m^2$

Backwash flow from backwash pump = 3.86 l / sec. / m^2 filtration area

Backwash flow duration = 15 minutes

Design calculations

Filter backwash water per filter (V_{bk})

V_{bk} = 3.86 l / sec./m^2 x 140 m^2/filter x 15 min. x 60 sec./min. = 486 m^3

Incoming water to a filter during backwash to be discharged (V_{in})

V_{in} = 8.8 l / sec. / 32 filters x 15 min. x 60 sec./min. = 248 m^3

Total water discharge during backwash per filter (V_{tbk})

$V_{tbk} = V_{bk} + V_{in}$ = 486 m^3 + 248 m^3 = 734 m^3

Filter backwash water discharge per day (Q_d)

Q_d = 734 m^3 / filter x 21 filters = **15,414 m^3 / day**

(3) Sludge contained in backwash water discharge

The purification plant is expected to operate under the normal mode (production = 6.75 m^3/sec.) or maximum mode after the commissioning of the sludge treatment facility. Sludge contained in backwash water discharge is calculated assuming that the treatment plant operates under normal mode. The excess sludge produced under the maximum operation shall be dehydrated by extended-hours operation of the dehydrators.

Design conditions

Design raw water turbidity = 3.6 mg/l

Product water turbidity = 0.5 mg/l (assumed)

Alum (as 17 % Al_2O_3) dose = 5 mg/l

For every mg/l of alum (as 17 % Al_2O_3) is added, 0.44 mg/l solid is formed.
(AWWA, ASCE. Water Treatment Plant Design. 1998, page 488)

Water production = 6.75 m^3/sec. (under normal operation)

Design calculations

Aluminum hydroxide sludge = 5 mg/l x 0.44 = 2.2 mg/l

Raw water solid removed by filtration = 3.6 mg/l – 0.5 mg/l = 3.1 mg/l

Total solids = 2.2 mg/l + 3.1 mg/l = 5.3 mg/l (per raw water flow)

Sludge contained in backwash water discharge per day (W_d) under normal operation

W_d = 6.75 m^3 / sec. x 5.3 mg/l = 6.75 m^3 / sec. x 86,400 sec./day x 5.3 x 10^{-6} ton /m^3

= **3.1 ton /day**

Dehydrator Operation hours: 10 hours per day (for 7 days per week)

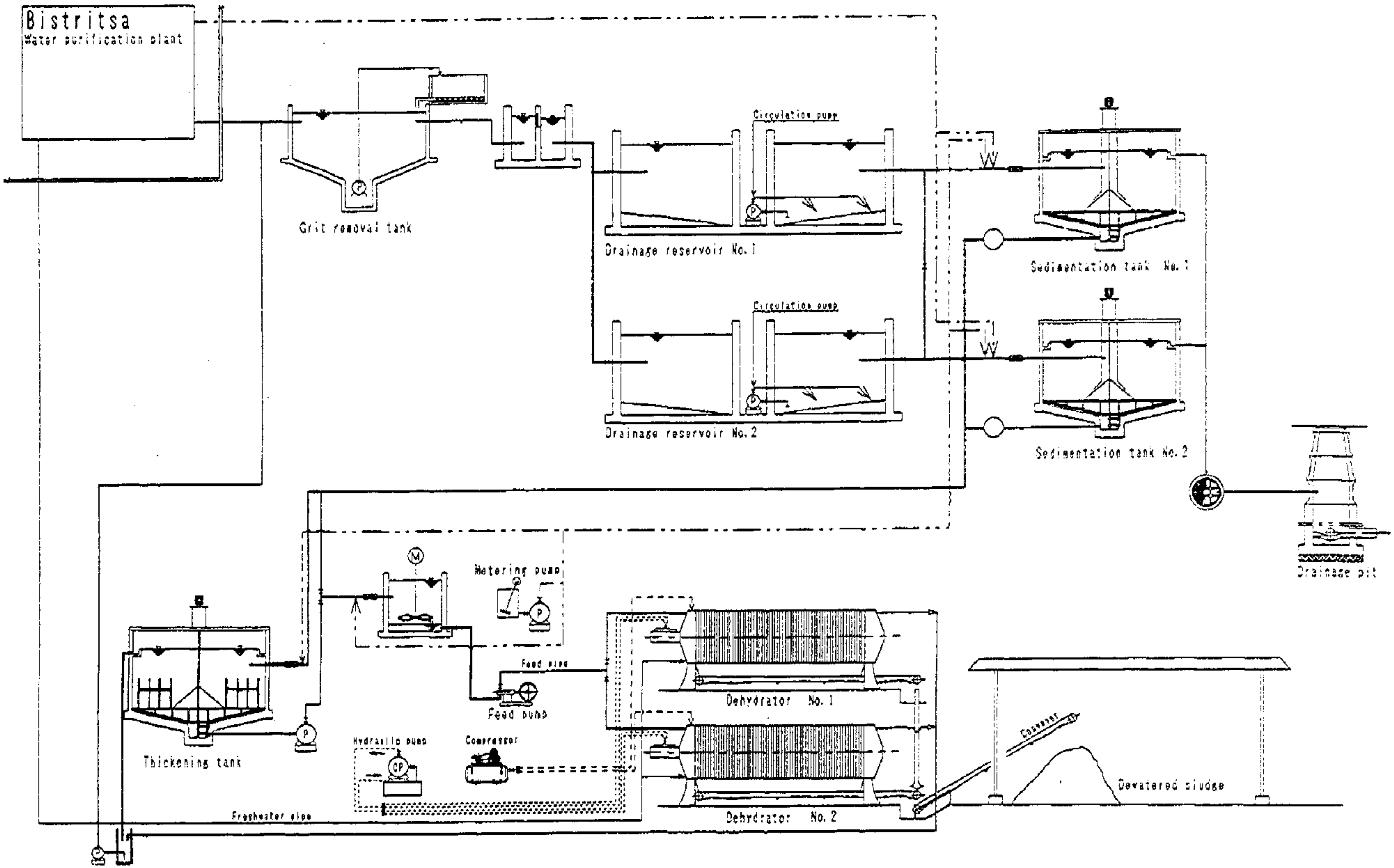
Cf. Sludge contained in backwash water discharge per day (W_d') under maximum operation (water production = 8.8 m^3/sec.)

W_d = 8.8 m^3 / sec. x 5.3 mg/l = 8.8 m^3 / sec. x 86,400 sec./day x 5.3 x 10^{-6} ton /m^3

= **4.0 ton /day**

Expected dehydrator operation hours under maximum operation: 14 hours per day (for 7 days per week)

ANNEX II Sludge Treatment Facility FLOW



MINUTES OF DISCUSSIONS
ON THE BASIC DESIGN STUDY ON THE PROJECT FOR CONSTRUCTION OF THE PURIFICATION PLANT FACILITIES IN SOFIA CITY MUNICIPALITY IN THE REPUBLIC OF BULGARIA
(CONSULTATION ON DRAFT REPORT)

In January 1998, the Japan International Cooperation Agency (JICA) dispatched a Basic Design Study Team on the Project for Construction of the Purification Plant Facilities in Sofia City Municipality (hereinafter referred to as "the Project"), and through discussions, field survey, and technical examination in Japan, has prepared the draft report of the study.

In order to explain and consult with Bulgarian side on the components of the draft report, JICA sent to Bulgaria the Draft Basic Design Report Explanation Team (hereinafter referred to as "the Team") , headed by Ms. Keiko Yamamoto, Water Supply Development Specialist, Institute for International Cooperation, JICA, from May 20 to 27, 1998.

As a result of discussions, both parties confirmed the main items described in the attachment.

Sofia, 26 May 1998

Ms. Keiko Yamamoto	Mr. Stefan Sofianski 26.5.98
Leader, Draft Basic Design Report Explanation Team, JICA	Mayor, Sofia City Municipality, Republic of Bulgaria

ATTACHMENT

1. Components of Draft Report

The Government of Sofia City Municipality has agreed and accepted in principle the components of the draft report presented by the Team.

2. Japan's Grant Aid System

1) The Government of Sofia City Municipality has understood the system of Japan's Grant Aid Scheme described in ANNEX-I explained by the Team.

2) The Government of Sofia City Municipality will take necessary measures, as described in ANNEX-II for the smooth implementation of the Project on condition that the Japan's Grant Aid is extended to the Project.

3. Responsible and Executive Agency on Bulgarian Side

Responsible Agency : Sofia City Municipality

Executing Agency : Sofia City Municipality

4. Items requested for Japan's Grant Aid by the Government of Sofia City Municipality

In the course of discussions with the Team, the Government of Sofia City Municipality requested the components listed in ANNEX-III.

5. Schedule of the Study

The Team will make the Final Report in accordance with the confirmed items, and send it to the Government of Sofia City Municipality in August 1998.

6. Items Discussed by the Both Parties

Items discussed by the both parties are shown in ANNEX- IV.

7. Other Relevant Issues

The Team underlined the importance on proper operation and maintenance of the facilities and equipment by Bulgarian side, which might be constructed and provided under Japan's Grant Aid scheme, especially on sufficient budget allocation for maintenance. Bulgarian side has accepted to operate the facilities sustainability under stable maintenance conditions.

ANNEX I

JAPAN'S GRANT AID PROGRAM

1. Japan's Grant Aid Procedures

(1) The Japan's Grant Aid Program is executed by the following procedures:

- Application (request made by a recipient county)
- Study (Preliminary Study / Basic Design Study conducted by JICA)
- Appraisal & Approval (Appraisal by the Government of Japan and Approval by the Cabinet of Japanese Government)
- Determination (Exchange of Notes between the both Governments)
- Implementation (Implementation of the Project)

(2) Firstly, an application or a request for a project made by the recipient country is examined by the Government of Japan (the Ministry of Foreign Affairs) to see whether or not it suitable for Japan's Grant Aid. If the request is deemed suitable, the Government of Japan entrusts a study on the request to JICA (Japan International Cooperation Agency)

Secondly, JICA conducts the Study (Basic Design Study), using a Japanese consulting firm. If the background and objective of the requested project are not clear, a Preliminary Study is conducted prior to a Basic Design Study.

Thirdly, the Government of Japan Appraises to see whether or not the Project is suitable for Japan's Grant Aid program, based on the Basic Design Study report prepared by JICA and the results are then submitted to the Cabinet for approval.

Fourthly, the Project approved by the Cabinet becomes official when pledged by the Exchange of Notes signed by the both Governments.

Finally, for the implementation of the Project, JICA assists the recipient country in preparing contracts and so on.

2. Contents of the Study

(1) Contents of the Study

The purpose of the Study (Preliminary Study / Basic Design Study) conducted on the Project requested by JICA is to provide a basic document necessary for appraisal of the Project by the Japanese Government. The contents of the Study are as follows:

a) to confirm background, objectives, benefits of the Project and also institutional capacity of agencies concerned of the recipient country necessary for the Project implementation,

b) to evaluate appropriateness of the Project for the Grant Aid Scheme from a technical, social and economical point of view,

c) to confirm items agreed on by the both parties concerning a basic concept of the Project

d) to prepare a basic design of the Project,

e) to estimate cost involved in the Project.

Final Project components are subject to approval by the Government of Japan and therefore may differ from an original Request.

Implementing the Project, the Government of Japan requests the recipient country to take necessary measures involved which are itemized on Exchange of Notes.

(2) Selecting (a) Consulting Firm(s)

For smooth implementation of the study, JICA uses (a) consulting firm(s) registered. JICA selects (a) firm(s) through proposals submitted by firms which are interested. The firm(s) selected carry(ies) out a Basic Design Study and write(s) a report, based upon terms of reference made by JICA.

The consulting firm(s) used for the study is(are) recommended by the JICA to a recipient country after Exchange of Notes, in order to maintain technical consistency.

(3) Status of a Preliminary Study in the Grant Aid Program

A Preliminary Study is conducted during the second step of a project formulation & preparation as mentioned above.

A result of the study will be utilized in Japan to decide if the Project is to be suitable for a Basic Design Study.

Based on the result of the Basic Design Study, the Government would proceed to the stage of decision making process (appraisal and approval).

It should be noted that at the stage of Preliminary Study, neither the Government of Japan, nor JICA, nor the Study Team make any commitment concerning the realization of the Project in the scheme of Grant Aid Program.

3. Japan's Grant Aid Scheme

(1) What is Grant Aid?

The Grant Aid Program provides a recipient country with non reimbursable funds needed to procure facilities, equipment and services for economic and social development of the country under the following principles in accordance with relevant laws and regulations of Japan.

(2) Exchange of Notes (E/N)

The Japan's Grant Aid is extended in accordance with the Exchange of Notes by both Governments, in which the objectives of the Project, period of execution, conditions and amount of the Grant etc. are confirmed.

(3) "The period of the Grant Aid" means one Japanese fiscal year which the Cabinet approves the Project for. All procedure such as Exchange of Notes, concluding a contract with (a) consulting firm(s) and (a) contractor(s) and making final payment to them must be completed within a single fiscal year or, when unavoidable, the next year at the latest.

(4) Under the Grant, in Principle, products and services to be purchased should be of origins of Japan or the recipient country.

When the two Government deem it necessary, the Grant may be used for the purchase of products, services, or both from (a) third country(ies).

However the prime contractors, namely, consulting, contractor and procurement firms, are limited to "Japanese nationals".(The term "Japanese nationals" means Japanese physical persons or Japanese juridical controlled by Japanese physical persons.)

(5) Necessity of the "Verification"

The Government of the recipient country or its designated authority will conclude into contracts in Japanese yen with Japanese nationals. Those contracts shall be verified by the Government of Japan. The "Verification" is deemed necessary to secure accountability to Japanese taxpayers.

(6) Undertakings required to the government of the recipient country

In the implementation of the Grant Aid, the recipient country is required to undertake necessary measures such as the following:

i) to secure land necessary for the sites of the Project and to clear and level the land prior to commencement of the construction work,

ii) to provide facilities for distribution of electricity, water supply and drainage and other incidental facilities in and around the sites,

iii) to secure buildings prior to the installation work in case the Project is providing equipment,

iv) to ensure all the expenses and prompt execution for unloading, customs clearance at the port of disembarkation and inland transportation of the products purchased under the Grant Aid,

v) to exempt Japanese nationals form customs duties, internal taxes and other fiscal levies which will be imposed in the recipient country with respect to the supply of the products and services under the Verified Contracts,

vi) to accord Japanese nationals whose services may be required in connection with the supply of the products and services under the Verified Contracts, such facilities as may be necessary for their entry into the recipient country and stay therein for the performance of their work.

(7) Proper Use

The recipient country is required to maintain and use facilities constructed and equipment purchased under the Grant Aid properly and effectively and to assign staff necessary for their operation and maintenance as well as to bear all expenses other than those to be borne by the Grant Aid.

(8) Re-export

The products purchased under the Grant Aid shall not be re-exported from the recipient country.

(9) Banking Arrangement (B/A)

a) The Government of the recipient country or its designated authority shall open an account in the name of the Government of the recipient country in a bank in Japan (hereinafter referred to as "the Bank"). The Government of Japan will execute the Grant Aid by making payments in Japanese yen to cover the obligations incurred by Government of the recipient country or its designated authority under the contracts verified.

b) The payments will be made when payment requests are presented by the Bank to the Government of Japan under an Authorization to Pay issued by the Government of the recipient country or its designated authority.

ANNEX II

Necessary measures to be taken by the Government of Sofia City Municipality

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

1. To bear commissions to the Japanese bank for its banking services based upon the Banking Arrangement;

2. To ensure prompt unloading, tax exemption, customs clearance of materials and equipment provided to the project at the port of disembarkation in Bulgaria;

3. To accord Japanese nationals whose services are required in connection with the supply of the products and the services under the verified contract, such facilities that may be necessary for their entry into Bulgaria and stay therein for the performance of their work;

4. To provide 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 facilities and equipment provided under the Grant Aid Scheme ;

6. To use and maintain properly and effectively all the facilities constructed and equipment provided under the Grant Aid Scheme;

7. To provide facilities for distribution of electricity, water supply and other incidental facilities in and around the sites; and

8. 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.

9. To secure land

10. To clear, level and reclaim the Site

ANNEX III

Construction of the Facilities

NO.	ITEMS	QT.
1	Grit Removal Chamber	1
2	Sedimentation tank	1
3	Thickening Tank	1
4	Dehydration House	1
5	Infrastructure within the site related to the waste water plant such as electricity, water supply and sewage	l.s.

Installation of the Equipment

NO.	ITEMS	QT.
1	Grit Removal Chamber	1
2	Drainage Reservoirs	2
3	Chemical Mixer	2
4	Sedimentation Tank	2
5	Thickening Tank	1
6	Dehydration Facility	2
7	Other Mechanical Facilities ・ Polymer dosing equipment ×2 ・ Flow Regulator ×2 ・ Alum Measuring Pump ×3 ・ Dump Truck (3ton) for dehydrated Cake ×2 ・ Spare parts for 2 years operation	

ANNEX IV

1. Utilization of the Existing Structures / Equipment

The Team has surveyed the existing structures / equipment such as two drainage reservoirs, one sedimentation tank, the scraper equipment and connecting pipes to each tank. In principle, these structures would be utilized on condition that the followings are provided by the Sofia City Municipality prior to the implementation of the construction of the sludge treatment facility.

Structures	Conditions
Drainage reservoirs	To clean up the reservoirs; and To carry out leakage test for 72 hrs.
Sedimentation tank (One under construction)	To complete the structure of the one tank now under construction; and To clean up the tank; and To carry out leakage test for 72 hrs.
Scraper equipment for three tanks (30 m dia.)	To provide the 3(three) complete sets of equipment; and To provide technical specifications and drawings of the equipment
Others	To construct temporary drainage system around tanks to avoid sudden inflow of rain water

2. Provision of Utility and Equipment

The following items are to be provided by the Sofia City Municipality for operation of the sludge treatment facility.

(1) Water for domestic use in the site and maintenance purpose for the facilities
(2) Electric power supply
(3) Inlet pipe to grit removal chamber
(4) Outlet overflow pipe from sedimentation and thickening tanks
(5) Drain channel for rain water
(6) Hot water supply for room heating
(7) Telephone line
(8) Fencing

3. Necessary Measures for Approvals

Sofia City Municipality will take necessary measures to obtain approvals for design, construction and commission of the Project without causing the delay for project schedule. The following approval processes are expected for the Project.

(1) Approval for design by the Technical Committee organized by Sofia City Municipality
(2) Approval for EIA (Environmental Impact Assessment) by Ministry of Environment and Waters including permissions for discharge of effluent and dumping of dehydrated sludge from the sludge treatment facility
(3) Approval for commissioning of the facility by National Inspectrate for Regional Construction Control.

Appendix – 5 Drainage (Sludge) Treatment Capacity Calculations

(1) Water production of Bistritsa Water Purification Plant (Phase I)

Water production

Under normal operation: $Q = 6.75\ m^3/sec.$ => Filter backwash interval = 48 hrs

Under maximum operation: $Q = 8.8\ m^3/sec.$ => Filter backwash interval = 36 hrs

Water quality

Raw water turbidity (monthly average between 1990 to 1996)

Month	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

Design raw water turbidity = 3.6 mg/l (maximum monthly average value)

(2) Filter backwash water discharge (incoming flow to the sludge treatment plant)

Filter backwash water discharge is calculated assuming that the purification plant operates under the maximum mode (production = $8.8\ m^3/sec.$) since the discharge from the filters should be received by the sludge treatment facility under all circumstances.

Design conditions

Under maximum operation: $Q = 8.8\ m^3/sec.$ => Filter backwash interval = 36 hrs

=> Number of filters backwashed per day = 21

Filtration area per filter = 140 m^2

Backwash flow from backwash pump = 3.86 l / sec. / m^2 filtration area

Backwash flow duration = 15 minutes

Design calculations

Filter backwash water per filter (V_{bk})

V_{bk} = 3.86 l / sec./m^2 x 140 m^2/filter x 15 min. x 60 sec./min. = 486 m^3

Incoming water to a filter during backwash to be discharged (V_{in})

V_{in} = 8.8 l / sec. / 32 filters x 15 min. x 60 sec./min. = 248 m^3

Total water discharge during backwash per filter (V_{tbk})

$V_{tbk} = V_{bk} + V_{in}$ = 486 m^3 + 248 m^3 = 734 m^3

Filter backwash water discharge per day (Q_d)

Q_d = 734 m^3 / filter x 21 filters = **15,414 m^3 / day**

Cf. under normal operation

Filter backwash water discharge per day (Q_d)

Q_d = 676 m^3 / filter x 16 filters = **10,816 m^3 / day**

(3) Sludge contained in backwash water discharge

The purification plant is expected to operate under the normal mode (production = 6.75 m^3/sec.) or maximum mode after the commissioning of the sludge treatment facility. Sludge contained in backwash water discharge is calculated assuming that the treatment plant operates under normal mode. The excess sludge produced under the maximum operation shall be dehydrated by extended-hours operation of the dehydrators.

Design conditions

Design raw water turbidity = 3.6 mg/l

Product water turbidity = 0.5 mg/l (assumed)

Alum (as 17 % Al_2O_3) dose = 5 mg/l

For every mg/l of alum (as 17 % Al_2O_3) is added, 0.44 mg/l solid is formed.

(AWWA, ASCE. Water Treatment Plant Design. 1998, page 488)

Water production = 6.75 m^3/sec. (under normal operation)

Design calculations

Aluminum hydroxide sludge = 5 mg/l x 0.44 = 2.2 mg/l

Raw water solid removed by filtration = 3.6 mg/l – 0.5 mg/l = 3.1 mg/l

Total solids = 2.2 mg/l + 3.1 mg/l = 5.3 mg/l (per raw water flow)

Sludge contained in backwash water discharge per day (W_d) under normal operation

W_d = 6.75 m^3 / sec. x 5.3 mg/l = 6.75 m^3 / sec. x 86,400 sec./day x 5.3 x 10^{-6} ton /m^3

= **3.1 ton /day**

Dehydrator Operation hours: 10 hours per day (for 7 days per week)

Cf. Sludge contained in backwash water discharge per day (W_d) under maximum operation (water production = 8.8 m^3/sec.)

W_d = 8.8 m^3 / sec. x 5.3 mg/l = 8.8 m^3 / sec. x 86,400 sec./day x 5.3 x 10^{-6} ton /m^3

= **4.0 ton /day**

Expected dehydrator operation hours under maximum operation: 14 hours per day (for 7 days per week)

Appendix - 6 Characteristics of Filter Backwash Water (Sludge): Test Results

The following tests are performed on filter backwash water in order to obtain basic parameters for sludge treatment plant design.

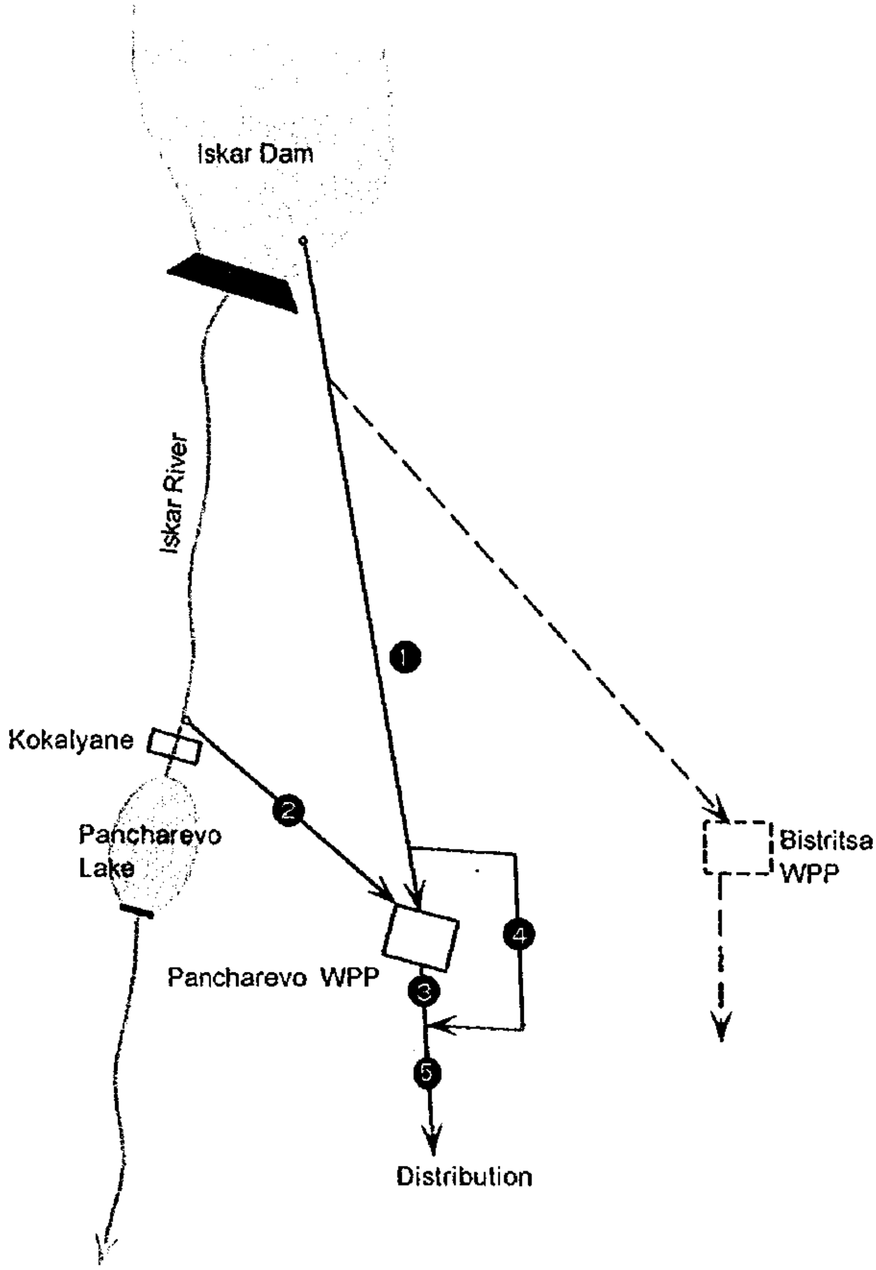
Test	Result	Related Design Parameters
① Jar Test	Optimum coagulant dose	Coagulant dose
② Cylinder test	Zone settling rate	Sizing of sedimentation tanks and thickener
③ Supernatant quality test	Effluent quality	Effluent discharge options
④ Sludge quality test	Heavy metal contents of sludge	Sludge disposal options

The above tests were performed at Pancharevo Water Purification Plant (WPP) and Chemical-Bacteriological Laboratory of Water Supply and Drainage company, Sofia. A part of heavy metal analysis was performed by National Centre of Environment and Sustainable Development (NCESD).

Those tents were performed on 10th February 1998 (Experiment I) and on 19 February 1998 (Experiment II). Samples are taken at Pancharevo WPP since Bistritsa WPP has not been operated yet. The operational conditions of Pancharevo WPP at the both experiments are shown in the following tables.

(Water Flow)

	Unit	Experiment I (10 Feb.1998)	Experiment II (19 Feb.1998)
Raw water flow			
From Iskar dam①	m^3/s	3.5	3.5
From Iskar river②	m^3/s	2.0 ~ 2.2	2.4 ~ 3.0
Pancahrevo WPP treated water flow③	m^3/s	4.0 ~ 4.2	3.7 ~ 3.9
By-pass water flow④	m^3/s	1.5	2.2 ~ 2.6
Total water distributed⑤	m^3/s	5.5 ~ 5.7	5.9 ~ 6.5



1	Iskar Dam	Q = 3.5m³/s (Constant)
2	Iskar River (Kokalyane)	Q = 2.0~3.3m³/s
3	Pancharevo WPP Production	Q = 3.5~4.2m³/s
4	By-pass (Only with Chlorination)	Q = 1.5~2.6m³/s
5	Distribution	Q = 5.5~6.8m³/s

(Water Quality)

Experiment I (10 Feb. 10 a.m.)

	Unit	Raw water	Sedimentation tank outlet	Filtered water	By-pass water
Water temperature	℃	4.1	4.0	4.0	4.2
Turbidity	mg/l	1.4	1.2	1.0	1.4
Color		4	3	2	4
pH		7.1			
Alkalinity	mg/l	40			

Experiment II (19 Feb. 10 a.m.)

	Unit	Raw water	Sedimentation tank outlet	Filtered water	By-pass water
Water temperature	℃	4.6			4.6
Turbidity	mg/l	19	2.3	1.4	2.1
pH		6.8			
Alkalinity	mg/l	35	25	25	35 ~ 40
Coagulant dosage	mg/l	30			

At Experiment I, no coagulant was added to purification process. At Experiment II, coagulant (aluminum sulfate) was added at dosing rate of 30 mg/l in response to increase in raw water turbidity from Iskar river caused by melting snow. At Experiment II, 80 % of the turbidity in raw water was removed at sedimentation tanks (Pulsators). The turbidity of raw water from Iskar dam was low and stable, 1.4 mg/l at Experiment I and 2.1 mg/l at Experiment II.

The sample taken at Experiment I is assumed to be similar in quality to backwash water from filters in Bistritsa WPP during winter period. The sample taken at Experiment II is assumed to be similar to backwash water in Bistritsa WPP in early spring with coagulant addition.

1) Sampling

Samples are taken at backwash water channel of filters at Pancharevo WPP. Filtration duration before backwash was 36 hours for Experiment I and 38 hours for Experiment II.

The results of water analysis on samples are shown in the table below.

	Unit	Experiment I	Experiment II
Temperature	℃	4.0	4.6
pH		7.0	6.6
Suspended Solids	mg/l	298	477
Alkalinity	mg $CaCO_3$/l	35 ~ 40	25

2) Test methods

① Jar test

i. Fill 4 x 1 liter beakers with 1.0 - 1.2 liters uniformly mixed sludge sample.

ii. Add coagulant ($Al_2(SO_4)$) to different concentration.

iii. Rapid-stir suspension (100 rpm) for 1 minutes followed by slow mixing (50 rpm x 5 min. + 20 rpm x 5 min).

Mixed suspension was used for cylinder test. Coagulant used was dissolved alum, the same alum that was used for Pancahrevo WPP. Aluminum oxide (Al_2O_3) content of alum was 15.6 %.

② Cylinder test

i. Fill 1 liter graduated cylinder with uniformly-mixed suspension from the above ① to 1 liter mark.

ii. Observe sedimentation of the suspension. Clear solids-liquid interface was not observed throughout Experiment I and II. Record duration between the start of sedimentation and end of sedimentation. Measure the settling distance between 1 liter mark and settled sludge interface.

iii. Calculate interface settling rate as dividing settling distance by duration in centimeters per minute.

③ Supernatant quality test

Collect supernatant from the cylinders after 30 minutes' sedimentation using siphon. Perform chemical analysis on the supernatant for pH, turbidity and alkalinity. The further analysis was made on the sample with optimum coagulant dosage, which decided later about heavy metals, organic and inorganic constituents.

④ Sludge quality test

Settled sludge from the cylinder suspension with optimum coagulant dosage. Settled sludge is obtained from the cylinder after decanting as much supernatant as possible.

3) Results and Discussions

① Jar test, cylinder test and supernatant quality test

Results of the above tests are shown in tables below.

Experiment I (10 Feb.)

	Unit	①	②	③	④
Alum dosage	mg/l	16	31	71	141
(Aluminum oxide equivalent)	mg/l	2.5	4.8	11	22
Settling duration	min	25	20	15	12
Settled sludge interface	ml	(200)	150	150	140
Settling distance	mm	265	282	282	285
Settling velocity	mm/min	(11)	14	19	24

Experiment I Supernatant Quality Analysis

	Unit	①	②	③	④	W.Q.S.*1 Category II	Remarks
pH		6.9	6.8	5.7	5.0	6.0 ~ 8.5	
Turbidity	mg/l	50	13	15	10	50*2	
Alkalinity	mg/l	30 ~ 35	20 ~25	5 ~ 10	< 5	-	Pack test

*1: Bulgarian Water Quality Standards
*2: As suspended solids

Experiment II (19 Feb.)

	Unit	①	②	③
Alum dosage	mg/l	21	31	52
(Aluminum oxide equivalent)	mg/l	3.3	4.8	8.1
Settling duration	min	20	15	12
Settled sludge interface	ml	150	160	140
Settling distance	mm	282	278	285
Settling velocity	mm/min	14	19	24

Experiment II Supernatant Quality Analysis

	Unit	①	②	③	W.Q.S.*1 Category II	Remarks
pH		6.1	6.0	5.45	6.0 ~ 8.5	
Turbidity	mg/l	11	7	4.5	50*2	SS で 50
Alkalinity	mg/l	20	10 ~15	5 ~ 10	-	Pack test

*1: Bulgarian Water Quality Standards
*2: As suspended solids

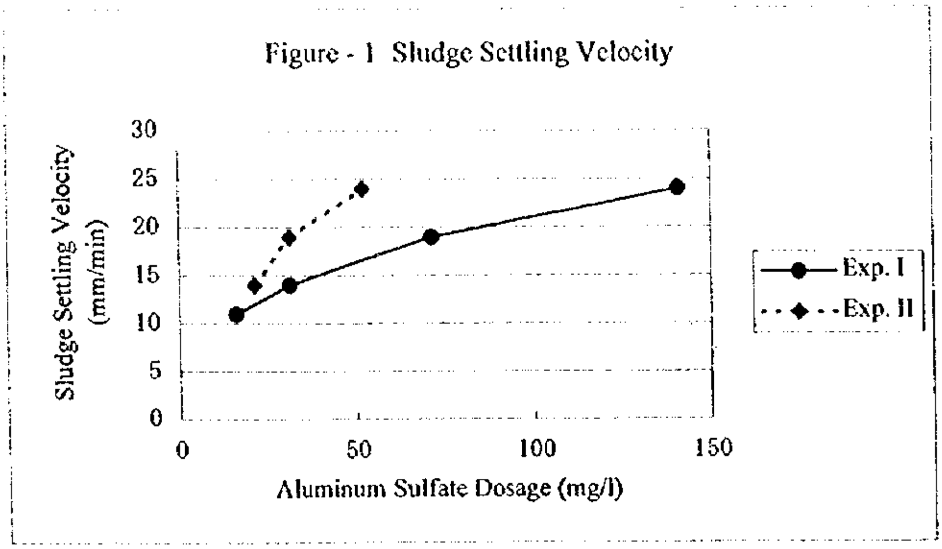


Figure - 1 Sludge Settling Velocity
Sludge Settling Velocity (mm/min)
30
25
20
15
10
5
0
0
50
100
150
Aluminum Sulfate Dosage (mg/l)
Exp. I
Exp. II

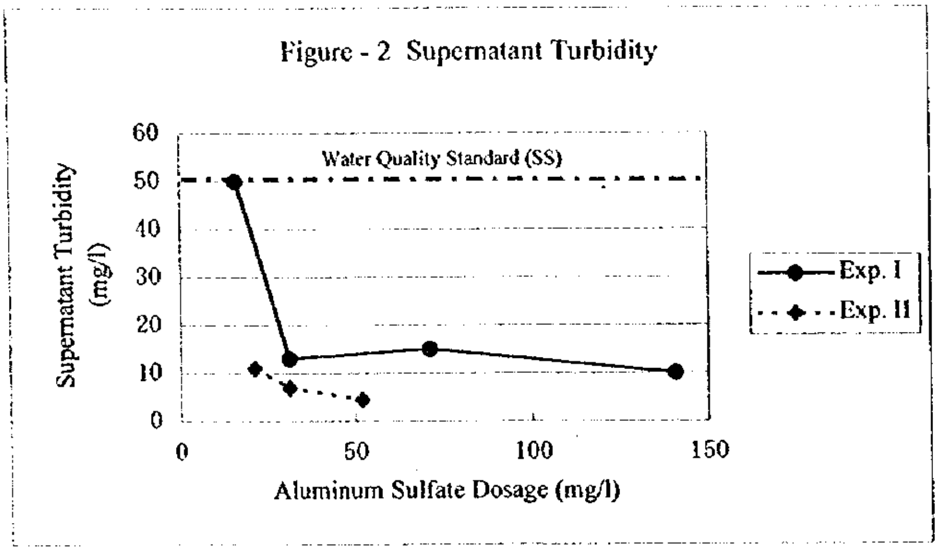


Figure - 2 Supernatant Turbidity
Supernatant Turbidity (mg/l)
60
50
40
30
20
10
0
Water Quality Standard (SS)
0
50
100
150
Aluminum Sulfate Dosage (mg/l)
Exp. I
Exp. II

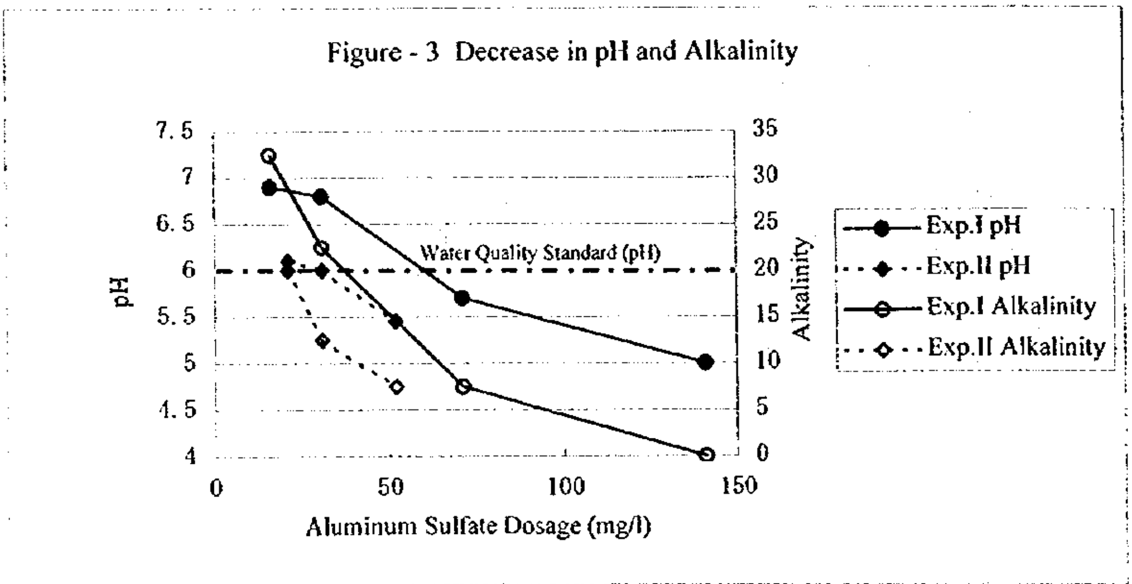


Figure - 3 Decrease in pH and Alkalinity
pH
7.5
7
6.5
6
5.5
5
4.5
4
Alkalinity
35
30
25
20
15
10
5
0
Water Quality Standard (pH)
0
50
100
150
Aluminum Sulfate Dosage (mg/l)
Exp.I pH
Exp.II pH
Exp.I Alkalinity
Exp.II Alkalinity

(Sludge settling velocity)

The results of Experience I, II show that sludge settling velocity increases as coagulant (aluminum sulfate) dosage increases. With addition of coagulant for purification process, settling velocity of Experience II is bigger than that of Experience I as shown in Figure 1.

(Supernatant quality)

Supernatant turbidity decreases as coagulant dosage increases in both experiments at coagulant dosage from 16 mg/l to 31 mg/l as shown in Figure 2. The decrease in turbidity was small in Experience I at coagulant dosage more than 31 mg/l. Coagulant dose decreases alkalinity in the supernatant as shown in Figure 2. As coagulant was added to purification process at Experiment II, alkalinity of supernatant was lower than that of Experiment I at the same coagulant dosage.

(Optimum Coagulant Dosage)

The result of Experiment I (Figure 2) shows that coagulant dosage of 20 –30 mg/l are required to make supernatant turbidity meets Water Quality Standards Category II (50 mg/l as suspended solids).

Drop in alkalinity down to less than 20 mg/l may result in drastic decrease in pH, normally to less than 6.0. Coagulant dosage shall be controlled in order to maintain alkalinity more than 20 mg/l. Addition of 1 mg/l alum (solid) causes 0.45 mg/l decrease in alkalinity. If 5 mg/l coagulant is added to raw water in purification process, coagulant dosage at the proposed sludge treatment plant shall be less than 30 mg/l to prevent pH drop below 6.0. (Water Quality Standards Category II: pH = 6.0 – 8.0)

Supernatant turbidity decreased as coagulant dosage increased from 0 mg/l to 32 mg/l in both experiments. The optimum coagulant dosage for the proposed sludge treatment plant is set to 30 mg/l.

② Supernatant quality test

Samples are taken from cylinders with coagulant dosage of 31 mg/l after 30 minutes of gravity settling. Samples are analyzed for physical, organic and inorganic constituents including heavy metals. A part of the sample from

Experiment I was filtered with filter paper and analyzed for organic and inorganic constituents. The results are shown in Table 1. The results show that both samples from Experiment I and II meet Water Quality Standards Category II for every parameter analyzed.

As heavy metal contents of filtered sample from Experience I is much lower than that of unfiltered sample, most of heavy metals are contained in the particle matters. Manganese and Iron contents samples are higher than that of raw water since both metals, oxidized by pre-chlorination and captured by the filters, are released into backwash water with particles.

Table- 1 Supernatant quality test results

Parameter	Unit	Experiment I		Experiment II	Water Quality Standard Category II
		Supernatant	Filtered Supernatant	Supernatant	
pH		6.98		6.7	6.0 - 8.5
Turbidity	mg/l	13.3			
SS	mg/l	15		6	50
VSS	%	30.7			
BOD_5	mg/l			1.2	15
COD_{Mn}	mg/l			4.5	30
TDS	mg/l	196		120	1000
Total Hardness	mg/l	3.3		0.2	10
NH_4-N	mg/l	0.0	0	0.06	2
NO_3-N	mg/l	1.7	1.7	0.49	10
NO_2-N	mg/l	0.03	0.03	<0.002	0.04
PO_4-P	mg/l	0.05	0	0.024	1
Cl^-	mg/l	6	6	7	300
SO_4^{-2}	mg/l	45	26	46	300
Aluminum	mg/l	0.11	0	1.96	-
Iron	mg/l	0.25	0.01	0.624	1.5
Manganese	mg/l	0.27	0.02	0.102	0.3
Cadmium	mg/l			0.001	0.01
Cyanide	mg/l	0.001	0.001	<0.002	0.5
Zinc	mg/l	0.28	0.28	0.163	5

(Design settling velocity for sedimentation tanks and thickening tank)

At optimum coagulant dosage of 30 mg/l, settling velocity in Experiment I was 14 mg/l. As increase in turbidity of supernatant may result in increase in heavy metal contents of supernatant up to the level of Water Quality Standard Category II, design settling velocity is set to 10 mg/l, which 30 % less than the above experiment results.

③ Sludge Quality Test

Settled sludge from cylinder with optimum coagulant dosage in Experiment II was taken for analysis of its heavy metal contents. The results are shown in Table 2.

Aluminum content of the sludge is 18.2 %, which is much higher than the theoretical aluminum content of 9.1 % for the sludge with 5 mg/l coagulant dosage in purification process under maximum operation mode (water production = 8.8 m^3/s). Therefore, in order to estimate heavy metal contents of sludge from Bistritsa WPP, those figures shall be adjusted by the factor of 1.1 (up 10 %) approximately.

Cadmium and Zinc contents of the sludge meet the limit values for concentrations in sludge which are stipulated in "Sludge in Agriculture Directive" of European Union. Amount of sludge that may be put on soil was calculated based on limit values on heavy metals (Cadmium: 0.15 kg/ha/yr, Zinc: 30 mg/ha/yr) from the same directive. Regarding Cadmium, amount of sludge put on soil in up to 6.8 $kg/m^2/hr$, for Zinc the amount is 7.2 $kg/m^2/hr$. Considering adjustment by aluminum content, 6 kg of sludge can be disposed on soil per square meter annually. Further study is necessary for agricultural reuse of sludge on the other heavy metal contents (Copper, Nickel, Lead, Mercury etc.) of sludge and characteristics of soil.

Table - 2 Sludge quality test results

Parameter	Sludge (mg/l)	Content (per dry sludge weight)		
		Ratio (%)	Content (mg/kg-DS)	EU "sludge for agriculture" limits (mg/kg-DS)
pH	6.5			
Turbidity				
SS	2730			
VSS	750	27%	274,725	
T-N	21.43	0.78%	7,850	
T-P	0.015	0.00%	5	
Aluminum	498.1	18%	182,454	
Iron	74.45	2.7%	27,271	
Manganese	11.25	0.41%	4,121	
Cadmium	0.006	0.00%	2.2	20 - 40
Cyanide	<0.002	0.00%	0.7	
Zinc	1.14	0.04%	418	2,500 - 4,000

Appendix - 7 Sludge Treatment Facilities Design Calculations

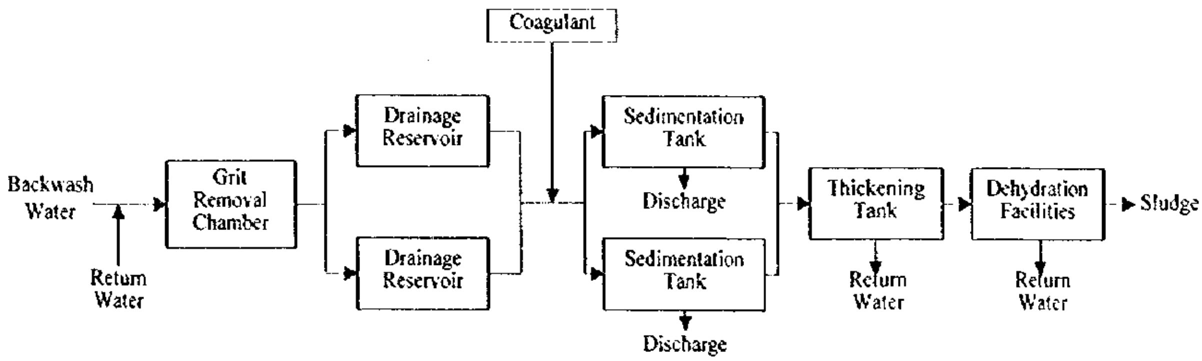
1. Basic considerations for design calculations

[Backwash water discharge]

	Water production		Backwash water		Dry sludge content
Normal operation	Q = 6.75 m^3/sec	⇒	10,816 m^3/day	⇒	3.1 t/day
Maximum operation	Q = 8.8 m^3/sec	⇒	15,414 m^3/day	⇒	4.0 t/day

[Design approach]

Process flow of sludge treatment facilities is shown below.



From grit removal chamber to thickener, facilities will be designed to treat amount of backwash water (15,414 m^3/d) under maximum operation. Dehydration facilities will dewater amount of sludge (3.1 t-DS/d) under normal operation by operation hours of 10 hours/day x 7 days. Under maximum operation, excess sludge will be dewatered by extended operation hours.

2. Grit Removal Chamber

[Design approach]

Grit removal Chamber will recover sand with diameter larger than 0.6 mm in order to recover reusable sand for filters. Removed sand will be dried at adjacent drying bed.

[Design conditions]

Drainage inflow (Q) (maximum):	734 m^3/15 min. = 0.816 m^3/s
Grit to be removed:	Sand with diameter larger than 0.6 mm
Effective depth (H):	3 - 4 m (Japanese design standards)
Free board: (High water level – top of chamber)	0.6 – 1.0 m (Japanese design standards)
Grit (sludge) depth:	0.5 – 1.0 m (Japanese design standards)

[Design calculations]

Settling distance L (m) required removing sand with diameter more than i mm.

$$L = K\left(\frac{H}{U}V\right) \quad \ldots \quad (1)$$

where

H: Effective depth (m)

U: Settling velocity of sand with diameter of i mm (cm/sec)

V: Average flow velocity (cm/sec)

K: Safety factor

when i = 0.6 mm, settling velocity U equals 6.2 cm/sec. (Kawamura, 1991)

Safety factor is set to 1 since sand discharged from grit removal chamber will not have detrimental effects on the following treatment process.

From the limitation of the space, the proposed grit removal chamber is to be circular, assuming the inflow will circle the chamber once before discharged.

While radius of the chamber equals r, settling distance L = π x r

Vertical area A (m^2) diagonal to the flow:

A = r x H

$V (cm/sec) = Q / A = 0.816 / (r \times H) \times 100$

From the above equation (1)

$L = \pi \times r = K(H/U \times Q/A) = 1.0\,(H/6.2 \times 0.816/(r \times H) \times 100)$

$r^2 = 13.2 / \pi$

$\therefore r = 2.05 \text{ m} \Rightarrow 2.1 \text{ m}$

Therefore, diameter of the circular chamber is set to 4.2 m.

Assuming H = 3.0 m and free-board (high water level – top of chamber) = 0.6 m, required vertical area A' (m^2) diagonal to the flow:

$2.1 \times \pi = 1.0\,(3.0/6.2 \times 0.816 / A \times 100)$

$A' = 6.0 \text{ m}^2$

Grit removal chamber is circular (cylindrical) with diameter of 4.2 meters, effective depth more than 3.0 meters and vertical area diagonal to the flow more than 6.0 m^2.

3. Drainage Reservoirs

[Design approach]

Drainage reservoir is designed to store backwash water from filters and to provide constant quantity and quality water to sedimentation tanks.

[Design conditions]

Drainage per filter backwash:	734 m^3 / filter	
Filter backwash operation mode:	Discharging water:	3 – 4 min (max. 5 min)
	Backwash (water):	5 min
	Air scour:	5 min
	Backwash (water):	10 min
	Total duration per filter:	25 min
Drainage inflow (Q_{in}):	734 m^3 /25 min = 1762 m^3 / hr	
Filter backwash interval:	36 hrs (under maximum operation)	
Number of filters backwashed:	21 filters /day (under maximum operation)	

Backwash duration per night: 25 min/filter x 21 filters = 8.75 hrs

Due to the cheaper electricity during night, filter backwash operation will be done in sequence during the night.

[Design calculations]

Discharge (underflow) (Q_{out}) from drainage reservoir is

Q_{out} = 734 m^3/ filter x 21 filters /24 hrs = 642 m^3 / hr

Required capacity (V_r) for drainage reservoir is calculated as the volume to be remained in reservoir after backwashing of 21 filters (8.75 hrs).

$V_r = (Q_{in} - Q_{out})$ x 8.75 hrs = (1762 m^3 / hr – 642 m^3 / hr) x 8.75 hrs = 9,800 m^3

Existing drainage reservoirs (cylindrical)

Number of reservoirs:	2
Diameter:	40 meters
Effective depth:	4.0 meters
Effective volume (V_e):	$(40/2)^2 \times \pi \times 4.0 \times 2$ = 10,053 m^3

$V_e > V_r$

Therefore, the existing reservoirs have enough capacity to hold backwash water discharge.

4. Sedimentation Tanks

[Design conditions] under maximum operation

Sludge settling velocity:	10 mm/min (from experiment result)
Drainage inflow:	15,414 m^3/day (4.0 t dry sludge/day)
Coagulant (alum) dose:	30 mg /l
Drainage inflow duration:	24 hours/day
Thickened sludge concentration:	0.5 % (assumed)
Effective depth:	3.25 m (data from the tank under construction)

[Design calculations]

Settling area A_1 (m^2) required obtaining clear supernatant

$$A_1 = \frac{Q}{\upsilon_1} = \frac{Q_f - Q_u}{\upsilon_1} \fallingdotseq \frac{Q_f}{\upsilon_1} \qquad (\because Q_f \gg Q_u)$$

where

Q_f: Drainage inflow (m^3/min) = 15,414 m^3/day = 10.7 m^3/min

Q_u: Sludge underflow (m^3/min)

V_1: Sludge settling velocity (m/min) = 10 mm/min = 0.01 m/min

A_1= 10.7 / 0.01 = 1,070 m^3/day

Assuming 2 sedimentation tanks are circular, the diameter required is 26 meters.

The sedimentation tank (diameter = 30 m) under construction has settling area of 704m^2. (A = 15 x 15 x 3.14 – 1 x 1 x 3.14)

To enable parallel (separate) operation of 2 trains (drainage tank - sedimentation tank), a sedimentation tank with the same diameter (30 meters) shall be built. In this case, total settling area is 1,408 m^2, which is larger than the required area of 1,070 m^2.

Therefore, 2 sedimentation tanks with the diameter of 30 meters shall be built.

Upflow velocity: 10.7 m^3/min / 1,408 m^2 = 7.6 mm/min

This value is smaller than the sludge settling velocity (10 mm/min), .

Drainage sludge content: 4.0 t/day

Aluminum hydroxide sludge: 15,414 m^3/day x 30 mg/l x 0.44 = 0.2 t /day

Total inflow sludge: 4.0 t/day + 0.2 t/day = 4.2 t/day

Sludge loading rate: 4.2 t/day / 1,408 m^2 = 3.0 kg/m^2 day

From the mass balance of sedimentation tanks,

S_{in} = X x 0.005 t/m^3 + (15,414 m^3/day – X) x 20 mg/l

where

Inflow sludge: S_{in}

Underflow of thickened sludge (0.5 %): X m^3/day

Drainage inflow: 15,414 m^3/day

Supernatant solid content: 20 mg/l (from the test data)

Therefore

Underflow X = 781 m^3/day

Supernatant flow: 15,414 m^3/day - 781 m^3/day = 14,633 m^3/day

Underflow (thickened sludge): 781 m^3/day

Water retention: 1,408 m^2 x 3.25 m / 15,414 m^3 = 0.3 day = 7 hours

Sludge retention: 1,408 m^2 x 1.0 m / 781 m^3 = 1.8 day = 43 hours

Under normal operation

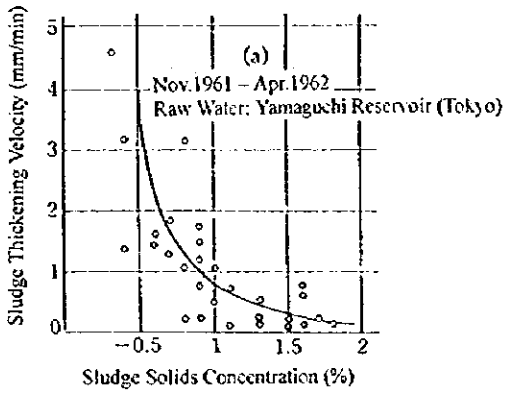
Drainage inflow:	10,816 m^3/day (3.1 t dry sludge/day)
Total inflow sludge:	3.24 t dry sludge /day
Underflow (thickened sludge):	607 m^3/day
Supernatant flow:	10,209 m^3/day
Water retention:	0.42 day = 10 hours
Sludge retention:	2.3 day = 55 hours

5. Thickening tank

[Design conditions] under maximum operation

Sludge settling velocity:	10 mm/min (from experiment result)
Sludge inflow:	781 m^3/day (4.0 t dry sludge/day)
Sludge inflow duration:	8 hours/day (assumed)
Solid loading ratio:	10 – 20 kg/m^2 day (Japanese design standards)
Sludge thickening velocity:	4 mm/min (at 0.5 % sludge concentration)
(data with the similar sludge)	0.8 mm/min (at 1.0 % sludge concentration)
	0.2 mm/min (at 2.0 % sludge concentration)
Thickened sludge concentration:	3 % (assumed)
Effective depth:	3.5 – 4.0 m (Japanese design standards)

Figure – 1 Sludge concentration and sludge thickening (interface settling) velocity



Soucce: Kobayashi (1991)

[Design calculations]

Thickener area shall be designed to meet the following conditions.

1. To obtain clear supernatant (to prevent overflow of the sludge)

2. To obtain target sludge concentration (3 %)

3. To meet the above sludge loading rate (15 kg/m^2 day)

Thickener area will be the minimum value that satisfies the above three conditions.

1. Thickener area A_1 (m^2) required to obtain clear supernatant

$A_1 = Q_f / V_1$

where

Q_f: Sludge inflow (m^3/min) = 781 m^3/day = 1.63 m^3/min

V_1: Sludge settling velocity = 10 mm/min

A_1= 1.63 / 10 = 163 m^3/day

Assuming thickener is circular, the diameter required is 15 meters.

2. Thickener area A_2 (m^2) required to obtain target sludge concentration

$A_{2i} = Q_f \times C_f \times 1/\upsilon_i \times (1/C_i - 1/C_u)$

where

A_{2i} : Required thickening area for sludge concentration C_i

C_f : Inflow sludge concentration (kg/m^3) = 0.5 % = 5 kg/m^3

υ_i : Sludge thickening velocity (m/day)

C_u : Thickened sludge concentration (kg/m^3) = 3 % = 30 kg/m^3

Sludge concentration (C_i)	Sludge settling velocity (υ_i)	Required thickening area (A_{2i})
C_i = 0.5 % = 5 kg/m^3	υ_i = 4 mm/min = 5.8 m/d	A_{2i} = 113 m^2 (ϕ =12m)
C_i = 1.0 % = 10 kg/m^3	υ_i = 0.8 mm/min = 1.2 m/d	A_{2i} = 216 m^2 (ϕ =17m)
C_i = 2.0 % = 20 kg/m^3	υ_i = 0.2 mm/min = 0.3 m/d	A_{2i} = 325 m^2 (ϕ =20m)

Assuming thickener is circular, the diameter required is 20 meters.

3. Thickener area A_3 (m^2) required to meet sludge loading rate L less than 15 $kg/m^2/day$

L = 15 kg/m^2 day > 4.0 dry sludge /day /A_3

A_3 > 4000 kg/day / 15 kg/m^2 day = 267 m^2

Assuming thickener is circular, the diameter required is 19 meters.

The minimum thickener diameter to meet the above 3 conditions is 20 meters. Therefore, the thickener diameter is designed to be 20 meters, effective depth to be 3.5 meters.

Thickener area: $10 \times 10 \times 3.14 = 314\ m^2$

Sludge loading rate L : 4,000 kg/day / 314 m^2 = 12.7 kg/m^2 day

Supernatant flow: 648 m^3/day

Underflow (thickened sludge): 133 m^3/day

Water retention: 314 m^2 x 3.5 m / 781 m^3 = 1.4 days

Sludge retention: 314 m^2 x 1.5 m / 133 m^3 = 3.5 days

Under normal operation

Sludge inflow:	607 m^3/day (3.1 t dry sludge/day)
Underflow (thickened sludge):	103 m^3/day
Supernatant flow:	504 m^3/day
Water retention:	1.8 days
Sludge retention:	4.6 days

6. Dehydration facilities

[Design approach]

Dehydration facilities will dewater amount of sludge (3.1 t-DS/d) under normal operation by operation hours of 10 hours/day x 7 days. Under maximum operation, excess sludge will be dewatered by extended operation hours. 2 redundant dehydrators with 50 % of total capacity each will be installed in order for one dehydrator to dewater sludge produced during repair and maintenance works.

[Design conditions]

Dehydrator type:	Pressure filter (filter press)	
Sludge feed flow:	103 m^3/day (3.1 t dry sludge/day)	
Dehydration yield (V) :	1.5 kg-DS / m^2 / hr (from operation data in Japan: 1.44 (Table1-13))	
Operation hours (T) :	10 hrs /day x 7 days / week	
Dewatering cycle:	Filtration	45 min
(provisional)	Compression	35 min
	Others (filter washing)	40 min
	Total	120 min

[Design calculation]

Required filter area of dehydrators A (m^2):

$$A = \frac{S}{V \times T}$$

where

S: Sludge feed rate (kg-DS / d) = 3,100 kg-DS / d

T: Dehydrator operation hours (hr) = 10 hrs

$$A = \frac{3{,}100kg - DS/d}{1.5kg - DS/m^3/hr \times 10hrs} = 207m^2$$

Filter area of each dehydrator shall be more than 104 m^2.

7. Chemical feed equipment

7.1. Coagulant feed equipment

[Design approach]

Approximately 10 % (w/v) dissolved alum from existing dissolver tanks will be used. Chemical metering pumps are used for feeding liquid coagulant from 2 storage tanks (90 m^2 x 2) through PVC pipes to sedimentation tanks. Application points are pipes between drainage reservoirs and sedimentation tanks. Average dosage of coagulant is 30 mg/l and maximum dosage, feeder capacity, is set to 60 mg/l.

[Design conditions]

Drainage flow rate (Q) per train under maximum operation:	321.13 m^3 / hr
Alum dosage (average):	30 mg / l
Alum dosage (maximum):	60 mg / l
Aluminum oxide content of alum:	Approx. 15 %
Dissolved alum concentration	10 %

[Design calculation]

Coagulant (alum) feed rate V (l/hr) is computed from dosage and drainage flow rate

$V = Q \times R_s \times 100/C \times 10^{-3}$

Where

R_s: Alum dosage (mg/l)

C: Liquid alum concentration (w/v) (%)

For average dosage of 30 mg/l

$V_{av} = 321.13$ mg/l x 30 mg/l x 100/10 x 10^{-3}

= 96 l / hr = 1.6 l / min

For maximum dosage of 60 mg/l

$V_{av} = 321.13$ mg/l x 60 mg/l x 100/10 x 10^{-3}

= 193 l / hr = 3.2 l / min

The capacity of chemical feeder pumps (2 working + 1 stand-by) shall be more than 3.2 l/min.

7.2. Flocculation aid (polymers) feed equipment

[Design consideration]

Increased dosage of coagulant will produce larger dehydrated sludge and may decrease efficiency of dehydrators. Decrease in effect of coagulant in winter may result in degradation of effluent quality. In order to enhance coagulation without increase in coagulant dosage, flocculation aid, polymers, will be added. Polymers are also known as sludge conditioners to improve dehydrator efficiency.

Application points are pipes after in-line blenders of coagulant.

[Design conditions]

Drainage flow rate (Q) per train under maximum operation:	321.13 m^3 / hr
Polymer dosage (average):	0.25 mg / l
Polymer dosage (maximum):	0.5 mg / l
Dissolved polymer concentration	0.1 %

[Design calculation]

Polymer feed rate V (l/hr) is computed from dosage and drainage flow rate

$V = Q \times R_s \times 100/C \times 10^{-3}$

where

R_s: Polymer dosage (mg/l)

C: Liquid polymer concentration (w/v) (%)

For average dosage of 0.25 mg/l

$V_{av} = 321.13$ mg/l x 0.25 mg/l x 100/0.1 x 10^{-3}

= 80 l / hr = 1.4 l / min

For maximum dosage of 0.5 mg/l

V_{av} = 321.13 mg/l x 0.5 mg/l x 100/0.1 x 10^{-3}

= 160 l / hr = 2.7 l / min

The capacity of chemical feeder pumps (2 working + 1 spare) shall be more than 2.7 l/min.

7.3. Flocculation aid (polymers) dissolver tanks

[Design approach]

Polymers available in dry form will be dissolved in water with mechanical mixers. Since dissolving process is normally batch process, 2 dissolver tanks are required to secure continuos feed of polymer. Capacity of one tank will be set to provide one-day storage.

[Design conditions]

Polymer dosage (average) V_{av} (l/s) :	80 l / hr / train

[Design calculation]

Average polymer feed per day: V_{day} (m^3/day)

V_{day} = V_{av} x 2 trains x 24 hr

= 80 l / hr / train x 2 trains x 24 hr

= 3,840 l ⇒ 4 m^3

Capacity of one polymer dissolver tank shall be 4 m^3. 2 same size tanks will be installed.

8. Driving units for sludge scrapers (in sedimentation tanks and thickeners)

8. 1. Driving units for sedimentation tanks sludge scrapers

[Design approach]

Existing driving units (0.75 kW) of sludge scrapers were examined for applicability to the proposed sedimentation tanks. Power requirement of driving unit for proposed scraper will be compared with that of existing drive units.

[Design conditions]

Scraper resistance (W) per length of scraper shaft: (from actual operation data)	15 kgf / m (sewerage sludge)
	30 kgf / m (paper mill sludge)
	60 kgf / m (silt, sand)
Length of scraper (R):	15 m (half of tank diameter)
Type diameter of drive unit (d):	0.4 m
Velocity of drive unit (V):	3.5 m / min (maximum)

[Design calculation]

Scraper resistance of 60 kgf / m will be used for this study since sludge is mostly composed of silt and fine sand.

Required torque T_s (kgf・m) for rotating scraper:

$T_s = W \times R \times R / 2$

$= 60$ kgf / m x 15 m x 15 m / 2 = 6,750 kgf・m

Required force F_s(kgf) at driving unit

F_s = Ts / R = 6,750 kgf・m / 15 m = 450 kgf

Required torque T_d (kgf・m) for rotating wheel (φ 0.4 m) of drive unit:

$T_d = F_s \times d / 2$ = 450 kgf x 0.4 m / 2 = 90 kgf・m

Rotation of scraper N (rpm):

$$N = \frac{V}{D \times \pi} = \frac{3.5m/\min}{30m \times \pi} = 0.0371rpm$$

where

D: Diameter of sedimentation tank (m) = 30 m

Rotation of drive unit n (rpm):

$$n = \frac{D \times \pi \times N}{d \times \pi} = \frac{30m \times 0.0371}{0.4} = 2.78rpm$$

Power requirement P (kW) of drive unit:

$P = (T_d \times n \times 2\pi / (102 \times 60 \times \eta)) \times \alpha$

where

η: Efficiency = 0.75

α: Safety factor = 2

P = (90 kgf / m x 2.78 x 2 π / (102 x 60 x 0.75)) x 2.0

= 0.68 kW

Power requirement is smaller than 0.75 kW of existing drive unit. Therefore, existing unit will be used for the sedimentation tanks.

8. 2. Driving units for thickener sludge scrapers

[Design approach]

Existing driving units (0.75 kW) of sludge scrapers were examined for applicability to the proposed thickener. Power requirement of driving unit for proposed scraper will be compared with that of existing drive units.

[Design conditions]

Scraper resistance (W) per length of scraper shaft: (from actual operation data)	15 kgf / m (sewerage sludge)
	30 kgf / m (paper mill sludge)
	60 kgf / m (silt, sand)
Length of scraper (R):	10 m (half of tank diameter)
Type diameter of drive unit (d):	0.4 m
Velocity of drive unit (V):	3.5 m / min (maximum)

[Design calculation]

Scraper resistance of 60 kgf / m will be used for this study since sludge is mostly composed of silt and fine sand.

Required torque T_s (kgf・m) for rotating scraper:

$T_s = W \times R \times R / 2$

$= 60$ kgf / m x 10 m x 10 m / 2 = 3,000 kgf・m

Required force F_s (kgf) at driving unit

$F_s = Ts / R = 3{,}000$ kgf・m / 10 m = 300 kgf

Required torque T_d (kgf・m) for rotating wheel (ϕ 0.4 m) of drive unit:

$T_d = F_s \times d / 2 = 300$ kgf x 0.4 m / 2 = 60 kgf・m

Rotation of scraper N (rpm):

$$N = \frac{V}{D \times \pi} = \frac{3.5m/\min}{30m \times \pi} = 0.0371rpm$$

where

D: Diameter of sedimentation tank (m) = 20 m

Rotation of drive unit n (rpm):

$$n = \frac{D \times \pi \times N}{d \times \pi} = \frac{30m \times 0.0371}{0.4} = 2.78rpm$$

Power requirement P (kW) of drive unit:

$P = (T_d \times n \times 2\pi / (102 \times 60 \times \eta)) \times \alpha$

where

η: Efficiency = 0.75

α: Safety factor = 2

$P = (60\ kgf / m \times 2.78 \times 2\pi / (102 \times 60 \times 0.75)) \times 2.0$

$= 0.46\ kW$

Power requirement is smaller than 0.75 kW of existing drive unit. Therefore, existing unit will be used for the sedimentation tanks.

Appendix – 8 Specifications for Mechanical and Electrical Equipment

Specifications for major mechanical and electrical equipment for sludge treatment facilities are shown below.

i) Grit removal chamber

No.	Equipment	Specifications	Qt.	Purpose
i -1	Grit discharge pump	Submersible pump for sludge Capacity: 0.3m^3/min × 9 m × 3.7 kW	1	To remove settled grits
i -2	Local control panel	Self-standing, outdoor	1	To control grit discharge pump

ii) Drainage reservoirs

No.	Equipment	Specifications	Qt.	Purpose
ii -1	Pump mixer	Submersible pump for sludge Capacity: 110 m^3/h Diffuser nozzle (air flow = 100 m^3/h)	4	To keep sludge homogeneous
ii -2	Flow meter	Ultrasonic flow meter (ϕ 350 mm)	2	To control flow (drainage reservoirs – sedimentation tank)
ii -3	Flow control valve	Motor-operated valve (ϕ 350 mm)	2	To control flow (drainage reservoirs – sedimentation tank)
ii -4	Controller	Flow controller	2	To control flow (drainage reservoirs – sedimentation tank)
ii -5	Local control panel	Self-standing, outdoor	1	To control drainage reservoirs

iii) Sedimentation tanks

No.	Equipment	Specifications	Qt.	Purpose
iii-1	In-line blender	ϕ 350 mm, L = 800 mm	2	To mix drainage and coagulant
iii-2	Sludge scraper	Peripheral driven (power: 0.75 kW) (use existing drive units)	2	To scrape sludge to the center of the tank
iii-3	Trough	W 300 mm x D 400 mm x L 80m Reinforced concrete	2	To collect supernatant
iii-4	Flow meter	Ultrasonic flow meter (ϕ 150 mm)	2	To control flow(sedimentation tanks – thickening tank)

No.	Equipment	Specifications	Qt.	Purpose
iii-5	Flow control valve	Motor-operated valve (ϕ 150 mm)	2	To control flow(sedimentation tanks – thickening tank)
iii-6	Controller	Flow controller	2	To control flow(sedimentation tanks – thickening tank)
iii-7	Local control panel	Self-standing, outdoor	2	To control sedimentation tanks

iv) Thickening tank

No.	Equipment	Specifications	Qt.	Purpose
iv-1	Sludge scraper	Peripheral driven (power: 0.75 kW) (use existing drive units)	2	To scrape sludge to the center of the tank
iv-2	Trough	W 300 mm x D 300 mm x L 60m Carbon steel	2	To collect supernatant
iv-3	Sludge discharge pump	Screw pump, FC Capacity: 0.3 m^3 x 5 m x 11 kW	2	To transfer sludge to sludge tank
iv-4	Local control panel	Self-standing, outdoor	1	To control sludge scraper

v) Sludge tank and overflow tank

No.	Equipment	Specifications	Qt.	Purpose
v-1	Mixer	Vertical shaft (shaft length: 3.5 m) Motor: 5.5 kW	2	To keep sludge homogeneous
v-2	Sludge feed pump (for dehydrators)	Screw pump, CR cast iron Capacity: 0.24m^3/minx15kg/cm^2	2	To feed sludge to dehydrators
v-3	Overflow pump	Volute pump, cast iron Capacity: 2m^3/min x 20m x 18.5kW	2	To send supernatant from thickening tank and dehydrator filtrate to distribution chamber
v-4	Local control panel	Self-standing, outdoor	2	To control sludge tank and overflow tank

vi) Dehydrators and dehydrator building

No.	Equipment	Specifications	Qt.	Purpose
vi-1	Dehydrator	Filter press without chemical conditioning Capacity: 1.55ton-dry solids /d Operation hours: 10h/d x 7d/week Filter area: > 104 m^2	2	To dehydrate thickened sludge

No.	Equipment	Specifications	Qt.	Purpose
vi -3	Press pump	Capacity: 80 l/min x 7 kgf/cm	2	To dehydrate thickened sludge
vi -4	Automatic cloth washer		2	To clean filter cloth
vi -5	Filter wash pump	Capacity: 155 l/min x 70 kgf/cm	2	To clean filter cloth
vi -6	Service water tank	$9m^3$	1	To clean filter cloth
vi -7	Compressor	283 l/min x 7 kgf/cm^2	1	To provide compressed air to dehydrators
vi -8	Blow air receiver	1000 L	1	To provide compressed air to dehydrators
vi -9	Belt conveyer	W 1050m x L 20m x 1.5 kW	2	To convey sludge to hopper
vi -10	Traveling crane	Capacity: 5 ton, Lift: 3 m	1	For dehydrator maintenance works
vi -11	Cake hopper	Carbon steel Capacity: 8 m^3	2	To store sludge cake and to load on trucks
vi -12	Wastewater pump	Submerged pump for sludge Capacity: 0.2m3/min x 26m x 3.7kW	1	To transfer waste water to treatment facility
vi -13	Control panel		2	To control dehydrators
vi -14	Auxiliary control panel		1	To control auxiliary equipment

vii) Chemical feed equipment

No.	Equipment	Specifications	Qt.	Purpose
vii-1	Coagulant feed pump	Chemical feeder pump Capacity: 3.2 lit/min x 20m x 0.75kW 10% aluminum sulfate Material: PVC	3	To feed coagulant
vii-2	Flocculation aid feed Pump	Chemical feeder pump Capacity: 3.0 lit/min x 20m x 0.75kW 0.1% polymer solution Material: PVC	2	To feed flocculation aid
vii-3	Flocculation aid dissolving tank	FRP, capacity: $4m^3$ Agitator: 2.2kW SUS304 x 2 Feeder: SUS304 x 2	2	To dissolve flocculation aid
vii-4	Local control panel	Self-standing, indoor	1	To control chemical feed

viii) Pipes

No.	Equipment	Specifications	Qt. (m)	Purpose
viii-1	Steel pipe	ϕ 800 mm	50	Distribution chamber - Drainage reservoirs
viii-2	Steel pipe	ϕ 350 mm	115	Drainage reservoirs - Sedimentation tanks
viii-3	Steel pipe	ϕ 600 mm	88	Supernatant pipeline for sedimentation tanks
viii-4	Steel pipe	ϕ 150 mm ϕ 250 mm	32 16	Sedimentation tanks - Thickening tank
viii-5	Steel pipe	ϕ 150 mm	192	Overflow tank – Distribution chamber
viii-6	Steel pipe	ϕ 250 mm	20	Thickening tank – Sludge tank
viii-7	Steel pipe	ϕ 150 mm	48	Sludge tank – Dehydrators
viii-8	PVC pipe	ϕ 15 mm	1600	Coagulant tank - Sedimentation tanks

Appendix - 9 Structure Analysis

1 Existing structures

1. 1 Drainage reservoirs

Civil structure of 2 existing reservoirs has been completed and tested for water tightness. Surface of concrete structure is rather rough and honeycombed, steel bars are visible and rusted in several spots on the walls. The wall surface shall be covered with appropriate coating materials.

1. 2 Sedimentation tank

Civil structure of one sedimentation tank is under construction. One part of pre-fabricated wall plates of reinforced concrete has not been put up and floor concrete not been cast yet. The wall surface shall be covered with appropriate coating materials.

2 Structure analysis

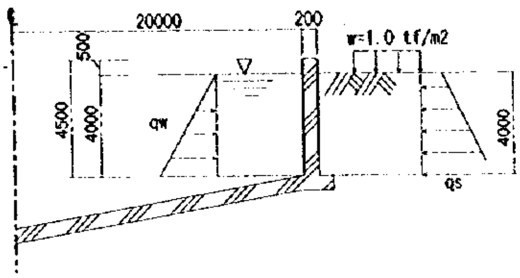
2．1 Conditions

Permissible stress in steel bars:	σ_{sa} = 1800 kgf/cm^2
Earth pressure coefficient:	K = 0.5 (static load)
Unit weight of soil (wet condition)	γ_s = 1.88 t/m^3
Unit weight of water	γ_w = 1.0 t/m^3
Vertical load on earth	w = 1.0 tf/m^2

2．2 Drainage reservoir

（1） Conditions

Shape of reservoir:	Cylindrical
Diameter:	D = 40.0 m
Wall height:	H_0 = 4.5 m
Free-board:	h = 0.5m
Water depth:	H = (H_0-h) = 4.0 m
Wall thickness:	t = 0.2 m



（2） Load calculations

Water pressure $q_w = \gamma_w \cdot h$

h: Water depth

for h_w= 0 m　　　q_0 = 0 tf/m^2

for h_w= 4.0 m　　　q_1 = 1.0×4.0 = 4.0 tf/m^2

Earth pressure $q_s = (w + \gamma_s \cdot h_s) \cdot K$

h_s : Earth depth

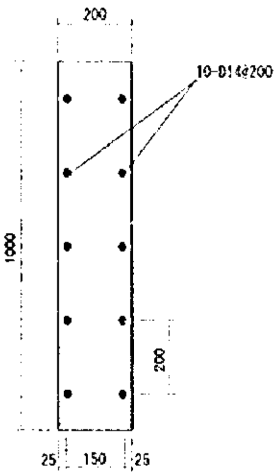
for h_s= 0 m　　　q_0 = 1.0×0.5 = 0.50 tf/m^2

for h_s=4.0 m　　　q_1 = (1.0+1.88×4.0)×0.5 = 4.76 tf/m^2

(3) Structure analysis

A. Hoop reinforcement

A 1 Hoop reinforcement by water pressure



$T = C_t \times \gamma_w \times h \times D/2$ T: Tention (t/m)

$= C_t \times 1.0 \times 4.0 \times 15.0$ C_t: Coeffient

$= 60.0 \times C_t$

C_t values varies according to parameters h^2/Dt and h, which are shown in Annex 1.

Horizontal steel area (A_s) of the existing wall:

$A_s = \pi \times (1.40/2)^2 \times 10 = 15.39cm^2$

(D14 at 200on each face; 10 bars per meter)

Stress in steel is calculated as T/A_s.

Point	Height h(m)	Coefficient C_t	Hoop tension T (tf/m)	Steel area A_s (cm^2)	Stress in steel σ (kg/cm^2)
0.0 H	0.00	0.234	14.04	15.39	912
0.1 H	0.40	0.251	15.06	15.39	978
0.2 H	0.80	0.273	16.38	15.39	1064
0.3 H	1.20	0.285	17.10	15.39	1111
0.4 H	1.60	0.285	17.10	15.39	1111
0.5 H	2.00	0.274	16.44	15.39	1068
0.6 H	2.40	0.232	13.92	15.39	904
0.7 H	2.80	0.172	10.32	15.39	671
0.8 H	3.20	0.104	6.24	15.39	405
0.9 H	3.60	0.031	1.86	15.39	121
1.0 H	4.00	0.000	0.00	15.39	0

The above table shows that maximum stress in steel is 1,111 kg/cm^2, which is smaller than permissible stress of 1,800 kg/cm^2. Therefore, the walls have enough reinforcement for hoop tension.

A 2 Hoop tension by earth pressure

Earth pressure will give compressive force to the walls. Normally, circular hoops of the wall designed for hoop tension from water pressure, along with wall concrete, withstand this pressure.

B. Vertical reinforcement

B 1 Horizontal sheer by water pressure

$M = C_m \times Q_w \times h^2$ — M: Bending moment (t·m/m)

$= C_m \times \gamma_w \times h^3$ — C_m: Coefficient

$= C_m \times 1.0 \times 4^3$

$= 64 \times C_m$

C_m values varies according to parameters h^2/Dt and h, which are shown in Annex 1.

Vertical steel area A_s:

for Upper wall (Depth from 0 – 2,455mm)

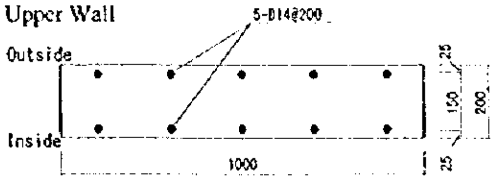
D14 at 200on each surface; 5 bars per meter

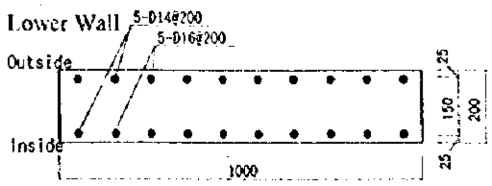
$A_s = \pi \times (1.40/2)^2 \times 5 = 7.69\text{cm}^2$

for Lower wall (Depth from 2,455 mm – 4,000 mm)

D14 at 200 plus D16 at 200 on each surface

$A_s = \pi \times (1.40/2)^2 \times 5 + \pi \times (1.60/2)^2 \times 5 = 17.74\text{cm}^2$





Stress in steel σ (kg/cm²) $= M \times 10^5 / (As \times (7/8) \times d)$

d: Effective depth 20.0 cm – 2.5 cm = 17.50cm

Point	Height h (m)	Coefficient C_m	Moment M (tf·m/m)	Steel area A_s (cm²)	Stress in steel σ (kg/cm²)
0.0 H	0.00	0	0	7.69	0
0.1 H	0.40	0.0010	0.064	7.69	54
0.2 H	0.80	0.0035	0.224	7.69	190
0.3 H	1.20	0.0068	0.435	7.69	369
0.4 H	1.60	0.0099	0.634	7.69	489
0.5 H	2.00	0.0120	0.768	7.69	652
0.6 H	2.40	0.0115	0.736	7.69	625
0.7 H	2.80	0.0075	0.480	17.74	177
0.8 H	3.20	-0.0021	-0.134	17.74	49
0.9 H	3.60	-0.0185	-1.184	17.74	436
1.0 H	4.00	-0.0436	-2.790	17.74	1027

The above table shows that maximum stress in steel is 1,027 kg/cm², which is smaller than permissible stress of 1,800 kg/cm². Therefore, the walls have enough vertical

reinforcement for water pressure.

B 2 Horizontal shear by earth pressure

$$M = C_m \times q_t \times h^2 \qquad \text{M: Bending moment (t·m/m)}$$
$$= C_m \times 4.76 \times 4^2 \qquad C_m\text{: Coefficient}$$
$$= 76.16 \times C_m$$

C_m values varies according to parameters h^2/Dt and h, which are shown in Annex 1.

Vertical steel area A_s:

<u>for Upper wall</u> (Depth from 0 – 2,455mm)

D14 at 200on each surface; 5 bars per meter

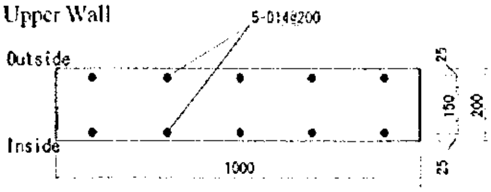
$As = \pi \times (1.40/2)^2 \times 5 = 7.69cm^2$

<u>for Lower wall</u> (Depth from 2,455 mm – 4,000 mm)

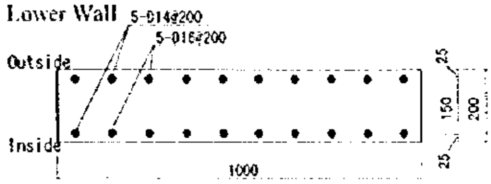
D14 at 200 plus D16 at 200 on each surface

$As = \pi \times (1.40/2)^2 \times 5 + \pi \times (1.60/2)^2 \times 5 = 17.74cm^2$

Upper Wall



Lower Wall



Stress in steel σ $(kg/cm^2) = M \times 10^5/(As \times (7/8) \times d)$

d: Effective depth 20.0 cm – 2.5 cm = 17.50cm

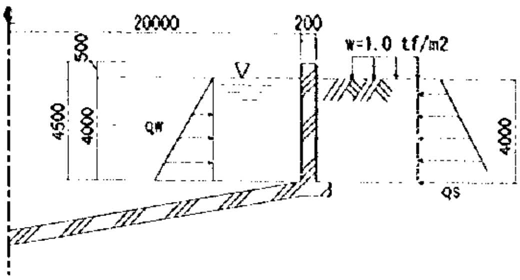
Point	Height h (m)	Coefficient C_m	Moment M (tf·m/m)	Steel area A_s (cm^2)	Stress in steel σ (kg/cm^2)
0.0	0.00	0	0	7.69	0
0.1	0.40	0.010	0.076	7.69	65
0.2	0.80	0.0035	0.267	7.69	227
0.3	1.20	0.0068	0.518	7.69	440
0.4	1.60	0.0099	0.754	7.69	640
0.5	2.00	0.0120	0.914	7.69	776
0.6	2.40	0.0115	0.876	7.69	744
0.7	2.80	0.0075	0.571	17.74	177
0.8	3.20	-0.0021	-0.160	17.74	59
0.9	3.60	-0.0185	-1.409	17.74	519
1.0	4.00	-0.0436	-3.321	17.74	1223

The above table shows that maximum stress in steel is 1,223 kg/cm^2, which is smaller than permissible stress of 1,800 kg/cm^2. Therefore, the walls have enough vertical reinforcement for earth pressure.

2. 3 Sedimentation tanks

(1) Conditions

Shape of reservoir: Cylindrical
Diameter: $D = 30.0$ m
Wall height: $H_0 = 3.75$ m
Free-board: $h = 0.4$m
Water depth: $H = (H_0\text{-}h) = 3.35$ m
Wall thickness: $t = 0.2$ m



(2) Load calculations

Water pressure $q_w = \gamma_w \cdot h$

h: Water depth

for h_w=0 m $\quad q_0 = 0$ tf/m^2

for h_w=3.35 m $\quad q_1 = 1.0 \times 3.35 = 3.35$ tf/m^2

Earth pressure $q_s = (w + \gamma_s \cdot h_s) \cdot K$

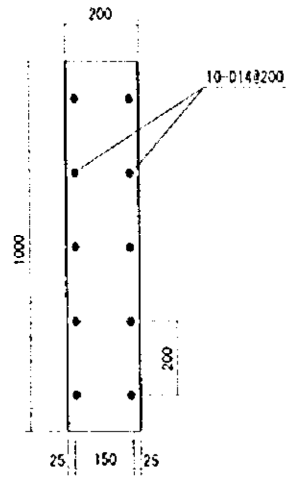
h_s : Earth depth

for h_s= 0 m $\quad q_0 = 1.0 \times 0.5 = 0.50$ tf/m^2

for h_s= 3.35 m $\quad q_1 = (1.0 + 1.88 \times 3.35) \times 0.5 = 3.65$ tf/m^2

(3) Structure analysis

A. Hoop reinforcement



A 1 Hoop reinforcement by water pressure

$T = C_t \times \gamma_w \times h \times D/2$ T: Tention (t/m)
$= C_t \times 1.0 \times 3.35 \times 15.0$ C_t: Coeffient
$= 50.25 \times C_t$

C_t values vary according to parameters, h^2/Dt and h, which are shown in Annex 1.

Horizontal steel area (A_s) of the existing wall:
$A_s = \pi \times (1.40/2)^2 \times 10 = 15.39 cm^2$
(D14 at 200on each face; 10 bars per meter)

Stress in steel is calculated as T/A_s.

Point	Height h(m)	Coefficient C_t	Hoop tension T (tf/m)	Steel area A_s (cm^2)	Stress in steel σ (kg/cm^2)
0.0	0.00	0.244	12.26	15.39	793
0.1	0.34	0.257	12.91	15.39	839
0.2	0.67	0.271	13.62	15.39	885
0.3	1.01	0.279	14.02	15.39	911
0.4	1.34	0.274	13.77	15.39	895
0.5	1.68	0.258	12.96	15.39	842
0.6	2.01	0.217	10.90	15.39	708
0.7	2.35	0.160	8.04	15.39	522
0.8	2.68	0.095	4.77	15.39	310
0.9	3.02	0.028	1.41	15.39	92
1.0	3.35	0.000	0.00	0	0

The above table shows that maximum stress in steel is 911 kg/cm^2, which is smaller than permissible stress of 1,800 kg/cm^2. Therefore, the walls have enough reinforcement for hoop tension.

A 2 Hoop tension by earth pressure

Earth pressure will give compressive force to the walls. Normally, circular hoops of the wall designed for hoop tension from water pressure, along with wall concrete, withstand this pressure.

B. Vertical reinforcement

B 1 Horizontal sheer by water pressure

$M = C_m \times q_x \times h^2$ M: Bending moment (t·m/m)

$= C_m \times \gamma_w \times h^3$ C_m: Coefficient

$= C_m \times 1.0 \times 3.35^3$

$= 37.60 \times C_m$

C_m values vary according to parameters, h^2/Dt and h, which are shown in Annex 1.

Vertical steel area A_s:

<u>for Upper wall</u> (Depth from 0 – 2,455mm)

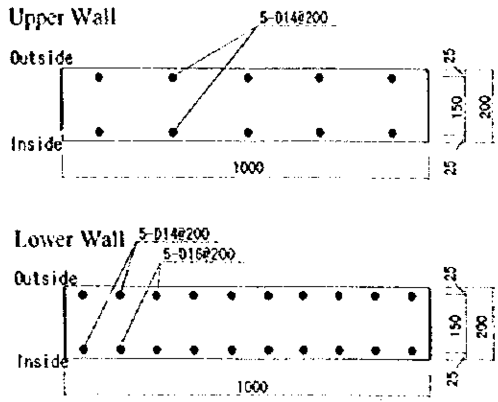
D14 at 200on each surface; 5 bars per meter

$A_s = \pi \times (1.40/2)^2 \times 5 = 7.69cm^2$

<u>for Lower wall</u> (Depth from 2,455 mm – 4,000 mm)

D14 at 200 plus D16 at 200 on each surface

$A_s = \pi \times (1.40/2)^2 \times 5 + \pi \times (1.60/2)^2 \times 5 = 17.74cm^2$



Stress in steel σ (kg/cm^2) = $M \times 10^5/(As \times (7/8) \times d)$

d: Effective depth 20.0 cm – 2.5 cm = 17.50cm

Point	Height h (m)	Coefficient C_m	Moment M (tf·m/m)	Steel area A_s (cm^2)	Stress in steel σ (kg/cm^2)
0.0	0.00				
0.1	0.34	0.0020	0.075	7.69	64
0.2	0.67	0.0048	0.180	7.69	153
0.3	1.01	0.0081	0.305	7.69	259
0.4	1.34	0.0106	0.399	7.69	339
0.5	1.68	0.0117	0.440	7.69	374
0.6	2.01	0.0114	0.429	7.69	364
0.7	2.35	0.0068	0.256	17.74	94
0.8	2.68	-0.0031	-0.117	17.74	43
0.9	3.02	-0.0200	-0.752	17.74	277
1.0	3.35	-0.0458	-1.722	17.74	634

The above table shows that maximum stress in steel is 1,027 kg/cm^2, which is smaller than permissible stress of 1,800 kg/cm^2. Therefore, the walls have enough vertical

reinforcement for water pressure.

B 2 Horizontal shear by earth pressure

$M = C_m \times q_1 \times h^2$ M: Bending moment (t·m/m)

$= C_m \times 3.65 \times 3.35^2$ C_m: Coefficient

$= 40.96 \times C_m$

C_m values vary according to parameters, h^2/Dt and h, which are shown in Annex 1.

Vertical steel area A_s as same as water pressure:

for Upper wall (Depth from 0 – 2,455mm)

$A_s = \pi \times (1.40/2)^2 \times 5 = 7.69cm^2$

for Lower wall (Depth from 2,455 mm – 4,000 mm)

$A_s = \pi \times (1.40/2)^2 \times 5 + \pi \times (1.60/2)^2 \times 5 = 17.74cm^2$

Stress in steel σ (kg/cm^2) = $M \times 10^5/(As \times (7/8) \times d)$

d: Effective depth 20.0 cm – 2.5 cm = 17.50cm

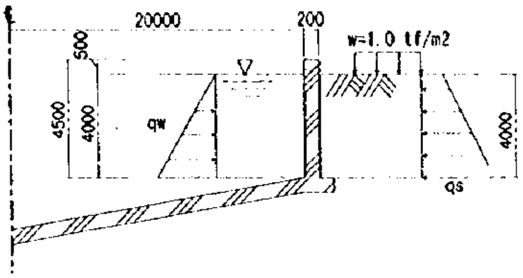
Point	Height h (m)	Coefficient C_m .	Moment M (tf·m/m)	Steel area A_s (cm^2)	Stress in steel σ (kg/cm^2)
0.0	0.00				
0.1	0.34	0.0020	0.082	7.69	67
0.2	0.67	0.0048	0.197	7.69	167
0.3	1.01	0.0081	0.332	7.69	282
0.4	1.34	0.0106	0.434	7.69	369
0.5	1.68	0.0117	0.479	7.69	407
0.6	2.01	0.0114	0.467	7.69	397
0.7	2.35	0.0068	0.279	17.74	103
0.8	2.68	-0.0031	-0.127	17.74	47
0.9	3.02	-0.0200	-0.819	17.74	301
1.0	3.35	-0.0458	-1.876	17.74	691

The above table shows that maximum stress in steel is 1,223 kg/cm^2, which is smaller than permissible stress of 1,800 kg/cm^2. Therefore, the walls have enough vertical reinforcement for earth pressure.

2．4 Thickening tank

(1) Conditions

Shape of reservoir: Cylindrical
Diameter: $D = 20.0$ m
Wall height: $H_0 = 4.25$ m
Free-board: $h = 0.75$ m
Water depth: $H = (H_0 - h) = 3.5$ m
Wall thickness: $t = 0.2$ m



(2) Load calculations

Water pressure $q_w = \gamma_w \cdot h$

h: Water depth

for $h_w = 0$ m　　$q_0 = 0$ tf/m^2

for $h_w = 3.5$ m　　$q_1 = 1.0 \times 3.5 = 3.5$ tf/m^2

Earth pressure $q_s = (w + \gamma_s \cdot h_s) \cdot K$

h_s : Earth depth

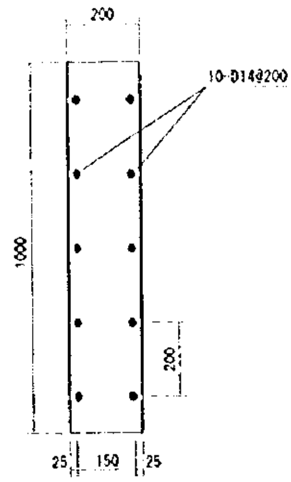
for $h_s = 0$ m　　$q_0 = 1.0 \times 0.5 = 0.50$ tf/m^2

for $h_s = 3.2$ m　　$q_1 = (1.0 + 1.88 \times 3.2) \times 0.5 = 3.51$ tf/m^2

(3) Structure analysis

A. Hoop reinforcement

A 1 Hoop reinforcement by water pressure



$T = C_t \times \gamma_w \times h \times D/2$ T: Tention (t/m)

$= C_t \times 1.0 \times 3.5 \times 15.0$ C_t: Coeffient

$= 52.5 \times C_t$

C_t values vary according to parameters, h^2/Dt and h, which are shown in Annex 1.

Horizontal steel area (A_s) of the existing wall:
$A_s = \pi \times (1.40/2)^2 \times 10 = 15.39 cm^2$
(D14 at 200on each face; 10 bars per meter)

Stress in steel is calculated as T/A_s.

Point	Height h(m)	Coefficient C_t	Hoop tension T (tf/m)	Steel area A_s (cm^2)	Stress in steel σ (kg/cm^2)
0.0	0.00	0.134	7.01	15.39	455
0.1	0.35	0.203	10.66	15.39	693
0.2	0.70	0.267	14.02	15.39	911
0.3	1.05	0.322	16.91	15.39	1098
0.4	1.40	0.357	18.74	15.39	1218
0.5	1.75	0.362	19.01	15.39	1235
0.6	2.10	0.330	17.33	15.39	1126
0.7	2.45	0.262	13.76	15.39	894
0.8	2.80	0.157	8.24	15.39	535
0.9	3.15	0.052	2.73	15.39	177
1.0	3.50	0.000	0.00	0	0

The above table shows that maximum stress in steel is 1,235 kg/cm^2, which is smaller than permissible stress of 1,800 kg/cm^2. Therefore, the walls have enough reinforcement for hoop tension.

A 2 Hoop tension by earth pressure

Earth pressure will give compressive force to the walls. Normally, circular hoops of the wall designed for hoop tension from water pressure, along with wall concrete, withstand this pressure.

B. Vertical reinforcement

B 1 Horizontal sheer by water pressure

$M = C_m \times q_w \times h^2$ M: Bending moment (t·m/m)

$= C_m \times \gamma_w \times h^3$ C_m: Coefficient

$= C_m \times 1.0 \times 3.5^3$

$= 42.88 \times C_m$

C_m values vary according to parameters, h^2/Dt and h, which are shown in Annex 1.

Vertical steel area A_s:

for Upper wall (Depth from 0 – 2,455mm)

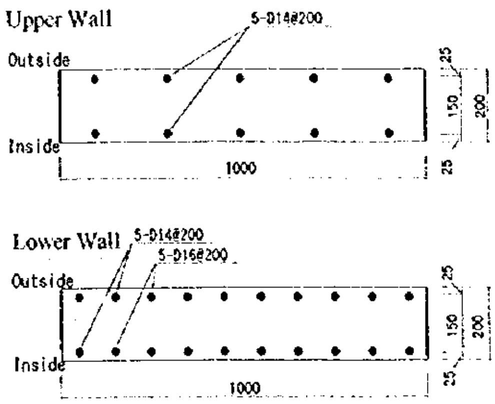
D14 at 200on each surface; 5 bars per meter

$A_s = \pi \times (1.40/2)^2 \times 5 = 7.69cm^2$

for Lower wall (Depth from 2,455 mm – 4,000 mm)

D14 at 200 plus D16 at 200 on each surface

$A_s = \pi \times (1.40/2)^2 \times 5 + \pi \times (1.60/2)^2 \times 5 = 17.74cm^2$



Stress in steel σ (kg/cm²) = $M \times 10^5/(As \times (7/8) \times d)$

d: Effective depth 20.0 cm – 2.5 cm = 17.50cm

Point	Height h (m)	Coefficient C_m	Moment M (tf·m/m)	Steel area A_s (cm²)	Stress in steel σ (kg/cm²)
0.0	0.00				
0.1	0.35	0.0006	0.026	7.69	22
0.2	0.70	0.0021	0.090	7.69	76
0.3	1.05	0.0047	0.202	7.69	172
0.4	1.40	0.0071	0.304	7.69	258
0.5	1.75	0.0090	0.386	7.69	328
0.6	2.10	0.0097	0.416	7.69	353
0.7	2.45	0.0077	0.330	17.74	121
0.8	2.80	0.0012	0.051	17.74	19
0.9	3.15	-0.0119	-0.510	17.74	188
1.0	3.50	-0.0333	-1.428	17.74	526

The above table shows that maximum stress in steel is 526 kg/cm², which is smaller than permissible stress of 1,800 kg/cm². Therefore, the walls have enough vertical

reinforcement for water pressure.

B 2 Horizontal shear by earth pressure

$M = C_m \times q_t \times h^2$ M: Bending moment (t·m/m)

$= C_m \times 3.51 \times 3.2^2$ C_m: Coefficient

$= 35.94 \times C_m$

C_m values vary according to parameters, h^2/Dt and h, which are shown in Annex 1.

Vertical steel area A_s as same as water pressure:

<u>for Upper wall</u> (Depth from 0 – 2,455mm)

$A_s = \pi \times (1.40/2)^2 \times 5 = 7.69cm^2$

<u>for Lower wall</u> (Depth from 2,455 mm – 4,000 mm)

$A_s = \pi \times (1.40/2)^2 \times 5 + \pi \times (1.60/2)^2 \times 5 = 17.74cm^2$

Stress in steel σ (kg/cm^2) = $M \times 10^5 / (As \times (7/8) \times d)$

d: Effective depth 20.0 cm – 2.5 cm = 17.50cm

Point	Height h (m)	Coefficient C_m	Moment M (tf·m/m)	Steel area A_s (cm^2)	Stress in steel σ (kg/cm^2)
0.0	0.00				
0.1	0.32	0.0008	0.029	7.69	25
0.2	0.64	0.0027	0.097	7.69	82
0.3	0.96	0.0056	0.201	7.69	171
0.4	1.28	0.0083	0.298	7.69	253
0.5	1.60	0.0103	0.370	7.69	314
0.6	1.92	0.0105	0.377	7.69	320
0.7	2.24	0.0076	0.273	17.74	100
0.8	2.56	-0.0003	-0.011	17.74	4
0.9	2.88	-0.0148	-0.532	17.74	196
1.0	3.20	-0.0378	-1.359	17.74	500

The above table shows that maximum stress in steel is 500 kg/cm^2, which is smaller than permissible stress of 1,800 kg/cm^2. Therefore, the walls have enough vertical reinforcement for earth pressure.

Annex 1 Cylindrical tanks with fixed base and free top

Coefficients for moments in cylindrical wall: C_m

H^2/Dt	0.1H	0.2H	0.3H	0.4H	0.5H	0.6H	0.7H	0.8H	0.85H	0.9H	0.95H	1.0H
0.4	0.0005	0.0014	0.0021	0.0007	-0.0042	-0.0150	-0.0302	-0.0529		-0.0816		-0.1205
0.8	0.0011	0.0037	0.0063	0.0080	0.0070	0.0023	-0.0063	-0.0224		-0.0465		-0.0795
1.2	0.0012	0.0042	0.0077	0.0103	0.0112	0.0090	0.0022	-0.0108		-0.0311		-0.0602
1.6	0.0041	0.0075	0.0107	0.0121	0.0111	0.0111	0.0053	-0.0051		-0.0232		-0.0505
2.0	0.0010	0.0035	0.0068	0.0099	0.0120	0.0115	0.0075	-0.0021		-0.0185		-0.0436
3.0	0.0006	0.0021	0.0047	0.0071	0.0090	0.0097	0.0077	0.0012		-0.0119		-0.0333
4.0	0.0003	0.0015	0.0028	0.0047	0.0056	0.0077	0.0069	0.0023		-0.0080		-0.0268
5.0	0.0002	0.0008	0.0016	0.0029	0.0046	0.0059	0.0059	0.0028		-0.0058		-0.0222
6.0	0.0001	0.0003	0.0008	0.0019	0.0032	0.0046	0.0051	0.0029		-0.0041		-0.0187
8.0	0.0000	0.0001	0.0002	0.0008	0.0016	0.0028	0.0038	0.0029		-0.0022		-0.0146
10.0	0.0000	0.0000	0.0001	0.0004	0.0007	0.0019	0.0029	0.0028		-0.0012		-0.0122
12.0	0.0000	-0.0001	0.0001	0.0002	0.0003	0.0015	0.0023	0.0026		-0.0005		-0.0104
20.0								0.0015	0.0014	0.0005	-0.0018	-0.0063
24.0								0.0012	0.0012	0.0007	-0.0013	-0.0053
32.0								0.0007	0.0009	0.0007	-0.0008	-0.0040
40.0								0.0002	0.0005	0.0006	-0.0005	-0.0032
48.0								0.0000	0.0001	0.0006	-0.0003	-0.0026
56.0								0.0000	0.0000	0.0004	-0.0001	-0.0023

Coefficients for tension in circular ring: Cm

H^2/Dt	0.0H	0.1H	0.2H	0.3H	0.4H	0.5H	0.6H	0.7H	0.8H	0.9H
0.4	0.149	0.134	0.120	0.101	0.082	0.066	0.049	0.029	0.014	0.004
0.8	0.263	0.239	0.215	0.190	0.160	0.130	0.096	0.063	0.034	0.100
1.2	0.283	0.271	0.254	0.234	0.209	0.180	0.142	0.099	0.054	0.016
1.6	0.265	0.268	0.268	0.266	0.250	0.226	0.185	0.134	0.075	0.023
2.0	0.234	0.251	0.273	0.285	0.285	0.274	0.232	0.172	0.104	0.031
3.0	0.134	0.203	0.267	0.322	0.357	0.362	0.330	0.262	0.157	0.052
4.0	0.067	0.164	0.256	0.339	0.403	0.429	0.409	0.334	0.210	0.073
5.0	0.025	0.137	0.245	0.346	0.420	0.477	0.469	0.398	0.259	0.092
6.0	0.018	0.119	0.234	0.344	0.441	0.504	0.514	0.441	0.301	0.112
8.0	0.011	0.104	0.218	0.335	0.443	0.534	0.575	0.530	0.381	0.151
10.0	0.011	0.098	0.206	0.323	0.437	0.542	0.608	0.589	0.440	0.179
12.0	0.005	0.097	0.202	0.312	0.429	0.543	0.628	0.633	0.494	0.211
14.0	0.002	0.098	0.200	0.306	0.420	0.539	0.639	0.666	0.541	0.241
16.0	0.000	0.099	0.199	0.304	0.412	0.531	0.641	0.687	0.582	0.265

Appendix – 10 Foundation analysis

1 Bearing capacity of foundation

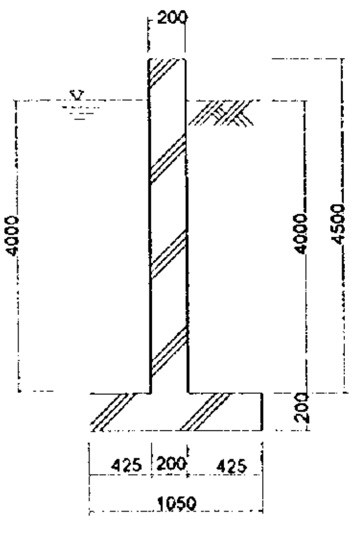
Existing drainage reservoirs use mat foundation (without piles). Bearing capacity of soil is calculated based on available boring and soil measurements for Bistritsa Water Purification Plant (WPP).

1．1 Foundation load

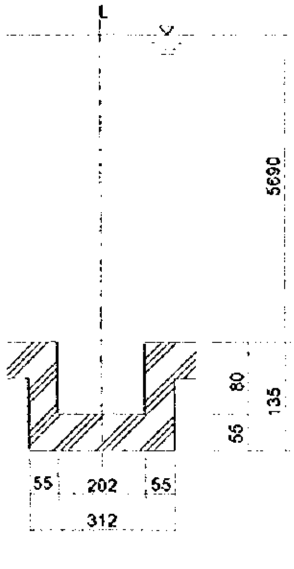
1．1．1 Conditions

Reinforced concrete unit weght	2.50 t/m^3
Soil unit weight	1.80 t/m^3
Water unit weight	1.00 t/m^3
Foundation type	Mat foundation

1．1．2 Drainage reservoirs



Wall



Center

(1) Wall footing load: W_c

Weight of wall and footing (Wall, base immediately under the wall): W_1	(0.20×4.50+0.20×1.05)×2.70×2.50 = 7.49 t
Weight of soil on footing: W_2	0.425×4.00×2.70×1.80 = 8.26 t

Weight of water on footing: W_3	$0.425\times4.00\times2.70\times1.00 = 4.59$ t
Footing area: A	$1.05\times2.70 = 2.84$ m^2

Wall footing load including effluent weir and trough: W_c

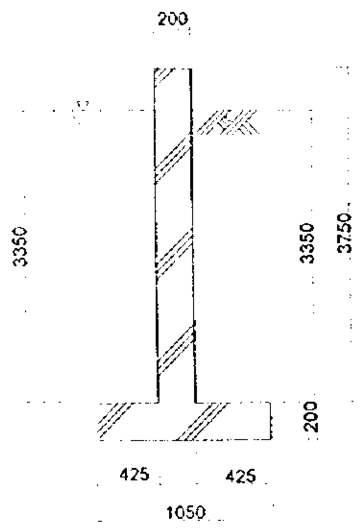
$W_c = (W_1+W_2+W_3)/A\times1.2 = 8.59$ t/m^2

(2) Footing load of center of reservoirs: W_s

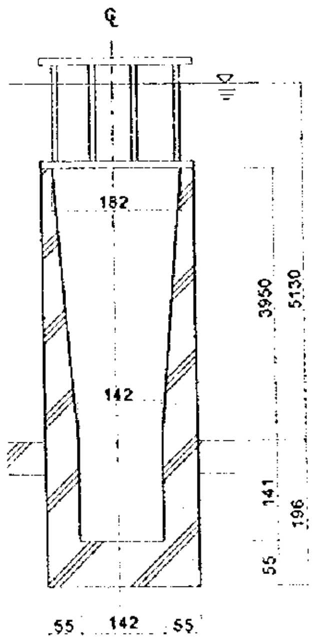
Weight of structure: W_1	$\{\pi/4\times(3.12)^2\times1.35-\pi/4\times(2.02)^2\times0.80\}\times 2.50 = 19.41$ t/m^2
Weight of water: W_2	$\{\pi/4\times(3.12)^2\times5.69+\pi/4\times(2.02)\times0.80\}\times 1.00 = 46.07$ t/m^2
Footing area: A	$\pi/4\times(3.12)^2 = 10.28$ t/m^2

$W_s = (W_1+W_2)/A\times1.2 = 10.28$(t/m^2)

1．1．2 Sedimentation tanks



Wall



Center

(1) Wall footing load: W_c

Weight of wall and footing (Wall, base immediately under the wall): W_1	$(0.20\times3.75+0.20\times1.05)\times2.70\times2.50 = 6.48$ t
Weight of soil on footing: W_2	$0.425\times3.35\times2.70\times1.80 = 6.92$ t
Weight of water on footing: W_3	$0.425\times3.35\times2.70\times1.00 = 3.83$ t
Footing area: A	$1.05\times2.70 = 2.84\ m^2$

Wall footing load including effluent weir and trough: W_c

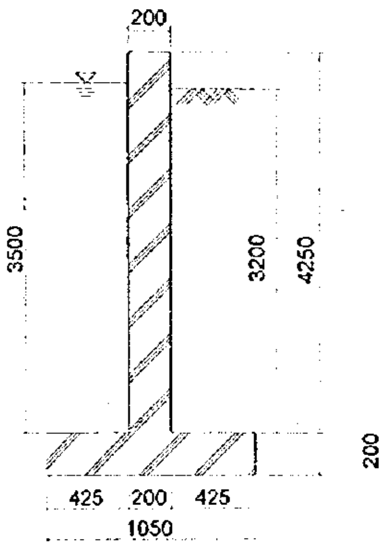
$W_c = (W_1+W_2+W_3)/A\times1.2 = 6.07\ t/m^2$

(2) Footing load of center of reservoirs: W_s

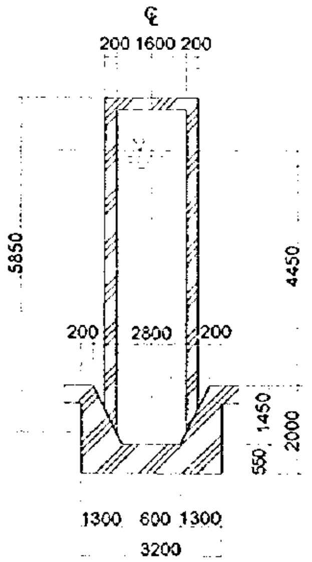
Weight of structure: W_1	$[\pi/4\times(2.52)^2\times591-\{(\pi/3\times3.95\times1/4\times((1.41)^2+1.42\times1.82+(1.82)^2)+\pi/4\times(1.42)^2\times1.41)\}]\times2.50 = 47.63$ t
Weight of water: W_2	$8.18+2.23+\pi/4\times(2.52)^2\times1.18 = 16.29$ t
Footing area: A	$\pi/4(2.52)^2 = 4.99\ m^2$

$W_s = (W_1+W_2)/A\times1.2 = 15.37\ (t/m^2)$

1. 1. 3 Thickening tank



Wall



Center

(1) Wall footing load: W_c

Weight of wall and footing (Wall, base immediately under the wall): W_1	$(0.20\times4.25+0.20\times1.05)\times2.70\times2.50 = 7.16$ t
Weight of soil on footing: W_2	$0.425\times3.20\times2.70\times1.80 = 6.61$ t
Weight of water on footing: W_3	$0.425\times3.50\times2.70\times1.00 = 4.02$ t
Footing area: A	$1.05\times2.70 = 2.84$ m^2

Wall footing load including effluent weir and trough: W_c

$W_c = (W_1+W_2+W_3)/A\times1.2 = 7.51$ t/m^2

(2) Footing load of center of reservoirs: W_s

Weight of structure: W_1	$[\pi/4\times(3.20)^2\times2.0-\pi/3\times\{(2.80)^2+0.60\times2.8+(0.60)^2\}\times1.45+\pi/4\times(2.20)^2\times5.85-\pi/4\times(1.60)^2\times5.65]\times2.50 = 29.93$ t
Weight of water: W_2	$\{\pi/4\times(3.20)^2\times4.45+\pi/3\times\{(2.80)^2+2.80\times0.60+(0.60)^2\}\times1.45]\times1.00 = 50.76$ t
Footing area: A	$\pi/4\times(3.20)^2 = 8.04$ m^2

$W_s = (W_1+W_2)/A\times1.2 = 12.04$ t/m^2

1. 2 Permissible bearing capacity of soil

1. 2. 1 Bearing capacity calculations based on Terzarghi equations

(1) Long-term bearing capacity of soil

$$q_a = \frac{1}{3} \times \left(\alpha \times C \times N_C + \beta \times \gamma_1 \times B \times N_r + \gamma_2 \times D_f \times N_q \right) \quad (t/m^2)$$

(2) Short-term bearing capacity of soil

$$q_a = \frac{2}{3} \times \left(\alpha \times C \times N_C + \beta \times \gamma_1 \times B \times N_r + \frac{1}{2} \gamma_2 \times D_f \times N_q \right) \quad (t/m^2)$$

q_a	Permissible bearing capacity of soil (t/m^2)
C	Soil cohesion (t/m^2)
γ_1	Average unit weight of soil under the base of footing (t/m^2) If under water table, use wet unit weight
γ_2	Average unit weight of soil over the base of footing (t/m^2) If under water table, use under wet unit weight
α, β	Footing-shape factors shown in Table 1
Nc, Nr, Nq	Bearing-capacity factors shown in Table2 for angle of internal friction ϕ
Df	Depth of the base of footing in ground (m)
B	Minimum footing width (m). Diameter if footing is round

Table 1: Footing-shape factors

Footing shape	Continuous	Square	Rectangular	Round
α	1.0	1.3	1.0+0.3×B/L	1.3
β	0.5	0.4	0.5-0.1×B/L	0.3

B: Length of shorter side
L: Length of longer side

Table 2 Bearing-capacity factors

ϕ	Nc	Nr	Nq
0	5.3	0	3.0
5	5.3	0	3.4
10	5.3	0	3.9
15	6.5	1.2	4.7
20	7.9	2.0	5.9
25	9.9	3.3	7.6
28	11.4	4.4	9.1
32	20.9	10.6	16.1
36	42.2	30.5	33.6
over 40	95.7	114.0	83.2

(3) Bearing-capacity factors

Soil measurement data used for calculation was No. 5 bore at Bistritsa WPP. Soil type is normally gravel with fines, foamed as alluvial deposit. Soil measurements are shown below.

Unit weight of soil	γ_1 = 1.8～2.1 t/m³
Angle of internal friction	ϕ = 34°
Soil cohesion	C = 0

Bearing-capacity factors are:

Nc = 29.5, Nr = 18.5, Nq =22.5

1．2．2 Drainage reservoirs

	Wall	Center
Footing shape	Width: 1.05m, Length: 2.70m	ϕ 3.12 m
Shape factor α	1.12	1.3
Shape factor β	0.46	0.3
Ground level	+732.0 m (+730.3～+733.7 m)	
Footing base level	+730.0 m	+727.1 m
Df	2.0	4.9
Long-term bearing capacity of soil	1/3×(1.12×0×29.5+0.46×1.90×1.05×18.5+1.80×2.0×22.5) = 32.66 t/m²	1/3×(1.3×0×29.5+0.3×1.90×3.12×18.5+1.80×4.9×22.5) = 77.12 t/m²
Short-term bearing capacity of soil	2/3×(1.12×0×29.5+0.46×1.90×1.05×18.5+1/2×1.80×2.0×22.5) = 38.32 t/m²	2/3×(1.3×0×29.5+0.3×1.90×3.12×18.5+1/2×1.80×1.0×22.5) = 88.08 t/m²

1．2．3 Sedimentation tanks

	Wall	Center
Footing shape	Width: 1.05m, Length: 2.70m	ϕ 2.52 m
Shape factor α	1.12	1.3
Shape factor β	0.46	0.3
Ground level	+727.0 m	
Footing base level	+723.6 m	+720.1 m
Df	3.4	6.8
Long-term bearing capacity of soil	1/3×(1.12×0×29.5+0.46×1.90×1.05×18.5+1.80×3.4×22.5) = 51.56 t/m²	1/3×(1.3×0×29.5+0.3×1.90×2.52×18.5+1.80×6.8×22.5) = 100.66 t/m²
Short-term bearing capacity of soil	2/3×(1.12×0×29.5+0.46×1.90×1.05×18.5+1/2×1.80×3.4×22.5) = 57.22 t/m²	2/3×(1.3×0×29.5+0.3×1.90×2.52×18.5+1/2×1.80×6.8×22.5) = 109.52 t/m²

1．2．4 Thickening tanks

	Wall	Center
Footing shape	Width: 1.05m, Length: 2.70m	3.20
Shape factor α	1.12	1.3
Shape factor β	0.46	0.3
Ground level	+722.8 m	
Footing base level	+721.1 m	+718.8 m
Df	1.7	3.0
Long-term bearing capacity of soil	1/3×(1.12×0×29.5+0.46×1.90×1.05×18.5+1.80×1.7×22.5) = 28.61 t/m²	1/3×(1.3×0×29.5+0.3×1.90×3.20×18.5+1.80×3.0×22.5) = 51.75 t/m²
Short-term bearing capacity of soil	2/3×(1.12×0×29.5+0.46×1.90×1.05×18.5+1/2×1.80×1.7×22.5) = 34.27 t/m²	2/3×(1.3×0×29.5+0.3×1.90×3.20×18.5+1/2×1.80×3.0×22.5) = 63.00 t/m²

1．3 Comparison of foundation load and permissible bearing capacity

(1) Drainage reservoir

	Load	Bearing capacity	
		Long-term	Short-term
Wall	8.59 t/m²	32.66 t/m²	38.32 t/m²
Center	10.28 t/m²	77.12 t/m²	88.08 t/m²

(2) Sedimentation tanks

	Load	Bearing capacity	
		Long-term	Short-term
Wall	6.07 t/m²	51.56 t/m²	57.22 t/m²
Center	15.37 t/m²	100.66 t/m²	109.52 t/m²

(3) Thickening tank

	Load	Bearing capacity	
		Long-term	Short-term
Wall	7.51 t/m²	28.61 t/m²	34.27 t/m²
Center	12.04 t/m²	51.75 t/m²	63.00 t/m²

All the footing loads calculated above are less than permissible bearing-capacity of soil. Therefore, bearing capacity of foundation is satisfactory for those tanks.

2 Immediate settlement

2.1 Calculation of immediate settlement

2.1.1 Conditions

The settlement of mat foundation on a soil mass immediately after application of load is computed from the following equation from the theory of elasticity.

$$S_E = I_S \frac{1-\nu^2}{E} qB$$

S_E	Immediate settlement (m)
B	Least lateral dimension of footing (diameter if footing is round) (m)
q	Intensity of contact pressure (t/m2)
E	Stress-strain modulus of soil (t/m2)
ν	Poisson's ratio of soil
I_S	Influence factor (see Table below)

Influence factor

Foundation Shape	Rigidity	Location on footing		I_S
Circle	0	Center		1
		Corner (edge)		0.636
	∞	Average		0.785
Rectangle	0	L/B	1	0.56
			1.5	0.68
			2.0	0.76
			2.5	0.84
			3.0	0.89
			4.0	0.98
			5.0	1.05
			10.0	1.27
			100.0	2.00

Typical value of Poisson's ration (ν) for sand is 0.3.

Stress-strain modulus of soil (E) is 1,000 t/m^2 from soil measurements of Bistritsa WPP.

2. 1. 2 Drainage reservoirs

	Wall	Center
Foundation dimensions	Width:1.05m, Length:2.70m	Diameter: 3.12m
Influence factor	Is=0.84	Is=0.785
Intensity of contact pressure	q = 8.59 t/m²	q = 10.28 t/m²
Immediate settlement	0.84×(1-(0.30)²)/1000× 8.59×1.05 = 0.0069 m	0.785×(1-(0.30)²)/1000× 10.28×3.12 = 0.0229 m

2. 1. 3 Sedimentation tanks

	Wall	Center
Foundation dimensions	Width:1.05m, Length:2.70m	Diameter: 2.52m
Influence factor	Is=0.84	Is=0.785
Intensity of contact pressure	q = 6.07 t/m²	q = 15.37 t/m²
Immediate settlement	0.84×(1-(0.30)²)/1000× 6.07×1.05 = 0.0049 m	0.785×(1-(0.30)²)/1000× 15.37×2.52 = 0.0277 m

2. 1. 4 Thickening tank

	Wall	Center
Foundation dimensions	Width:1.05m, Length:2.70m	Diameter: 3.20m
Influence factor	Is=0.84	Is=0.785
Intensity of contact pressure	q = 7.51 t/m²	q = 12.04 t/m²
Immediate settlement	0.84×(1-(0.30)²)/1000× 7.51×1.05 = 0.0060 m	0.785×(1-(0.30)²)/1000× 12.04×3.20 = 0.0275 m

2. 2 Permissible settlement

Permissible settlement of mat foundation is 3 cm as standard , 6 cm as maximum by Japanese building design standards.

All the immediate settlement values computed above are less than permissible settlement value of 3 cm.

Appendix-11 Financial Status of Water Supply and Sewerage Company, Sofia

BALANCE SHEET

(1000 Leva)

		year 1996	year 1997
Assets	Fixed Assets	4,436,987	93,582,993
	Current Assets	792,063	3,633,101
	Total	5,229,050	97,216,094
Liabilities	Own Capital	4,572,407	93,499,174
	Capital	4,658,924	4,658,924
	Reserves	34,197	88,512,327
	Financial Result	-120,714	327,923
	Attractive Capital	656,643	3,716,920
	Total	5,229,050	97,216,094

Plofit and Loss Statement

(Actual Cost Basis)

Water Supply and Sewerage Company, Sofia (1000LV)

			1992	1993	1994	1995	1996	1997
Income	Turnover Income (operated)	Water selling	105,400	288,256	417,170	861,280	4,118,712	8,906,547
		Incomes from drains and purified drain w	77,775	168,160	301,210	395,920	2,274,012	5,079,633
		Others	2,225	6,752	8,710	18,690	87,204	197,886
	Non Turnover Income	Received interests	4,075	3,488	10,140	8,120	155,961	174,408
		Subsidies	0	0	0	0	23,478	15,093
		Others	100	0	0	2,660	389,064	256,581
	Special Income		4,600	5,600	7,085	69,160	211,302	145,899
		Total	194,175	472,256	744,315	1,355,830	7,259,733	14,776,047
Expenses	Operated Expenses	Labor	60,550	109,760	181,220	285,880	1,982,214	6,634,212
		Electricity	29,425	37,632	45,695	57,960	598,689	1,484,145
		Chemicals	10,875	13,888	19,240	34,510	149,253	152,607
		Water buying up	9,775	24,960	31,395	67,480	288,444	425,958
		Other materials and fuels	18,075	44,096	88,530	171,570	981,045	2,406,495
		Construction repair through assignment	17,150	74,080	95,615	287,350	1,051,479	989,430
		Othter outside services	10,975	27,392	53,820	106,190	362,232	652,353
		Depreciation	14,800	199,104	210,405	226,450	863,655	345,462
		Other	3,600	5,984	11,245	20,580	489,684	652,353
	Non Operative Expens	Paid interests	50	64	0	350	18,447	134,160
		Others	75	96	390	1,260	30,186	88,881
	Incidental Expenses		725	352	2,015	12,180	38,571	67,080
		Total	176,075	537,408	739,570	1,271,760	6,853,899	14,031,459
Balance			18,100	-65,152	4,745	84,070	405,834	744,588

Profit and Loss Statement

(Year 1997 Value by Using the Past Inflation Rate)

Water Supply and Sewerage Company, Sofia

(1000LV, year 1997 value)

			1992	1993	1994	1995	1996	1997
Income	Turnover Income (operated)	Water selling	23,954,545	40,035,556	26,237,107	40,626,415	47,341,517	8,906,547
		Incomes from drains and purified drain w	17,676,136	23,355,556	18,944,025	18,675,472	26,138,069	5,079,633
		Others	505,682	937,778	547,799	881,604	1,002,345	197,886
	Non Turnover Income	Received interests	926,136	484,444	637,736	383,019	1,792,655	174,408
		Subsidies	0	0	0	0	269,862	15,093
		Others	22,727	0	0	125,472	4,472,000	256,581
	Special Income		1,045,455	777,778	445,597	3,262,264	2,428,759	145,899
		Total	44,130,682	65,591,111	46,812,264	63,954,245	83,445,207	14,776,047
Expenses	Operated Expenses	Labor	13,761,364	15,244,444	11,397,484	13,484,906	22,784,069	6,634,212
		Electricity	6,687,500	5,226,667	2,873,899	2,733,962	6,881,483	1,484,145
		Chemicals	2,471,591	1,928,889	1,210,063	1,627,830	1,715,552	152,607
		Water buying up	2,221,591	3,466,667	1,974,528	3,183,019	3,315,448	425,958
		Other materials and fuels	4,107,955	6,124,444	5,567,925	8,092,925	11,276,379	2,406,495
		Construction repair through assignment	3,897,727	10,288,889	6,013,522	13,554,245	12,085,966	989,430
		Othter outside services	2,494,318	3,804,444	3,384,906	5,008,962	4,163,586	652,353
		Depreciation	3,363,636	27,653,333	13,233,019	10,681,604	9,927,069	345,462
		Other	818,182	831,111	707,233	970,755	5,628,552	652,353
	Non Operative Expens	Paid interests	11,364	8,889	0	16,509	212,034	134,160
		Others	17,045	13,333	24,528	59,434	346,966	88,881
	Incidental Expenses		164,773	48,889	126,730	574,528	443,345	67,080
		Total	40,017,045	74,640,000	46,513,836	59,988,679	78,780,448	14,031,459
Balance			4,113,636	-9,048,889	298,428	3,965,566	4,664,759	744,588

Price Index (1997 price: 100)

0.44	0.72	1.59	2.12	8.70	100

Inflation Rate

79%	64%	122%	33%	310%	1049%

Appendix 12 Cost Estimation Borne by the Republic of Bulgaria

1.	Water for domestic use in the site and maintenance purpose for the facilities : Approx. 75 mm Dia., 3.5 L/sec	14,700 US$
2.	Electric power supply : Approx. 200 KVA, 380 V, 4 W	115,500 US$
3.	Inlet pipe to grit removal tank	3,075 US$
4.	Outlet overflow pipe from sedimentation and thickening tanks	16,650 US$
5.	Drain channel for rain water	2,250 US$
6.	Hot water supply for room heating	32,500 US$
7.	Telephone line	16,200 US$
8.	Fencing	62,000 US$
Total		262,875 US$

Appendix 13 References

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