CONSTRUCTION AUTHORITY FOR
POTABLE WATER AND WASTEWATER (CAPW)
MINISTRY OF HOUSING,UTILITIES AND
URBAN DEVELOPMENT (MOHUUD)

PREPARATORY STUDY FOR ABU RAWASH WASTEWATER TREATMENT PLANT IMPROVEMENT IN CAIRO, ARAB REPUBLIC OF EGYPT

FINAL REPORT

VOLUME I：FACILITIES PLANNING

JANUARY 2010

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
TOKYO ENGINEERING CONSULTANTS CO., LTD. (TEC)

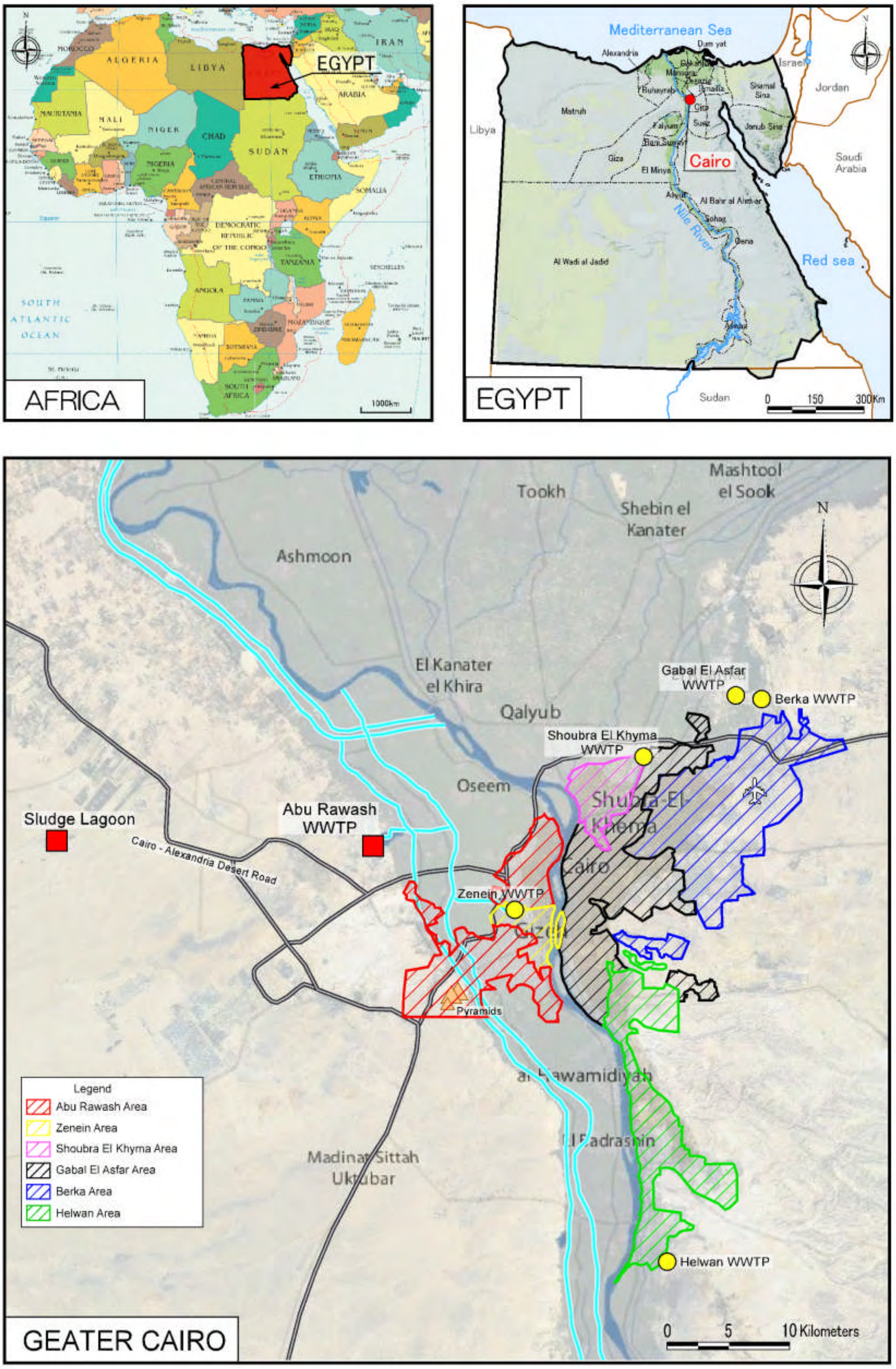
MEE
CR(10)
10-001

Foreign Exchange Rate:

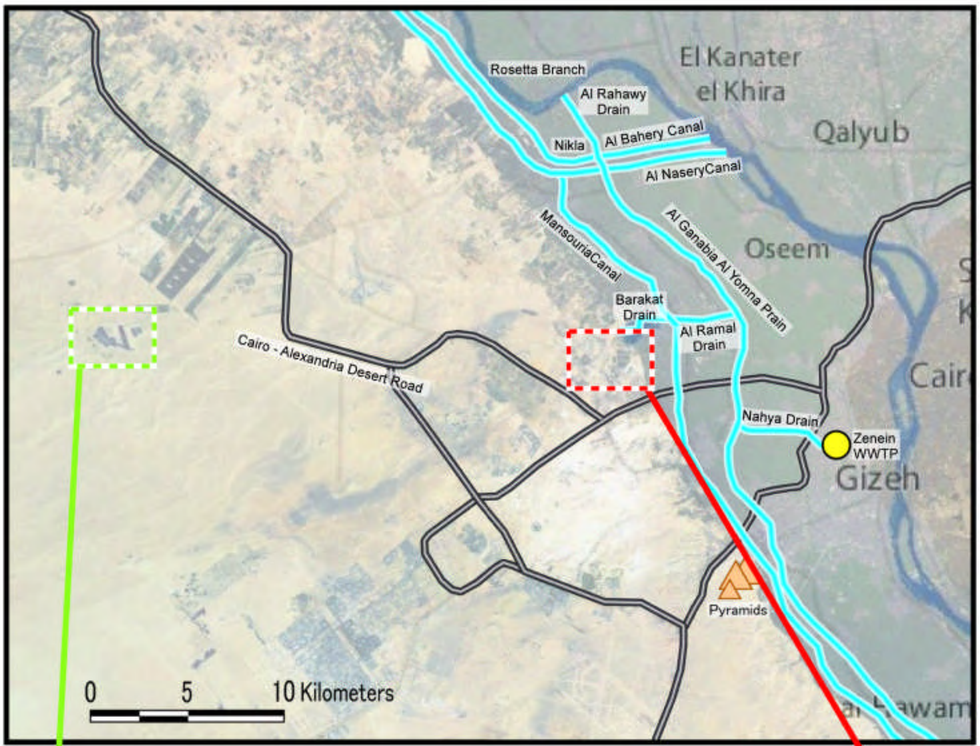
USD 1 = JPY 96.60

USD 1 = LE 5.56

(Average Between March 2009 and August 2009)



LOCATION MAP (1)



West Bank of River Nile

Sludge Lagoons

Abu Rawash WWTP Site

LOCATION MAP (2)

FINAL REPORT

VOLUME I

FACILITIES PLANNING

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ABBREVIATIONS

BOD	Biochemical Oxygen Demand
CAPW	The Construction Authority for Potable water and Wastewater
COD	Chemical Oxygen Demand
EEAA	Egyptian Environmental Affairs Agency
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
F.C.	Foreign Currency
FIRR	Financial Internal Rate of Return
FY	Financial Year
GCSDC	Greater Cairo Sanitary Drainage Company
GCWSC	Greater Cairo Water Supply Company
GDP	Gross Domestic Product
GWWC	Giza Water and Wastewater Company
HCWW	Holding Company for Water and Wastewater
JBIC	Japan Bank for International Cooperation
JETRO	Japan External Trade Organization
JICA	Japan International Cooperation Agency
JPY	Japanese Yen
km	Kilometer
L.C.	Local Currency
LE	Egyptian Pound
lpcd	Liter per capita per day
MALR	Ministry of Agriculture and Land Reclamation
MOF	Ministry of Finance
MOHP	Ministry of Health and Population
MOHUUD	Ministry of Housing, Utilities and Urban Development
MOIC	Ministry of International Cooperation
MOP	Ministry of Planning (now called Ministry of Economic Development)
MSEA	Ministry of State for Environmental Affairs
MWRI	Ministry of Water Resources and Irrigation
m^3/day	Cubic Meter per Day
NIB	National Investment Bank
NOPWASD	National Organization for Potable Water and Sanitary Drainage
ODA	Official Development Assistance
O&M	Operations and Maintenance
PIs	Performance Indicators
PID	Proportional Integral Differential
PLC	Programming Logic Controller
PS	Pumping Station
SCADA	Supervisory Control and Data Acquisition
SS	Suspended Solids
TSS	Total Suspended Solids
WWTP	Wastewater Treatment Plant

SUMMARY

(1) Introduction

(A) Background of the Study

Abu Rawash WWTP located on the West Bank of Nile River is one of the major WWTPs in Greater Cairo and is supposed to solely treat the increasing sewage generated in the West Bank area. Its capacity as of 2008 is 0.4 million m^3/day but the current flow to the WWTP is expected to have reached 1.1 million m^3/day and the flow exceeding the capacity is discharged to the nearby drain without any treatment. Hence, CAPW began to extend the plant in 2006 with the capacity of 0.8 million m^3/day. The extension works is delayed and expected to complete in the beginning of 2010 but the treatment level stays primary. Therefore, the effluent will not be able to meet the effluent standards and the problem of water pollution will be left unsolved.

From this background, Egyptian Government requested the Japanese Government in November 2007 for ODA Loan and Japan International Cooperation Agency (JICA) decided to conduct the Study including the preparation of EIA report and the assistance for its approval. The Study also includes collection of necessary data and analysis for preparation of concrete concept of the future project for which the request for ODA Loan was made.

(B) Outline of the Study

The Study is to be conducted for the purpose of EIA report preparation and the assistance for its approval and necessary data/information collection and their analysis to formulate JICA ODA Loan financed project.

Overall Goal:	Improved quality of life through environmental improvement
Project Purpose:	To abate water pollution in effluent receiving water bodies and thus to improve water and living environment through the implementation of secondary treatment facilities at Abu Rawash WWTP
Expected outcome:	Implementation of Abu Rawash secondary treatment
Indicators:	Improved effluent qualities
Relating agency:	Ministry of Housing, Utilities and Urban Development (MOHUUD) Ministry of Water Resources and Irrigation (MWRI) Ministry of International Cooperation (MOIC) Holding Company for Water and Wastewater (HCWW) Construction Authority for Potable water and Wastewater (CAPW) Giza Water and Wastewater Company (GWWC)

Study area: Abu Rawash WWTP site
Sludge lagoon site
Stretches of drains till the confluence of these drains with Nile River

(2) Current State of Sewerage System and Necessity of Project

(A) Current Condition of Sewerage System

Sewerage systems in Greater Cairo are geographically divided into three independent districts, viz. East Bank of the River Nile, West Bank of River Nile and Helwan. The current total wastewater amount, which flows to WWTPs in Greater Cairo, has reached to 4.8 million m^3/day while the total of these design capacities is 4.1 million m^3/day. It means that approximately 0.7 million m^3/day of wastewater in excess of the existing treatment capacity is discharged into nearby drains and finally goes into River Nile without any treatment. In addition, taking into account future increase of wastewater due to population growth, treatment capacities of the existing sewerage facilities are urgently needed to increase.

The extensions, rehabilitation and repair works have been undertaken independently by sewerage districts. However, it seems that these activities are not based on the best practices plan for the whole Greater Cairo. After 1990s when financial assistance from overseas development agencies decreased, the Egyptian government policy inclined to the implementation of necessary projects based on their own plans and available government funds. However, the extension and rehabilitation of the sewerage systems would certainly require a huge amount of investment. Therefore, financial assistance from overseas donor agencies would be required.

(B) National Water Resource Plan, CAPW New Five-Year Plan and Sewerage Master Plan Update

National Water Resources Plan 2017 was prepared by the Ministry of Water Resource and Irrigation in January 2005 and the Plan was allegedly revised recently due to project readjustments. The main objective of the Plan is to describe how Egypt will safeguard its water resources in future, both with respect to quantity and quality, and how it will use these resources in the best way from socio-economic and environmental point of view. The total planned investment cost was originally LE 145 billion, but it has been revised to LE 245 billion recently. Increasing municipal sewerage and wastewater treatment of MOHUUD is the most important measure in the Plan and its share is 43%, which includes Abu Rawash WWTP in Greater Cairo, upgrading treatment method from primary treatment to secondary treatment as well as increasing treatment capacity from 0.4 to 1.2 million m^3/day.

CAPW's new five-year development plan in accordance with the sixth national development plan has been approved by the Ministry of Planning (now called Ministry of Economic Development). A total investment is expected to reach approximately LE 10 billion for Greater Cairo water and wastewater during five-year period from fiscal year 2007/08 to 2011/12. Approximately LE 5.3 billion, more than half of the total, will be invested in wastewater projects. Under the new five-year plan, 15 wastewater projects have been identified and a total of LE 900 million has been allocated to Abu Rawash WWTP for discharge of treated wastewater from WWTP to wooden forest areas or to secondary treatment. This allocation of large amount of budget can be utilized for construction of secondary treatment facilities and also indicates high priority given to the project by CAPW, MOHUUD and Ministry of Planning (now called Ministry of Economic Development).

Population projection in Greater Cairo up to 2037 has been made as shown in Table S-1 considering the data obtained by the latest population census in the Master Plan Update.

Table S-1 Population Projection of Greater Cairo

District Name	Population (thousand persons)			
	2007	2017	2027	2037
East and South Nile	7,123	9,615	11,415	13,552
West Nile	4,148	5,684	6,789	8,109
Helwan	854	1,175	1,369	1,596
Shobra El-Kheima	1,176	1,593	1,857	2,165
Total	13,302	18,066	21,430	25,422

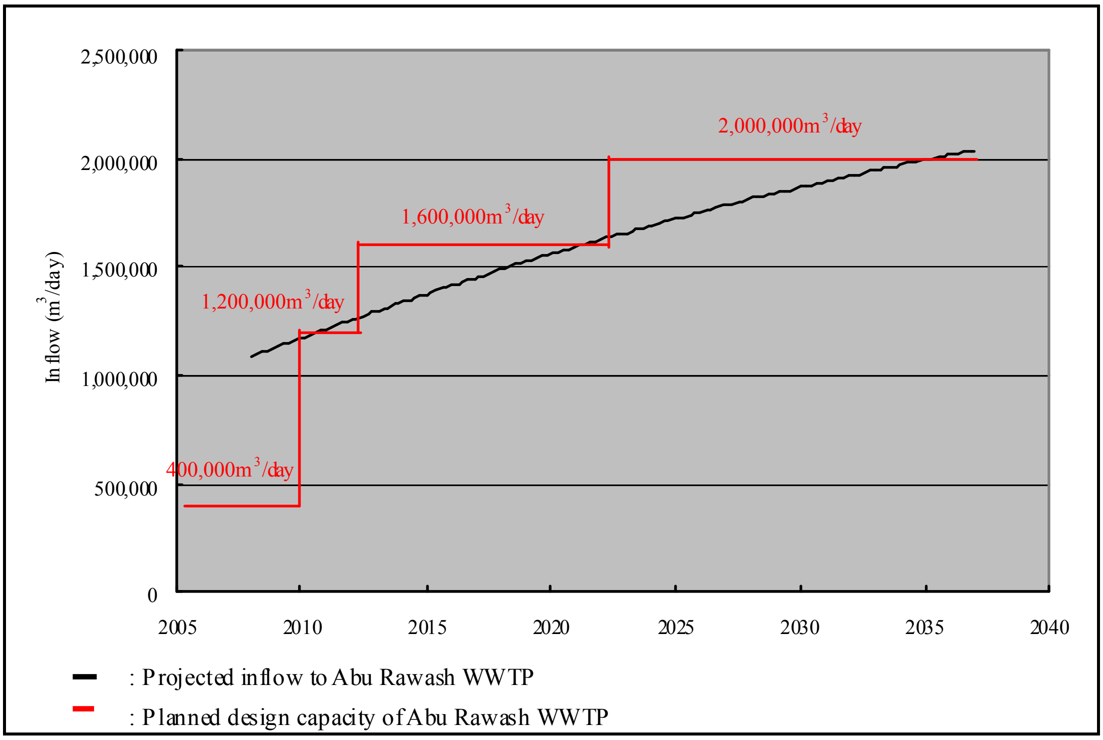
Wastewater generation in Greater Cairo has been estimated up to 2037 and planned to be allocated to the following main WWTPs in Greater Cairo as shown in Table S-2 with the current design capacity and inflow of these WWTPs.

Table S-2 Current Design Capacity and Allocation of Wastewater Discharge

	Current Design Capacity (m^3/day)	Estimated Inflow in 2008 (m^3/day)	Projected Inflow (m^3/day)	
			2017	2037
Al-Gabal Al-Asfer	1,700,000	1,850,000	2,900,000	4,000,000
El-Berka	600,000	565,000	634,000	644,000
Zenein	330,000	260,000	300,000	360,000
Abu Rawash	400,000	1,085,000	1,450,000	2,039,000
Helwan	350,000	564,000	740,000	1,056,000
Shobra El-Kheima	600,000	372,0000	450,000	565,000
Total	3,980,000	4,696,000	6,474,000	8,664,000

Projected inflow to Abu Rawash WWTP is presented in Figure S-1 with the staged development plan of its treatment capacity. According to development plan, the expansion of sewage treatment with a capacity 0.4 million m^3/day is planned to be operational in 2012 and can be sufficient to accommodate until 2021. The final expansion to reach its ultimate capacity, 2.0 million m^3/day, is planned to be operational by 2022.

Figure S-1 Projected Inflow to Abu Rawash WWTP



(C) Expected Improvement due to the Provision of Secondary Treatment Facilities

In order to evaluate the contribution of the provision of secondary treatment facilities, comparison analysis is carried out for the cases of with project and without project and the result is summarized in Table S-3.

Table S-3 Comparisons of With and Without the Project

Items	Present situation	Future situation	
		Without project	With project
Discharged Pollution Load into the Rosetta Branch (BOD)	107 ton/day	108 ton/day	29 ton/day
Water Quality in Al Rahawy drain (BOD)	71 mg/l	60 mg/l	16 mg/l
Comparison to water quality standard of the maximum limits for re-use of treated effluent (Decree No.44 of 2000)	Exceed the standard	Exceed the standard	Within the standard

Comparison to effluent limits for treated discharges into water bodies (Decree No.8 of 1983)	Exceed the standard	Exceed the standard	Within the standard
Odor problem in Nikla	Continues	Continues	Resolves

Based on the result of comparison analysis, the following improvements are expected.

- It is estimated that, after implementation of the project, the discharged pollution loads into the Rosetta Branch reduces to 29 ton/day as BOD compared to 107 ton/day in case of present load and 108 ton/day in case of the future load if the project is not implemented.
- The existing and future BOD levels in the case of without-project are estimated as 71 mg/l and 60 mg/l, and estimated level of BOD in case of the with-project situation is 16 mg/l.
- Through the implementation of this project, the treated effluent quality level would satisfy the water quality standard of the maximum limits for re-use of treated effluent (2nd group water treated secondarily: Decree No.44 of 2000) and the effluent limits for treated discharges into water bodies (Decree No.8 of 1983).
- Moreover, since dissolved oxygen shall be recovered by water quality improvement (reduction of BOD level), the mitigation of odor problem in Nikla and native habitat of the drains are also expected.

(3) Facility Planning

(A) Basic for Planning

Currently, substantial amount of wastewater is diverted directly to El Beeny drain from South Muheit pump station on temporary basis of operation due to the lack of hydraulic capacity of the existing effluent channel of Abu Rawash WWTP. It seems to result in lower influent pollution load by diverting relatively high loaded wastewater since 2007, in which diversion started. Influent wastewater characteristics are expected to return to the early level before the diversion once the ongoing expansion is completed. Therefore, design influent BOD and SS concentrations have been set as 310 mg/l and 360 mg/l, respectively, considering monthly average of the past six years recorded from 2001 to 2006.

The average inflow amounting 0.65 million m^3/day in 2001 already reached to 0.85 million m^3/day in 2006. The current inflow is expected to increase substantially considering population growth in the recent years and is assumed to reach 1.1 million m^3/day considering rate of increase of inflow. Design capacity for this Project has been determined to be 1.2 million m^3/day considering the fact that the capacity of the primary treatment facilities after completion of the ongoing extension would be 1.2 million m^3/day.

(B) Scope of the Project

The full scale of development of Abu Rawash WWTP will require a large amount of capital investment and many years to complete since planned ultimate capacity is 2.0 million m^3/day. In general, such large projects become feasible in terms of implementation if they are implemented through several construction stages with appropriate development steps.

CAPW considers that protection of water quality of receiving drains and Nile River is the first priority. Primary treatment does not satisfy required effluent standards. Hence, the construction of secondary treatment facilities having treatment capacity of 1.2 million m^3/day is considered as the first priority. The second priority goes to the expansion of sewage treatment facilities providing an additional capacity of 0.8 million m^3/day to meet inflow quantity due to rapid population growth and current deficit of treatment capacity. Sludge treatment facilities are considered as the third priority since the land for sludge lagoons has been already acquired by HCWW. General layout of the ultimate stage of Abu Rawash WWTP is shown in Figure S-2 with the priority determined by CAPW.

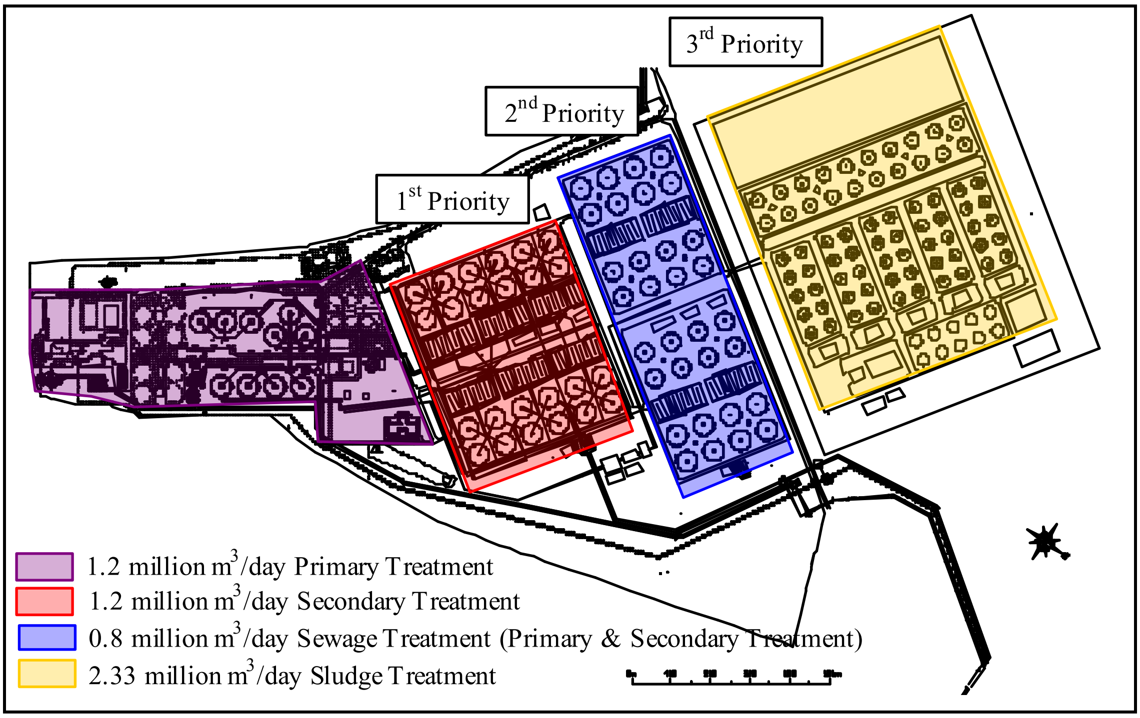


Figure S-2 General Layout of Ultimate Stage of Abu Rawash WWTP

Design parameters for the secondary treatment facilities and sludge treatment facilities of Abu Rawash WWTP are summarized in Table S-4.

Table S-4 Design Parameters for Wastewater Treatment

No.	Item	Values	Remarks
1.	Flow Rate and Raw Sewage Characteristics		
1-1	Daily Average	1,200,000 m^3/day	
1-2	Peak Flow	1,800,000 m^3/day	Daily Avg. ×1.5
1-3	BOD (Raw Sewage)	310 mg/l	
1-4	SS (Raw Sewage)	360 mg/l	
2.	Design Values and Removal Ratio		
2-1	BOD (to Primary Tank)	310 mg/l	
2-2	BOD (to Aeration Tank)	155 mg/l	
2-3	BOD Removal Ratio (Primary Treatment)	50 %	
2-4	BOD Removal Ratio (Secondary Treatment)	85 %	
2-5	BOD Total Removal Ratio	93 %	
2-6	SS (to Primary Tank)	360 mg/l	
2-7	SS (to Aeration Tank)	144 mg/l	
2-8	SS Removal Ratio (Primary Treatment)	60 %	
2-9	SS Removal Ratio (Secondary Treatment)	85 %	
2-10	SS Total Removal Ratio	94 %	
3.	Treated Effluent		
3-1	BOD	23 mg/l	
3-2	SS	22 mg/l	
4.	Sludge		
4-1	Primary Sludge of Abu Rawash WWTP	12,960 m^3/day (259,200 kg/day)	Concentration = 2.0%
4-2	Excess Sludge of Abu Rawash WWTP	30,076 m^3/day (180,459 kg/day)	Concentration = 0.6%
4-3	Mixed Sludge of Zenein WWTP	10,000 m^3/day (100,000 kg/day)	Concentration = 1.0%

(C) Concept of Facilities Planning

CAPW expects to introduce reliable technologies in order to enable steady and secured treatment for a large scale WWTP such as Abu Rawash WWTP. At the same time, CAPW expects to introduce technologies that would result in resource saving and energy saving from the view point of sustainability, the ideas that have not been considered well so far. Concepts adopted for facility planning are summarized below.

- Consideration of life cycle cost including initial investment, costs for operation & maintenance and replacement
- Utilization of the existing facilities such as sludge transfer facilities and lagoons
- Stable and easy operation by introducing necessary backup and automation by SCADA system and instrument
- Total energy saving by introducing highly efficient technology, optimizing operation and minimizing hydraulic loss
- Consideration of environmental and social impact

Results of facilities planning regarding sewage treatment facilities, electrical facilities and sludge treatment facilities are summarized in Table S-5.

Table S-5 Summary of Facilities Planning

Sewage Treatment Facilities Planning	
Optimization of Grouping Secondary Treatment Facilities	2.0 million m^3/day of sewage treatment facilities are planned to locate in the existing WWTP site and grouping of treatment facilities is reviewed so as to optimize array and operation of facilities. Six series of secondary treatment facilities and four series of future sewage facilities, in which each series has 0.2 million m^3/day capacity, is decided considering space saving, less hydraulic loss and systematic operation.
Hydraulic Profile Planning	Additional effluent channel up to Barakat drain is required to avoid new pump facilities while satisfying the following concepts: ➢ Distribution tank with weirs to provide even flow to aeration tanks ➢ Distribution tank with weirs to provide even flow to final settling tanks ➢ Free weirs are adopted generally so as not to be affected by downstream
Alternative of Aeration Equipment	Ultra fine bubble diffuser device (Whole area type) is applied due to the followings: ➢ Most effective in terms of energy saving due to high efficiency ➢ Non-clogging feature by adequate operation ➢ Flexibility for various operations due to wide operational range of air flow ➢ Most economical in terms of life cycle cost due to high efficiency
Optimization of Blower System	Decentralized system with one blower building is applied due to the followings: ➢ Flow control to each aeration tank is much easier than centralized system ➢ Energy saving is expected from high accuracy of flow control ➢ Rehabilitation and renovation is easy ➢ O&M is easier since blowers are centralized in the same building
Electrical Facilities Planning	
Power Substation System	New power substation is planned to have required capacity for secondary treatment facilities with a capacity of 1.2 million m^3/day and future expansion of sewage treatment facilities with a capacity of 0.8 million m^3/day. The required capacity for sludge treatment facilities is not included since timing of the implementation has not been decided and also required capacity is uncertain at present.
Supervision Control System	Introduction of SCADA (Supervisory Control and Data Acquisition) System is recommended due to the following advantages: ➢ To improve quality and efficiency of treatment and reduce workload ➢ To reduce operation cost by labor saving and energy saving ➢ To improve and stabilize process through appropriate operation ➢ To understand characteristic of process better by collecting and analyzing data
Generator System	Generators are planned to have capacity for the followings in order to keep minimum function of WWTP and avoid any disaster during power failure ➢ Inlet pumps to prevent submergence of facilities and damaging equipment

	➢ Disinfection equipment to assure safety of effluent from WWTP ➢ Blowers to keep activated sludge alive and preventing aerator from clogging ➢ Administration building such as monitoring system and utilities of office
Sludge Treatment Facilities Planning	
Sludge Transfer Facilities	The existing facilities of sludge pumps and pipeline has enough capacity for additional sludge generated from secondary treatment facilities since hydraulic gradient is always higher than pipeline profile at any location of pipeline alignment. However, the installation of one series of pumps is required as standby since two series of the existing pumps are required to convey all sludge.
Sludge Lagoon	Required area of sludge lagoon is estimated as 424 ha based on drying period of current operation and sludge generation gained from mass balance calculation. Hence, the expansion of 183 ha of sludge lagoon is required in order to accommodate increased sludge and the location of expansion of sludge lagoon is proposed within area reserved for future expansion under CAPW planning.

(D) Preliminary Design

Design Criteria for secondary treatment facilities and sludge treatment facilities are determined based on design standards of Egypt and Japan. Dimensions of main facilities and specifications of equipment are calculated and summarized in Table S-6. The general layout of proposed facilities under this Project along with the existing, ongoing facilities and future expansion is shown in Figure S-3.

Table S-6 Dimensions and Specifications of Proposed Facilities

No.	Facilities / Dimensions / Specifications	Number of Units
1.	Aeration Tank	
1-1	Rectangular Tank W10m×L162m×D6m (9,315m^3)	24 tanks (4 tanks×6 series)
1-2	Membrane Panel Aerator	24 tanks
1-3	Air Blower 260 m^3/min × 380kW	9 nos. (3 standby)
2.	Final Settling Tank	
2-1	Circular Tank Dia 51m × D3.5m (7,151m^3)	24 tanks (4 tanks × 6 series)
2-2	Clarifier Dia51m × D3.5m × 3.7kW	24 nos.
2-3	Return Sludge Pump 34.7m^3/min × H6m × 55kW	24 nos.
2-4	Waste Sludge Pump 5.2m^3/min × H10m × 15kW	12 nos. (6 standby)
3.	Chlorine Contact Tank	
3-1	Rectangular Tank W5m × L90m × D3m (1,350m^3)	3 tanks
3-2	Chlorine Cylinder 1ton	42 nos.
3-3	Water Supply Pump 4.0m^3/min × H40m × 45kW	6 nos. (3 standby).
4.	Sludge Transfer	
4-1	Sludge Pump 22.8m^3/min × H80m × 450kW	2 nos.
5.	Sludge Lagoon	
5-1	Sludge Lagoon (expansion)	183 ha.

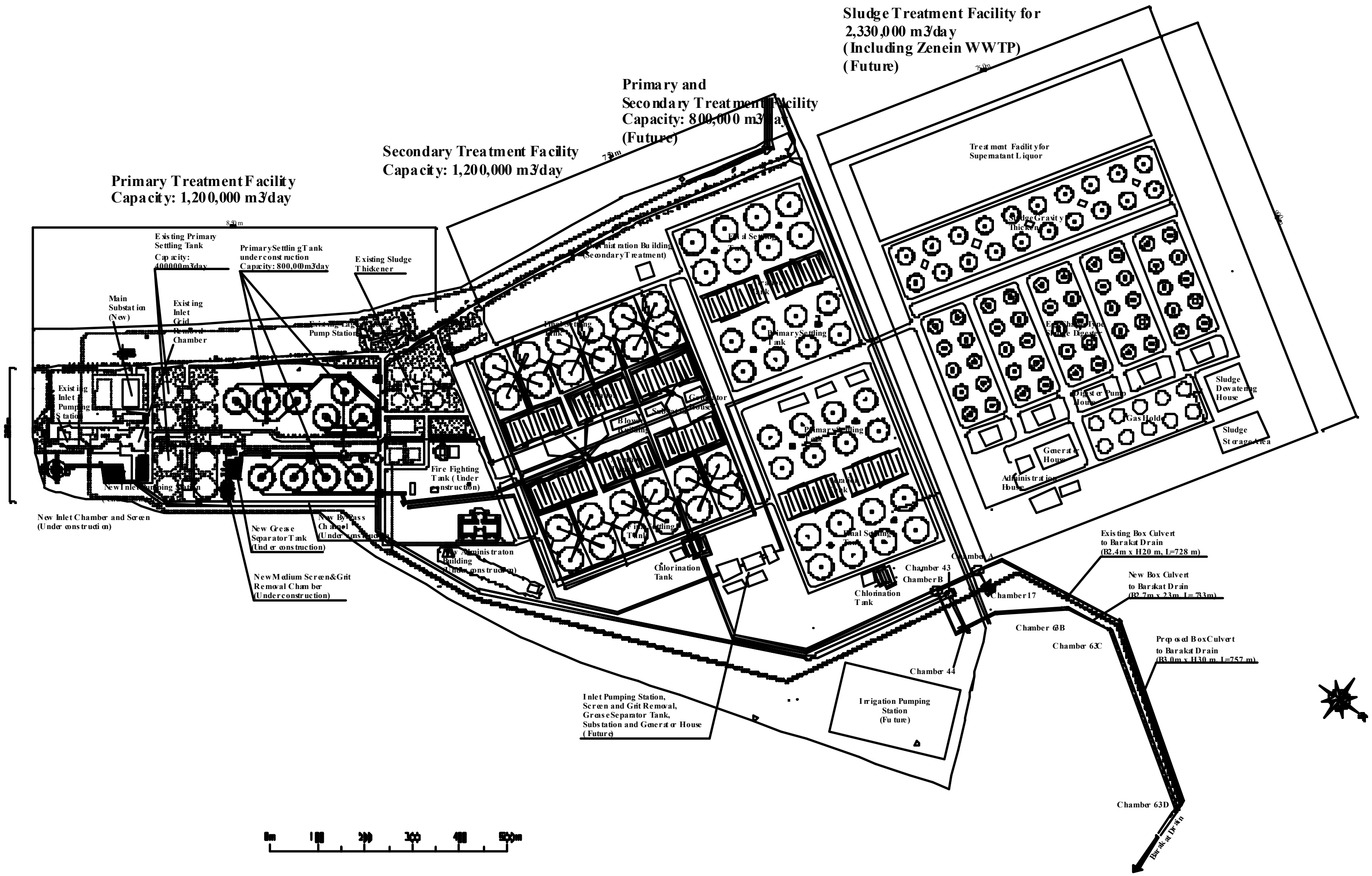


Figure S-3 General Layout of Planned Facilities of Abu Rawash WWTP

(E) Project Cost

Cost estimation has been carried out and is shown in Table S-7. The estimated project cost for this Project is LE 3,101 million (JPY 53.9 billion) including taxes and LE 2,651 million (JPY 46.1 million) excluding taxes.

Table S-7 Estimated Project Cost

No.	Items	L.C. (1,000 LE)	F.C. (1,000 LE)	Total (1,000 LE)
1.	Construction Cost			
A	Sewage Treatment Facilities			
A-1	Connection channel and chamber	42,122	41,195	83,317
A-2	Aeration Tank	164,348	277,749	442,097
A-3	Final Settling Tank	362,478	345,674	708,152
A-4	Chlorination	11,062	15,375	26,437
A-5	Effluent channel and chamber	34,188	50,596	84,784
A-6	Administration facility	15,554	34,950	50,504
A-7	Power facility	41,125	96,912	138,037
A-8	Maintenance road and parking lot	7,559	840	8,399
	Sub-total of A	678,436	863,291	1,541,727
B	Sludge Treatment Facilities			
B-1	Sludge transfer pump	1,694	9,603	11,297
B-2	Sludge lagoon	81,014	48,706	129,720
	Sub-total of B	82,708	58,309	141,017
	Sub-total (1)	**761,144**	**921,600**	**1,682,744**
2.	Administration Cost	16,827	0	16,827
3.	Engineering Cost	53,280	64,512	117,792
4.	Physical Contingency	83,125	98,611	181,736
5.	Price Contingency	402,004	166,197	568,201
6.	Interest during construction	0	79,476	79,476
7.	Commitment charge	0	4,397	4,397
8.	Tax and Duty	196,141	253,827	449,968
	Sub-total (2-8)	**751,377**	**667,020**	**1,418,397**
	Total including Tax	**1,512,521**	**1,588,620**	**3,101,141**
	Total excluding Tax	**1,316,380**	**1,334,793**	**2,651,173**

(F) Implementation Schedule and Disbursement Schedule

Implementation schedule based on condition that this Project is financed through JICA ODA Loan and procured under Design-Build contract has been developed taking into account necessary steps that would be required. Implementation of this Project has been estimated to extend over 60 months (5 years) in total. On the assumption that Loan Agreement is entered between both governments in the middle of 2010, the facilities under this Project will be operational in the middle of 2015 as shown in Table S-8.

Table S-8 Implementation Schedule

	Period	2010	2011	2012	2013	2014	2015	2016	2017
Signing of LA	-	▼							
Selection of Contractor	12month	■	■						
Design Works	10month		■	■					
Construction Works	42month			■	■	■	■		
Commissioning	24month						■	■	■

(4) Financial and Economic Analysis of the Project

(A) Water and Wastewater Tariff Structure and Settings

Tariff structure and levels currently adopted by GWWC are set based on geographic category (urban and rural), beneficiary category (households, government flats, and other 53 detailed classification), and income level. Water tariff varies from the "free" to LE 0.65/m^3, whereas wastewater surcharge varies from "free" to 70% of water tariff. In many categories except for household and government flat beneficiaries, flat unit price is applied while increased block tariff is applied in case of exceptions.

According to the assumption of GWWC and HCWW, the tariff could be 1.25 LE/m^3 and 2.2 LE/ m^3 to achieve the returns in terms of O&M cost and O&M cost/depreciation cost, respectively, while the average of current tariff is 0.25 LE/m^3. GWWC is now preparing a proposed tariff increase in which the average percentage of hike is only 1.5 percent. The aggregate of billing and collection amounted to LE 293 million and LE 238 million in 2008, resulting into overall collection rate of 80.6 percent.

(B) Internal Rate of Return Analysis

Model of configuration for IRRs estimation is summarized in Table S-9.

Table S-9 Model of Configuration for IRRs Estimation

Item	Numerical Assumptions and Parameters
Project life	30 years of project period (6 year construction and 24 year operation period)
Physical and price contingency	Physical contingency = 10% Price contingency : L.C = 3.7%, F.C. = 9.6%
Demand forecast	1.2 million m^3/day = 438 million m^3/year
Financial and economic costs	Financial costs (Capital = LE 3,287 million, O&M =24.3 million LE/year) Economic costs (Capital = LE 1,890 million, O&M =21.8 million LE/year)

Annual investment schedule	Annual investment schedule is prepared based on implementation schedule. (Year1 = 0.1%, 2 = 0.9%, 3 = 26.2%, 4 = 27.8%, 5 = 29.4% and 6 = 15.6%)
Financial and economic benefits	(i) O&M cost recovery = LE 49.6 million/year (ii) O&M cost + capital expenditure (CAPEX) recovery = 153.5 million/year (iii) LRMC pricing = LE 279.8 million/year
OCC and SDR	Opportunity Cost of Capital (OCC) = 9.7% Social Discount Rate (SDR) = 10.0%
Salvage value	No salvage value is assumed.
Sensitivity analysis	(i) lowering of benefit by 10% (ii) capital cost overrun by 10% (iii) one year delay in project completion

Estimated IRRs and NPVs are given in Table S-10.

Table S-10 Estimated IRRs and NPVs

	O&M cost recovery	O&M cost + CAPEX recovery	LRMC pricing
FIRR (FNPV)	NA (LE - 1,546.3 million)	1.6 % (LE - 998.2 million)	7.4 % (LE - 331.8 million)
EIRR (ENPV)	-	-	10.3% (LE 38.4 million)

FIRRs in case of all of three tariff options including (i) O&M cost recovery, (ii) O&M cost + CAPEX recovery and (iii) LRMC pricing are lower than the cut-off ratio of 9.7 percent (OCC). However, EIRR in case of (iii) LRMC pricing is estimated at 10.3 percent exceeding 10.0 percent (SDR) and revealed a profound basis of economic feasibility in case of applying the Long-Run Marginal Cost pricing. In this view, this Project is economically viable and worth to be proceeded under leadership of public sector.

Assuming that people's willingness to pay (WTP) for wastewater could presumably be deemed at 0.5 percent of house income, the specific WTP amounts to 8.3 LE/month. In case of (ii), the unit price of surcharge is 0.4 LE/m^3 and wastewater bill is estimated as 7.3 LE/month - 9.2 LE/month applying average consumption of ordinary household as 20-25m^3. It seems that (ii) O&M cost CAPEX recovery pricing is a ceiling in pricing acceptable. It should be noted that this tariff level does not assure financial viability and soundness of service undertaking, as reflected by estimated FIRR.

The Project's robustness in face of plausible changes in benefit and cost is evaluated by sensitivity analysis for FIRR and EIRR. Results of sensitivity analysis for (i) lowering benefit by 10 percent, (ii) capital cost overrun by 10 percent and (iii) one year delay in construction are assessed and given in Table S-11.

Table S-11 Sensitivity analysis and the resulting FIRRs and EIRRs

	Base Case	(i) Benefit - 10%	(ii) Cost + 10%	(iii) 1-year delay
FIRR (O&M cost recovery)	NA	NA	NA	NA
FIRR (O&M cost + CAPEX recovery)	1.6 %	NA	NA	1.2 %
FIRR (LRMC pricing)	7.4 %	6.3 %	6.4 %	6.6 %
EIRR (LRMC pricing)	10.4 %	9.2 %	9.3 %	9.2 %

(5) Organization for Project Implementation and Operation and Maintenance

Ministry of Housing, Utilities and Urban Development (MOHUUD) is responsible for sewerage systems at national level. Under MOHUUD, Construction Authority of Portable Water and Wastewater (CAPW) is responsible for planning, design and construction of facilities for water supply and sewerage services for the Governorates that constitute Greater Cairo and town of Alexandria and Holding Company for Water and Wastewater (HCWW) is established to own water supply and sewerage assets in entire Egypt. Water and sewerage companies under HCWW are responsible for operation and maintenance of water supply and sewerage facilities. Giza Water and Wastewater Company (GWWC), one of those subsidiary companies, is responsible for both water supply and wastewater in Giza, West Bank of Nile River.

(A) Construction Authority for Portable Water and Wastewater (CAPW)

Assessment of organization and capability of CAPW, implementation agency of this Project, are summarized below.

Organization Structure and Function	CAPW consists of 3 central departments and 10 advisory departments. "Technical Research Department" and "Design & Survey Department" under the "Central Department for Planning and Projects Studies" is responsible for planning and designing. "Ordering Level Determination and Tenders/Offers Department" under "Central Department for Planning and Projects Studies" is responsible for tendering. "Central Department for Execution Affairs" is responsible for the supervision of construction.
Staff Composition and Capabilities	Total number of staff members is 766, 34% of the members have university degrees. CAPW is considered to be an organization with high level of professionals and expertise.
Financial Analysis	Due largely to financial supports extended through the Ministry of Finance and the Central Bank of Egypt, CAPW could keep on track to pursue its operational mission in the Capital region.

(B) Holding Company for Water and Wastewater (HCWW)

Assessment of organization and capability of HCWW is summarized below.

Organization Structure and Function	HCWW is responsible to manage subsidiary companies including GWWC and to improve their performance. HCWW developed the evaluation method, which utilizes performance indicators (PIs), in order to monitor performance of subsidiary companies. HCWW consists of four divisions, which are Technical Affairs, Planning and Research, Performance Development and Administration and Financial Affairs.
Staff Composition and Capabilities	Total number of staff members is 259. HCWW is considered to be an organization with highly educated professionals in order to manage and administer subsidiary companies.
Financial Analysis	In the light of financial stability, the company has a large stock of capital with very little borrowings and secured inflow of government funds now and on, thus leading to a positive situation.

(C) Giza Water and Wastewater Company (GWWC)

Assessment of organization and capability of GWWC, operation and maintenance agency of facilities constructed under this Project, are summarized below.

Organization Structure and Function	GWWC consists of 5 divisions and 10 advisory departments. "General Department for Abu Rawash WWTP" under "Operation and Maintenance Division for Wastewater for Giza and New Cities" is responsible for the operation and maintenance of Abu Rawash WWTP.
Staff Composition and Capabilities	Total number of staff members is 8,820, 8% of the members have university degrees. Permanent staff occupies 57% of employees working for GWWC, while temporary staff occupies 43%.
Financial Analysis	GWWC receives government subsidiary finance through HCWW, besides its own internally generated income inclusive of water tariff and wastewater surcharge and others. In the light of financial profitability and stability, GWWC was not too bad with a positive net profit in 2008/09.
Current Capacity Development	GWWC has 2 training centers to provide internal trainings programs classified into 3 categories of administrative / financial / security programs, PCs / information technology programs and technical programs. Besides internal trainings, external trainings are provided by utilizing outsourced organizations.

(D) Abu Rawash Wastewater Treatment Plant

Assessment of organization of Abu Rawash WWTP and recommended training programs for this Project are summarized below.

Organization Structure and Staff Composition	The organization structure consists of 7 departments responsible for administration, operation, sludge lagoon, electricity, maintenance, laboratory and security. Total number of current staff members is 219 and increasing of 127 staff member is requested for O&M of the ongoing expansion facilities.
Recommended training programs	For the introduction of secondary treatment facilities, practical trainings by using the facilities of Zenein WWTP, personnel exchange and the training programs (i) Technology of biological treatment, (ii) Concept of life cycle cost, and (iii) Technology of ultra fine bubble diffuser device are recommended.
Monthly Report	Abu Rawash WWTP submits monthly report including the followings: ➢ Operation record regarding flow, quality, efficiency, sludge and treatment ➢ Record including administration, consumption and expenditure

(6) Performance Indicators

PIs of International Water Association manual is used in order to evaluate effect of this Project. PIs, which are directly affected and evaluated quantitatively, are selected and presented in Table S-12 with their category, code and analysis of tendency of the effect.

Table S-12 Performance Indicators Selected for Project Evaluation

Category	Code	Indicator	Tendency
Environmental Indicators	*wEn1*	WWTP compliance with discharge consents (%/year)	⇧
	wEn2	Wastewater reuse (%)	⇧
	wEn6	Sludge production in WWTP (kgDS/p.e./year)	⇧
Personnel Indicators	*wPe1*	Personnel in WWTP per population equivalent (No./1000p.e.)	⇧
	wPe10	Technical WWTP personnel (No./1000p.e.)	⇧
Physical Indicators	*wPh11*	Automation degree (%)	⇧
	wPh12	Remote control degree (%)	⇧
Operational Indicators	*wOp13*	WWTP flow meters calibration (-/year)	⇧
	wOp14	Wastewater quality monitoring equipment calibration (-year)	⇧
	wOp15	Emergency power system inspection (-/year)	⇧
	wOp16	Signal transmission inspection (-/year)	⇧
	wOp17	Electrical switchgear inspection (-/year)	⇧
	wOp18	WWTP energy consumption (kWh/p.e./year)	⇧
	wOp44	Wastewater quality tests carried out (-year)	⇧
	wOp45	- BOD tests (-year)	⇧
	wOp46	- COD tests (-year)	⇧
	wOp47	- TSS tests (-year)	⇧

Category	Code	Indicator	Tendency
	wOp48	- total phosphorus tests (-year)	⇧
	wOp49	- nitrogen tests (-year)	⇧
	wOp50	- fecal coli tests (-year)	⇧
	wOp52	Sludge tests carried out (-year)	⇧
Quality of Service Indicators	*wQS7*	Treated wastewater in WWTP - primary treatment (%)	⇩
	wQS8	Treated wastewater in WWTP - secondary treatment (%)	⇧
	wQS19	Total complaints (No./1000 person./year)	⇩
	wQS22	- pollution incidents complaints (No./1000 person./year)	⇩
	wQS23	- odor complaints (No./1000 person./year)	⇧
Economic and Financial Indicators	*wFi5*	Unit cost per p.e. (US$/p.e./year)	⇧
	wFi7	- unit running cost per p.e. (US$/p.e./year)	⇧
	wFi9	- unit capital cost per p.e. (US$/p.e./year)	⇧

(7) Conclusions and Recommendations

The preparatory study for Abu Rawash Wastewater Treatment Plant has been conducted by JICA Study Team and the conclusions and recommendations are given as follows:

(A) Conclusions

1. Government of Egypt gives higher priority on increase of capacity of wastewater treatment plants in respect to National Water Resource Plan, which was prepared by MWRI to safeguard its water resource in future. A total budget of LE 900 million can be utilized for the provision of secondary treatment facilities of Abu Rawash WWTP according to CAPW New Five-Year Plan in accordance with the Six National Development Plan indicating high priority of this Project given by CAPW, MOHUUD and Ministry of Planning (now called Ministry of Economic Development).

2. The provision of the secondary treatment facilities with a capacity of 1.2 million m^3/ay is the first priority from the aspect of improvement of water quality in receiving drains and in Nile River. The second priority goes to the expansion of sewage treatment facilities with a capacity of 0.8 million m^3/day (Primary and Secondary Treatment) due to the rapid increase of population in Greater Cairo and the current deficit in treatment capacity. The provision of sludge treatment facilities is considered as the third priority since the land for sludge lagoons, which is enough to treat sludge generated, has been already acquired.

3. The major results of facilities planning relating to the provision of the secondary treatment facilities are as follows:

- Hydraulic Profile has been planned by gravity without lift pumps from the connecting points with the existing and on-going facilities to receiving body, Barakat drain. However, the increase of hydraulic loss by the provision of secondary treatment facilities requires an additional effluent channel to Barakat drain.

- Ultra fine bubble diffuser (whole area differed type) is chosen for aeration equipment due to economical advantage owing to its high efficiency, long lasting feature and flexibility for various operation.

- The existing sludge transfer facilities including pipeline and pumps can accommodate additional amount generated from this Project, but one series of additional pumps are required as standby. The expansion of 183 ha of sludge lagoons is required in order to accommodate increased sludge generated from the secondary treatment facilities.

4. Estimated project cost is LE 3,101 million (JPY 53.9 billion) including taxes and LE 2,651 million (JPY 46.1 billion) excluding taxes. Additional annual O&M cost for the secondary treatment facilities is 24.3 million LE/year (0.42 billion JPY/year) and all annual O&M cost of Abu Rawash WWTP is and 49.6 million LE/year (0.86 billion JPY/year).

5. FIRRs in case of all of three tariff options including (i) O&M cost recovery, (ii) O&M cost + CAPEX recovery and (iii) LRMC pricing are lower than the cut-off ratio of 9.7 percent (OCC). However, EIRR in case of (iii) LRMC pricing is estimated at 10.3 percent exceeding 10.0 percent (SDR) and revealed a profound basis of economic feasibility in case of applying the Long-Run Marginal Cost pricing. In this view, this Project is economically viable and worth to be proceeded under leadership of public sector.

6. It seems that CAPW, the implementation agency, has enough capability to execute this Project since they have experiences of the same scale of projects such as Al-Gabal-Al-Asfer WWTP under their supervision. It also seems that GWWC, the O&M agency, can manage planned facilities since they already have enough experiences to manage secondary treatment facilities, which utilizes the same technology and process to purify organic load. In addition to training programs and one year of on-the-job training during commissioning period, practical training by using facilities of Zenein WWTP and personnel exchange between Zenein WWTP are effective to get necessary knowledge and techniques.

(B) Recommendations

1. Approval of EIA report by Egyptian Environmental Affairs Agency (EEAA) is required for the implementation of this Project. The CAPW, the executing agency, should go through official procedure in order to get approval from relevant authorities as soon as possible.

2. The commencement of the next stage extension of sewage treatment facilities with a capacity of 0.4 million m^3/day (of the remaining 0.8 million m^3/day to be expanded after this Project) is recommended immediately after completion of this Project due to the rapid increase of population.

3. Utilization of secondary treated effluent for the plantation of Jatropha should be enhanced aiming at forestation of desert area and production of bio diesel energy, which is produced from Jatropha and effective in reducing CO_2 emission.

4. Regarding the introduction of sludge treatment facilities with anaerobic digesters process and digested gas generation system, which can be applied to Clean Mechanism Development project, it is also desirable to consider the introduction of sludge treatment facilities as soon as feasible.

5. Increase of tariff is inevitable to strengthen financial capability and stability of service undertakings. Public awareness campaign about pollution should be enhanced in order to gain people's acceptance for tariff increase.

6. Utilization of dried sludge for desert soil improvement should be enhanced by treating generated sludge appropriately and periodical monitoring of the presence of heavy metals and toxic substance should be strictly conducted.

7. Proper management of industrial wastewater should be established since heavy metals and toxic substances, which are potentially contained in industrial wastewater, causes negative influence on biological treatment process and reuse of treated effluent and sludge.

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

Population of Greater Cairo was estimated to be 12.4 million by the census conducted in 2006 which accounts for around 20% of the total population of Egypt. While the total wastewater generation of the area in 2008 is estimated to be 4.8 million m^3/day, wastewater treatment capacity is 4.1 million m^3/day that is less than the generated wastewater. Besides, some sewerage facilities do not function as designed due to their aging and/or failure. As a result, considerable amount of untreated sewage is discharged to public water bodies, which leads to serious water pollution there. The population in the area is expected to continuously increase and will be 25.4 million in 2037 or twice the population in 2006. Wastewater generation in 2037 is estimated to be 8.7 million m^3/day (1.8 times the generation in 2008) due to the population and industrial wastewater increase. Projects on trunk sewers, pumping stations and wastewater treatment plants need to be urgently implemented to cope with the increasing wastewater.

The sixth five year plan of Egypt (for fiscal 2007 to 2011) defines water supply and sewerage sectors as one of most important infrastructure and allocates more than 25% of the total budget for the sectors.

Abu Rawash WWTP located on the West Bank of Nile River is one of the major WWTPs in Greater Cairo and is supposed to solely treat the increasing sewage generated in the West Bank area. Its capacity as of 2008 is 0.4 million m^3/day but the current flow to the WWTP is expected to have reached 1.1 million m^3/day and the flow exceeding the capacity is discharged to the nearby drain without any treatment. Hence, CAPW began to extend the plant in 2006 with the capacity of 0.8 million m^3/day. The extension works is delayed and expected to complete in the beginning of 2010 but the treatment level stays primary. Therefore, the effluent will not be able to meet the effluent standards and the problem of water pollution will be left unsolved.

Under these circumstances, Japan External Trade Organization (JETRO) conducted feasibility study (JETRO F/S) based on the request of the Government of Egypt. The JETRO F/S proposed the construction of 1.2 million m^3/day secondary treatment facilities and sludge treatment facilities and investigated whether JICA ODA Loan was appropriate. It also revealed that preparation of Environmental Impact Assessment (EIA) report and its approval is required according to the relevant laws of Egypt.

From this background, Japan International Cooperation Agency (JICA) decided to conduct the Study including the preparation of EIA report and the assistance for its approval. The Study also includes collection of necessary data and analysis for preparation of concrete concept of the future project to be financed by JICA.

1.2 Outline of the Study

The Study is to be conducted for the purpose of EIA report preparation and the assistance for its approval and necessary data/information collection and their analysis to formulate JICA ODA Loan financed project.

Overall Goal:	Improved quality of life through environmental improvement
Project Purpose:	To abate water pollution in the effluent receiving water bodies and thus to improve water and living environment through the implementation of secondary treatment facilities at Abu Rawash WWTP
Expected outcome:	Implementation of Abu Rawash secondary treatment
Indicators (numerical):	Improved effluent qualities

1.3 Counterpart Agency in Egypt

The organizations in charge of sewage works in Egypt were drastically restructured in 2004. First of all, Ministry of Housing, Utilities and Urban Development (MOHUUD) is to manage water supply and sewage works at central level under which Holding Company for Water and Wastewater (HCWW) is established to own all the water supply and sewerage assets throughout Egypt. In addition, water supply and sewerage facilities are to be operated and maintained by regional/city based water and sewerage companies established under HCWW. On the other hand, two organizations, namely The Construction Authority for Potable water and Wastewater (CAPW) and National Organization for Potable Water and Sanitary Drainage (NOPWASD) are established to plan, design and construct all the water supply and sewerage facilities in the country. The former is in charge of Greater Cairo and Alexandria and the latter is in charge of all the national territory other than Greater Cairo and Alexandria. CAPW has undergone minor amendment since its establishment in 2004 and its current features were established in 2007. CAPW is the counterpart agency for this Study.

1.4 Study Area

The Study area includes Abu Rawash WWTP, the area including sludge lagoons and the stretches of drains between the point where Abu Rawash WWTP effluent is discharged and the confluence of these drains with Nile River. The Study area is illustrated in Figure 1.1 and Figure 1.2.

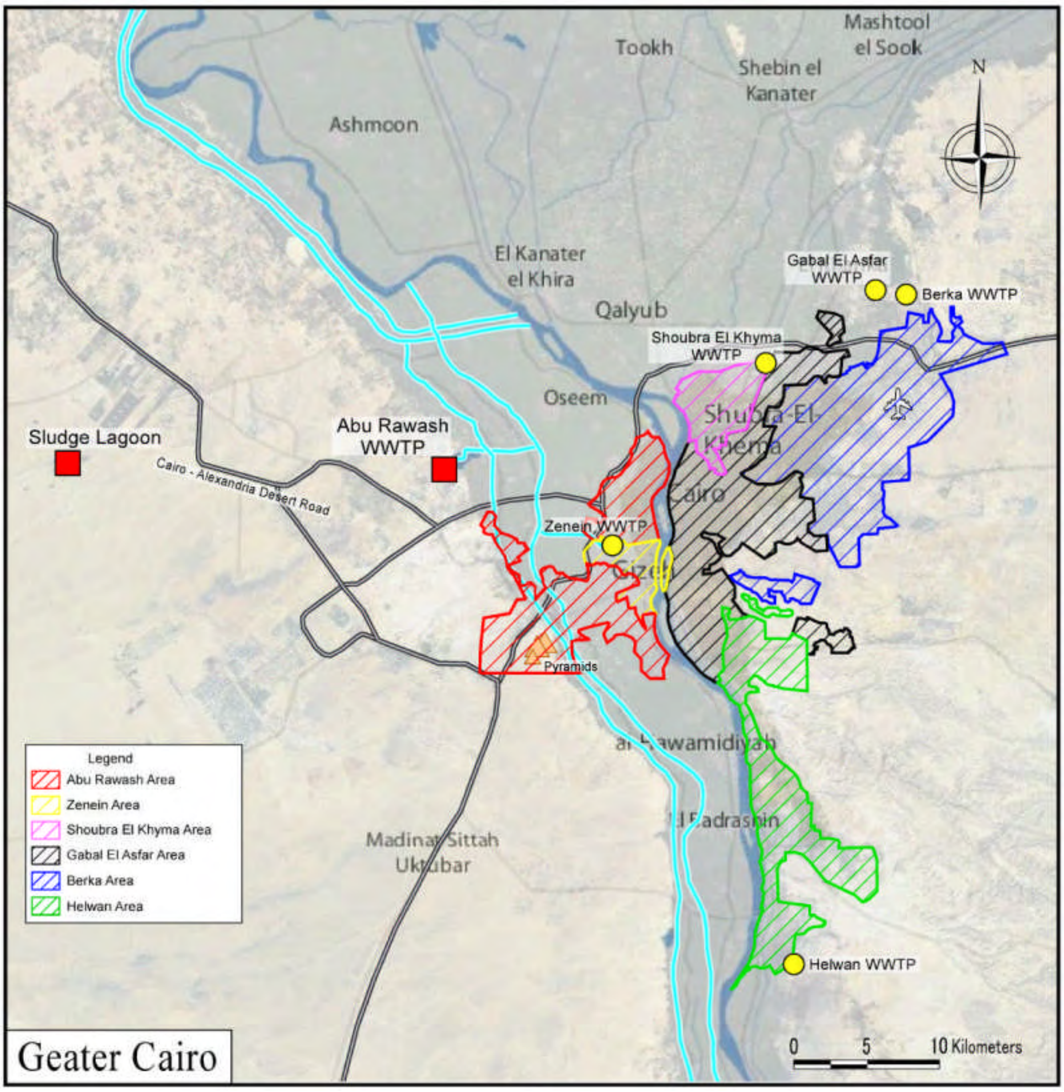


Figure 1.1 Sewerage Areas of Greater Cairo

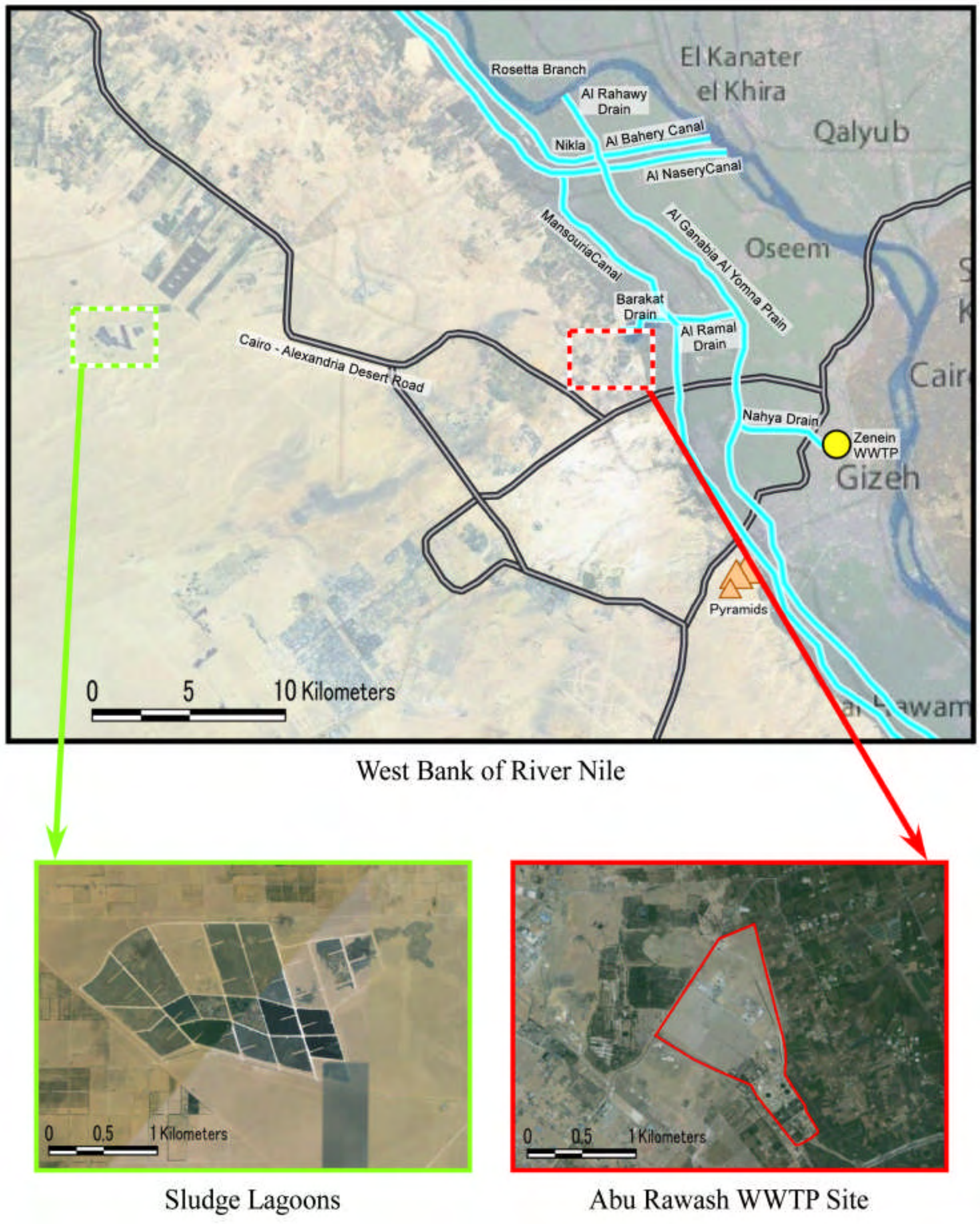


Figure 1.2 Location Map of Study Area

1.5 Outline of Terms of Reference (TOR)

The Study is planned to be conducted from July to December 2009 and the entire period is divided into the following seven (7) stages.

1. Preparatory Home Work
2. First On-site Work
3. First Home Work
4. Second On-site Work

5. Second Home Work
6. Third On-site Work
7. Third Home Work

TOR items included under each stage are as follows and TOR prepared by JICA is described in Appendix-1.

1.5.1 Preparatory Home Work

TOR 1.1 Preparatory work

1.5.2 First On-site Work

TOR 2.1 Explanation and discussion of Inception Report
TOR 2.2 Promotion of environmental and social considerations procedure
  TOR 2.2.1 Assistance in the preparation of EIA Report
  TOR 2.2.2 Assistance in preparation of land acquisition and resettlement plan
  TOR 2.2.3 Assistance in preparation of environmental checklist
TOR 2.3 Assistance in establishing the Project plan
  TOR 2.3.1 Confirmation of the latest conditions
  TOR 2.3.2 Ascertainment of scope of the Project and confirmation of plant site
  TOR 2.3.3 Relevance of secondary treatment process proposed in JETRO F/S
  TOR 2.3.4 Ascertainment of the effects of effluent quality on receiving water bodies
  TOR 2.3.5 Investigation of sludge treatment processes and disposal methods
  TOR 2.3.6 Relevance of facilities planned in JETRO F/S
  TOR 2.3.7 Relevance of implementation schedule proposed in JETRO F/S
  TOR 2.3.8 Investigation of the project cost
  TOR 2.3.9 Investigation and recommendations on implementation schedule
  TOR 2.3.10 Investigation and recommendations on financial plan
  TOR 2.3.11 Investigation of JICA ODA Loan conditions including STEP scheme
  TOR 2.3.12 FIRR and EIRR analysis
  TOR 2.3.13 Investigation and recommendations on organization for project execution
  TOR 2.3.14 Investigation and recommendations on O & M organization
  TOR 2.3.15 Analysis and recommendations on tariff structure including its collection system
TOR 2.4 Others
  TOR 2.4.1 Verification of performance indicators
  TOR 2.4.2 Clarification of the needs for technical cooperation

1.5.3 First Home Work

TOR 3.1 Report on First On-site Work
TOR 3.2 Preparation of Interim Report
TOR 3.3 Preparation for Second On-site Work

1.5.4 Second On-site Work

TOR 4.1 Explanation and Consultation of Second On-site Work
TOR 4.2 Follow-up of First On-site Work
TOR 4.3 Explanation and consultation of results of second on-site work

1.5.5 Second Home Work

TOR 5.1 Preparation of Draft Final Report

1.5.6 Third On-site Work

TOR 6.1 Explanation and consultation of Draft Final Report and provide assistance for organization of workshop

1.5.7 Third Home Work

TOR 7.1 Preparation of Final Report

1.6 Report Structure

Report is comprised of the following two separate volumes considering the convenience in the use of second volume as independent EIA report.

Volume 1 FACILITIES PLANNING REPORT
Volume 2 ENVIRONMENTAL AND SOCIAL IMPACTS ASSESSMENT REPORT

CHAPTER 2 CURRENT STATE OF SEWERAGE SYSTEM AND NECESSITY OF PROJECT

2.1 Current Conditions of Water Supply System and Sewerage System

2.1.1 Water Supply System

Former Greater Cairo Water Supply Company (GCWSC) was responsible for treatment of raw water and distribution of treated water in Greater Cairo until reformation of water and wastewater companies in 2007. Newly established Cairo Water Company is responsible for water supply systems on East Bank, and Giza Water and Wastewater Company (GWWC) is responsible for those on West Bank. The service area of former GCWSC covers entire urban areas and major part of the rural areas.

There are presently sixteen (16) surface water treatment plants (WTPs) and two (2) planned WTPs serving the Greater Cairo. Design capacities and actual production of these WTPs in 2006 is presented in Table 2.1. Of these, eleven (11) WTPs draw raw water from Nile River. Of the remaining five (5) WTPs, three (3) WTPs draw their raw water from Ismailia canal, one from Al-Sharkawaia canal and the other one from Al-Rayah Al-Beheimy canal. The total water treatment capacity of all these eighteen (18) WTPs including two (2) planned ones is 7.8 million m^3/day while the total actual production in 2006 was 6.8 million m^3/day. In addition to surface water, some area also receives water supply from groundwater. However, the share of groundwater is very small compared to the total water supplied.

Table 2.1 Design Capacities and Actual Production of WTPs in Greater Cairo

No.	Name of WTP	Design Capacity (m^3/day)	Actual Production in 2006 (m^3/day)	Planned Extension of Capacity (m^3/day)	Total Capacity after Extension (m^3/day)
	West Bank				
1	Imbaba WTP	900,000	923,000	400,000	1,300,000
2	Giza WTP	160,000	158,000	140,000	300,000
3	Gezerat Al-Dahab WTP	375,000	510,500	0	375,000
4	Al-Sheikh Zayed	450,000	120,000	0	450,000
5	6th October City	267,800	213,300	0	267,800
	Sub total of West Bank	**2,152,800**	**1,924,800**	**540,000**	**2,692,800**
	East Bank				
6	Shobra El-Kheima WTP	400,000	340,400	200,000	600,000
7	Al-Ameria WTP	300,000	441,600	200,000	500,000
8	Mostorod WTP	1,000,000	1,155,000	100,000	1,100,000
9	Roud El-Farag WTP	800,000	752,000	0	800,000

No.	Name of WTP	Design Capacity (m^3/day)	Actual Production in 2006 (m^3/day)	Planned Extension of Capacity (m^3/day)	Total Capacity after Extension (m^3/day)
10	Al-Rodha WTP *	110,000	180,000	0	110,000
11	Al-Fostat WTP	900,000	1,155,000	100,000	1,000,000
12	Al-Maadi WTP **	40,000	43,700	400,000	400,000
13	Helwan WTP	350,000	211,000	0	350,000
14	Al-Tbeen WTP	200,000	156,000	200,000	400,000
15	Kafr El-Alo WTP	80,000	64,000	320,000	400,000
16	Al-Marg	600,000	-	-	600,000
17	Al Obour	400,000	419,000	200,000	600,000
18	New Cairo City	500,000	-	-	500,000
	Sub total of East Bank	**5,680,000**	**4,917,000**	**1,720,000**	**7,360,000**
	Total	**7,832,800**	**6,841,800**	**2,260,000**	**10,052,800**

*: Pumps capacity is 180,000 m^3/day
**: The old 40,000m^3/day will be replaced
Source: HCWW

In the West Bank, there are five (5) WTPs whereas on the East Bank there are thirteen (13) WTPs, including the two (2) planned one of Al-Marg and New Cairo City. The West Bank area is divided into six water utility divisions and all these divisions have their own operation and maintenance, customer service and economic units. These divisions are Al-Haram, Sakiet Meky, Ket Kat, West Al-Monira, Al-Warak and Al-Remaya. On the East Bank, there are 20 water utility divisions. These divisions are Shobra El-Kheima, Bahteem, Al-Marg, Ain Shams, Al-Salam, Al-Nohdha City, Masr Al-Gadeda, Al-Khlafawi, Al-Zaytoon, Al-Zawia Alhamra, Alhai Al Asher, Naser City, Al-Waily, Monshait Nasar, Ain Al Seira, Al-Mokatam, New Cairo City, Al-Maadi, Helwan, 15th May City, and Al-Tbeen.

It is reported that, in 2006, the water supply networks included 100 pumping stations and 81 surface and elevated reservoirs to distribute treated water from WTPs to the service area throughout Greater Cairo. At that time, the existing potable water distribution system of Greater Cairo including the New Cities had a total length of 13,200 km excluding house connections with diameters ranging from 150 mm to 2,000 mm and served more than 970,000 registered customers.

2.1.2 Sewerage Systems

Former Greater Cairo Water Sanitary Drainage Company (GCSDC) was responsible for sewage collection and treatment of collected sewage in Greater Cairo until reformation of water and wastewater companies in 2007. Newly established Cairo Sanitary Drainage Company is responsible for sewerage systems on East Bank, and Giza Water and Wastewater Company (GWWC) is responsible for those on West Bank. The service area of former GCSDC covers entire urban areas and major part of the rural areas.

Sewerage systems in Greater Cairo are geographically divided into three independent districts, viz. East Bank of the River Nile, West Bank of River Nile and Helwan, as illustrated in Figure 2.1.

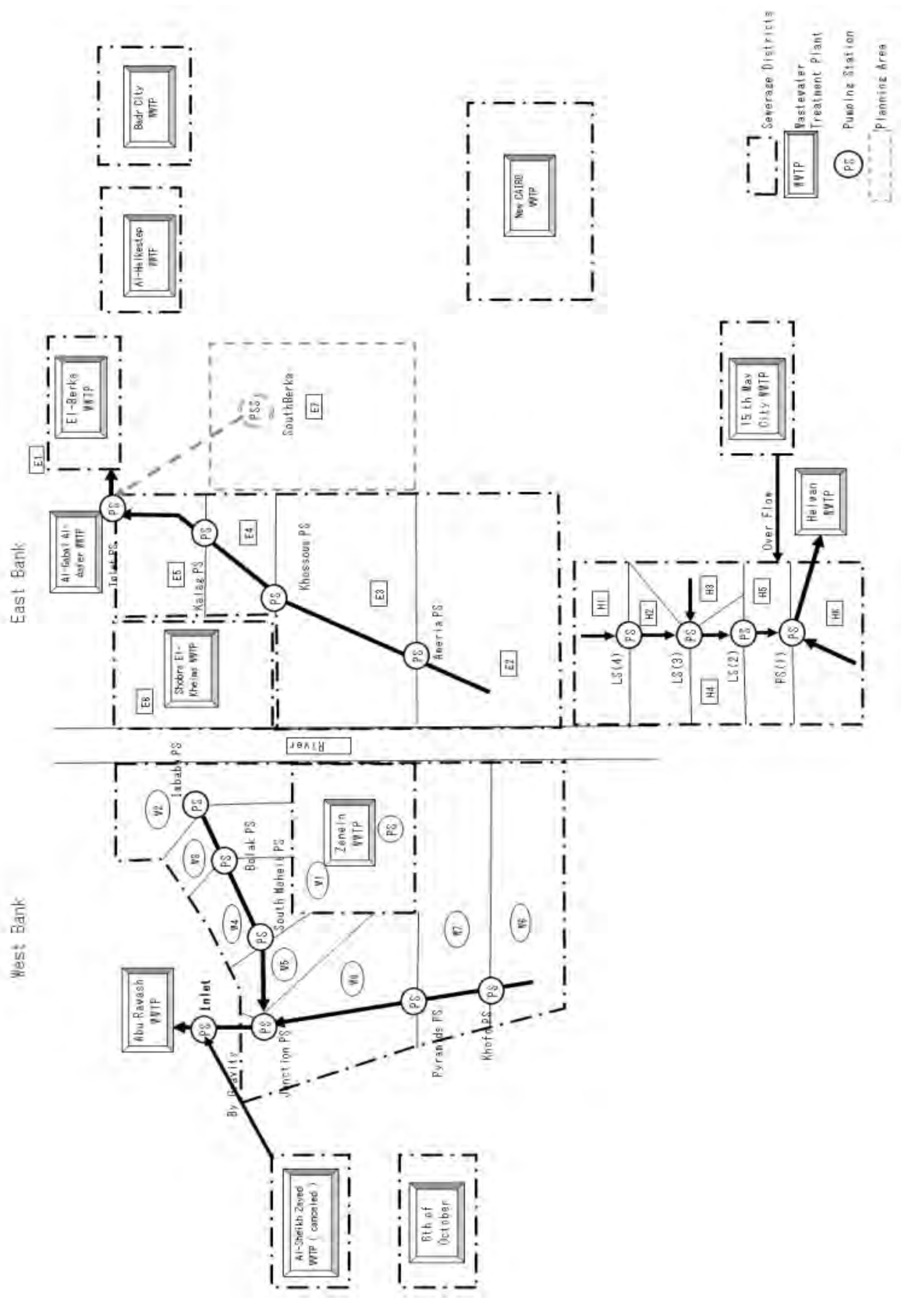


Figure 2.1 Sewerage System in Greater Cairo

Map in Figure 2.1 shows existing sewerage facilities in Greater Cairo including wastewater treatment plants (WWTPs), major trunk sewers and main pumping stations in these districts. In each of these three districts, there are still some pockets that are not served by existing sewer networks. Altogether, there are six (6) major WWTPs in Greater Cairo. There are four (4) major WWTPs on East Bank including Al-Gabal Al-Asfer (two stages), El-Berka, Shobra El-Kheima and Arab Abu Saed (Helwan). The West Bank is served by two (2) major WWTPs including Zenein and Abu Rawash. In addition to this, on the East Bank, four (4) small WWTPs also exist located in 15th May City, Al-Haikestep, Badr City and New Cairo City. On the West Bank also, one small WWTP is working in 6th October City. Another WWTP was operated at Al-Sheikh Zayed but at present its operation has been abandoned. This WWTP used oxidation ponds for treatment of wastewater and the flow to this WWTP increased manifolds making it very difficult to handle total flow. The elevation of this WWTP is high and therefore, at present the flow from this WWTP is diverted to Abu Rawash WWTP by gravity. Design capacities and current inflow to these WWTPs in 2008 is presented in Table 2.2.

Table 2.2 Design Capacities and Current Inflow of WWTPs in Greater Cairo

No.	Name of WWTPs	Treatment Process	Current Design Capacity (m^3/day)	Estimated Inflow in 2008 (m^3/day)
	East Bank			
1	Al-Gabal Al-Asfer / Cairo city	Activated Sludge	1,700,000	1,850,000
2	El-Berka / Cairo city	Activated Sludge	600,000	565,000
3	Helwan / Cairo city	Activated Sludge	350,000	564,000
4	Balaks / Shobra El-Kheima city	Activated Sludge	600,000	372,000
5	15th May City / 15th May city	Activated Sludge	30,000	30,000
6	Al-Haikestep / Al-Shrook city	Activated Sludge	27,000	20,000
7	Badr City / Badr city	Oxidation Ponds	3,880	3,880
8	New Cairo City / New cairo	Activated Sludge	1,000	1,000
	Sub total of East Bank		**3,311,880**	**3,405,880**
	West Bank			
9	Zenein / Al-Gaza city	Activated Sludge	330,000	260,000
10	Abu Rawash / Abu Rawash	Primary Treatment	400,000	1,085,000
11	6th October / 6th October city	Activated Sludge	100,000	90,000
12	Al-Sheikh Zayed / Al-Sheikh Zayed city	Oxidation Ponds	0	0
	Sub total of West Bank		**830,000**	**1,435,000**
	Total		**4,141,880**	**4,840,880**

As shown in the above, the current total wastewater amount, which flows to WWTPs in Greater Cairo, has reached to 4.8 million m^3/day while the total of these design capacities is 4.1 million m^3/day. It means that approximately 0.7 million m^3/day of wastewater in excess of the existing treatment capacity is discharged into nearby drains and finally goes into

River Nile without any treatment. In addition, taking into account future increase of wastewater due to population growth, treatment capacities of the existing sewerage facilities are urgently needed to increase. This includes expansion of WWTPs facilities, increase in capacity of pumping stations, and construction of trunk sewers, which could serve the unsewered areas at present. Rehabilitation and renewal of the existing facilities are also required because appropriate maintenance and repair works have not been carried out under severe financial conditions in the past.

The extensions, rehabilitation and repair works have been undertaken independently by sewerage districts. However, it seems that these activities are not based on the best practices plan for the whole Greater Cairo. After 1990s when financial assistance from overseas development agencies decreased, the Egyptian government policy inclined to the implementation of necessary projects based on their own plans and available government funds. However, the extension and rehabilitation of the sewerage systems would certainly require a huge amount of investment. Therefore, financial assistance from overseas donor agencies would be required.

2.2 National Water Resource Plan, CAPW New Five-Year Plan and Sewerage Master Plan Update

2.2.1 National Water Resource Plan

National Water Resources Plan 2017 was prepared by the Ministry of Water Resource and Irrigation in January 2005 and the Plan was allegedly revised recently due to project readjustments. The main objective of the Plan is to describe how Egypt will safeguard its water resources in future, both with respect to quantity and quality, and how it will use these resources in the best way from socio-economic and environmental point of view.

Major sources of water pollution in Egypt originate from the domestic, agricultural and industrial sectors. The total amount of domestic wastewater has been estimated as 4.3 billion m^3/year in 1997. In number of cases, municipal and rural domestic wastewater is discharged directly into water body, often without treatment or with insufficient treatment. The discharge increases year by year due to the construction of water supply networks. In spite of efforts of the Government of Egypt, the coverage rates of sanitary services are much less than those of water supply. Just over 50 percent of the urban population has access to sewerage services. Therefore, one of the strategies of the Ministry of Housing, Utilities and Urban Development for the Plan is to increase the number and capacity of wastewater treatment plants and to reuse treated wastewater.

The total planned investment cost was originally LE 145 billion, but it has been revised to LE 245 billion recently. Original cost breakdowns are shown in Table 2.3 and Table 2.4.

Revised cost breakdown is not clear but the cost allocation is allegedly almost same as the original.

The major shares in this investment belong to the MOHUUD (62%) and MWRI (32%). As shown in Table 2.3, increasing municipal sewerage and wastewater treatment of MOHUUD is the most important measure in the Plan and its share is 43%, which includes Abu Rawash WWTP in Greater Cairo, upgrading treatment method from primary treatment (sedimentation) to secondary treatment (biological treatment, Activated Sludge Process) as well as increasing treatment capacity from 0.4 to 1.2 million m^3/day.

Table 2.3 Stakeholder-wise Investment Cost Breakdown of NWRP (Original Plan)

	Investment Cost (million LE)	Share (%)
1. Ministry of Water Resources and Irrigation	45,741	31.5
2. Ministry of Agriculture and Land Reclamation	70	0.0
3. Ministry of Industry	203	0.1
4. Ministry of Housing, Utilities and Urban Development	90,134	62.1
(1) Increase municipal sewerage and wastewater treatment	(61,765)	(42.5)
(2) Increase drinking water treatment capacity	(28,250)	(19.5)
(3) Other measures	(119)	(0.1)
5. Municipalities	253	0.2
6. Ministry of Health and Population	398	0.3
7. Ministry of Local Development	1,505	1.0
8. Egypt's Environmental Affairs Agency	9	0.0
9. Ministry of Transportation	3	0.0
10. Private Sector	6,779	4.7
Total	145,095	100.0

Source: NWRP

Table 2.4 Measure-wise Investment Cost Breakdown of NWRP (Original Plan)

	Investment Cost (million LE)	Share (%)
1. Developing Additional Resources	8,274	5.7
2. Making Better Use of Existing Resources	41,512	28.6
3. Protection of Public Health and Environment	95,031	65.5
(1) Increase municipal sewerage and wastewater treatment	(61,765)	(42.6)
(2) Increase drinking water treatment capacity	(28,250)	(19.5)
(3) Other measures	(5,016)	(3.4)
4. General Institutional, Legal and Financial Measures	245	0.2
Total	145,062	100.0

Source: NWRP

2.2.2 CAPW New Five-Year Plan

CAPW's new five-year development plan in accordance with the sixth national development plan has been approved by the Ministry of Planning (now called Ministry of Economic Development). A total investment is expected to reach approximately LE 9.9 billion for Greater Cairo water and wastewater expansion and improvement during five-year period from fiscal year 2007/08 to 2011/12 as shown in Table 2.5. Approximately LE 5.3 billion, more than half of the total, will be invested in wastewater projects.

Under the new five-year plan, 15 wastewater projects have been identified among which 9 projects have already commenced and the remaining 6 projects are new ones and are planned to start. The sources of fund are solely local fund except for Screw Pumps in the West Bank for which loan from Spanish Government is expected against the foreign portion of the cost. Detail on the Project yearly disbursement schedule and salient features of 15 wastewater projects are presented in Table 2.6 and Table 2.7. A total of LE 900 million (LE 450 million each for fiscal years 2007 and 2008) has been allocated to Abu Rawash WWTP for discharge of treated wastewater from WWTP to wooden forest areas or to secondary treatment as shown in Table 2.6. This allocation of large amount of budget can be utilized for construction of secondary treatment facilities and also indicates high priority given to the project by CAPW, MOHUUD and Ministry of Planning (now called Ministry of Economic Development).

Table 2.5 Investment of CAPW New Five-Year Plan (Greater Cairo)

	Total Cost (million LE)	Previous Investment (million LE)	New Investment (million LE)
Water Supply	5,113	494	4,619
Wastewater	6,001	690	5,311
Total	11,114	1,184	9,930

Table 2.6 Wastewater Projects under CAPW New Five-Year Plan and Project Costs

No.	Project Name and Description	Total Cost (million LE)	Total Previous Investment (million LE)	Suggested Investments Distributed Through Years (million LE)				
				2007/ 2008	2008/ 2009	2009/ 2010	2010/ 2011	2011/ 2012
Wastewater Projects in Cairo (Related to Al-Gabal Al-Asfer WWTP)								
1	Pumping Station and Force Main from El-Berka to Al-Gabal Al-Asfer (execution period 3 years)	246	172	74	-	-	-	-
2	Rocky Tunnel from Al-Maadi North to main tunnel (execution period 3 years)	120	75	45	-	-	-	-
3	Second part of the second phase for Al-Gabal Al-Asfer (execution period 4 years)	1000	-	10	250	250	250	240
4	Extension of Al-Ameria pump station (execution period 3 years)	550	-	180	200	170	-	-
5	Doubling of collectors from Al-Ameria to Khossous (execution period 3 years)	250	-	50	100	100	-	-
6	Enhancement of the benefit from the first phase in Al-Gabal Al-Asfer Treatment Plant (execution period 3 years)	450	-	20	150	150	130	-
Wastewater Projects in Cairo (Related to Helwan WWTP)								
7	Second phase Helwan Treatment Plant (execution period 3 years)	400	155	125	120	-	-	-
8	Helwan New Treatment Plant	450	-	-	150	150	150	-
9	New Pumping Stations in Helwan	200	-	40	60	60	40	-
10	Doubling of wastewater collectors in Helwan Project	150	-	25	50	50	25	-
Wastewater Projects in Giza (Related to Abu Rawash WWTP)								
11	Abu Rawash Treatment Plant "Second Phase" (execution period 3 years)	715	195	270	250	-	-	-
12	Collectors and networks in Bashteel, Nahia, El-Barageel, El-Mansouria, El-Moatamidia, Birak El-Khayam, El-Baqqar	470	70	100	100	100	100	-
13	Screw pumps in Bolak, El-Moheet, and Al-Etisal (Spanish loan for foreign component)	39MLE + 8MEuro	22	8	5	4	-	-
14	Extension of culvert from Al-Etisal Station to Abu Rawash plant (execution period 3 years)	61	1	30	30	-	-	-
15	Discharge of treated wastewater from Abu Rawash WWTP to Wooden forest areas or to secondary treatment	900	-	450	450	-	-	-

Table 2.7 Wastewater Projects under CAPW New Five-Year Plan and Features

No.	Project Name	Salient Features of Projects
Wastewater Projects in Cairo (Related to Al-Gabal Al-Asfer WWTP)		
1	Pumping Station and Force Main from El-Berka to Al-Gabal Al-Asfer (execution period 3 years)	Doubling of collectors from Khossous to Al-Gabal Al-Asfer. Extension of Kalag and Khossous PS to serve future population of 5 million inhabitants from Cairo and Qalyobia Governorates.
2	Rocky Tunnel from Al-Maadi North to main tunnel (execution period 3 years)	Secondary tunnels 3.7 km long to connect regions of Dar El Salam, Dar El Salam island, and Imam El Leithy to Al-Maadi Rocky tunnel
3	Second part of the second phase for Al-Gabal Al-Asfer (execution period 4 years)	Capacity: 500,000 m^3/day 2 million inhabitants in Cairo and Qalyobia Governorates Works: Secondary treatment plant and mechanical sludge treatment
4	Extension of Al-Ameria pump station (execution period 3 years)	Station capacity: 1.2 million m^3/day Population served: 4.8 million Works: Increase capacity from 2 million m^3/day to 3.2 million m^3/day
5	Doubling of collectors from Al-Ameria to Khossous (execution period 3 years)	Main collector 7 km long with capacity 2 million m^3/day
6	Enhancement of the benefit from the first phase in Al-Gabal Al-Asfer Treatment Plant (execution period 3 years)	Capacity: 300,000 m^3/day Population: 1.2 million inhabitants in Cairo and Qalyobia Governorates Works: Secondary treatment plant
Wastewater Projects in Cairo (Related to Helwan WWTP)		
7	Second phase Helwan Treatment Plant (execution period 3 years)	Increase the capacity of secondary treatment of the existing plant from 350,000 m^3/day to 550,000 m^3/day
8	Helwan New Treatment Plant	New treatment plant with capacity of 1,000,000 m^3/day to serve the future extensions
9	New Pumping Stations in Helwan	New pumping stations in Helwan to serve the new WWTP
10	Doubling of wastewater collectors in Helwan Project	Doubling of collectors with capacity 500,000 m^3/day to serve the future extensions in area
Wastewater Projects in Giza (Related to Abu Rawash WWTP)		
11	Abu Rawash Treatment Plant "Second Phase" (execution period 3 years)	Increasing the capacity of treatment plant from 400,000 m^3/day to 1.2 million m^3/day
12	Collectors and networks in Bashteel, Nahia, El-Barageel, El-Mansouria, El-Moatamidia, Birak El-Khayam, El-Baqqar	Network to serve the deprived villages in west of river Nile for which population reaches 750,000 inhabitants
13	Screw pumps in Bolak, El-Moheet, and Al-Etisal (Spanish loan for foreign component)	Increase the pumping capacity in Bolak, South El-Moheet and Al-Etisal by 200,000, 200,000, and 800,000 m^3/day respectively.
14	Extension of culvert from Al-Etisal Station to Abu Rawash plant (execution period 3 years)	Concrete collector 1.8 km long to serve Dokki, Mohandessin, Giza, El Haram, Faysal and others
15	Discharge of treated wastewater from Abu Rawash WWTP to Wooden forest areas or to secondary treatment	Project for the use of 1.2 million m^3/day treated wastewater for irrigation.

2.2.3 Sewerage Master Plan Update

According to the latest population census conducted in 2006, population in Greater Cairo was 12.4 million. Population projection in Greater Cairo up to 2037 has been made considering the data obtained by the latest population census in the Master Plan Update, which was carried out by local consultants. As a result of Master Plan Update, population projection shown in Table 2.8 has been authorized by HCWW as planning basis for both water supply and wastewater. Comparing the previous projection adopted for JBIC study and JETRO F/S, population growth rate is considerably higher since the latest population projection considers planned satellite cities around the existing urbanized areas of Greater Cairo. As shown in Table 2.8, population in Greater Cairo is expected to increase from 12.4 million in 2006 to 25.4 million in 2037.

Table 2.8 Population Projection of Greater Cairo

District Name	Population (thousand persons)			
	2007	2017	2027	2037
East and South Nile	7,123	9,615	11,415	13,552
West Nile	4,148	5,684	6,789	8,109
Helwan	854	1,175	1,369	1,596
Shobra El-Kheima	1,176	1,593	1,857	2,165
Total	13,302	18,066	21,430	25,422

Water supply demand and wastewater generation have been calculated based on the above latest population projection in the Master Plan Update. With the increase of population, water supply demand and wastewater generation in the entire Greater Cairo is expected to increase significantly.

Water supply demand has been estimated based on Egyptian standards which are summarized in Table 2.9 and these figures are considered to be constant till 2037.

Table 2.9 Egyptian Standards for Water Supply

Item	Consumption	Leakage
Domestic (Cairo district)	280 lit/capita/day	95 lit/capita/day
Domestic (Giza district)	280 lit/capita/day	95 lit/capita/day
Domestic (New cities district)	320 lit/capita/day	60 lit/capita/day
Service buildings	100 lit/capita/day	
Hospitals	1000 lit/bed/day	
Hotels	1000 lit/bed/day	
Fire fighting	No. of hours * discharge * 10,000/pop	
Industrial	3 lit/hec/sec	
Green area	50 m^3/hec/day	
Urban extension (construction)	20 m^3/hec/day	

Source: Master Plan Update

Water supply demand and design capacity of water production in Greater Cairo have been estimated up to 2037 and is summarized in Table 2.10. As shown in Table 2.10, water supply demand in Greater Cairo is expected to increase from 6.7 million m^3/day in 2006 to 12.5 million m^3/day in 2037 and also design capacity of water production is expected to increase from 6.9 million m^3/day in 2006 to 13.8 million m^3/day in 2037.

Table 2.10 Projection of Water Demand and Production

Item	2007	2017	2027	2037
Population (thousand persons)	13,302	18,066	21,430	25,422
Average Water Demand (m^3/day)	6,667,000	8,209,000	9,205,000	12,461,000
Design Capacity of Water Production (m^3/day)	6,930,000	11,723,000	12,623,000	13,823,000

Wastewater generation in Greater Cairo has been estimated based on Egyptian Standard of discharge rates shown in Table 2.11.

Table 2.11 Egyptian Standards of Discharge Rate

	East and South Nile	West Nile	Helwan	Shobra El-Kheima
Urban area	297.0 lit/capita/day	297.0 lit/capita/day	—	—
Sub-urban area	265.5 lit/capita/day	265.5 lit/capita/day	225.0 lit/capita/day	198.0 lit/capita/day
Village area	—	211.5 lit/capita/day	—	198.0 lit/capita/day
New cities	—	297.0 lit/capita/day	—	—
Industrial zones	25.2 m^3/fed/day	25.2 m^3/fed/day	—	25.2 m^3/fed/day
Commercial zones	16.8 m^3/fed/day	16.8 m^3/fed/day	16.8 m^3/fed/day	16.8 m^3/fed/day
Visitors	110.0 lit/capita/day	70.0 lit/capita/day	60.0 lit/capita/day	50.0 lit/capita/day

Source: Master Plan Update

Wastewater generation in Greater Cairo has been estimated up to 2037 and is summarized in Table 2.12. As shown in Table 2.12, wastewater discharge in Greater Cairo is expected to increase from 4.7 million m^3/day in 2007 to 8.7 million m^3/day in 2037.

Table 2.12 Projection of Wastewater Discharge

Item	2007	2017	2027	2037
Population (thousand persons)	13,302	18,066	21,430	25,422
Average Wastewater Discharge (m^3/day)	4,694,000	6,474,000	8,482,000	8,664,000

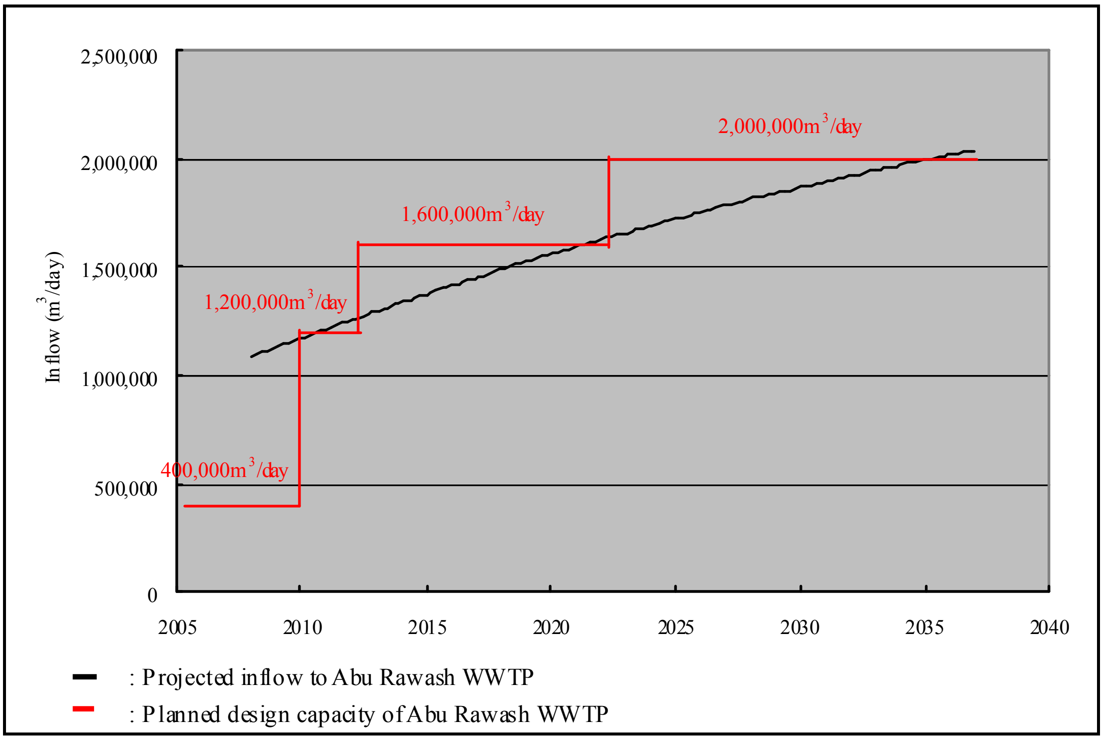
In the Master Plan Update, total of wastewater discharge is planned to be allocated to the following main WWTPs in Greater Cairo as shown in Table 2.13 with the current design capacity and inflow of these WWTPs.

Table 2.13 Current Design Capacity and Allocation of Wastewater Discharge

WWTP	Current Design Capacity (m^3/day)	Estimated Inflow in 2008 (m^3/day)	Projected Inflow (m^3/day)	
			2017	2037
Al-Gabal Al-Asfer	1,700,000	1,850,000	2,900,000	4,000,000
El-Berka	600,000	565,000	634,000	644,000
Zenein	330,000	260,000	300,000	360,000
Abu Rawash	400,000	1,085,000	1,450,000	2,039,000
Helwan	350,000	564,000	740,000	1,056,000
Shobra El-Kheima	600,000	372,0000	450,000	565,000
Total	3,980,000	4,696,000	6,474,000	8,664,000

Projected inflow to Abu Rawash WWTP is presented in Figure 2.2 with the staged development plan of its treatment capacity.

Figure 2.2 Projected Inflow to Abu Rawash WWTP



The design capacity of Abu Rawash WWTP is currently 0.4 million m^3/day and expected to increase to 1.2 million m^3/day in the beginning of 2010 by on-going expansion of primary treatment facilities. According to development plan shown in the above, the expansion of sewage treatment with a capacity 0.4 million m^3/day, which makes its total capacity 1.6 million m^3/day, is planned to be operational in 2012 and can be sufficient to accommodate until 2021. The final expansion with a capacity of 0.4 million m^3/day to reach its ultimate capacity, 2.0 million m^3/day, is planned to be operational by 2022.

The progress of development is obviously behind the schedule planned in Master Plan Update. In order to accommodate projected inflow in the near future, the expansion with a capacity of 0.4 million m^3/day should have been already started considering necessary period of its construction. Furthermore, the current facilities and on-going facilities are only primary treatment which can not satisfy the effluent standards.

2.3 Expected Improvement due to the provision of Secondary Treatment Facilities

The provision of secondary treatment facilities at Abu Rawash WWTP shall improve the quality of treated effluent resulting into improvement of water pollution level in receiving water bodies, availability of better quality water for agricultural uses and mitigation of odor problem along the drain networks.

The existing regional distribution of discharged pollution load is shown in Figure 2.3. According to Figure 2.3, the pollution load from Abu Rawash WWTP and South Muheit pump station, at which wastewater is directly diverted to El Beeny drain, contributes about 92% of the total pollution load discharges into effluent receiving water bodies. Hence, the provision of secondary treatment facilities is expected to have significant impact on the water quality in effluent receiving water bodies.

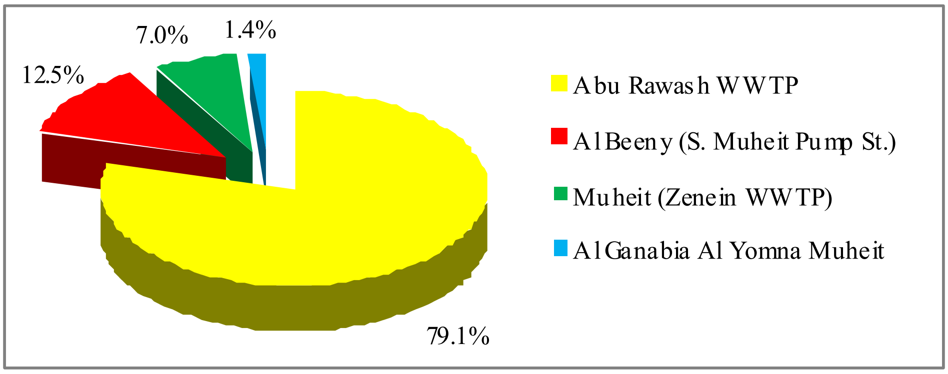


Figure 2.3 Distribution Ratio of Discharged Load in the Existing Situation

In order to evaluate the contribution of the provision of secondary treatment facilities, comparison analysis is carried out for the cases of with project and without project and the result is summarized in Table 2.14.

Table 2.14 Comparisons of With and Without the Project

Items	Present situation	Future situation	
		Without project	With project
Discharged Pollution Load into the Rosetta Branch (BOD)	107 ton/day	108 ton/day	29 ton/day
Water Quality in Al Rahawy drain (BOD)	71 mg/l	60 mg/l	16 mg/l
Comparison to water quality standard of the maximum limits for re-use of treated effluent (Decree No.44 of 2000)	Exceed the standard	Exceed the standard	Within the standard
Comparison to effluent limits for treated discharges into water bodies (Decree No.8 of 1983)	Exceed the standard	Exceed the standard	Within the standard
Odor problem in Nikla	Continues	Continues	Resolves

Based on the result of comparison analysis, the following improvements are expected.

- It is estimated that, after implementation of the project, the discharged pollution loads into the Rosetta Branch reduces to 29 ton/day as BOD compared to 107 ton/day in case of present load and 108 ton/day in case of the future load if the project is not implemented.
- The existing and future BOD levels in the case of without-project are estimated as 71 mg/l and 60 mg/l, and estimated level of BOD in case of the with-project situation is 16 mg/l.
- Through the implementation of this project, the treated effluent quality level would satisfy the water quality standard of the maximum limits for re-use of treated effluent (2nd group water treated secondarily: Decree No.44 of 2000) and the effluent limits for treated discharges into water bodies (Decree No.8 of 1983).
- Moreover, since dissolved oxygen shall be recovered by water quality improvement (reduction of BOD level), the mitigation of odor problem in Nikla and native habitat of the drains are also expected.

2.4 JBIC and JETRO Studies

2.4.1 JBIC Pilot Study

JBIC Pilot Study was conducted with following main objectives.

- Review the current situation of sanitation sector and examination of necessity for the projects.

- Preparation of candidate projects for JBIC ODA loan.
- Examination of project implementation, operation and maintenance of the projects.

The study area includes entire Greater Cairo, Capital of Egypt, which consists of three Governorates: Cairo, Giza and Qalyobia. The study was conducted from April to October 2007. Final report of the study was submitted in October 2007.

Population and wastewater projection were based on Master Plan Update which was in process of preparation at the time of the study. Among the several candidate projects, provision of secondary wastewater treatment with a capacity of 1.2 million m^3/day together with sludge treatment at Abu Rawash WWTP was identified as candidate project for JBIC ODA loan. Preliminary design of the facilities was carried out and based on which project cost was estimated. Preparation of full EIA report and its approval by EEAA was found to be prerequisite for implementation of the project, since the project is categorized as “Black” according to Egyptian Law.

Based on the results of the study, Egyptian government added the project on list of projects for JBIC ODA Loan and submitted to Japanese government.

2.4.2 JETRO F/S Study

Following the JBIC study, a study was conducted under the Study on Economic Partnership Projects in Developing Countries by Japan External Trade Organization, which is usually called as JETRO F/S. The study was conducted during the period from October 2007 to January 2008. The final report of the study was submitted in March 2008.

The study was focused on Abu Rawash WWTP, and technical and financial feasibility of the project was examined and confirmed more in detail than JBIC study. Most appropriate technologies for both wastewater treatment and sludge treatment were proposed in view of life cycle cost and environment. Provision of sludge treatment by means of sludge digestion was proposed considering that it will contribute to reduction of green house gases emission substantially which currently emits from sludge lagoons. Electric power generation utilizing digestion gas was also considered to contribute to reduction of green house gases. Possibility of the project to be approved as CDM project was studied and confirmed to be promising.

2.5 PPP for Wastewater Project

One of the wastewater treatment plants in Greater Cairo in the new cities will be constructed as PPP projects. The New Cairo Wastewater Treatment Project is one of the key

PPP pilot projects under MOHUUD. Outline of the project is as follows.

Sector:	Wastewater Treatment Plant
Contracting Authority:	New Urban Communities Authority (NUCA) under Ministry of Housing, Utilities and Urban Development
Supervisor:	PPP Central Unit of Ministry of Finance
Project Duration:	20 years
Construction Period:	2 years
Operation Duration:	18 years
Location:	New Cairo City
Date of the Project:	27 May 2009
Awarded Party:	Orasqualia (Orascom Construction Industries, Egypt, Aqualia and Aqualia Infrastructions, Spain)
Date of Contract Signing:	29 June, 2009

MOHUUD through NUCA with technical assistance from PPP Central Unit invited private sector participation in December 2007, through a competitive bidding process to enter into PPPs for the design, construction, financing, operation and maintenance of a new wastewater treatment plant with a total capacity of 250,000 m^3/day. Main activities since bid invitation to signing of contract are shown as follows.

Invitation for Prequalification:	16 Dec. 2007
Deadline for Submission of Prequalification:	3 Feb. 2008
Announcement of Prequalified Bidders:	23 Feb. 2008
Issuing of Data Room:	Jul. 2008
Bidders Conference:	Jul. 2008
Issuance of Invitation for Bids including Tender Documents and Draft Contract and Annexes:	1 Dec. 2008
Individual Meetings with Bidders on the Contract and Annexes:	19, 20, 21 Jan. 2009
Issuance of the amended Tender Documents:	15 Feb. 2009
Bids Submission Deadline and Date of Technical Bids Opening:	31 Mar. 2009 (12:00)
Notification on Technical Bid Evaluation Results and Announcement of the Date of the Financial Bids Opening Session:	May 2009
Financial Bids Opening Session and Announcement of the Successful Bidder for the Project:	May 2009
Notification of Award of Contract for the Project:	Jun. 2009
Signing of the Contract:	29 Jun. 2009

Final capacity of the plant is 500,000 m^3/day, and construction will be carried out in stages. Initially, the construction of infrastructures with a capacity of 250,000 m^3/day will be undertaken by the project. Prequalification criteria requires the bidders that they shall have experience of design and construction of wastewater treatment plant with aggregate capacity of 250,000 m^3/day including one plant with a capacity of at least 100,000 m^3/day. Experience of operating a facility complying with standards substantially equivalent to or higher than Egyptian Code, i.e. Guidelines for Reuse of Treated Wastewater in Agriculture, 2005, is also required. Five companies and consortiums applied during prequalification, including successful group of Orasqualia.

CHAPTER 3 FACILITIES PLANNING

3.1 Basis for Planning

3.1.1 Design Influent Characteristics of Abu Rawash WWTP

Influent wastewater characteristics, which flow into Abu Rawash WWTP in the past nine years from 2001 to 2009, are analyzed to determine design parameters. Figure 3.1 and Figure 3.2 show trends of monthly average and fluctuation of BOD and SS, respectively. Monthly averages of influent BOD concentration were nearly constant between 300 and 310 mg/l for six years from 2001 to 2006. However, monthly averages of influent BOD concentration were observed to suddenly change and fluctuate in a relatively wider range from 200 to 310 mg/l for the last two years from 2007 to 2009. Monthly averages of influent SS concentration show the same trend as those of BOD concentration. Monthly averages of influent SS concentration were observed to be nearly constant varying from 320 to 360 mg/l for six years from 2001 to 2006. However, monthly averages of influent SS concentration suddenly changed and fluctuated in a relatively wider range from 160 to 260 mg/l in the last two years from 2007 to 2009.

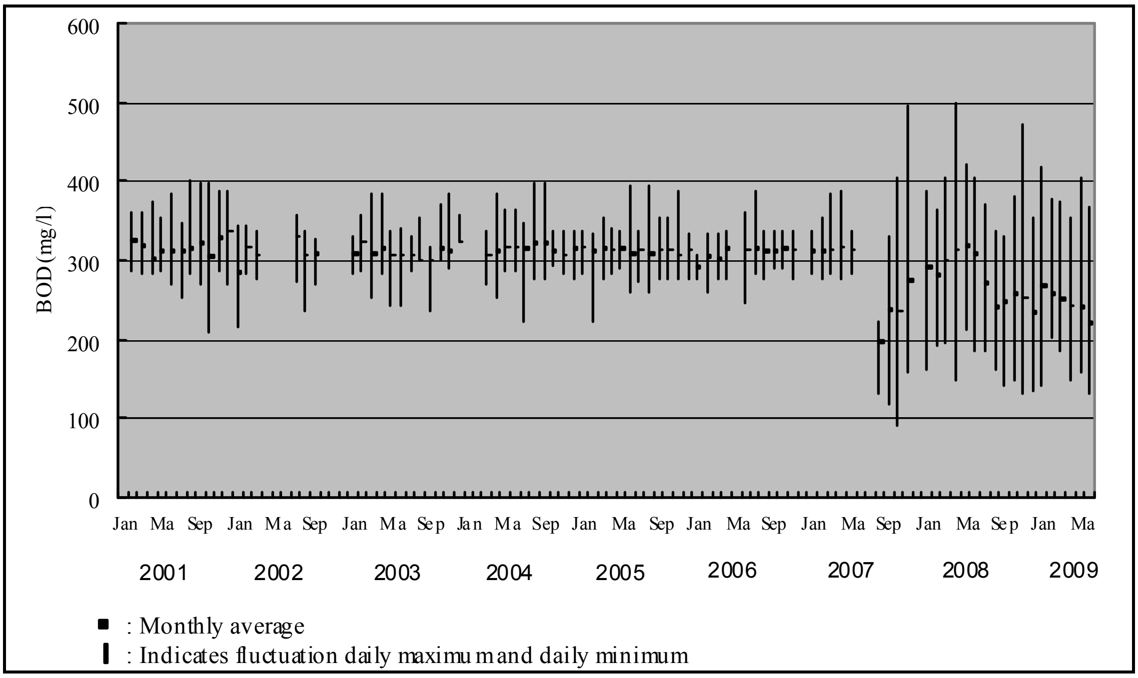


Figure 3.1 Influent BOD

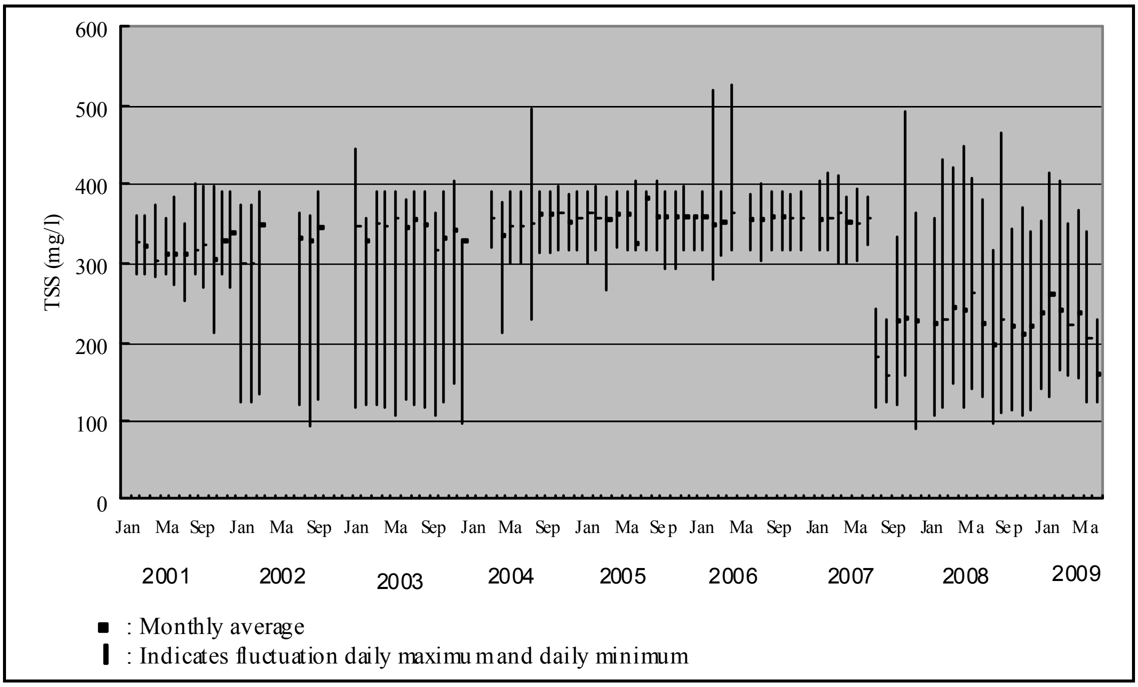


Figure 3.2 Influent SS

Since there is clear distinction in influent characteristics within a very short period, reasons for this have been investigated during site visits. It has been revealed that substantial amount of wastewater is diverted directly to El Beeny drain from South Muheit pump station on temporary basis of operation, which finally flows into the same drain as effluent from Abu Rawash WWTP. South Muheit pump station is one of the lift pump stations located on trunk sewer lines, which conveys wastewater collected from the northeast of West Bank service area to Abu Rawash WWTP. Abu Rawash WWTP cannot accommodate all wastewater due to the lack of hydraulic capacity of the existing effluent cannel. Hence, limited wastewater is directed to Abu Rawash WWTP and the excess flow is diverted directly to El Beeny drain at South Muheit pump station. There are two main trunk sewers to collect wastewater from its service area and to convey to Abu Rawash WWTP as show in Figure 3.3. One of trunk sewers, in which South Muheit pump station is located, is collecting wastewater generated from northeast part of West Bank, which consists of old downtown area where low income residents are dominant. The other one is collecting wastewater generated from south part of West Bank, which includes relatively newly developed areas of high income residents and luxury hotels. Concentration of wastewater characteristics generated from low income residential areas is supposed to be higher since residents consume less water due to their life style. Considering these facts, it has been concluded that diversion of highly loaded wastewater collected from northeast of West Bank results into decreased concentrations of BOD and SS.

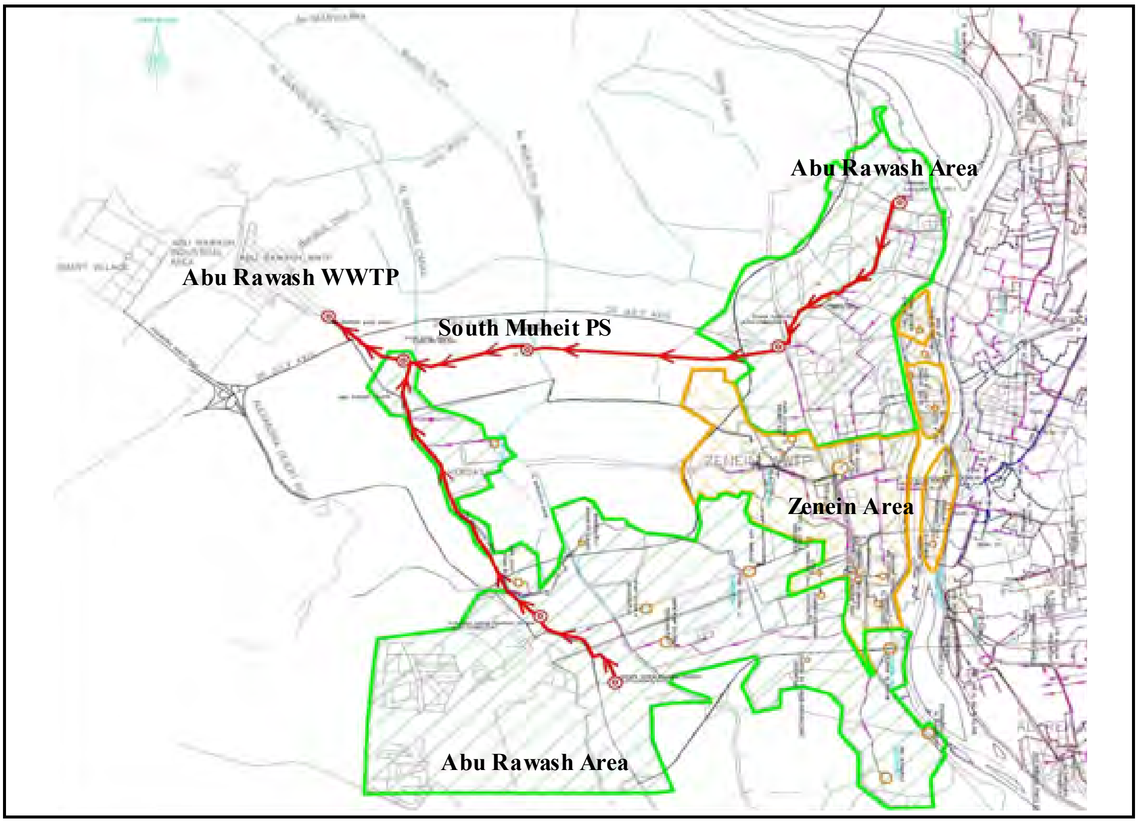


Figure 3.3 Sewerage System in West Bank Area

Once new primary treatment facility (0.8 million m^3/day) and related facilities are completed and start operating, Abu Rawash WWTP can accommodate all wastewater generated in its served area and the diversion would become unnecessary. Therefore, influent BOD and SS concentration is expected to return to the earlier level of 2001 to 2006. Design influent BOD and SS concentrations have been set as 310 mg/l and 360 mg/l, respectively, considering monthly average of the past six years recorded from 2001 to 2006.

3.1.2 Design Flow of Abu Rawash WWTP

Inflow into Abu Rawash WWTP and treated flow amount of the primary treatment in the past 6 years (from 2001 to 2006) are shown in Table 3.1. The average inflow amounting 0.65 million m^3/day in 2001 already reached to 0.85 million m^3/day in 2006.

Table 3.1 Average Flow to Abu Rawash WWTP

	2001	2002	2003	2004	2005	2006
Influent Flow (m^3/day)	650,000	650,000	678,182	700,000	754,273	850,000
Treated Flow (m^3/day)	398,707	400,000	400,000	400,000	400,000	406,532

Inflow into Abu Rawash WWTP has not been recorded since diversion started in 2007 and the current entire flow (including the currently diverted wastewater at South Muheit pump station) to Abu Rawash WWTP is not known. The current inflow is expected to increase substantially considering population growth in the recent years and is assumed to reach 1.1 million m^3/day considering rate of increase of inflow from 2001 to 2006.

Design capacity for this Project has been determined to be 1.2 million m^3/day considering the fact that the capacity of the primary treatment facilities after completion of the ongoing extension works would be 1.2 million m^3/day. However, according to development plan shown in Figure 2.2, inflow is projected to reach 1.2 million m^3/day in 2012, very near future. Hence, it is desirable to commence the next extension with a capacity of 0.4 million m^3/day immediately after this Project.

3.1.3 Mixed Sludge from Zenein WWTP

Mixed sludge coming from Zenein WWTP in the past three years from 2007 to 2009 is analyzed to determine design parameters. No data is available regarding sludge flow transferred from Zenein WWTP to Abu Rawash WWTP since there is no operational flow meter installed to measure flows. Hence, the transferred sludge volume is assumed as 10,000 m^3/day based on information collected during the site visits. Since, the O&M agency estimate this figure by calculating the capacity of transfer pumps and operation hours, this figure is reliable to some extent. The data on solids concentration of sludge is maintained in daily operation records. Dry solid amount of sludge can be calculated from sludge volume and its concentration, and is also estimated by mass balance calculation using inflow and characteristics, which are available in daily operation records. These figures of dry solid amount, which are estimated both from the records of actual operation and using theoretical calculation, have been compared so as to determine amount of generated sludge in the existing condition and to forecast in the future. Estimated figures from both calculations are summarized in Table 3.2. As observed in Table 3.2, estimated figures by mass balance calculation tend to be slightly higher. This tendency can be explained by the fact that accuracy of transferred sludge volume is less reliable since discharge rate of pumps varies according to actual operation head.

Table 3.2 Comparison of Dry Solid of Operation and Mass Balance Calculation

	Operation		Mass Balance Calculation				Operation /Mass Balance
	Concentration (%)	Dry Solid (kg/day)	Flow (m^3/day)	Influent BOD (mg/l)	Influent SS (mg/l)	Dry Solid (kg/day)	
2007	0.57	57,000	320,296	262	243	75,342	76 %
2008	0.69	69,000	325,738	252	241	75,415	91 %
2009	0.59	59,000	340,073	235	252	81,042	73 %

Since mass balance calculation is thought to be more reliable to estimate amount of sludge generation, dry solid amount generated in the future is forecasted by mass balance calculation to determine design parameters. Design amount of dry solid is estimated based on design figures of Zenein WWTP and shown in Table 3.3.

Table 3.3 Estimated Dry Solid at Zenein WWTP

Design Flow	Water Quality (Influent & Effluent)		Estimated Dry Solid
	BOD	SS	
330,000 m^3/day	300 mg/l	300 mg/l	96,504 kg/day
	< 30 mg/l	< 30 mg/l	

The solids concentration of sludge for transfer is to be less than 2.0 % considering the viscosity of sludge. The optimum solids concentration of sludge for long distance transfer is 1.0 % in terms of economical efficiency, operation and maintenance. In the current operation, generated sludge is diluted with treated wastewater prior to transfer. Hence, the solids concentration of sludge is set as 1.0 % in the future. Considering solids concentration and estimated dry solid, transferred volume of sludge remains the same as in case of the current operation. Characteristics of mixed sludge from Zenein WWTP to Abu Rawash are summarized in Table 3.4.

Table 3.4 Characteristics of Mixed Sludge from Zenein WWTP for Designing

Flow	Solids Concentration	Dry Solid
10,000 m^3/day	1.0 %	100,000 kg/day

3.2 Scope of the Project

3.2.1 Confirmation of the Priority Determined by CAPW

The full scale of development of Abu Rawash WWTP will require a large amount of capital investment and many years to complete since planned ultimate capacity is 2.0 million m^3/day. In general, such large projects become feasible in terms of implementation if they are implemented through several construction stages with appropriate development steps. Further, phased development is needed for determining realistic investment plan taking into account financial capability of Egyptian government or investment institutions.

CAPW, responsible agency, considers that protection of water quality of receiving drains and Nile River is the first priority and concerns the current condition that effluent from Abu Rawash WWTP is a main source which is contributing to the pollution of Nile River. In this regard, CAPW is implementing the expansion of primary treatment facilities with a capacity of 0.8 million m^3/day to accommodate current inflow, which is exceeding the existing capacity. Upon completion, which is already delayed by one year behind its schedule, the capacity of WWTP will become 1.2 million m^3/day. However, primary treatment does not satisfy required effluent standards. Therefore, the construction of secondary treatment facilities having treatment capacity of 1.2 million m^3/day is considered as the first priority.

Population in Greater Cairo is increasing rapidly and it will not take long time for wastewater inflow into Abu Rawash WWTP to exceed its capacity of 1.2 million m^3/day. Considering the implementation schedule of the first priority project presented in Table 3.26, the project can be expected to take 6 years to complete from signing of Loan Agreement. Immediately after the completion of the first priority project, it is expected to proceed with the expansion of its capacity to meet inflow quantity. Hence, the second priority goes to the expansion of sewage treatment facilities providing an additional capacity of 0.8 million m^3/day.

Sludge treatment facilities at the existing Abu Rawash WWTP site, which can treat sludge generated from 2.0 million m^3/day of Abu Rawash WWTP and 0.33 million m^3/day of Zenein WWTP, is considered as the third priority since the land for sludge lagoons, which is enough to treat sludge generated from 2.33 million m^3/day of sewage treatment, has been already acquired by HCWW. The priority determined by CAPW is summarized in Table 3.5.

Table 3.5 Priority Determined by CAPW

First Priority	Second Priority	Third Priority
Secondary treatment facilities (Capacity: 1.2 million m^3/day)	Primary and secondary treatment facilities (Capacity: 0.8 million m^3/day)	Sludge treatment facilities for Abu Rawash / Zenein WWTP (Abu Rawash: 2.0 million m^3/day) (Zenein: 0.33 million m^3/day)

3.2.2 Selection of Wastewater Treatment Process

Primary treatment process, which utilizes function of gravity settlement to remove pollution load, cannot achieve effluent standards of Egypt. Hence, introduction of secondary treatment process, which utilizes function of microbes to purify organic road, is required to satisfy effluent standards. Among various treatment processes, aerobic biological processes are considered as the most suitable for this purpose. Alternatives of biological treatment, which can be applied for sewage treatment, are summarized in Table 3.6 with their brief explanations.

Table 3.6 Alternatives of Biological Treatment Process

Alternatives	Explanation
Conventional Activated sludge process (CASP)	Conventional Activated Sludge Process is a suspended growth aerobic process. It requires primary clarification prior to biological treatment. Detention period in aeration tank is maintained usually 4-6 hours. Activated sludge and liquid are separated in secondary clarification after aeration tank.
Oxidation Ditch	Oxidation Ditch is a suspended growth aerobic process and operates at lower BOD-SS loading compared to CASP. It does not require primary clarification. Detention period of aeration tank is maintained 14-28 hours usually. It is mainly applicable to small scale plants.
Extended Aeration	Extended Aeration is a suspended growth aerobic process and operates at lower BOD-SS loading compared to CASP. It does not require primary clarification. Detention period of aeration tank is maintained 12-14 hours usually. Solid retention time is longer than CASP.
Sequential Batch Reactor	Sequential Batch Reactor is an aerobic process where raw sewage is treated in batches. It does not require primary clarification. Operation takes place in cycle order and biological process and sedimentation take place in one reactor. It is mainly applicable to small scale plants.
Aerated Lagoon	Aerated Lagoon is a completely mixed aerobic biological reactor without recycling. Overflow of aerated lagoon is sent to sedimentation basin. Since detention period is 3-4 days, lagoons require a very large area. Operation is simple but power consumption is high.
Waste Stabilization Pond	Waste Stabilization Pond treats sewage in a series of ponds. After screening sewage is fed to an anaerobic pond for initial pretreatment and then enters to an aerobic pond. Waste Stabilization Pond requires a very large area and it is normally used for small capacity plants.

Aerated Lagoon and Waste Stabilization Pond cannot achieve required effluent standards of Egypt since its removal efficiencies of BOD and SS cannot reach 90 %. Oxidation Ditch, Extended Aeration and Sequential Batch Reactor do not require primary clarification to reduce the organic load prior to biological reactor. Hence, the existing and ongoing primary treatment facilities would not be utilized if these processes are adopted. The merits and reasons to adopt conventional activated sludge process for secondary treatment are as follows.

- Required effluent standard can be achieved since more than 90 % of removal efficiencies of BOD and SS are expected.
- Sewage treatment facilities with a total capacity of 2.0 million m^3/day can be located within the existing WWTP site.
- Other WWTPs of large scale in Greater Cairo also adopt CASP and operation and maintenance technology is well established in Egypt.

- It is possible to design larger capacity for one series, which leads to higher efficient and economy of scale and easy operation.
- Utilization of the existing and ongoing primary treatment facilities is possible to reduce pollution load prior to secondary treatment.

3.2.3 Abu Rawash WWTP at Ultimate Stage

In JETRO F/S, the scope of the proposed project includes 1.2 million m^3/day of secondary treatment facilities and 1.53 million m^3/day of sludge treatment facilities which includes sludge from Zenein WWTP. Those planned facilities were located in the existing WWTP site. According to the priority of CAPW as shown in Table 3.5, the expansion of 0.8 million m^3/day of sewage treatment facilities will be implemented prior to sludge treatment facilities due to rapid population increase and current deficit of treatment capacity. Therefore, in this Study, total 2.0 million m^3/day of sewage treatment facilities are planned in the existing WWTP site and sludge treatment facilities are planned in the site adjacent to the existing WWTP considering the implementation order and ease of operation. The provision of sludge treatment facilities require approximately 48 ha (800 m x 600 m) of land and the most suitable site is in northwest of the existing WWTP, which already belongs to HCWW. General layout of the ultimate stage of Abu Rawash WWTP is shown in Figure 3.4. Facility planning and process calculation of ultimate stage is presented in Appendix-2.

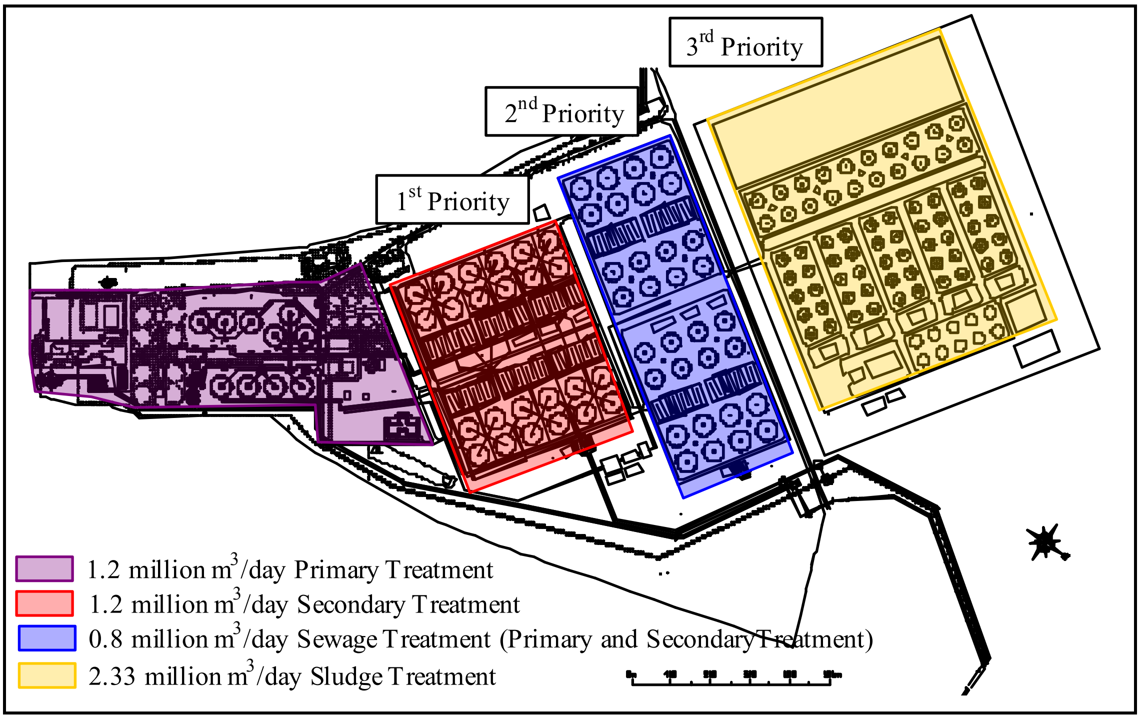


Figure 3.4 General Layout of Ultimate Stage of Abu Rawash WWTP

For the expansion of 0.8 million m^3/day of sewage treatment facilities, inlet chamber and coarse screen facility has been installed under the ongoing construction. Hence, facilities from lift pump to chlorination should be provided under second phase project. Further, effluent channel up to Abdel Rahman drain and three reversed siphons, which are located between Abu Rawash WWTP and Rosetta branch, are required to be newly constructed and/or augment its capacities since those capacities seem to be not enough for 2.0 million m^3/day flow.

Main power substation is planned to be installed in this Project including the required capacity for the future expansion of 0.8 million m^3/day of sewage treatment facilities as explained later. Emergency generators are proposed to be provided under this Project. These generators were not included in JETRO F/S since gravity thickener and anaerobic digester with digested gas generator system were proposed, but these are omitted from current project scope. Further, sewage treatment facilities, which separately treat side stream from sludge treatment facilities, will be required as explained later. Prior to the implementation, it is recommended that actual volume and characteristics of generated sludge be examined to grasp actual condition so as to optimize the facilities design when sludge treatment facilities are planned.

3.2.4 Secondary Treatment and Sludge Treatment

(A) Basic Planning of Secondary Treatment

Water qualities of both influent and treated effluent of the primary treatment in the past nine years from 2001 to 2009 are shown in Table 3.7.

Table 3.7 Average Removal Rate of BOD and SS

	BOD			SS		
	Influent (mg/l)	Effluent (mg/l)	Removal Rate (%)	Influent (mg/l)	Effluent (mg/l)	Removal Rate (%)
2001	317	112	65	408	89	77
2002	302	122	61	324	91	72
2003	310	114	64	340	101	70
2004	314	114	64	352	98	71
2005	312	106	66	357	102	72
2006	309	105	66	355	102	71
2007	275	128	51	281	108	57
2008	273	157	42	227	96	55
2009	295	122	58	318	98	67

According to the priority of CAPW, sludge treatment facilities will be implemented in the last phase of development of Abu Rawash WWTP and expected to take considerable time after completion of this Project. If it assumed that sewage treatment facilities of this Project receive side stream from future sludge treatment facilities, design pollution load of treatment facilities increase considerably due to contribution of side stream since sludge treatment facilities generate highly loaded discharge. Taking into account the lifetime of equipment, it is planned that side stream is not considered at present for this Project. Treatment facilities for side stream will be considered together with sludge treatment facilities.

As explained before, there is clear distinction regarding removal ratios of BOD and SS owing to the change of influent qualities since 2007. Since current diversion is temporary, the characteristics of influent and removal ratios is expected to resume to the previous level once Abu Rawash WWTP receives all wastewater after the completion of ongoing construction. Hence, removal ratios before 2006 have been analyzed to determine removal efficiencies for designing purpose. As shown in Table 3.7, BOD and SS of primary effluent from 2001 to 2006 were stable in the ranges between 105 and 122 mg/l for BOD and between 89 and 102 mg/l for SS, respectively. Average of BOD and SS removal ratios during the same period were as high as 64% and 72%, respectively, which is relatively high owing to the regularized flow into primary treatment facilities. Actual flow into treatment facilities inevitably varies on daily and hourly basis, but in the current operation the constant flow is introduced to primary sedimentation tanks by bypassing excess amount of flow. By increasing its capacity and treating all flow, daily and/or hourly flow fluctuation is expected to reduce the treatment efficiencies. Therefore, removal efficiencies of BOD and SS are assumed to be 50 % and 60%, respectively, to be on the safe side for designing purposes.

Effluent standard stipulated by Decree 8 (1983) requires effluent BOD and SS of less than 60 mg/l and 50 mg/l, respectively. However, current plan sets both effluent BOD and SS to be less than 30 mg/l taking the future effluent reuse into account. Design parameters for the secondary treatment facilities of Abu Rawash WWTP are summarized in Table 3.8.

Table 3.8 Design Parameters for Wastewater Treatment

No.	Item	Values	Remarks
1.	Flow Rate and Raw Sewage Characteristics		
1-1	Daily Average	1,200,000 m^3/day	
1-2	Peak Flow	1,800,000 m^3/day	Daily Avg. ×1.5
1-3	BOD (Raw Sewage)	310 mg/l	
1-4	SS (Raw Sewage)	360 mg/l	
2.	Design Values and Removal Ratio		
2-1	BOD (to Primary Tank)	310 mg/l	
2-2	BOD (to Aeration Tank)	155 mg/l	
2-3	BOD Removal Ratio (Primary Treatment)	50 %	
2-4	BOD Removal Ratio (Secondary Treatment)	85 %	

No.	Item	Values	Remarks
2-5	BOD Total Removal Ratio	93 %	
2-6	SS (to Primary Tank)	360 mg/l	
2-7	SS (to Aeration Tank)	144 mg/l	
2-8	SS Removal Ratio (Primary Treatment)	60 %	
2-9	SS Removal Ratio (Secondary Treatment)	85 %	
2-10	SS Total Removal Ratio	94 %	
3.	Treated Effluent		
3-1	BOD	23 mg/l	
3-2	SS	22 mg/l	

(B) Basic Planning of Sludge Treatment

Amount and concentration of generated sludge for the sludge treatment facilities is calculated based on above prerequisites and mass balance calculations and is summarized in Table 3.9.

Table 3.9 Volume and Solids Concentration of Generated Sludge

No.	Item	Dry Solid	Volume	Solids Concentration
1.	Abu Rawash WWTP			
1-1	Primary Sludge	259,200 kg/day	12,960 m^3/day	2.0 %
1-2	Excess Sludge	180,459 kg/day	30,076 m^3/day	0.6 %
2.	Zenein WWTP			
2-1	Mixed Sludge	100,000 kg/day	10,000 m^3/day	1.0 %

3.3 Concept of Facilities Planning

CAPW expects to introduce reliable technologies in order to enable steady and secured treatment for a large scale WWTP such as Abu Rawash WWTP. At the same time, CAPW expects to introduce technologies that would result in resource saving and energy saving from the view point of sustainability, the ideas that have not been considered well so far. Concepts adopted for facility planning are summarized below.

- Consideration of life cycle cost including initial investment, costs for operation & maintenance and replacement
- Utilization of the existing facilities such as sludge transfer facilities and lagoons
- Stable and easy operation by introducing necessary backup and automation by SCADA system and instrument
- Total energy saving by introducing highly efficient technology, optimizing operation and minimizing hydraulic loss
- Consideration of environmental and social impact

3.3.1 Sewage Treatment Facilities Planning

(A) Optimization of Grouping Secondary Treatment Facilities

In JETRO F/S, the scope of the project was secondary treatment facilities with a capacity of 1.2 million m^3/day and sludge treatment facilities with a capacity of 1.53 million m^3/day. Secondary treatment facilities were planned to be composed of three series of 0.4 million m^3/day considering layout within the existing WWTP site coordinating with 1.53 million m^3/day of sludge treatment facilities. However, in this Study, 2.0 million m^3/day of sewage treatment facilities are planned to locate in the existing WWTP site as explained earlier. Hence, grouping of secondary treatment facilities is reviewed so as to optimize array and operation of facilities. Six series of secondary treatment facilities and four series of future sewage facilities, in which each series has 0.2 million m^3/day capacity, is recommended considering space saving, less hydraulic loss and systematic operation. Primarily treated water from the exiting 0.4 million m^3/day and ongoing 0.8 million m^3/day is separately treated in two series and four series of secondary treatment facilities, respectively. The secondary treated water is merged prior to chlorination tank and then conveyed to Barakat drain. Grouping of sewage treatment facilities at Abu Rawash WWTP is shown in Figure 3.5.

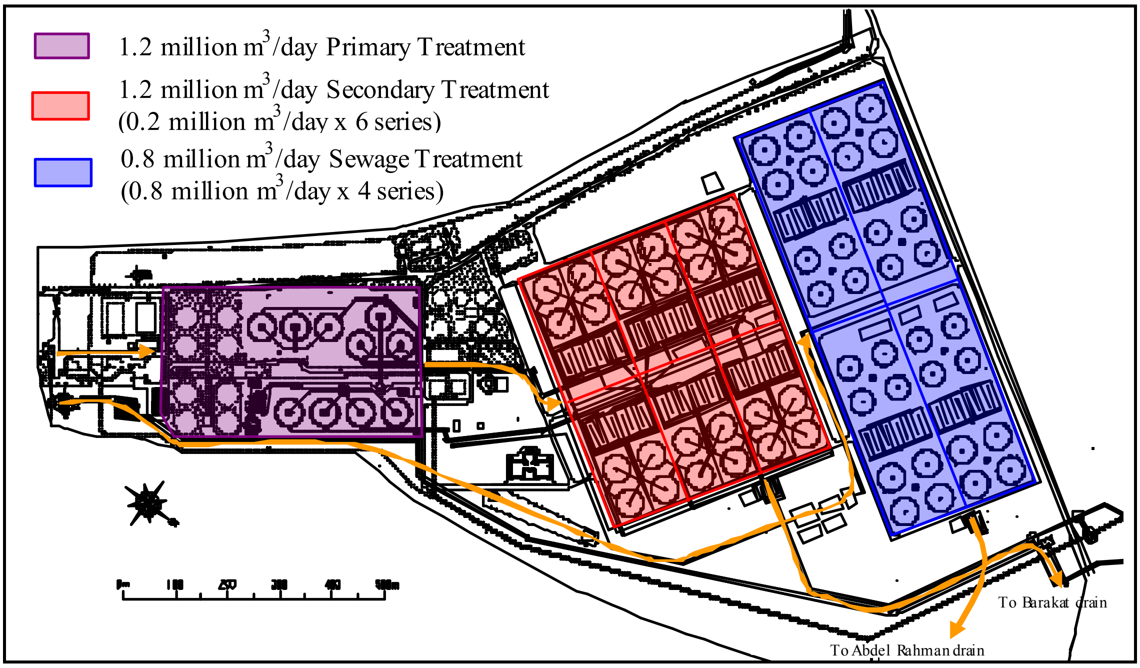


Figure 3.5 Grouping of Sewage Treatment Facilities

(B) Hydraulic Profile Planning

Hydraulic profile has been planned so as to set the secondary treatment facilities between the exiting / ongoing primary treatment facilities and Barakat drain. The following concepts are adopted for planning of hydraulic profile.

- Propose the third effluent channel to avoid new effluent pump facility
- Propose distribution tank with weirs to provide even flow to aeration tanks
- Propose distribution tank with weirs to provide even flow to final settling tanks
- Free weirs are adopted generally so as not to be affected by downstream condition, but submerged condition is allowed at outlet weir of chlorination tank to reduce overall head loss at peak flow condition, although the effect of Barakat drain is considered to reach chlorination tank only

Hydraulic conditions are summarized in Table 3.10. Detailed calculation of hydraulic profile planning is presented in Appendix-3.

Table 3.10 Conditions of Hydraulic Planning

Item	Water Level	Location
Connection level with ongoing expansion of primary treatment facilities	+ 20.79 m	Chamber # 39
Connection level with existing primary treatment facilities	+ 21.10 m	Discharge chamber of Lift pump
High water level of Barakat drain (Peak factor is 1.5)	+ 16.50 m	Start point of Barakat drain

Hydraulic profile is shown in Figure 3.6 including connecting points with the existing facilities, ongoing facilities and Barakat drain. Provision of the secondary treatment facilities increases hydraulic loss. As a result, additional effluent channel up to Barakat drain, with the dimension of W3.0 m x D3.0 m, is to be newly constructed to accommodate design capacity of flow satisfying above conditions.

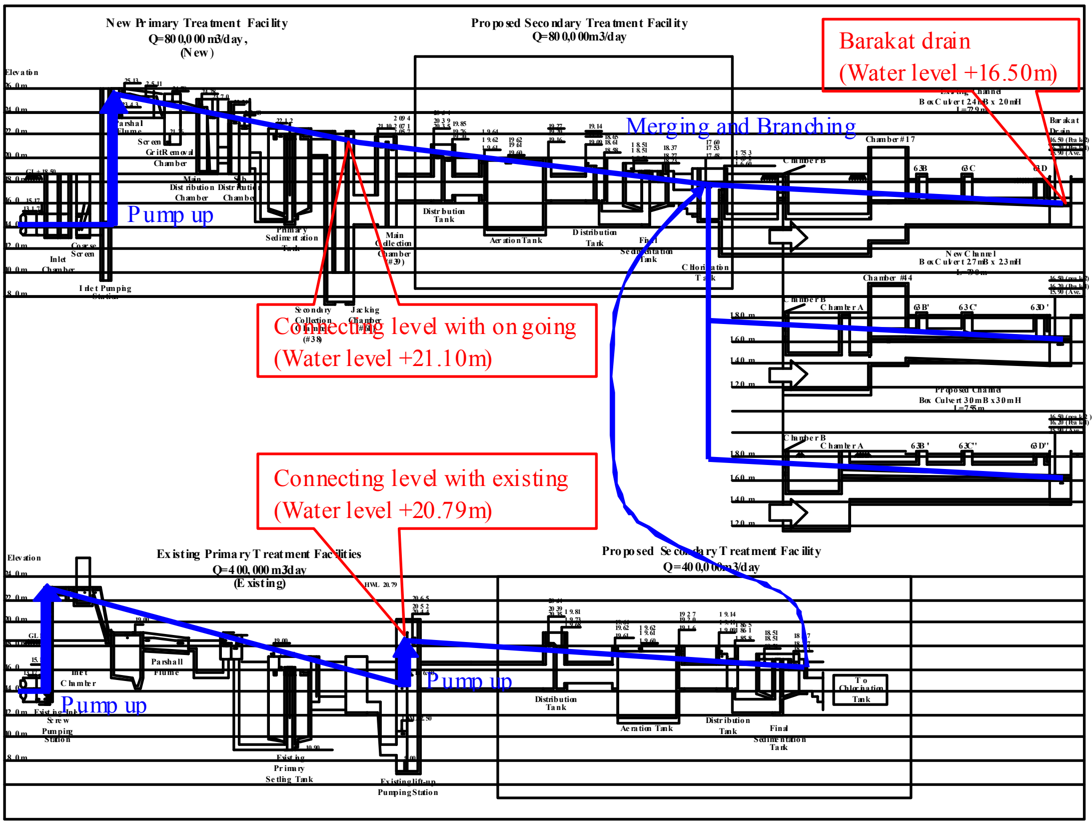


Figure 3.6 Hydraulic Profile Planning

(C) Alternative of Aeration Equipment

Removal of pollution load in activated sludge process is carried out by the action of microbes that are present in activated sludge. Activated sludge removes pollution load by absorption, ingestion, oxidization and elaboration in the presence of appropriate amount of oxygen. Therefore, aeration device that supplies oxygen to activated sludge and mixes wastewater and activated sludge, is vital for sewage treatment.

In diffuser method, airlift function is used by injecting air supplied from blowers in shape of fine bubbles into sewage in order to supply oxygen and mixing at the same time. On the other hand, mechanical mixing method makes use of the pumping function and mixing function by rotating blades in sewage in order to supply oxygen.

Aeration device consumes significant portion of total electricity used in sewage treatment. In addition, its role is vital in activated sludge process. Therefore, aeration method should be selected considering all factors regarding the efficiency of dissolving oxygen, economical aspect, operation and maintenance, etc. In Egypt, mixing type of mechanical aeration device has been common so far due to factors such as easy maintenance and low initial cost. Fine bubble diffuser device was initially introduced in aeration facilities of

Stage 2 of Al-Gabal Al-Asfer WWTP, which has been operative since 2006. In this Project, the application of ultra fine bubble diffuser device, which is more effective than fine bubble diffuser device, is considered. The candidates considered for comparison of aeration method are shown below and the comparison of aeration method is described in the following paragraphs and in Table 3.11.

	Options of Aeration Method
Case 1	Fine bubble diffuser device (Spiral flow type)
Case 2	Fine bubble diffuser device (Whole area differed type)
Case 3	Ultra fine bubble diffuser device (Whole area differed type)
Case 4	Mechanical aeration device (Mixing type)
Case 5	Mechanical aeration device (Submerged aeration type)

Case 3 Ultra fine bubble diffuser device (Whole area differed type) is recommended due to the following factors.

- It is most effective in terms of energy saving due to its high efficiency of dissolving oxygen.
- It can be utilized for relatively longer time due to its non-clogging feature by adequate operation.
- It has high level of flexibility for various operations due to its feature of wide operational range of air flow.
- It is the most economical in terms of life cycle cost since it requires the lowest O&M cost due to its high efficiency.

Table 3.11 Comparison of Aeration Method

	Case 1	Case 2	Case 3	Case 4	Case 5
Aeration device	It is shaped drum or board made of uniform particles of ceramic or synthetic resin and produces fine bubbles.	It is placed in whole area of aeration tank with fine bubble diffuser device so as to improve its efficiency.	It is membrane made of synthetic resin sheet fixed to the plate with fine aperture and produces ultra fine bubbles.	It constitutes motor above the water and blades below the water and supply oxygen by using pumping and mixing function.	It constitutes submerged driving device with motor and blades mixing and breaking up air supplied from blower.
Efficiency	Efficiency (15-18%) is inferior to ultra fine device / its whole area diffuser type and superior to mechanical mixing device.	Efficiency (20-32%) is slightly inferior to ultra fine device and superior to its spiral flow type and mechanical aeration.	Efficiency (25-35%) is the highest and its energy saving effect is considerable.	Efficiency is the worst and it consumes more electricity than diffuser method.	Efficiency (20-30%) is slightly inferior to ultra fine device but it additionally requires electricity for aerator.
Maintenance	It requires periodical replacement within 5-10 years due to clogging from aged deterioration.	It requires periodical replacement within 5-10 years due to clogging from aged deterioration.	It does not require periodical change by appropriate operation due to its structural feature.	It requires periodical maintenance such as greasing of above water actuator and rotating blades.	It requires periodical maintenance such as greasing of submerged aerator and rotating blades.
Experience in Egypt	Experience in Egypt is recent and there is concern about replacement cost in the near future.	Experience in Egypt is recent and there is concern about replacement cost in the near future.	There is no experience of its use yet in Egypt but it can be covered by OJT. Effect of reducing O&M cost is considerable.	Widely used in Egypt but energy consumption is a problem due to its low efficiency.	There is no experience of its use yet in Egypt but it can be covered by OJT.
Initial cost	LE 186.1 million (90)	LE 228.3 million (110)	LE 207.8 million (100)	LE 141.3 million (68)	LE 238.9 million (115)
Repayment O&M cost Lifecycle cost	10.8 million LE/year 10.1 million LE/year 21.0 million LE/year (107)	14.1 million LE/year 8.2 million LE/year 22.3 million LE/year (114)	13.1 million LE/year 6.5 million LE/year 19.6 million LE/year (100)	9.4 million LE/year 13.4 million LE/year 22.8 million LE/year (116)	14.8 million LE/year 13.5 million LE/year 28.3 million LE/year (144)
CO_2 Emission Reduction	5,046 ton/year (39)	9,983 ton/year (78)	12,875 ton/year (100)	0 ton/year (0)	2,152 ton/year (17)

For introduction of ultra fine diffuser device, which has not been installed in Egypt, the following attention related to operation and maintenance is required. Membrane made of synthetic resin sheet is fragile against heat, ultraviolet radiation and physical shock. Hence, it is required that tanks are kept filled with water so as to keep the membrane always under water level even in cases when its operation is stopped and tank are drained after installation. Adherence of slimes to membrane causes its efficiency to worsen considerably. In case of adherence of slimes, slimes can be removed by stop and open blowing repeatedly. This handling can be done automatically at regular intervals by installing control panel and results in maintaining its high efficiency. Taking into account of proper operation of Stage 2 of Al-Gabal Al-Asfer WWTP, in which fine bubble diffuser device has been installed and operated, it is expected that ultra fine diffuser device will be also properly managed by on-the-job training during commissioning stage. Effect of energy saving by introducing high efficiency technology to a large scale of sewage treatment facilities such as Abu Rawash WWTP is extensive.

(D) Optimization for Blower System

As explained before, aeration consumes significant portion of total electricity used in sewage treatment facilities. Hence, efficiency of aeration equipment is vital for total electricity consumption of WWTP. Air to aeration equipment is supplied by blowers, so efficiency of bower system is also important for saving energy. Efficiency of blower itself is similar since machine technology is well established. However, it can make difference on reducing electricity consumption to supply required amount of air without excessive daily operation. Hence, it is vital how to control flow to aeration equipment. Required amount inevitably varies on the daily and hourly basis according to inflow and pollution load of wastewater. Therefore, blower system should be selected considering all influencing factors such as the efficiency, economical aspect, operation and maintenance as a system, etc. The options considered for comparison of blower system are listed below and the comparison of blower system is described in the following paragraphs and in Table 3.12.

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<tr><th></th><th>Options of Blower System</th></tr>
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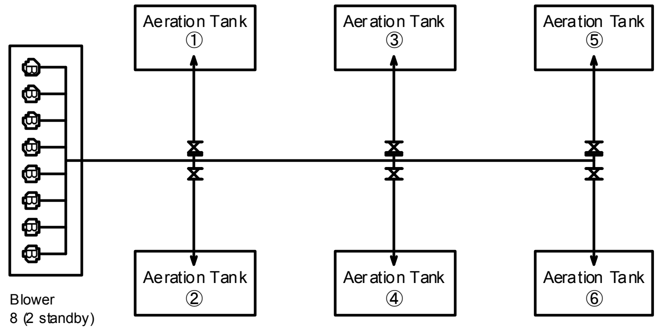
Centralized system with one blower building</td><td>
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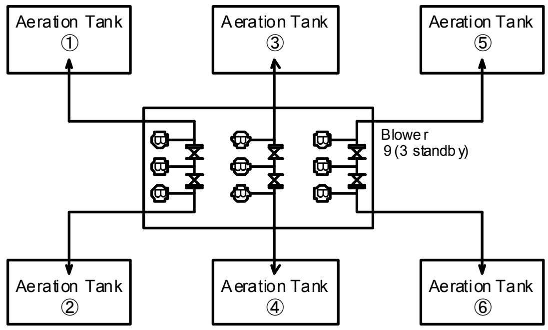
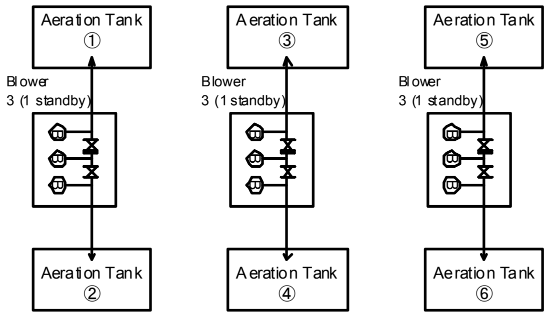
Decentralized system with one blower building</td><td>
</td></tr>
<tr><td>Case 3
Decentralized system with three blower buildings</td><td>
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Case 2 Decentralized system with one blower building is recommended due to the following factors.

- Flow control to each aeration tank is much easier since blowers can control flow separately. Flow control is difficult in centralized system since flow to each tank is affected by others.
- Energy saving is expected from high accuracy of flow control.
- Replacement and renovation of blowers is easy since the blowers are operated separately for each sewage treatment series. Aeration depth and type of aeration is optional owing to not being influenced by other series at replacement and renovation.
- Operation and maintenance of blowers is easier since blowers are centralized in the same building.

Table 3.12 Comparison of Blower System

	Case 1	Case 2	Case 3
Concept	Air is supplied to each aeration tank by branching from main header pipeline. All blowers are connected to main header pipeline and installed in the same building.	Air is supplied to each aeration tank separately from any blower in series. All blowers are gathered and installed in the same building.	Air is supplied to each aeration tank separately from any blower in series. Blowers are separately installed in three building to reduce length of pipeline.
Flow control	Flow control is relatively difficult since flow to each tank affects others due to common header pipeline.	Flow control is relatively easy since air is controlled to each aeration tank separately from any blower in series.	Flow control is relatively easy since air is controlled to each aeration tank separately from any blower in series.
Operation and maintenance	It has advantage on operation and maintenance since all blowers are gathered in the same place.	It has advantage on operation and maintenance since all blowers are gathered in the same place.	It has disadvantage on operation and maintenance since blowers are distributed in three places.
Initial cost	LE 113.1 million (93)	LE 122.2 million (100)	LE 129 million (106)

Inlet flow control mechanism of blowers, which can control flow by changing angle of inlet blade, is introduced to improve accuracy of flow control and avoid energy loss.

3.3.2 Electrical Facilities Planning

(A) Power Substation System

Power substation in the WWTP site has function to receive high voltage of electricity from Cairo Electricity Production Company and distribute electricity to load facilities after transforming to adequate voltage for each load facility. The existing power substation facilities and connected load facilities are summarized in Table 3.13 and Table 3.14, respectively.

Table 3.13 Exiting Power Substation Facilities

Item	Specification
Receiving voltage	66 kV
Capacity of the existing power receiving and transforming equipment	26.6 MVA x 2 sets (duty) 20.0 MVA x 1 set (standby)
Number of lead in line	6 lines (3 duty / 3 standby)

Table 3.14 Exiting Connected Load Facilities

Item	Specification
Inlet pump station	2.0 MVA x 2 lines
Lift pump station	3.0 MVA x 2 lines
Sludge pump station	4.5 MVA x 2 lines
Middle voltage distribution station	10.7 MVA x 2 lines

Middle voltage distribution station, which is under construction for the expansion of primary treatment facilities with a capacity of 0.8 million m^3/day, has excess capacity for lift pumps of future expansion of sewage treatment facilities with a capacity of 0.8 million m^3/day. In this Project, new power substation is required since the existing substation does not have enough capacity for proposed facilities and also there is no possibility to expand its capacity. New power substation is planned to have required capacity for secondary treatment facilities with a capacity of 1.2 million m^3/day and future expansion of sewage treatment facilities with a capacity of 0.8 million m^3/day since the expansion is required soon after completion of this Project. However, the required capacity for sludge treatment facilities is not included since timing of the implementation has not been decided and also required capacity is uncertain at present. Key one line diagram including the existing, ongoing, this Project and future expansion is shown in Figure 3.7.

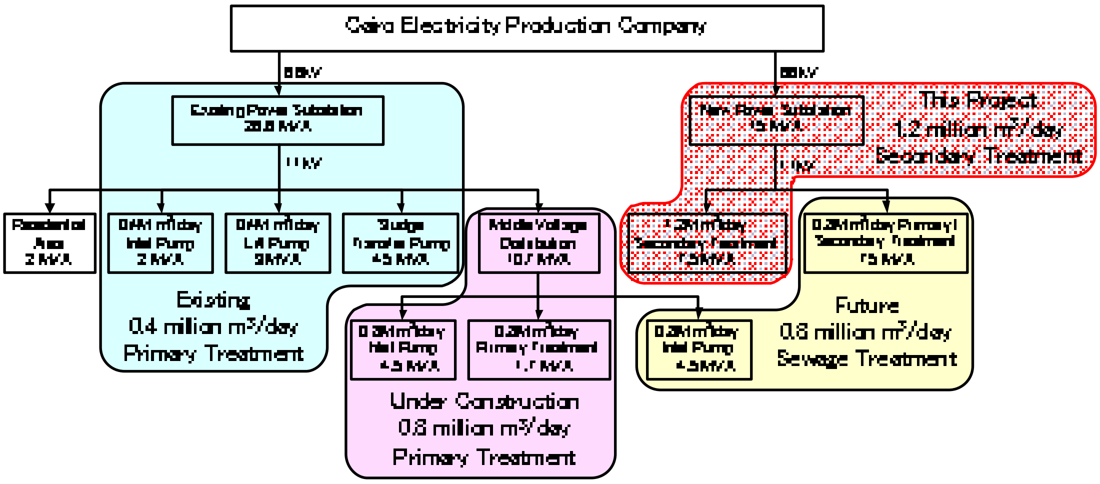


Figure 3.7 Key One Line Diagram

(B) Supervision Control System

Supervision control system is equipment that monitors and controls operation of plant and processes the operation information effectively. It consists of digital control device, operation control device, monitoring device, and data processing device. Therefore, supervision control device is key part of equipment to operate and manage whole of wastewater treatment plant. The application of supervisory control system should be decided considering factors such as the scale of WWTP, administrative structure, technical level of staffs and economical aspect.

Abu Rawash WWTP is regarded as a large scale WWTP since it is proposed to consist secondary treatment facilities having capacity of 1.2 million m^3/day. Therefore, introduction of SCADA (Supervisory Control and Data Acquisition) System is recommended in order to establish central control room in the administration building for effective and rational operation, monitoring, control, collection and analysis of data for a large scale WWTP. As a result of introduction of SCADA, following advantages are expected.

- To improve quality and efficiency of wastewater treatment and reduce workload
- To reduce operation cost by labor saving and energy saving
- To improve and stabilize process through appropriate operation
- To understand characteristics of process better by collecting and analyzing data

PLC (Programmable Logic Controller) monitoring system in local areas and optical cable network is installed in order to cope efficiently and promptly with a great deal of data from SCADA system. It enables controlling operation of equipments both from local areas by PC and from administration building by operation device of SCADA System. By using this, it is possible to adjust control parameter such as PID and timer setting from operation device of SCADA system of administration building in order to be flexible toward fluctuation of quality and quantity of influent wastewater. Furthermore, trend of water quality on each process and operation hour of equipment are displayed on PC. It enables to improve safety and smooth operation by alarming in case if monitored parameters exceed the set levels.

Better visibility than graphic panel can be expected if pictures produced by PC are displayed on 100 inch high resolution screen. Also, easy operation and better applicability can be expected, because real time response on PC display can be carried out.

Monitored and controlled items for better understanding of process state at each stage and operation state of facilities and equipments are listed in Table 3.15.

Table 3.15 Monitored and Controlled Items of SCADA System

Major division	Minor division	Individual item
Display of operation states	On / Off of machinery	On / Off, Open / Close
	Operation place	Center / Local, Remote / Field
	Mode of operation	Auto / Manual, Interlock / Single
	Failure of machinery	Failure and breakdown of machinery Abnormal process status

Major division	Minor division	Individual item
Display of instrumental value	Instrumental value of power receiving and transferring, and process treatment	Voltage, Current, Electricity, Phase factor, Level, Pressure, Flow, Chemical, Density, DO, MLSS, etc.
Control and operation	Operation items	On / Off of main machinery, Emergency stop, Selection of operation mode
	Setting items	Setting and adjustment of operation parameters on each process (target value, operation hour, operating sequence, controlled parameter, alarm setting and etc)
Report and record	Instrumental value of power receiving and transferring, and process treatment	Trend (daily, monthly and yearly), Record of Instruments
	Failure and operation status	Record of failure and operation by printer

(C) Generator System

Facilities in WWTP are generally operated by using electricity supplied from the national grid. Power failure sometime happens, 3-5 times in a year on average even though occurrence in Cairo is relatively rare comparing other rural cities in Egypt. Further, periodical power shut down is required for maintenance of power substation. Generators are planned for keeping minimum function of WWTP and avoiding any disaster during power failure. The capacity of generators is calculated based on the following concepts and specifications of required generators are shown in Table 3.16.

- Capacity required for inlet pumps, which can lift peak flow, is included to prevent submergence of facilities and damaging equipment.
- Capacity required for disinfection equipment is included to assure safety of effluent from WWTP
- Capacity required for minimum treatment and maintaining of function such as operating of blowers to keep activated sludge alive and preventing aerator devices from clogging.
- Capacity required for administration building such as monitoring system and utilities of office.

Table 3.16 Specification of Generators

	Specification
Engine	Diesel engine
Type	Three-phase alternate current generator
Capacity	3,500 kVA
Voltage	3,300 V
Number	2 nos.

3.3.3 Sludge Treatment Facilities Planning

(A) Sludge Transfer Facilities

One of the principles of sewage treatment is to treat sludge produced from wastewater treatment stably and efficiently on a permanent basis. At present, the primary sludge generated from the primary treatment of Abu Rawash WWTP having 0.4 million m^3/day capacity and mixed sludge of Zenein WWTP having 0.33 million m^3/day capacity are mixed, conveyed to the desert area 35 km away from Abu Rawash WWTP and treated by sludge lagoons. Once ongoing expansion of primary treatment and planned facilities in this Project are operational, amount of generated sludge on dry solid basis will be expected to increase by approximately 2.7 times of current generation owing to additional primary sludge from primary treatment with 0.8 million m^3/day capacity and excess sludge from secondary treatment with 1.2 million m^3/day capacity.

CAPW puts the priority on sewage treatment in order to reduce adverse impact of discharge from WWTP on qualities of water body. Since their budget is limited and rapid development is required to catch up with the rate of wastewater generation, CAPW has strong intention to utilize the existing facilities of sludge transfer and sludge lagoons to treat sludge generated form proposed facilities in this Project. Further, HCWW has already acquired enough space of land for the future expansion of Abu Rawash WWTP.

Taking the above into considerations, the capacity of existing sludge transfer facilities is evaluated whether they can accommodate additional amount from this Project or require improvement or modification. The conditions of evaluation are summarized in Table 3.17. The capacity of existing facilities is calculated using Hazen – William formula by modifying with sludge viscosity.

Table 3.17 Conditions of Sludge Transfer

Item	Value / Remark
Total dry solid	539,659 kg/day (mass balance calculation)
Total flow	53,036 m^3/day
Concentration	1.0%
Existing sludge transfer pump	Q22.8 m^3/min x H75-85m x 450 kW x 2 nos. x 2 series (Two pumps are directly connected)
Existing pipeline	DCIP diameter 800mm x 35km
Hydraulic calculation	Hazen – Williams formula / C value = 110
Coefficient	1.11 (sludge viscosity)

Figure 3.8 shows pipeline profile from Abu Rawash WWTP to sludge lagoon with

calculated hydraulic gradient. As shown in Figure 3.8, hydraulic gradient is always higher than pipeline profile at any location of pipeline alignment. Hence, it has been confirmed that the existing facilities of sludge pumps and pipeline has enough capacity for additional amount of sludge generated from secondary treatment facilities. However, the installation of one series of pumps is required as standby since two series of the existing pumps are required to convey all sludge. In the existing sludge pump building, there are spaces for four series, of which two has been already occupied. Hence, additional series of pumps can be installed in the available spaces of the existing sludge pump building.

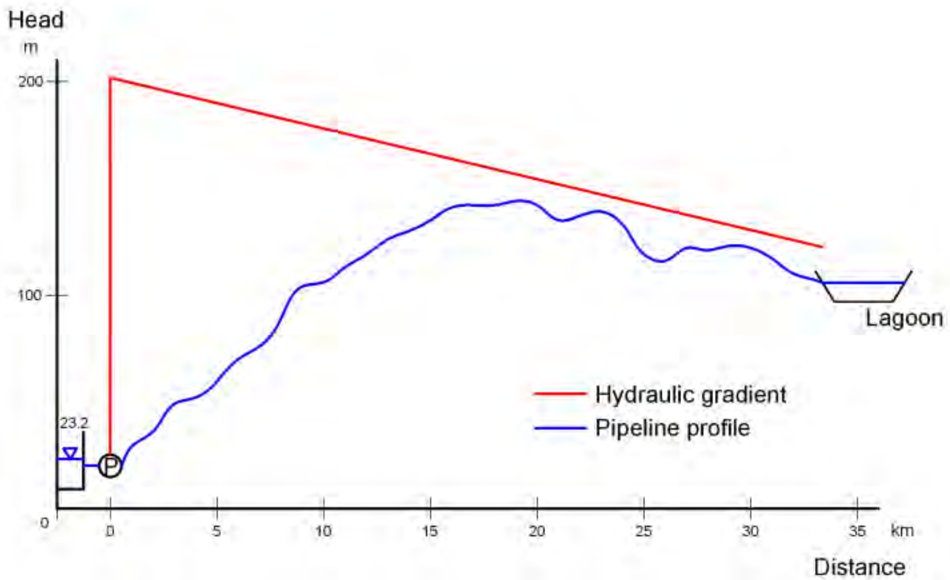


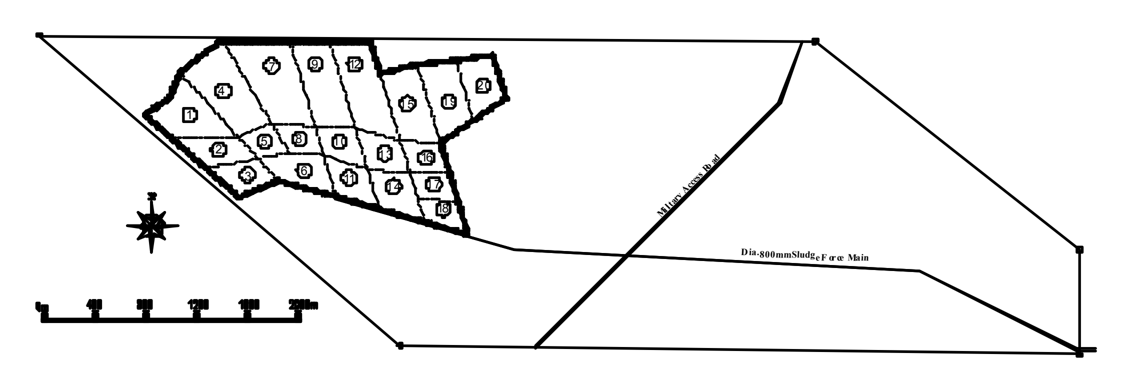
Figure 3.8 Hydraulic Gradient with Pipeline Profile

(B) Sludge Lagoon

Required drying period of sludge lagoons is significantly affected by climatic and physical characteristics of location such as temperature, humidity, sunlight, wind and permeability of soil. Hence, experience of actual operation of the existing sludge lagoons has been analyzed to set up required drying period for designing purpose. Since there is no operation record, information of operation has been obtained from site visits. Current operation and area of the existing sludge lagoons are shown in Table 3.18 and Figure 3.9, respectively.

Table 3.18 Current Operation

Item	Value
Depth of sludge	0.5 m
Drying period in summer	25 days
Drying period in winter	40 days



1	16.6 ha	5	4.9 ha	9	19.7 ha	13	8.4 ha	17	5.6 ha
2	8.8 ha	6	11.1 ha	10	7.9 ha	14	8.9 ha	18	5.5 ha
3	8.2 ha	7	26.4 ha	11	8.3 ha	15	16.3 ha	19	16.1 ha
4	23.6 ha	8	5.7 ha	12	21.2 ha	16	6.5 ha	20	11.8 ha
Total = 241.5 ha									

Figure 3.9 Area of the Existing Sludge Lagoons

Sludge volume transferred to sludge lagoons in the past three years from 2007 to 2009 is estimated by summing volumes of mixed sludge from Zenein WWTP and of primary sludge from Abu Rawash WWTP, which is maintained in daily operation records. Based on estimated total sludge volume and drying periods of current operation, required area of sludge lagoons is calculated as shown in Table 3.19.

Table 3.19 Sludge Volume and Required Area of Sludge Lagoons

Year	Sludge volume (m^3/day)	Required area in summer (ha)	Required area in winter (ha)	Required area on average (ha)
2007	15,368	76.8	122.9	99.9
2008	21,155	105.8	169.2	137.5
2009	20,820	104.1	166.6	135.3
Average	19,114	95.6	152.9	124.2

According to the information obtained during site visits, roughly half of lagoons are utilized even though the number of operating sludge lagoons varies by the season. Average required area corresponds to the half of the existing sludge lagoon area, which is half of 241.5 ha. Maximum required area in winter is calculated to be approximately 170 ha, which is much less than existing area. Four lagoons of No.7, No.15, No.19 and No.20 are not utilized yet and total area is 70.6 ha. Hence, calculated required area corresponds to 170.9 ha of total area of utilized lagoons. Taking into account above confirmation, required drying periods can be set as 25 days in summer and 40 days in winter for designing purpose.

Once 1.2 million m^3/day of secondary treatment facilities are operational, total amount of generated sludge is expected to increase to 53,036 m^3/day by mass balance calculation, which is approximately three times of the current amount on volume basis. Required area of sludge lagoon is estimated as 265 ha in summer and 424 ha in winter based on drying periods and sludge generation. Hence, the expansion of 183 ha of sludge lagoon is required in order to accommodate increased sludge generated from secondary treatment facilities. The location of expansion of sludge lagoon is proposed within area reserved for future expansion under CAPW planning. This location was chosen avoiding negative impact as much as possible considering that the direction of regular wind is from north to south in most of seasons and development occurs mainly in the northern side of sludge lagoon. Expansion of sludge lagoons with the existing sludge lagoons is shown in Figure 3.10.

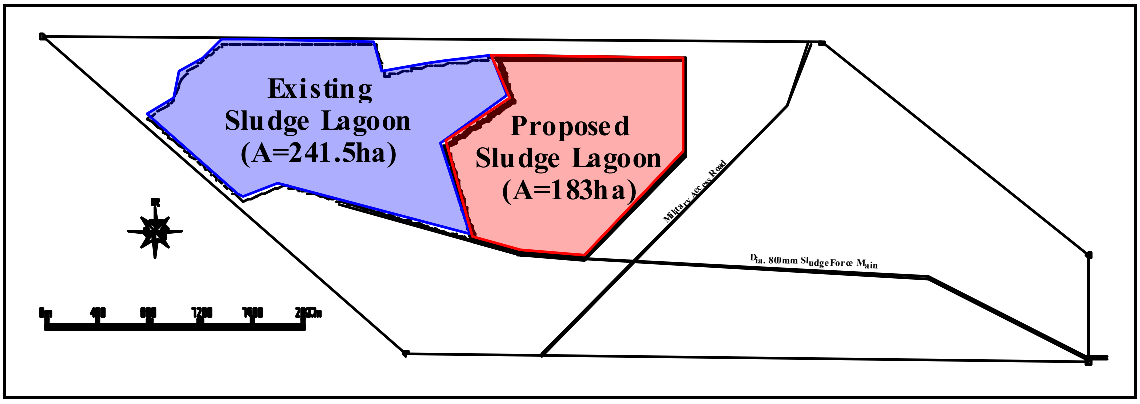


Figure 3.10 Proposed Sludge Lagoon

3.4 Preliminary Design

3.4.1 Design Criteria

Design Criteria for secondary treatment facilities and sludge treatment facilities are summarized as shown in Table 3.20 based on design standards of Egypt and Japan.

Table 3.20 Design Criteria

No.	Item	Design Criteria
1.	Aeration Tank	
1-1	MLSS Concentration	2,000 mg/l
1-2	Dissolved Oxygen	2.0 mg/l
1-3	Hydraulic Retention Time (HRT)	4.5 hour
1-4	Solid Concentration in Return Sludge	0.6 %
1-5	Return Sludge Ratio	46 %
1-6	Oxygen required to remove BOD	0.6 $kgO_2/kgBOD$
1-7	Oxygen required for endogenous respiration	0.1 $kgO_2/MLVSS/d$
2.	Final Settling Tank	
2-1	Hydraulic Surface Loading	25 $m^3/m^2/d$

No.	Item	Design Criteria
2-2	Hydraulic Retention Time (HRT)	3.5 hour
2-3	Effective Depth	3.5 m
2-4	Weir Overflow Rate	150 $m^3/m/d$
2-5	Free Board	0.5 m
3.	Chlorine Contact Tank	
3-1	Maximum Chlorine Dosing Rate	15.0 mg/l
3-2	Average Chlorine Dosing Rate	5.0 mg/l
3-3	Chlorine Contact Time	5 minutes*
4.	Sludge Lagoon	
4-1	Drying Period in Summer	25 day
4-2	Drying Period in Winter	40 day

*:Chlorine contact time of 30 minutes is secured in effluent channel

3.4.2 Outline of Specification and Drawing of Proposed Facilities

Dimensions of main facilities and specifications of equipment are calculated according to above design criteria and shown in Table 3.21. Facility and process calculation of planned facilities is show in Appendix-4. The general layout of proposed facilities under this Project along with the existing, ongoing facilities and future expansion is shown in Figure 3.11. The hydraulics profile and the flow diagram of secondary treatment facilities are shown in Figure 3.12 and Figure 3.13, respectively. Drawings of planned facilities are presented in Appendix-5.

Table 3.21 Dimensions and Specifications of Proposed Facilities

No.	Facilities / Dimensions / Specifications	Number of Units
1.	Aeration Tank	
1-1	Rectangular Tank W10m×L162m×D6m (9,315m^3)	24 tanks (4 tanks×6 series)
1-2	Membrane Panel Aerator	24 tanks
1-3	Air Blower 260 m^3/min × 380kW	9 nos. (3 standby)
2.	Final Settling Tank	
2-1	Circular Tank Dia 51m × D3.5m (7,151m^3)	24 tanks (4 tanks × 6 series)
2-2	Clarifier Dia51m × D3.5m × 3.7kW	24 nos.
2-3	Return Sludge Pump 34.7m^3/min × H6m × 55kW	24 nos.
2-4	Waste Sludge Pump 5.2m^3/min × H10m × 15kW	12 nos. (6 standby)
3.	Chlorine Contact Tank	
3-1	Rectangular Tank W5m × L90m × D3m (1,350m^3)	3 tanks
3-2	Chlorine Cylinder 1ton	42 nos.
3-3	Water Supply Pump 4.0m^3/min × H40m × 45kW	6 nos. (3 standby).
4.	Sludge Transfer	
4-1	Sludge Pump 22.8m^3/min × H80m × 450kW	2 nos.
5.	Sludge Lagoon	
5-1	Sludge Lagoon (expansion)	183 ha.

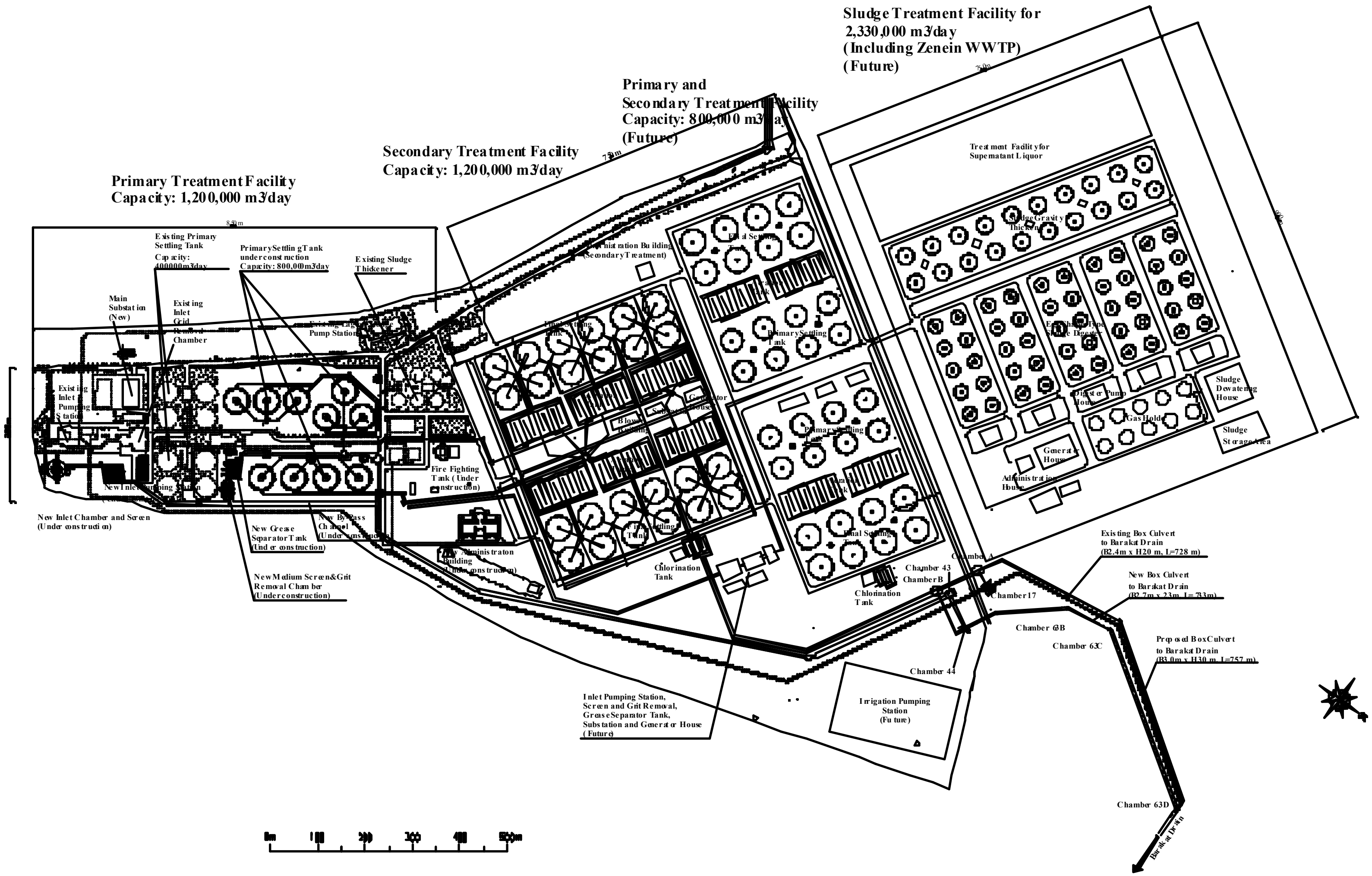


Figure 3.11 General Layout of Planned Facilities of Abu Rawash WWTP

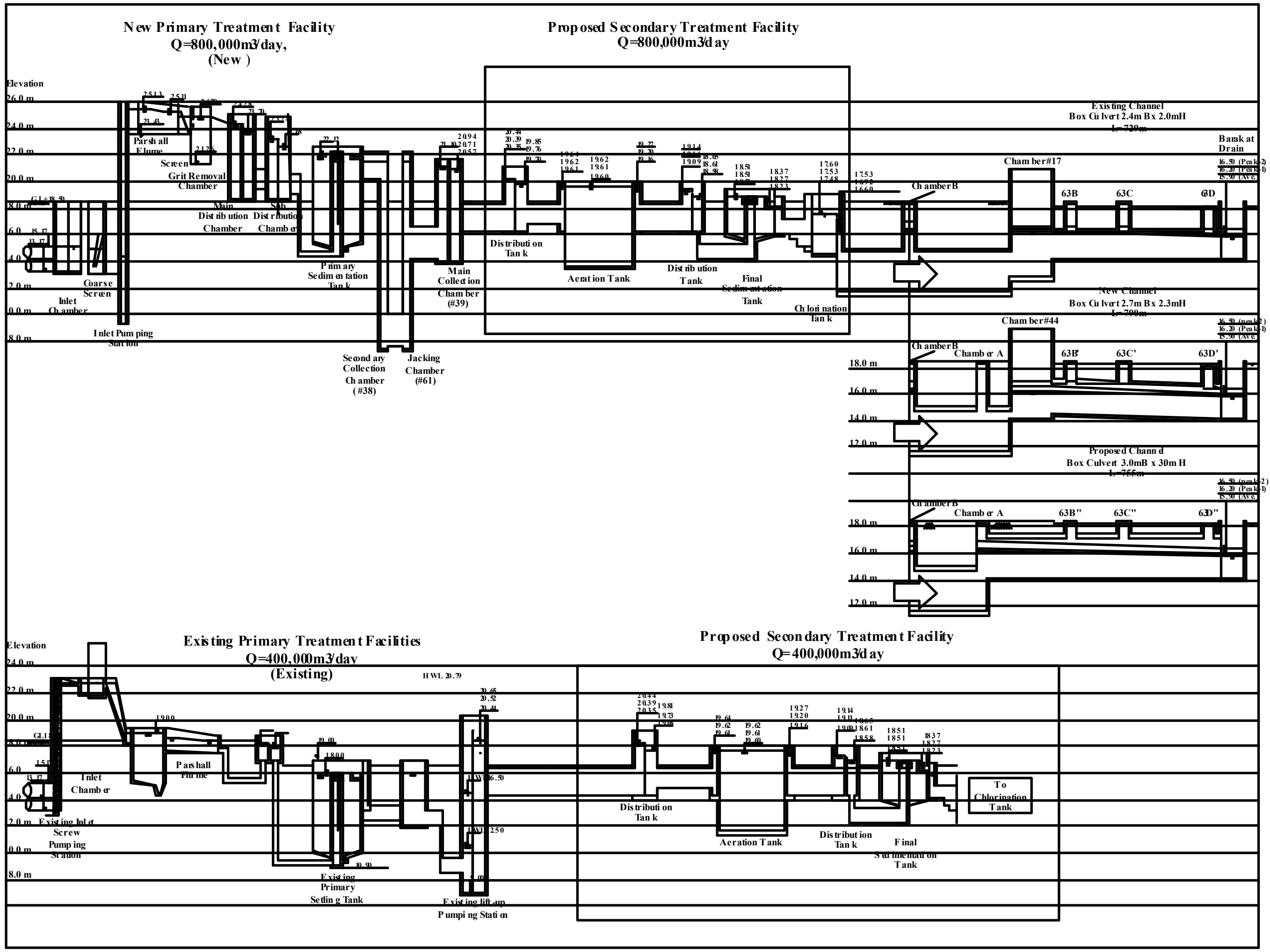


Figure 3.12 Hydraulic Profile of Abu Rawash WWTP

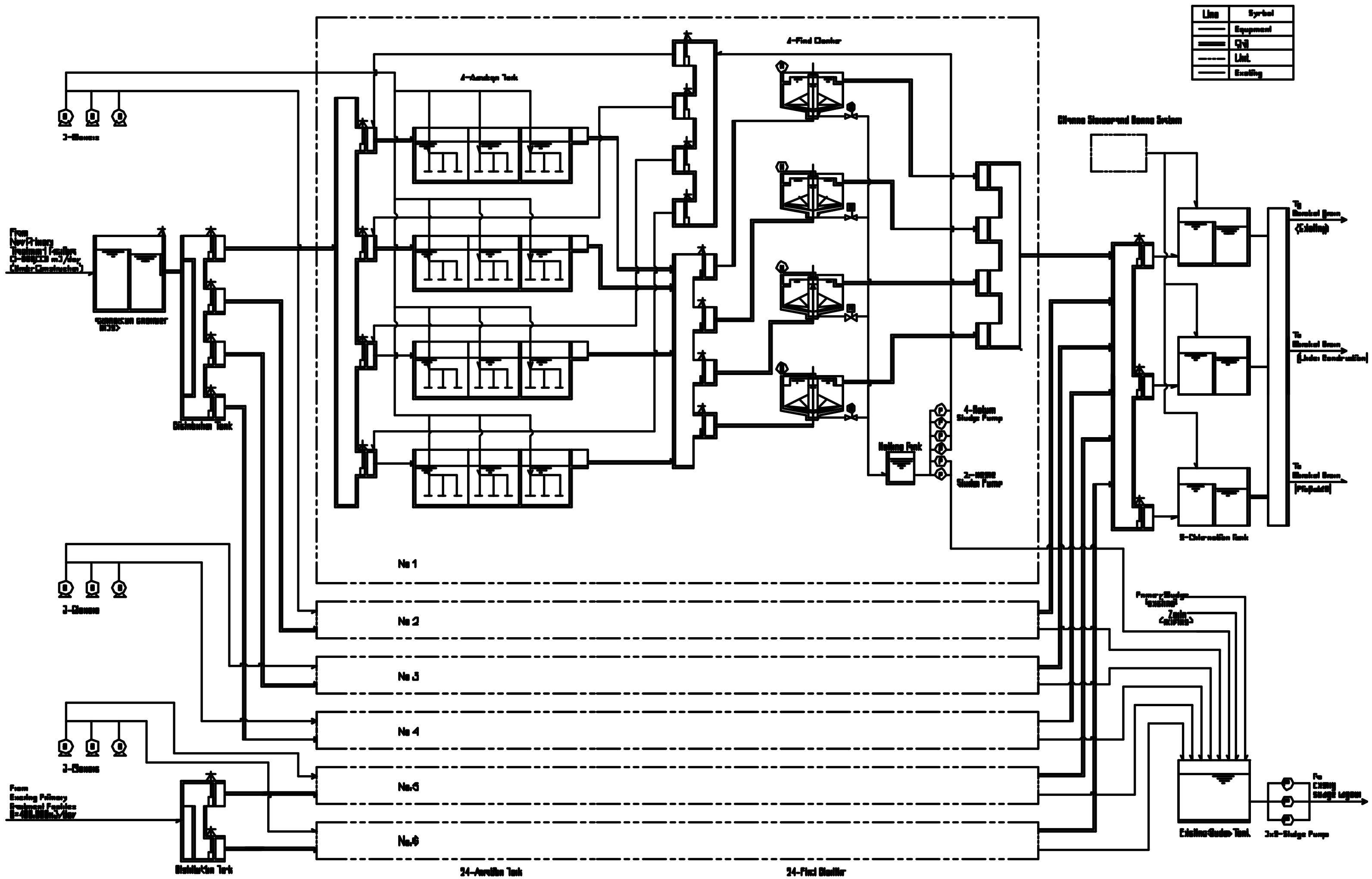


Figure 3.13 Flow Diagram of Abu Rawash WWTP

3.5 Project Cost

3.5.1 Conditions of Cost Estimation

The project cost is estimated based on the conditions stated below.

- The project cost comprises construction cost, administration cost, engineering cost, contingency (physical and price escalation), interest during construction, commitment charge and relevant tax.
- The project cost is composed of the local currency potion (L.C.) and foreign currency portion (F.C.).
- Administration cost in recipient country is assumed to be 1.0 percent of the construction cost.
- Engineering cost is assumed to be 7.0 percent of the construction cost.
- Physical contingency is considered as 10.0 percent of total of construction cost, administration cost, and engineering cost.
- Price contingency of 9.6 percent per annum for the local currency portion and 3.7 percent per annum for the foreign currency portion are applied estimated based on implementation schedule shown in Table 3.26.
- The base period of cost estimation is August in 2009.
- The exchange rate considered is the average rate for six months until August, 2009. (1 LE = 17.38 Yen, 1 USD=96.60 Yen)
- The cost for land acquisition is not considered since the land required for this Project is a part of the existing Abu Rawash WWTP and sludge lagoon area belongs to the government.
- Interest during construction is estimated taking into consideration that foreign portion of the Project cost is financed by JICA ODA loan.
- Commitment charge, which is 0.1 percent of loan outstanding from signing of Loan Agreement, is estimated in order to enhance the implementation of project.
- Custom rate including service tax is in the range between 5 and 13 % for imported goods taking custom tariff of Egypt into account. Tax rate is 14.9 % including sales taxes and other relevant taxes.

3.5.2 Condition of Estimating the Construction Cost

The construction cost is estimated based on the conditions listed as follows.

- The materials for civil and building works, labor and construction machineries are basically procured from the local market.
- Mechanical and electrical equipment are basically procured from abroad

including the third counties such as EU. Procurement is decided considering factors such as quality, economical aspect and maintenance.

- Utilization of local contractors is considered for planning of execution since they have enough experiences and abilities.
- Local physical conditions such as geographical, geological and meteorological conditions and local regulations and customs such as occurrence of Ramadan, etc., are taken into consideration.

3.5.3 Estimated Project Cost

Cost estimation has been carried out considering factors mentioned above and is shown in Table 3.22. The estimated project cost for this Project is LE 3,101 million (JPY 54.0 billion) including taxes and LE 2,651 million (JPY 46.1 billion) excluding taxes. The breakdown of the estimates is presented in Appendix-6.

Table 3.22 Estimated Project Cost

No.	Items	L.C. (1,000 LE)	F.C. (1,000 LE)	Total (1,000 LE)
1.	Construction Cost			
A	Sewage Treatment Facilities			
A-1	Connection channel and chamber	42,122	41,195	83,317
A-2	Aeration Tank	164,348	277,749	442,097
A-3	Final Settling Tank	362,478	345,674	708,152
A-4	Chlorination	11,062	15,375	26,437
A-5	Effluent channel and chamber	34,188	50,596	84,784
A-6	Administration facility	15,554	34,950	50,504
A-7	Power facility	41,125	96,912	138,037
A-8	Maintenance road and parking lot	7,559	840	8,399
	Sub-total of A	678,436	863,291	1,541,727
B	Sludge Treatment Facilities			
B-1	Sludge transfer pump	1,694	9,603	11,297
B-2	Sludge lagoon	81,014	48,706	129,720
	Sub-total of B	82,708	58,309	141,017
	Sub-total (1)	**761,144**	**921,600**	**1,682,744**
2.	Administration Cost	16,827	0	16,827
3.	Engineering Cost	53,280	64,512	117,792
4.	Physical Contingency	83,125	98,611	181,736
5.	Price Contingency	402,004	166,197	568,201
6.	Interest during construction	0	79,476	79,476
7.	Commitment charge	0	4,397	4,397
8.	Tax and Duty	196,141	253,827	449,968
	Sub-total (2-8)	**751,377**	**667,020**	**1,418,397**
	Total including Tax	**1,512,521**	**1,588,620**	**3,101,141**
	Total excluding Tax	**1,316,380**	**1,334,793**	**2,651,173**

The percentage of the estimated construction cost by facilities is analyzed as shown in Figure 3.14. The construction costs of secondary treatment facilities including aeration tank, final setting tank, chlorination and channel occupy 80 % of the construction cost. The sludge treatment facilities including sludge transfer pump and sludge lagoon occupy 9 %. The communal facilities including administration facilities, power facilities and maintenance/parking lot occupy 11 %.

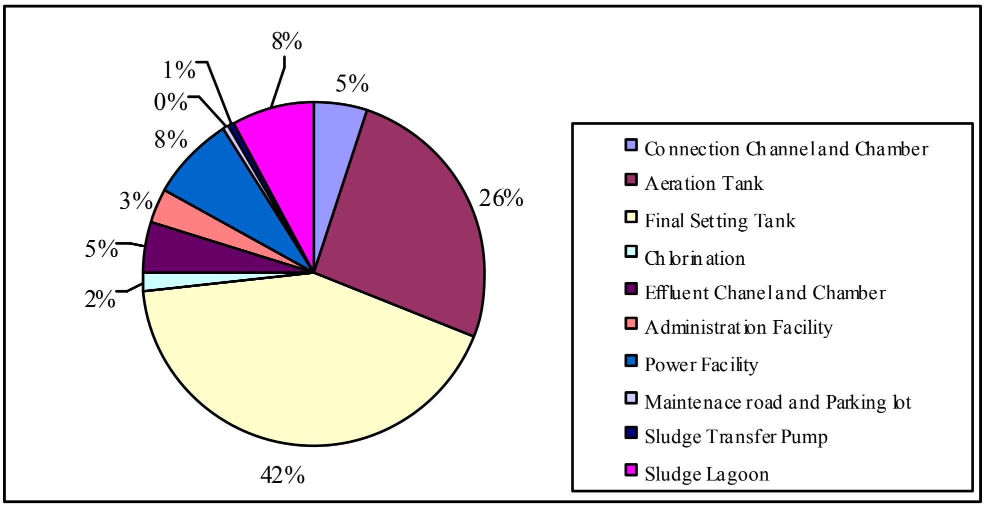


Figure 3.14 Percentage of Facilities of the Construction Cost

The percentage of the estimated project cost by components is analyzed as shown in Figure 3.15. The direct construction cost accounts for 53 % of the total project cost and indirect construction cost including remaining costs accounts for 47 %.

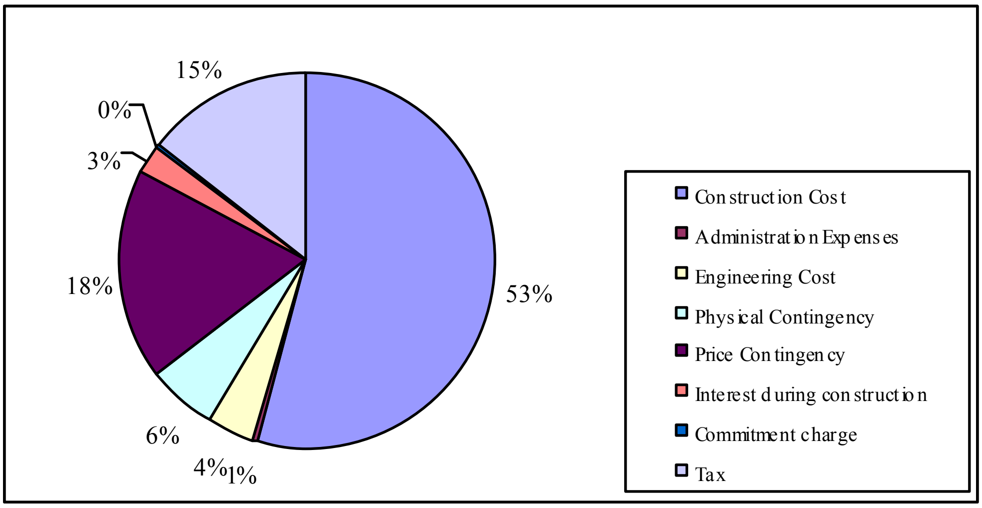


Figure 3.15 Percentage of Components of the Project Cost

3.5.4 Estimated Operation and Maintenance Cost

Implementation of this Project will increase annual O&M cost for proper operation of facilities constructed. The O&M cost comprises of expenses on salary, consumable, electricity, maintenance and others. Annual O&M cost of the existing facilities (0.4 million m^3/day of primary treatment) based on the data obtained from Abu Rawash WWTP is presented in Table 3.23. Annual O&M cost of proposed facilities of 1.2 million m^3/day of secondary treatment is estimated and summarized in Table 3.24. Annual O&M cost of all facilities in Abu Rawash WWTP including existing, ongoing and proposed facilities is also summed and given in Table 3.25. Additional annual O&M cost and all annual O&M cost is 24.3 million LE/year (0.42 billion Yen/year) and 49.6 million LE/year (0.86 billion JPY/year), respectively.

Table 3.23 Operation and Maintenance Cost of Existing Facilities

No.	Items	Expenses (million LE)
1.	Salary	3.65
2.	Consumable	0.10
3.	Electricity	3.77
4.	Maintenance	0.87
5.	Others	0.02
	Total	**8.43**

Source: O&M Cost presented in Monthly Report from January to December 2008

Table 3.24 O&M Cost of Facilities Constructed in this Project

No.	Items	Expenses (million LE)
1.	Salary	2.39
2.	Consumable	2.74
3.	Electricity	8.30
4.	Maintenance	9.70
5.	Others	1.16
	Total	**24.29**

Table 3.25 O&M Cost of All Facilities in Abu Rawash WWTP

No.	Items	Expenses (million LE)
1.	Salary	13.37
2.	Consumable	3.03
3.	Electricity	19.62
4.	Maintenance	12.32
5.	Others	1.23
	Total	**49.56**

3.6 Implementation Schedule and Disbursement Schedule

3.6.1 Implementation Schedule

If this Project is financed through JICA ODA Loan, the Government of Egypt must follow JICA procurement guidelines for the selection of the consultants and contractors to implement the Project. There are two types of contracts in the procurement procedure. One is Design-Bid-Build contract, which is a common practice under JICA procurement guideline, and the other is Design-Build contract, in which the contractor for works including detailed design and construction is procured under one bidding only.

In this Project, the procurement procedure of Design-Build contract is applied since it can reduce duration necessary before start of construction works compared to Design-Bid-Build contract. Taking into account current situation of poor effluent quality causing serious pollution to receiving water body, the provision of secondary treatment facilities is urgent and merit of shortening of implementation duration is important.

Implementation schedule starting from signing of Loan Agreement has been developed taking into account necessary steps that would be required. Implementation of this Project has been estimated to extend over 60 months (5 years) in total. On the assumption that Loan Agreement is entered between both governments in the middle of 2010, the facilities under this Project will be operational in the middle of 2015 as shown in Table 3.26

Table 3.26 Implementation Schedule

	Period	2010	2011	2012	2013	2014	2015	2016	2017
Signing of LA	-	▼							
Selection of Contractor	12months	■	■						
Design Works	10months		■	■					
Construction Works	42months			■	■	■	■		
Commissioning	24months						■	■	■

Duration necessary for selection of the contractor has been developed as shown in Table 3.27 and is expected to extend over 12 months until the finalization of Design-Build contract.

Table 3.27 Detailed Implementation Schedule of Selection of Contractor

Month	1	2	3	4	5	6	7	8	9	10	11	12
Preparation of tender document	■	■	■									
Concurrence to TD by JICA				■	■							
Prequalification of tenderers					■	■						
Concurrence to PQ by JICA						■						
Tender period							■	■	■			
Evaluation of tender										■		
Concurrence to evaluation by JICA											■	
Contract negotiation with candidate											■	■
Concurrence to contract by JICA												■
Contract award												▼

Duration necessary for construction works has been planned to ensure the proper execution of the work considering conditions including ability of contractors, procurement of materials and labor force, manner of construction in Egypt and construction scale. The construction schedule is mainly estimated according to procedure and working volume of construction such as excavation and concrete casting since there is rarely restriction regarding procurement. Implementation schedule of the construction has been estimated to extend over 42 months in total and is shown in Table 3.28.

Table 3.28 Implementation Schedule of Construction Works

Year	1		2		3		4	
Mobilization and site preparation	■	■						
Aeration tank		■	■	■				
Final setting tank	■	■	■	■	■			
Connection channel				■	■	■		
Chlorination and effluent channel				■	■	■		
Building work		■	■	■	■	■		
Mechanical and electrical work				■	■	■	■	

Two years of commissioning period including on-the-job training is planned after the construction so that government organization, which is responsible for operation and maintenance, takes over operation of facilities smoothly.

3.6.2 Disbursement Schedule

The disbursement schedule based on the implementation schedule has been prepared as shown in Table 3.29.

Table 3.29 Disbursement Schedule

(Million LE)

		2010	2011	2012	2013	2014	2015	2016	2017	Total
Direct construction cost	L.C	0	0	217.5	217.5	217.5	108.7	0	0	761.1
	F.C	0	0	263.3	263.3	263.3	131.7	0	0	921.6
	Total	0	0	480.8	480.8	480.8	240.4	0	0	1,682.7
Indirect construction cost	L.C	2.3	15.0	163.6	197.6	234.9	137.9	0	0	751.4
	F.C	1.5	12.5	168.5	182.2	196.5	105.7	0	0	667.0
	Total	3.8	27.5	332.2	379.9	431.4	243.6	0	0	1,418.4
Total	L.C	2.3	15.0	381.1	415.1	452.4	246.6	0	0	1,512.5
	F.C	1.5	12.5	431.9	445.6	459.8	237.4	0	0	1,588.6
	Total	3.8	27.5	813.0	860.7	912.2	484.0	0	0	3,101.1

3.6.3 Consulting Services

In the procurement of Design-Build contract, detailed design work is included into the contract and also supervision of construction works should be done by the contractor since the contractor takes full responsibility for the entire works. In Design-Build contract, consulting services including the followings will be required for smooth implementation of the Project by assisting the executing agency, CAPW, as owner's consultants.

- Preparation of tender documents for Design-Build contract
- Assistance in tender/qualification evaluation and contract negotiation
- Confirmation of design and specification of the construction works

Owner's consultants are composed of international and local experts. The local experts should support international experts in all the activities of the Project. The proposed work schedule of the consultants should accord with the implementation schedule as shown in Table 3.26. Required international and local experts along with man-months for consulting services for the implementation of the Project are presented in Table 3.30. Based on the estimation of required man-months, 57 man-months of international experts and 179 man-months of local experts would be required for assisting the executing agency for the Project.

Table 3.30 Consulting Services

	International			Local		
	No.	Month	MM	No.	Month	MM
Project manager	1	31	31	0	0	0
Deputy project manager	0	0	0	1	54	54
Civil engineer	1	8	8	1	36	36
Architect	0	0	0	1	14	14
Mechanical engineer	1	6	6	1	30	30
Electrical engineer	1	6	6	1	30	30
Environmental expert	1	6	6	1	15	15
Total	5		57	7		179

Consultant office should be set up in Cairo for carrying out the consulting services of the Project and executing agency office is proposed to be stationed full time at the consultant Cairo office for smooth implementation of the Project.

If this Project is financed by JICA ODA Loan, it is recommended for managers of the executing agency relating to this Project to participate in the training courses which are provided by JICA training centers in Japan regarding management of wastewater services and O&M of wastewater utilities.

CHAPTER 4 FINANCIAL AND ECONOMIC ANALYSES OF THE PROJECT

In this Chapter, initially the water and associated wastewater issues will be discussed, and explanation of the structure of tariff setting and levels, operational frameworks for billing and collection, and financial position envisaged by the proposed tariff and surcharge increase will also be explained. Subsequently, methodological approach to wastewater pricing for internal rate of return (IRR) analysis will follow, with the pricing alternatives of (i) O&M cost recovery, (ii) O&M cost + capital expenditure (CAPEX) recovery, and (iii) the Long-Run Marginal Cost (LRMC) pricing. It is important to emphasize here that financial soundness and sustainability of the project could be treated by the first two alternatives above, whereas allocative efficiency in the national economy by the LRMC pricing alternative.

Following the initiating remarks on pricing as briefed above, internal rate of return (IRR) analysis will be undertaken to numerically evaluate project sustainability in terms of finance and efficient resource allocation in the economy. In so doing, qualitative economic analysis will be carried out, with the analytical constraints of environmental improvement in a quantitative approach in view. Sensitivity analyses for FIRR and EIRR will be carried out to evaluate the Project's robustness in the face of plausible changes in benefit and cost. Last but not the least, financing plan with a possible JICA ODA Loan in view and associated debt burdens the Project would have to bear are considered in a bid to numerically estimate the financial impact of the concerned project on the entity and the state finance.

4.1 Water and Wastewater Tariff Structure and Settings

4.1.1 Outline of the Operation Framework

(A) Tariff Structure Currently in Place in GWWC

Basically following the practices of former Greater Cairo Sanitary and Drainage Company, the tariff structure and levels currently adopted by GWWC are set based on geographic category (urban and rural), beneficiary category (households, government flats, and other 53 detailed classification), and income level. Water tariff varies from the lowest "free" to the highest of 0.65 LE/m^3 for garden irrigation and government flats with more than three rooms, respectively. Surcharge rates of wastewater to potable water also varies from the lowest "free" (in case of irrigation and other 4 categories) to 35% (student hostels and other 2 categories), 40% (households and government flats), and to the highest of 70% (remaining 45 categories).

In many categories except for household and government flat beneficiaries, water tariff and thereby wastewater surcharge are calculated by a simple linear function, that is unit prices multiplied by the volume used. In case of household and government flat beneficiaries, these charges are calculated based on increased block tariff (0-10 m^3, -20 m^3, -30 m^3, and more than 30 m^3), and the number of rooms (1, 2, 3, and more).While cross-subsiding policy is partly in place by the differentiated unit price per cubic meter, a increased block tariff system is not incorporated in the most of categories, thereby leading to a policy without consideration and incentives for water saving. Current tariff setting and levels of GWWC is given in Table 4.1.

Table 4.1 Current Tariff Setting and Levels of GWWC

Category	Unit price of water supply	Wastewater surcharge
Domestic: 0-10 meters cubed 10-20 meters cubed 20-30 meters cubed > 30 meters cubed	 LE 0.23 LE 0.27 LE 0.38 LE 0.50	40 %
Fixed rate for governorate house: One-room apartment Two-room apartment Three-room apartment > Three-rooms	 LE 3.30 LE 3.90 LE 5.20 LE 6.50	40 %
Unions, factions premises, Syndicate and political parties	LE 0.55	70 %
Non-governmental places of worship	LE 0.55	70 %
Embassies	LE 0.85	70 %
Commercial	LE 0.85	70 %
Large Factories	LE 0.85	70 %
Investment	LE 1.35	70 %
Raw Water	LE 0.21	70 %
National Organization	LE 0.55	70 %
Class B Social Clubs	LE 0.55	70 %
Governmental medical insurance hospitals	LE 0.85	70 %
Class A Social Clubs	LE 1.10	70 %
Bakeries (supported by government)	LE 0.28	70 %
Raw Water for Investment purposes	LE 0.21	0 %
Al Nasr Company	LE 0.50	0 %
Governmental Institutions	LE 0.70	70 %
Treated water	LE 0.25	0 %
Student Hostels (governmental)	LE 0.23	35 %
Gardens (governmental)	LE 0.70	0 %
Youth Centers (governmental)	LE 0.55	35 %
Social Clubs (governmental)	LE 0.00	0 %
National Organizations (governmental)	LE 0.55	35 %
Governmental Bakeries (supported by government)	LE 0.30	70 %
Private Investment Activities	LE 2.10	70 %
Potable Water for low income household	LE 0.00	0 %
Garden Irrigation (utilization of effluent form WWTP)	LE 0.00	0 %
Class B & C Hotels	LE 1.35	70 %
Private Organization & Institutions	LE 1.35	70 %

Category	Unit price of water supply	Wastewater surcharge
Public Squares	LE 0.55	70 %
Youth Centers	LE 0.55	70 %
Workshops	LE 0.85	70 %
Local Restaurants	LE 0.85	70 %
Coffee shop	LE 0.85	70 %
Commercial Shops	LE 0.85	70 %
Garages	LE 0.85	70 %
Touristic Bakeries	LE 0.85	70 %
Trading Company	LE 0.85	70 %
Private Clinics	LE 0.85	70 %
Ice Factories	LE 0.85	35 %
Small Factories	LE 0.85	70 %
Banks	LE 0.85	70 %
Commercial Activities	LE 0.85	70 %
Buildings	LE 2.10	70 %
Gasoline Stations	LE 0.85	70 %
Local Hotels	LE 1.35	70 %
Private Schools	LE 1.35	70 %
Educational Activities	LE 2.10	70 %
Violations	LE 2.10	70 %
Class A Hotels	LE 2.10	70 %
Funfairs	LE 2.10	70 %
Touristic Restaurants	LE 2.10	70 %
Investment Companies	LE 2.10	70 %
Investment Banks	LE 2.10	70 %
Free Zones Companies	LE 2.10	70 %

Source: Giza Water and Wastewater Company, November 2009

Based on the discussion with GWWC and HCWW it is learnt that to achieve the returns in terms of O&M cost and O&M cost + depreciation (capital investment) cost, the tariff could be fixed as 1.25 LE/m^3 and 2.25 LE/m^3 respectively, whereas the current tariff is 0.25 LE/m^3 on average. With this in view, GWWC is now preparing a proposed tariff increase effective of January 2010. While the augmented rates vary by location and beneficiary, on average the hike percentage is a modest value of 1.5 percent.

(B) Billing and Collection

Trade Division of the Company is responsible for billing and collection of tariff and surcharge. The aggregates of billing and collection amounted to LE 293 million (JPY 5.1 billion) and LE 238 million (JPY 4.1 billion) in 2008, respectively. It is reported in the "Tariff Study, 2009" by GWWC that the overall collection rate was 80.6 percent, with the collection rate for beneficiary categories of urban, rural, and governmental at 66.4 percent, 92.8 percent, and 52.3 percent, respectively. Meanwhile, GWWC has improved the performance of tariff collection since its reformation from GCSDC. This is in part due to an incentive system newly introduced, that offers bonus payments to the Company tariff collectors and provision of some small electric devices such as water heater or alike to customers by lottery selection.

4.1.2 Methodological Approach to Wastewater Break-even Pricing for IRR Analyses

(A) Methodology

Issue of pricing (tariff) has been studied in the framework of break-even "cost recovery" in the light of financial soundness and sustainability of the service entities, as well as the basis on which IRR analyses come in place. The concept of "cost recovery" herewith include, among others, (i) operation and maintenance (O&M) cost recovery as is commonly in place in the development partner institutions (the African Development Bank, the World Bank, and others), and (ii) O&M cost + CAPEX recovery.

In addition, a Long-Run Marginal Cost (LRMC) pricing method will also be analyzed while considering an efficient scarce resource allocation in the economy, and a benchmark economic price of the concerned services. Marginal cost, by definition, is the change in total cost (incremental) incurred to one-unit change in outputs ($\partial C/\partial Q$). With the standard allocative efficiency considerations in view, it is useful to obtain an indication of the benchmark level at which the price should be set.

Schematic framework for the analysis of financial and economic pricing is given in Figure 4.1.

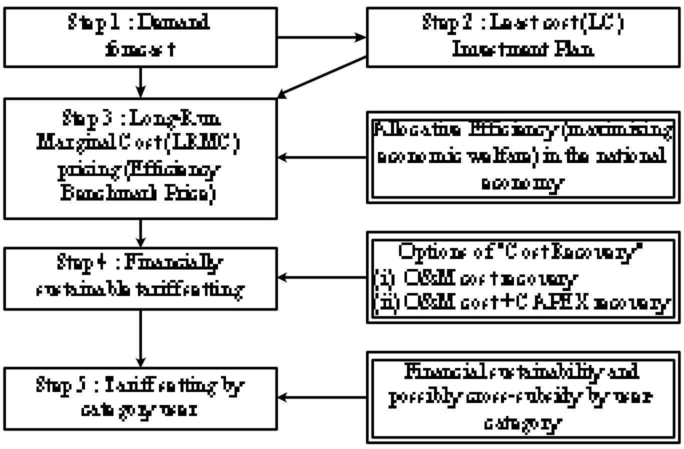


Figure 4.1 Schematic framework for pricing (tariff setting)

Mathematically when looked more closely, LRMC is defined as:

$$\text{LRMC} = \text{MC of construction} + \text{Recurrent (O\&M) cost}$$

The rational for setting price equal to marginal cost may be clarified in mathematical terms as follows:

Net Benefit (NB) = Total Revenue (TR) – Total Cost (TC)

That is,

$$NB\ (Q) = TR\ (Q) - TC\ (Q) = p\ (Q) \times Q - TC\ (Q)$$

where p and Q denote price (the equation of demand schedule) and quantity of supply (the equation of supply schedule), respectively. The necessary first order condition for maximizing net social benefits is to set the derivative of the net benefit function at zero, which is mathematically derived as follows:

$$\frac{d}{dQ}NB = \frac{\partial p}{\partial Q}Q + p - \frac{\partial TC}{\partial Q} = 0$$
$$\frac{\partial p}{\partial Q}\left(\frac{Q}{p}\right)p + p - \frac{\partial TC}{\partial Q} = 0$$
$$p\left[\frac{\partial p}{\partial Q}\left(\frac{Q}{p}\right) + 1\right] - \frac{\partial TC}{\partial Q} = 0$$

Now, the price elasticity of supply denoted as ε is introduced hereby, which is defined by $\varepsilon = (\partial Q / \partial p) \times (p / Q)$. Then the above equation is rewritten as below.

$$\frac{1}{(\partial Q / \partial p) \times (p / Q)}p + p = \frac{\partial TC}{\partial Q}$$
$$p\left(\frac{1}{\varepsilon} + 1\right) = \frac{\partial TC}{\partial Q}$$

Provided that $\varepsilon = \infty$, under the assumption of "perfectly competitive market",

$$p = \frac{\partial TC}{\partial Q} = \text{Marginal Cost}$$

It is one of the basic axioms of economics that at the price p and supply (demand) Q, total net benefit of consumption attributed to society is maximized with the optimum market clearing point (p, Q).

(B) Results

LRMC pricing tariff was estimated at LE 279.8 million (JPY 4.86 billion) per year, with capital recovery factor (CRF) of 0.103. CRF by definition $\frac{i(1+i)^n}{(1+i)^n - 1}$ was based on the project life of 30 years and discount rate of 0.97.

4.2 Internal Rate of Return Analyses

4.2.1 Internal Model Configuration

Subject to technical and other most relevant and best available data/information, model configuration for IRRs estimation will be formulated, with a set of numerical assumptions and parameters as specified hereunder.

(A) Project Life

Current analysis assumes 30 years of project period in total, with six (6) year construction and subsequent 24 year operation period, while commencing this Project from 2010 and closing in 2039.

(B) Physical and Price Contingencies

Physical contingency is assumed as 10 percent of base financial cost, whereas price contingencies for the foreign and local cost portions are assumed as 3.7 percent and 9.6 percent referring to inflationary pressures in developed countries and Egypt. For reference, general price increase as consumer price index (CPI) is presented in Figure 5.4.

(C) Demand Forecast (Project's Envisaged Capacity of Wastewater Treatment)

As reflected in the Chapter 3, service demand attributable to the project is presumably set at 1.2 million m^3/day, that results into total demand of 438.0 million m^3/year throughout the project duration.

(D) Financial and Economic Costs

Based on the estimated project cost shown in Table 3.22, the aggregate financial cost of capital expenditure (CAPEC, initial investment) is envisaged at LE 3,287.3 million (JPY 57.1 billion), including the foreign and local cost portions of LE 1,595.6 million (JPY 27.7 billion, 48.5%) and LE 1,691.7 million (JPY 29.4 billion, 51.5%), respectively, as per 2009 price as shown in
Table 4.2. It may be noted that the financial cost for the estimation of financial internal rate of return (FIRR) is LE 2,494.0 million (JPY 43.3 billion), which is Base Cost plus Physical Contingency, as defined. Associated operation and maintenance cost is estimated at 24.3 million LE/year (0.42 billion JPY/year) as shown in Table 3.24. It is envisages that no replacement cost is incurred on equipment and facilities during the project life.

Table 4.2 Aggregate Financial Costs

Item	L.C. (million LE)	F.C. (million LE)	Total (million LE)
Construction	761.1	921.6	1,682.7
Land Acquisition	0.0	0.0	0.0
Incremental Administration Cost	16.8	0.0	16.8
Consultancy Fees	53.3	64.5	117.8
Taxes and Duties	196.1	253.8	450.0
Base Cost (BC)	1,027.3	1,239.9	2,267.2
Physical Contingency (PhC)	102.7	124.0	226.7
BC+PhC	1,130.1	1,363.9	2,494.0
Price Contingency (PhC)	561.6	231.7	793.2
Aggregate Financial Cost	**1,691.7**	**1,595.6**	**3,287.3**

The economic cost is revalued while excluding built-in market failures due to non-competitive pricing, externality of the economy, political preference for lower incomers by way of the minimum wage law and fiscal distortions such as taxes and duties levied on goods and services in the markets. In so doing, conversion factors are estimated while considering the prevailing import duties, value added tax (VAT), and others of relevance.

Standard conversion factor (SCF) was set at 0.9, thereby transferring to the economic cost of LE 1,907.6 million (JPY 33.2 billion), including the foreign and local costs of LE 1,084.7 million (JPY 18.9 billion, 56.9%) and LE 822.9 million (JPY 14.3 billion, 43.1%), respectively as shown in Table 4.3. Economic operation and maintenance cost accrued to the whole facilities in Abu Rawash was assumed as 21.8 million LE/year (0.38 billion JPY/year).

Table 4.3 Aggregate Economic Costs

Item	L.C. (million LE)	F.C. (million LE)	Total (million LE)
Construction	685.0	921.6	1,606.6
Land Acquisition	0.0	0.0	0.0
Incremental Administration Cost	15.1	0.0	15.1
Consultancy Fees	48.0	64.5	112.5
Taxes and Duties	0.0	0.0	0.0
Base Cost (BC)	748.1	986.1	1,734.2
Physical Contingency (PhC)	74.8	98.6	173.4
Aggregate Economic Cost	**822.9**	**1,084.7**	**1,907.7**

(E) Annual Investment Schedule

Annual investments needed over the initial construction period are envisaged as shown in Table 4.4.

Table 4.4 Annual Investment Schedule

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
0.1 %	0.9 %	26.2 %	27.8 %	29.4 %	15.6 %

(F) Financial and Economic Benefits

Financial benefit is a set of tariff revenues collected from customers, with specifically elaborated as (i) O&M cost recovery pricing at LE 49.6 million (JPY 0.86 billion) per year, (ii) O&M cost + CAPEX recovery pricing at LE 153.5 million (JPY 2.67 billion), and (iii) LRMC price of LE 279.8 million (JPY 4.86 billion) per year. Likewise, economic benefit quantitatively measured by LRMC pricing is at LE 279.8 million (JPY 4.86 billion) per year, with capital recovery factor (CRF) of 0.103.

Qualitative analysis of the project expects a number of benefits in the light of environment improvement, as detailed in Volume 2 of the Study report. Briefly, these include, among others, (i) reduction of wastewater pollution load to drains and Rosetta branch of Nile River, (ii) reduction of bad smell at Nikla Village along Al Rahawy drain after the siphon, and (iii) reduction of wastewater contamination and consequent negative impact to plants in irrigation uses. These effects could not be quantified for EIRR estimation due largely to a paucity of data and uncertain cause and effect relationship.

(G) Opportunity Cost of Capital (OCC) and Social Discount Rate (SDR)

For the financial and economic IRR analyses, cut-off rates of Opportunity Cost of Capital (OCC) and Social Discount Rate (SDR) for project feasibility have been set at 9.7% and 10.0%, respectively. OCC refers to 91 days Treasury Bills issued by the Central Bank, whereas SDR as an intuitive benchmark figure that has commonly been used in project analysis by WB, JICA and other relevant organizations.

(H) Salvage Value

No salvage value attributed to the facilities and equipment belonging to this Project is assumed, in compliance with generally accepted guidelines for project analysis.

(I) Sensitivity Analysis

Sensitivity analysis that indicates the resiliency of the project against project risks is undertaken with variation in relevant parameters such as (i) lowering of benefit by 10 percent, (ii) capital cost overrun by 10 percent, and (iii) one year delay in project completion and associated impact on benefit. In case of the third case of feasibility simulation, indicative investment (disbursement) share in consecutive years is set as shown in Table 4.5.

Table 4.5 Investment Schedule in case of one-year delay

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
0.1 %	0.7 %	19.7 %	21.0 %	22.3 %	23.6 %	12.6 %

4.2.2 Results and Implication

In line with the methodology discussed above, IRRs have duly been estimated and results are given in Table 4.6. FIRRs for the cases of O&M cost recovery, O&M cost + CAPEX recovery, and LRMC pricing methods turned out to be NA, 1.6%, and 7.4%, respectively. Financial Net present values (FNPVs) associated with the same pricing methods were at LE - 1,546.3 million (JPY - 26.9 billion), LE - 998.2 (JPY - 17.3 billion), and LE -331.8 million (JPY - 5.8 billion) for three cases respectively, with the discount rate of 9.7%.

Likewise, Long-Run Marginal Cost pricing (LRMC)-based EIRR was 10.3%, due to the lower economic cost of the project. Net present values (ENPV) turned out to be LE 38.4 million (JPY 0.7 billion), with the discount rate of 10.0% in view. The numerical outputs and summary cash-flow tables of FIRR and EIRR are given in Appendix-7.

Table 4.6 Estimated IRRs and NPVs (percentage and JPY)

	O&M cost recovery	O&M cost + CAPEX recovery	LRMC pricing
FIRR (FNPV)	NA (LE - 1,546.3 million)	1.6 % (LE - 998.2 million)	7.4 % (LE - 331.8 million)
EIRR (ENPV)	-	-	10.3% (LE 38.4 million)

FIRRs obtained in case of all of the three tariff options, namely, break-even (i) O&M cost recovery, (ii) O&M cost + CAPEX recovery, and (iii) LRMC pricing, did not outnumber the cut-off rate of 9.7 percent (Opportunity Cost of Capital), thus it could be concluded that the project in concern would not be viable for these levels of tariff setting. Alternatively, EIRR was estimated at 10.4 percent and revealed a profound basis of economic feasibility, while applying the Long-Run Marginal Cost pricing method. By nature economic benefits attributable to environment-related development projects are intangible thus making it difficult to quantify. Consequently, those projects in general are evaluated for lower EIRR cut-off rates of around 6-8 percent or even lower.

In view of the above discussion, the concerned project is economically sound and it would be worth to proceed with this project under the auspices and leadership of the public sector, or through incorporation of some way of PPP scheme.

4.2.3 Willingness to Pay (WTP) and Policy Implication on Tariff Issue

As discussed earlier, the annual O&M cost of the proposed secondary treatment facilities and all the facilities in Abu Rawash, and the envisaged construction cost are estimated at 24.3 million LE/year (0.42 billion JPY/year), 49.6 million LE/year (0.86 billion JPY/year), and LE 2,494.1 million (JPY 43.3 billion) exclusive of price contingency, respectively. Daily treatment volume is 1.2 million m^3, thus making the annual volume at 438.0 million m^3. Depreciation period that is equal to the operation period of the facility is set at 24 years.

With the parameters described above, unit prices of wastewater by modality are LE 0.11 (JPY 2.0), LE 0.4 (JPY 6.1), and LE 0.6 (JPY 11.1) per cubic meter for (i) O&M cost recovery, (ii) O&M cost + CAPEX recovery, and (iii) LRMC pricing, in that order. In nominal term, the average household income in 2009 is LE 1,662 (JPY 28,887) per month (Estimated based on household income of LE 1,280 in 2008 and inflation rates of 11.7 and 16.2% in last two years). Likewise in assumption, people's willingness to pay (WTP) for wastewater could presumably be deemed at 0.5 percent of household income, with specific WTP amounts to LE 8.3 per month. Provided that ordinary household consumes 20-25 m^3 of water per month and (ii) O&M cost + CAPEX recovery tariff is in place, wastewater bills each household would receive is estimated as LE 7.3 (JPY 122.1) - LE 9.2 (JPY 152.0) per month.

Subsequently, it is considered acceptable that (ii) O&M cost + CAPEX recovery tariff of LE 0.4 (JPY 6.1) would be a ceiling in pricing, while taking people's WTP in view. In addition, it should be noted that this tariff level does not assure financial viability and soundness of the concerned service undertaking, as reflected in the previous section.

4.2.4 Sensitivity Analysis

Sensitivity analysis that indicates the resiliency of the concerned project against risks, has been undertaken, in the form of (i) lowering benefit by 10 percent, (ii) capital cost overrun by 10 percent, and (iii) one year delay in construction, and their impact on benefit generation for both financial and economic analyses has been assessed. Results are summarized in Table 4.7.

Table 4.7 Sensitivity analysis and the resulting FIRRs and EIRRs

	Base Case	(i) Benefit - 10%	(ii) Cost +10%	(iii) 1-year delay
FIRR (O&M cost recovery)	NA	NA	NA	NA
FIRR (O&M cost + CAPEX recovery)	1.6 %	NA	NA	1.2 %
FIRR (LRMC pricing)	7.4 %	6.3 %	6.4 %	6.6 %
EIRR (LRMC pricing)	10.3 %	9.2 %	9.3 %	9.2 %

4.3 Financing Plan and Dept Analysis

It is envisaged that discussions on the possibility of extending JICA ODA Loan for the proposed project would be articulated following further study and analysis that come. While the issue of application of Private-Public Partnership (PPP) scheme in the area of wastewater treatment in the region is also possible, discussions made here highlights the financial plan of the plausible Yen-loan amounting to the foreign cost portion of this Project, that is JPY 27.7 billion (LE 1,595.6 million), be extended, and estimate of the debt to be borne by the recipient partner is carried out.

4.3.1 Financing Plan Envisaged

(A) Methodology

The model highlights only the impacts on finance accrued to the prospective JICA ODA Loan of the project for the simplicity in discussions, while leaving other conditions on a ceteris-paribus basis.

(B) Model Configuration

In the analysis carried out here, the following variables and parameters are set forth as shown in Table 4.8. Broadly speaking, loan amount will be JPY 27.7 billion (LE 1,595.6 million) as noted above with the annual interest rate of 0.2 percent. Repayment period will be 30 years with 10 years of grace period. Repayment of principal will take place semi-annually, with the interest payment accruable to the amount of principal disbursed and outstanding. Commitment charge and on-lent interest will not be incorporated in the analysis.

Table 4.8 Variables and Assumed Parameters

Item	Value and Parameter
Loan Amount	JPY 27.7 billion (LE 1,595.6 million)
Concessional Interest Rate	0.65 percent per annum
Loan Period	Six (6) years
Repayment Period	30 years
of which Grace Period	10 years
Repayment Schedule	Semi-Annual
Repayment	Equalized Principal Repayment
Commitment Charge	Not Available (N/A)
On-lending Interest Rate	Not Available (N/A)

(C) Result

The heaviest debt (principal repayments and interest payments) of JPY 1.54 billion (LE 26.8 million) is expected to occur in the 16th year (presumably 2026) after the commencement of disbursement. Alternatively, this takes place in the 11th year after the beginning of repayment period when principal repayments have started. Indicative semi-annual amortization schedule is given in Appendix-7.

CHAPTER 5 ORGANIZATION FOR PROJECT IMPLEMENTATION AND OPERATION AND MAINTENANCE

5.1 Organizations Relating to the Project

Ministry of Housing, Utilities and Urban Development (MOHUUD) is responsible for sewerage systems at national level. There are two organizations under this Ministry, i.e., the Construction Authority for Potable water and Wastewater (CAPW) and National Organization for Potable Water and Sanitary Drainage (NOPWASD) that are responsible for water supply and sewerage systems. CAPW is responsible for planning, design and construction of municipal drinking water distribution systems, purification plants, sewage collection systems and wastewater treatment plants to facilitate water supply and sewerage services for the Governorates that constitute Greater Cairo and town of Alexandria. On the other hand, NOPWASD plays similar role for the remaining part of Egypt. There exists an additional organization namely Holding Company for Potable Water and Wastewater (HCWW) that holds water supply and sewerage assets in entire Egypt.

For operation and maintenance of water supply and sewerage facilities, water companies are established district-wise under HCWW. Reformation of organizations for Greater Cairo has been implemented in 2008 by Ministerial Decree No. 369. Previously, Greater Cairo Water Supply Company (GCWSC) is responsible for operation and maintenance of water supply utilities in Greater Cairo and Greater Cairo Sanitary Drainage Company (GCSDC) is responsible for operation and maintenance of wastewater utilities in Greater Cairo. Currently, Giza Water and Wastewater Company (GWWC) is responsible for both water supply and wastewater in Giza, West Bank. Cairo Water Company (CWC) and Cairo Sanitary Drainage Company (CSDC) is responsible for water supply and wastewater in East Bank, respectively.

A regulatory agency is organized with relevant ministries and monitors activities of HCWW. This agency considers appropriateness of water and sewerage tariff and submits a report to the cabinet. The regulatory agency was created in 2004 by Presidential Decree No.136 and has now become active for the purpose of two aspects, one is economic regulation focusing on water tariff and non-revenue water and another is technical regulation focusing on water quality improvement and capacity development for O&M. The board of regulatory agency consists of MOHUUD as the chairman and other members from MOHP, MSEA, Ministry of Finance, HCWW, CAPW, CWC, CSDC, GWWC etc., which can be modified according to the needs from time to time.

5.2 Construction Authority for Portable Water and Wastewater (CAPW)

CAPW was established in 2005 by Ministerial Decree No. 372 for the purpose of preparing the necessary plans and designs for expansion and improvement of the potable water supply and treatment systems and the wastewater collection and treatment systems in Greater Cairo and Alexandria, and for implementing the approved projects. CAPW is also responsible for preparing tender documents, tendering, awarding, contracting and supervising the execution of contracts.

CAPW is administratively and financially under MOHUUD. Its capability can be observed from the on-going projects realized and being supervised by CAPW. When established, the previous name of CAPW was the Organization for the Execution of Greater Cairo and Alexandria Potable Water and Wastewater Project (CAPWO) and later on in July 2007 it was renamed as CAPW.

5.2.1 Organization Structure of CAPW

The organization structure of CAPW is shown in Figure 5.1. CAPW consists of three (3) central departments and ten (10) advisory departments that directly assist the Director. For the formation and implementation of projects, “Central Department for Planning and Projects Studies” and “Central Department for Execution Affairs” are the most related departments. Any prospective project for improvement of water supply and sewerage services in Greater Cairo and Alexandria is planned and designed by “Technical Research Department” and “Design & Survey Department”, which are under the “Central Department for Planning and Projects Studies”. The tendering is executed by “Ordering Level Determination and Tenders/Offers Department” under “Central Department for Planning and Projects Studies” and if the land required for proposed project belongs to private owners or any other agencies, the land acquisition is carried out by “Department of Property Confiscation & Real Estate Affairs” under “Central Department for Planning and Projects Studies”. “Central Department for Financial and Administrative Affairs” is responsible for managing the disbursement of Foreign Loans such as JICA ODA Loan. After awarding, the project will be implemented under the supervision of “Central Department for Execution Affairs”.

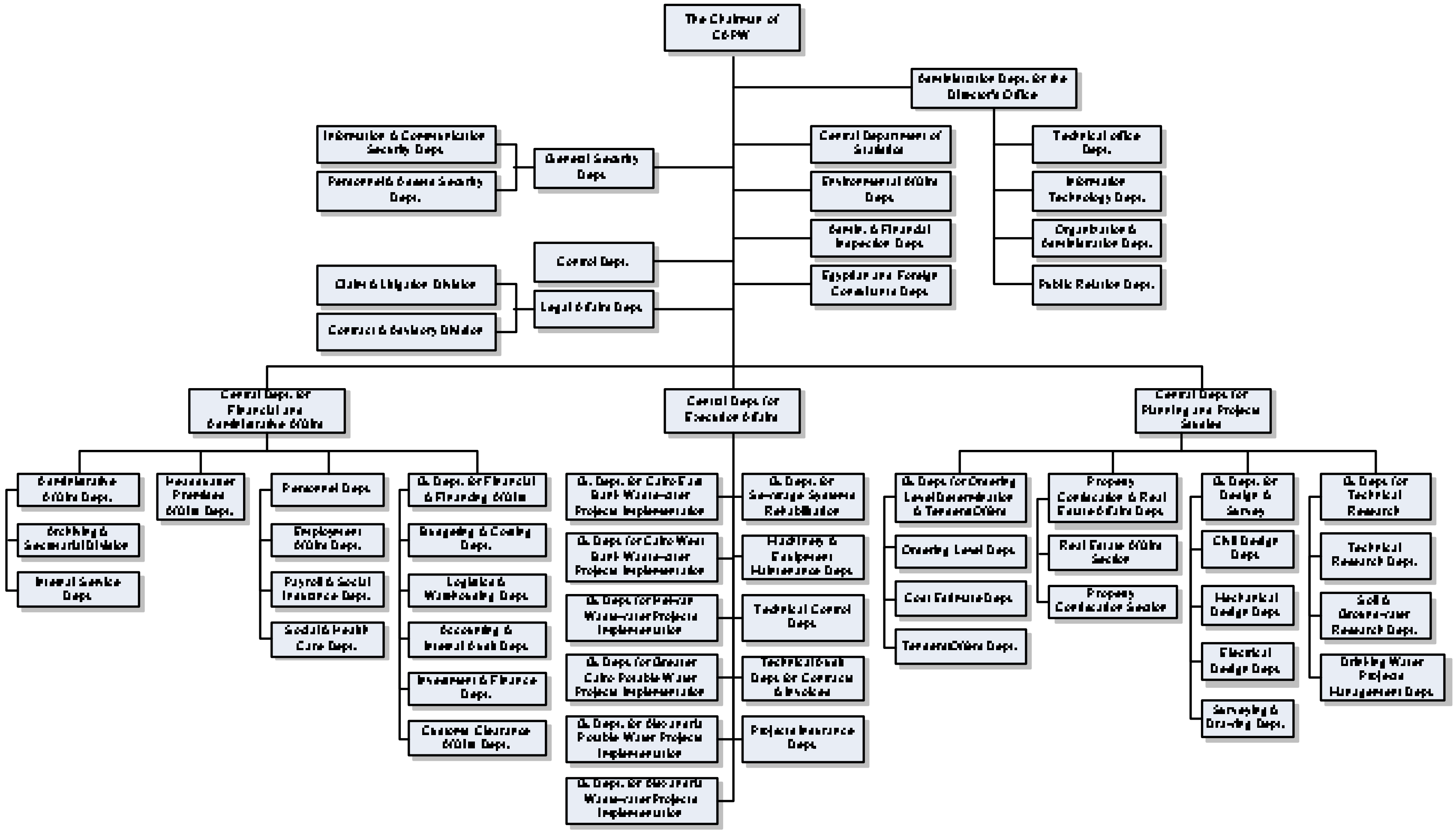


Figure 5.1 Organization Structure of CAPW

5.2.2 Staff Composition and Capabilities of CAPW

To evaluate technical level of CAPW, information on staff number and their qualification has been collected. Staff composition of CAPW according to their qualification is shown in Table 5.1. Total number of CAPW staff members is 766, 34% of the members have university degrees including 2 PhD and 5 Master degree holders. Approximately, 13% of the staff members are technical expertise without university degree. CAPW is considered to be an organization with high level of professionals and expertise. Permanent staff is a group of employees working for CAPW with permanent employment contract, while temporary staff is employed by an employment contract signed for one year subject to renewal. CAPW renews their contracts on regular basis and does not terminate any of them. There is no difference between the two types of employees, with an exception that permanent employees have a right to ask for an unpaid leave and could keep their position reserved for him until their return from the leave.

Table 5.1 Staff Composition of CAPW and their Qualifications

Profession	Permanent	Temporary	Total	Bachelor Degree	Master Degree	PhD
Engineer	75	53	128	125	2	1
Technician	15	62	77			
Mechanic	3	3	6			
Electrician	4	14	18			
Chemist	0	4	4	4		
Health care	2	1	3	1		
Accountant	41	44	85	84		1
Statistic	8	3	11	11		
Law	6	12	18	16	2	
Social worker	7	3	10	9	1	
Administrator	23	17	40			
Clerk	103	86	189			
Driver	11	72	83			
Security	2	2	4	4		
Services	32	58	90			
Total	332	434	766	254	5	2

Source: CAPW

5.2.3 Accounting Analysis of CAPW

(A) Outline View of Financial Management and Accounting Principles

While the Construction Authority of Potable water and Wastewater (CAPW) as a legal entity established by the special law does not issue Financial Statements, this public service undertaking only records Statement of Sources and Use of Funds (Cash flow or Fund flow Statement) since the first one of FY2004 (July 2004-June 2005). Based on the information collected from CAPW, for the preparation of the Statements, to carry out daily routinely jobs of financial recording and cash management, and to prepare the report for accounts management, three expert staff-members are dispatched to CAPW from the Ministry of Finance.

For the purpose of internal check and approval by the Chairman, Financial Statements is to be submitted to the Ministry of Housing Utilities and Urban Development (MOHUUD) for final approval, and consequently forwarded to the Central Audit Organization (CAO, a supreme audit institute in Egypt) for review and auditing. For the fiscal year 2008, CAO carried out this processing and signed the documents by the end of fiscal year 2008.

While CAPW receives public funds as a kind of allotments for construction works, financing comes in the form of borrowings and loans mostly from the National Investment Bank. The amount of fund inflow to the CAPW totaled LE 2.7 billion (JPY 47 billion) as of July 2009. Debt services will be borne by the Ministry of Finance and the Central Bank of Egypt for principal repayments and interest payments, respectively.

(B) Financial Position of CAPW FY2004-2008

Information was collected from CAPW related to Statement of Sources and Use of Funds (including cash and accrual accounts). Based on this information, outline of change in financial position is presented in the form of Income Statement and Statement of Change in Cash Position as of June 2008.

Change in financial position in the past four years is summarized in Figure 5.2. Total source of funds in nominal term was LE 5,095 million (JPY 88.6 billion) in 2008, increasing from LE 370 million (JPY 6.4 billion) in 2004, with growth rate of 96.2 percent per annum. Against this, total use of funds increased from LE 536 million (JPY 9.3 billion) in 2004 to LE 5,392 million (JPY 93.7 billion) in 2008, with the annual rate of 78.1 percent on average. In real term as per 2004 price, total source and use of funds in 2008 are LE 3,607 million (JPY 62.7 billion) and LE 3,839 million (JPY 66.7 billion), respectively, with the average growth rates of 78.4 percent and 63.6 percent.

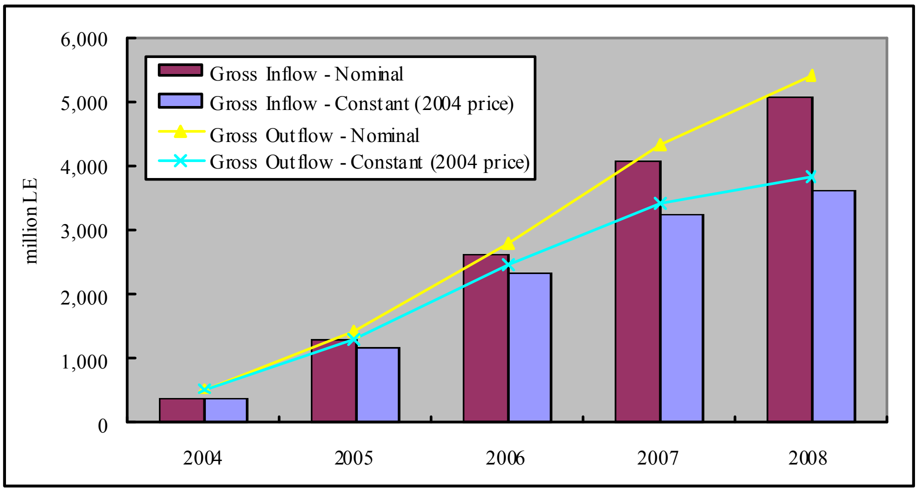


Figure 5.2 Change in Financial Position of CAPW 2004-08

Over the past five years of operation, CAPW posted deficits of LE 180 million (JPY 3.1 billion) in 2004 and LE 326 million (JPY 5.7 billion) in 2008, and these losses had been carried over to the subsequent year when the service receive borrowings from, among others, the National Investment Bank.

Breakdown of inflows and outflows by category is presented in Figure 5.3. In 2008, borrowings accounted for 92.5 percent of aggregate fund inflows, whereas grants from the government for 0.7 percent. Of the aggregate, 78.4 percent of fund outflow was for investment and operational activities, inclusive of purchases of fixed assets.

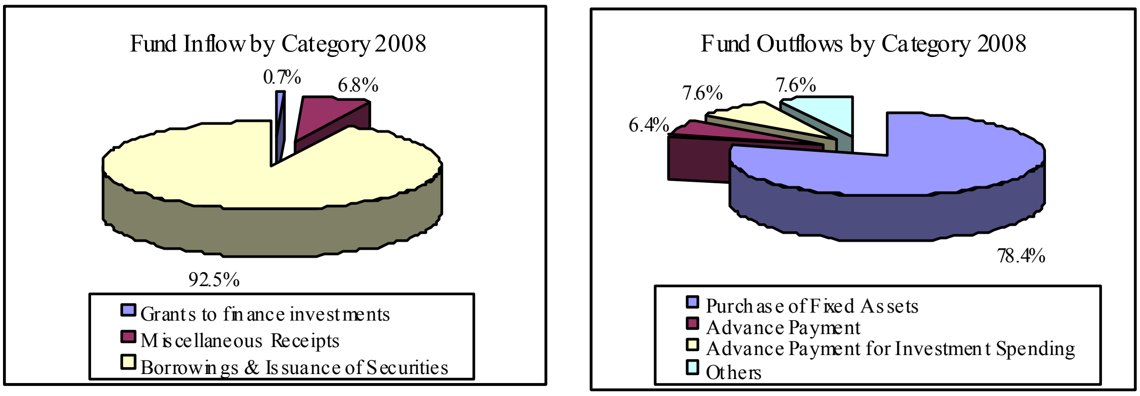


Figure 5.3 Breakdown of Inflows and Outflows by Category, 2008

Meanwhile, annual change in Macro-disequilibrium in market price (inflation) over the period of 1980 through 2008 (actual) and 2009 (estimated) is depicted in Figure 5.4.

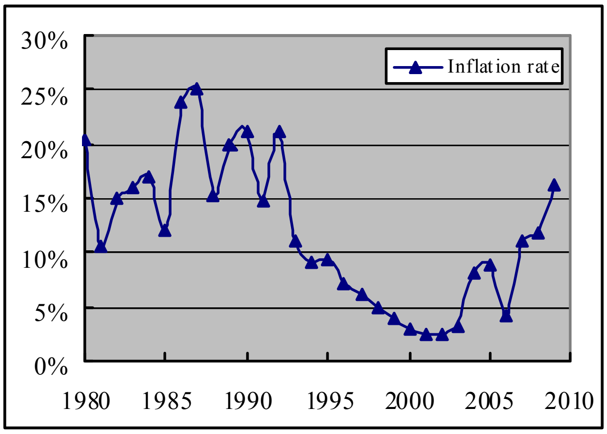


Figure 5.4 Historical Change in General Price Increase (Inflation) 1980 - 2009

(C) Observation

Due largely to financial supports extended through the Ministry of Finance and the Central Bank of Egypt, the entity could keep on track to pursue its operational mission in the Capital region. Nonetheless, the financial sources and liquidity in particular from which the entity draws their operational as well as administrative expenses on routinely basis is weak. Operational losses are accrued and carried over to the next year leaving massive current liabilities. In this light, it would be in need for the government to realign and streamline budget allotment procedures to enabling the service entity to finance its daily expenses as adequate and timely, while managing cash position on a sound basis.

5.3 Holding Company for Portable and Wastewater (HCWW)

HCWW was established in 2004 by Presidential Decree No. 135 for the purpose of holding water supply and sewerage assets of current twenty six companies including GWWC. HCWW is expected to be an economic organization with a significant degree of autonomy.

HCWW developed the evaluation method, which utilizes performance indicators (PIs), in order to monitor performance of water supply and wastewater companies. Hence, companies are responsible to submit reports including monthly figures of PIs. If HCWW recognizes decline in PI, they inquire the company about reason for the decline and ways of improvement. HCWW might even call the chairman of the company if they are not satisfied with report.

5.3.1 Organization Structure of HCWW

The organization structure of HCWW is shown in Figure 5.5. HCWW consists of four (4) divisions, which are Administration and Financial Affairs, Performance Development, Planning and Research and Technical Affairs. The former 2 divisions are directed by a Deputy Chairman and assisted by a general department of Internal Audit for Subsidiary Companies. The latter 2 are directed by another Deputy Chairman. Under these 4 divisions mentioned above, there are 17 general departments in total.

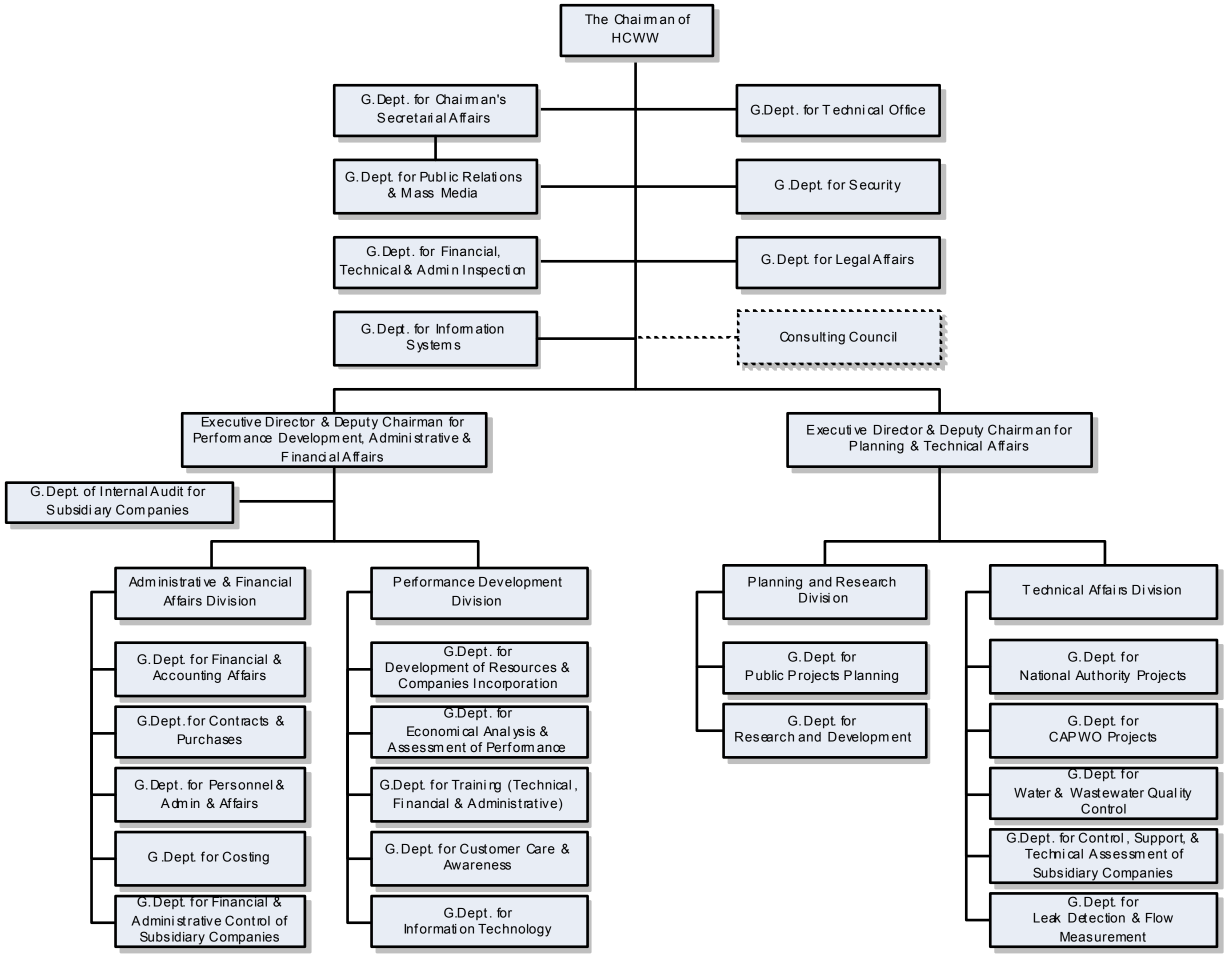


Figure 5.5 Organization Structure of HCWW

5.3.2 Staff Composition and Capabilities of HCWW

Since HCWW has the responsibility to manage twenty six subsidiaries including GWWC and to improve their business performances, the staff composition shows a group of professionals and experts who are capable and skillful for high level of management and administration of these subsidiaries.

Table 5.2 Staff Composition of HCWW

	Advisory Departments Assisting Chairman	Administration & Financial Affairs Div. and Performance Development Div.	Planning & Research Div. and Technical Affairs Div.	Total
Head of General Department	7	10	7	24
Department Manager	7	13	10	30
Section Manager	2	5		7
Engineer	15	23	21	59
Accountant & Finance	6	32		38
Administration/Clerk	6	18	3	27
Interpreter	2			2
Specialist	9	9		18
Chemist			20	20
Technician/Assistant Worker		10	4	14
Information Technology		2		2
Others		18		18
Total	**54**	**65**	**140**	**259**

Source: HCWW

5.3.3 Accounting Analysis of HCWW

(A) Schematic Flow of Funds amongst Game Players in O/M Arena

HCWW currently includes twenty six subsidiary companies that are responsible for operation and management of water supply and sewerage services in various cities and governorates. With the mission of providing safe water to the people in timely manner and at affordable price, the company is responsible for the formulation and administration of financial functions of the entity and the subsidiary companies.

In pursuance of the above objectives, HCWW and the Ministry of Finance has an agreement to appropriately and timely allot the government funds in three ways for the routine operations of the services. These include (i) annual budget to HCWW for the entity's administrative costs accrued and O&M operations borne by the subsidiary companies, (ii) budget for the small scale construction works enlisted on the Crash (Urgent) Plan, and (iii) the budget for rehabilitation projects borne by the subsidiary companies. For the fiscal year of 2008, the amounts of these allotments stood at LE 0.7 billion, LE 3.4 billion, and LE 1.0 billion, for items (i), (ii), and (iii), respectively. Besides, every year HCWW receives one (1) percent equivalent of water and wastewater bills issued by each of the subsidiary companies to customers, as management fee.

Current value of holding stocks of the subsidiary companies amounts to 24.8 billion LE (JPY 421 billion), of which Giza Water and Wastewater Company (GWWC) accounts for 1.1 percent (LE 0.27 billion).

(B) Accounting Analysis

As of 30 June 2009, the total assets of HCWW was valued at LE 21.5 billion (JPY 374 billion), including current and fixed assets accounting for 3.8 percent (LE 0.8 billion) and 96.2 percent (LE 20.7 billion), respectively. On the liability side, current and long-term liabilities and owner's equity account for 2.9 percent (LE 0.6 billion) and 97.1 percent (LE 20.9 billion), respectively. Of the aggregate current assets, the share of accounts receivables was 55.5 percent (LE 0.45 billion), where as that of cash and equivalent was at 32.2 percent (LE 0.26 billion). Likewise, current and long-term liabilities accounted for 83.2 percent and 16.8 percent, respectively.

Gross revenues and expenses are presented in Figure 5.6 with the approximate expressions of those. Gross revenues in 2008 was LE 41.1 million (JPY 714 million) with no expenses of sales, increasing from LE 2.2 million (JPY 39 million) in 2004 with average growth rate of 107.4 percent per annum. Nonetheless, due to a large amount of LE 731 million (JPY 12.7 billion) of administrative expenses, the company posted deficit with earnings before income tax (EBIT) and net profit at LE 698 million (JPY 12.1 billion) and LE 701 million (JPY 12.2 billion), respectively. Of the aggregate expenses, salaries and wages, expenses without depreciation, depreciations, losses, and spare parts and materials accounted for 77.0, 8.0, 6.0, 8.0, and 1.0 percent respectively. Cash outflow surpassed inflow with the difference of LE 91.7 million (JPY 1.6 billion). A large part of cash outflow (LE 3.4 billion) is for payments to subsidiary companies for their operation and maintenance works, small-scale construction and rehabilitation works. The end-of-year balance of cash and equivalents was LE 329 million (JPY 5.7 billion) with the increase of 24.9 percent from the previous year.

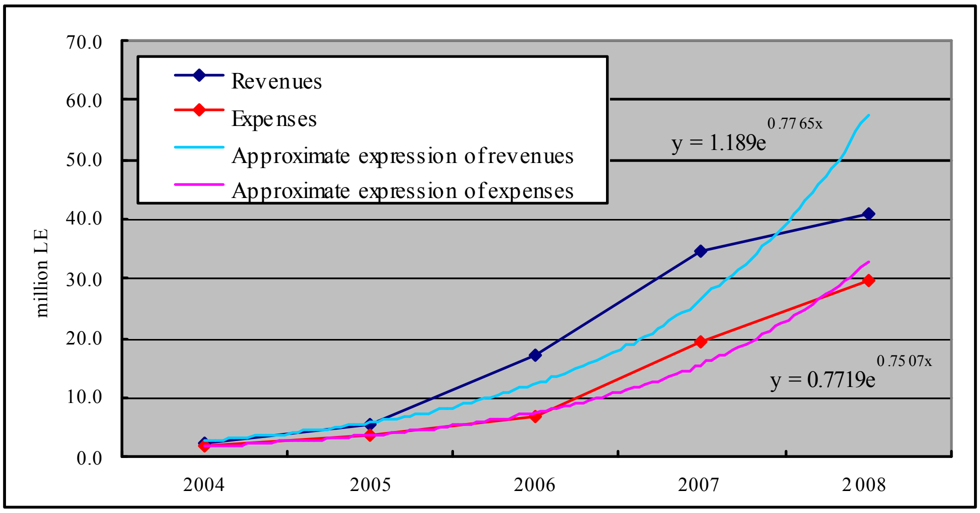


Figure 5.6 Gross Revenues and Expenses

(C) Observation

In the light of financial stability, the company has a large stock of capital with very little borrowings and secured inflow of government funds now and on, thus leading to a positive situation. Nonetheless, it would be noteworthy that, among others, the cash position is weaker, with the current ratio of 1.3, the receivables turnover rate of 0.09, and net cash balance standing at negative LE 91.7 million (JPY 1.6 billion), respectively. Debt service is not specified in the Statement, therefore no guess is made on debt burden on the entity's finance.

Meanwhile, with the growth parameters of 0.7765 and 0.7507 in each of the exponential functions in Figure 5.6, it is observed that revenues and expenses are somewhat on the same paths of marginal tendency of growth. Nonetheless, growth increase in 2008 was a bit curbed, thereby requires careful observation and managerial guidance to keep same growth trend in future.

5.4 Giza Water and Wastewater Company (GWWC)

GWWC was established in 2008 by the reformation of operation and maintenance organization for Greater Cairo. GWWC is responsible for operation and maintenance for water supply and wastewater service in Giza, Helwan and 6th October Governorates. Upon the completion of construction of new facilities, ownership of these facilities is transferred from CAPW to HCWW, and GWWC is responsible for the operation and maintenance of these facilities.

GWWC is administratively and financially under HCWW and expected to be an economic organization with a significant degree of autonomy. GWWC has not fixed with the contents of performance indicators to inform HCWW since its reformation. Hence, GWWC is supposed to submit proposal of performance indicators with target figures in order to get its approval from HCWW.

5.4.1 Organization Structure of GWWC

The organization structure of GWWC is shown in Figure 5.7. GWWC consists of five (5) divisions and ten (10) advisory departments directly assisting the Chairman. "General Department for Abu Rawash WWTP" under "Operation and Maintenance Division for Wastewater for Giza and New Cities" is responsible for the operation and maintenance of Abu Rawash WWTP.

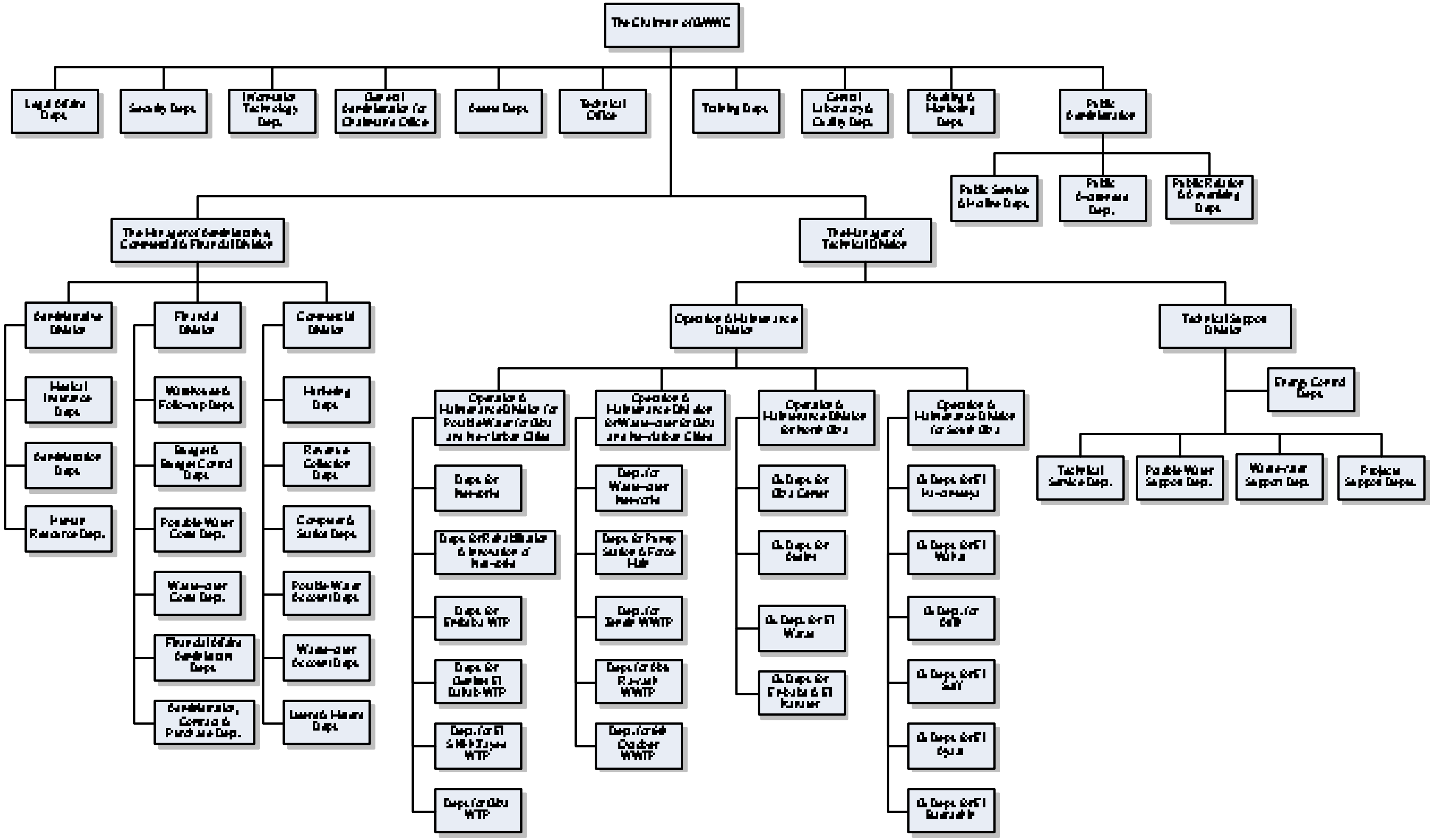


Figure 5.7 Organization Structure of GWWC

5.4.2 Staff Composition and Capabilities of GWWC

To evaluate technical level of GWWC, information on staff number and their qualification has been collected. Staff composition of GWWC according to their qualification is shown in Table 5.3. Total number of GWWC staff members is 8,820, 8% of the members have university degrees. Permanent staff occupies 57 percentages of employees working for GWWC with permanent employment contract, while temporary staff occupies 43 percentages with employment contract signed for one year subject to renewal.

Table 5.3 Staff Composition of GWWC and their Qualifications

Profession	Permanent	Temporary	Total	Bachelor Degree	Master Degree	PhD
Engineer	154	66	220	220		
Technician	771	479	1,250			
Mechanic	380	22	402			
Electrician	108	20	128			
Chemist	30	52	82	82		
Health care	2	0	2			
Accountant	88	160	248			
Statistic	3	52	55	55		
Law	5	26	31	31		
Social worker	0	0	0			
Administrator	73	213	286	286		
Clerk	787	766	1,553			
Driver	283	155	438			
Security	186	254	440	28		
Services	2,118	315	2,433			
O&M	30	1,189	1,219			
Others	25	8	33	33		
Total	5,043	3,777	8,820	735		

Source: GWWC

5.4.3 Finance Analysis of GWWC

(A) Schematic Flow of Funds amongst Game Players in Construction Arena

Subsequent to the establishment in 2008, GWWC was legally legitimatized to be instituted as one of the twenty six subsidiary companies of the HCWW in a bid to carry over part of the services rendered by GCSDC. The first financial statements (F/S) that recorded financial position and performances of GWWC as of 30 June 2009 was submitted to HCWW, and consequently forwarded to the MOHUUD for concurrence.

In the light of income sources, the company receives government subsidiary finance through HCWW, besides its own internally generated income inclusive of water tariff and wastewater surcharge, the sales of water meter, and others. Based on the Financial Statement of GWWC, Balance Sheet as of 30 June 2009, in the fiscal year 2008, the government provided an amount of LE 50.0 million (JPY 0.9 billion) to GWWC through HCWW, of which LE 28.0 million (JPY 0.5 billion) was capitalized in the company's owner' equity, and the balance for routine O&M activities. Later this year, during period of July-November 2009, the government subsidy for the company's expenses on O&M activities amounted to LE 5.0 million (to be recorded in Income Statement of 30 June 2010).

(B) Accounting Analysis

The total assets of GWWC at the end of fiscal year 2008 was valued at LE 1,814 million LE (JPY 31.5 billion), of which current and fixed assets accounts for 20.5 percent (LE 372 million) and 79.5 percent (LE 1,442 million), respectively. On the liability side, current and long-term liabilities and owner's equity account for 2.9 percent (LE 0.61 billion) and 97.1 percent (LE 20.6 billion), respectively. Of the total current assets, the share of accounts receivables was 73.9 percent (LE 273 million), where as that of cash and equivalent was 4.2 percent (LE 16 million). Likewise, current and long-term liabilities accounted for 29.8 percent (LE 437 million) and 70.6 percent (LE 1,059 million), respectively.

Gross revenues was LE 400 million (JPY 7.0 billion) with LE 384 million (JPY 6.7 billion) as the amount of sales. Gross sales ratio is as little as 3.3 percent. Nonetheless, LE 22.0 million LE (JPY 382 million) revenue other than current revenue in the form of subsidy from the Ministry of Finance through HCWW, the company posted current profit and net profit of LE 41.7 million (JPY 724 million) and LE 12.8 million (JPY 511 million), respectively. With the cash collection of LE 238 million (JPY 4.1 billion) from customers and other sources, cash inflow surpassed outflow with the difference of LE 15.6 million (JPY 270 million). A large part of cash outflow was in the form of investment to and for purchase of supplies and material for routine operation and maintenance work (LE 136 million). The end-of-year balance of cash and equivalents was 15.6 million (JPY 270 million).

(C) Observation

In the light of financial profitability and stability, the company was not too bad with a positive net profit in 2008/09. Nonetheless, this financial output was largely attributed to the government grants of LE 50 million (LE 28 million for capitalization and LE 22 million as subsidy for operation/maintenance works), and the issue of weak liquidity remains. Current ratio and the receivables turnover rates were at 0.84 and 0.74, respectively. Fixed assets are also very old and obsolete, with accumulated depreciation of 49.8 percent of book value. Money for further investment would be needed to purchase new machineries and develop new facilities. Own capital ratio is 17.0 percent and the remaining capital is from borrowings. While debt service is not specified in the Statement, little evaluation is made on debt position of the company. Nonetheless, further investment and infusion of resources from the government side would be indispensable for the improvement of water supply and sewerage services by the company.

5.4.4 Current Capacity Development Practice of GWWC

GWWC is enthusiastic about the training of their staffs by means of internal and external trainings. After the reformation, GWWC manages Zenein training center and Embaba training center for the internal trainings. Zenein training center, which owns facilities such as a library, classrooms, laboratory for analysis of heavy metals and workshops for screw pumps, mechanical equipment, generators and electrical equipment, is mainly providing technical programs while Embaba training center is mainly providing administrative and software programs. Internal training programs and number of trainees, which were provided by these two training centers during fiscal year of 2008/2009, are presented in Table 5.4. Internal training programs are classified into three categories, administrative / financial / security programs, PCs / information technology programs and technical programs. Total number of trainees attended those categories is 654, 322 and 660, respectively.

Table 5.4 Internal Training Program of GWWC (2008/2009)

No	Training Programs	Number of Trainees
Administrative / Financial / Security Programs		
1	Security guard and specialist	135
2	Trainer preparation	25
3	Procurement and contract	23
4	Role of the managing director	19
5	Cost estimation	11
6	Evacuation planning	109
7	Performance development program	19
8	Preparation of work strategy	19
9	Preparation of budget and resources control	19
10	Provision of the employees regulations	38
11	Quality control	15
12	Security measure	14
13	Accounting guidance	17
14	Tender and bidding	29
15	Data analysis management	19
16	House connection procedures	18

No	Training Programs	Number of Trainees
17	Accounting system	18
18	Human resource affairs	19
19	Monitoring of employee performance	19
20	Public relation and customer services	12
21	Effective communication	19
22	Solving problems and decision making	19
23	Evidence and authorization	19
PCs and Information Technology Programs		
1	Software training (Windows)	88
2	Software training (Word)	69
3	Software training (Excel)	68
4	Software training (Access)	59
5	Software training (Auto CAD)	20
6	Establishment of PCs run network	9
7	Maintenance of PCs	9
Technical Programs		
1	Technology of water treatment	50
2	Process of water treatment	26
3	Quality control of potable water	19
4	Primary treatment of sewage	13
5	Secondary treatment of sewage	10
6	Technology and process of sludge treatment	11
7	Fundamentals of mechanical engineering	21
8	Fundamentals of electrical engineering	8
9	Fundamentals of generators	30
10	Fundamentals of baring	9
11	Operation and Maintenance of centrifugal pumps	41
12	Operation and Maintenance of drainage pumps and ventilators	7
13	Operation and Maintenance of pumps	25
14	Operation and Maintenance of generators	55
15	Operation and Maintenance of screw pumps	11
16	Operation and Maintenance of clarifiers	8
17	Operation and Maintenance of electric breakers	18
18	Operation and Maintenance of filters	9
19	Operation and Maintenance of distribution panels	20
20	Leak detection of water supply network	15
21	Maintenance of sewage network	27
22	Maintenance of batteries	10
23	Maintenance of lubricating pump and baring of screw pumps	10
24	Maintenance of gates and valves	17
25	Maintenance of gear box	12
26	Measurement instrument and electric circuit protection	24
27	Dismantling of baring	12
28	Oil, grease and petroleum usage	31
29	Identification of screw pump problems	12
30	Identification of generator problems	18

No	Training Programs	Number of Trainees
31	Working record analysis of screws pumps	8
32	Chlorine safety	13
33	Industrial safety	53
34	First aid	7

Source: GWWC

For the external trainings, GWWC utilizes 31 outsource organizations such as universities, government institutions, private companies and research centers to train their staffs. GWWC choose relevant organizations according to subject of training and detail of training programs is flexible to adjust request of trainees.

5.5 Abu Rawash Wastewater Treatment Plant

5.5.1 Organization Structure and Staff Composition of Abu Rawash WWTP

The organization structure of Abu Rawash WWTP is shown in Figure 5.8. Organization structure of Abu Rawash WWTP consists of seven (7) departments under a director, each of these departments is responsible for administration, operation, sludge lagoon, electricity, maintenance, laboratory and security. There are technical office manager, safety manager and training manager directly assisting the director.

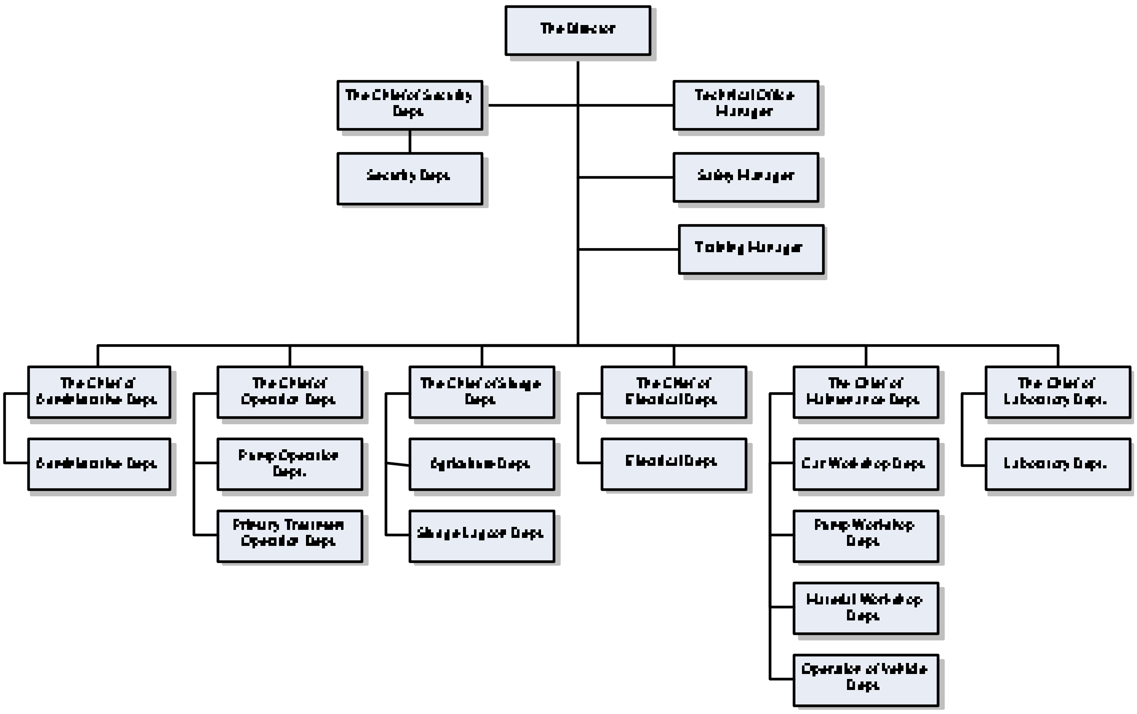


Figure 5.8 Organization Structure of Abu Rawash WWTP

There are three shift groups for operation of pump station / treatment facility / sludge lagoon and security to keep operating facilities 24 hours. These three shift groups operate facilities from 07:00 to 15:00, from 15:00 to 23:00 and from 23:00 to 07:00, respectively and working hours of shift groups are rotated every month. Current staff composition of these departments according to their job positions is shown in Table 5.5. Total number of staff members is 219 as of November 2009, composed of (5) engineers, (51) technicians, (101) workers, (18) administrators, (2) chemists, (13) drivers and (29) securities.

Table 5.5 Current Staff Composition of Abu Rawash WWTP

Profession	Management	Administration dept.	Operation dept.	Sludge lagoon dept.	Electricity dept.	Maintenance dept.	Security dept.	Laboratory dept.
Engineer	1		1	1	1	1		
Technician	4		24	9	4	8		2
Worker			49	36	3	12		1
Chemist								2
Administrator		18						
Drivers						13		
Security							29	
Total	5	18	74	46	8	34	29	5

Source: Abu Rawash WWTP

Upon the completion of current expansion of primary treatment with a capacity of 0.8 million m^3/day, one year of commissioning operation by staffs of the contractor will be started. During the period, commissioning for handover by checking performance through one year of operation and on-the-job training regarding operation and maintenance of newly constructed facilities for staffs of Abu Rawash WWTP will be conducted. Once the facilities are handed over to HCWW, staffs of Abu Rawash WWTP will take over its management. Currently, the director is requesting to GWWC for increase of (127) staff member, which composes of (7) engineers, (17) technicians, (73) workers, (2) administrators and (28) securities, for management after handover.

Regarding this Project, one year of on-the-job training during commissioning period and increase of staff number is also required to manage planned secondary treatment facilities. For the introduction of secondary treatment facilities, knowledge of biological treatment and handling of new equipment such as aerators are particularly required to maintain the facilities properly and operate adequately and effectively. In addition to utilization of current training programs, practical trainings by using the facilities of Zenein WWTP, which has been operating secondary treatment facilities, and personnel exchange between Zenein WWTP are effective to get necessary knowledge and techniques. Recommended training programs are presented in Table 5.6 with their brief contents.

Table 5.6 Recommended Training Programs

Technology of biological treatment

Planned secondary treatment utilizes function of microbes to purify organic road. Acquisition of fundamental knowledge regarding purification function of microbes is vital to operate facilities properly. Removal of pollution load in activated sludge process is carried out by the action of microbes that are present in activated sludge.

In the process of purification function by activated sludge process, removal of carbonaceous organic matter requires a) absorption of organic matter by activated sludge, b) oxidation and integration of absorbed organic matter and c) sedimentation and separation of activated sludge. The advanced purification requires d) nitrification, e) denitrification and f) biological removal of phosphorous.

a) Concentration of organic matter on the surface of activated sludge

b) Decomposition by oxidation to produce energy for microbes and composition by integration

c) Separation of activated sludge from liquid body to obtain treated water

d) Nitrification of nitrogen compound by nitrifying bacterium, autotrophic bacteria

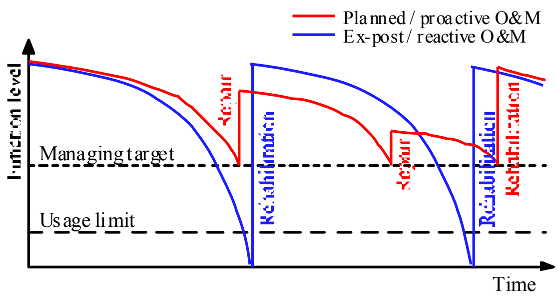
e) Denitrification of nitrite-nitrogen by denitrifying bacteria, facultative anaerobic bacteria

f) Phenomenon of excessive consumption of phosphorous by activated sludge

Concept of life cycle cost

Main concept of facility planning is consideration of life cycle cost including initial investment, costs for O&M and replacement from the view point of sustainability. For this purpose it is important to draw up a maintenance plan from a long-term and comprehensive point of view, and to perform adequate maintenance to keep facilities in proper condition.

A concept of planned / proactive O&M is shown in figure compared with a concept of ex-post / reactive O&M. This shows that performing premeditated repairing works contributes to maintaining function level, the prolongation of facilities' lifetime and the reduction of the total cost.



The planned/proactive O&M is a maintenance technique aiming at the prolongation of facilities' lifetime through the early detection of abnormal point and the preventive measures of sudden accident by the analysis of premeditated machinery investigation/check and repair record. By this planned/proactive O&M, operation and maintenance cost is paid out premeditatedly in a preventive manner, expenditure by sudden trouble/accident is controlled and as a result it aims at reducing the O&M total sum. This technique is based on idea of life cycle cost from the beginning of commencement, operation, repair and disposal.

Technology of ultra fine bubble diffuser device

The application of ultra fine bubble diffuser device, which is most effective in terms of energy saving due to its high efficiency in dissolved oxygen, is proposed. This ultra fine bubble diffuser device is the latest technology and it has not been introduced in Egypt yet. For the introduction, acquisition of knowledge of its technology and maintenance is vital to maintain equipment properly and operate adequately and effectively.

Ultra fine bubble diffuser of membrane type can produce finer bubbles by utilizing membrane technology to make opening slits smaller than ordinary diffusers. Since opening slits are smaller, they are clogged if O&M is not properly conducted. The adhesion of slime to the membrane surface results in decreasing the efficiency of oxygen transfer and merit of this equipment can not be realized fully. The reliable countermeasure for adhesion of slime is to conduct “Blow Down Method”, which is to stop the air supply for a short time with a certain interval making the membrane shrink first and then restart the air supply to re-expand the membrane and thus cause removal of slime from the membrane surface. This countermeasure is an operational management and can be done automatically at regular intervals by installing control panel effective keeping high efficiency.

5.5.2 Monthly Report of Abu Rawash WWTP

Abu Rawash WWTP is responsible for submitting monthly reports to headquarter of GWWC regarding management of WWTP. GWWC monitors their performance and evaluates monthly figures presented in these reports by comparing historical figures in the past and figures of other WWTPs. Monthly report contains the following information shown in Table 5.7.

Table 5.7 Contents of Monthly Report of Abu Rawash WWTP

Operation Records	
Flow	➢ Influent flow to primary treatment facilities (m^3/day)
Quality	➢ Suspended solid (SS) of influent and effluent (mg/L) ➢ Biochemical oxidation demand (BOD) of influent and effluent (mg/L)
Efficiency	➢ Removal rate of SS and BOD (%)
Sludge	➢ Mixed sludge flow (m^3/day) and total solid (%) receiving from Zenein WWTP ➢ Primary sludge flow (m^3/day) and total solid (%) of Abu Rawash WWTP ➢ Mixed Sludge flow (m^3/day) and total solid (%) transferring to sludge lagoon
Treatment	➢ Surface loading of primary settling tanks ($m^3/day/m^2$) ➢ Weir loading of primary settling tanks (m^3/day/m) ➢ Detention time of primary settling tanks (hour) ➢ Solid loading of primary settling tanks (kg/day/m^2)
Administration and Financial Records	
Administration	➢ Total number of employee according to job position (person) ➢ Inspection hours (hour/month) and repairing (hour/month) ➢ Training hours (hour/month)
Operation	➢ Monthly electricity consumption (kWh/month) ➢ Amount of garbage removed by screen (m^3/month) ➢ Amount of sand removed by grit chamber (m^3/month)
Expenditure	➢ Total salary of employee (LE/month) ➢ Electricity charge (LE/month) ➢ Purchase expense of spare parts (LE/month) ➢ Expense of consumables such as fuel (LE/month) ➢ Expense of laboratory (LE/month) ➢ Outsourcing contract for maintenance (LE/month) ➢ Other expense such as telephone (LE/month)

CHAPTER 6 PERFORMANCE INDICATORS

6.1 Performance Indicators (PIs)

Performance indicators (PIs) can be considered as a management tool to evaluate the degree of undertaking's efficiency and effectiveness. Efficiency is the extent to which the resources of an undertaking are utilized to provide the services, e.g. maximizing services delivery by the minimum use of available resources. Effectiveness is the extent to which declared or imposed objectives, such as levels of service, are achieved. PIs can also be used for quantitative comparative assessment of performance. This quantitative comparison can be conducted between undertakings, or historically within an undertaking comparing the past and present or actual performance against pre-defined target.

In order to evaluate the performance of water supply and wastewater undertakings, regardless of they are public or private, PIs have been developed and introduced worldwide. International Water Association (IWA) developed PIs for water supply services and published "Performance Indicators for Water Supply Services" in 2000 and for wastewater services namely "Performance Indicators for Wastewater Services" in 2003, respectively. International Organization for Standardization (ISO) developed international standards regarding activities related to drinking water and wastewater services and published "Guidelines for the Assessment and for the Improvement of the Service to Users: ISO 24510", "Guidelines for the Management of Wastewater Utilities and for the Assessment of Wastewater Services: ISO 24511" and "Guidelines for the Management of Drinking Water Utilities and for the Assessment of Drinking Water Services: ISO 24512" in 2007.

6.2 Application of Performance Indicators (PIs)

ISO guidelines focus on presenting a conceptual planning of performance indicators rather than practical contents of PIs. There are few examples of PIs in ISO guidelines since ISO guidelines target some PIs mostly referring from IWA manual and encourage to develop own PIs according to objectives of evaluation. Hence, PIs included in IWA manual is used in order to evaluate effect of this Project since they are practical PIs covering all the aspects of wastewater services.

There are 179 PIs in IWA manual of "Performance Indicators for Wastewater Service" which are classified into six (6) performance categories, viz. environmental, personnel, physical, operational, quality of service and economic and financial. Number of indicators in each category is show in Table 6.1.

Table 6.1 Performance Indicators Classified by Category

Performance Category	Code	Nos. of PIs
Environmental Indicators	*wEn*	15
Personnel Indicators	*wPe*	22
Physical Indicators	*wPh*	12
Operational Indicators	*wOp*	56
Quality of Service Indicators	*wQS*	29
Economic and Financial Indicators	*wFi*	45
Total		179

PIs presented in Table 6.1 cover comprehensively all the aspects of wastewater services. Hence, substantial PIs are considered to remain the same regardless of implementation of this Project or for which the effect in this Project can not be evaluated quantitatively. PIs, which are directly affected and evaluated quantitatively, are selected and presented in Table 6.2 with their category, code and analysis of tendency of the effect in the Project. Detailed concepts of these PIs are presented in Appendix-8.

Provision of secondary treatment facilities at the plant which currently has only primary treatment facilities obviously enhances compliance with discharge consents (*wEn1)* and wastewater reuse (*wEn2)* owing to better quality of effluent. Production of sludge (*wEn6*) increases due to addition of excess sludge generated from secondary treatment.

The provision of proposed facilities requires additional staff for O&M resulting in increase of personnel (*wPe1* and *wPe10*).

Installation of new mechanical and electrical facilities under this Project requires increases of maintenance works (*wQp13*, *wQp14*, *wQp15*, *wQp16* and *wQp17*) and consumption of electricity (*wQp18*). Degree of automation and remote control (*wPh11* and *wPh12*) is planned to increase owing to introduction of SCADA system and instrument according to the concept of stable and easy operation. Secondary treatment process, which utilizes function of microbes to purify organic load, requires more careful attention regarding raw and treated water quality (*wOp45*, *wOp46*, *wOp47*, *wOp48*, *wOp49*, *wOp50* and *wOp52*).

Complains (*wQS19* and *wQS22*) caused by discharge of poor quality or non-treated wastewater is expected to be minimized owing to improvement of effluent quality. However, there is possibility of odor complains (*wQS23*) around sludge lagoons due to increased amount of sludge.

Provision of secondary treatment facilities requires investment and increase in O&M cost (*wFi5*, *wFi5* and *wFi5*) as shown in Table 3.22 and Table 3.24.

Table 6.2 Performance Indicators Selected for Project Evaluation

Category	Code	Indicator	Tendency
Environmental Indicators	*wEn1*	WWTP compliance with discharge consents (%/year)	⇧
	wEn2	Wastewater reuse (%)	⇧
	wEn6	Sludge production in WWTP (kgDS/p.e./year)	⇧
Personnel Indicators	*wPe1*	Personnel in WWTP per population equivalent (No./1000p.e.)	⇧
	wPe10	Technical WWTP personnel (No./1000p.e.)	⇧
Physical Indicators	*wPh11*	Automation degree (%)	⇧
	wPh12	Remote control degree (%)	⇧
Operational Indicators	*wOp13*	WWTP flow meters calibration (-/year)	⇧
	wOp14	Wastewater quality monitoring equipment calibration (-year)	⇧
	wOp15	Emergency power system inspection (-/year)	⇧
	wOp16	Signal transmission inspection (-/year)	⇧
	wOp17	Electrical switchgear inspection (-/year)	⇧
	wOp18	WWTP energy consumption (kWh/p.e./year)	⇧
	wOp44	Wastewater quality tests carried out (-/year)	⇧
	wOp45	- BOD tests (-/year)	⇧
	wOp46	- COD tests (-/year)	⇧
	wOp47	- TSS tests (-/year)	⇧
	wOp48	- total phosphorus tests (-/year)	⇧
	wOp49	- nitrogen tests (-/year)	⇧
	wOp50	- fecal coli tests (-/year)	⇧
	wOp52	Sludge tests carried out (-/year)	⇧
Quality of Service Indicators	*wQS7*	Treated wastewater in WWTP - primary treatment (%)	⇩
	wQS8	Treated wastewater in WWTP - secondary treatment (%)	⇧
	wQS19	Total complaints (No./1000 person./year)	⇩
	wQS22	- pollution incidents complaints (No./1000 person./year)	⇩
	wQS23	- odor complaints (No./1000 person./year)	⇧
Economic and Financial Indicators	*wFi5*	Unit cost per p.e. (US$/p.e./year)	⇧
	wFi7	- unit running cost per p.e. (US$/p.e./year)	⇧
	wFi9	- unit capital cost per p.e. (US$/p.e./year)	⇧

CHAPTER 7 CONCLUSIONS AND RECOMMENDATIONS

The preparatory study for Abu Rawash Wastewater Treatment Plant has been conducted by JICA Study Team and the conclusions and recommendations are given as follows:

7.1 Conclusions

1. Government of Egypt gives higher priority on increase of capacity of wastewater treatment plants in respect to National Water Resource Plan, which was prepared by MWRI to safeguard its water resource in future. A total budget of LE 900 million can be utilized for the provision of secondary treatment facilities of Abu Rawash WWTP according to CAPW New Five-Year Plan in accordance with the Six National Development Plan indicating high priority of this Project given by CAPW, MOHUUD and Ministry of Planning (now called Ministry of Economic Development).

2. The provision of the secondary treatment facilities with a capacity of 1.2 million m^3/ay is the first priority from the aspect of improvement of water quality in receiving drains and in Nile River. The second priority goes to the expansion of sewage treatment facilities with a capacity of 0.8 million m^3/day due to the rapid increase of population in Greater Cairo and the current deficit in treatment capacity. The provision of sludge treatment facilities is considered as the third priority since the land for sludge lagoons, which is enough to treat sludge generated, has been already acquired.

3. The major results of facilities planning relating to the provision of the secondary treatment facilities are as follows:

   - Hydraulic Profile has been planned by gravity without lift pumps from the connecting points with the existing and on-going facilities to receiving body, Barakat drain. However, the increase of hydraulic loss by the provision of secondary treatment facilities requires an additional effluent channel to Barakat drain.

   - Ultra fine bubble diffuser (whole area differed type) is chosen for aeration equipment due to economical advantage owing to its high efficiency, long lasting feature and flexibility for various operation.

   - The existing sludge transfer facilities including pipeline and pumps can accommodate additional amount generated from this Project, but one series of additional pumps are required as standby. The expansion of 183 ha of sludge lagoons is required in order to accommodate increased sludge generated from the secondary treatment facilities.

4. Estimated project cost is LE 3,101 million (JPY 53.9 billion) including taxes and LE 2,651 million (JPY 46.1 billion) excluding taxes. Additional annual O&M cost for the secondary treatment facilities is 24.3 million LE/year (0.42 billion JPY/year) and all annual O&M cost of Abu Rawash WWTP is and 49.6 million LE/year (0.86 billion JPY/year).

5. FIRRs in case of all of three tariff options including (i) O&M cost recovery, (ii) O&M cost + CAPEX recovery and (iii) LRMC pricing are lower than the cut-off ratio of 9.7 percent (OCC). However, EIRR in case of (iii) LRMC pricing is estimated at 10.3 percent exceeding 10.0 percent (SDR) and revealed a profound basis of economic feasibility in case of applying the Long-Run Marginal Cost pricing. In this view, this Project is economically viable and worth to be proceeded under leadership of public sector.

6. It seems that CAPW, the implementation agency, has enough capability to execute this Project since they have experiences of the same scale of projects such as Al-Gabal-Al-Asfer WWTP under their supervision. It also seems that GWWC, the O&M agency, can manage planned facilities since they already have enough experiences to manage secondary treatment facilities, which utilizes the same technology and process to purify organic load. In addition to training programs and one year of on-the-job training during commissioning period, practical training by using facilities of Zenein WWTP and personnel exchange between Zenein WWTP are effective to get necessary knowledge and techniques.

7.2 Recommendations

1. Approval of EIA report by Egyptian Environmental Affairs Agency (EEAA) is required for the implementation of this Project. The CAPW, the executing agency, should go through official procedure in order to get approval from relevant authorities as soon as possible.

2. The commencement of the next stage extension of sewage treatment facilities with a capacity of 0.4 million m^3/day (of the remaining 0.8 million m^3/day to be expanded after this Project) is recommended immediately after completion of this Project due to the rapid increase of population.

3. Utilization of secondary treated effluent for the plantation of Jatropha should be enhanced aiming at forestation of desert area and production of bio diesel energy, which is produced from Jatropha and effective in reducing CO_2 emission.

4. Regarding the introduction of sludge treatment facilities with anaerobic digesters process and digested gas generation system, which can be applied to Clean Mechanism Development project, it is also desirable to consider the introduction of sludge treatment facilities as soon as feasible.

5. Increase of tariff is inevitable to strengthen financial capability and stability of service undertakings. Public awareness campaign about pollution should be enhanced in order to gain people's acceptance for tariff increase.

6. Utilization of dried sludge for desert soil improvement should be enhanced by treating generated sludge appropriately and periodical monitoring of the presence of heavy metals and toxic substance should be strictly conducted.

7. Proper management of industrial wastewater should be established since heavy metals and toxic substances, which are potentially contained in industrial wastewater, causes negative influence on biological treatment process and reuse of treated effluent and sludge.

APPENDIX – 1

TOR prepared by JICA

Terms of Reference (TOR) prepared by JICA for the Study are described in this Appendix.

The Study is divided into the following seven (7) stages.

1. Preparatory Home Work
2. First On-site Work
3. First Home Work
4. Second On-site Work
5. Second Home Work
6. Third On-site Work
7. Third Home Work

TOR is prepared in order of stages.

1. Preparatory Home Work

TOR 1.1 Preparatory work

a) To confirm status of the project in Egypt Sixth Five Year Plan, and analyze the previous reports, request from Ministry of International Cooperation, and relevant documents regarding the project, and grasp components and background of the project and information of concerned sectors.

b) To hold meetings with JICA to confirm details of the study, JICA's policy for formulation of JICA ODA Loan project, points to be considered, depth of study, matters about estimation of project costs, conditions of anticipated JICA ODA Loan, implementation schedule and so on.

c) To establish Study plan taking into account concept, components and scope of cooperation, policy for study, study items, and study methodology.

d) To sort out the available data and list up necessary data and information to be collected. To sort out items to be confirmed with relevant authorities during on-site work and prepare questionnaire.

e) To prepare Inception Report for explanation to Egyptian authorities concerned. The Report includes basic policy for the study, team organization, implementation schedule, study methodology (method, timeframe, depth of study), roles of team members. To explain the Report to JICA.

2. First On-site Work

TOR 2.1 Explanation and discussion of Inception Report

At the early stage of first on-site work, the Study Team should explain and discuss Inception Report with Egyptian authorities concerned and confirm its contents.

TOR 2.2 Promotion of environmental and social considerations procedure

TOR 2.2.1 Assistance in the preparation of EIA Report

a) Confirmation of EIA procedures in Egypt

b) Preparation of EIA Report based on "JBIC Guidelines (2002) for Confirmation of Environmental and Social Considerations, April 2002" (JBIC Guidelines (2002)) including the following contents. EIA Report based on Egyptian laws and regulations should also be prepared.

(Contents of EIA Report)

- Formal name of the project and report
- Environmental category and reasons for this
- Project implementing agency
- Outline of the project (objectives, necessity/appropriateness, requested activities, scope and contents of the study, etc.)
- Outline of project area (maps, natural and socio-economic environment, etc.)
- System for environmental and social considerations in Egypt

i. Laws and regulations for environmental and social considerations (requisites and procedures for environmental and social considerations, inhabitants participation, disclosure of information)

ii. Concerned authorities

- Outline of environmental and social considerations study (reasons for conduct, major impacts)
- Examination of alternatives (including non project case)
- Avoidance or mitigation measures for major environmental and social impacts
- Monitoring of environmental and social impacts (implementing organization, methodology, etc.)
- Results of stakeholder meeting (objectives, participants, contents of meeting, comments, etc.)
- Results of consultation with authorities concerned (agreement for avoidance or mitigation measures, capacity building program, future issues)
- Relevant data

c) Assistance in holding public consultation at scoping stage

TOR 2.2.2 Assistance in preparation of land acquisition and resettlement plan

a) Confirmation of necessity and magnitude of land acquisition and involuntary resettlement

b) If large scale involuntary resettlement is envisaged, assistance in preparation of

"Resettlement Plan Report" based on JBIC Guidelines (2002) and Egyptian laws and regulations. Contents of the Report shall be referred to Annex A of Operational Policy 4.12 (OP4.12), World Bank.

c) If large scale involuntary resettlement is not envisaged, assistance in preparation of "Framework for land acquisition and resettlement" based on JBIC Guidelines (2002) and Egyptian laws and regulations. In the Framework, procedures for compensation, implementing organization, entitlement matrix and budget shall be included.

TOR 2.2.3 Assistance in preparation of environmental checklist

Assistance in preparation of environmental checklist based on EIA Report and Resettlement Plan Report

TOR 2.3 Assistance in establishing the Project plan

TOR 2.3.1 Confirmation of the latest conditions

a) Population projection in Greater Cairo

b) Estimation of wastewater flow

c) Design characteristics of wastewater

TOR 2.3.2 Ascertainment of scope of the Project and confirmation of plant site

a) To make clear necessity of each components formulating project scope

b) To make clear scale/quantity, construction method and their appropriateness of each component

c) To recommend necessary soft components such as training of operation of secondary treatment by contractor

d) To recommend outline of consulting services

TOR 2.3.3 Relevance of secondary treatment process proposed in JETRO F/S

a) Confirmation of treatment process

b) Study on alternatives

c) Explanation of appropriateness of secondary treatment process based on technical, energy saving and financial aspects

- Confirmation of appropriateness of design criteria used in JETRO F/S based on additional data of influent characteristics
- For activated sludge process a large quantity of air is required for supply of oxygen and substantial amount of electricity is consumed. It is necessary to consider adoption of ultrafine bubble system which has very high oxygen transfer ratio, optimum design of blower, and its arrangement plan according to variation of load. Special attention should be paid to ultrafine system by selecting suitable filters.

d) Examination of applicability of STEP Loan

TOR 2.3.4 Ascertainment of the effects of effluent quality on receiving water bodies

Treated effluent discharges to Barakat drain and then flows through many drains, and finally discharges to Rosetta branch of River Nile. Water quality standards for agricultural reuse will be applied when the effluent is used from these drains. All water quality items other than BOD and COD should be examined and the results should be reflected in design of secondary treatment.

TOR 2.3.5 Investigation of sludge treatment processes and disposal methods

Estimation of sludge generation from proposed facility and confirmation of additional facilities to send sludge to the existing sludge lagoon should be carried out. Study on environmental impact caused by increasing sludge generation also be carried out.

Currently sludge is sent to sludge lagoons located in desert area at a distance of 35 km from the Abu Rawash WWTP and dried by natural process. It is desirable to reuse dried sludge for agricultural purposes. However, concentrations of heavy metals are considered to increase and might exceed permissible limits. Concentrations of heavy metals should be investigated and monitoring and controlling system should be recommended together with other monitoring items such as BOD and COD.

TOR 2.3.6 Relevance of facilities planned in JETRO F/S

Appropriateness of preliminary design proposed in JETRO F/S, including dimensions and specifications of facilities should be confirmed.

TOR 2.3.7Relevance of implementation schedule proposed in JETRO F/S

Procurement package based on analysis of trend of market should be prepared.

Since this is very large scale public utilities project, it is necessary to analyze trend of market for procurement of materials, goods and services, and prepare implementation schedule and procurement package.

TOR 2.3.8 Investigation of the project cost

Estimation of the project cost based on the scope of the project proposed in this Study, including capital investment and O & M costs should be carried out.

Costs for consulting services, price escalation, physical contingency, administration, and land acquisition should be estimated based on the construction costs of project components. Cost should be divided into foreign and local currency portions.

In estimating the project cost, cost reduction should be considered taking into account the following matters (a) to d) below). Cost reduction measures and its effects should be discussed with the executing agency and presented in prescribed format. “Examination and Improvement of ODA, 2007” and its annex “Comprehensive ODA Cost Improvement Program” published by Ministry of Foreign Affairs should be understood in considering cost reduction.

a) Establishment of most appropriate plan

Most appropriate plan in respect of project cost and time should be established comparing conventional plan with alternative plans which may lead to cost reduction, in view of construction method, construction technology and contract method.

- Optimizing construction method

  Construction methods which may lead to cost reduction should be considered and compared with standard method.

- Optimizing construction technology

  Innovative construction technology which may lead to cost reduction should be considered and compared with standard technology.

- Optimizing contract method

  Different contract methods other than standard method should be considered for possible cost reduction.

b) Reconsideration of ancillary works

Conventional scales or specifications of ancillary works should be reconsidered for cost reduction, and possibility that these works are to be implemented by executing agency should be sought.

c) Partial amendment of implementation plan

Implementation plan should be amended taking into account scale and function of the project in order to formulate efficient implementation plan.

d) Setting appropriate construction period

Cost reduction should be considered by working out appropriate construction period till completion of the project under JICA ODA Loan. Division of the project into several appropriate lots considering cost reduction through competitive bidding should be considered. These should be consulted with executing agency.

TOR 2.3.9 Investigation and recommendations on implementation schedule

Realistic implementation schedule should be presented in bar chart which shows each component of the project. Timing and period of such components as detail design of each facility, preparation of tender documents, prequalification, evaluation of PQ documents, bidding, evaluation of bidding documents, contract negotiation and award of contract should be clearly indicated. Also, consultant selection procedures needed for JICA ODA Loan project such as short listing, TOR preparation, request for proposal, proposal preparation, evaluation of proposal, contract negotiation, award of contract should be indicated. The term “completion is to be clearly defined.

TOR 2.3.10 Investigation and recommendations on financial plan

Information on financial plans of both JICA and Egyptian side should be collected and reviewed. Phased implementation plan should be considered as required.

TOR 2.3.11 Investigation of JICA ODA Loan conditions including STEP scheme

TOR 2.3.12 FIRR and EIRR analysis

FIRR and EIRR should be analyzed clarifying cost, benefit and project life.

TOR 2.3.13 Investigation and recommendations on organization for project execution

Relevant organizations concerning the project together with their roles, organization charts, roles of respective staff members should be clarified. The roles and activities of major members of executing agency should be clarified.

Financial and technical capabilities of CAPW should be confirmed. Capacity building program should be incorporated in the project if necessary.

TOR 2.3.14 Investigation and recommendations on O & M organization

Organization for operation and maintenance of the facilities constructed under the project should be clarified with organization chart, staff structure and roles of major staff members.

Currently, total number of technical staff at treatment plant is 28 including chemical and mechanical/electrical. It is necessary to establish O & M structure and to provide necessary staff when secondary treatment is in operation. Capacity building program should be incorporated if necessary.

TOR 2.3.15 Analysis and recommendations on tariff structure including its collection system

O & M cost should be estimated and resources for the cost should be examined.

Equipment of secondary treatment requires not only considerable operation work but also maintenance and repair work. Overall O & M cost should include personnel and utility costs, and repair and depreciation costs.

TOR 2.4 Others

TOR 2.4.1 Verification of performance indicators

Performance indicators (setting of baseline and target, how to obtain data), baseline data, targeted indicator values after completion of the project and targeted qualitative effects should be recommended.

TOR 2.4.2 Clarification of the needs for technical cooperation

Needs for technical cooperation in such fields as wastewater treatment plant operation, water quality management, and environmental monitoring which are required throughout implementation of the project should be identified.

Note:

TOR 2.2 to 2.4 mentioned above are mandatory for the Study. However, completion of all the TOR during first on-site work period seems to be difficult because of limited time. Consultant can propose timing of completion of each item on overall work schedule.

3. First Home Work

TOR 3.1 Report on First On-site Work

Results of the first on-site work should be reported to JICA.

TOR 3.2 Preparation of Interim Report

Interim Report should be prepared based on analysis of data and information collected during first on-site work and should be explained to JICA.

TOR 3.3 Preparation for Second On-site Work

Policy for second on-site work should be established taking into account contents of Interim Report. Information available in Japan which can be utilized for the Study should be collected and reviewed for preparation for second on-site work.

4. Second On-site Work

TOR 4.1 Explanation and Consultation of Second On-site Work

At the commencement of second on-site work, Interim Report should be explained to Egyptian authorities concerned, and agreed on work plan for second on-site work.

TOR 4.2 Follow-up First On-site Work

Based on the data and information collected during first on-site work and on the concept of the project, Study on items mentioned in section 2 above should be continued.

TOR 4.3 Explanation and consultation of results of second on-site work

Toward the end of second on-site work, progress of major works should be explained to Egyptian counterpart. Coordination with Egyptian counterpart regarding recognition of present situation and direction of Draft Final Report should be sought.

Note:

Study during both first and second on-site works should be carried out as efficiently as possible. Collection of data and information needed for the Study should be ensured, and this should be consulted with Egyptian counterpart.

5. Second Home Work

TOR 5.1 Preparation of Draft Final Report

Results of second on-site work should be reported to JICA, and based on the results, necessary analysis work should be carried out. Draft Final Report which covers all the Study results should be prepared. Draft Final Report should be submitted to JICA for discussion and confirmation prior to explanation to Egyptian authorities concerned.

6. Third On-site Work

TOR 6.1 Explanation and consultation of Draft Final Report and conduct of workshop

Draft Final Report should be explained to the executing agency, and workshop to explain the results of the Study to all Egyptian authorities concerned should be held. If comments are received from them, these should be reflected in Final Report after consultation with JICA.

7. Third Home Work

TOR 7.1 Preparation of Final Report

Final Report should be prepared by the end of January, 2010.

APPENDIX – 2

Design Calculations of Activated Sludge WWTP

(Design Capacity = 2,000,000 m^3/day)

Design Calculations of Activated Sludge WWTP

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1 DESIGN PARAMETERS AND CRITERIA

1.1 Wastewater Quantity and Characteristics

Average daily flow	Q_{ad} =	2,000,000	m^3/d
Peak flow	Q_{mh} =	0	m^3/d
BOD concentration	=	310	mg/L
SS concentration	=	360	mg/L

1.2 Pollutants Removal Efficiencies

BOD concentration including sidestream flow	=	310	mg/L
BOD concentration treated with primary system	=	155	mg/L
BOD removal efficiency with primary system	=	50	%
BOD removal efficiency with secondary system	=	85	%
Overall BOD removal efficiency	=	93	%
SS concentration including sidestream flow	=	360	mg/L
SS concentration treated with primary system	=	144	mg/L
SS removal efficiency with primary system	=	60	%
SS removal efficiency with secondary system	=	85	%
Overall SS removal efficiency	=	94	%

1.3 Effluent Qualities

BOD concentration	=	23	mg/L
SS concentration	=	22	mg/L

1.4 Component Facilities

(a) Primary Clarifiers

Hydraulic overflow rate	=	35.0	$m^3/m^2/d$
Hydraulic retention time	=	1.7	hr
Effective depth	=	2.5	m
Weir overflow rate	=	250.0	$m^3/m/d$ or lower
Free board	=	0.5	m or more
Sludge solids concentration	=	2.0	%

(b) Aeration Tank

MLSS concentration	=	2,000	mg/L
Dissolved oxygen in mixed liquor	=	2.0	mg/L
Hydraulic retention time (HRT)	=	4.5	hr
Solids content in return sludge	=	0.6	%
Return sludge ratio	=	46	%
Oxygen required to remove BOD	=	0.6	$kgO_2/kgBOD$
Oxygen required for endogenous	=	0.10	$kgO_2/MLVSS/day$

(c) Final Clarifiers

Hydraulic overflow rate	=	25	$m^3/m^2/d$
Hydraulic retention time	=	3.5	hr
Effective depth	=	3.5	m
Weir overflow rate	=	150	$m^3/m/d$ or lower
Free board	=	0.5	m or more
Excess sludge solids concentration	=	0.6	%

(d) Disinfection

Maximum Chlorine dosing rate	=	15.0	mg/L
Average Chlorine dosing rate	=	5.0	mg/L
Chlorine contact time	=	5.0	minutes

(e) Gravity Sludge Thickeners

Thicken sludge solids concentration	=	4.0	%
Solids recovery rate	=	85	%
Solids surface loading	=	50	$kg/m^2/day$
Effective depth	=	4.0	m

(f) Anaerobic Sludge Digester

Hydraulic retention time	=	24	days
Sludge heating temperature	=	35	℃
Volatile material contents	=	70	%
Digestion rate	=	50	%
Gas calorific value	=	21,000	kJ/m^3
Gas production rate	=	0.50	m^3/kg

(g) Sludge Lagoon

Drying period in summer	=	25	days
Drying period in winter	=	40	days

2 DESIGN CALCULATIONS OF WATER TREATMENT FACILITIES

2.1 Primary Clarifiers

(1) Design Bases

Average daily flow	Q_{ad} =	800,000 m^3/d			
Hydraulic overflow rate	q_o =	35 $m^3/m^2/d$			
Total number of clarifiers	n =	16 units		4 clusters x	4 tanks
Hydraulic load on each basin is	=	800,000 / 16	= 50,000	m^3/d	
Required surface area of each tank	=	50,000 / 35	= 1428.6	m^2	

(2) Tank Geometry

Internal diameter	D =	43.0 m
Effective depth	d =	2.5 m
Number of basins	n =	16 units
Required surface area of each tank	A =	1,452 m^2
Hydraulic capacity of a basin	Q_p =	3,631 m^3

(3) Check for Hydraulic Conditions

HRT for average daily flow rate,	T_{ad} =	3,631 x 24 / 50,000	= 1.7	hr
HRT for hourly max flow rate,	T_{mh} =	3,631 x 24 / 80,000	= 1.1	hr.
Overflow rate for design flow	Q_{md} =	50,000 / 1452	= 34.4	$m^3/m^2.d$
Overflow rate for peak flow	Q_{mh} =	80,000 / 1452	= 55.1	$m^3/m^2.d$

Tank Shape and Dimensions

Internal diameter	43.0 m	
Efficient depth	2.5 m	
Tank capacity	3,631 m^3	
No. of tank units and clusters	4 tanks x	4 clusters

2.2 Aeration Tank

(1) Design Bases

Design flow	Q_{in} =	1,978,400 m^3/d
BOD concentration	$C_{BOD, in}$ =	155 mg/L
S-BOD concentration (= 66.7%)	$C_{S-BOD, in}$ =	103 mg/L
SS concentration	$C_{SS, in}$ =	144 mg/L
MLSS concentration	X=	2,000 mg/L
HRT (Hydraulic retention time)	θ=	4.5 hour

(2) Check for effluent Qualities

The volume of waste sludge can be estimated by the following equation:

$$Q_w \cdot X_w = (a \cdot C_{S-BOD, in} + b \cdot C_{SS, in} - c \cdot \theta \cdot X) Q_{in}$$

where,

Q_w :	Excess sludge volume (m^3/d)		
X_w :	Average solids concentration of waste sludge	=	0.6 %
Q_{in} :	Inflow rate to reactor basins	=	1,978,400 m^3/d
X :	MLSS concentration in reactor basins	=	2,000 mg/L
$C_{S-BOD, in}$:	Influent S-BOD concentration to reactor basins	=	103 mg/L
$C_{SS, in}$:	Influent SS concentration to reactor basins	=	144 mg/L
a :	Biomass yield coefficient of S-BOD (0.4～0.6)	=	0.5 mg MLSS/mg BOD
b :	Biomass yield coefficient of SS (0.9～1.0)	=	0.95 mg MLSS/mg SS
c :	Sludge reduction coefficient due to endogenous respiration of micro-organisms (0.03～0.05)	=	0.04 L/d

θ : Hydraulic retention time (HRT) in reactors = 4.5 hour

$Q_w X_w$ = 343,186 kg/d

SRT of reactor can be estimated by the following equation:

$SRT = \theta \cdot X / (a \cdot C_{S\text{-}BODY, in} + b \cdot C_{SS, in} - c \cdot \theta \cdot X)$

SRT = 2.2 d

C-BOD of effluent qualities can be estimated by the following equation:

$C_{C\text{-}BOD} = 10.42 * SRT^{-0.519}$ (15℃ < Lowest =18℃ < 20℃)

$C_{C\text{-}BOD}$ = 7.0 mg/l

C_{BOD} = 21.0 mg/l

$C_{C\text{-}BOD} = 9.75 * SRT^{-0.671}$ (20℃ < Average =23℃ < 25℃)

$C_{C\text{-}BOD}$ = 5.8 mg/l

C_{BOD} = 17.4 mg/l

$C_{C\text{-}BOD} = 11.54 * SRT^{-0.744}$ (25℃ < Highest =29℃)

$C_{C\text{-}BOD}$ = 6.5 mg/l

C_{BOD} = 19.5 mg/l

Nitration can be estimated by the following equation:

Required SRT = *20.65*exp(-0.0639*Temperature)*

Highest Sewage Temperature = 29 ℃

= 3.2 d > 2.2 d

Therefore, nitration is not expected to occur.

(3) Tank Dimensions

Tank width W = 10.0 m

Tank effective depth d = 6.0 m

Tank cross sectional area A = 6.0 x 10 - 1/2 x 1.0^2 x 4 - 1/2 x 0.5^2 x 4

= 57.5 m^2

Number of tanks n = 4 tanks x 10 clusters = 40 tank units

Capacity of each tank V_e = 370,950 / 40 = 9,274 m^3

Tank length 9,274 / 57.5 = 161.3 m ⟶ 162 m 54mL x 3lines

Tank Shape and Dimensions

Width	10.0 m	
Depth	6.0 m	
Tank capacity	9,315 m^3	
Tank length	162 m	54mL x 3lines
No. of tank units and clusters	4 tanks x	10 clusters

Check actual aeration time under the average daily flow rate condition.

Tank capacity V = 57.5 x 162 x 40 = 372,600 m^3

Aeration time T_a = 372,600 x 24 / 1,978,400 = 4.5 hr.

BOD to SS Loads : $L_{BOD/X}$ (kg BOD / kgMLSS・d)

$L_{BOD/X} = Q_{in} \cdot C_{BOD,in} / X \cdot V$

$L_{BOD/X}$ = 0.41 kg BOD / kgMLSS・d

BOD to Volume Loads : $L_{BOD/V}$ (kg BOD / m^3・d)

$L_{BOD/V} = Q_{in} \cdot C_{BOD,in} / V * 10^{-3}$

$L_{BOD/V}$ = 0.82 kg BOD / m3 / d

2.3 Final Clarifier

(1) Tank Dimensions

Design flow rate	Q_{ad} =	1,978,400 m^3/d		
Hydraulic overflow rate	=	25 $m^3/m^2/d$		
Total number of clarifiers	n =	40 units	10 clusters x	4 tanks
Hydraulic load on each basin is	=	1,978,400 / 40 =	49,460 m^3/d	
Required tank surface area	A =	49,460 / 25 =	1,978 m^2	

(2) Tank Geometry

Internal diameter	D =	51.0 m
Effective depth	d =	3.5 m
Number of basins	n =	40 units
Surface area of each tank	A_e =	2,043 m^2
Hydraulic capacity of a tank	V_{fc} =	7,151 m^3

(3) Check for Hydraulic Conditions

HRT for Design flow	T_{ad} =	7,151 x 24 / 49,460 = 3.5	hr
HRT for hourly max flow	T_{mh} =	7,151 x 24 / 74,460 = 2.3	hr.
Overflow rate for design flow	Q_{md} =	49,460 / 2043 = 24.2	$m^3/m^2.d$
Overflow rate for peak flow	Q_{mh} =	74,460 / 2043 = 36.4	$m^3/m^2.d$

Tank Shape and Dimensions

Internal diameter	51.0 m	
Efficient depth	3.5 m	
Tank capacity	7,151 m^3	
No. of tank units and clusters	4 tanks x	10 clusters

2.4 Chlorine Contact Tank

(1) Tank Dimension

Design flow	=	1,928,273 m^3/d	
Chlorine contact time	=	5 minutes	
Required tank capacity	=	1,928,273 /1,440 x 5 =	6,695 m^3
Channel width:	=	5.0 m	
Effective depth:	=	3.0 m	
Tank length:	=	6,695 / 5.0 / 3.0 =	446.4 m
Number of tanks	=	5 tanks	
Length channel	=	89 m/tanks	
No. of lines		30 m x	3 lines
Capacity of Tank	=	1,350 m^3	

(2) Check for Contact Time

Contact time for design flow	T_{ad} =	1,350 x 1440 / 385,655 = 5.0	minutes
Contact time for peak flow	T_{mh} =	1,350 x 1440 / 585,655 = 3.3	minutes

Tank Shape and Dimensions

Width	5.0 m	
Depth	3.0 m	
Tank capacity	1,350 m^3	
Tank length	90 m	30mL x 3lines
No. of tank units	5 tanks	

3 DESIGN CALCULATION OF REQUIRED AERATION

3.1 AOR (Actual Oxygen Requirement) for Aeration Tank

Required oxygen O_2 for aeration is estimated as:

$$AOR = OD_1 + OD_2 + OD_3$$

where

OD_1 = Oxygen required for BOD oxygenation (kg/day)

OD_2 = Oxygen required for endogenous respiration (kg/day)

OD_3 = Oxygen to be utilized for maintaining required dissolved oxygen level (kg/day)

3.2 Oxygen for BOD Oxidation, OD_1 (cell synthesis)

OD_1 = A x (kg O_2/kg BOD) x BOD removed (kg BOD/day)

where

A = Oxygen required to remove BOD (kgO_2/kgBOD, 0.5～0.7)

= 0.6 kgO_2/kgBOD

Q = 1,978,400 m^3/d

BOD = 155 - 23 = 132 mg/L

OD_1 = 0.6 x Q x 132 x 10^{-3}

= 0.079 Q kgO_2/d

3.3 Oxygen for Endogenous Respiration OD_2

OD_2 = B (kgO_2/kg MLVSS/day) × V_A (m_3) x MLVSS (kg MLVSS/m_3)

where

B = Oxygen required for endogenous respiration per MLVSS (kgO_2/MLVSS/day, 0.05～0.15)

= 0.1 kgO_2/MLVSS/day

V_A = Capacity of aerobic zone of reactor 4.5 ÷ 24 = 0.188 Q (m^3)

$MLVSS/MLSS$ = 0.8

OD_2 = 0.1 x 0.188 x Q x 2,000 x 10^{-3} x 0.8

= 0.030 Q kgO_2/d

3.4 Oxygen for Maintaining Dissolved Oxygen Level OD_3

OD_3 = $C_{O,A}$ x (Q + Qr) x 10^{-3} (kg BOD/day)

where

C_{OA} = Dissolved oxygen concentration in tank 2.0 mg/L

Qr = Returned sludge = 0.46 x Q

OD_3 = 2.0 x (Q + Qr) x 10^{-3}

= 0.003 x Q kg O_2/d

3.5 Total AOR

AOR = OD_1 + OD_2 + OD_3

= 0.079 Q + 0.030 Q + 0.003 Q

= 0.112 Q(kgO_2/d)

3.6 SOR (Standard Oxygen Requirement) for Aeration Tank

Required oxygen O_2 for aeration in the condition (clean water, 20℃and 1atm) is estimated as:

$$SOR = \frac{AOR \times Csw \times \gamma}{1.024^{(1-20)} \times a\,(\beta \times Cs \times \gamma - C_{OA})} \times \frac{101.3}{P}$$

where

Csw = Oxygen saturation concentration in clean water at temperature at 20 ℃

8.8 mg/L

Cs = Oxygen saturation concentration in clean water at temperature at T ℃

9.8 mg/L

α =	Correction Factor	0.83	
β =	Correction Factor	0.95	
γ =	Correction Factor for CS by Water Depth		
γ =	1+(h/2)/10.332	1.276	
H =	water depth	5.7	m
P =	Atmospheric Factor	101.3	kPa
T =	Minimum Temperature of Waste Water	18	℃

SOR＝ 321,561 kgO2/d

3.7 Aeration Requirement

Oxygen transfer efficiency of aerator is estimated as:

Ea= Ea(5.0) －6.0（5－H)

where

Ea= Oxygen transfer Efficiency in clean Water

Ea(5.0)= Oxygen transfer Efficiency in clean Water at 5m depth

31 %

Ea= 35.2 %

Required total air demand (GS) for aeration is estimated as:

$$GS = \frac{SOR \times (273+20)}{Ea \times 10^{-2} \times \rho \times Ow \times 273 \times 60 \times 24}$$

where

ρ=	Air Density	1.292	kg/Nm^3
Ow=	Oxygen Weight per Unit Air	0.232	kg-O2/kg-air

GS= 2,276 m^3/min

4 DESIGN CALCULATIONS OF SLUDGE TREATMENT FACILITIES

4.1 Design Bases

(1) Raw Sludge from Abu Rawash WWTP

Sludge solids production	=	2,000,000 x 360 x 10^{-6} x 0.60	
	=	432,000 kg/d	
Solids concentration of sludge	=	2.0 %	
Raw sludge generation	=	432,000 / 10 / 2.0 =	21,600 m^3/d

(2) Mixed Sludge from Zenein WWTP

Sludge solids production	=	100,000 kg/d	
Solids concentration of sludge	=	1.0 %	
Mixed sludge generation	=	100,000 / 10 / 1.0 =	10,000 m^3/d

(3) Mixed Sludge from Sidestream WWTP

Sludge solids production	=	136,694 kg/d	
Solids concentration of sludge	=	1.0 %	
Mixed sludge generation	=	136,694 / 10 / 1.0 =	13,669 m^3/d

(4) Waste Sludge from Abu Rawash WWTP

The volume of waste sludge can be estimated by the following equation:

$$Q_w \cdot X_w = (a \cdot C_{S\text{-}BOD,\ in} + b \cdot C_{SS,\ in} - c \cdot \theta \cdot X)\, Q_{in}$$

where,

Q_w :	Excess sludge volume (m^3/d)		
X_w :	Average solids concentration of waste sludge	=	0.6 %
Q_{in} :	Inflow rate to reactor basins	=	1,978,400 m^3/d
X :	MLSS concentration in reactor basins	=	2,000 mg/L
$C_{S\text{-}BOD,\ in}$:	Influent S-BOD concentration to reactor basins	=	103 mg/L
$C_{SS,\ in}$:	Influent SS concentration to reactor basins	=	144 mg/L
a :	Biomass yield coefficient of S-BOD (0.4～0.6)	=	0.5 mg MLSS/mg BOI
b :	Biomass yield coefficient of SS (0.9～1.0)	=	0.95 mg MLSS/mg SS
c :	Sludge reduction coefficient due to endogenous respiration of micro-organisms (0.03～0.05)	=	0.04 L/d
θ :	Hydraulic retention time (HRT) in reactors	=	4.5 day

$Q_w X_w$ = 343,186 kg/d

Sludge solids in effluence flow	=	1,928,273 x 22 x 10^{-6} =	42,422 kg/d
Sludge solids production	=	300,764 kg/d	
Solids concentration of sludge	=	0.6 %	
Waste sludge generation	=	300,764 / 10 / 0.6 =	50,127 m^3/d

4) Return Sludge

Sludge return ratio	=	46 %		
Return sludge volume	=	1,978,400 x 0.46 =	917,978 m^3/d	= 637 m^3/min.

4.2 Gravity Sludge Thickener

(1) Design Bases

Input sludge solids	=	969,458 kg/d
Input sludge Volume	=	95,397 m^3/d
Input sludge solids concentration	=	1.0 %

Thicken sludge solids concentrat	=	4.0	%
Solids recovery rate	=	85	%
Solids surface loading	=	50	kg/m2/day
Required surface area	=	19,389	m^2

(2) Tank Geometry

Internal diameter	=	35.0	m
Effective depth	=	4.0	m
Number of tanks	=	20	tanks
Water surface area	=	19,233	m^2
Hydraulic retention time	=	19.4	hr.

Tank Shape and Dimensions

Internal diameter	35.0 m
Efficient depth	4.0 m
Tank capacity	3,847 m^3
No. of tank units	20 tanks

(3) Thickened Sludge

Output sludge solids	=	824,040	kg/d
Output sludge volume	=	20,601	m^3/d

(4) Waste Water

Sludge solids in waste water	=	145,419	kg/d
Waste water volume	=	74,796	m^3/d

4.3 Anaerobic Sludge Digester

(1) Design Bases

Thicken Sludge from Gravity Sludge Thickener

Input sludge solids	=	824,040	kg/d	
Input sludge volume	=	20,601	m^3/d	
Input sludge solids concentration	=	4.0	%	
Hydraulic retention time	=	24	days	
Sludge heating temperature	=	35	℃	
Volatile material contents	=	70	%	
Digestion rate	=	50	%	
Required digester tank capacity	=	494,424	m^3	
Gas production rate (Average)	=	0.50	m^3/kg-vs	* Used for digested power plant
Gas production rate (Maximum)	=	0.60	m^3/kg-vs	* Used for gas holder
Gas calorific value	=	21,000	kJ/m3	

(2) Tank Geometry

Internal diameter	=	27.4	m
Curvature factor	=	16.0	m
Effective depth	=	36.5	m
Number of tanks	=	50	tanks
Digester tank capacity	=	10,000	m^3

Tank Shape and Dimensions

Internal diameter	27.4 m
Efficient depth	36.5 m
Tank capacity	10,000 m^3
No. of tank units	50 tanks

(3) Digested Sludge

Digested sludge solids = 824,040 x (1.0 - 0.7 x 0.5) = 535,626 kg/d

Digested sludge volume = 20,601 m^3/d

Digested sludge solids concentrati = 2.6 %

(4) Gas Holder

Maximum gas production = 824,040 x 0.7 x 0.60

= 346,097 m^3/d

Gas retention time in tank = 6 hr

Storage capacity = 346,097 x 6 / 24 = 86,524 m^3/d

Gas Holder Shape and Dimensions

Type	Water Seal Type
Internal diameter	30.0 m
Effective depth	18.0 m
Tank capacity	9,500 m^3
No. of Gas Holder	10 tanks

(5) Digested Gas Generator

Average gas production = 824,040 x 0.7 x 0.50

= 288,414 m^3/d

Gas calorific value = 21,000 kJ/m^3

Total gas energy production = 6,056,691 MJ/day

Possible electric power productior = 639,317 Wh/day = 26,638 kW

Specification of Digested Power Plant

Type	Gas Generator
Capacity	3000 kW
Power generation efficiency	38 %
Total heat energy usage efficiency	63 %
No. of generator set	10 sets (1 Standby)

4.4 Sludge Transfer

(1) Design Bases

Input sludge solids = 535,626 kg/d

Input sludge volume = 20,601 m^3/d

Input sludge solids concentration = 2.6 %

Concentration = 1.0 %

Sending sludge volume = 53,563 m^3/d

(2) Existing Sludge Pump

Capacity = 22.8 m3/min

Head working range = 75-85 m

Number of pups = 3 sets (Two pumps is one set connected directly)

(3) Additional Sludge Pump

Existing Capacity	=	65,664	m3/d (as one set is standby)	
	<	53,563	m^3/d	→ OK

4.5 Sludge Lagoon

(1) Design Bases

Input sludge solids	=	535,626	kg/d	
Input sludge Volume	=	53,563	m^3/d	
Input sludge solids concentration	=	1.0	%	
Required drying period in summe	=	25	days	
Required drying period in winter	=	40	days	
Depth of sludge	=	0.5	m	
Existing lagoon area	=	424.3	ha	
Drying period	=	40	day	
	<	40	day	→ OK

5 SPECIFICATION OF MECHANICAL EQUIPMENT FOR WATER TREATMENT

5.1 Primary Setting Tank

(1) Primary Clarifier

Specification of Clarifier

Type	Peripheral Driven Center Column Type
Size	Dia.43m × 2.5mD
Motor Output	2.2 kW
Quantity	16 unit

(2) Primary Sludge Pump

Specification of Waste Sludge Pump

Type	Non-Clog Type Sludge Pump
Excess Sludge Volume	8,640 m3/day
Pump Capacity	3.0 m3/min
Total head	10 m
Motor Output	7.5 kW
Quantity	8 unit (4 standby)

5.2 Aeration Tank

(1) Aerator

Specification of Aerator

Type	Membrane Panel
Quantity	64,800 m2 (1,620 / tank)

(2) Blower

Specification of Blower

Type	Multistage turbo blower
Blower Capacity	260 m3/min (at 20 ℃, 1atm)
Pressure	64.0 kPa
Motor Output	380 kW
Quantity	15 unit (5 standby)

5.3 Final Setting Tank

(1) Final Clarifier

Specification of Clarifier

Type	Peripheral Driven Center Column Type
Size	Dia.51m × 3.5mD
Motor Output	3.7 kW
Quantity	24 unit

(2) Waste Sludge Pump

Specification of Waste Sludge Pump

Type	Non-Clog Type Sludge Pump
Excess Sludge Volume	50,127 m3/day
Pump Capacity	5.2 m3/min
Total head	10 m
Motor Output	15.0 kW
Quantity	20 unit (10 standby)

(3) Return Sludge Pump

Specification of Return Sludge Pump

Type	Vertical Shaft Mixed Flow Pump
Influent Flow Rate	2,000,000 m3/day
Return Sludge Ratio	100 %
Pump Capacity	34.7 m3/min
Total head	6 m
Motor Output	55.0 kW
Quantity	40 unit

5.4 Disinfection

(1) Chlorine Cylinder

Specification of Chlorine Cylinder

Type	Chlorine Cylinder
Capacity	1 ton
Storage Days	7 days
Quantity	70 unit

(2) Supply Pump

Specification of Supply Pump

Type	Centrifugal Pump
Pump Capacity	4.0 m3/min
Total head	40 m
Motor Output	45.0 kW
Quantity	10 unit (5 standby)

6 SPECIFICATION OF MECHANICAL EQUIPMENT FOR SLUDGE TREATMENT

6.1 Gravity Sludge Thickener

(1) Sludge Thickener

Specification of Sludge Thickener

Type	Peripheral Driven Center Column Type
Size	Dia.35m × 4.0mD
Motor Output	2.2 kW
Quantity	20 unit

(2) Thickened Sludge Pump

Specification of Thickened Sludge Pump

Type	Progressive Capacity Pump
Pump Capacity	6.0 m3/min
Total head	20 m
Motor Output	110.0 kW
Quantity	10 unit (5 standby)

6.2 Anaerobic Sludge Digester

(1) Sludge Stirrer

Specification of Sludge Stirrer

Type	Vertical Shaft Screw type
Capacity	5,000 m3/hr
Motor Output	55.0 kW
Quantity	50 unit

(2) Sludge Heat Exchanger

Specification of Sludge Heat Exchanger

Type	Spiral Type
Capacity	450 kW
Quantity	50 unit

(3) Sludge Circulation Pump

Specification of Sludge Circulation Pump

Type	Progressive Capacity Pump
Pump Capacity	1.5 m3/min
Total head	20 m
Motor Output	22.0 kW
Quantity	60 unit (10 Standby)

(4) Digested Sludge Pump

Specification of Digested Sludge Pump

Type	Progressive Capacity Pump
Pump Capacity	6.0 m3/min
Total head	20 m
Motor Output	110.0 kW
Quantity	10 unit (5 Standby)

(6) Desulfuriser

Specification of Desulfuriser

Type	Dry Type
Size	Dia. 4.0m
Quantity	10 unit

(7) Gas Holder

Specification of Gas Holder

Type	Water Seal Type
Capacity	9,500 m3
Quantity	10 unit

Mass Balance Calculation of Abu Rawash WWTP

Design Flow	Flow	2,000,000	m3/day
	BOD	310	mg/l
	SS	360	mg/l
Sidestream DS	Input	0	kg/day
	Calculate	145,419	kg/day
Adjudication			
Sidestream Flow	Input	0	m3/day
	Calculate	74,795	m3/day
Adjudication			

Design quality

Design Flow		2,000,000	m3/day
WWTP Inflow Quality	BOD	310	mg/l
	SS	360	mg/l
Design Quality	BOD	310	mg/l
	SS	360	mg/l
Aeration Tank Inflow Quality	BOD	155	mg/l
	SS	144	mg/l
Effluent Quality	BOD	23	mg/l
	SS	22	mg/l

Removal rate of SS

First Setting	60	%
Final Setting	85	%

Removal rate of BOD

First Setting	50	%
Final Setting	85	%

Coefficient of waste sludge generation

Detention Time	4.5	hr
a	0.5	
b	0.95	
c	0.04	

Return sludge

Return Rate	46	%
Density of Sludge	6,000	mg/l
MLSS	2,000	mg/l

Zennin WWTP

Mixed Sludge DS	100,000	kg/day
Density of Sludge	99.0	%
Amount of Sludge	10,000	m3/day

Percentage of water content

Raw Sludge	98.0	%
Waste Sludge	99.4	%
Gravity Thickened	96.0	%
Mechanical Thickened		
Digested Sludge	97.4	%
Dried Sludge	60.0	%

Recovery rate of DS

Gravity Thickener	85	%
Mechanical Thickener	95	%
Mechanical Dewater	95	%

Coefficient of digestion

Organic rate	70	%
Digestion rate	50	%

First Setting

＜SS removal rate 60 %＞

Flow/Quality	Flow m3/day	SS mg/l	DS kg/day
① Inflow			
Inflow	2,000,000	360	720,000
Sidestream	0	0	0
Total	2,000,000	360	720,000
② Outflow			
Outflow	1,978,400	144	288,000
Raw sludge	Flow m3/day	Concentration %	DS kg/day
Generation	21,600	98.0	432,000

Aeration Tank / Final Setting

＜Return rate 46 %＞
＜SS removal rate 88 %＞

	Flow m3/day	SS mg/l	DS kg/day
① Inflow			
Inflow	1,978,400	144	288,000
Waste sludge	1,978,400		343,186
Total	1,978,400	173	343,186
Return sludge	917,978	6,000	5,507,868
② Outflow			
Outflow	1,928,273	22	42,422
Waste sludge	Flow m3/day	Concentration %	DS kg/day
Generation	50,127	99.4	300,764

Gravity Thickener

＜Recovery rate 85 %＞

Sludge	Flow m3/day	Concentration %	DS kg/day
Raw sludge(Abu)	21,600	98.0	432,000
Waste sludge(Abu)	50,127	99.4	300,764
Mixed sludge(Zenin)	10,000	99.0	100,000
Mixed sludge(Sludge	13,669	99.0	136,694
Thickened sludge	20,601	96.0	824,039
Sidestream	Flow m3/day	SS mg/l	DS kg/day
Sidestream	74,795	1,944	145,419

Digestion Tank

＜Organic rate 70 %＞
＜Digestion rate 50 %＞

Sludge	Flow m3/day	Concentration %	DS kg/day
Feeded sludge	20,601	96.0	824,039
Digested sludge	20,601	97.4	535,625
Digested gas	DS kg/day	Generation m3/day	
Digested gas	288,414	259,572	

Sludge Transfer

＜Concentration 99 %＞

Sludge	Flow m3/day	Concentration %	DS kg/day
Feeded sludge	20,601	97.4	535,625
Dilution water	32,962		
Transferred sludge	53,563	99.0	535,625

Sludge Lagoon

＜Concentration 60.0 %＞

Sludge	Amount m3/day	Concentration %	DS kg/day
Dried cake	1,339	60.0	535,625

Design Flow / Quality	Flow m3/day	BOD mg/l	SS mg/l	
WWTP Inflow	2,000,000	310	360	
Design quality		310	360	
Design Flow / Quality	Flow m3/day	BOD mg/l	SS mg/l	DS kg/day
First Setting	2,000,000	310	360	720,000
Aeration Tank	1,978,400	155	144	288,000
Final Setting	1,978,400	155	144	288,000
(Return Sludge)	917,978		6,000	5,507,868
Design Amount / DS	Flow m3/day	Concentration %	DS kg/day	
Gravity Thickener	21,600	98.0	432,000	
Digestion Tank	20,601	96.0	824,039	

※ Sidestream from sludge treatment facilities is treated exclusively

	Flow m3/day	SS mg/l	DS kg/day
＜Sidestream from thickening＞			
Gravity Thickener	74,795	1,944	145,419
＜Sidestream from dewatering＞			
＜Washing water＞			
Total	74,795	1,944	145,419

DS of Inflow	720,000
DS of waste sludge	55,186
DS of Zenin WWTP	100,000
DS of coagulant	0
Total	875,186
DS of effluent	51,147
DS of sludge cake	535,625
DS of Digested gas	288,414
Total	875,186

APPENDIX – 3

Design Calculations of Hydraulic Profile

Summary

Facility 1 (800,000 m^3/d)

(m)

Position	Average Flow	Peak Flow 1	Peak Flow 2
Design Flow (m^3/d)	800,000	960,000	1,200,000
1. Barakat Drain	15.90	16.20	16.50
2. Chlorination Tank	17.48	17.53	17.60
3. Final Setting Tank	18.51	18.51	18.51
4. Dustribution Tank for FST	19.09	19.11	19.14
5. Aeration Tank	19.60	19.61	19.62
6. Distribution Tank	20.35	20.39	20.44
7. Connection Chamber	20.57	20.71	20.94

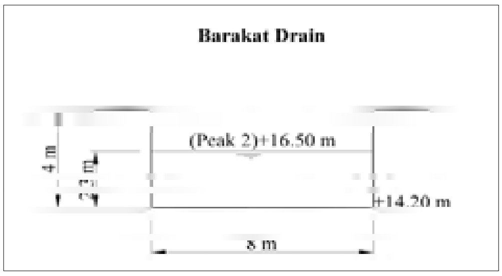
Facility 2 (400,000 m^3/d)

Position	Average Flow	Peak Flow 1	Peak Flow 2
Design Flow (m^3/d)	400,000	480,000	600,000
1. Barakat Drain	15.90	16.20	16.50
2. Chlorination Tank	17.48	17.53	17.60
3. Final Setting Tank	18.51	18.51	18.51
4. Dustribution Tank for FST	19.09	19.11	19.14
5. Aeration Tank	19.60	19.61	19.62
6. Distribution Tank	20.35	20.39	20.44
7. Connection Chamber	20.44	20.52	20.65

A. Barakat Drain

A.1 Water Level at Barakat Drain

	Design Flow (m^3/d)	Water Level (m)
Average Flow	1,200,000	15.90
Peak Flow 1 (PF=1.2)	1,440,000	16.20
Peak Flow 2 (PF=1.5)	1,800,000	16.50

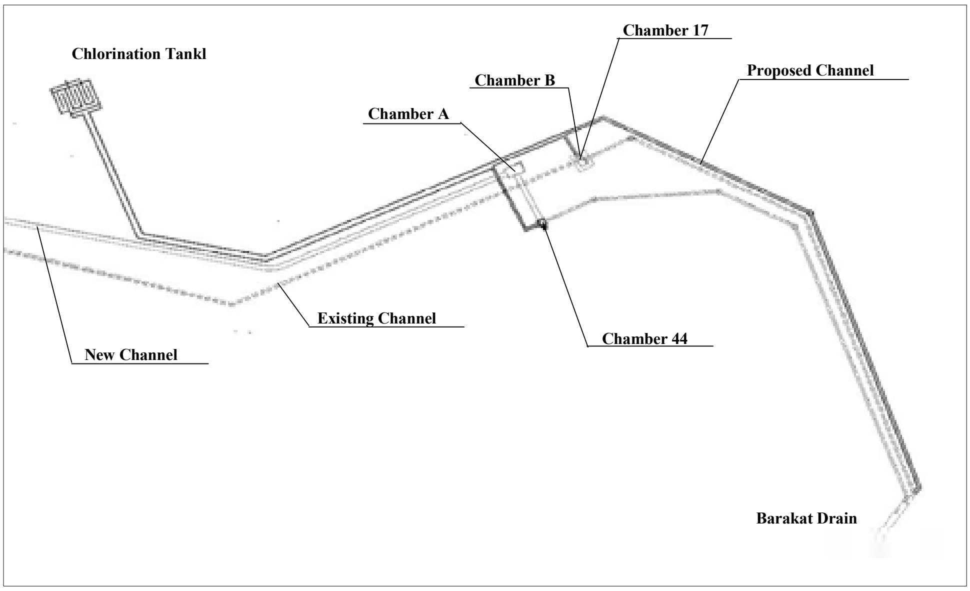


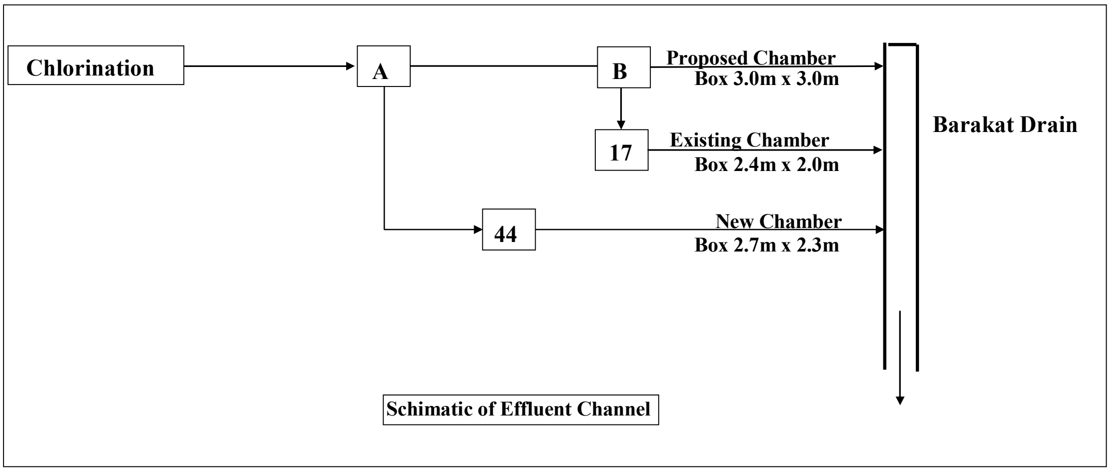
A.2 Hydlauric Calculation

		Average Flow	Peak Flow 1 (PF=1.2)	Peak Flow 2 (PF=1.5)
Design Flow	m^3/d	1,200,000	1,440,000	1,800,000
Design Flow	m^3/s	13.889	16.667	20.833
Width	m	8.00	8.00	8.00
Height	m	4.00	4.00	4.00
n (Concrete plastering work)		0.018	0.018	0.018
I		0.00027	0.00027	0.00027
Water Depth	m	1.69	1.92	2.24
Water Area	m^2	13.55	15.36	17.92
Wet Length	m	11.39	11.84	12.48
Hydraulic Radius	m	1.19	1.30	1.44
Velocity	m/s	1.03	1.09	1.16
Calculated Flow	m^3/s	13.891	16.676	20.816
Calculated Flow	m^3/d	1,200,181	1,440,783	1,798,479
Invert Level	m	14.20	14.20	14.20
Water Level	m	15.89	16.12	16.44
Water Level (rounded)	m	15.90	16.20	16.50

B. Effluent Channel

B.1 Average Flow





1. Water Level at Barakat Drain

	Water Level at Barakat Drain (m)	Remarks
Average Flow	15.90	
Peak Flow 1 (PF=1.2)		
Peak Flow 2 (PF=1.5)		

2. Result

		Average Flow Base Allocation (m^3/d)	Result: Water Level at Outflow Pit of Chlorination Tank (m)		
			PF=1.0	PF=1.2	PF=1.5
Existing Channel	Use	290,000	16.58		
New Channel	Use	400,000	16.62		
Proposed Channel	Use	510,000	16.60		
Total /Average		1,200,000	16.60		

3. Hydlauric Calculation

Existing Effluent Culvert

Flow Allocation (Average flow base) 290,000 m^3/d

Peak factor 1.0

	Structure	From	To	Flow	
				(m^3/d)	(m^3/d)
Existing Effluent	Box Culvert	Chamber 63D'	Barakart Drain	290,000	3.356
Existing Effluent	Box Culvert	Chamber 63C'	Chamber 63D'	290,000	3.356
Existing Effluent	Box Culvert	Chamber 63B'	Chamber 63C'	290,000	3.356
Existing Effluent	Box Culvert	Chamber 17	Chamber 63B'	290,000	3.356
Section 5	Box Culvert	Chamber B	Chamber 17	290,000	3.356
Section 3	Box Culvert	Chlorination Outlet	Chamber B	1,200,000	13.889

Cross Section				Invert	Length	Water	Velocity	Water Level		Depth	Depth
Shape	Width	Hight	Stream	Level		Area		Up	Down	(Up)	(Down)
	(m)	(m)		(m)	(m)	(m^2)	(m/s)	(m)	(m)	(m)	(m)
Open	2.4	2.0	1	14.2	16.0	4.06	0.83	15.96	15.90	1.76	1.70
Open	2.4	2.0	1	14.2	406.0	4.30	0.78	16.09	15.96	1.89	1.76
Open	2.4	2.0	1	14.2	238.0	4.54	0.74	16.18	16.09	1.98	1.89
Open	2.4	2.0	1	14.2	69.0	4.71	0.71	16.23	16.18	2.03	1.98
Open	2.4	3.0	1	14.5	145.0	4.23	0.79	16.36	16.23	1.86	1.73
Open	7.0	3.0	1	14.5	639.0	13.84	1.00	16.58	16.36	2.08	1.86

Head Loss	Friction Loss (Manning Equation)					Other Loss (Duarcy-Weisbach Equation)					
	n	WL	WA	R	Loss	Inflow	Outflow	Bend	Sum of Constant	Velocity	Loss
(m)		(m)	(m^2)	(m)	(m)	(0.5)	(1.0)	(0.3)		(m/s)	(m)
0.06	0.015	5.8	4.1	0.70	0.00	1	1	0	1.5	0.826	0.05
0.13	0.015	6.0	4.3	0.71	0.09	1	1	0	1.5	0.780	0.05
0.09	0.015	6.2	4.5	0.73	0.04	1	1	0	1.5	0.739	0.04
0.05	0.015	6.3	4.7	0.74	0.01	1	1	0	1.5	0.713	0.04
0.14	0.015	5.9	4.2	0.72	0.03	2	2	1	3.3	0.793	0.11
0.21	0.015	10.9	13.8	1.27	0.10	1	1	2	2.1	1.004	0.11

New Effluent Culvert

Flow Allocation (Average flow base) 400,000 m^3/d

Peak factor 1.0

	Structure	From	To	Flow	
				(m^3/d)	(m^3/d)
New Effluent	Box Culvert	Chamber 63D	Barakart Drain	400,000	4.630
New Effluent	Box Culvert	Chamber 63C	Chamber 63D	400,000	4.630
New Effluent	Box Culvert	Chamber 63B	Chamber 63C	400,000	4.630
New Effluent	Box Culvert	Chamber 44	Chamber 63B	400,000	4.630
Section 4	Box Culvert	Chamber A	Chamber 44	400,000	4.630
Section 2	Box Culvert	Chamber B	Chamber A	910,000	4.630
Section 3	Box Culvert	Chlorination Outlet	Chamber B	1,200,000	13.889

Cross Section				Invert	Length	Water	Velocity	Water Level		Depth	Depth
Shape	Width	Hight	Stream	Level		Area		Up	Down	(Up)	(Down)
	(m)	(m)		(m)	(m)	(m^2)	(m/s)	(m)	(m)	(m)	(m)
Open	2.4	2.0	1	14.2	8.0	4.09	1.13	16.00	15.90	1.80	1.70
Open	2.7	2.3	1	14.2	399.0	4.96	0.93	16.18	16.00	1.98	1.80
Open	2.7	2.3	1	14.2	104.0	5.31	0.87	16.26	16.18	2.06	1.98
Open	2.7	2.3	1	14.2	224.0	5.58	0.83	16.36	16.26	2.16	2.06
Box	2.7	3.0	1	11.0	25.0	8.01	0.58	16.39	16.36	5.39	5.36
Open	5.7	3.0	1	14.5	99.0	10.57	0.44	16.41	16.39	1.91	1.89
Open	7.0	3.0	1	14.5	639.0	13.91	1.00	16.62	16.41	2.12	1.91

Head Loss	Friction Loss (Manning Equation)					Other Loss (Duarcy-Weisbach Equation)					
	n	WL	WA	R	Loss	Inflow	Outflow	Bend	Sum of Constant	Velocity	Loss
(m)		(m)	(m^2)	(m)	(m)	(0.5)	(1.0)	(0.3)		(m/s)	(m)
0.10	0.015	5.9	4.1	0.69	0.00	1	1	0	1.5	1.133	0.10
0.18	0.015	6.4	5.0	0.77	0.11	1	1	0	1.5	0.934	0.07
0.08	0.015	6.7	5.3	0.79	0.02	1	1	0	1.5	0.872	0.06
0.10	0.015	6.9	5.6	0.81	0.05	1	1	0	1.5	0.830	0.05
0.03	0.015	11.4	8.0	0.70	0.00	1	1	0	1.5	0.578	0.03
0.02	0.015	9.5	10.6	1.12	0.00	1	1	1	1.8	0.438	0.02
0.21	0.015	11.0	13.9	1.27	0.10	1	1	2	2.1	0.998	0.11

Proposed Effluent Culvert

Flow Allocation (Average flow base) 510,000 m^3/d

Peak factor 1.0

	Structure	From	To	Flow	
				(m^3/d)	(m^3/d)
Section 1	Box Culvert	Chamber 63C"	Barakart Drain	510,000	5.903
	Box Culvert	Chamber 63B"	Chamber 63C"	510,000	5.903
	Box Culvert	Chamber A	Chamber 63B"	510,000	5.903
Section 2	Box Culvert	Chamber B	Chamber A	910,000	10.532
Section 3	Box Culvert	Chlorination Outlet	Chamber B	1,200,000	13.889

Cross Section				Invert Level	Length	Water Area	Velocity	Water Level		Depth (Up)	Depth (Down)
Shape	Width	Hight	Stream					Up	Down		
	(m)	(m)		(m)	(m)	(m^2)	(m/s)	(m)	(m)	(m)	(m)
Open	3.0	3.0	1	14.2	401.0	5.37	1.10	16.14	15.90	1.94	1.70
Open	3.0	3.0	1	14.2	98.0	5.91	1.00	16.27	16.14	2.07	1.94
Open	3.0	3.0	1	14.2	260.0	6.33	0.93	16.41	16.27	2.21	2.07
Box	5.7	3.0	1	11.0	99.0	17.01	0.62	16.45	16.41	2.25	2.21
Open	7.0	3.0	1	14.5	639.0	16.15	0.86	16.60	16.45	2.40	2.25

Head Loss	Friction Loss (Manning Equation)					Other Loss (Duarcy-Weisbach Equation)					
	n	WL	WA	R	Loss	Inflow	Outflow	Bend	Sum of Constant	Velocity	Loss
(m)		(m)	(m^2)	(m)	(m)	(0.5)	(1.0)	(0.3)		(m/s)	(m)
0.24	0.015	6.7	5.4	0.81	0.15	1	1	0	1.5	1.099	0.09
0.13	0.015	7.0	5.9	0.84	0.03	1	1	2	2.1	0.999	0.11
0.14	0.015	7.3	6.3	0.87	0.06	1	1	1	1.8	0.933	0.08
0.04	0.015	17.4	17.0	0.98	0.01	1	1	0	1.5	0.619	0.03
0.15	0.015	11.7	16.2	1.39	0.07	1	1	2	2.1	0.860	0.08

B.2 Peak Flow 1 (PF=1.2)

1. Water Level at Barakat Drain

	Water Level at Barakat Drain (m)	Remarks
Average Flow		
Peak Flow 1 (PF=1.2)	16.20	
Peak Flow 2 (PF=1.5)		

2. Result

		Average Flow Base Allocation	Result: Water Level at Outflow Pit of Chlorination Tank (m)		
		(m^3/d)	PF=1.0	PF=1.2	PF=1.5
Existing Channel	Use	299,000		16.92	
New Channel	Use	394,000		16.92	
Proposed Channel	Use	507,000		16.93	
Total /Average		1,200,000		16.92	

3. Hydlauric Calculation

Existing Effluent Culvert

Flow Allocation (Average flow base) 299,000 m^3/d

Peak factor 1.2

	Structure	From	To	Flow	
				(m^3/d)	(m^3/d)
Existing Effluent	Box Culvert	Chamber 63D'	Barakart Drain	358,800	4.153
Existing Effluent	Box Culvert	Chamber 63C'	Chamber 63D'	358,800	4.153
Existing Effluent	Box Culvert	Chamber 63B'	Chamber 63C'	358,800	4.153
Existing Effluent	Box Culvert	Chamber 17	Chamber 63B'	358,800	4.153
Section 5	Box Culvert	Chamber B	Chamber 17	358,800	4.153
Section 3	Box Culvert	Chlorination Outlet	Chamber B	1,440,000	16.667

Cross Section				Invert	Length	Water	Velocity	Water Level		Depth	Depth
Shape	Width	Hight	Stream	Level		Area		Up	Down	(Up)	(Down)
	(m)	(m)		(m)	(m)	(m^2)	(m/s)	(m)	(m)	(m)	(m)
Box	2.4	2.0	1	14.2	16.0	4.71	0.88	16.26	16.20	2.06	2.00
Box	2.4	2.0	1	14.2	406.0	4.71	0.88	16.43	16.26	2.23	2.06
Box	2.4	2.0	1	14.2	238.0	4.71	0.88	16.56	16.43	2.36	2.23
Box	2.4	2.0	1	14.2	69.0	4.71	0.88	16.64	16.56	2.44	2.36
Open	2.4	3.0	1	14.5	145.0	5.84	0.71	16.75	16.64	2.55	2.44
Open	7.0	3.0	1	14.5	639.0	17.97	0.93	16.92	16.75	2.72	2.55

Head	Friction Loss (Manning Equation)					Other Loss (Duarcy-Weisbach Equation)					
Loss	n	WL	WA	R	Loss	Inflow	Outflow	Bend	Sum of	Velocity	Loss
(m)		(m)	(m^2)	(m)	(m)	(0.5)	(1.0)	(0.3)	Constant	(m/s)	(m)
0.06	0.015	6.4	4.7	0.73	0.00	1	1	0	1.5	0.882	0.06
0.17	0.015	6.6	4.7	0.71	0.11	1	1	0	1.5	0.882	0.06
0.13	0.015	6.8	4.7	0.69	0.07	1	1	0	1.5	0.882	0.06
0.08	0.015	7.0	4.7	0.68	0.02	1	1	0	1.5	0.882	0.06
0.11	0.015	7.3	5.8	0.80	0.02	2	2	1	3.3	0.711	0.09
0.17	0.015	12.1	18.0	1.48	0.07	1	1	2	2.1	0.927	0.09

New Effluent Culvert

Flow Allocation (Average flow base) 394,000 m^3/d

Peak factor 1.2

	Structure	From	To	Flow	
				(m^3/d)	(m^3/d)
New Effluent	Box Culvert	Chamber 63D	Barakart Drain	472,800	5.472
New Effluent	Box Culvert	Chamber 63C	Chamber 63D	472,800	5.472
New Effluent	Box Culvert	Chamber 63B	Chamber 63C	472,800	5.472
New Effluent	Box Culvert	Chamber 44	Chamber 63B	472,800	5.472
Section 4	Box Culvert	Chamber A	Chamber 44	472,800	5.472
Section 2	Box Culvert	Chamber B	Chamber A	1,081,200	5.472
Section 3	Box Culvert	Chlorination Outlet	Chamber B	1,440,000	16.667

Cross Section				Invert	Length	Water	Velocity	Water Level		Depth	Depth
Shape	Width	Hight	Stream	Level		Area		Up	Down	(Up)	(Down)
	(m)	(m)		(m)	(m)	(m^2)	(m/s)	(m)	(m)	(m)	(m)
Box	2.4	2.0	1	14.2	8.0	4.71	1.16	16.31	16.20	2.11	2.00
Open	2.7	2.3	1	14.2	399.0	5.85	0.94	16.48	16.31	2.28	2.11
Open	2.7	2.3	1	14.2	104.0	6.15	0.89	16.56	16.48	2.36	2.28
Box	2.7	2.3	1	14.2	224.0	6.12	0.89	16.70	16.56	2.50	2.36
Box	2.7	3.0	1	11.0	25.0	8.01	0.68	16.74	16.70	2.54	2.50
Open	5.7	3.0	1	14.5	99.0	14.45	0.38	16.76	16.74	2.56	2.54
Open	7.0	3.0	1	14.5	639.0	18.25	0.91	16.92	16.76	2.72	2.56

Head	Friction Loss (Manning Equation)					Other Loss (Duarcy-Weisbach Equation)					
Loss	n	WL	WA	R	Loss	Inflow	Outflow	Bend	Sum of	Velocity	Loss
(m)		(m)	(m^2)	(m)	(m)	(0.5)	(1.0)	(0.3)	Constant	(m/s)	(m)
0.11	0.015	8.8	4.7	0.54	0.01	1	1	0	1.5	1.162	0.10
0.17	0.015	7.1	5.9	0.82	0.10	1	1	0	1.5	0.935	0.07
0.08	0.015	7.3	6.1	0.84	0.02	1	1	0	1.5	0.890	0.06
0.14	0.015	10.0	6.1	0.61	0.08	1	1	0	1.5	0.894	0.06
0.04	0.015	11.4	8.0	0.70	0.00	1	1	0	1.5	0.683	0.04
0.02	0.015	10.8	14.4	1.34	0.00	1	1	1	1.8	0.379	0.01
0.16	0.015	12.3	18.3	1.49	0.07	1	1	2	2.1	0.913	0.09

Proposed Effluent Culvert

Flow Allocation (Average flow base) 507,000 m^3/d

Peak factor 1.2

	Structure	From	To	Flow	
				(m^3/d)	(m^3/d)
Section 1	Box Culvert	Chamber 63C"	Barakart Drain	608,400	7.042
	Box Culvert	Chamber 63B"	Chamber 63C"	608,400	7.042
	Box Culvert	Chamber A	Chamber 63B"	608,400	7.042
Section 2	Box Culvert	Chamber B	Chamber A	1,081,200	12.514
Section 3	Box Culvert	Chlorination Outlet	Chamber B	1,440,000	16.667

Cross Section				Invert Level	Length	Water Area	Velocity	Water Level		Depth (Up)	Depth (Down)
Shape	Width	Hight	Stream					Up	Down		
	(m)	(m)		(m)	(m)	(m^2)	(m/s)	(m)	(m)	(m)	(m)
Open	3.0	3.0	1	14.2	401.0	6.27	1.12	16.43	16.20	2.23	2.00
Open	3.0	3.0	1	14.2	98.0	6.87	1.02	16.57	16.43	2.37	2.23
Open	3.0	3.0	1	14.2	260.0	7.29	0.97	16.72	16.57	2.52	2.37
Box	5.7	3.0	1	11.0	99.0	17.01	0.74	16.77	16.72	2.57	2.52
Open	7.0	3.0	1	14.5	639.0	18.67	0.89	16.93	16.77	2.73	2.57

Head Loss	Friction Loss (Manning Equation)					Other Loss (Duarcy-Weisbach Equation)					
	n	WL	WA	R	Loss	Inflow	Outflow	Bend	Sum of Constant	Velocity	Loss
(m)		(m)	(m^2)	(m)	(m)	(0.5)	(1.0)	(0.3)		(m/s)	(m)
0.23	0.015	7.2	6.3	0.87	0.14	1	1	0	1.5	1.123	0.10
0.14	0.015	7.6	6.9	0.90	0.03	1	1	2	2.1	1.025	0.11
0.15	0.015	7.9	7.3	0.92	0.06	1	1	1	1.8	0.966	0.09
0.05	0.015	17.4	17.0	0.98	0.01	1	1	0	1.5	0.736	0.04
0.15	0.015	12.4	18.7	1.51	0.07	1	1	2	2.1	0.893	0.09

B.3 Peak Flow 2 (PF=1.5)

1. Water Level at Barakat Drain

	Water Level at Barakat Drain (m)	Remarks
Average Flow		See Section A
Peak Flow 1 (PF=1.2)		
Peak Flow 2 (PF=1.5)	16.50	

2. Result

		Average Flow Allocation (m^3/d)	Result: Water Level at Outflow Pit of Chlorination Tank (m)		
			PF=1.0	PF=1.2	PF=1.5
Existing Channel	Use	275,000			17.54
New Channel	Use	360,000			17.52
Proposed Channel	Use	565,000			17.54
Total /Average		1,200,000			17.53

3. Hydlauric Calculation

Existing Effluent Culvert

Flow Allocation (Average flow base) 275,000 m^3/d

Peak factor 1.5

	Structure	From	To	Flow	
				(m^3/d)	(m^3/d)
Existing Effluent	Box Culvert	Chamber 63D'	Barakart Drain	412,500	4.774
Existing Effluent	Box Culvert	Chamber 63C'	Chamber 63D'	412,500	4.774
Existing Effluent	Box Culvert	Chamber 63B'	Chamber 63C'	412,500	4.774
Existing Effluent	Box Culvert	Chamber 17	Chamber 63B'	412,500	4.774
Section 5	Box Culvert	Chamber B	Chamber 17	412,500	4.774
Section 3	Box Culvert	Chlorination Outlet	Chamber B	1,800,000	20.833

Shape	Cross Section Width	Hight	Stream	Invert Level	Length	Water Area	Velocity	Water Level Up	Down	Depth (Up)	Depth (Down)
	(m)	(m)		(m)	(m)	(m^2)	(m/s)	(m)	(m)	(m)	(m)
Box	2.4	2.0	1	14.2	16.0	4.71	1.01	16.59	16.50	2.39	2.30
Box	2.4	2.0	1	14.2	406.0	4.71	1.01	16.88	16.59	2.68	2.39
Box	2.4	2.0	1	14.2	238.0	4.71	1.01	17.09	16.88	2.89	2.68
Box	2.4	2.0	1	14.2	69.0	4.71	1.01	17.20	17.09	3.00	2.89
Box	2.4	3.0	1	14.5	145.0	7.11	0.67	17.30	17.20	3.10	3.00
Box	7.0	3.0	1	14.5	639.0	20.91	1.00	17.54	17.30	3.34	3.10

Head Loss	Friction Loss (Manning Equation) n	WL	WA	R	Loss	Other Loss (Duarcy-Weisbach Equation) Inflow	Outflow	Bend	Sum of Constant	Velocity	Loss
(m)		(m)	(m^2)	(m)	(m)	(0.5)	(1.0)	(0.3)		(m/s)	(m)
0.09	0.015	8.8	4.7	0.54	0.01	1	1	0	1.5	1.014	0.08
0.29	0.015	8.8	4.7	0.54	0.22	1	1	0	1.5	1.014	0.08
0.21	0.015	8.8	4.7	0.54	0.13	1	1	0	1.5	1.014	0.08
0.12	0.015	8.8	4.7	0.54	0.04	1	1	0	1.5	1.014	0.08
0.10	0.015	10.8	7.1	0.66	0.03	2	2	1	3.3	0.671	0.08
0.24	0.015	20.0	20.9	1.05	0.13	1	1	2	2.1	0.996	0.11

New Effluent Culvert

Flow Allocation (Average flow base) 360,000 m^3/d

Peak factor 1.5

	Structure	From	To	Flow	
				(m^3/d)	(m^3/d)
New Effluent	Box Culvert	Chamber 63D	Barakart Drain	540,000	6.250
New Effluent	Box Culvert	Chamber 63C	Chamber 63D	540,000	6.250
New Effluent	Box Culvert	Chamber 63B	Chamber 63C	540,000	6.250
New Effluent	Box Culvert	Chamber 44	Chamber 63B	540,000	6.250
Section 4	Box Culvert	Chamber A	Chamber 44	540,000	6.250
Section 2	Box Culvert	Chamber B	Chamber A	1,387,500	6.250
Section 3	Box Culvert	Chlorination Outlet	Chamber B	1,800,000	20.833

Shape	Cross Section Width	Hight	Stream	Invert Level	Length	Water Area	Velocity	Water Level Up	Down	Depth (Up)	Depth (Down)
	(m)	(m)		(m)	(m)	(m^2)	(m/s)	(m)	(m)	(m)	(m)
Box	2.4	2.0	1	14.2	8.0	4.71	1.33	16.64	16.50	2.44	2.30
Box	2.7	2.3	1	14.2	399.0	6.12	1.02	16.90	16.64	2.70	2.44
Box	2.7	2.3	1	14.2	104.0	6.12	1.02	17.03	16.90	2.83	2.70
Box	2.7	2.3	1	14.2	224.0	6.12	1.02	17.21	17.03	3.01	2.83
Box	2.7	3.0	1	11.0	25.0	8.01	0.78	17.26	17.21	3.06	3.01
Box	5.7	3.0	1	14.5	99.0	17.01	0.37	17.28	17.26	3.08	3.06
Box	7.0	3.0	1	14.5	639.0	20.91	1.00	17.52	17.28	3.32	3.08

Head Loss	Friction Loss (Manning Equation) n	WL	WA	R	Loss	Other Loss (Duarcy-Weisbach Equation) Inflow	Outflow	Bend	Sum of Constant	Velocity	Loss
(m)		(m)	(m^2)	(m)	(m)	(0.5)	(1.0)	(0.3)		(m/s)	(m)
0.14	0.015	8.8	4.7	0.54	0.01	1	1	0	1.5	1.327	0.13
0.26	0.015	10.0	6.1	0.61	0.18	1	1	0	1.5	1.021	0.08
0.13	0.015	10.0	6.1	0.61	0.05	1	1	0	1.5	1.021	0.08
0.18	0.015	10.0	6.1	0.61	0.10	1	1	0	1.5	1.021	0.08
0.05	0.015	11.4	8.0	0.70	0.01	1	1	0	1.5	0.780	0.05
0.02	0.015	17.4	17.0	0.98	0.00	1	1	1	1.8	0.367	0.01
0.24	0.015	20.0	20.9	1.05	0.13	1	1	2	2.1	0.996	0.11

Proposed Effluent Culvert

Flow Allocation (Average 565,000 m^3/d

Peak factor 1.5

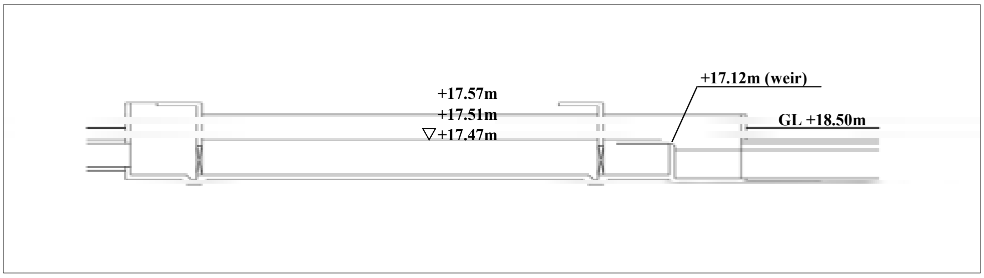
	Structure	From	To	Flow	
				(m^3/d)	(m^3/d)
Section 1	Box Culvert	Chamber 63C"	Barakart Drain	847,500	9.809
	Box Culvert	Chamber 63B"	Chamber 63C"	847,500	9.809
	Box Culvert	Chamber A	Chamber 63B"	847,500	9.809
Section 2	Box Culvert	Chamber B	Chamber A	1,387,500	16.059
Section 3	Box Culvert	Chlorination Outlet	Chamber B	1,800,000	20.833

Cross Section				Invert Level	Length	Water Area	Velocity	Water Level		Depth (Up)	Depth (Down)
Shape	Width	Hight	Stream					Up	Down		
	(m)	(m)		(m)	(m)	(m^2)	(m/s)	(m)	(m)	(m)	(m)
Open	3.0	3.0	1	14.2	401.0	7.29	1.35	16.82	16.50	2.62	2.30
Open	3.0	3.0	1	14.2	98.0	8.04	1.22	17.01	16.82	2.81	2.62
Open	3.0	3.0	1	14.2	260.0	8.61	1.14	17.21	17.01	3.01	2.81
Box	5.7	3.0	1	11.0	99.0	17.01	0.94	17.30	17.21	3.10	3.01
Box	7.0	3.0	1	14.5	639.0	20.91	1.00	17.54	17.30	3.34	3.10

Head Loss	Friction Loss (Manning Equation)					Other Loss (Duarcy-Weisbach Equation)					
	n	WL	WA	R	Loss	Inflow	Outflow	Bend	Sum of Constant	Velocity	Loss
(m)		(m)	(m^2)	(m)	(m)	(0.5)	(1.0)	(0.3)		(m/s)	(m)
0.32	0.015	7.9	7.3	0.93	0.18	1	1	0	1.5	1.346	0.14
0.19	0.015	8.4	8.0	0.96	0.03	1	1	2	2.1	1.220	0.16
0.20	0.015	8.8	8.6	0.98	0.08	1	1	1	1.8	1.139	0.12
0.09	0.015	17.4	17.0	0.98	0.02	1	1	0	1.5	0.944	0.07
0.24	0.015	20.0	20.9	1.05	0.13	1	1	2	2.1	0.996	0.11

C. Proposed Sewage Treatment Facility

1. Chrolination Tank



(1) Design Flow

	Q (m^3/d)	Q (m^3/s)	Remarks
Average Flow	1,200,000	13.889	
Peak Flow 1 (PF=1.2)	1,440,000	16.667	PF=1.2
Peak Flow 2 (PF=1.5)	1,800,000	20.833	PF=1.5

(2) Start Point of Effluent Channel (m)

	Water Level at Effluent Channel	Remarks
Average Flow	16.60	
Peak Flow 1 (PF=1.2)	16.92	
Peak Flow 2 (PF=1.5)	17.53	

(3) Outflow Weir

Width	37.0	m
Number of Weir	1	nos
Margin	0.2	m
Weir Level	17.12	m

(m)

	Weir Level	Overflow Depth	Water Level at Outflow Pit	Remarks
Average Flow	17.12	0.35	17.47	Francis Equation c=1.84
Peak Flow 1 (PF=1.2)	17.12	0.39	17.51	
Peak Flow 2 (PF=1.5)	17.12	0.45	17.57	

(4) Outflow Gate

Gate Width	1.8	m
Gate Hight	2.7	m
Number of Gate	6	nos

(m)

	Water Level at Outflow Pit	Loss at Gate	Water Level at Tank	Remarks
Average Flow	17.47	0.01	17.48	Darcy-Weisbach Equation f=1.0
Peak Flow 1 (PF=1.2)	17.51	0.02	17.53	
Peak Flow 2 (PF=1.5)	17.57	0.03	17.60	

(4) Chlorination Tank

Width of Channel	5.0	m
Depth	3.0	m
Length	90	m
Number of Tank	3	
Capacity	4,050	m^3
Detension Time (Ave)	4.9	min

(m)

	Water Level (down stream)	Loss at Tank	Water Level (up stream)	Remarks
Average Flow	17.48	0.01	17.49	Manning Equation n=0.015
Peak Flow 1 (PF=1.2)	17.53	0.02	17.54	
Peak Flow 2 (PF=1.5)	17.60	0.03	17.63	

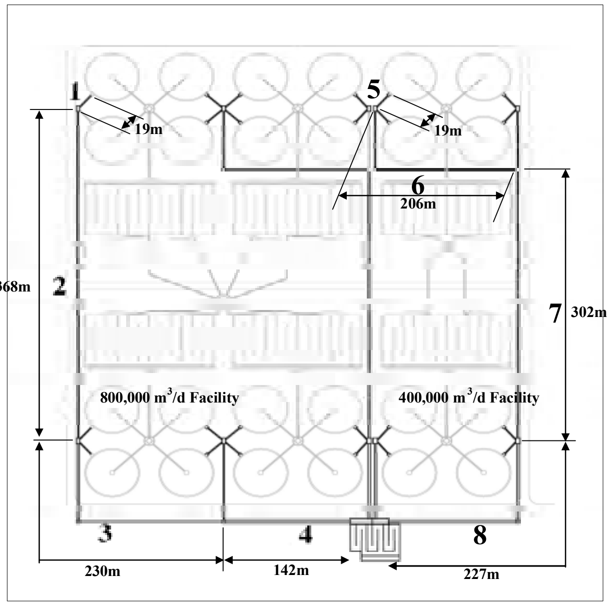
(5) Inflow Gate

Gate Width	1.8	m
Gate Hight	2.7	m
Number of Gate	6	nos

(m)

	Water Level (down stream)	Loss at Gate	Water Level (up stream)	Remarks
Average Flow	17.49	0.01	17.50	Darcy-Weisbach Equation f=1.0
Peak Flow 1 (PF=1.2)	17.54	0.02	17.56	
Peak Flow 2 (PF=1.5)	17.63	0.03	17.65	

2. Channel (from Final Settling Tank to Chlorination Tank)



A. Channel for 800,000 m^3/d Facility

(1) Design Flow (m^3/d)

Section	1	2	3	4
Number of Contributing FST	1	2	4	8
Average Flow	50,000	100,000	200,000	400,000
Peak Flow 1 (PF=1.2)	60,000	120,000	240,000	480,000
Peak Flow 2 (PF=1.5)	75,000	150,000	300,000	600,000

(2) Cross Section and Length

Section	1	2	3	4
Shape	Pipe	Box	Box	Box
Width / Diameter (m)	1.0	2.0	2.0	3.0
Hight (m)		2.0	2.0	2.0
Water Area (m^2)	0.8	3.9	3.9	5.9
Length (m)	18.9	368.0	230.0	142.0

(3) Friction Loss (m, m/s)

Section	1	2	3	4	Total	Remarks
Maninng's N	0.015	0.015	0.015	0.015		Manning Equation n=0.015
Hydraulic Radius	0.39	0.49	0.49	0.59		
Velocity (Average)	0.74	0.30	0.59	0.78		
Velocity (Peak 1)	0.88	0.36	0.71	0.94		
Velocity (Peak 2)	1.11	0.44	0.89	1.18		
Friction Loss (Average)	0.01	0.02	0.05	0.04	0.11	
Friction Loss (Peak 1)	0.01	0.03	0.07	0.06	0.16	
Friction Loss (Peak 2)	0.02	0.04	0.11	0.09	0.26	

(4) Inflow and Outflow Loss (m)

Section	1	2	3	4	Total	Remarks
Inflow Loss (f=0.5)	1	1	2	1		Darcy-Weisbach Equation f=1.0
Outflow Loss (f=1.0)	1	1	2	1		
Total of f Value	1.5	1.5	3.0	1.5		
Loss (Average)	0.04	0.01	0.05	0.05	0.15	
Loss (Peak 1)	0.06	0.01	0.08	0.07	0.21	
Loss (Peak 2)	0.09	0.02	0.12	0.11	0.33	

(5) WaterLevel at Outflow Pit of Final Settling Tank (m)

	Water Level at Choli. Tank	Friction Loss	Inflow and Outflow Loss	Water Level at Outflow Pit
Average Flow	17.50	0.11	0.15	17.76
Peak Flow 1 (PF=1.2)	17.56	0.16	0.21	17.94
Peak Flow 2 (PF=1.5)	17.65	0.26	0.33	18.24

B. Channel for 400,000 m^3/d Facility

(1) Design Flow (m^3/d)

Section	5	6	7	8
Number of Contributing FST	1	2	6	8
Average Flow	50,000	100,000	200,000	400,000
Peak Flow 1 (PF=1.2)	60,000	120,000	240,000	480,000
Peak Flow 2 (PF=1.5)	75,000	150,000	300,000	600,000

(2) Cross Section and Length

Section	5	6	7	8
Shape	Pipe	Box	Box	Box
Width / Diameter (m)	1.0	2.0	3.0	3.0
Hight (m)		2.0	3.0	3.0
Water Area (m^2)	0.8	3.9	8.9	8.9
Length (m)	18.9	206.0	302.0	227.0

(3) Friction Loss (m, m/s)

Section	5	6	7	8	Total	Remarks
Maninng's N	0.015	0.015	0.015	0.015		Manning Equation n=0.015
Hydraulic Radius	0.39	0.49	0.74	0.74		
Velocity (Average)	0.74	0.30	0.26	0.52		
Velocity (Peak 1)	0.88	0.36	0.31	0.62		
Velocity (Peak 2)	1.11	0.44	0.39	0.78		
Friction Loss (Average)	0.01	0.01	0.01	0.02	0.05	
Friction Loss (Peak 1)	0.01	0.02	0.01	0.03	0.07	
Friction Loss (Peak 2)	0.02	0.02	0.02	0.05	0.10	

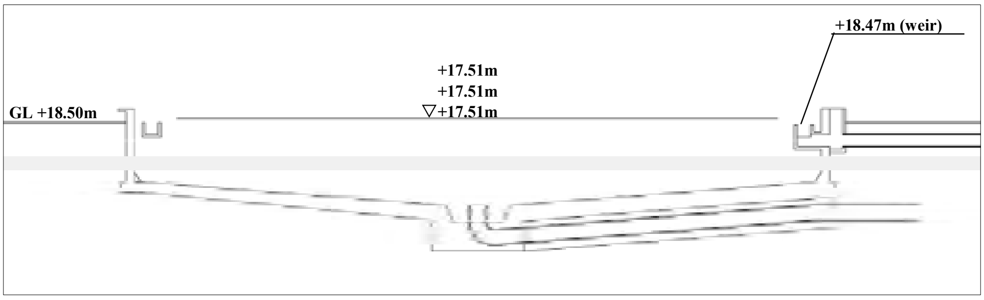
(4) Inflow and Outflow Loss (m)

Section	5	6	7	8	Total	Remarks
Inflow Loss (f=0.5)	1	1	2	1		Darcy-Weisbach Equation f=1.0
Outflow Loss (f=1.0)	1	1	2	1		
Total of f Value	1.5	1.5	3.0	1.5		
Loss (Average)	0.04	0.01	0.01	0.02	0.08	
Loss (Peak 1)	0.06	0.01	0.01	0.03	0.11	
Loss (Peak 2)	0.09	0.02	0.02	0.05	0.18	

(5) WaterLevel at Outflow Pit of Final Settling Tank

	Water Level at Choli. Tank	Friction Loss	Inflow and Outflow Loss	Water Level at Outflow Pit
Average Flow	17.50	0.05	0.08	17.63
Peak Flow 1 (PF=1.2)	17.56	0.07	0.11	17.74
Peak Flow 2 (PF=1.5)	17.65	0.10	0.18	17.93

3. Final Settling Tank



(1) Design Flow (per Tank)

	Q (m^3/d)	Q (m^3/s)	Remarks
Average Flow	50,000	0.579	
Peak Flow 1 (PF=1.2)	60,000	0.694	PF=1.2
Peak Flow 2 (PF=1.5)	75,000	0.868	PF=1.5

(2) Overflow Trough

Inner Diameter	51.0	m
Trough Diameter	50.0	m
Half length of Trough	78.5	m
Trough Width	1.0	m
Inver Level of Trough	17.94	m

	at Down stream of Trough		at Upstream of Trough		Remarks
	Water Depth	Water Level	Water Depth	Water Level	
Average Flow	0.20	18.14	0.29	18.23	Free flow
Peak Flow 1 (PF=1.2)	0.23	18.17	0.33	18.27	
Peak Flow 2 (PF=1.5)	0.30	18.24	0.43	18.37	Plug Flow

(3) Overflow Weiar (Triangle Weir)

Overflow Weiar (Triangle Weir, 90-deg, 0.2m in pitch)

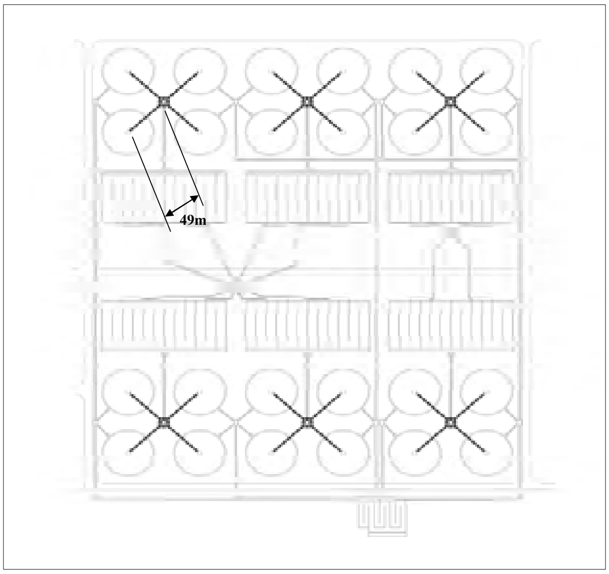
Diameter of Overflow Trough	50	m
Number of Weir Row	2	nos
Total Length of Weir	314	m
Number of Weir Row	1,570	nos/tank
Margin	0.10	
Weir level	18.47	m

	Flow per each Weir (m^3/s)	Overflow Depth (m)	Remarks
Average Flow	0.00037	0.037	q'=(1.334+0.0205/(h)^0.5) x h^(5/2)
Peak Flow 1 (PF=1.2)	0.00044	0.040	h: 0.044 m
Peak Flow 2 (PF=1.5)	0.00055	0.044	q: 0.000581424 m^3/s

(3) Water Level at Final Settling Tank (m)

	Weir Level	Overflow Depth	Water Level at FST
Average Flow	18.47	0.04	18.51
Peak Flow 1 (PF=1.2)	18.47	0.04	18.51
Peak Flow 2 (PF=1.5)	18.47	0.04	18.51

4. Pipe from FST Distribution Tank to FST



(1) Design Flow (per one FST)

Design flow includes return sludge flow which is 50% of average flow.

	Sewage	Return Sludge	Total	
	(m^3/d)	(m^3/d)	(m^3/d)	(m^3/s)
Average Flow	50,000	25,000	75,000	0.868
Peak Flow 1 (PF=1.2)	60,000	25,000	85,000	0.984
Peak Flow 2 (PF=1.5)	75,000	25,000	100,000	1.157

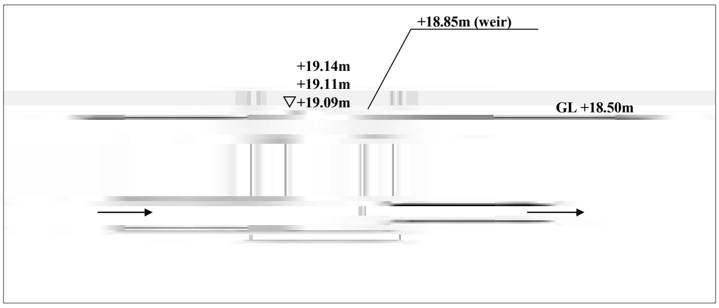
(2) Losses in Pipe (m)

	Diameter	Length	Friction Loss	Inflow-Outflow Loss	Remarks
Average Flow	1.2	49.0	0.03	0.05	Manning Equation, n=0.015 Darcy-Weisbach Equation, f=1.5
Peak Flow 1 (PF=1.2)	1.2	49.0	0.04	0.06	
Peak Flow 2 (PF=1.5)	1.2	49.0	0.06	0.08	

(3) Water Level at Outflow Pit of FST Distribution Tank

	Water Level at FST	Friction Loss	Inflow-Outflow Loss	Water Level at Distribution Tank Pit
Average Flow	18.51	0.03	0.05	18.58
Peak Flow 1 (PF=1.2)	18.51	0.04	0.06	18.61
Peak Flow 2 (PF=1.5)	18.51	0.06	0.08	18.65

5. Distribution Tank for Final Settling Tank



(1) Design Flow (per one FST)

Design flow includes return sludge flow which is 50% of average flow.

	Sewage	Return Sludge	Total	
	(m^3/d)	(m^3/d)	(m^3/d)	(m^3/s)
Average Flow	50,000	25,000	75,000	0.868
Peak Flow 1 (PF=1.2)	60,000	25,000	85,000	0.984
Peak Flow 2 (PF=1.5)	75,000	25,000	100,000	1.157

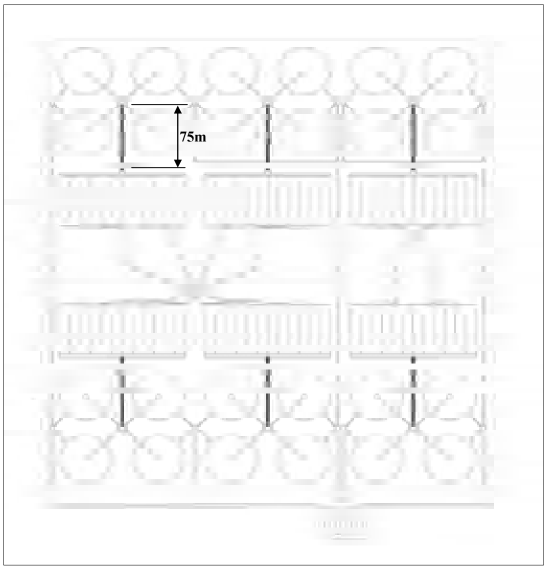
(2) Distribution Weir

Weir Width	4.0	m
Margin	0.2	m
Weir Level	18.85	m

(m)

	Weir Level	Overflow Depth	Water Level at Distribution Tank	Remarks
Average Flow	18.85	0.24	19.09	Francis Equation c=1.84
Peak Flow 1 (PF=1.2)	18.85	0.26	19.11	
Peak Flow 2 (PF=1.5)	18.85	0.29	19.14	

6. Channel from Outflow Pit of Aeration Tank to Distribution Tank for FST



(1) Design Flow (per one Aeration Tank)

Design flow includes return sludge flow which is 50% of average flow.

	Sewage (m^3/d)	Return Sludge (m^3/d)	Total (m^3/d)	Total (m^3/s)
Average Flow	200,000	100,000	300,000	3.472
Peak Flow 1 (PF=1.2)	240,000	100,000	340,000	3.935
Peak Flow 2 (PF=1.5)	300,000	100,000	400,000	4.630

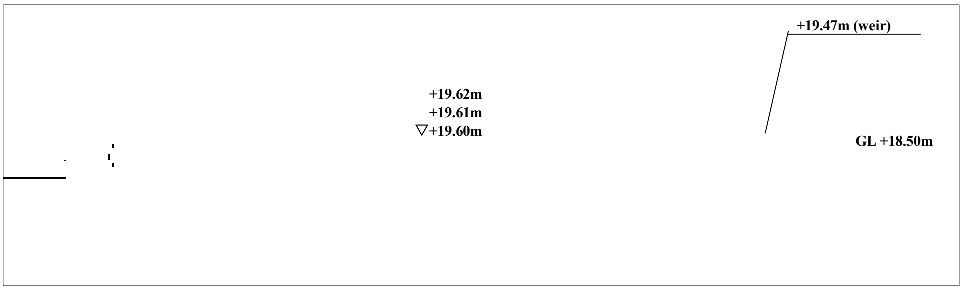
(2) Channel from Outflow Pit of Aeration tank to Distribution Tank for FST (m)

	Width	Hight	Length	Friction Loss	Inflow-Outflow Loss	Remarks
Average Flow	2.0	2.0	75.0	0.01	0.06	Manning Equation, n=0.015 Darcy-Weisbach Equation, f=1.5
Peak Flow 1 (PF=1.2)	2.0	2.0	75.0	0.02	0.07	
Peak Flow 2 (PF=1.5)	2.0	2.0	75.0	0.02	0.10	

(3) Water Level at Outflow Pit of Aeration Tank (m)

	Water Level at Distribution Tank	Friction Loss	Inflow-Outflkow Loss	Water Level at Outflow Pit
Average Flow	19.09	0.01	0.06	19.16
Peak Flow 1 (PF=1.2)	19.11	0.02	0.07	19.20
Peak Flow 2 (PF=1.5)	19.14	0.02	0.10	19.27

7. Aeration Tank



(1) Design Flow (per one Aeration Tank)

Design flow includes return sludge flow which is 50% of average flow.

	Sewage (m^3/d)	Return Sludge (m^3/d)	Total (m^3/d)	Total (m^3/s)
Average Flow	200,000	100,000	300,000	3.472
Peak Flow 1 (PF=1.2)	240,000	100,000	340,000	3.935
Peak Flow 2 (PF=1.5)	300,000	100,000	400,000	4.630

(2) Outflow Weir

Weir Width	10.0	m
Number of Weir	4	nos
Total Weir Width	40.0	m
Margin	0.2	m
Weir Level	19.47	m

	Weir Level	Overflow Depth	Water Level at AT	Remarks
Average Flow	19.47	0.13	19.60	Francis Equation c=1.84
Peak Flow 1 (PF=1.2)	19.47	0.14	19.61	
Peak Flow 2 (PF=1.5)	19.47	0.16	19.62	

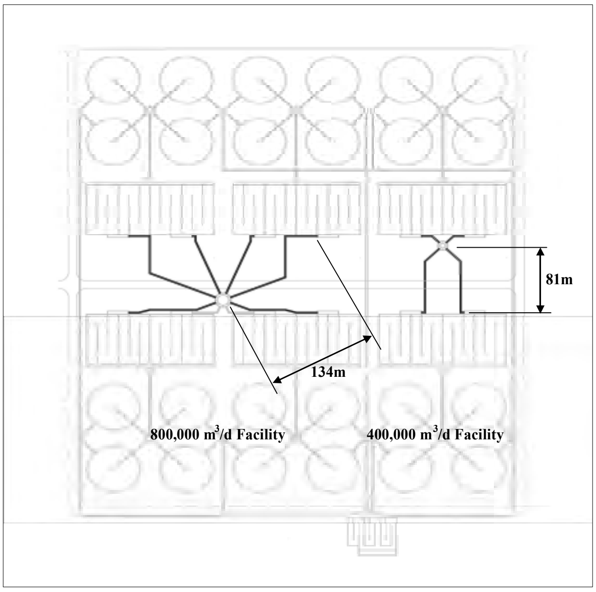
(3) Inflow Gate

Width 2.0 m
Hight 2.0 m
Number of Gate 2 nos

(m)

	Water Level at Aeration Tank	Loaa at Gate	Water Level at Inflow Pit of Aeration Tank	Remarks
Average Flow	19.60	0.01	19.61	Darcy-Weisbach Equation f=1.0
Peak Flow 1 (PF=1.2)	19.61	0.01	19.62	
Peak Flow 2 (PF=1.5)	19.62	0.02	19.64	

8. Pipe from Distribution tank to Aeration Tank



A. Channel for 800,000 m^3/d Facility

(1) Design Flow per 1/2 of Aeration Tank

	Q (m^3/d)	Q (m^3/s)
Average Flow	100,000	1.157
Peak Flow 1 (PF=1.2)	120,000	1.389
Peak Flow 2 (PF=1.5)	150,000	1.736

(2) Pipe from Distribution tank to Aeration Tank (m)

	Diameter	Length	Friction Loss	Inflow-Outflow Loss	Remarks
Average Flow	1.5	134.0	0.05	0.05	Manning Equation, n=0.015 Darcy-Weisbach Equation, f=1.5
Peak Flow 1 (PF=1.2)	1.5	134.0	0.07	0.07	
Peak Flow 2 (PF=1.5)	1.5	134.0	0.11	0.10	

(3) Water Level at Outflow Pit of Distribution Tank (m)

	Water Level at Inflow Pit of Aeration Tank	Friction Loss	Inflow-Outflow Loss	Water Level at Inflow Pit of Distribution Tank
Average Flow	19.61	0.05	0.05	19.70
Peak Flow 1 (PF=1.2)	19.62	0.07	0.07	19.76
Peak Flow 2 (PF=1.5)	19.64	0.11	0.10	19.85

B. Channel for 400,000 m^3/d Facility

(1) Design Flow per 1/2 of Aeration Tank

	Q (m^3/d)	Q (m^3/s)
Average Flow	100,000	1.157
Peak Flow 1 (PF=1.2)	120,000	1.389
Peak Flow 2 (PF=1.5)	150,000	1.736

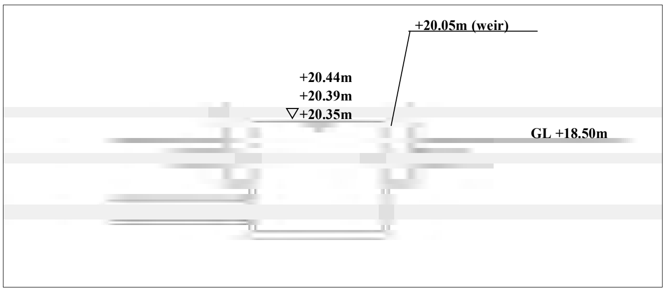
(2) Pipe from Distribution tank to Aeration Tank (m)

	Diameter	Length	Friction Loss	Inflow-Outflow Loss	Remarks
Average Flow	1.5	81.0	0.03	0.05	Manning Equation, n=0.015 Darcy-Weisbach Equation, f=1.5
Peak Flow 1 (PF=1.2)	1.5	81.0	0.04	0.07	
Peak Flow 2 (PF=1.5)	1.5	81.0	0.06	0.10	

(3) Water Level at Outflow Pit of Distribution Tank (m)

	Water Level at Inflow Pit of Aeration Tank	Friction Loss	Inflow-Outflow Loss	Water Level at Inflow Pit of Distribution Tank
Average Flow	19.61	0.03	0.05	19.68
Peak Flow 1 (PF=1.2)	19.62	0.04	0.07	19.73
Peak Flow 2 (PF=1.5)	19.64	0.06	0.10	19.81

9. Distribution Tank



(1) Design Flow per 1/2 of Aeration Tank

	Q (m^3/d)	Q (m^3/s)
Average Flow	100,000	1.157
Peak Flow 1 (PF=1.2)	120,000	1.389
Peak Flow 2 (PF=1.5)	150,000	1.736

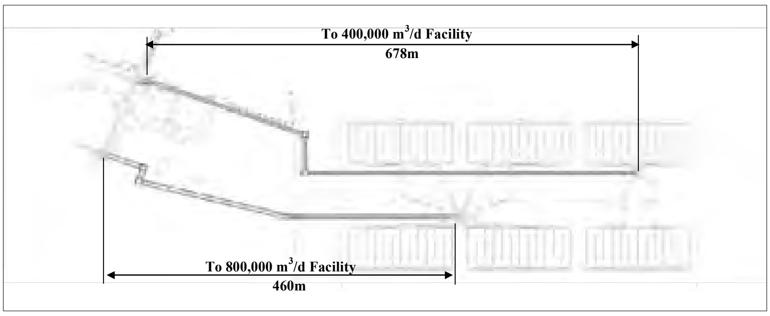
(2) Distribution Weir

Weir Width	3.9	m
Margin	0.2	m
Weir level	20.05	m

(m)

	Weir Level	Overflow Depth	Water Level at Distribution Tank	Remarks
Average Flow	20.05	0.30	20.35	Francis Equation c=1.84
Peak Flow 1 (PF=1.2)	20.05	0.33	20.39	
Peak Flow 2 (PF=1.5)	20.05	0.39	20.44	

10. Channel from Connection Point of Existing Facility to Distribution Tank



A. Channel for 800,000 m^3/d Facility

(1) Design Flow

	Q (m^3/d)	Q (m^3/s)
Average Flow	800,000	9.259
Peak Flow 1 (PF=1.2)	960,000	11.111
Peak Flow 2 (PF=1.5)	1,200,000	13.889

(2) Channel from Connection Point of Existing Facility to Distribution Tank (m)

	Width	Hight	Length	Friction Loss	Inflow-Outflow Loss	Remarks
Average Flow	5.0	2.0	460.0	0.09	0.10	Manning Equation, n=0.015 Darcy-Weisbach Equation, f=1.5
Peak Flow 1 (PF=1.2)	5.0	2.0	460.0	0.13	0.15	
Peak Flow 2 (PF=1.5)	5.0	2.0	460.0	0.20	0.24	

(3) Water Level at Connecting Point (m)

	Water Level at Distribution Tank	Friction Loss	Inflow-Outflow Loss	Water level at Outflow Pit of Connection Chamber
Average Flow	20.35	0.09	0.10	20.54
Peak Flow 1 (PF=1.2)	20.39	0.13	0.15	20.67
Peak Flow 2 (PF=1.5)	20.44	0.20	0.24	20.87

(4) Gate at Connection Chamber

Width	2.5	m
Hight	2.5	m
Number of Gate	2	nos

	Water level at Outflow Pit of Connection Chamber	Gate Loss	Water level at Connecting Point	Remarks
Average Flow	20.54	0.03	20.57	Darcy-Weisbach Equation f=1.0
Peak Flow 1 (PF=1.2)	20.67	0.04	20.71	
Peak Flow 2 (PF=1.5)	20.87	0.06	20.94	

Water level at connection Chamber (#39) is **+21.10m** according to hydraulic profile drawing of "new facility".

B. Channel for 400,000 m^3/d Facility

(1) Design Flow

	Q (m^3/d)	Q (m^3/s)
Average Flow	400,000	4.630
Peak Flow 1 (PF=1.2)	480,000	5.556
Peak Flow 2 (PF=1.5)	600,000	6.944

(2) Channel from Connection Point of Existing Facility to Distribution Tank

	Width	Hight	Length	Friction Loss	Inflow-Outflow Loss	Remarks
Average Flow	4.0	2.0	678.0	0.05	0.04	Manning Equation, n=0.015 Darcy-Weisbach Equation, f=1.5
Peak Flow 1 (PF=1.2)	4.0	2.0	678.0	0.07	0.06	
Peak Flow 2 (PF=1.5)	4.0	2.0	678.0	0.11	0.09	

(3) Water Levela at Connecting Point

(m)

	Water Level at Distribution Tank	Friction Loss	Inflow-Outflow Loss	Water level at Outflow Pit of Connection Chamber
Average Flow	20.35	0.05	0.04	20.44
Peak Flow 1 (PF=1.2)	20.39	0.07	0.06	20.52
Peak Flow 2 (PF=1.5)	20.44	0.11	0.09	20.65

Water level at lift-up pumpis **+20.79m** according to hydraulic profile drawing of "existing facility".

APPENDIX – 4

Design Calculations of Activated Sludge WWTP

(Design Capacity =1,200,000 m^3/day)

Design Calculations of Activated Sludge WWTP

1 DESIGN PARAMETERS AND CRITERIA

1.1 Wastewater Quantity and Characteristics

Average daily flow	Q_{ad} =	1,200,000	m^3/d
Peak flow	Q_{mh} =	0	m^3/d
BOD concentration	=	310	mg/L
SS concentration	=	360	mg/L

1.2 Pollutants Removal Efficiencies

BOD concentration including sidestream flow	=	310	mg/L
BOD concentration treated with primary system	=	155	mg/L
BOD removal efficiency with primary system	=	50	%
BOD removal efficiency with secondary system	=	85	%
Overall BOD removal efficiency	=	93	%
SS concentration including sidestream flow	=	360	mg/L
SS concentration treated with primary system	=	144	mg/L
SS removal efficiency with primary system	=	60	%
SS removal efficiency with secondary system	=	85	%
Overall SS removal efficiency	=	94	%

1.3 Effluent Qualities

BOD concentration	=	23	mg/L
SS concentration	=	22	mg/L

1.4 Component Facilities

(a) Aeration Tank

MLSS concentration	=	2,000	mg/L
Dissolved oxygen in mixed liquor	=	2.0	mg/L
Hydraulic retention time (HRT)	=	4.5	hr
Solids content in return sludge	=	0.6	%
Return sludge ratio	=	46	%
Oxygen required to remove BOD	=	0.6	$kgO_2/kgBOD$
Oxygen required for endogenous	=	0.10	kgO_2/MLVSS/day

(b) Final Clarifiers

Hydraulic overflow rate	=	25	$m^3/m^2/d$
Hydraulic retention time	=	3.5	hr
Effective depth	=	3.5	m
Weir overflow rate	=	150	$m^3/m/d$ or lower
Free board	=	0.5	m or more
Excess sludge solids concentration	=	0.6	%

(c) Disinfection

Maximum Chlorine dosing rate	=	15.0	mg/L
Average Chlorine dosing rate	=	5.0	mg/L
Chlorine contact time	=	5.0	minutes

(d) Sludge Lagoon

Drying period in summer	=	25	days
Drying period in winter	=	40	days

2 DESIGN CALCULATIONS OF WATER TREATMENT FACILITIES

2.1 Aeration Tank

(1) Design Bases

Design flow	Q_{in} =	1,187,040	m^3/d
BOD concentration	$C_{BOD,\ in}$=	155	mg/L
S-BOD concentration (= 66.7%)	$C_{S\text{-}BOD,\ in}$=	103	mg/L
SS concentration	$C_{SS,\ in}$=	144	mg/L
MLSS concentration	X=	2,000	mg/L
HRT (Hydraulic retention time)	θ=	4.5	hour

(2) Check for effluent Qualities

The volume of waste sludge can be estimated by the following equation:

$$Q_w \cdot X_w = (a \cdot C_{S\text{-}BOD,\ in} + b \cdot C_{SS,\ in} - c \cdot \theta \cdot X)\, Q_{in}$$

where,

Q_w :	Excess sludge volume (m^3/d)			
X_w :	Average solids concentration of waste sludge	=	0.6	%
Q_{in} :	Inflow rate to reactor basins	=	1,187,040	m^3/d
X :	MLSS concentration in reactor basins	=	2,000	mg/L
$C_{S\text{-}BOD,\ in}$:	Influent S-BOD concentration to reactor basins	=	103	mg/L
$C_{SS,\ in}$:	Influent SS concentration to reactor basins	=	144	mg/L
a :	Biomass yield coefficient of S-BOD (0.4 ～0.6)	=	0.5	mg MLSS/mg BOD
b :	Biomass yield coefficient of SS (0.9 ～1.0)	=	0.95	mg MLSS/mg SS
c :	Sludge reduction coefficient due to endogenous respiration of micro-organisms (0.03 ～0.05)	=	0.04	L/d
θ :	Hydraulic retention time (HRT) in reactors	=	4.5	hour

$$Q_w X_w = 205{,}912 \quad \text{kg/d}$$

SRT of reactor can be estimated by the following equation:

$$SRT = \theta \cdot X / (a \cdot C_{S\text{-}BOD,\ in} + b \cdot C_{SS,\ in} - c \cdot \theta \cdot X)$$

$$SRT = 2.2 \quad \text{d}$$

C-BOD of effluent qualities can be estimated by the following equation:

$C_{C\text{-}BOD}$ = $10.42 \cdot SRT^{-0.519}$ (15℃ < Lowest =18℃ < 20℃)

$C_{C\text{-}BOD}$ = 7.0 mg/l

C_{BOD} = 21.0 mg/l

$C_{C\text{-}BOD}$ = $9.75 \cdot SRT^{-0.671}$ (20℃ < Average =23℃ < 25℃)

$C_{C\text{-}BOD}$ = 5.8 mg/l

C_{BOD} = 17.4 mg/l

$C_{C\text{-}BOD}$ = $11.54 \cdot SRT^{-0.744}$ (25℃ < Highest =29℃)

$C_{C\text{-}BOD}$ = 6.5 mg/l

C_{BOD} = 19.5 mg/l

Nitration can be estimated by the following equation:

Required SRT = *20.65*exp(-0.0639*Temperature)*

Highest Sewage Temperature = 29 ℃

= 3.2 d > 2.2 d

Therefore, nitration is not expected to occur.

(3) Tank Dimensions

Tank width	W =	10.0 m
Tank effective depth	d =	6.0 m
Tank cross sectional area	A =	6.0 x 10 - 1/2 x 1.0^2 x 4 - 1/2 x 0.5^2 x 4

= 57.5 m^2

Number of tanks n = 4 tanks x 6 clusters = 24 tank units

Capacity of each tank V_e = 222,570 / 24 = 9,274 m^3

Tank length 9,274 / 57.5 = 161.3 m → 162 m 54mL x 3lines

Tank Shape and Dimensions

Width	10.0 m	
Depth	6.0 m	
Tank capacity	9,315 m^3	
Tank length	162 m	54mL x 3lines
No. of tank units and clusters	4 tanks x	6 clusters

Check actual aeration time under the average daily flow rate condition.

Tank capacity V = 57.5 x 162 x 24 = 223,560 m^3

Aeration time T_a = 223,560 x 24 / 1,187,040 = 4.5 hr.

BOD to SS Loads : $L_{BOD/X}$ (kg BOD / kgMLSS・d)

$L_{BOD/X}$ = Q_{in} ・ $C_{BOD,in}$ / X ・ V

$L_{BOD/X}$ = 0.41 kg BOD / kgMLSS・d

BOD to Volume Loads : $L_{BOD/V}$ (kg BOD / m^3 ・d)

$L_{BOD/V}$ = Q_{in} ・ $C_{BOD,in}$ / V $*10^{-3}$

$L_{BOD/V}$ = 0.82 kg BOD / m3 / d

2.2 Final Clarifier

(1) Tank Dimensions

Design flow rate Q_{ad} = 1,187,040 m^3/d

Hydraulic overflow rate = 25 $m^3/m^2/d$

Total number of clarifiers n = 24 units 6 clusters x 4 tanks

Hydraulic load on each basin is = 1,187,040 / 24 = 49,460 m^3/d

Required tank surface area A = 49,460 / 25 = 1,978 m^2

(2) Tank Geometry

Internal diameter D = 51.0 m

Effective depth d = 3.5 m

Number of basins n = 24 units

Surface area of each tank A_e = 2,043 m^2

Hydraulic capacity of a tank V_{fc} = 7,151 m^3

(3) Check for Hydraulic Conditions

HRT for design flow T_{ad} = 7,151 x 24 / 49,460 = 3.5 hr

HRT for peak flow T_{mh} = 7,151 x 24 / 74,460 = 2.3 hr.

Overflow rate for design flow Q_{md} = 49,460 / 2043 = 24.2 $m^3/m^2.d$

Overflow rate for Peak flow Q_{mh} = 74,460 / 2043 = 36.4 $m^3/m^2.d$

Tank Shape and Dimensions

Internal diameter	51.0 m	
Efficient depth	3.5 m	
Tank capacity	7,151 m^3	
No. of tank units and clusters	4 tanks x	6 clusters

2.3 Chlorine Contact Tank

(1) Tank Dimension

Design flow	=	1,156,964 m^3/d
Chlorine contact time	=	5 minutes
Required tank capacity	=	1,156,964 /1,440 x 5 = 4,017 m^3
Channel width:	=	5.0 m
Effective depth:	=	3.0 m
Tank length:	=	4,017 / 5.0 / 3.0 = 267.8 m
Number of tanks	=	3 tanks
Length channel	=	89 m/tanks
No. of lines		30 m x 3 lines
Capacity of Tank	=	1,350 m^3

(2) Check for Contact Time

Contact time for design flow	T_{ad} =	1,350 x 1440 / 385,655 = 5.0	minutes
Contact time for peak flow	T_{mh} =	1,350 x 1440 / 585,655 = 3.3	minutes

Tank Shape and Dimensions

Width	5.0 m	
Depth	3.0 m	
Tank capacity	1,350 m^3	
Tank length	90 m	30mL x 3lines
No. of tank units	3 tanks	

3 DESIGN CALCULATION OF REQUIRED AERATION

3.1 AOR (Actual Oxygen Requirement) for Aeration Tank

Required oxygen O_2 for aeration is estimated as:

AOR = $OD_1 + OD_2 + OD_3$

where

OD_1 = Oxygen required for BOD oxygenation (kg/day)

OD_2 = Oxygen required for endogenous respiration (kg/day)

OD_3 = Oxygen to be utilized for maintaining required dissolved oxygen level (kg/day)

3.2 Oxygen for BOD Oxidation, OD_1 (cell synthesis)

OD_1 = A x (kg O_2/kg BOD) x BOD removed (kg BOD/day)

where

A = Oxygen required to remove BOD (kgO_2/kgBOD, 0.5～0.7)

= 0.6 kgO_2/kgBOD

Q = 1,187,040 m^3/d

BOD = 155 - 23 = 132 mg/L

OD_1 = 0.6 x Q x 132 x 10^{-3}

= 0.079 Q kgO_2/d

3.3 Oxygen for Endogenous Respiration OD_2

OD_2 = B（kgO_2/kg MLVSS/day）× V_A (m_3) x MLVSS (kg MLVSS/m_3)

where

B = Oxygen required for endogenous respiration per MLVSS (kgO_2/MLVSS/day, 0.05～0.15)

= 0.1 kgO_2/MLVSS/day

V_A = Capacity of aerobic zone of reactor 4.5 ÷ 24 = 0.188 Q（m^3）

$MLVSS/MLSS$ = 0.8

OD_2 = 0.1 x 0.188 x Q x 2,000 x 10^{-3} x 0.8

= 0.030 Q kgO_2/d

3.4 Oxygen for Maintaining Dissolved Oxygen Level OD_3

OD_3 = $C_{O,A}$ x (Q + Qr) x 10^{-3} (kg BOD/day)

where

C_{OA} = Dissolved oxygen concentration in tank 2.0 mg/L

Qr = Returned sludge = 0.46 x Q

OD_3 = 2.0 x (Q + Qr) x 10^{-3}

= 0.003 x Q kg O_2/d

3.5 Total AOR

AOR = OD_1 + OD_2 + OD_3

= 0.079 Q + 0.030 Q + 0.003 Q

= 0.112 Q(kgO_2/d)

3.6 SOR (Standard Oxygen Requirement) for Aeration Tank

Required oxygen O_2 for aeration in the condition (clean water, 20℃and 1atm) is estimated as:

$$SOR = \frac{AOR \times Csw \times \gamma}{1.024^{(1-20)} \times a\,(\beta \times Cs \times \gamma - C_{OA})} \times \frac{101.3}{P}$$

where

C_{sw} = Oxygen saturation concentration in clean water at temperature at 20℃ 8.8 mg/L

C_s = Oxygen saturation concentration in clean water at temperature at T℃ 9.8 mg/L

α =	Correction Factor	0.83	
β =	Correction Factor	0.95	
γ =	Correction Factor for CS by Water Depth		
	γ = 1+(h/2)/10.332	1.276	
H =	water depth	5.7	m
P =	Atmospheric Factor	101.3	kPa
T =	Minimum Temperature of Waste Water	18	℃

SOR＝ 192,936 kgO2/d

3.7 Aeration Requirement

Oxygen transfer efficiency of aerator is estimated as:

Ea= Ea(5.0) −6.0（5−H)

where

Ea= Oxygen transfer Efficiency in clean Water

Ea(5.0)= Oxygen transfer Efficiency in clean Water at 5m depth 31 %

Ea= 35.2 %

Required total air demand (GS) for aeration is estimated as:

$$GS = \frac{SOR \times (273+20)}{Ea \times 10^{-2} \times \rho \times Ow \times 273 \times 60 \times 24}$$

where

ρ=	Air Density	1.292	kg/Nm^3
Ow=	Oxygen Weight per Unit Air	0.232	kg-O2/kg-air

GS= 1,366 m^3/min

4 DESIGN CALCULATIONS OF SLUDGE TREATMENT FACILITIES

4.1 Design Bases

(1) Raw Sludge from Abu Rawash WWTP

Sludge solids production	=	1,200,000 x 360 x 10^{-6} x 0.60
	=	259,200 kg/d
Solids concentration of sludge	=	2.0 %
Raw sludge generation	=	259,200 / 10 / 2.0 = 12,960 m^3/d

(2) Mixed Sludge from Zenein WWTP

Sludge solids production	=	100,000 kg/d
Solids concentration of sludge	=	1.0 %
Mixed sludge generation	=	100,000 / 10 / 1.0 = 10,000 m^3/d

(3) Waste Sludge from Abu Rawash WWTP

The volume of waste sludge can be estimated by the following equation:

$$Q_w \cdot X_w = (a \cdot C_{S\text{-}BOD,\,in} + b \cdot C_{SS,\,in} - c \cdot \theta \cdot X)\,Q_{in}$$

where,

Q_w :	Excess sludge volume (m^3/d)			
X_w :	Average solids concentration of waste sludge	=	0.6	%
Q_{in} :	Inflow rate to reactor basins	=	1,187,040	m^3/d
X :	MLSS concentration in reactor basins	=	2,000	mg/L
$C_{S\text{-}BOD,\,in}$:	Influent S-BOD concentration to reactor basins	=	103	mg/L
$C_{SS,\,in}$:	Influent SS concentration to reactor basins	=	144	mg/L
a :	Biomass yield coefficient of S-BOD (0.4 〜0.6)	=	0.5	mg MLSS/mg BOI
b :	Biomass yield coefficient of SS (0.9 〜1.0)	=	0.95	mg MLSS/mg SS
c :	Sludge reduction coefficient due to endogenous respiration of micro-organisms (0.03 〜0.05)	=	0.04	L/d
θ :	Hydraulic retention time (HRT) in reactors	=	4.5	day

$Q_w X_w$ = 205,912 kg/d

Sludge solids in effluence flow	=	1,156,964 x 22 x 10^{-6} = 25,453 kg/d
Sludge solids production	=	180,459 kg/d
Solids concentration of sludge	=	0.6 %
Waste sludge generation	=	180,459 / 10 / 0.6 = 30,076 m^3/d

4) Return Sludge

Sludge return ratio	=	46 %
Return sludge volume	=	1,187,040 x 0.46 = 550,787 m^3/d = 382 m^3/min.

4.2 Sludge Transfer

(1) Design Bases

(Raw and Waste Sludge of Abu Rawash WWTP and Mixed Sludge of Zenein WWTP)

Input sludge solids	=	539,659 kg/d
Input sludge Volume	=	53,036 m^3/d
Input sludge solids concentration	=	1.0 %

(2) Existing Sludge Pump

Capacity	=	22.8 m3/min
Head working range	=	75-85 m
Number of pups	=	2 sets (Two pumps is one set connected directly)

(3) Additional Sludge Pump

Existing Capacity	=	32,832	m3/d (as one set is standby)
	<	53,036	m^3/d
Existing + Additional (1) Capaci	=	65,664	m3/d (as one set is standby)
	>	53,036	m^3/d

Specification of Sludge transfer Pump

Type	Horizontal Shaft Mixed Flow Pump
Pump Capacity	22.8 m3/min
Total head	80 m
Motor Output	450.0 kW
Quantity	2 unit

4.3 Sludge Lagoon

(1) Design Bases

Input sludge solids	=	539,659	kg/d
Input sludge Volume	=	53,036	m^3/d
Input sludge solids concentration	=	1.0	%
Required drying period in summe	=	25	days
Required drying period in winter	=	40	days
Depth of sludge	=	0.5	m
Required lagoon area in summer	=	265.2	ha
Required lagoon area in winter	=	424.3	ha
Existing lagoon area	=	241.5	ha
Additional lagoon area	=	182.8	ha

Shape and Dimensions

Type	Sludge lagoon
Depth of sludge	0.5 m
Area	183 ha

5 SPECIFICATION OF MECHANICAL EQUIPMENT FOR WATER TREATMENT

5.1 Aeration Tank

(1) Aerator

Specification of Aerator

Type	Membrane Panel
Quantity	38,880 m2 (1,620 / tank)

(2) Blower

Specification of Blower

Type	Multistage turbo blower
Blower Capacity	260 m3/min (at 20 ℃, 1atm)
Pressure	64.0 kPa
Motor Output	380 kW
Quantity	9 unit (3 standby)

5.2 Final Setting Tank

(1) Final Clarifier

Specification of Clarifier

Type	Peripheral Driven Center Column Type
Size	Dia.51m × 3.5mD
Motor Output	3.7 kW
Quantity	24 unit

(2) Waste Sludge Pump

Specification of Waste Sludge Pump

Type	Non-Clog Type Sludge Pump
Excess Sludge Volume	30,076 m3/day
Pump Capacity	5.2 m3/min
Total head	10 m
Motor Output	15.0 kW
Quantity	12 unit (6 standby)

(3) Return Sludge Pump

Specification of Return Sludge Pump

Type	Vertical Shaft Mixed Flow Pump
Influent Flow Rate	1,200,000 m3/day
Return Sludge Ratio	100 %
Pump Capacity	34.7 m3/min
Total head	6 m
Motor Output	55.0 kW
Quantity	24 unit

5.3 Disinfection

(1) Chlorine Cylinder

Specification of Chlorine Cylinder

Type	Chlorine Cylinder
Capacity	1 ton
Storage Days	7 days
Quantity	42 unit

(2) Supply Pump

Specification of Supply Pump

Type	Centrifugal Pump
Pump Capacity	4.0 m3/min
Total head	40 m
Motor Output	45.0 kW
Quantity	6 unit (3 standby)

6 SPECIFICATION OF MECHANICAL EQUIPMENT FOR SLUDGE TREATMENT

6.1 Sludge Transfer

(1) Sludge Transfer Pump

Specification of Sludge transfer Pump

Type	Horizontal Shaft Mixed Flow Pump
Pump Capacity	22.8 m3/min
Total head	80 m
Motor Output	450.0 kW
Quantity	2 unit

Mass Balance Calculation of Abu Rawash WWTP

Design Flow	Flow	1,200,000	m3/day
	BOD	310	mg/l
	SS	360	mg/l
Sidestream DS	Input	0	kg/day
	Calculate	0	kg/day
Adjudication		○	
Sidestream Flow	Input	0	m3/day
	Calculate	0	m3/day
Adjudication		○	

Design quality

Design Flow		1,200,000	m3/day
WWTP Inflow Quality	BOD	310	mg/l
	SS	360	mg/l
Design Quality	BOD	310	mg/l
	SS	360	mg/l
Aeration Tank Inflow Quality	BOD	155	mg/l
	SS	144	mg/l
Effluent Quality	BOD	23	mg/l
	SS	22	mg/l

Removal rate of SS

First Setting	60	%
Final Setting	85	%

Removal rate of BOD

First Setting	50	%
Final Setting	85	%

Coefficient of waste sludge generation

Detention Time	4.5	hr
a	0.5	
b	0.95	
c	0.04	

Return sludge

Return Rate	46	%
Density of Sludge	6,000	mg/l
MLSS	2,000	mg/l

Zennin WWTP

Mixed Sludge DS	100,000	kg/day
Density of Sludge	99.0	%
Amount of Sludge	10,000	m3/day

Percentage of water content

Raw Sludge	98.0	%
Waste Sludge	99.4	%
Gravity Thickened	96.0	%
Mechanical Thickened		
Digested Sludge	0.0	%
Dried Sludge	60.0	%

Recovery rate of DS

Gravity Thickener	85	%
Mechanical Thickener	95	%
Mechanical Dewater	95	%

Coefficient of digestion

Organic rate	70	%
Digestion rate	50	%

First Setting

＜SS removal rate 60 %＞

Flow/Quality	Flow m3/day	SS mg/l	DS kg/day
① Inflow			
Inflow	1,200,000	360	432,000
Sidestream			
Total	1,200,000	360	432,000
② Outflow			
Outflow	1,187,040	144	172,800
Raw sludge	Flow m3/day	Concentration %	DS kg/day
Generation	12,960	98.0	259,200

Aeration Tank / Final Setting

＜Return rate 46 %＞
＜SS removal rate 88 %＞

	Flow m3/day	SS mg/l	DS kg/day
① Inflow			
Inflow	1,187,040	144	172,800
Waste sludge	1,187,040		205,912
Total	1,187,040	173	205,912
Return sludge	550,787	6,000	3,304,722
② Outflow			
Outflow	1,156,964	22	25,453
Waste sludge	Flow m3/day	Concentration %	DS kg/day
Generation	30,076	99.4	180,459

Gravity Thickener

＜Recovery rate 85 %＞

Sludge	Flow m3/day	Concentration %	DS kg/day
Sidestream	Flow m3/day	SS mg/l	DS kg/day
Sidestream			

Digestion Tank

＜Organic rate 70 %＞
＜Digestion rate 50 %＞

Sludge	Flow m3/day	Concentration %	DS kg/day
Feeded sludge			
Digested sludge			
Digested gas	DS kg/day	Generation m3/day	
Digested gas			

Sludge Transfer

＜Concentration 98.5 %＞

Sludge	Flow m3/day	Concentration %	DS kg/day
Raw sludge(Abu)	12,960	98.0	259,200
Waste sludge(Abu)	30,076	99.4	180,459
Mixed sludge(Zenin)	10,000	99.0	100,000
Transferred sludge	53,036	99.0	539,659

Dried Cake

＜Concentration 60.0 %＞

Sludge	Amount m3/day	Concentration %	DS kg/day
Dried cake	1,349	60.0	539,659

Design Flow / Quality	Flow m3/day	BOD mg/l	SS mg/l	
WWTP Inflow	1,200,000	310	360	
Design quality		310	360	
Design Flow / Quality	Flow m3/day	BOD mg/l	SS mg/l	DS kg/day
First Setting	1,200,000	310	360	432,000
Aeration Tank	1,187,040	155	144	172,800
Final Setting	1,187,040	155	144	172,800
(Return Sludge)	550,787		6,000	3,304,722
Design Amount / DS	Flow m3/day	Concentration %	DS kg/day	
Gravity Thickener				
Digestion Tank				

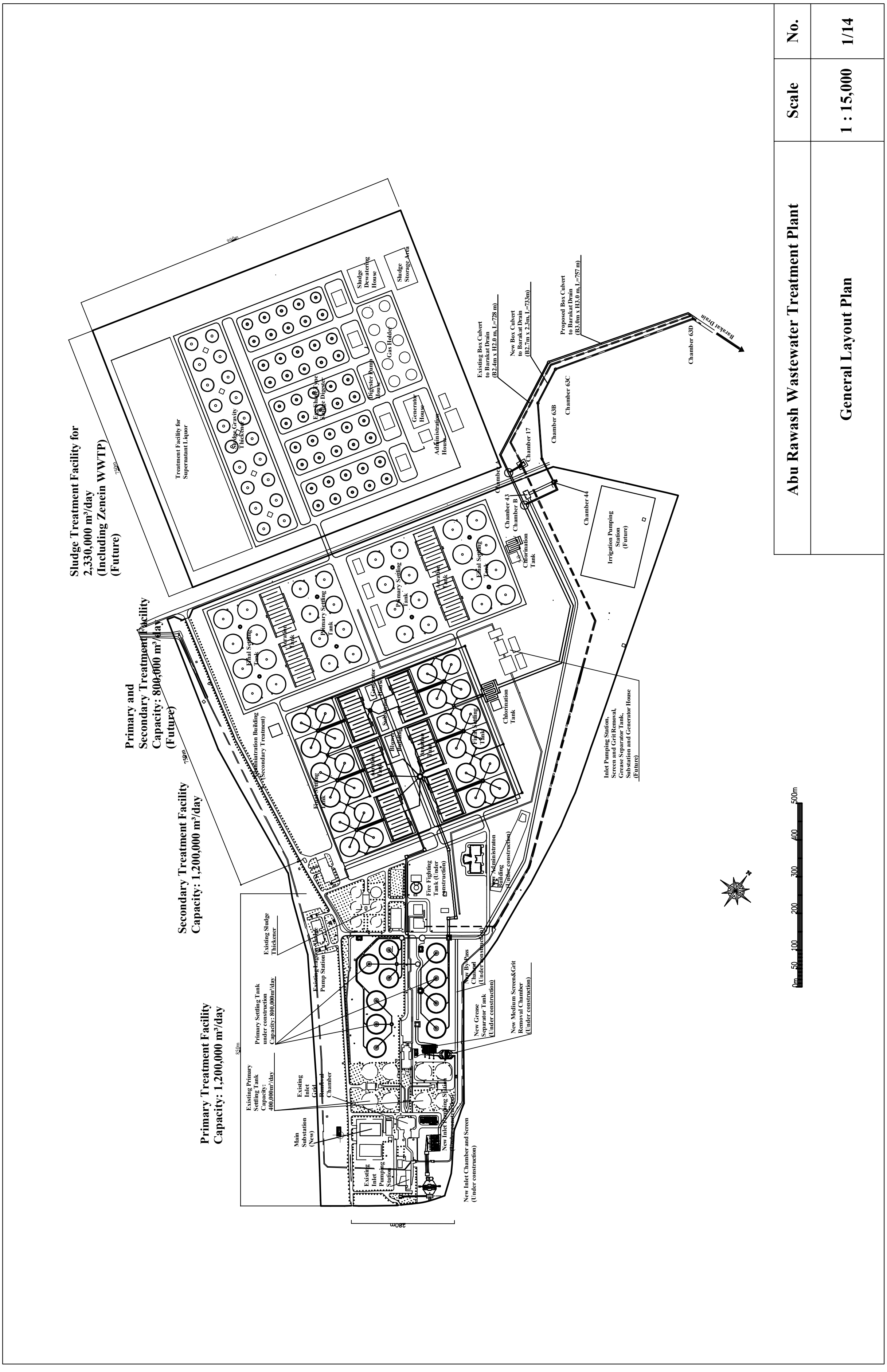
※ Sidestream

	Flow m3/day	SS mg/l	DS kg/day
＜Sidestream from thickening＞			
Gravity Thickener			
Mechanical Thickener			
＜Sidestream from dewatering＞			
Mechanical Dewater			
＜Washing water＞			
Total	0	#DIV/0!	0

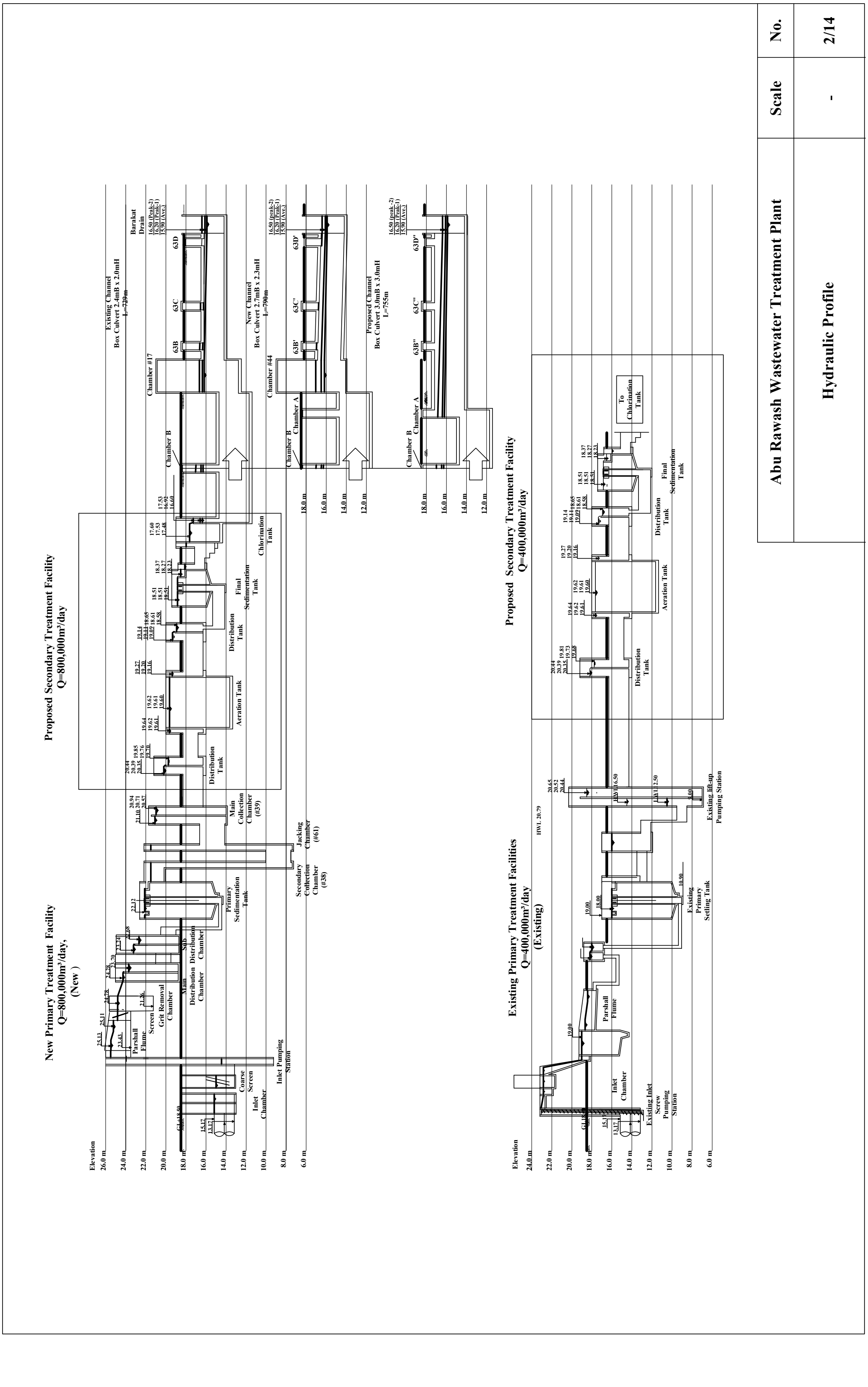
DS of Inflow	432,000
DS of waste sludge	33,112
DS of Zenin WWTP	100,000
DS of coagulant	0
Total	565,112
DS of effluent	25,453
DS of sludge cake	539,659
DS of Digested gas	0

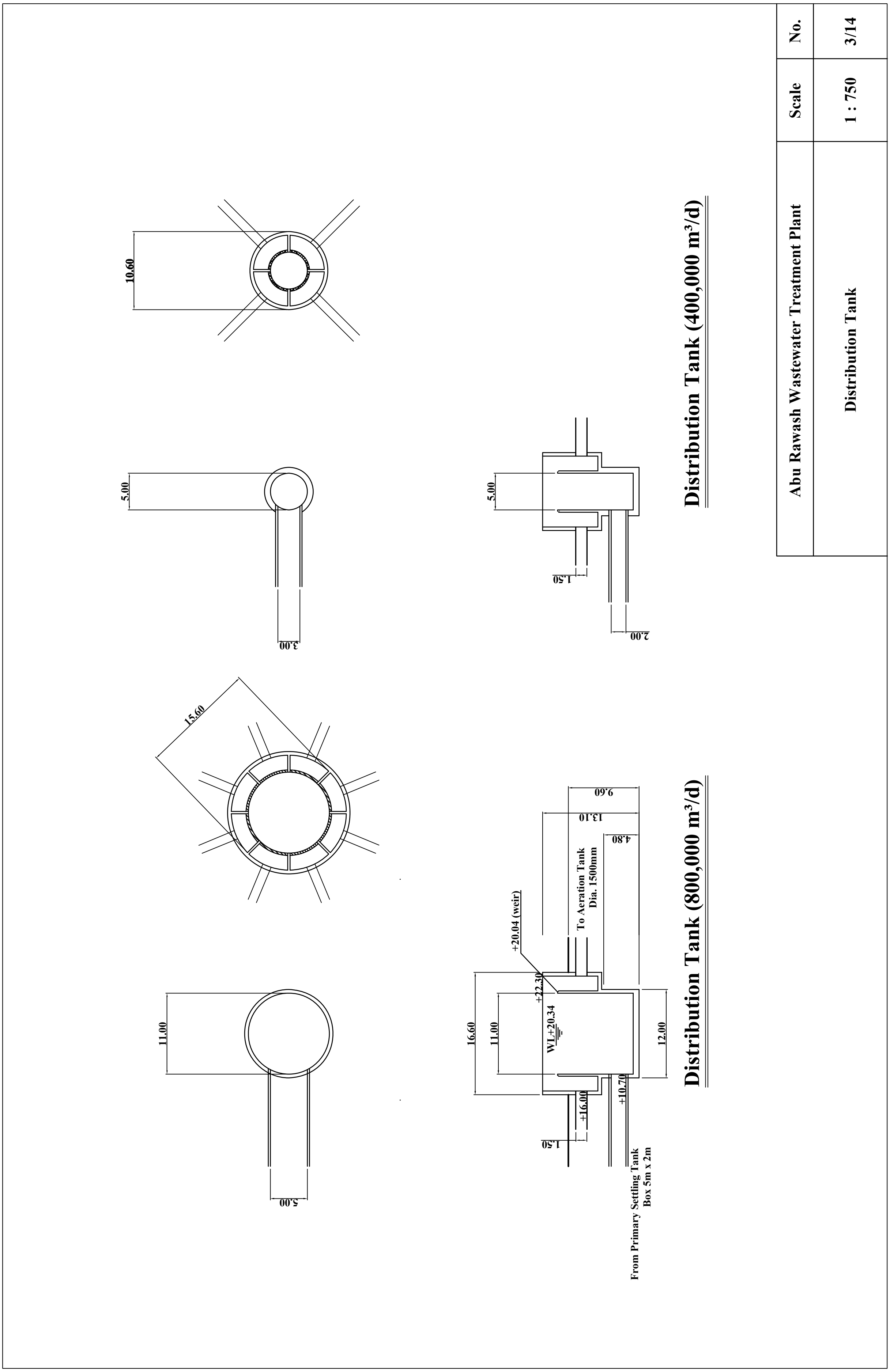
APPENDIX – 5

Drawings of Abu Rawash WWTP Facilities

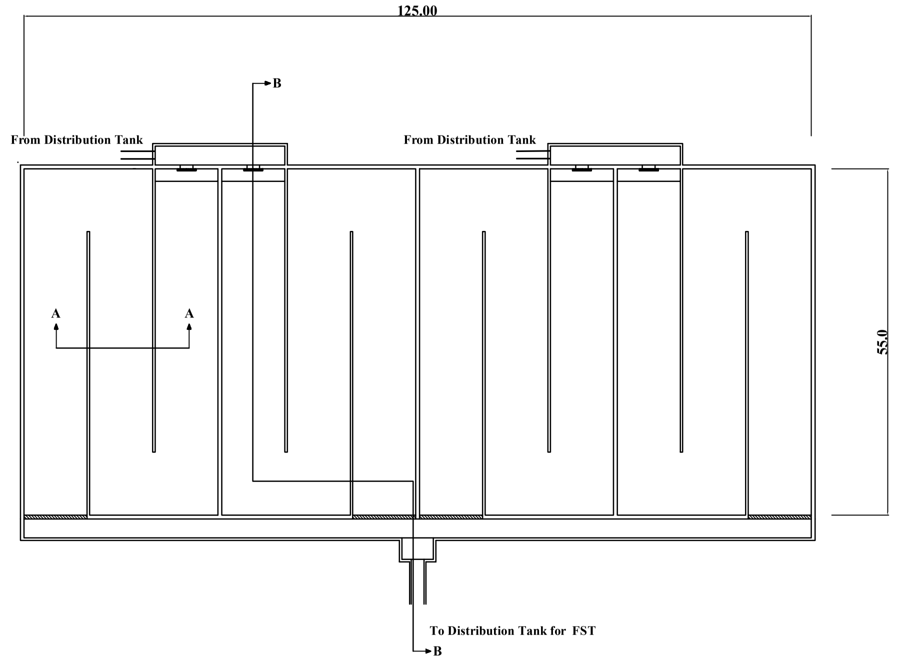


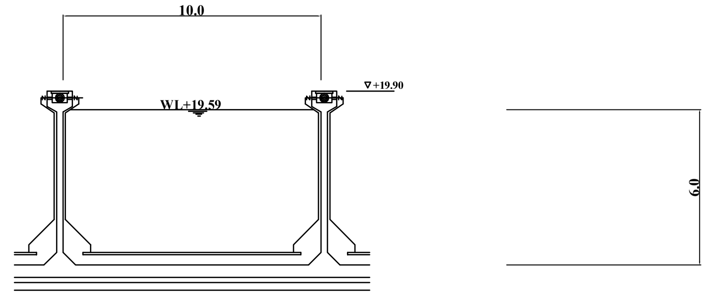
Abu Rawash Wastewater Treatment Plant
General Layout Plan
Scale
1 : 15,000
No.
1/14
Sludge Treatment Facility for 2,330,000 m³/day (Including Zenein WWTP) (Future)
Primary and Secondary Treatment Facility Capacity: 800,000 m³/day (Future)
Secondary Treatment Facility Capacity: 1,200,000 m³/day
Primary Treatment Facility Capacity: 1,200,000 m³/day
Treatment Facility for Supernatant Liquor
Sludge Gravity Thickener
Sludge Dewatering House
Sludge Storage Area
Gas Holder
Digester Pump House
Generator House
Administration House
Final Settling Tank
Primary Settling Tank
Aeration Tank
Chlorination Tank
Administration Building (Secondary Treatment)
Irrigation Pumping Station (Future)
Inlet Pumping Station, Screen and Grit Removal, Grease Separator Tank, Substation and Generator House (Future)
Existing Box Culvert to Barakat Drain (B2.4m x H2.0 m, L=728 m)
New Box Culvert to Barakat Drain (B2.7m x 2.3m, L=733m)
Proposed Box Culvert to Barakat Drain (B3.0m x H3.0 m, L=757 m)
Barakat Drain
Chamber 17
Chamber 43
Chamber 44
Chamber 63B
Chamber 63C
Chamber 63D
New Administration Building (Under construction)
Fire Fighting Tank (Under construction)
Existing Sludge Thickener
Existing Sludge Pump Station
Primary Settling Tank under construction Capacity: 800,000m³/day
Existing Primary Settling Tank Capacity: 400,000m³/day
Existing Inlet Grit Removal Chamber
Main Substation (New)
Existing Inlet Pumping Station
New Grease Separator Tank (Under construction)
New Medium Screen&Grit Removal Chamber (Under construction)
New By Pass Channel (Under construction)
New Inlet Chamber and Screen (Under construction)
0m 50 100 200 300 400 500m


New Primary Treatment Facility
Q=800,000m³/day,
(New)
Proposed Secondary Treatment Facility
Q=800,000m³/day
Existing Primary Treatment Facilities
Q=400,000m³/day
(Existing)
Proposed Secondary Treatment Facility
Q=400,000m³/day
Abu Rawash Wastewater Treatment Plant
Hydraulic Profile
Scale
-
No.
2/14

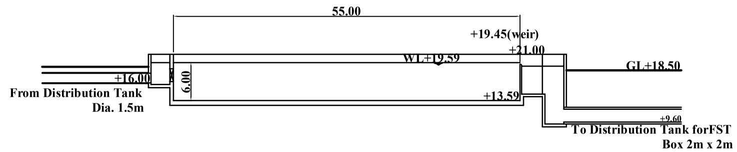


Distribution Tank (400,000 m³/d)
Distribution Tank (800,000 m³/d)
10.60
5.00
3.00
5.00
1.50
2.00
15.60
11.00
5.00
16.60
11.00
12.00
+20.04 (weir)
+22.30
WL+20.34
+16.00
+10.70
1.50
9.60
13.10
4.80
To Aeration Tank
Dia. 1500mm
From Primary Settling Tank
Box 5m x 2m
Abu Rawash Wastewater Treatment Plant
Distribution Tank
Scale
1 : 750
No.
3/14



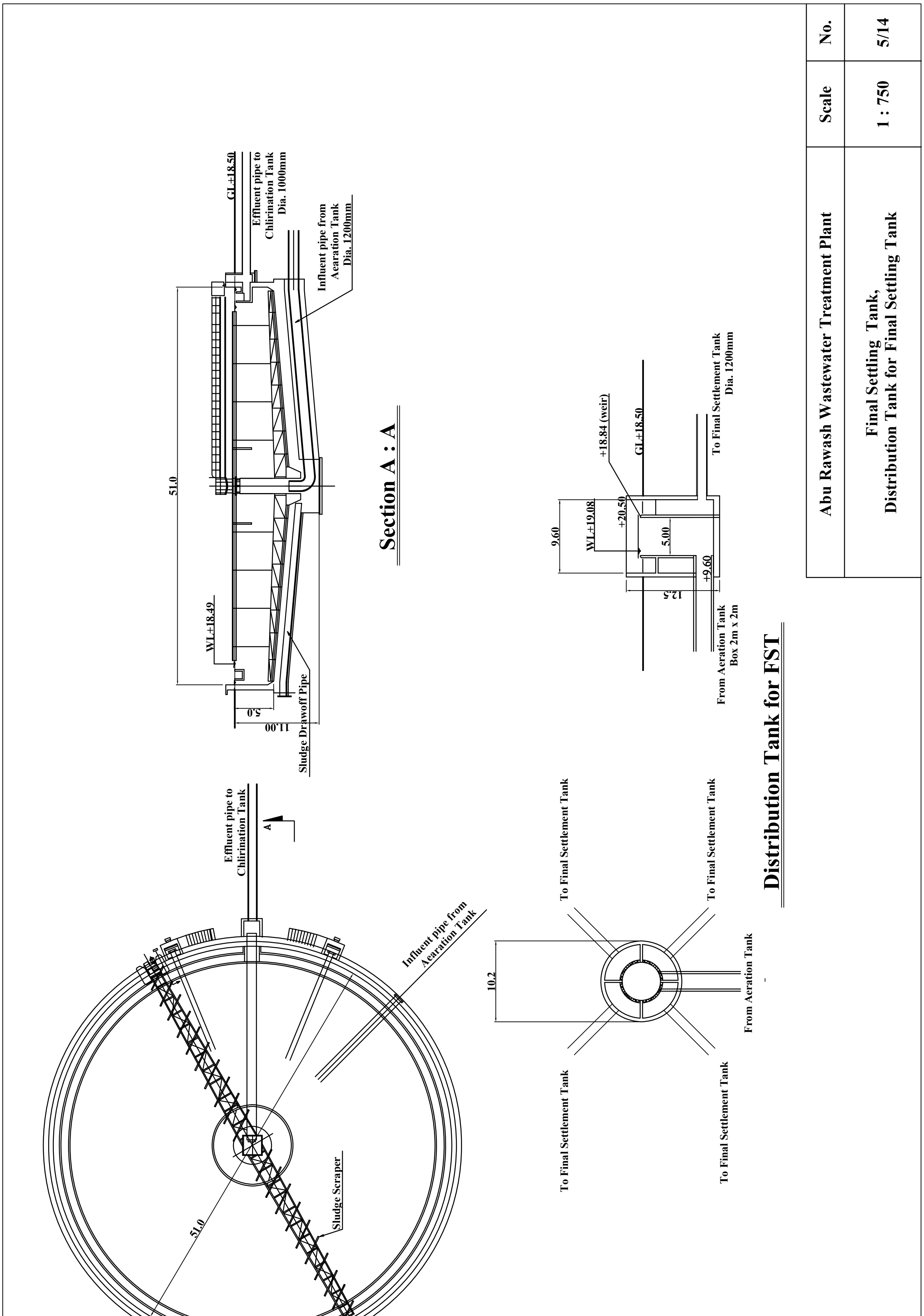


Section A : A

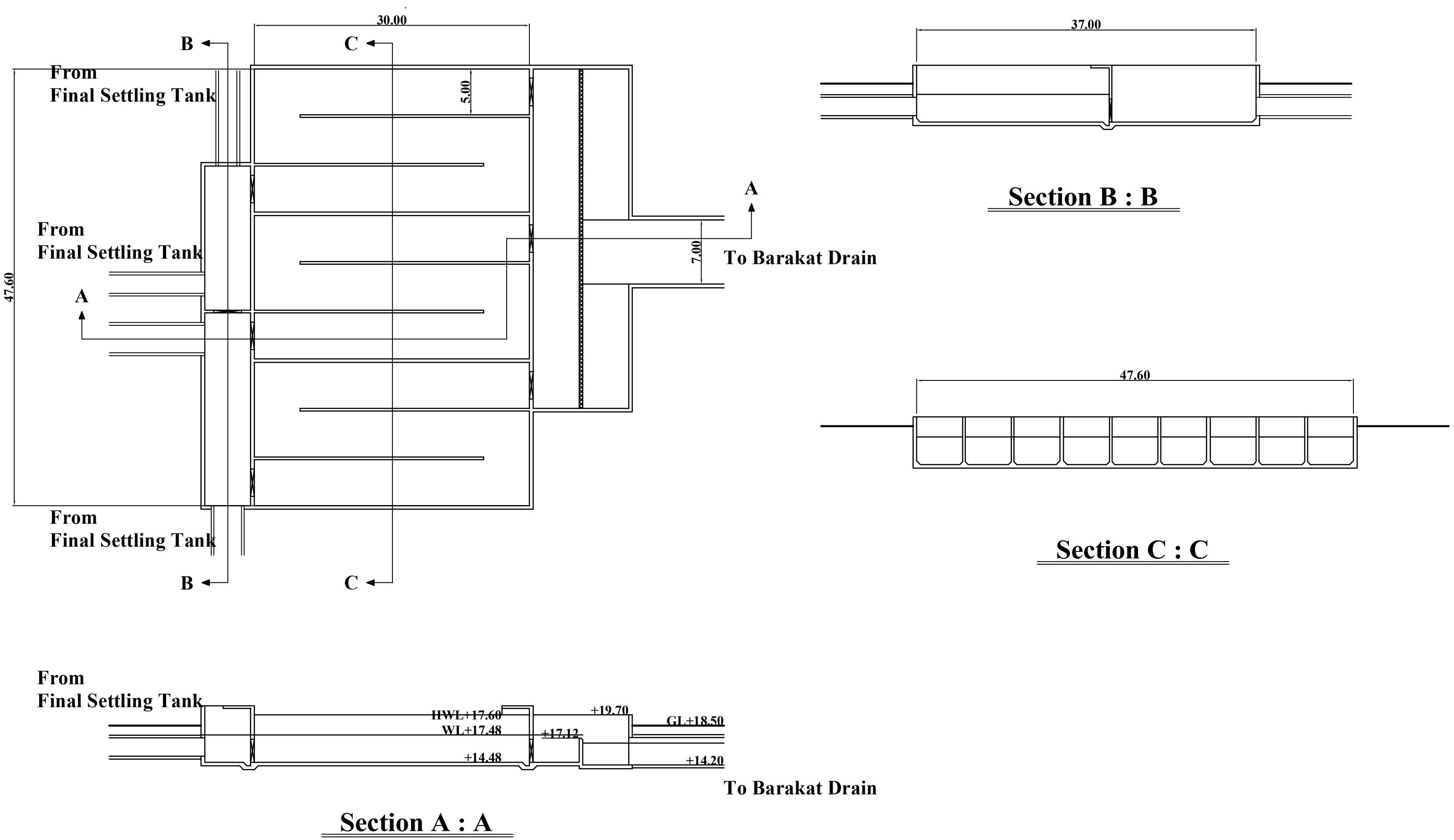


Section B : B

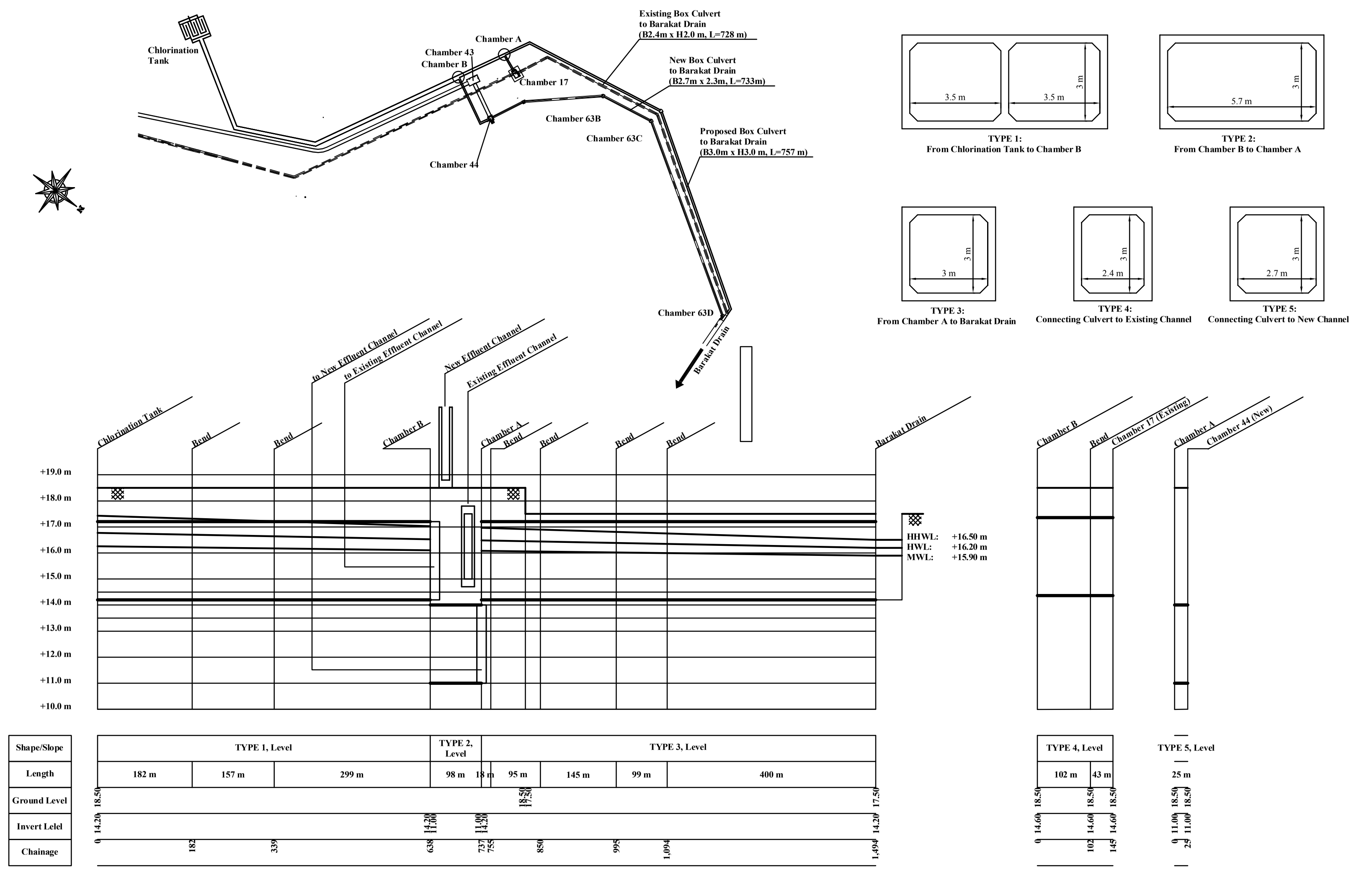
Abu Rawash Wastewater Treatment Plant	Scale	No.
Aeration Tank	1 : 1,200 1 : 300	4/14



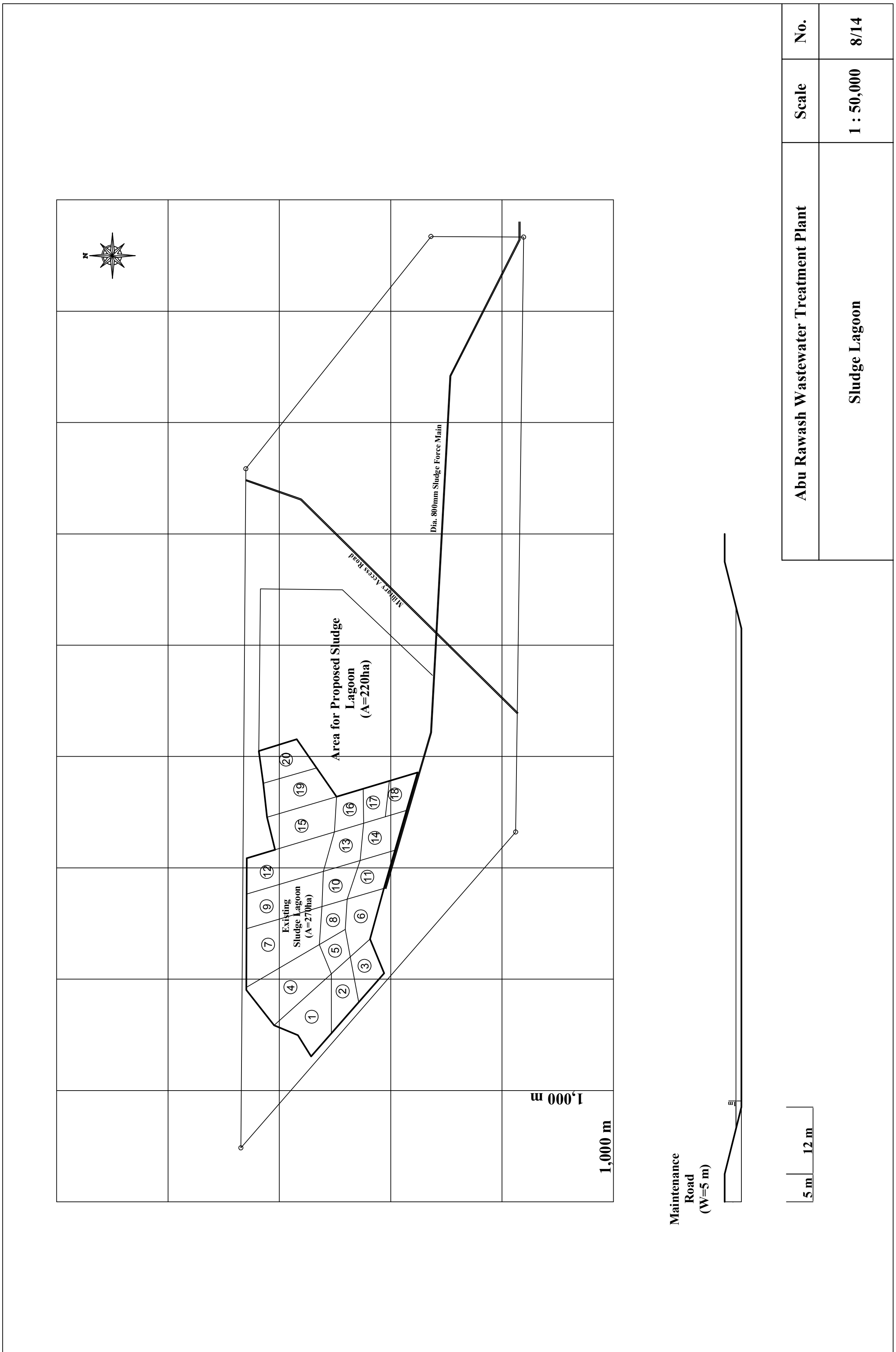
Abu Rawash Wastewater Treatment Plant
Final Settling Tank,
Distribution Tank for Final Settling Tank
Scale
1 : 750
No.
5/14
Section A : A
GL+18.50
Effluent pipe to Chlirination Tank Dia. 1000mm
Influent pipe from Aearation Tank Dia. 1200mm
51.0
WL+18.49
5.0
11.00
Sludge Drawoff Pipe
Distribution Tank for FST
+18.84 (weir)
GL+18.50
To Final Settlement Tank Dia. 1200mm
9.60
WL+19.08
+20.50
5.00
+9.60
12.5
From Aeration Tank Box 2m x 2m
Effluent pipe to Chlirination Tank
Influent pipe from Aearation Tank
A
A
51.0
Sludge Scraper
10.2
To Final Settlement Tank
To Final Settlement Tank
To Final Settlement Tank
To Final Settlement Tank
From Aeration Tank

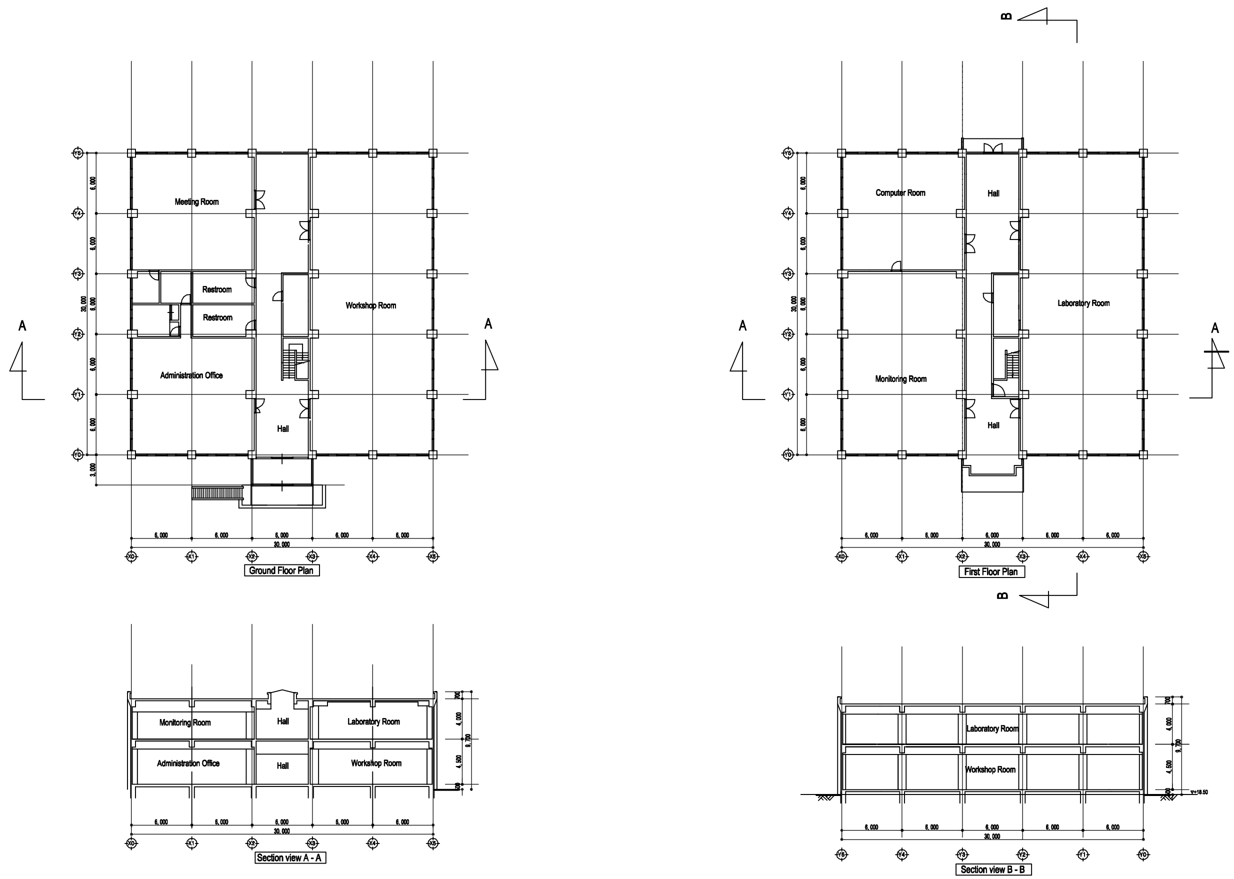


Abu Rawash Wastewater Treatment Plant	Scale	No.
Chlorination Tank	1 : 750	6/14

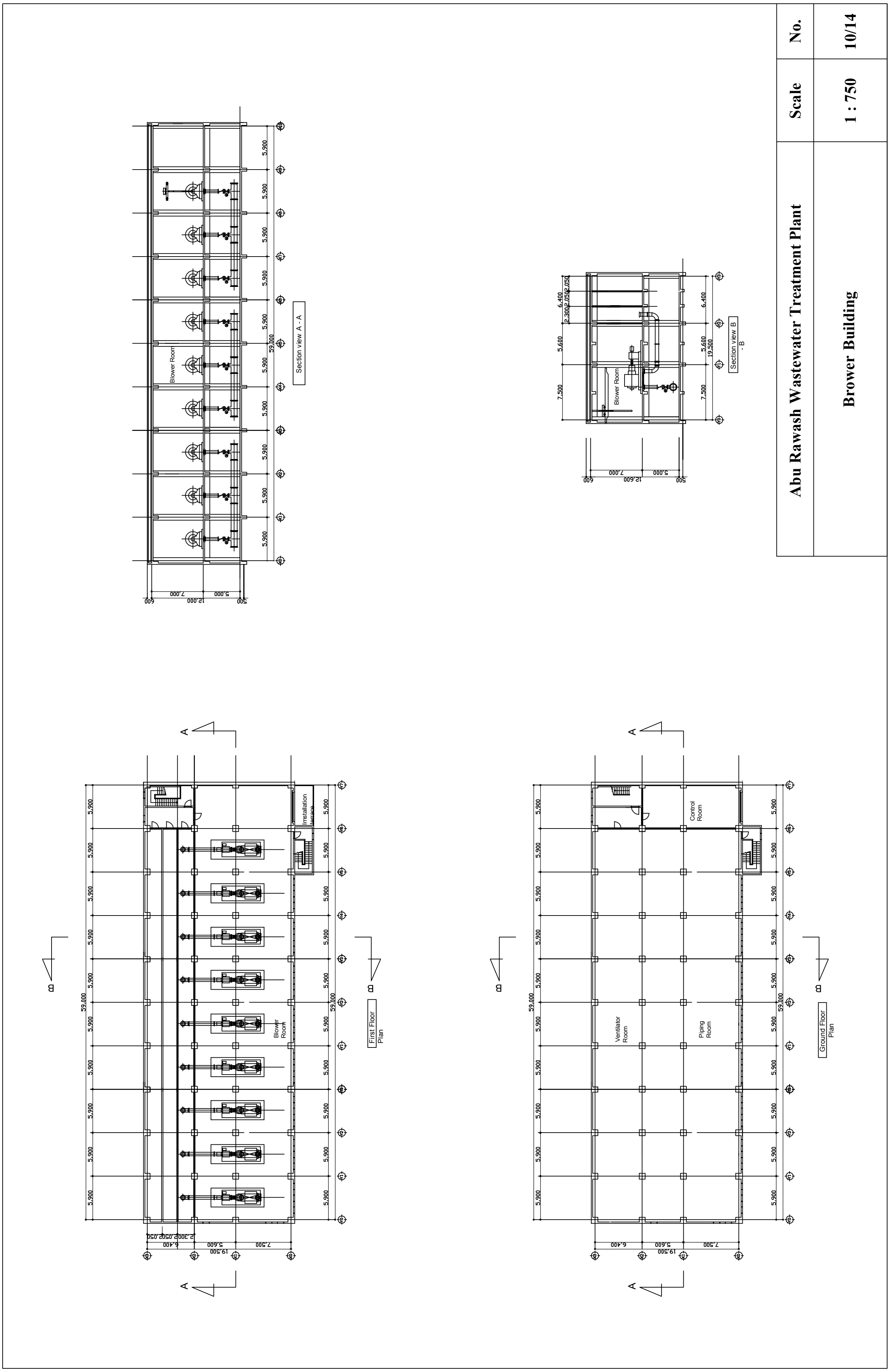


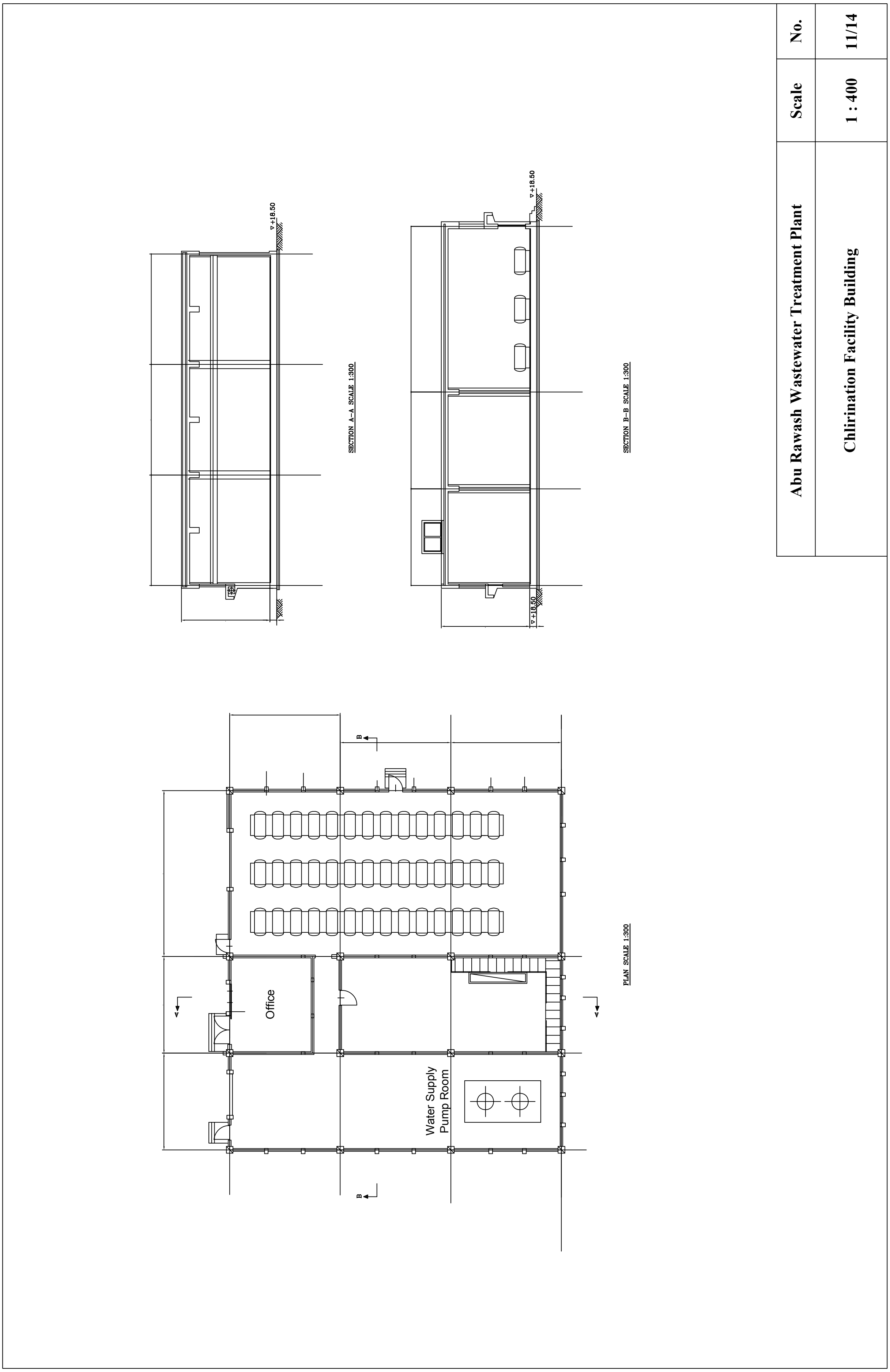
Abu Rawash Wastewater Treatment Plant	Scale	No.
Effluent Channel	-	7/14


Abu Rawash Wastewater Treatment Plant
Sludge Lagoon
Scale
1 : 50,000
No.
8/14
Area for Proposed Sludge Lagoon
(A=220ha)
Existing
Sludge Lagoon
(A=270ha)
Dia. 800mm Sludge Force Main
Military Access Road
1,000 m
1,000 m
Maintenance
Road
(W=5 m)
5 m
12 m

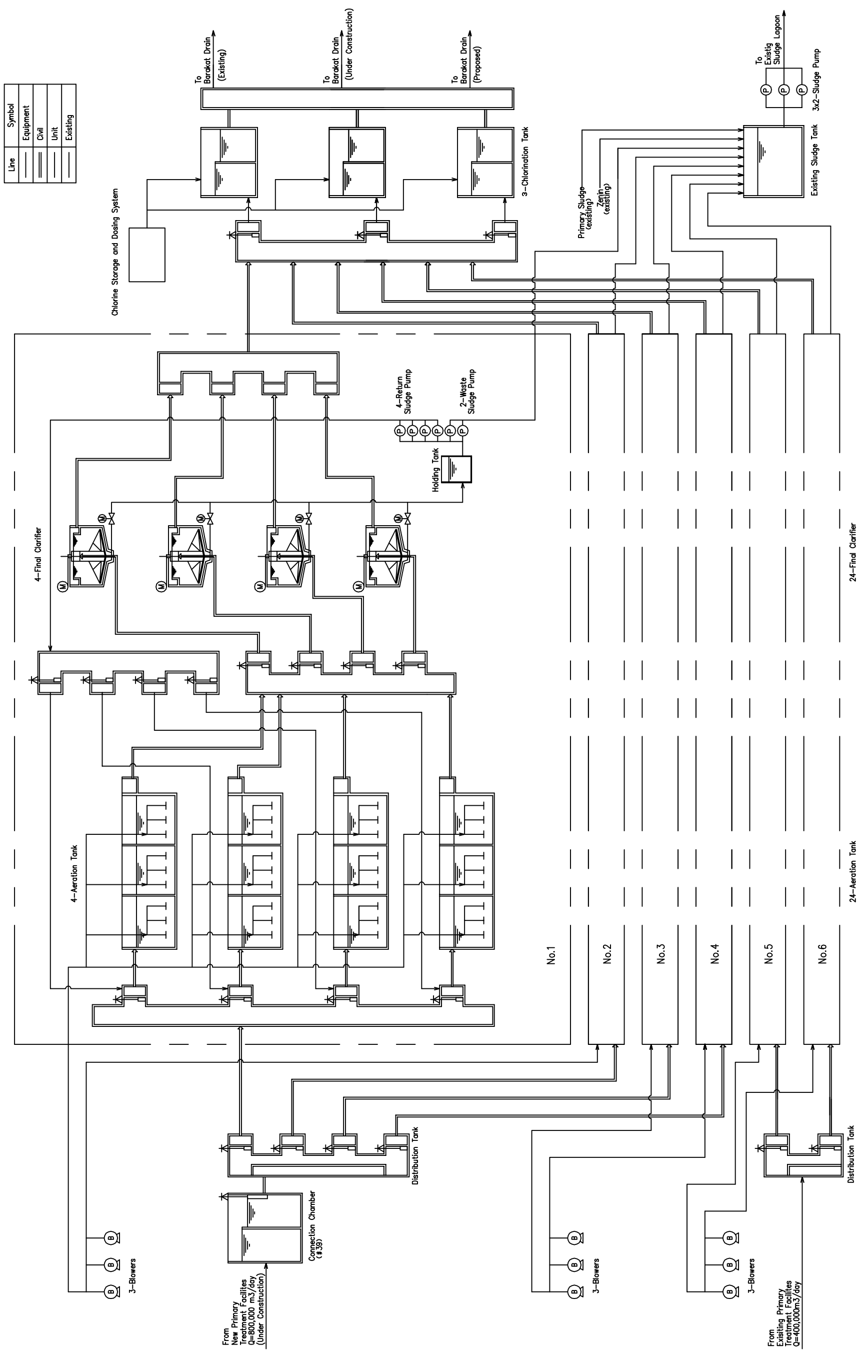


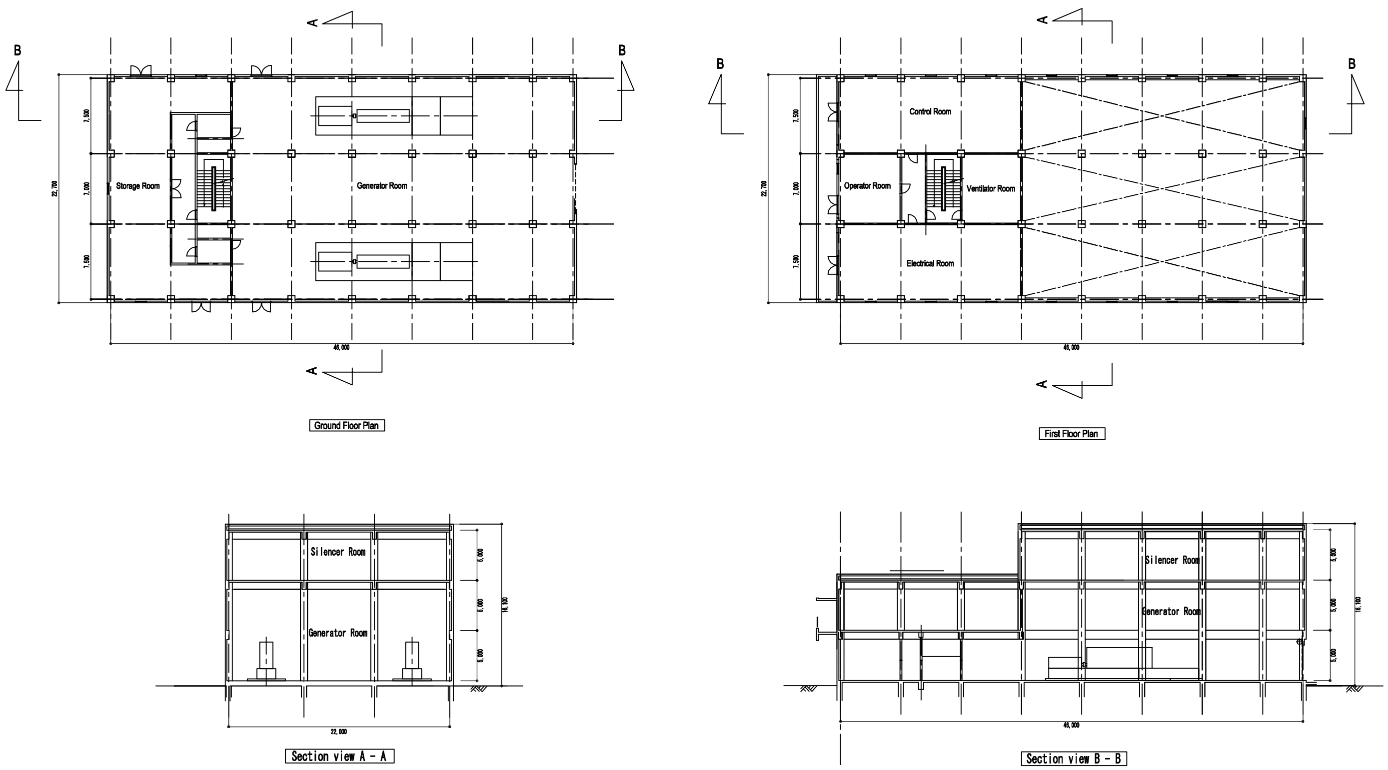
Abu Rawash Wastewater Treatment Plant	Scale	No.
Administration Building	1 : 750	9/14


No.
10/14
Scale
1 : 750
Abu Rawash Wastewater Treatment Plant
Brower Building
Section view A - A
Section view B - B
Blower Room
First Floor Plan
Ground Floor Plan
Installation terrace
Control Room
Ventilator Room
Piping Room
59,000
19,500
5,900
7,500
5,600
6,400
12,000
7,000
5,000
600
500

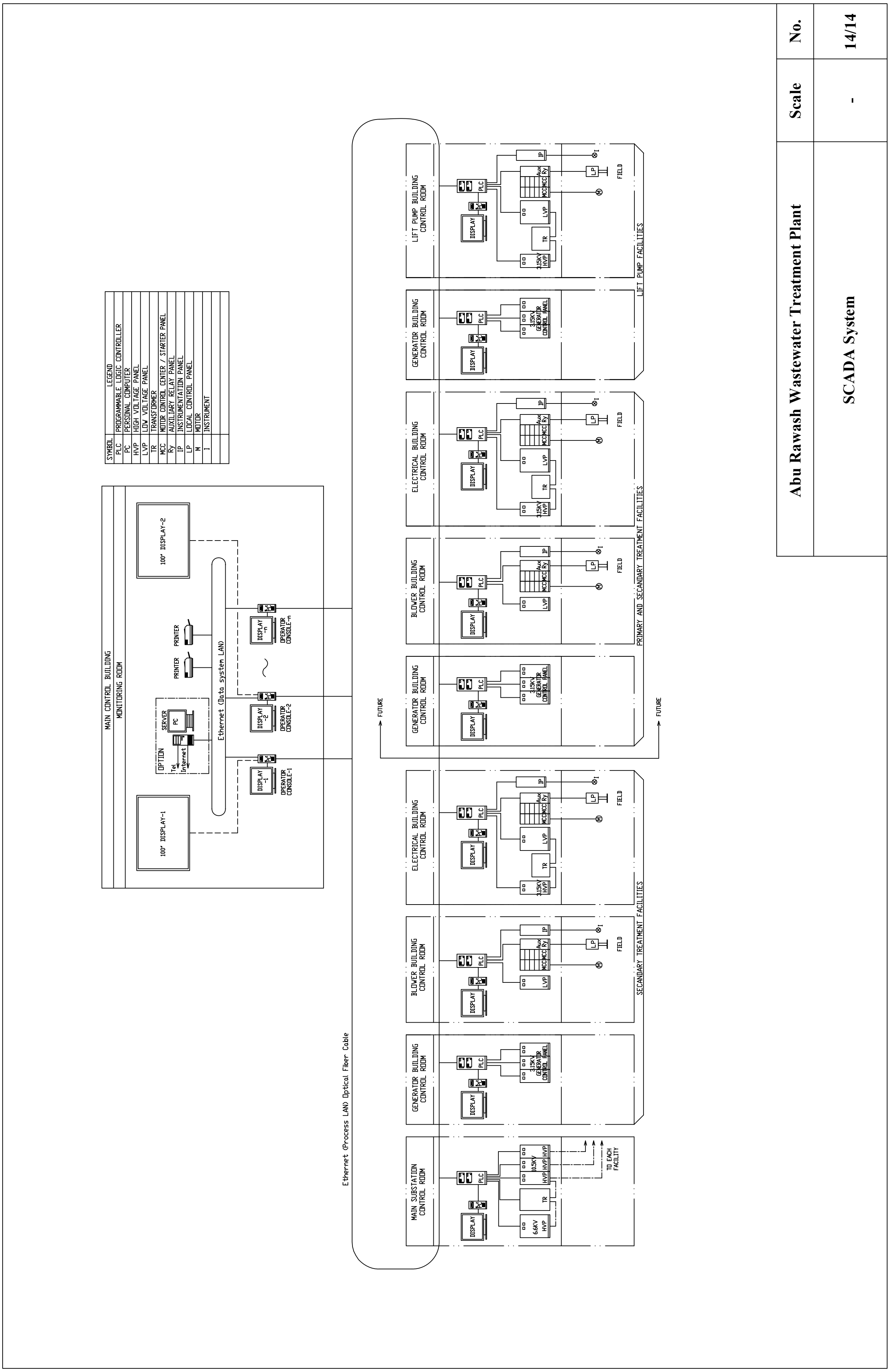

Abu Rawash Wastewater Treatment Plant
Chlirination Facility Building
Scale
1 : 400
No.
11/14
SECTION A–A SCALE 1:300
SECTION B–B SCALE 1:300
PLAN SCALE 1:300
▽+18.50
Office
Water Supply
Pump Room

No.	Scale	Abu Rawash Wastewater Treatment Plant
12/14	-	Flow Diagram





Abu Rawash Wastewater Treatment Plant	Scale	No.
Generator Building	1 : 750	13/14


No.
14/14
Scale
-
Abu Rawash Wastewater Treatment Plant
SCADA System
SYMBOL
LEGEND
PLC
PROGRAMMABLE LOGIC CONTROLLER
PC
PERSONAL COMPUTER
HVP
HIGH VOLTAGE PANEL
LVP
LOW VOLTAGE PANEL
TR
TRANSFORMER
MCC
MOTOR CONTROL CENTER / STARTER PANEL
Ry
AUXILIARY RELAY PANEL
IP
INSTRUMENTATION PANEL
LP
LOCAL CONTROL PANEL
M
MOTOR
I
INSTRUMENT
MAIN CONTROL BUILDING
MONITORING ROOM
100" DISPLAY-1
100" DISPLAY-2
OPTION
SERVER
PC
PRINTER
Ethernet (Data system LAN)
OPERATOR CONSOLE-1
OPERATOR CONSOLE-2
OPERATOR CONSOLE-n
Ethernet (Process LAN) Optical Fiber Cable
MAIN SUBSTATION CONTROL ROOM
GENERATOR BUILDING CONTROL ROOM
BLOWER BUILDING CONTROL ROOM
ELECTRICAL BUILDING CONTROL ROOM
LIFT PUMP BUILDING CONTROL ROOM
DISPLAY
TO EACH FACILITY
FUTURE
FIELD
SECANDARY TREATMENT FACILITIES
PRIMARY AND SECANDARY TREATMENT FACILITIES
LIFT PUMP FACILITIES

APPENDIX – 6

Estimated Project Cost

Estimated Project Cost

Item Description			Amount (LE) L.C	Amount (LE) F.C	Total Amount (LE)
1	**Construction Cost**				
A	Sewage Treatment				
-A1	Connection Channel and Chamber				
	Civil Works		41,350,000	35,223,000	76,573,000
	Mechanical Works		731,000	5,606,000	6,337,000
	Electrical Works		41,000	366,000	407,000
	Sub Total of -A1		**42,122,000**	**41,195,000**	**83,317,000**
-A2	Aeration Tank				
	Civil Works		125,903,000	30,702,000	156,605,000
	Architecture Works		22,669,000	12,206,000	34,875,000
	Mechanical Works		13,147,000	211,176,000	224,323,000
	Electrical Works		2,629,000	23,665,000	26,294,000
	Sub Total of -A2		**164,348,000**	**277,749,000**	**442,097,000**
-A3	Final Setting Tank				
	Civil Works		300,801,000	53,148,000	353,949,000
	Architecture Works		10,980,000	5,912,000	16,892,000
	Mechanical Works		42,414,000	212,068,000	254,482,000
	Electrical Works		8,283,000	74,546,000	82,829,000
	Sub Total of -A3		**362,478,000**	**345,674,000**	**708,152,000**
-A4	Chlorination				
	Civil Works		5,639,000	1,347,000	6,986,000
	Architecture Works		3,153,000	1,698,000	4,851,000
	Mechanical Works		2,025,000	10,124,000	12,149,000
	Electrical Works		245,000	2,206,000	2,451,000
	Sub Total of -A4		**11,062,000**	**15,375,000**	**26,437,000**
-A5	Effluent Chanel and Chamber				
	Civil Works		28,829,000	7,776,000	36,605,000
	Mechanical Works		4,057,000	31,105,000	35,162,000
	Electrical Works		1,302,000	11,715,000	13,017,000
	Sub Total of -A5		**34,188,000**	**50,596,000**	**84,784,000**
-A6	Administration Facility				
	Architecture Works		9,598,000	5,168,000	14,766,000
	Electrical Works		5,956,000	29,782,000	35,738,000
	Sub Total of -A6		**15,554,000**	**34,950,000**	**50,504,000**
-A7	Power Facility				
	Architecture Works		24,367,000	13,121,000	37,488,000
	Electrical Works		16,758,000	83,791,000	100,549,000
	Sub Total of -A7		**41,125,000**	**96,912,000**	**138,037,000**
-A8	Maintenance road and Parking lot				
	Civil Works		7,559,000	840,000	8,399,000
	Sub Total of -A8		**7,559,000**	**840,000**	**8,399,000**
	Sub Total of A		**678,436,000**	**863,291,000**	**1,541,727,000**
	Civil Works		**510,081,000**	**129,036,000**	**639,117,000**
	Architecture Works		**70,767,000**	**38,105,000**	**108,872,000**
	Mechanical Works		**62,374,000**	**470,079,000**	**532,453,000**
	Electrical Works		**35,214,000**	**226,071,000**	**261,285,000**
B	Sludge Treatment				
-B1	Sludge Transfer Pump				
	Mechanical Works		1,412,000	7,061,000	8,473,000
	Electrical Works		282,000	2,542,000	2,824,000
	Sub Total of -B1		**1,694,000**	**9,603,000**	**11,297,000**

-B2	Sludge Lagoon				
	Civil Works		81,014,000	48,706,000	129,720,000
	Sub Total of -B2		**81,014,000**	**48,706,000**	**129,720,000**
	Sub Total of B		**82,708,000**	**58,309,000**	**141,017,000**
	Civil Works		**81,014,000**	**48,706,000**	**129,720,000**
	Architecture Works		**0**	**0**	**0**
	Mechanical Works		**1,412,000**	**7,061,000**	**8,473,000**
	Electrical Works		**282,000**	**2,542,000**	**2,824,000**
	Sub Total of Construction Cost		**761,144,000**	**921,600,000**	**1,682,744,000**
	Civil Works		**591,095,000**	**177,742,000**	**768,837,000**
	Architecture Works		**70,767,000**	**38,105,000**	**108,872,000**
	Mechanical Works		**63,786,000**	**477,140,000**	**540,926,000**
	Electrical Works		**35,496,000**	**228,613,000**	**264,109,000**
2	**Administration Expenses**				
-1	Administration Cost				
	Administration Cost of Item 1	1.0%	16,827,000	0	16,827,000
	Sub-Total of -1		**16,827,000**	**0**	**16,827,000**
3	**Engineering Cost**				
-1	Engineering Cost				
	Engineering Cost of Item 1	7.0%	53,280,000	64,512,000	117,792,000
	Sub-Total of -1		**53,280,000**	**64,512,000**	**117,792,000**
4	**Physical Contingency**				
-1	For Local Portion of Item 1-3	10.0%	83,125,000	0	83,125,000
-2	For Foreign Portion of Item 1-3	10.0%	0	98,611,000	98,611,000
	Sub-Total of -1+-2		**83,125,000**	**98,611,000**	**181,736,000**
5	**Price Contingency**				
-1	For Local Portion of Item 1-3	4.2%	402,004,000	0	402,004,000
-2	For Foreign Portion of Item 1-3	1.3%	0	166,197,000	166,197,000
	Sub-Total of -1+-2		**402,004,000**	**166,197,000**	**568,201,000**
6	**Interest during construction**				
-1	Interest during construction	0.65%	0	79,476,000	79,476,000
	Sub-Total of -1		**0**	**79,476,000**	**79,476,000**
7	**Commitment charge**				
-1	Commitment charge	0.10%	0	4,397,000	4,397,000
	Sub-Total of -1		**0**	**4,397,000**	**4,397,000**
8	**Tax**				
-1	TAX	14.9%	196,141,000	198,884,000	395,025,000
-2	Custom	5-10%	0	54,943,000	54,943,000
	Sub-Total of -1		**196,141,000**	**253,827,000**	**449,968,000**
	Total of 1+2+3+4+5+6+7+8		**1,512,521,000**	**1,588,620,000**	**3,101,141,000**
	(including TAX)				
	Total of 1+2+3+4+5+6+7		**1,316,380,000**	**1,334,793,000**	**2,651,173,000**
	(excluding TAX)				

Note:

Cost for goods and services which can be purchased locally in Cairo is considered as Local Currency (L.C.) portion, and cost for those items which should be imported is considered as Foreign Currency (F.C.) portion. For civil and architecture works, most of the costs are considered as L.C. On the contrary, F.C. comprises the cost for heavy machineries, and costs for mechanical and electrical equipment. In addition, in Mechanical and Electrical Works, only half of the transportation and installation cost is assumed to be in the form of L.C.

APPENDIX – 7

Financial and Economic Analysis of the Project

1. Summary Cash-flow Tables of FIRR and EIRR

[FIRR] (i) O&M cost recovery

	Capital Cost	O/M	Total Cost	Tariff Revenue (OM)	Total Benenefit	Net Benefit
2010	3.06		*3.06*			**-3.06**
2011	22.12		*22.12*			**-22.12**
2012	653.84		*653.84*			**-653.84**
2013	692.20		*692.20*			**-692.20**
2014	733.61		*733.61*			**-733.61**
2015	389.25		*389.25*			**-389.25**
2016		24.29	*24.29*	49.56	*49.56*	**25.27**
2017		24.29	*24.29*	49.56	*49.56*	**25.27**
2018		24.29	*24.29*	49.56	*49.56*	**25.27**
2019		24.29	*24.29*	49.56	*49.56*	**25.27**
2020		24.29	*24.29*	49.56	*49.56*	**25.27**
2021		24.29	*24.29*	49.56	*49.56*	**25.27**
2022		24.29	*24.29*	49.56	*49.56*	**25.27**
2023		24.29	*24.29*	49.56	*49.56*	**25.27**
2024		24.29	*24.29*	49.56	*49.56*	**25.27**
2025		24.29	*24.29*	49.56	*49.56*	**25.27**
2026		24.29	*24.29*	49.56	*49.56*	**25.27**
2027		24.29	*24.29*	49.56	*49.56*	**25.27**
2028		24.29	*24.29*	49.56	*49.56*	**25.27**
2029		24.29	*24.29*	49.56	*49.56*	**25.27**
2030		24.29	*24.29*	49.56	*49.56*	**25.27**
⋮		⋮	⋮	⋮	⋮	⋮
2038		24.29	*24.29*	49.56	*49.56*	**25.27**
2039		24.29	*24.29*	49.56	*49.56*	**25.27**
Total	2494.1	583.0	583.0	1189.4	1189.4	-1887.6

FIRR = NA
FNPV = -1,546.3 LE million (DR)
OCC = 9.7%

[FIRR] (ii) O&M cost + CAPEX recovery

	Capital Cost	O/M	Total Cost	Tariff Revenue (OM+CAPEX)	Total Benenefit	Net Benefit
2010	3.06		*3.06*			**-3.06**
2011	22.12		*22.12*			**-22.12**
2012	653.84		*653.84*			**-653.84**
2013	692.20		*692.20*			**-692.20**
2014	733.61		*733.61*			**-733.61**
2015	389.25		*389.25*			**-389.25**
2016		24.29	*24.29*	153.48	*153.48*	**129.19**
2017		24.29	*24.29*	153.48	*153.48*	**129.19**
2018		24.29	*24.29*	153.48	*153.48*	**129.19**
2019		24.29	*24.29*	153.48	*153.48*	**129.19**
2020		24.29	*24.29*	153.48	*153.48*	**129.19**
2021		24.29	*24.29*	153.48	*153.48*	**129.19**
2022		24.29	*24.29*	153.48	*153.48*	**129.19**
2023		24.29	*24.29*	153.48	*153.48*	**129.19**
2024		24.29	*24.29*	153.48	*153.48*	**129.19**
2025		24.29	*24.29*	153.48	*153.48*	**129.19**
2026		24.29	*24.29*	153.48	*153.48*	**129.19**
2027		24.29	*24.29*	153.48	*153.48*	**129.19**
2028		24.29	*24.29*	153.48	*153.48*	**129.19**
2029		24.29	*24.29*	153.48	*153.48*	**129.19**
2030		24.29	*24.29*	153.48	*153.48*	**129.19**
⋮		⋮	⋮	⋮	⋮	⋮
2038		24.29	*24.29*	153.48	*153.48*	**129.19**
2039		24.29	*24.29*	153.48	*153.48*	**129.19**
Total	2494.1	583.0	3,077.0	3683.5	3683.5	606.5

FIRR = 1.6%
FNPV = -998.2 LE million (DR)
OCC = 9.7%

[FIRR] (iii) LRMC recovery

	Capital Cost	O/M	Total Cost	LRMC pricing	Total Benefit	Net Benefit
2010	3.06		*3.06*			**-3.06**
2011	22.12		*22.12*			**-22.12**
2012	653.84		*653.84*			**-653.84**
2013	692.20		*692.20*			**-692.20**
2014	733.61		*733.61*			**-733.61**
2015	389.25		*389.25*			**-389.25**
2016		24.29	*24.29*	279.83	*279.83*	**255.54**
2017		24.29	*24.29*	279.83	*279.83*	**255.54**
2018		24.29	*24.29*	279.83	*279.83*	**255.54**
2019		24.29	*24.29*	279.83	*279.83*	**255.54**
2020		24.29	*24.29*	279.83	*279.83*	**255.54**
2021		24.29	*24.29*	279.83	*279.83*	**255.54**
2022		24.29	*24.29*	279.83	*279.83*	**255.54**
2023		24.29	*24.29*	279.83	*279.83*	**255.54**
2024		24.29	*24.29*	279.83	*279.83*	**255.54**
2025		24.29	*24.29*	279.83	*279.83*	**255.54**
2026		24.29	*24.29*	279.83	*279.83*	**255.54**
2027		24.29	*24.29*	279.83	*279.83*	**255.54**
2028		24.29	*24.29*	279.83	*279.83*	**255.54**
2029		24.29	*24.29*	279.83	*279.83*	**255.54**
2030		24.29	*24.29*	279.83	*279.83*	**255.54**
⋮		⋮	⋮	⋮	⋮	⋮
2038		24.29	*24.29*	279.83	279.83	**255.54**
2039		24.29	*24.29*	279.83	279.83	**255.54**
Total	2494.1	583.0	3,077.0	6,716.0	6,716.0	3,638.9

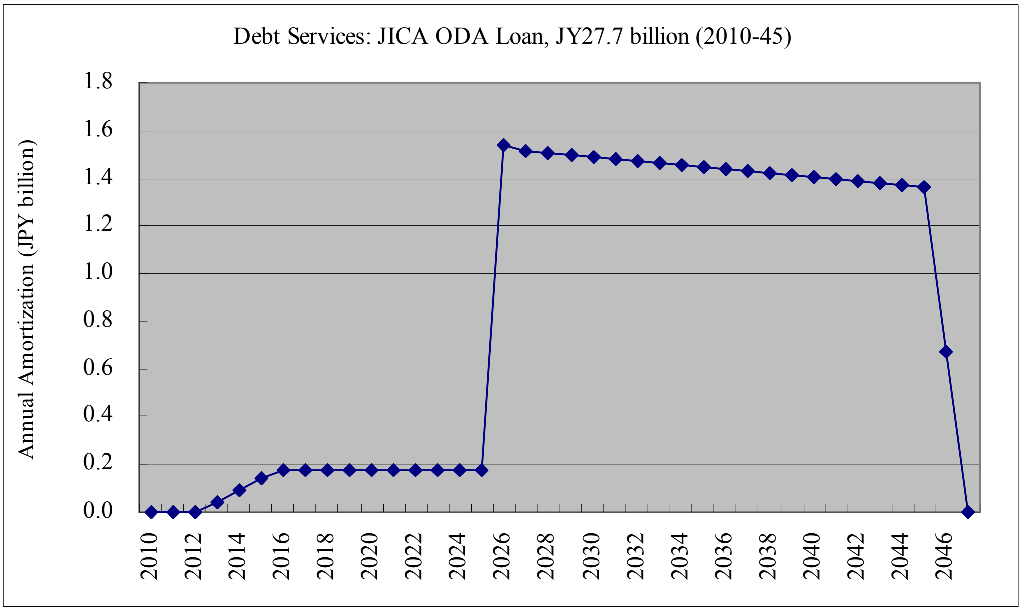
FIRR = 7.4%
FNPV = -331.8 LE million (DR)
OCC = 9.7%

[EIRR] (iii) LRMC recovery

	Capital Cost	O/M	Total Cost	LRMC pricing	Total Benefit	Net Benefit
2010	2.34		*2.34*			**-2.34**
2011	16.92		*16.92*			**-16.92**
2012	500.11		*500.11*			**-500.11**
2013	529.45		*529.45*			**-529.45**
2014	561.13		*561.13*			**-561.13**
2015	297.73		*297.73*			**-297.73**
2016		21.86	*21.86*	279.83	*279.83*	**257.97**
2017		21.86	*21.86*	279.83	*279.83*	**257.97**
2018		21.86	*21.86*	279.83	*279.83*	**257.97**
2019		21.86	*21.86*	279.83	*279.83*	**257.97**
2020		21.86	*21.86*	279.83	*279.83*	**257.97**
2021		21.86	*21.86*	279.83	*279.83*	**257.97**
2022		21.86	*21.86*	279.83	*279.83*	**257.97**
2023		21.86	*21.86*	279.83	*279.83*	**257.97**
2024		21.86	*21.86*	279.83	*279.83*	**257.97**
2025		21.86	*21.86*	279.83	*279.83*	**257.97**
2026		21.86	*21.86*	279.83	*279.83*	**257.97**
2027		21.86	*21.86*	279.83	*279.83*	**257.97**
2028		21.86	*21.86*	279.83	*279.83*	**257.97**
2029		21.86	*21.86*	279.83	*279.83*	**257.97**
2030		21.86	*21.86*	279.83	*279.83*	**257.97**
⋮		⋮	⋮	⋮	⋮	⋮
2038		21.86	*21.86*	279.83	279.83	**257.97**
2039		21.86	*21.86*	279.83	279.83	**257.97**
Total	1,907.7	524.7	2,432.3	6,716.0	6,716.0	4,283.6

EIRR = 10.3%
ENPV = 38.4 LE million (DR)
SCD = 10.0%

2. Indicative Semi-annual Amortization Schedule 2010-2045



	semi-ann	Principal Balance Beginning	Disbursement	Principal Repaym	Principal Balance End	Interest Payment	Amortization	
2010	1	0.00000	0.01309		0.01309	0.00004	0.00004	0.00013
	2	0.01309	0.01309		0.02618	0.00009	0.00009	
2011	3	0.02618	0.10910		0.13528	0.00044	0.00044	0.00123
	4	0.13528	0.10910		0.24438	0.00079	0.00079	
2012	5	0.24438	3.76953		4.01391	0.01305	0.01305	0.03834
	6	4.01391	3.76953		7.78344	0.02530	0.02530	
2013	7	7.78344	3.88910		11.67254	0.03794	0.03794	0.08851
	8	11.67254	3.88910		15.56165	0.05058	0.05058	
2014	9	15.56165	4.01304		19.57469	0.06362	0.06362	0.14028
	10	19.57469	4.01304		23.58772	0.07666	0.07666	
2015	11	23.58772	2.07198		25.65970	0.08339	0.08339	0.17352
	12	25.65970	2.07198		27.73168	0.09013	0.09013	
2016	13	27.73168		0.00000	27.73168	0.09013	0.09013	0.18026
	14	27.73168		0.00000	27.73168	0.09013	0.09013	
2017	15	27.73168		0.00000	27.73168	0.09013	0.09013	0.18026
	16	27.73168		0.00000	27.73168	0.09013	0.09013	
2018	17	27.73168		0.00000	27.73168	0.09013	0.09013	0.18026
	18	27.73168		0.00000	27.73168	0.09013	0.09013	
2019	19	27.73168		0.00000	27.73168	0.09013	0.09013	0.18026
	20	27.73168		0.00000	27.73168	0.09013	0.09013	
2020	21	27.73168		0.00000	27.73168	0.09013	0.09013	0.18026
	22	27.73168		0.00000	27.73168	0.09013	0.09013	
2021	23	27.73168		0.00000	27.73168	0.09013	0.09013	0.18026
	24	27.73168		0.00000	27.73168	0.09013	0.09013	
2022	25	27.73168		0.00000	27.73168	0.09013	0.09013	0.18026
	26	27.73168		0.00000	27.73168	0.09013	0.09013	
2023	27	27.73168		0.00000	27.73168	0.09013	0.09013	0.18026
	28	27.73168		0.00000	27.73168	0.09013	0.09013	
2024	29	27.73168		0.00000	27.73168	0.09013	0.09013	0.18026
	30	27.73168		0.00000	27.73168	0.09013	0.09013	
2025	**31**	**27.73168**		**0.69168**	**27.04000**	**0.08788**	**0.77956**	**1.54124**
	32	27.04000		0.67600	26.36400	0.08568	0.76168	
2026	33	26.36400		0.67600	25.68800	0.08349	0.75949	1.51678
	34	25.68800		0.67600	25.01200	0.08129	0.75729	
2027	35	25.01200		0.67600	24.33600	0.07909	0.75509	1.50799
	36	24.33600		0.67600	23.66000	0.07690	0.75290	
2028	37	23.66000		0.67600	22.98400	0.07470	0.75070	1.49920
	38	22.98400		0.67600	22.30800	0.07250	0.74850	
2029	39	22.30800		0.67600	21.63200	0.07030	0.74630	1.49041
	40	21.63200		0.67600	20.95600	0.06811	0.74411	
2030	41	20.95600		0.67600	20.28000	0.06591	0.74191	1.48162
	42	20.28000		0.67600	19.60400	0.06371	0.73971	
2031	43	19.60400		0.67600	18.92800	0.06152	0.73752	1.47284
	44	18.92800		0.67600	18.25200	0.05932	0.73532	
2032	45	18.25200		0.67600	17.57600	0.05712	0.73312	1.46405
	46	17.57600		0.67600	16.90000	0.05493	0.73093	
2033	47	16.90000		0.67600	16.22400	0.05273	0.72873	1.45526
	48	16.22400		0.67600	15.54800	0.05053	0.72653	
2034	49	15.54800		0.67600	14.87200	0.04833	0.72433	1.44647
	50	14.87200		0.67600	14.19600	0.04614	0.72214	
2035	51	14.19600		0.67600	13.52000	0.04394	0.71994	1.43768
	52	13.52000		0.67600	12.84400	0.04174	0.71774	
2036	53	12.84400		0.67600	12.16800	0.03955	0.71555	1.42890
	54	12.16800		0.67600	11.49200	0.03735	0.71335	
2037	55	11.49200		0.67600	10.81600	0.03515	0.71115	1.42011
	56	10.81600		0.67600	10.14000	0.03295	0.70895	
2038	57	10.14000		0.67600	9.46400	0.03076	0.70676	1.41132
	58	9.46400		0.67600	8.78800	0.02856	0.70456	
2039	59	8.78800		0.67600	8.11200	0.02636	0.70236	1.40253
	60	8.11200		0.67600	7.43600	0.02417	0.70017	
2040	61	7.43600		0.67600	6.76000	0.02197	0.69797	1.39374
	62	6.76000		0.67600	6.08400	0.01977	0.69577	
2041	63	6.08400		0.67600	5.40800	0.01758	0.69358	1.38496
	64	5.40800		0.67600	4.73200	0.01538	0.69138	
2042	65	4.73200		0.67600	4.05600	0.01318	0.68918	1.37617
	66	4.05600		0.67600	3.38000	0.01098	0.68699	
2043	67	3.38000		0.67600	2.70400	0.00879	0.68479	1.36738
	68	2.70400		0.67600	2.02800	0.00659	0.68259	
2044	69	2.02800		0.67600	1.35200	0.00439	0.68039	1.35859
	70	1.35200		0.67600	0.67600	0.00220	0.67820	
2045	71	0.67600		0.67600	0.00000	0.00000	0.67600	0.67600
	Total	1,189.5		27.7		3.9	31.6	31.6

0	2010	0.00000
1	2011	0.00013
2	2012	0.00123
3	2013	0.03834
4	2014	0.08851
5	2015	0.14028
6	2016	0.17352
7	2017	0.18026
8	2018	0.18026
9	2019	0.18026
10	2020	0.18026
11	2021	0.18026
12	2022	0.18026
13	2023	0.18026
14	2024	0.18026
15	2025	0.18026
16	2026	**1.54124**
17	2027	1.51678
18	2028	1.50799
19	2029	1.49920
20	2030	1.49041
21	2031	1.48162
22	2032	1.47284
23	2033	1.46405
24	2034	1.45526
25	2035	1.44647
26	2036	1.43768
27	2037	1.42890
28	2038	1.42011
29	2039	1.41132
30	2040	1.40253
31	2041	1.39374
32	2042	1.38496
33	2043	1.37617
34	2044	1.36738
35	2045	1.35859
36	2046	0.67600
37	2047	0.00000
	Total	31.59753

APPENDIX – 8

Performance Indicators

1. Environmental Indicators (*wEn*)

Environmental indicators evaluate the performance of the undertaking regarding environmental impacts, including the compliance with discharge standards intermittent overflow discharges and final disposal of solid wastes (sludge, sediments and screenings).

Subgroup	Code	Indicator	Concept
Wastewater	*wEn1*	WWTP compliance with discharge consents (%/year)	*population equivalent* that is served by *wastewater treatment plants* complying with discharge consents / *population equivalent served by wastewater treatment plants* managed by the undertaking x 100, at the reference date
	wEn2	Wastewater reuse (%)	Volume of reused treated wastewater / volume of wastewater treated by the undertaking x 100, during the assessment period
	wEn6	Sludge production in WWTP (kgDS/p.e./year)	(Dry weight of *sludge* produced in *wastewater treatment plants* managed by the undertaking during the assessment period x 365 / assessment period) / *population equivalent served by wastewater treatment plants* at the reference date x 1000

2. Personnel Indicators (*wPe*)

Personnel indicators assess efficiency and effectiveness of the wastewater undertaking personnel, considering functions, activities and qualifications. Matters like training, health and safety and absenteeism are also taken into account. Correct interpretation of these PI entail a cross-reference to outsourcing data.

Subgroup	Code	Indicator	Concept
Total personnel	*wPe1*	Personnel in WWT per population equivalent (No./1000p.e.)	Number of full time equivalent employees working on wastewater treatment / *population equivalent* served by wastewater treatment managed by the undertaking x 1000, at the reference date
Technical personnel per activity	*wPe10*	Technical WWT personnel (No./1000p.e.)	Number of full time equivalent employees working on WWT planning, design, construction, operation, maintenance and *repair* activities / *population equivalent*

Subgroup	Code	Indicator	Concept
			served by wastewater treatment managed by the undertaking x 1000, at the reference date

3. Physical Indicators (*wPh*)

Physical PIs aim to evaluate if wastewater treatment and sewerage assets still have enough capacity (headroom) to operate correctly and safely, assuring that their service targets can be attained. The utilization of preliminary, primary, secondary and tertiary treatment is considered as well as the degree of surcharging in the sewers. Pumping capacity utilization and automation and the degree of control are also included.

Subgroup	Code	Indicator	Concept
Automation and control	*wPh11*	Automation degree (%)	Number of automated control units / number of control units x 100, at the reference date
	wPh12	Remote control degree (%)	Number of remote control units / number of control units x 100, at the reference date

4. Operational Indicators (*wOp*)

In this group, PIs are intended to assess the performance of the undertaking as regards operation and maintenance activities. The areas to be assessed include sewers, ancillaries, pumps and pumping station inspection and maintenance, equipment calibration, electrical equipment inspection, energy consumption, sewer and pump rehabilitation, inflow/infiltration/exfiltration, failures, wastewater and sludge quality monitoring, vehicle availability and safety equipment.

Subgroup	Code	Indicator	Concept
Equipment calibration	*wOp13*	WWTP flow meters calibration (-/year)	(Number of *calibrations* carried out during the assessment period for flow meters permanently installed in *wastewater treatment plants* x 365 / assessment period) / number of permanently installed flow meters in wastewater treatment plants at the reference date
	wOp14	Wastewater quality monitoring equipment	(Number of permanent automatic wastewater quality monitoring instrument *calibrations* carried out in *wastewater treatment plants* during the assessment period x 365 / assessment period) / number of

Subgroup	Code	Indicator	Concept
		calibration (-/year)	wastewater quality instruments installed permanently in wastewater treatment plants at the reference date
Electrical and signal transmission equipment inspection	*wOp15*	Emergency power system inspection (-/year)	(Sum of the nominal power of the emergency power systems *inspected* during the assessment period x 365 / assessment period) / total nominal power of the emergency power systems at the reference date x 100
	wOp16	Signal transmission equipment inspection (-/year)	(Number of signal transmission units *inspected* during the assessment period x 365 / assessment period) / total number of signal transmission units as the reference date
	wOp17	Electrical switchgear equipment inspection (-/year)	(Number of electrical switchgear *inspected* during the assessment period x 365 / assessment period) / total number of electrical switchgear units as the reference date
Energy consumption	*wOp18*	WWT energy consumption (kWh/p.e./year)	(Energy consumed by wastewater treatment facilities during the assessment period x 365 / assessment period) / *population equivalent* served by *wastewater treatment plants* managed by the undertaking at the reference date
Wastewater and sludge quality monitoring	*wOp44*	Wastewater quality tests carried out (-/year)	(Total number of tests carried out during the assessment period x 365 / assessment period) / total number of tests required by applicable standards or legislation during the assessment period
	wOp45	- BOD tests (-/year)	(Number of BOD tests carried out during the assessment period x 365 / assessment period) / number of BOD tests required by applicable standards or legislation during the assessment period
	wOp46	- COD tests (-/year)	(Number of COD tests carried out during the assessment period x 365 / assessment period) / number of COD tests required by applicable standards or legislation during the assessment period
	wOp47	- TSS tests (-/year)	(Number of TSS tests carried out during the assessment period x 365 / assessment period) / number of TSS tests required by applicable standards or legislation during the assessment period

Subgroup	Code	Indicator	Concept
	wOp48	- total phosphorus tests (-/year)	(Number of total phosphorus tests carried out during the assessment period x 365 / assessment period) / number of total phosphorus tests required by applicable standards or legislation during the assessment period
	wOp49	- nitrogen tests (-/year)	(Number of nitrogen tests carried out during the assessment period x 365 / assessment period) / number of nitrogen tests required by applicable standards or legislation during the assessment period
	wOp50	- faecal E.cole tests (-/year)	(Number of faecal Escherichia coli tests carried out during the assessment period x 365 / assessment period) / number of faecal E.coli tests required by applicable standards or legislation during the assessment period
	wOp52	Sludge tests carried out (-/year)	(Number of tests carried out to *sludge* produced during the assessment period x 365 / assessment period) / number of tests required by applicable standards or legislation during the assessment period

5. Quality of Service Indicators (*wQS*)

Quality of service PIs measure the level of service provided to customers. Area include level of service coverage, flooding and relations with customers, such as reply to requests, complaints, third party damage and traffic disruption caused by undertaking activities.

Subgroup	Code	Indicator	Concept
Treated wastewater	*wQS7*	Treated wastewater in WWTP primary treatment (%)	Volume of wastewater receiving only *primary treatment* at *wastewater treatment plants* / *collected sewage* x 100, during the assessment period
	wQS8	Treated wastewater in WWTP secondary treatment (%)	Volume of wastewater receiving *Secondary treatment* at *wastewater treatment plants* / *collected sewage* x 100, during the assessment period
Complaints	*wQS19*	Total complaints (No./1000 inhab./year)	(Total number of *complaints* related to wastewater system performance, during the assessment periods x 365 / assessment period) / resident population as the

Subgroup	Code	Indicator	Concept
			reference date x 1000
	wQS22	- population incidents complaints (No./1000 inhab./year)	(Number of *complaints* as a result of pollution incidents, during the assessment periods x 365 / assessment period) / resident population as the reference date x 1000
	wQS23	- odor complaints (No./1000 inhab./year)	(Number of *complaints* as a result of odors, during the assessment periods x 365 / assessment period) / resident population as the reference date x 1000

6. Economic and Financial Indicators (*wFi*)

Indicators in this group deal with the effectiveness and efficiency of the use of financial resources. Additionally, they provide a means to interpret the business management, indicating the company financial behavior and ability to expand. The US dollar in used as a reference unit in order to allow easier international comparisons. Revenues, costs, composition of running costs per type of cost, per main function and per technical activity, composition of capital costs, investment and efficiency, leverage, liquidity and profitability indicators are included.

Subgroup	Code	Indicator	Concept
Costs	*wFi5*	Unit total cost per p.e. (US$/p.e./year)	[(Running costs plus capital costs, related to wastewater treatment and *sewer system*, during the assessment period) x 365 / assessment period] / total *population equivalent* served by the wastewater service at the reference date
	wFi7	- unit running cost per p.e. (US$/p.e./year)	(Running costs related to wastewater treatment and *sewer system* during the assessment period x 365 / assessment period) / total *population equivalent* served by the wastewater service at the reference date
	wFi9	- unit capital cost per p.e. (US$/p.e./year)	Capital costs related to *sewer system* during the assessment period x 365 / assessment period) / total *population equivalent* served by the wastewater service at the reference date

APPENDIX – 9

Minutes of Discussions

MINUTES OF DISCUSSIONS
OF INTERIM REPORT PRESENTATION
ON PREPARATORY STUDY FOR ABU RAWASH WASTEWATER TREATMENT
PLANT IMPROVEMENT IN CAIRO, ARAB REPUBLIC OF EGYPT

The members of Tokyo Engineering Consultants Co., Ltd. (hereinafter referred to as "JICA Study Team"), which is headed by Mr. Masafumi MIYAMOTO, is assigned by Japan International Cooperation Agency (JICA) to conduct the Preparatory Study for Abu Rawash Wastewater Treatment Plant Improvement in Cairo, Arab Republic of Egypt. JICA Study Team made a presentation on Interim Report and held discussions with the officials of the Construction Authority for Potable Water and Wastewater (hereinafter referred to as "CAPW"), the Egyptian Environmental Affairs Agency (hereinafter referred to as "EEAA"), the Holding Company of Water and Wastewater (hereinafter referred to as "HCWW"), the Ministry of Water Resources and Irrigation (hereinafter referred to as "MWRI") and other participants in the presentation held on 27th October 2009 in the Meeting Room of the CAPW on 6th floor from 1200 hrs to 1400 hrs.

In the course of discussions, both parties confirmed the main items described in the attached sheets. JICA Study Team will proceed with the Study and prepare the Report, which fulfills all the information that is needed.

2nd November 2009

宮本 正史	Z. Monir
Mr. Masafumi MIYAMOTO Team Leader JICA Study Team	Eng. Zeinab Monir Chief of Project Department CAPW

ATTACHMENT

List of Participants in the Interim Report Presentation

Location: 6th Floor, CAPW　　　　Date & Time: 27th October 2009, 1200 ~ 1400 hrs

S. No.	Name	Organization	Telephone No.
1	Ms. Laila Darwish	Ministry of Housing, Utilities and Urban Development	
2	Dr. Ali Abu-Sedira	Secretary General EEAA, Ministry of State for Environmental Affairs	02 5253123
3	Eng. Zeinab Monir	Chief, Project Department CAPW	0122197544
4	Dr. Mohamed Abd El-Moneim ShehataWahba	General Director, Irrigation Department MWRI	0103965239
5	Mr. Saleh Wanees	Consultant Engineer HCWW, Giza	0122777532
6	Mr. Shihata Dorh	Head of West Bank GWWC	0125816681
7	Mr. Mahmoud A. Azeem	Professor, Faculty of Engineering Ain Shams University	0106051641
8	Mr. Mohamed Abdel Ghany	Senior Engineer EWRA	0114846943
9	Mr. Sobhy Sayed	Mechanical & Environmental Engineer EWRA	0100041290
10	Mr. Samir Gabr	Engineer, CAPW	0104781955
11	Mr. Gamal Zenhom	General Manager CAPW	0105464005
12	Mr. Mohamed Monir	Director, Drainage Water Sector CAPW	0106094380
13	Mr. Nihad Anwar	Engineer CAPW	010190
14	Dr. Ashraf M. El-Abd	Chief Program Officer JICA Egypt Office	0123380287
15	Ms. Satoko KIMURA	Senior Program Officer JICA Egypt Office	0181611334
16	Mr. Masafumi MIYAMOTO	JICA Study Team	0173453195
17	Mr. Yarai SATO	JICA Study Team	0174628584
18	Mr. Masahiro KAWACHI	JICA Study Team	0174629161
19	Mr. Norio TANAKA	JICA Study Team	0182457692
20	Mr. Alok Kumar	JICA Study Team	0170246826

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S. No.	Name	Organization	Telephone No.
21	Ms. Sammer Yousif	Environmental Engineer ECG	
22	Mr. Ahmed Tarik	Infrastructure Engineer ECG	

The following main points were discussed and agreed upon by the parties:

1. The JICA Study Team made a presentation of the Interim Report before all the participants. The presentation included results of Facilities Planning and Environmental Impact Assessment. It was informed that the EIA report prepared under this Study is almost in the form of Draft Final Report and it could be used by CAPW to submit to EEAA for its approval. On completion of the presentation, the Study Team requested all the participants for suggestions, comments and discussion.

2. The HCWW asked Study Team why the extension of Sludge Lagoon is needed if construction of sludge treatment facilities is also proposed. The CAPW explained that according to the priority and considering the use of existing sludge pumps and sludge lagoons, extension of sludge lagoons is proposed under this Project on priority basis. However, in future, on the completion of wastewater treatment facilities to the capacity of 2 million m^3/day, construction of sludge treatment facilities near Abu Rawash WWTP is proposed. The Study Team affirmed to it. The HCWW expressed that no information has been presented on implementation schedule for this Project and added that any information on implementation schedule shall be helpful in planning. The Study Team replied that implementation schedule has not yet been finalized and shall be included in Report in next presentation.

3. The EEAA expressed that this Study is very comprehensive and result of this Study could be utilized for improvement of environmental conditions in Abu Rawash area. It added that EIA report prepared under this Study should be submitted for approval.

4. The EEAA further added that there has been some modification in Law No. 4 of 1994 in 2009 and it should be incorporated in the Report and JICA Study Team agreed to it. The EEAA also informed that there have been some amendments to the environmental law concerning the penalties against the environmental violations.

5. The EEAA requested that Abu Rawash WWTP contributes only 1.2 million m^3/day of flow (out of total 3 million m^3/day) to Rosetta branch of River Nile. The project in this Study shall contribute to improvement of problem only partly. Therefore, Ministry of Housing should plan for wholesome improvement in environmental conditions for the villages/small towns located along the drains flowing to Rosetta.

6. EEAA asked the Study Team if consideration has been given to effect of infiltration from sludge lagoon on groundwater quality in the area, and to the use/management of dried sludge from sludge lagoon. Study Team replied that groundwater level in the area of

sludge lagoons is 50-100 m below the ground level. Also, according to AMBRIC report, there exists a hard rock layer at about 30 m below the ground and therefore infiltration from these lagoons shall not have any negative impact on the groundwater quality in the region. Regarding the management of sludge lagoon, the Study Team shall incorporate in the Report.

7. The EEAA also added that Sanitation agency should monitor the effluents from industrial area. It also informed that the Projects that are undertaken for improvement of environment are exempted from taxes and duties. It also added that consideration should be given to application of EM for sludge treatment.

8. The MWRI expressed that the Project could consider the reduction of cost through measures for saving water thereby leading to reduction of amount of generated wastewater. The CAPW replied that Abu Rawash WWTP is already receiving 1 million m^3/day of wastewater in existing condition and is expected to increase further in future. Therefore, this Project should be undertaken to address existing problem.

The meeting was closed with vote of thanks from Eng. Zeinab Monir of CAPW.

MINUTES OF DISCUSSIONS ON DRAFT FINAL REPORT
ON PREPARATORY STUDY FOR ABU RAWASH WASTEWATER TREATMENT
PLANT IMPROVEMENT IN CAIRO, ARAB REPUBLIC OF EGYPT

JICA Study Team, which is headed by Mr. Masafumi MIYAMOTO, explained contents of Draft Final Report and held discussions with Eng. Zeinab of the Construction Authority for Potable Water and Wastewater (hereinafter referred to as "CAPW"), on 20th December 2009 in CAPW on 6th floor from 1100 hrs to 1300 hrs.

In the course of discussions, both parties confirmed the contents of the Draft Final Report including proposed treatment process, advantages and disadvantages of the proposed equipment in particular. Discussions exchanged and conclusions agreed on at the Public Consultation Meeting held on the previous day, 19th December at Abu Rawash WWTP were reviewed in the meeting. Consequently, both parties agreed that workshop to explain the Draft Final Report shall not be held since representatives from all of the concerned authorities including those from MWRI, MOHP, MSEA, EEAA, HCWW, GWWC, and CAPW attended at the Public Consultation Meeting, and that CAPW and JICA Study Team explained the results of the Study in detail.

It was agreed that CAPW will gather comments, if any, on the Draft Final Report from authorities concerned and will submit to the Study Team through JICA Cairo office in writing not later than 4th January 2010. Then, JICA Study Team will proceed with the Study and prepare the Final Report to be submitted to JICA by the end of January 2010. CAPW will proceed EIA report approval procedures with the Final Report

21st December 2009

宮本 正史	Z Monir
Mr. Masafumi MIYAMOTO Team Leader JICA Study Team	Eng. Zeinab Monir Chief of Project Department CAPW