APPENDIX – E

OPERATION AND MAINTENANCE MANUALS

APPENDIX - E OPERATION AND MAINTENANCE MANUALS

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E.1 Outline of Operation and Maintenance Manual

E.1.1 O & M of Treatment Plant

Duties of a treatment plant operator are summarized in the following table. Most of these duties have to do with the efficient operation of the plant and some are related to the maintenance of the plant.

Table E.1 Typical Activities in Water Treatment Plant Operation

1.	Start up, shut down, and make periodic operating checks of plant equipment, such as pumping systems, chemical feeders, auxiliary equipment (compressors), and measuring and control systems.
2.	Perform routine preventive maintenance, such as lubrication, operating adjustments, cleaning, and painting equipment.
3.	Load and unload chemicals, such as chlorine cylinders, bulk liquids, powder etc.
4.	Perform minor corrective maintenance on plant mechanical equipment, for example chemical feed pumps and small units.
5.	Maintain plant records, including operating logs, daily diaries, chemical inventories, and data logs
6.	Monitor the status of plant operating guidelines, such as flows, pressures, chemical feeds, levels, and water quality indicators, by reference to measuring systems
7.	Collect representative water samples and perform laboratory tests on samples for basic parameters (turbidity, color, odor, Coliforms, chlorine residual, and other tests as required).
8.	Order chemicals, repair parts and tools.
9.	Estimate and justify budget needs for equipment and supplies.
10.	Conduct safety inspections, follow safety rules for plant operations, and also develop and conduct safety meetings and exercises.
11.	Communicate with other operators and supervisors on technical aspects (for instance with Production Manager and Team Leader 2 based at Terminal Point, and Water Quality Manager).
12.	Determine feed rates, flow quantities, detention and contact times, and hydraulic loading as required for plant operation.
13.	Monitor backwash water and sludge disposal.

(A) Maintenance Program

The major elements of a good maintenance program include the following:

i) Planning and scheduling

The planning and scheduling effort should define the specific maintenance tasks to be done and the time intervals. The following items are important considerations in developing a good maintenance plan:

(i) Routine procedures – operator will inspect various mechanical and electrical equipment to check for proper operation, and will perform a number of maintenance functions,
(ii) Special procedures (equipment overhaul)
(iii) Skills needed
(iv) Special tools and equipment requirements, and
(v) Parts availability

An important source of information for planning routine maintenance is equipment manufacturer's operating and maintenance instructions that should be furnished with the equipment at the time of purchase.

ii) Records management

Good record management is an important administrative feature of the maintenance program and one that is often overlooked. A comprehensive record management system provides the basis for daily task assignments, provides a permanent record of work performed, and becomes an historical reference source for reviewing equipment performance.

iii) Spare parts management

Certain parts of mechanical equipment, such as shaft bearings, require periodic replacement because they have a useful life which is shorter that the predicted overall equipment life. This requires that an adequate stock of spare parts is kept on hand at the treatment plant to facilitate planned replacement.

iv) Cost and budget control

Accurate records of labor and equipment expenditures are an important part of the overall budget and cost control program. A thorough and up-to-date written performance history of equipment operations, repairs, and replacement costs will significantly improved the budget planning process.

v) Training program

Training should be an ongoing feature of the operation program and operators should be encouraged to participate. Such training can increase the expertise of the maintenance and operation personnel in the general repair of equipment, in specialized procedures required for calibrating and repairing selected equipment items, and in their ability to quickly and properly respond to changes in raw and finished water.

(B) Maintenance Activities

Mechanical and electrical maintenance is of prime importance. Manufacturers provide information on the mechanical maintenance of their equipment. Their literature should be thoroughly read and the procedures should be clearly understood. The instructions must be followed very carefully when performing maintenance on equipment.

This is particular true for specialized equipment used for treatment processes such as flocculation and filtration. Other electrical and mechanical equipment includes pumps and motors for which preventive maintenance services should be carried out. Additional equipment is pipes and fittings and reservoirs for which maintenance are also required.

(C) Operating Records

Records are essential for effective management of water treatment facilities. They are many different types of records that are required for effective management and operation such as:

- Raw water records
- Plant Operation records
- Plant Maintenance records
- Plant Laboratory records
- Chemical inventory and usage records
- Purchase records etc.

Other important management records are the procurement records, inventory records, and equipment records. Detail on record formats for water treatment plant components are presented later also.

E.1.2 O & M of Storage Facilities

Two types of reservoirs have been proposed for Juba Water Supply: Ground Level Reservoirs and Overhead Service Reservoirs.

(A) Inspection

Inspection should be conducted to determine the structural condition of the storage reservoir, to identify any sanitary defects in the storage system, to evaluate the need for cleaning the storage facility, to determine maintenance needs and the effectiveness of the maintenance program, and also to identify any existing or potential water quality problems. Inspections may be routine, periodic or comprehensive:

- Routine inspections are part of the normal, daily routine and include a check of security items.
- Periodic inspections are more detailed than routine inspections and may require climbing on the facility and looking inside.
- Comprehensive inspections should be conducted every three to five years.

Vents and overflows must be properly screened to keep out birds, rodents and insects. Special attention must be given to cracks which may allow either leakage or the inflow of contaminated water.

The concrete tanks are not usually coated on the inside and are painted on the exterior for appearance purposes only. This would seem to indicate that maintenance on concrete tanks is minimal, but this may not be true. The concrete tanks are all reinforced with steel which can rust causing the structural strength to be threatened.

(B) Cleaning

Either out-of-service cleaning methods or in-service cleaning methods may clean storage tanks.

- Out-of-service cleaning consists of draining, washing, and disinfecting the tank before bringing it into service.
- In-service cleaning uses divers or remotely operated equipment. This equipment is similar to a vacuum cleaner and it removes soft material from the bottom of the tank.

Frequency of cleaning storage tanks depends on sediment build-up, development of biofilms and results from water quality monitoring. Covered facilities are cleaned every three to five years, but possibly more often based on the result of water quality monitoring and inspections. Uncovered storage facilities should be cleaned annually or possibly twice a year, if needed.

(C) Painting and Coating

Outside painting should be made at least once every five years. Tank's interior coating (Steel Tanks) will generally protect the interior for three to five years, depending on local conditions. Routine inspection is the best way to determine when a tank requires maintenance. New tanks or newly painted tanks should be inspected after one year of use. Otherwise a tank should be drained, cleaned, and inspected once a year.

The time a coating lasts depends on: (i) proper surface preparation, (ii) good, durable paint, (iii) good workmanship, (iv) adequate drying and ageing, (v) proper maintenance through periodic inspection and spot, partial or complete removal of old paint and repainting as necessary.

Three types of coating inspections can be made:

- A visual inspection, which is made from the roof hatch with the water level lowered to about half full or less;
- A detailed inspection, accomplished by draining the tank, washing it, and then inspecting the interior coating, and
- A detailed inspection (may be under water using divers and video-cameras) and then cleaning the tank with a device similar to a vacuum cleaner.

A visual inspection may be made in the odd numbered years and a detailed cleaning and inspection may be made in the even numbered years.

(D) Disinfection

New storage facilities and facilities that have been repaired and cleaned must be disinfected. Various methods can be used to disinfect a water storage facility. Standard method is as follows:

1. Spray or brush the interior of the storage facility with 200 mg/l chlorine solution
2. Fill the tank with water with a high enough chlorine concentration to produce a chlorine residual of 3 mg/l
3. Fill the tank with water that has been treated to provide a chlorine residual of at least 10 mg/l after a six-hour contact period.
4. Enough chlorine should be added to the water to produce 50 mg/l of available chlorine when the storage tank is approximately 5% full.

Liquid chlorine, calcium hypochlorite, and sodium hypochlorite are commonly used as disinfectants.

E.1.3 O & M of Pumps

Manufacturers manual and guidelines should be followed in this regard. Some basic features are as follows.

(A) Operation

Following recommendations are made regarding pump operation:

- Dry running of the pump should be avoided.
- Pump should be operated only within the recommended range on the H-Q characteristics of the pumps
- Operation near to the shut-off should be avoided
- Delivery valve should be operated gradually
- Pumps in parallel should be started/stopped with an adequate time lag to let the pressure gauge stabilize; pumps in series should be started and stopped sequentially with the minimum time lag.
- Stuffing box should let a drip of leakage to ensure that no air is passing into the pump and that the packing is getting adequate water for cooling and lubrication
- Stand-by pumps should always be in ready-to-run condition.

(B) Maintenance

Pumps must be firmly installed to prevent problems from operating noise levels and alignment during the life of the equipment. Alignment procedures for the pump and driver are critical. There should be no strain on the pump case from the suction and discharge piping connections.

Inspection and preventive maintenance procedures will cover many types of operations. Some of the more important procedures are listed below:

1. Observe and record pump pressures and output (flow) and pump's current (electricity) demands.
2. Regularly check for excessive or abnormal noise, vibration, heat and odor.
3. Provide grease and oil lubrication in accordance with the manufacturer's instructions. Lubrication should never be overdone as the addition of too much grease will cause a bearing to overheat, and too much oil will result in foaming. Proper lubrication for pump bearings cannot be overemphasized. The condition of operation will determine how often a bearing should be greased.
4. Check bearing temperatures once per month with a thermometer. If the bearings are found to be running too hot, it could be the result of too much lubricant. Every three months, check the lubricated bearings for "saponification", which is a foamy condition of the lubricant which usually results from water or other fluid infiltrating the bearing shaft seals. If the grease appears as a white foamy substance, the bearings should be cleaned with kerosene or solvent.
5. Listen for any bearing noise. Usually a ball bearing will give audible notice of impending failure. This early warning will give time to plan a shutdown for maintenance.
6. Tighten the packing glands if they are leaking excessively. The tightening should be sufficient to permit only a small amount of leakage, but not result in an increase in packing-follower heating. Packing glands should never be tightened to the point where there is no leakage since this will cause undue packing wear and even a scored shaft or sleeve. Check the leakage rate daily. When the packing wears or is compressed so that the gland cannot be tightened farther, install a new set of rings. While mechanical seals require higher initial cost than packing, long-term cost may be lower.
7. Inspect the pump priming system. A priming system must be used to prevent the pump from running dry if the pump operates with a suction lift. To protect against lost of prime, check valves or foot valves on the intake or suction piping of a pump are a necessity. Use only clean water for the priming. To facilitate priming, ejectors or vacuum pumps are also available.
8. Routinely, operate internal combustion-driven pumps on stand-by for 15 minutes once per week. Also check any automatic pump controls. If they fail during an emergency, the pumps must be operated with manual overrides.

9. Check pump alignment periodically to guard against premature bearing and coupling wear. Alignment should be checked when the pump is cold, and again when a unit has run long enough for it to reach the proper operating temperature. Alignment on new installations can change considerably in a short period of time. Daily checks should be made until a stable operation has been established.

E.1.4 O & M of Distribution Facilities

(A) Pipelines

(i) Pipe Maintenance

Pipe maintenance is performed to prevent leakage, maintain or restore the pipe's carrying capacity, maintain proper water quality conditions in the pipe, and prolong the effective life of the pipe. The type of maintenance carried out includes repairing leaks and breaks, flushing, cleaning, disinfection, and relining.

(ii) Main Breaks

Breaks in water mains can occur at any time. Sometimes break location is obvious, sometimes it is not and exploration by poke holes may be needed. In the context of intermittent supply repair of the break can be done when the water is not running. When the pipes are permanently under pressure, valves will have to be closed to isolate the break and to carry out the repair.

(iii) Installation of Pipe and Service Connections

The most satisfactory policy in respect of pipe and service connections laying is for the water utility to install all service pipes and meters. The work can also be sub-contracted but in this case, required procedures and fittings must be clearly defined and all installations must be inspected and tested for leaks before an installation is covered with backfill.

(iv) Pipe Flushing

Flushing is done to clean out distribution pipelines by removing deposits, encrustation, sediments and any other materials. Deposits may result in taste, odor, and turbidity problems. Encrustation may restrict the water flow. Sand, rust and biological materials cause quality problems.

(v) Pipe Cleaning

Mechanical cleaning devices can be used to clean pipes. Foam swabs and pressurized air can be used to remove loose sediments and soft scales from mains. Scrapers or brushes may have to be used in mains with hardened scales, generally prior to relining. Pipe cleaning should produce improved pipe carrying capacity. For small pipes a mixture of air under pressure and water can be used to clean the pipe. After the cleaning operation is completed flushing and disinfection are required.

(B) Valves

Distribution system shutoff valves provided to isolate areas are very often suffering from lack of operation rather than from wear. Comprehensive programs of inspection, exercising, and maintenance of valves are required.

One of the main problems in maintaining the valves is to know where they are exactly located. Other problems include valves that won't close or open after they are located. The same devices used to locate the mains are used to locate valves.

Routine valve inspection should be conducted and the following tasks performed:

1. Verify the accuracy of the location of the valve boxes on the system map.
2. After removing the valves box cover, inspect the stem and nut for damage or obvious leakage.
3. Close the valve fully, if possible, and record the number of turns to the fully closed position.
4. Reopen the valves to re-establish system flows
5. Clean valve box cover seat. Sometimes covers on valve boxes will come off when traffic passes over them due to dirt in the seat.

One of the most important factors in maintaining valves is the availability of current and correct maps of the distribution system, and also the availability of current record. Valve boxes can often be covered with road surfacing. In that respect, road improvements require constant attention from water system operators to ensure that valves are not lost.

In general it is recommended that all valves be checked at least once a year. Any valve that does not completely open or close should be replaced. The condition of the valve packing, stem, stem nut, and gearing should be noted. A maintenance program should be initiated to correct any problems found during the inspection and checking.

While operating a valve, two types of typical hydraulic problems can occur: cavitation and water hammer. A noisy or vibrating valve may be an indication that cavitation is occurring and that the valve may eventually have to be replaced. Water hammer can be prevented by always closing the valves

slowly, regardless of size or type.

Corrosion may be a problem in some areas and can cause failure of bonnet and packing gland bolts. This is apparent when stem leakage occurs or when a valve is closed and the bonnet separates from the body.

Valves left closed in error can cause severe problem in a distribution system. Separate pressure zones may be established by closing valves.

(C) Water Meters

Like any other mechanical device, water meters need regular servicing to maintain their efficiency. Water meters can over- or under-register because of wear, deposits, or turbulence resulting from valves and fittings. Periodic meter testing based on meter use, water quality, age of meter, cost of testing, and water revenue loss, is required.

Small meters should be tested once every five to ten years and large ones every one to four years. New meters should also be tested before installation. Information on status and accuracy of the water meters should be carefully recorded and analyzed for procedure improvement and economic analysis. Meters may be tested at workshop or directly on site by running a measured volume of water through the meter (small meter), or connecting a calibrated test meter in series with the meter to be tested (large meter which has provision for attaching a test meter).

Meter maintenance and repair consist essentially of dismantling and thoroughly cleaning the meter and inspecting all of its parts.

E.1.5 Appointment of Qualified Staff

It is expected that the proposed project components would strengthen the capacity of the UWC in terms of water supply facilities. However, in order to manage its water supply system efficiently, productively, economically and in a sustainable manner, strengthening of human resources within the department is a necessary requirement.

It is suggested that staff requirements considering the new facilities proposed in the Master Plan are assessed and arrangements to recruit new staff are made. For this purpose, the recruitment policy and plan to accomplish needs should be prepared. The details should be prepared for staff placement and if needed, pre-service training should be provided. Together with planning for new recruitments a salary review need to be carried out.

It is also proposed that job functions and description are prepared, reviewed and finalized. Once job descriptions are prepared, a job analysis should be carried out to assess whether the descriptions cover all functional areas of the organization and thereby to identify duplications as well as missing gaps, if any. The job analysis should include all the offices. Initially, the emphasis should be to review and prepare job descriptions for all of the professional staff.

E.1.6 Supplies and Spare Parts

Timely availability in adequate numbers of the right spare parts is an essential necessity for effective operation and maintenance of the water supply system. Management of spare parts and supplies is all the more important in case of Juba given the lengthy pipeline network, the use of many pumps and other machinery, and the aged-old pipe network. The frequently used spare parts include pipes and fittings, lead, joints and chemicals such as alum and chlorine.

In the present practices, the spare parts are not stocked properly and often it is purchased from the local market whenever required. Reliance on open purchases poses some obvious problems such as price variation and the unavailability of parts of the correct size, dimension and specifications. Under such circumstances, staff is forced to use parts of lower standards creating many other problems.

Most of the spare parts are not locally manufactured and therefore are imported from neighboring markets. Also chemicals such as chlorine and aluminum sulphate (alum) are imported from either Uganda or Nairobi.

It is appropriate that UWC stocks adequate quantity of right spare parts in its own store to be used in water supply operations. Such a strategy would contribute to an effective management of O&M and repairs in addition to being more economical. Also the store should be properly organized with spare parts properly numbered and displayed and time to time should be expanded in such a way to stock the total departmental requirements of spare parts and chemicals. The store should be located nearest to the water treatment plant, reservoirs, and/or pumping stations as the case may be for easy access.

E.2 Work Process Flow, Record Sheets and Reports

The main purposes of operation and maintenance of water supply systems is:

- To ensure continued and sufficient water supply at sufficient pressure and of good quality to Consumers
- Cost Efficient Operation, and
- Increased service life

Broad categories of operation activities include routine jobs, measurement and tests, monitoring and reporting. Maintenance includes activities that could be broadly categorized as preventive maintenance, reactive maintenance, important repairs and overhauling, and stores and purchases. In O&M, the role of managers is to provide directions, make decisions, and control. The roles of operators are to maintain quality of output and match rate of working with requirements. Maintenance staff members are responsible for carrying out repair or replacement of worn or defective components to ensure continued satisfactory level of services. In this part, work process flow and record sheets for various components of the water supply system are described.

E.2.1 Intake Facilities

The function of intake facilities is to take raw water from source to the treatment facilities. Any change in quantity of the quality of raw water influences the purification process.

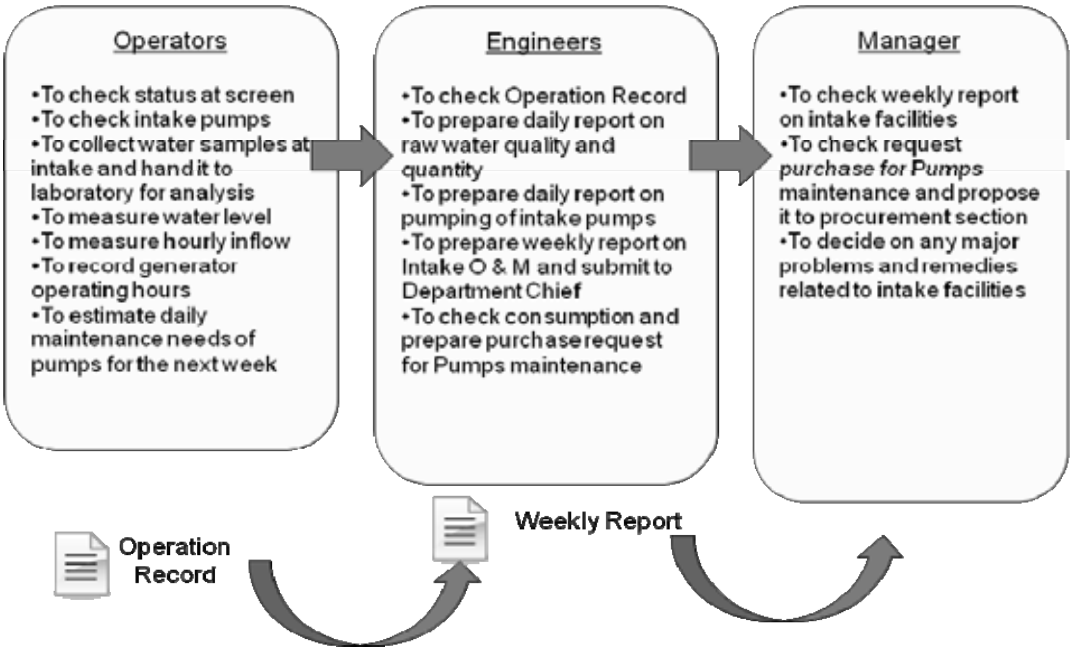

Figure E.1 Work Process Flow for Intake Facilities

The key parameters that should be monitored for intake facilities include water level in river, debris near intake, inflow, and raw water quality parameters such as turbidity, color, pH, alkalinity, and electrical conductivity. A diagram showing work process flow has been illustrated in Figure 4.1 including roles of operators, engineers and manager. It could be updated as and when needed. Operation record for intake facilities should be prepared by the operator on daily basis and the collected information should be compiled in digital form in the computers. An example of record sheet is presented in Figure below.

Operating Record Intake Facility - General Data

Year: _____ Month: _____ Date: _____ .

	Shift 1 (7:00 ~ 14:00)	Shift 2 (14:00 ~ 20:00)	Shift 3 (20:00 ~ 7:00)
Recording Time			
Weather			
Check for flow obstruction at Intake Point in River			
Solid Waste, Woods			
Oil			
Others (animals, big logs, etc.)			
Check water level (m)			
Intake Valve Status (Open/Close)			
Check stability of intake pump (noise, vibration, leakeage every shift)			
Noise			
Vibration			
Leakage			
Inflow (m^3)			
Total Inflow for Day			0:00
Checked by			

Record Checked by:

_____

Head, Purification Section

Operating Record Intake Facility - Pumps Working Hours

Year: 2009 Month: June Date: 22 .

Time	Shift 1 (7:00 ~ 14:00)	Shift 2 (14:00 ~ 20:00)	Shift 3 (20:00 ~ 7:00)	Total Daily
Recording Time				
Intake/Raw Water Pumps				
Pump No. 1				
Previous Hour Meter Reading	690.00	694.00	697.92	
Hour Meter Reading	694.00	697.92	702.00	
Total hours of Operation per Shift	4.00	3.92	4.08	12.00
Pump No. 2				
Last Hour Meter Reading	691.00	693.50	696.90	
Hour Meter Reading	693.50	696.90	699.00	
Total hours of Operation per Shift	2.50	3.40	2.10	8.00
Pump No. 3				
Last Hour Meter Reading	354.00	356.00	359.77	
Hour Meter Reading	356.00	359.77	362.00	
Total hours of Operation per Shift	2.00	3.77	2.23	8.00
Total pumping hours for all pumps per day				28.00

Record Checked by:

_____

Head, Purification Section

Operating Record Intake Facility - Generator Working Hours

Year: 2009 Month: June Date: 22 .

Time of General Power Supply Start	Time of General Power Supply Failure	Generator 1				Generator 2				Checked By
		Start Time	Stop Time	Fuel Level in Tank at Stop	Duration of Running	Start Time	Stop Time	Fuel Level in Tank at Stop	Duration of Running	
					0:00				0:00	
		13:00	15:27		2:27				0:00	
15:27										
Total					**2:27**				**0:00**	

Record Checked Record Checked by:

Head, Purification Head, Purification Section

Figure E.2 Example of Record Sheet for Intake Facilities

In addition, general public should not be allowed to enter area near the intakes to avoid accidents or pollution of raw water. Sluice valves and gates should be inspected regularly.

E.2.2 Flocculation and Sedimentation Facilities

The main functions of flocculation and sedimentation are conversion of small non-settleable particles into large settleable flocs, settling of large flocs through gravitation, and finally removal of settled sediments as sludge. In these processes, monitoring of raw water quality, and effectiveness of process is very important. Based on the raw water quality, application quantity of coagulant is judged through jar test. The main control and measurement activities include flow rate, water level, chemical dosing rate, flocculator driving, water level and drainage of sedimentation basin, and water quality after sedimentation. Work process flow for coagulation-flocculation and sedimentation facilities are shown

below.

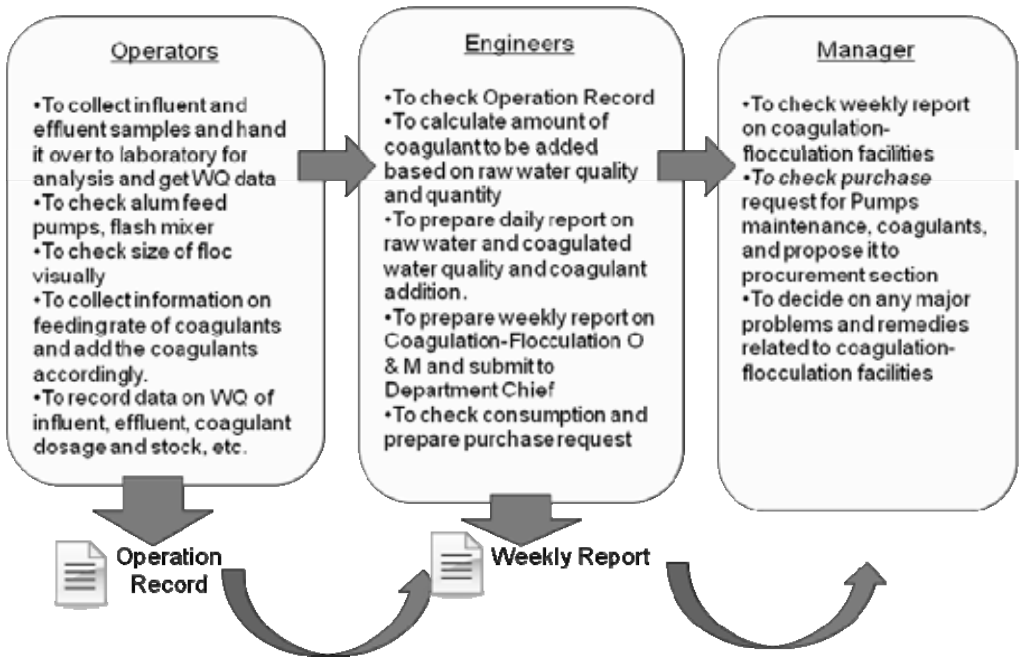

Figure E.3 Work Process Flow for Coagulation-Flocculation Facilities

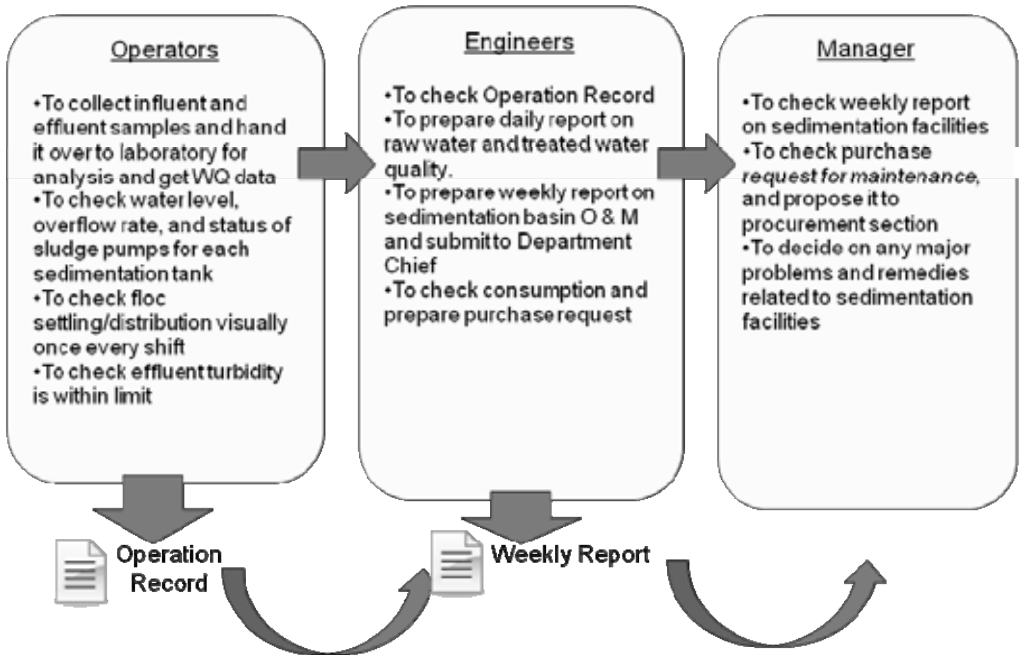

Figure E.4 Work Process Flow for Sedimentation Facilities

The operators should prepare operation record sheets on daily basis for coagulation and sedimentation facilities. Examples of record sheet formats have been given in the Figures below for these facilities.

Operating Record Coagulation-Flocculation Facility - Chemical Feeding Pump

Year: _____ Month: _____ Date: _____ .

	Shift 1 (7:00 ~ 14:00)	Shift 2 (14:00 ~ 20:00)	Shift 3 (20:00 ~ 7:00)
Recording Time			
Status of Alum Feed Pumps (ON/OFF)			
Pump 1			
Pump 2			
Pump 3			
Alum Mixing Tank Level (Once every Day)			
Pump 1			
Pump 2			
Pump 3			
Status of Soda Ash Feed Pumps (ON/OFF)			
Pump 1			
Pump 2			
Soda Ash Mixing Tank Level (Once every Day)			
Pump 1			
Pump 2			
Chemical Dosing Flow Rate (l/hr)			
Alum			
Pump 1			
Pump 2			
Pump 3			
Soda Ash			
Pump 1			
Pump 2			
Pump 3			
Operating Problems, Remedies, and Remarks			
Checked by			

Record Checked by:

_____

Head, Purification Section

Operating Record Coagulation-Flocculation Facility - Chemicals Used

Month: _____ Year: _____ (Check Everyday in the Afternoon)

Day	Alum Used (kg)	Alum in Stock (kg)	Soda Ash Used (kg)	Soda Ash in Stock (kg)	Alum Purchased (kg)	Soda Ash Purchased (kg)	Checked By
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							
31							

Record Checked by:

_____

Head, Purification Section

Figure E.5 Record Sheet Format for Coagulation-Flocculation Facility

Operating Record Sedimentation Facility - Sedimentation Tank

Year: _____ Month: _____ Date: _____ .

	Shift 1 (7:00 ~ 14:00)	Shift 2 (14:00 ~ 20:00)	Shift 3 (20:00 ~ 7:00)
Recording Time			
Status of Floc Carryover (YES/NO, if YES please write comments)			
Tank 1			
Tank 2			
Hours of sludge pumping for each Basin (Weekly or whenever required)			
Tank 1			
Tank 2			
Effluent Channel Cleaning for each Basin (Weekly or whenever required)			
Tank 1			
Tank 2			
Operating Problems, Remedies, and Remarks			
Sludge Lagoons in Service (YES/NO)			
Checked by			

Record Checked by:

_____

Head, Purification Section

Figure E.6 Record Sheet Format for Sedimentation Facility

E.2.3 Filtration Facilities

The main purpose of filtration is to remove floc, suspended matter, precipitates, and microorganisms carried over from preceding units, and to remove chemical precipitates in case of removal of hardness,

iron and manganese. Main operation activities include maintenance of constant depth of water over filter media and flow rate within design range. Also, backwashing should be carried out when the effluent turbidity gets higher than standard or when the head loss increases significantly.

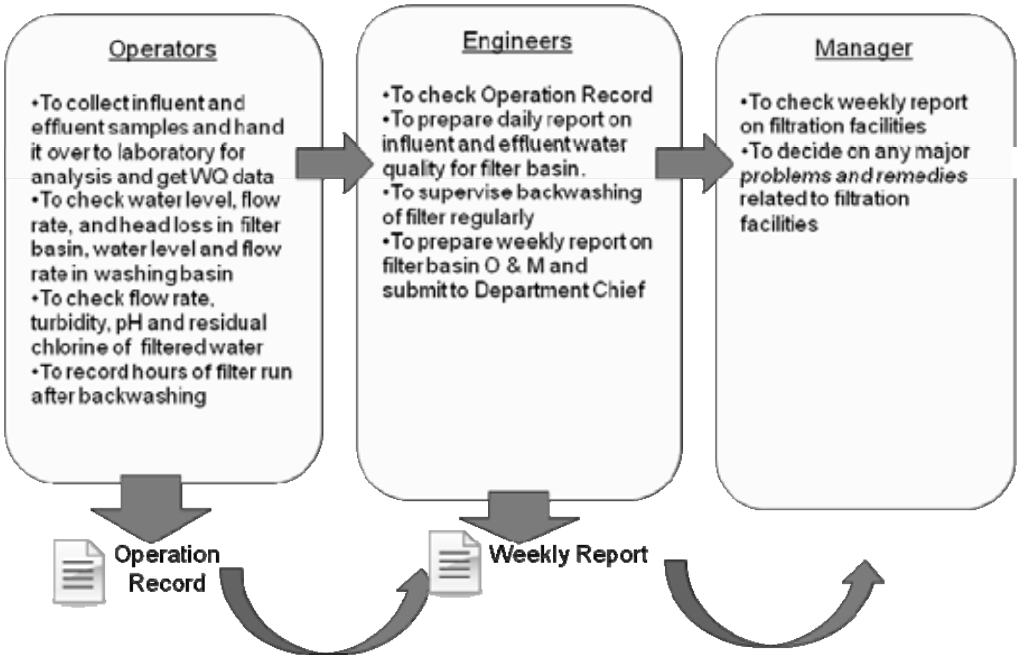

Figure E.7 Work Process Flow for Filtration Facilities

For the filters, it is important to monitor water level and head also in filter basin. It is also important to monitor the water level and flow rate in washing basin. Daily records should also be made of the amount of water treated through filters and the water quality of filtered water. Examples of record sheet formats have been presented in Figure below.

Daily Filter Record

Year: _____ Month: _____ Date: _____ . Filter Number:_____. Previous Run:_____hours

Time	Recording Time	Working Status (YES/NO)	Depth below High Water Level (m)	Backwashing			Operating Problems, Remedies, Remarks	Checked By
				Start Time (hh:mm)	Close Time (hh:mm)	Duration (hh:mm)		
0:00								
1:00								
2:00								
3:00								
4:00								
5:00								
6:00								
7:00								
8:00								
9:00								
10:00								
11:00								
12:00								
13:00								
14:00								
15:00								
16:00								
17:00								
18:00								
19:00								
20:00								
21:00								
22:00								
23:00								

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Head, Purification Section

Figure E.8 Record Sheet Formats for Filtration Facilities

E.2.4 Disinfection Facilities

Disinfection is a process used to destroy or inactivate disease-causing (pathogenic) organisms in water, such as viruses, bacteria, fungi, or protozoa and it does not sterilize the water. Chlorine is the most commonly used disinfectant for water and is primarily used as either pre-chlorination (to raw water) of post-chlorination (to treated water) or in the form of booster chlorination (water from clean water reservoir). Low turbidity is favorable to disinfection. In its operation, care should be taken against its leakage and one of the key problems is formation of THM (trihalomethane), which is carcinogenic substance and harmful to human health.

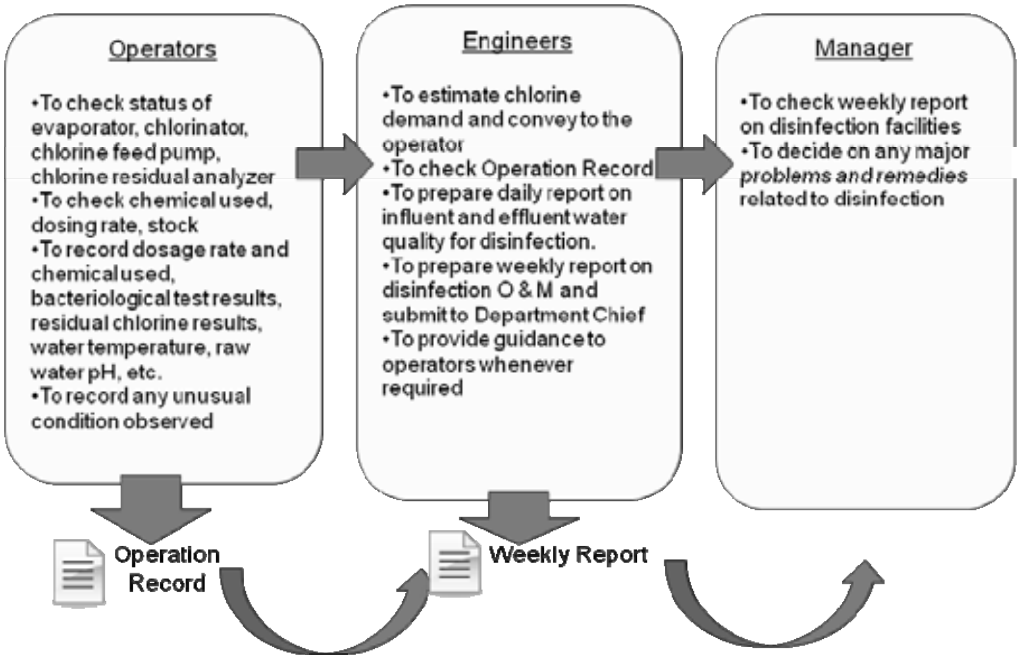

Figure E.9 Work Process Flow for Disinfection

Following key points should be taken care of during operation of chlorination facilities:

- No direct heat to chlorine cylinder
- Chlorinator, evaporator, storage tanks should be inspected daily. Check should be made for low gas pressure and feeding.
- Diffusers should be inspected for plugging or clog
- A total free residual chlorine of >0.2 mg/L or ppm at users end should be maintained through application of appropriate chlorine dosing rate. Treated water quality should be monitored daily.
- Test leak detectors and emergency equipment every 6 months and verify operator training
- Stock of chlorine should be checked daily.

The operators should prepare daily operation record for disinfection. An example of record sheet is presented below.

Operating Record Disinfection Facility - Chlorination Pump

Year: _____ Month: _____ Date: _____ .

	Shift 1 (7:00 ~ 14:00)	Shift 2 (14:00 ~ 20:00)	Shift 3 (20:00 ~ 7:00)
Recording Time			
Status of Chlorine Injection (ON/OFF)			
Pump I			
Pump II			
Chlorine Dosing Flow Rate (l/hr)			
Pump I			
Pump II			
Operating Problems, Remedies, and Remarks			
Checked by			

_____
Head, Purification Section

Operating Record Disinfection Facility - Chlorine Stock

Month: _____ Year: _____ (Check Everyday in the Afternoon)

Day	Level in Mixing Tank		Chlorine Used (kg)	Chlorine in Stock (kg)	Chlorine Purchased (kg)	Checked By
	Tank I	Tank II				
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						

Record Checked by:

_____

Head, Purification Section

Figure E.10 Record Sheet Example for Disinfection Facility

E.2.5 Pumps and Reservoir

Main function of pumping is to supply water to distribution system with sufficient pressure and in adequate quantity, in case when it cannot be accomplished under gravity. Reservoir is used to take care of the time fluctuation in demand and to supply during power source or pump failure. It also increases detention time and helps disinfection.

The pumps should be inspected daily for pump condition, discharge head, motor and bearing temperature, and any unusual noise. The valve positions and switchgear selector switch positions should be checked. The pumps should be inspected annually for impeller wear, wear ring clearance, seal and bearing condition. The logs on each pump should be maintained, noting pumping hours, performance and any maintenance performed.

Elevated tanks and ground-level tanks should periodically be drained, cleaned, inspected, and repaired (if necessary). All storage facilities must be completely inspected and cleaned every 3-5 years. Record should be made for location, inspection date and findings, maintenance date and content. Work process flow and record sheet for pumping and storage facilities are given below.

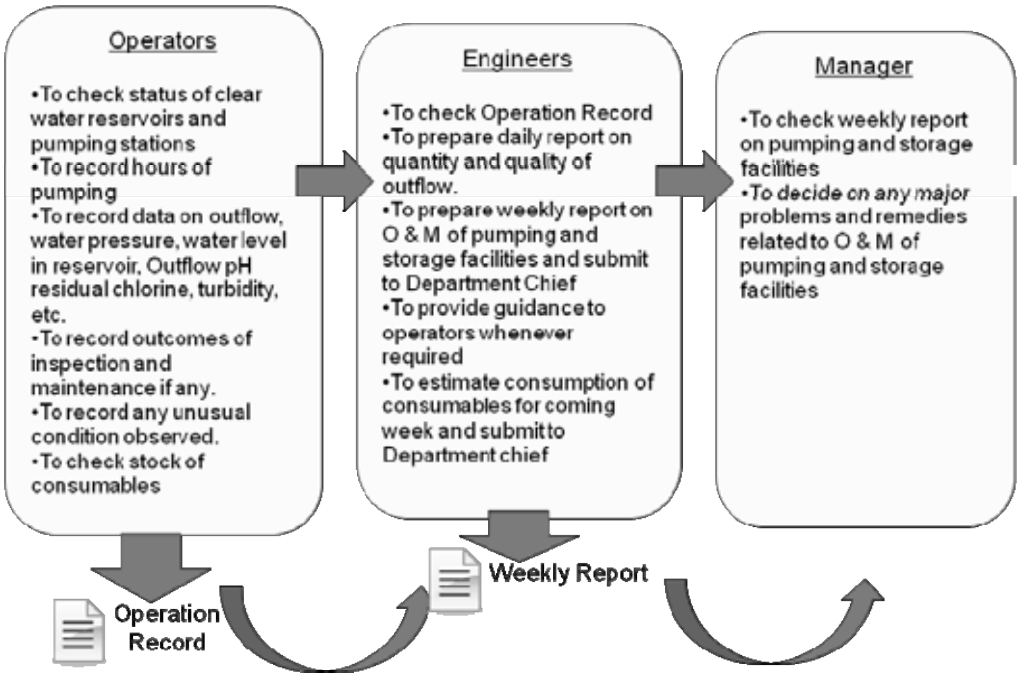

Figure E.11 Work Process Flow for Pumping and Storage Facilities

Operating Record Pumping Facility - General Data

Year: _____ Month: _____ Date: _____ .

	Shift 1 (7:00 ~ 14:00)	Shift 2 (14:00 ~ 20:00)	Shift 3 (20:00 ~ 7:00)
Recording Time			
Pump No. 1			
Check stability of intake pump (noise, vibration, leakage every shift)			
Noise			
Vibration			
Leakage			
Pump No. 2			
Check stability of intake pump (noise, vibration, leakage every shift)			
Noise			
Vibration			
Leakage			
Pump No. 3			
Check stability of intake pump (noise, vibration, leakage every shift)			
Noise			
Vibration			
Leakage			
Operating Problems, Remedies, and Remarks			
Checked by			

Record Checked by:

_____

Head, Purification Section

Operating Record Pumping Facility - Pumps Working Hours

Year: _____ Month: _____ Date: _____ .

Time	Shift 1 (7:00 ~ 14:00)	Shift 2 (14:00 ~ 20:00)	Shift 3 (20:00 ~ 7:00)	Total Daily
Recording Time				
Treated Water Pumps				
Pump No. 1				
Previous Hour Meter Reading				
Hour Meter Reading				
Total hours of Operation per Shift				0.00
Pump No. 2				
Last Hour Meter Reading				
Hour Meter Reading				
Total hours of Operation per Shift				0.00
Pump No. 3				
Last Hour Meter Reading				
Hour Meter Reading				
Total hours of Operation per Shift				0.00
Total pumping hours for all pumps per day				0.00

Record Checked by:

_____

Head, Purification Section

Figure E.12 Record Sheet for Pumps

Operating Record Storage Facility - Clear Water Reservoir at WTP

Year: _____ Month: _____ Date: _____ .

	Shift 1 (7:00 ~ 14:00)	Shift 2 (14:00 ~ 20:00)	Shift 3 (20:00 ~ 7:00)
Recording Time			
Water Level (m)			
Groundwater Reservoir I			
Groundwater Reservoir II			
Groundwater Reservoir III			
Status of Water Withdrawal (YES/NO)			
Groundwater Reservoir I			
Groundwater Reservoir II			
Groundwater Reservoir III			
Operating Problems, Remedies, and Remarks			
Checked By			

_____
Head, Distribution Section

Operating Record Storage Facility - 2

Year: _____ (To be carried out once every year). **Location: _____ .**

	Location	Inspection Date	Expected Next Inspection Date	Observation during Inspection	Maintenance Date	Content of Maintenance Activities	Expected Next Maintenance Date
Elevated Tank 1				- If there is any deposition or dirt in reservoir - If air vent is working properly - If water level indicator is working properly - If the paint on walls is ok. - If there is any crack, hole, or corrosion, either inside or outside.		- Reservoir should be drained. - Dirt and deposition should be cleaned and all water and dirt should be drained - After repairing and painting, tanks must be disinfected before being used. - Air vent should be cleaned.	
Elevated Tank 2							
Elevated Tank 3							
Checked By							

_____
Head, Distribution Section

Figure E.13 Record Sheet for Storage Facilities

E.2.6 Distribution Pipelines

Main role of water distribution pipelines is to convey water from treatment plant to consumers. It provides transmission and distribution functions and it also provides storage function to some extent.

For the case of distribution pipelines, the alignment of pipelines should be inspected for illegal connections, right-of-way encroachments, construction activity near pipelines, slime growth in pipes, leaks and damages. The operation of air-release and vacuum valves should be checked bimonthly. Positive pressure should be maintained in pipelines to keep water safe and certain minimum pressure should be maintained at the buildings. Operational data should be recorded on daily basis in record sheet. Work process flow and example of record sheets have been presented in Figures below.

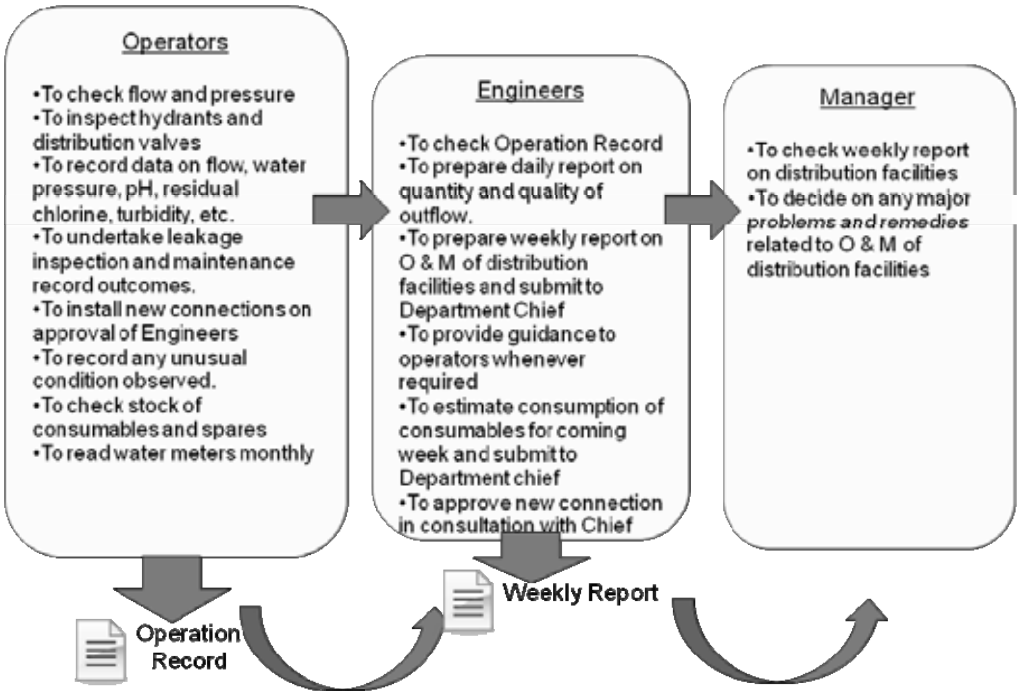

Figure E.14 Work Process Flow for Distribution Pipelines

Operating Record Distribution Facility - Pipe Repairing Records

Year: _____ Month: _____.

S. No.	Date	Location/ Address	Reference Drawing No.	Pipe Diameter (mm)	Pipe Material	Content of Repairing Activities	Supervising Engineer-in-charge
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

_____

Head, Distribution Section

Operating Record Distribution Pipelines Facility - Valves and Water Meter Inspection

Year: _____ **Month:** _____.

Date of Inspection							
Condition of Air-Release Valve							
Leakage condition near Valves							
Location							
Condition after repair							
Water Meter Inspection							
Location							
Last month reading							
This month reading							
Leakage condition							
Any other faults							
Problems, Remedies, and Remarks							
Checked by							

_____
Head, Distribution Section

Figure E.15 Record Sheets for Distribution Pipelines

E.2.7 Water Quality Monitoring

It is important to monitor WQ of source at intake or receiving well to watch for pollution of raw water and to determine dosage of reagents (alum), to monitor WQ of treated water to confirm quality at each step of purification, and to confirm final quality of service water at end of pipelines. Work process flow and example of record sheets for WQ monitoring has been shown below.

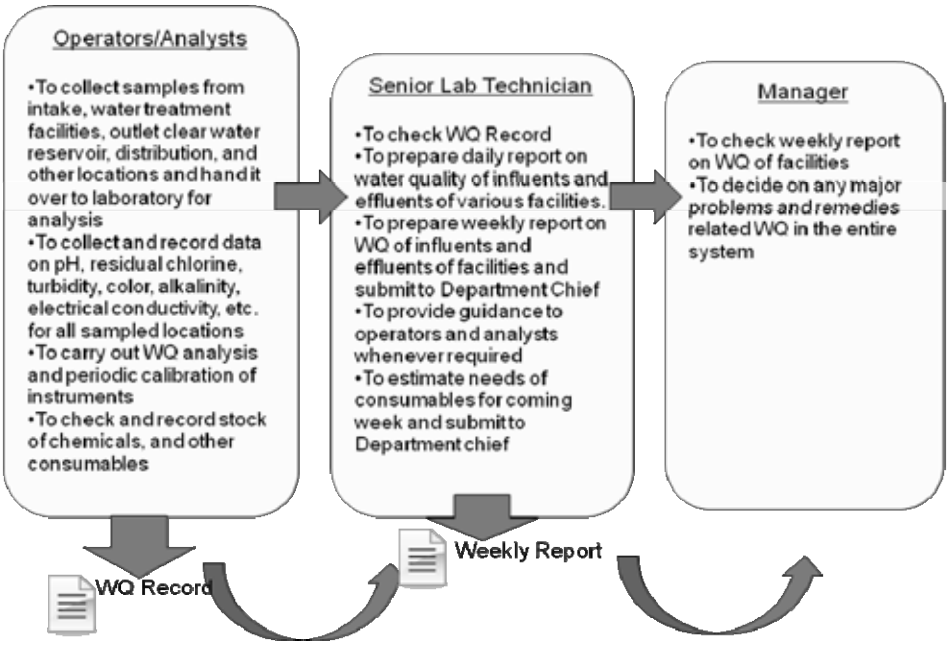

Figure E.16 Work Process Flow for Water Quality Monitoring

Daily Water Quality Monitoring Parameters

Year: 2009 Month: June Date: 26 .

			Sampling Time	14:25	
	Paremeter	Unit	Maximum allowable limit in Treated Water (SSMO)	Raw Water	Treated Water
1	Water Temperature	°C		29.7	29.8
2	pH	-	6.0-8.5	8.29	7.87
3	Color	CU	Nil	Little turbid	No color
4	Odor	-	Nil	No odor	No odor
5	Turbidity	NTU	5.0	22.3	2.04
6	Conductivity	μS	150.0	78	201
7	Total Dissolved Solids	mg/L	1000	56	130
8	Alkalinity				
9	Hardness	mg/L	200		
10	Residual Chlorine	mg/L			0.27
11	Salinity			44	100

Note:

Frequency of WQ monitoring has been kept minimal to make it practicable in existing condition.

Frequency of monitoring should be increased if necessary and practically feasible.

Record Checked by:

_____

Head, Purification Section

Weekly Water Quality Monitoring Parameters

Year: _____ Month: _____ .

	Paremeter	Unit	Maximum allowable limit in Treated Water (SSMO)	First Week		Second Week		Third Week		Fourth Week	
				Raw Water	Treated Water	Raw Water	Treated Water	Raw Water	Treated Water	Raw Water	Treated Water
1	Iron (Fe)	mg/L	0.5								
2	Manganese (Mn)	mg/L	0.4								
3	Nitrate	mg/L	30								
4	Nitrite	mg/L	0.5								
5	Chloride	mg/L	200								
6	Ammonia Nitrogen	mg/L									
7	Residual Chlorine										
8	Fecal Coliform	CFU/100 mL	Nil								
9	Total Coliform	CFU/100 mL	See note 1								

Note:

1: - 95% from the samples checked during the year must be free of any coliform bacteria in 100 mL of the sample.

2: -These weekly parameters should be monitored in addition to the daily parameters.

Record Checked by:

_____

Head, Purification Section

Free Residual Chlorine (mg/L) Record for the Month of _____20_____.

Day	Treated water	Public Tap - 1	Public Tap - 2	Public Tap - 3	Public Tap - 4	Public Tap - 5	Water Tanker - 1	Water Tanker - 2	Water Tanker - 3	Water Tanker - 4	Water Tanker - 5
1											
2											
3											
4											
5											
6											
7											
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Head, Purification Section

Figure E.17 Record Sheet Forms for Water Quality Monitoring

E.3 Check Lists for Operation and Maintenance

E.3.1 Daily Maintenance Check List

The minimum items that should be checked on daily basis are listed in Table below.

Table E.2 Check List for Minimum Daily Maintenance

	Item	Content	Daily
Water Purification Facilities (Coagulation, Sedimentation, Rapid Sand Filter)			
1	Water quality confirmation	① Residual chlorine	○
		② pH	○
		③ Turbidity	○
2	Flow rate confirmation	Visually, uniformly influent?	○
		Flow rate as specified?	○
3	Chemical dosing rate confirmation	① Chemical dosing rate proper?	○
		② Confirm chemical quantity held in the chemical tank.	○
4	Sedimentation Tank	Sludge not accumulated too much?	○
5	Rapid Sand Filter	Filtration resistance not high?	○
6	Mixer	Current values in proper ranges?	○
		Free from abnormal sound and abnormal vibration?	○
		Surface temperature not too high?	○
		Temperature rise not rapid?	○
		Lubricant oil filled up to proper level?	○
		Free from oil or grease leaking from gear, etc.?	○
Water Supply Pump			
1		Pressure value normal?	○
2		Current values in proper ranges?	○
3		Free from abnormal sound and abnormal vibration?	○
4		Bearing temperature not too high? (Not higher than 80 °C)	○
5		Free from water leakage from mechanical seals?	○
6		Mounting bolts not loosened?	○
Chemical Pumps (Chlorination Aluminum sulfate)			
1		Chemicals dosed properly?	○
2		Properties of chemical having no problem? (Not crystallized, etc.)	○
3		Free from abnormal sound and abnormal vibration?	○
4		Temperature not too high?	○
5		Free from liquid leakage from pump and pipe?	○

E.3.2 Periodic Maintenance Check List

The list of items that should be monitored periodically is presented in Table below.

Table E.3 Check List for Periodic Maintenance

	Item	Content	6-monthly
Water Purification Facilities (Coagulation, Sedimentation, Rapid Sand Filter)			
1	Apparatus and piping	① Mounting bolts not loosened?	○
		② Occurrence of rusting?	○
		③ Check for damage?	○
2	Coagulation Tank	① Not badly contaminated?	○
	Sedimentation Tank	② Sludge not accumulated?	○
3	Rapid Sand Filter	Filter sand not contaminated?	○
Water Supply Pump			
		Grease packed in proper quantity?	○
Chemical Pumps (Aluminum sulfate)			
		Confirm tightened conditions of pump head mounting bolts.	○

E.3.3 Chlorination Facilities

The residual chlorine concentration that should be maintained at the draw-off tap finally, was taken as 0.2 mg/l or greater normally.

Table E.4 Operation and Maintenance Requirements of Chlorination Facilities

Activity	**Frequency**	**Materials and Spare Parts**	**Tools and equipment**
Refill the chlorine tank.	Once or twice a week.	Chlorine compound, water.	Spoon, scale, bucket, stirring rod.
Adjust and clean the chlorinator.	Regularly.	Water.	Measuring cup, stopwatch..
Check and adjust chlorine doses.	Regularly.	Test media, water samples.	Test kit.
Replace the hoses and chlorinator.	Occasionally.	Hose, small tubes (plastic, glass, etc.), plug, bowl.	Knife, nail.
Paint the steel tank.	Annually.	Latex paint.	Steel brush, paint brush.

E.3.4 Generator

To ensure safe and stable operation daily, the following items are to be monitored:

(i) Power output, voltage (load state)
(ii) Temperature and pressure of lubricating oil and cooling water (lubrication and cooling states)
(i) Exhaust temperature and pressure (state of diesel engine)
(ii) Start and stop times (state of start control equipment)
(iii) RPM, voltage, frequency (state of speed and voltage control equipment)

The diesel engine is to be inspected by inspecting the output, rpm and so on from the operation

monitoring instruments, and deformation and looseness in anti-vibration base and anchor bolts should be checked especially in engines where reciprocating operation is being performed, and abnormalities in pipe connections should be carefully checked.

The points related to daily inspection and maintenance, and the measures to be adopted are summarized below.

Table E.5 Inspection of Diesel Generating Equipment

Function		Period	Details of inspection
Routine inspection	Common	During operation	Appearance, vibrations, foul odor, abnormal noise, temperature, discoloration, deformation, damage, slackness, pressure, rpm, leaks, piping supports, etc.
	Starting equipment	Monthly during operation	Battery gauge liquid level, leakage from starting valve and piping, start condition indicator
	Fuel equipment	Monthly during operation	Fuel stored quantity, fuel pump heating, fuel pressure, fuel consumed
	Lubricating oil equipment	Monthly during operation	Lubricating oil quantity and pollution, L.O. pump pressure, drains and cleaning of L.L filter L.O. temperature, L.O. cooler
	Cooling equipment	Monthly during operation	Leakage from cooling water pipe, cooling water temperature, cooling water pump operation, temperature and leakage from cooling water tank and radiator
	Intake and exhaust equipment	Monthly during operation	Intake and exhaust temperatures, leakage and color of exhaust from exhaust pipe and silencer
	Generator	During operation	Ammeter, frequency and power meters, state of couplings
	Instruments and cooling devices	During operation	Pressure gauge, rpm meter, temperature gauge, voltmeter

Table E.6 Problems and Remedies in Generator

Breakdown	Cause	Measures
Does not start or difficult to start	Low starting air pressure	Run the charging compressor, restore air pressure, switch over to auxiliary air tank
	Leak in air piping system, or malfunctioning of starting valve	Repair locations where air is leaking; inspect and repair starting valve
	Drop in capacity of battery for starting; breakdown of motor for starting	Charge battery; inspect and repair motor for starting
	Incorrect viscosity of lubricating oil; priming inadequate	Use oil of appropriate viscosity; adopt correct priming or automatic priming controls
	Inadequate fuel; inflow of air into the fuel pipe	Re-fuel and bleed out air completely
	Breakdown of control equipment	Inspect and repair the control equipment
Equipment starts, but rpm does not reach the specific level or rpm is irregular	Contamination of fuel by water and so on; entry of air in fuel pipe, poor quality of fuel	Drain out water, bleed out air, and replace fuel with good quality of fuel
	Faulty injection timing of fuel pump; defective governor operation	Inspect, adjust and repair fuel pump or governor
	Clogging of fuel filter	Clean out drain or replace
Output is inadequate	Part of the fuel pump and nozzle fuel pipe is defective	Examine and repair defective parts; inspect and repair explosive state
	Clogging of fuel filter	Drain out and clean filter
	Inadequate supply of air	Inspect and repair turbocharger; clean or replace air filter
	Faulty injection timing of fuel pump and defective governor operation	Inspect, adjust and repair fuel pump or governor
	Drop in compressive pressure of piston	Repair and replacement of piston rings; extra tightening of head gaskets
	In case of overload	Adjust to obtain the appropriate load
Machinery becomes heated up	Overload and defective injection timing of fuel pump	Adjust to the appropriate injection timing
	Inadequate cooling water; leakage/ clogging of radiator	Ensure appropriate quantity of cooling water; inspect and repair radiator
	Inadequate or defective lubricating oil; drop in pressure	Refill lubricating oil; replace with the appropriate lubricating oil; repair the lubricating oil pump
Machinery stopped suddenly	Fuel used up; air or foreign matter mixed up in fuel system	Refuel; bleed out air from piping and pump
	Breakdown of governor, turbocharger	Repair and adjust defective parts

E.3.5 Pumping Facilities

The parameters that should be considered during routine and periodic inspection of pumps are listed in Table below.

Table E.7 Inspection of Pumps

Category	Equipment	Period	Details of inspection
Routine inspection	Common	During patrol	Appearance, vibration, foul odor, abnormal noise, temperature, oil pressure, discoloration, deformation, damage
	Pumps	Monthly	Quantity, contamination, leaks of lubricating oil (oil, grease), oil-ring operation, heat generated in gland packing
	Control equipment and instruments	Monthly	Indicated values on pressure gauge, temperature gauge, and so on
Periodic inspection	Common	During inspection	Slackness, vibration, wear, deterioration and damage to various parts
	Pumps	Annually	State of replacement of lubrication oil, filling, cleaning and painting, adjustment, loading, replacement of gland packing, centering adjustments
	Control equipment and instruments	Annually	Calibration of pressure gauge, temperature gauge, and so on

Table E.8 Problems and Remedies with Pumps

Breakdown	Cause	Measures
Pump does not fill up fully	Air is being sucked from the gland	Replace or tighten gland packing, and adjust the gland seal
	Air is being sucked in from the discharge valve	Improve the water tightness of valve
	Air is being sucked in from pipe joint	Tighten or replace the packing at the leakage location
	Foot valve is deficient	Disassemble and inspect the valve or repair it
	Vacuum pump is defective	Inspect the pump and repair it if necessary
	Defect in the solenoid valve for suction	Inspect the valve and repair it if necessary
Does not start	Starting conditions are not satisfied	Examine and confirm each condition
	Protective circuit is activated	Examine the protective circuit and eliminate the cause
	Motor breakdown	Inspect and repair
No water discharged when pump operated	Water is not filled up adequately in the pump or the suction pipe	Prime the pump again
	Suction valve or discharge valve is closed	Inspect and open the valve fully
	Strainer or inlet pipe is clogged	Disassemble, check and clean the pipe
	Foreign matter clogging the impeller	Disassemble and remove the foreign matter
	Direction of rotation is reversed	Change over the wiring of the motor
Specified water flow rate not obtained	Air mixed up in water	Check for entry of air from the suction pipe joint and pump gland; prevent air entry
	Immersed depth of suction pipe is inadequate because of low water level	Raise the water level to above the specified level. Extend the suction pipe to ensure adequate immersion
	Foreign matter clogging the impeller	Disassemble and remove the foreign matter
	Liner ring is worn out.	Repair
	Abnormal wear of impeller	Repair or replace
Water discharges initially but stops soon after	Water is not filled up adequately in the pump or the suction pipe	Prime the pump again
	Air is mixed in the water	Examine and repair the suction pipe flange

Breakdown	Cause	Measures
	Gland packing or sleeve has deteriorated or has abnormal wear	Seal off the gland packing adequately; replace the worn-out part
	Air pocket is formed in the suction pipe	Modify the pipe and remove air pocket
Overloading occurs	Operates outside the operating range of specified water flow and specified head	Adjust the degree of opening of discharge valve
	Contamination by dirt or other foreign matter	Clean the pump suction tank and prevent entry of foreign matter
	Gland packing is excessively tightened	Adjust to normal tightening pressure

Table E.9 Inspection of Electric Motors

	Equipment	Period	Details of inspection
Routine inspection	Common	During patrol	Appearance, vibration, foul odor, abnormal noise, temperature, oil pressure, discoloration, deformation, damage
	Body	Monthly	State of voltage, current, frequency, air temperature, ventilation, cooling, etc. State of dirtiness of oil, oil quantity, leaking oil or grease, lubricating oil port, and plugs

Table E.10 Problems in Electric Motors and Remedies

Breakdown	Cause	Measures
Start is disabled Phenomenon other than abnormal noise, abnormal odor, abnormal vibration and heat	Abnormality in control circuit, overloading, defective alignment, unbalanced rotating body	Inspect control circuit and interlocking circuit; adjust alignment, measured power source voltage, ensure appropriate voltage, remove the cause of overload.
Does not start Speed does not increase	Power and protective device has not been reset; oil quantity is inadequate; electrodes are dislodged; or breakdown of control circuit	Check power source voltage, inspect wiring connections, repair the disconnected location
Abnormal noise, abnormal odor, abnormal vibration and heating	Oils and greases used up, load connection is defective or, metallic resistor is burnt out	Insulate, examine power source and clean filters of cooling equipment, inspect power source voltage
Primary current is unstable and rpm does not stabilize. Specified rpm is not reached	Power source abnormality, abnormal load, defective contact of short-circuit equipment, dirty electrode/ electrolyte	Examine unbalanced power source and restore normal power, inspect and maintain electrolyte and electrodes
Does not start even after switching on power, or if it starts protective device activates.	Contact defect or break in wiring, fuse, or switch	Check the power circuit from the power source to the electric motor terminals; examine and remove the cause of protective action
	Interlocking circuit does not reset	Examine the interlocking conditions, confirm safety and then reset the conditions and try again
	Defect in starting equipment	Repair or replace defective part

E.3.6 Valves

The body of the check valve is raised perpendicularly with respect to the flow within the pipe. Thus, if used with the valve open at the intermediate position, the body may deform, so such an operation is not preferred. The valve is always under strong water pressure and is easily contaminated by foreign

matter or is likely to wear out easily. So, the inspections and checks below must be frequently made.

	Equipment	Period	Details of inspection
Routine inspection	Common	During patrol	Flange leak, vibration, abnormal noise, deformation, damage
	Valve body	Monthly	Water leak from gland packing, anti-vibration fitting and shaft connection
	Drive equipment and control equipment	Monthly	Quantity of lubricating oil (oil, grease), dirtiness and state of leakage, state of oil filling port and plugs
Periodic inspection	Common	During inspection	Slackness, vibration, paint and rusting of various parts
	Valve body	Annually	Excessive tightening of bolts and nuts, replacement of gland packing
	Drive equipment and control equipment	Annually	Adjusting the opening

APPENDIX – F

CAPACITY DEVELOPMENT PLAN

APPENDIX - F CAPACITY DEVELOPMENT PLAN

This appendix includes following supporting materials to capacity development plan.

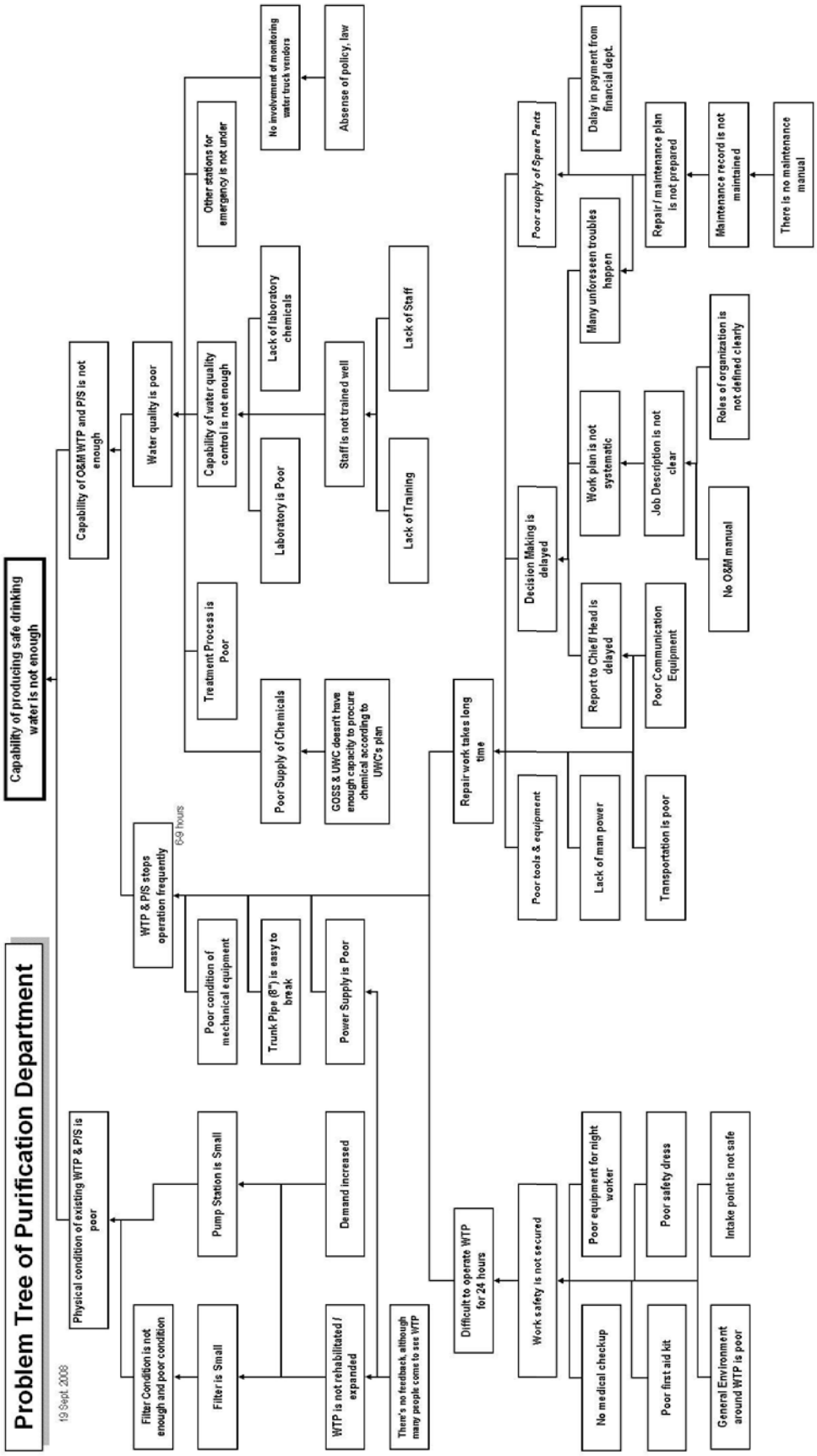

Figure F.1 Problem Tree of Purification Department

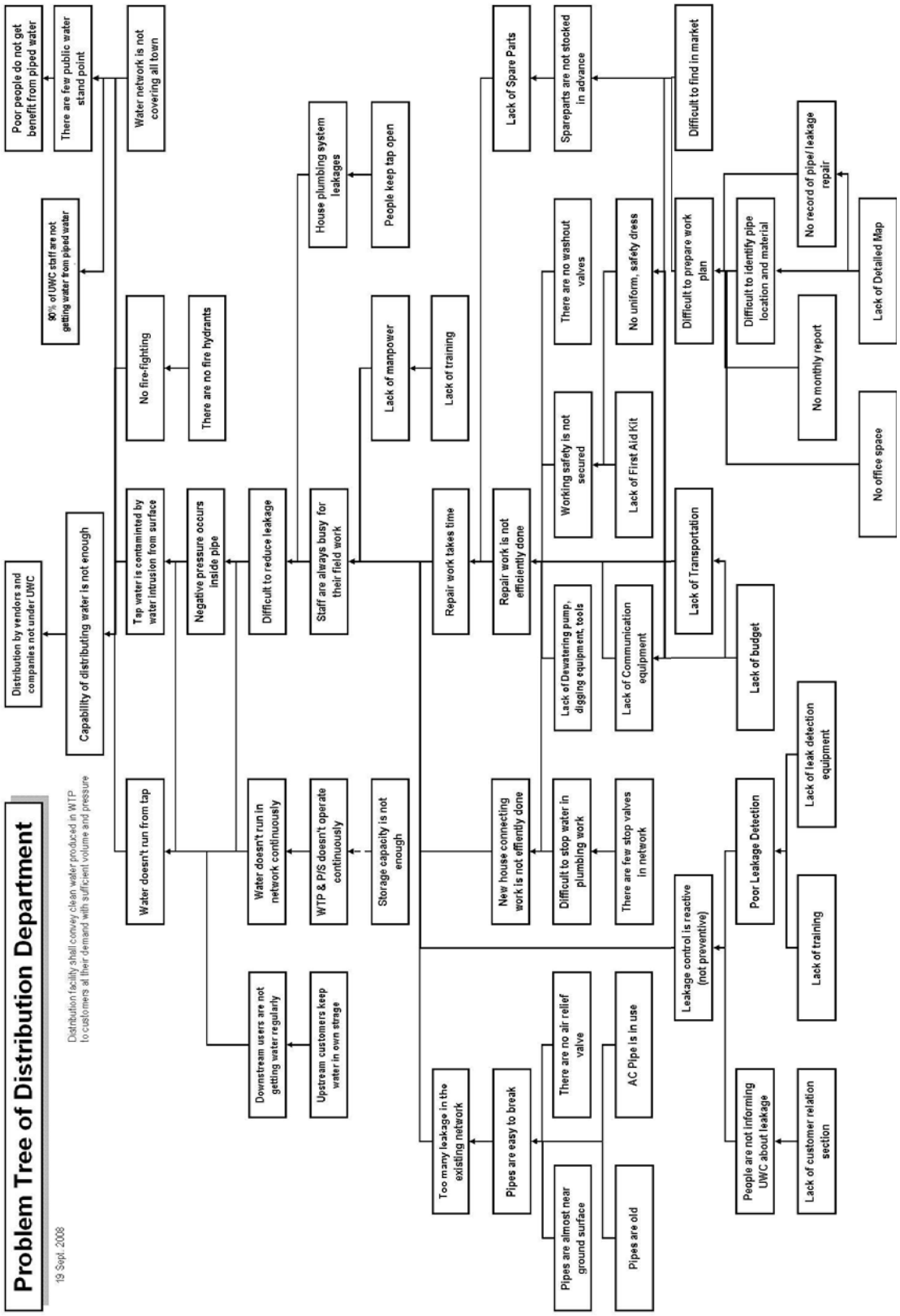

Figure F.2 Problem Tree of Distribution Department

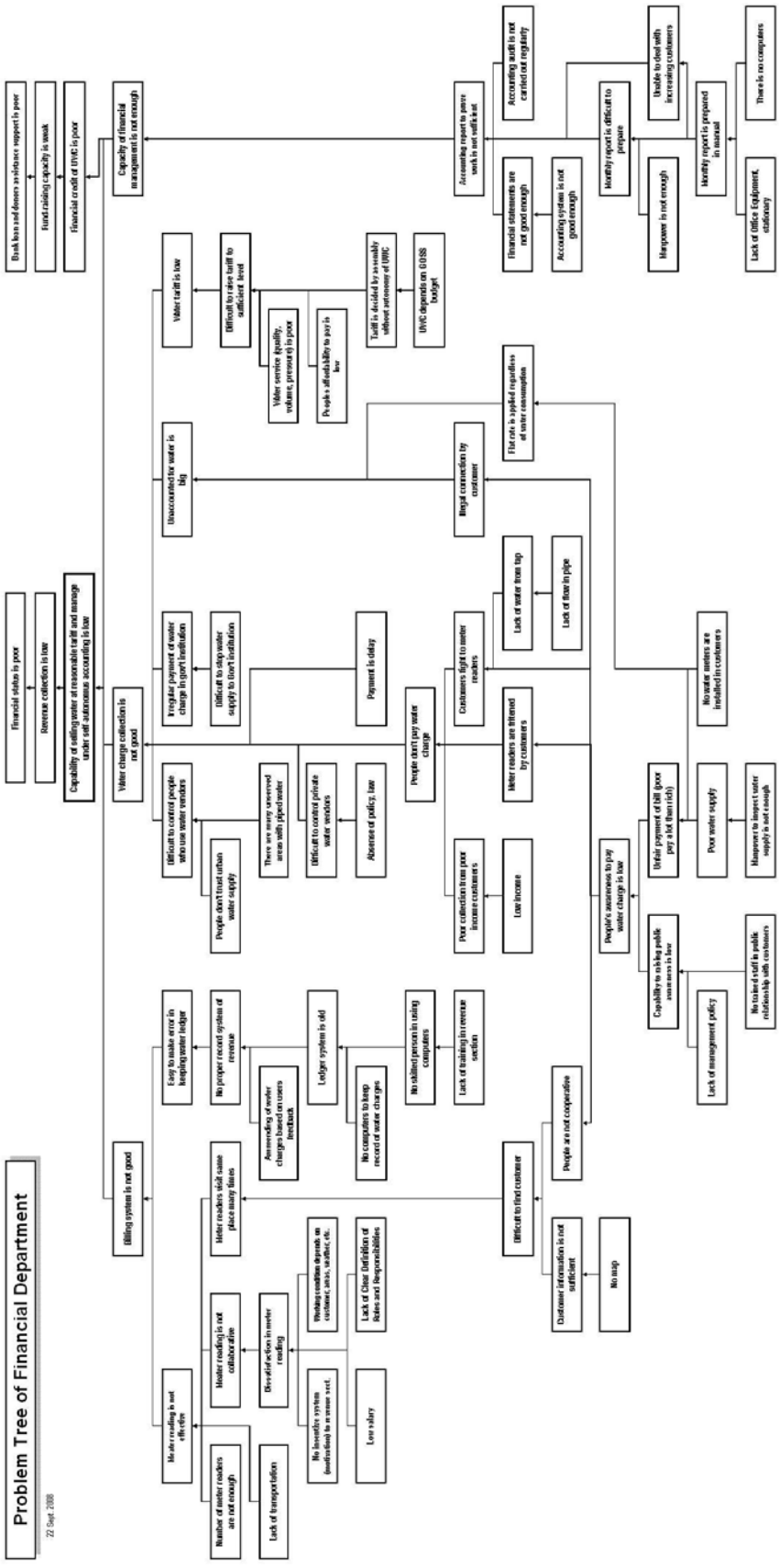

Figure F.3 Problem Tree of Financial Department

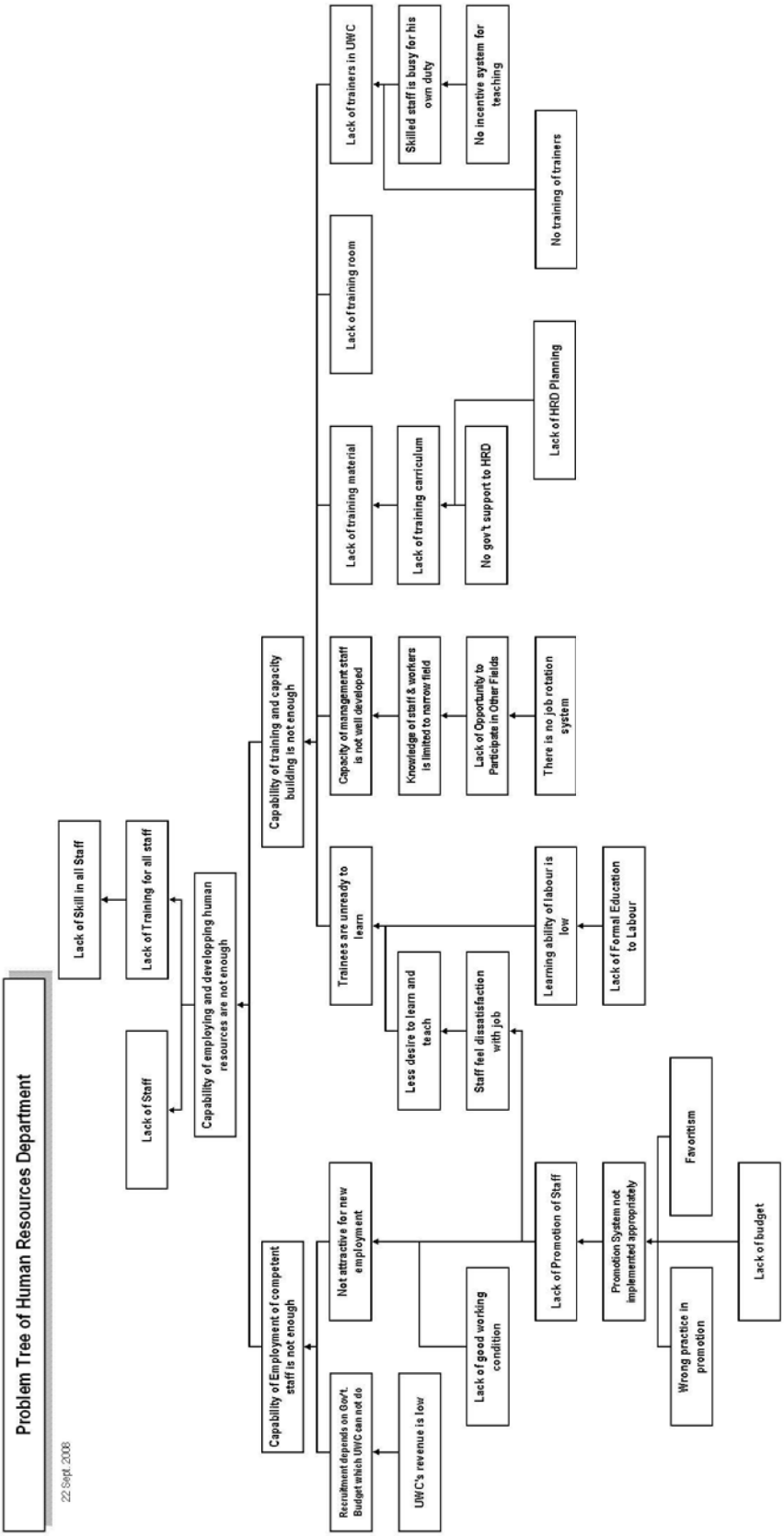

Figure F.4 Problem Tree of Human Resources Department

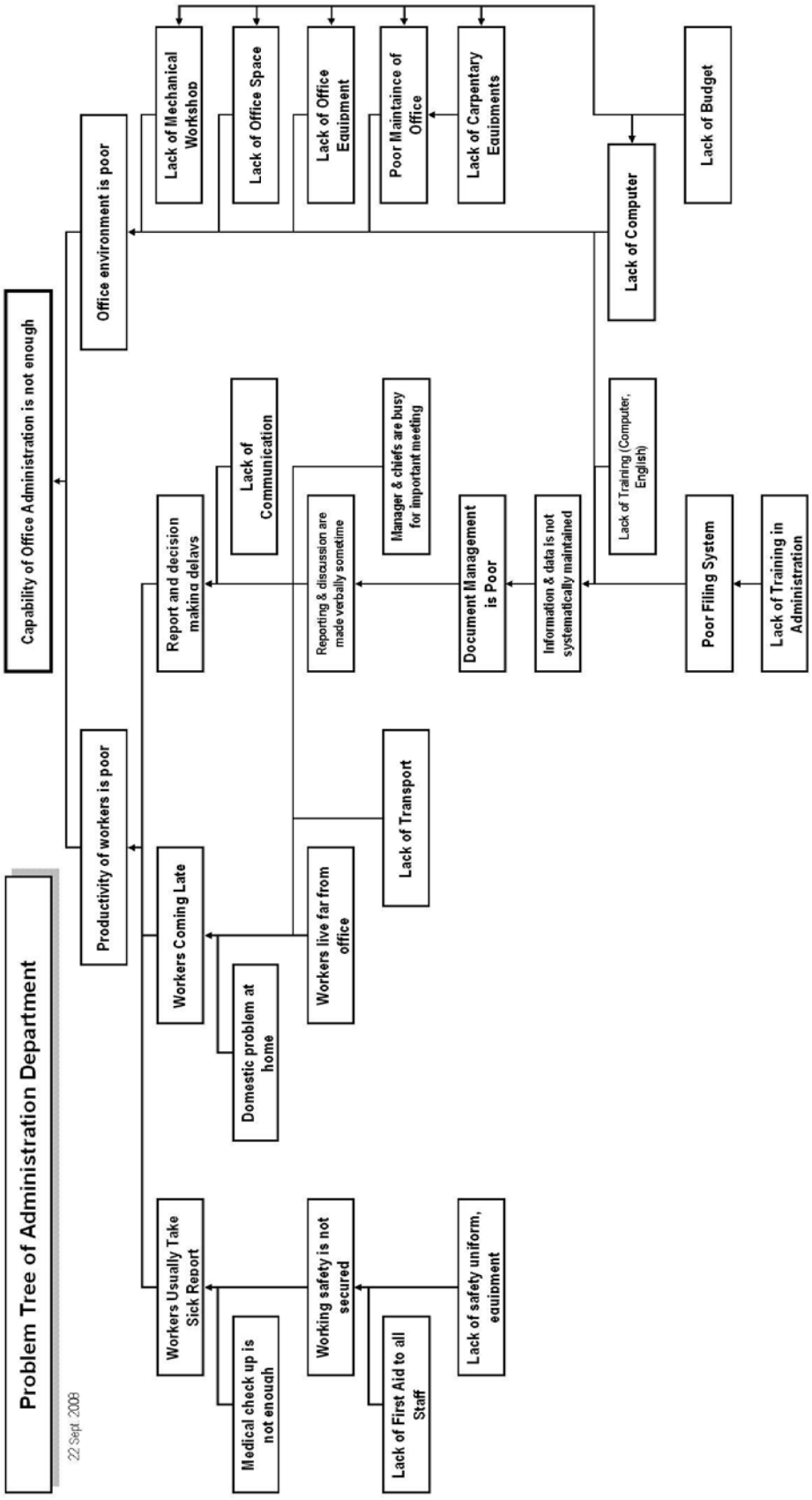

Figure F.5 Problem Tree of Administration Department

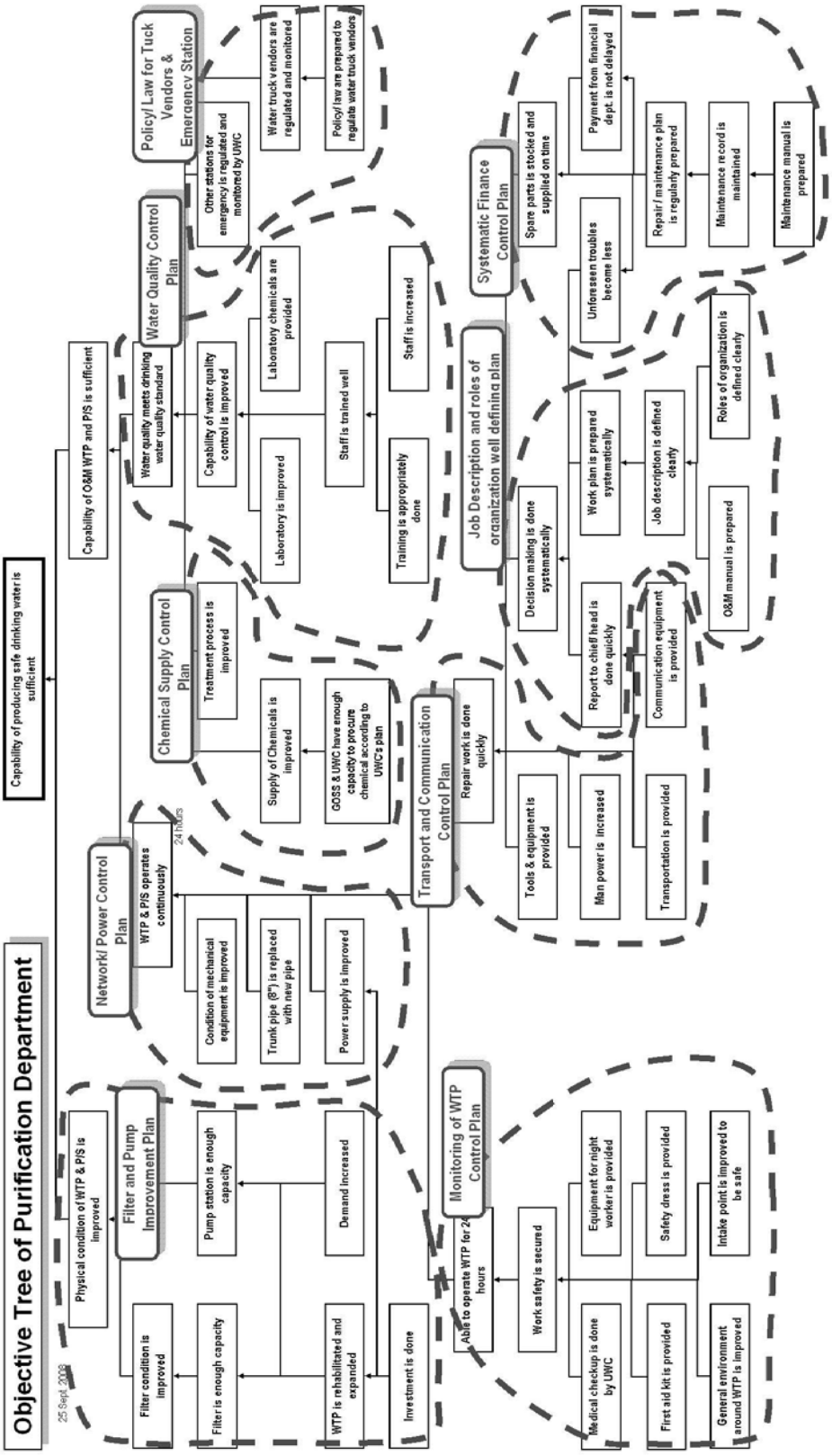

Figure F.6 Objective Tree of Purification Department

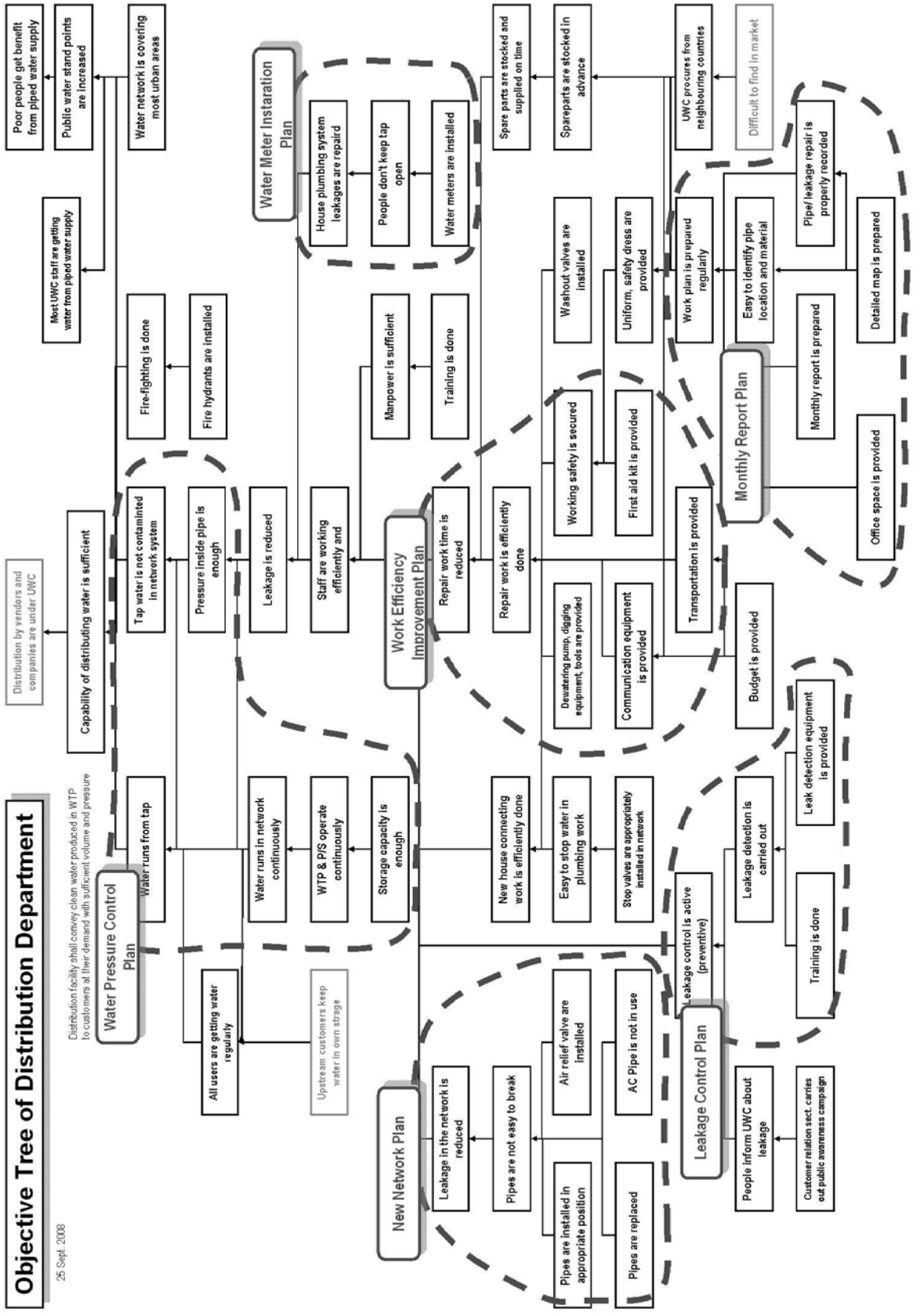

Figure F.7 Objective Tree of Distribution Department

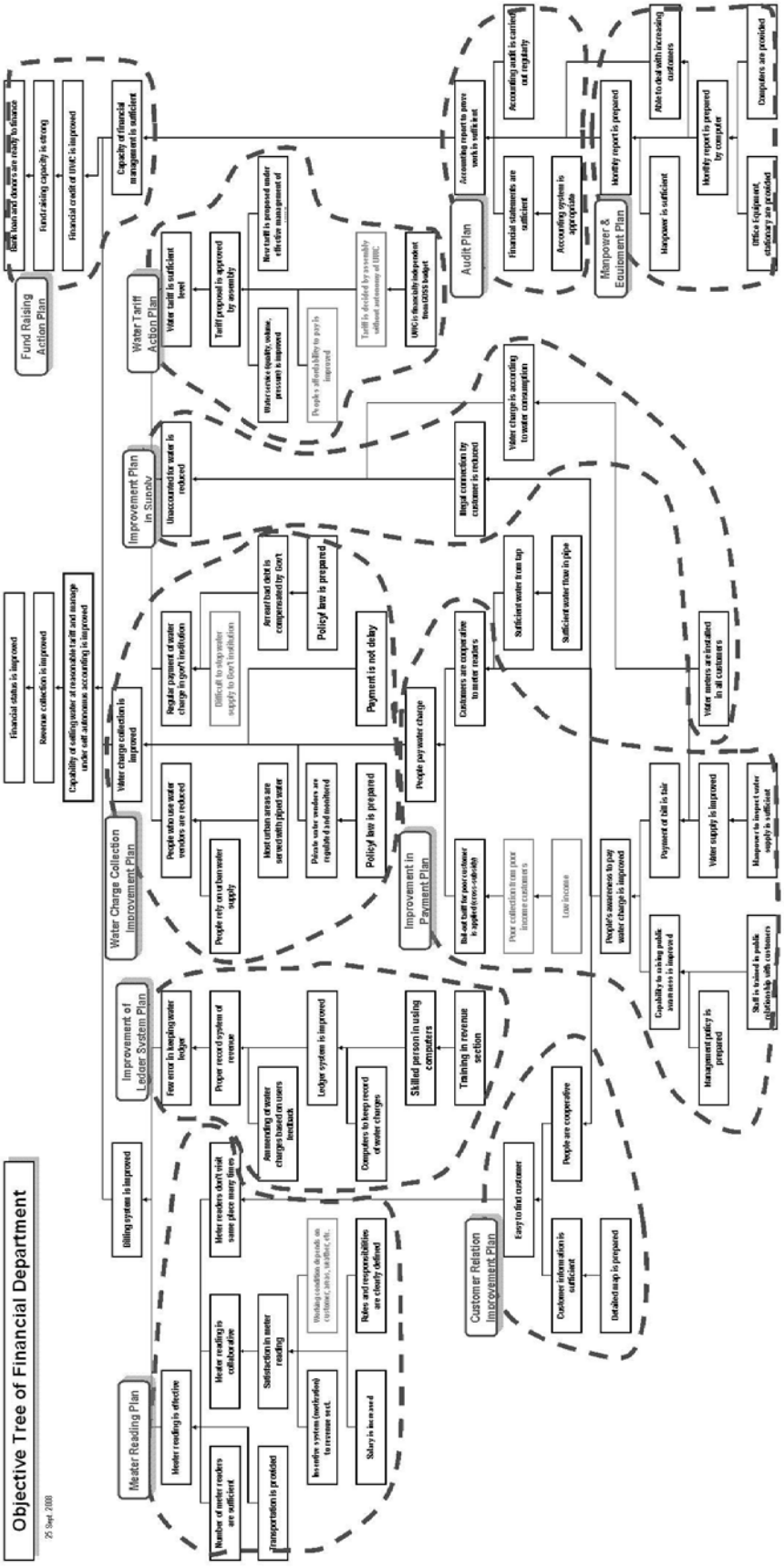

Figure F.8 Objective Tree of Financial Department

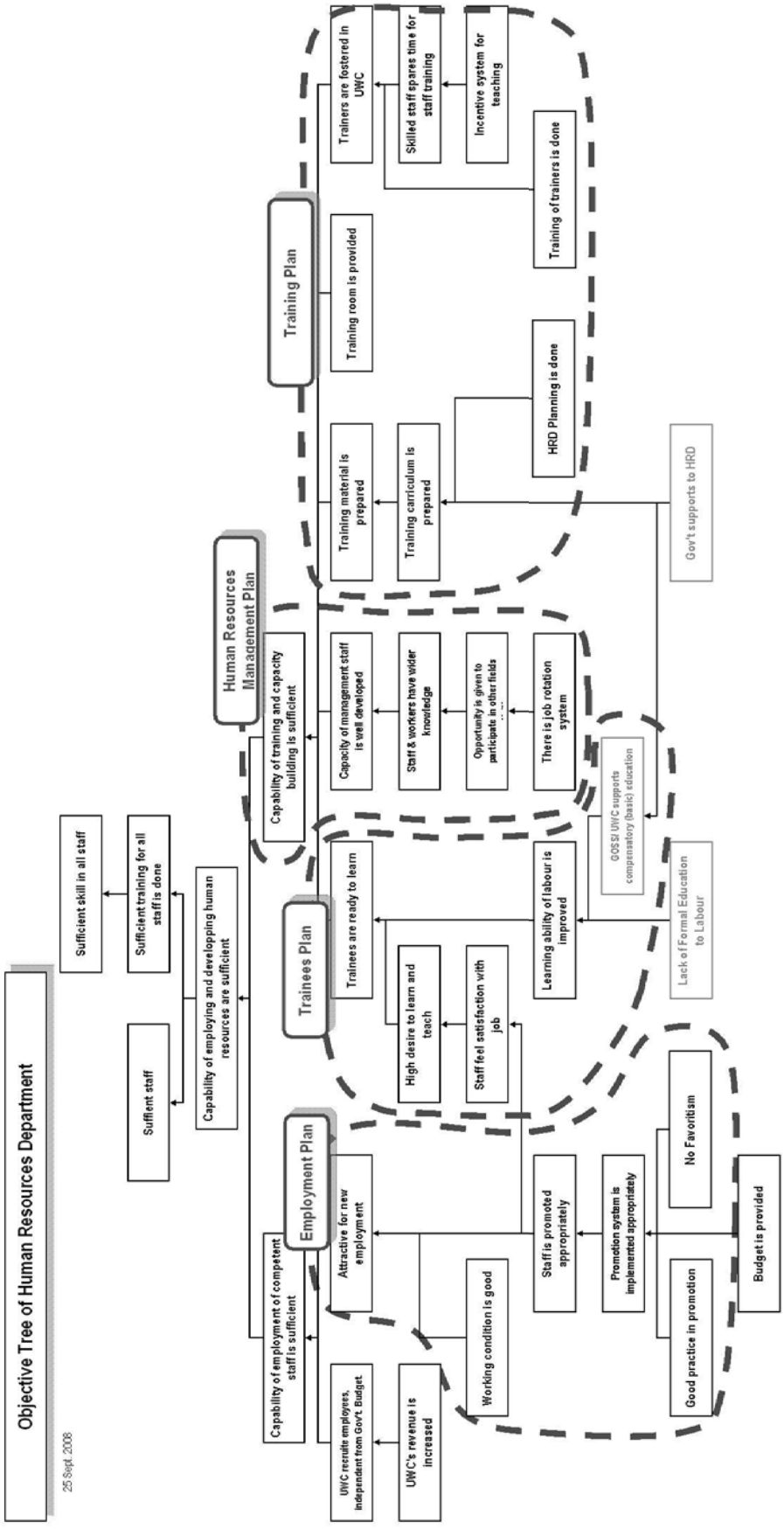

Figure F.9 Objective Tree of Human Resources Department

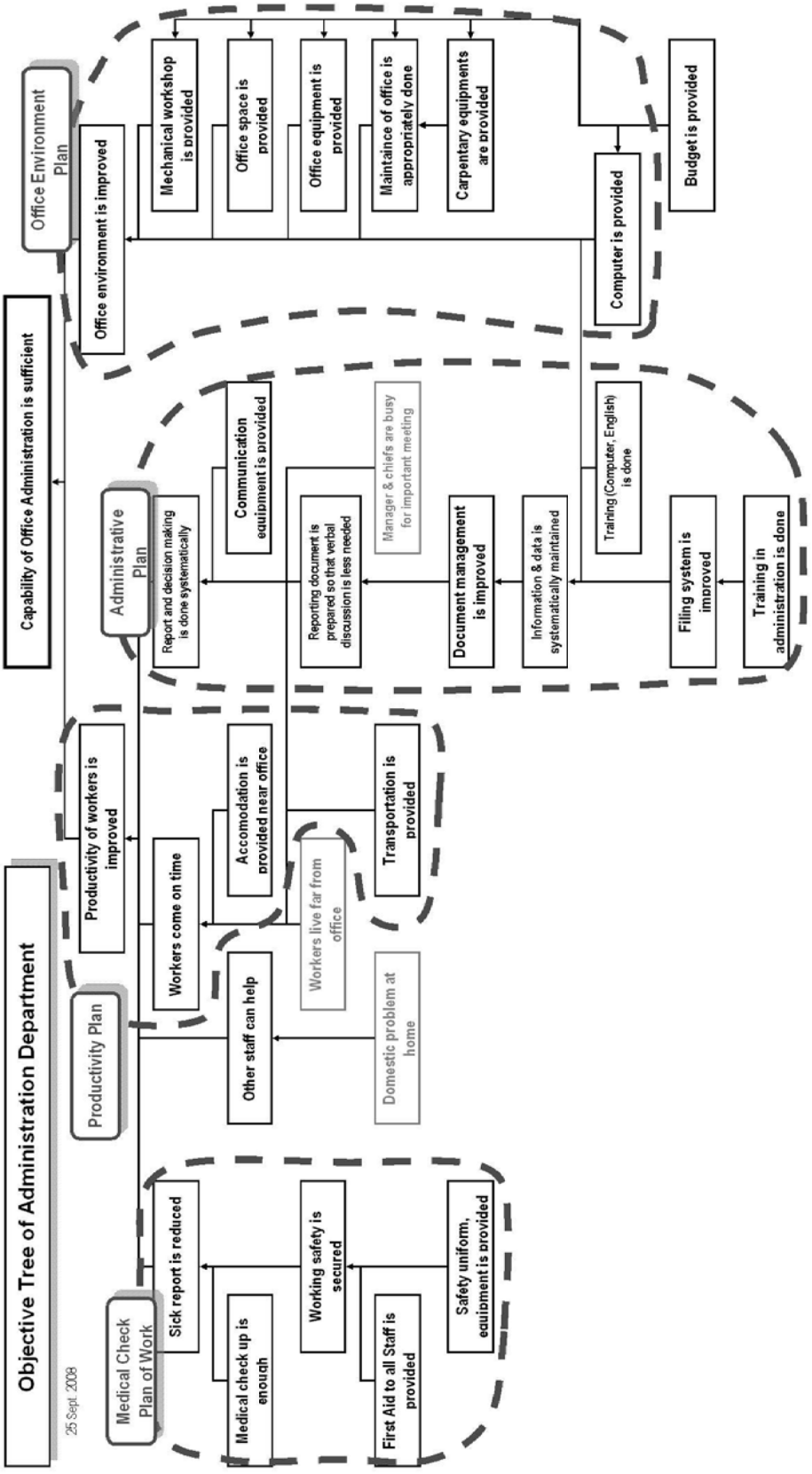

Figure F.10 Objective Tree of Administration Department

Table F.1 List of CD Action Plans Identified through PCM Workshop

	Name	Outcome	Main Activity
1	Network/ power control plan	WTP & PS operates continuously	− Improvement of power supply − Replacement of trunk pipe (8") − Improvement of condition of mechanical equipment
2	Filter & pump improvement plan	Physical condition of WTP & PS is improved	− Rehabilitation of WTP − Upgrading capacity of pumping station
3	Monitoring of WTP control plan	Staff is able to operate WTP for 24 hours	− Provision of medical checkup − Provision of first aid kit − Provision of safety ware − Improvement of general environment of WTP
4	Transport & communication control plan	Repair work is done quickly	− Provision of tools and equipment − Increase of manpower − Provision of transportation − Provision of communication equipment
5	Chemical supply control plan	Treatment process is improved	− Improvement of chemical supply
6	Water quality control plan	Water quality meets drinking water quality standard	− Improvement of laboratory − Provision of laboratory chemical − Staff is trained (laboratory)
7	Job description & roles of organization well defining plan	Decision making is done systematically	− Preparation of O&M manual − Definition of roles & organization − Preparation of work plan
8	Systematic finance control plan	Spare parts are stocked and supplied on time	− Preparation of maintenance manual − Preparation of repair/ maintenance plan
9	Policy/ law for truck vendors & emergency station	Water truck vendors and other stations for emergency are regulated and monitored by UWC	− Preparation of policy and law to regulate water truck vendors
10	Water pressure control plan	Water runs from tap without contamination through network	− Increase of capacity of storage reservoir − Continuous operation of WTP & P/S
11	Water meter installation plan	House plumbing system leakages are repaired	− Installation of water meter
12	New network plan	Leakage in the network is reduced	− Replacement of old pipes − Installation of air relief valves
13	Leakage control plan	Leakage control is active (preventive)	− Provision of leakage detection equipment − Training for leak detection
14	Work efficiency improvement plan	Repair work is efficiently done and repair work time is reduced	− Provision of transportation − Provision of communication equipment − Provision of dewatering pump, digging equipment and tools − Provision of first aid kit
15	Monthly report plan	Work plan is prepared regularly	− Provision of office space − Preparation of detailed map − Preparation of monthly report − Preparation of pipe/ leakage repair record
16	Meter reading plan	Meter reading is effective	− Provision of job description (roles & responsibility) − Introduction of incentive system − Provision of transportation − Increase in number of meter readers
17	Improvement of ledger system plan	Few error in keeping water ledger	− Improvement of ledger system − Improvement of record system of revenue − Training in revenue section, including computer operation − Provision of computer to keep record of water charges
18	Customer relationship	Easy access to customer	− Preparation of detailed map of customers

	Name	Outcome	Main Activity
	improvement plan		− Improvement of customer information
19	Improvement in payment plan	People pay water charge	− Increase of manpower to inspect water supply − Staff training on public relationship with customers − Raising public awareness to pay water charge − Introduction of bail-out for poor customer
20	Water charge collection improvement plan	Water charge collection is improved	− Preparation of policy/law to regulate and monitor private water vendors − Preparation of policy/law to compensate arrear or bad debts by Gov't
21	Improvement plan in supply	Unaccounted for water is reduced	− Installation of customer water meter − Reduction of illegal connection
22	Water tariff action plan	Water tariff is at sufficient level	− Proposal of new water tariff by UWC − Approval of new water tariff by assembly
23	Audit Plan	Accounting report to prove work is sufficient	− Introduction of new accounting system − Preparation of financial statements − Implementation of accounting audit
24	Manpower & equipment plan	Monthly report is prepared	− Preparation of monthly report by computer − Provision of computers − Provision of office equipment, stationary
25	Fund raising action plan	Bank loan and donors are ready to finance	− Improvement of financial management capability − Improvement of financial credit
26	Employment plan	UWC is attractive for new employment	− Implementation of good practice in promotion − Exclusion of favoritism − Improvement of working conditions
27	Trainees plan	Trainees are ready to learn	− Provision of supporting policy for compensatory (basic) education − Introduction of job satisfaction improving policy
28	Human resources management plan	Capability of training and capacity building is improved	− Introduction of job rotation system to give opportunity to participate in other fields
29	Training plan	Improvement of training capacity	− Planning HRD − Preparation of training curriculum − Preparation of training material − Training of trainers − Provision of training room − Introduction of incentive system or teaching
30	Medical check plan of work	Sick report is reduced	− Implementation of medical checkup − Provision of safety uniform and equipment − Provision of first aid kit
31	Productivity plan	Productivity of workers is improved	− Provision of transportation − Provision of accommodation near office
32	Administrative plan	Report and decision making is done systematically	− Training in administration, computer and English − Improvement of filing system, document management − Provision of communication equipment
33	Office environment plan	Office environment is improved	− Provision of computers − Provision of carpentry equipment to maintain office − Provision of office space and equipment − Provision of mechanical workshop

(Note) Tentatively prepared by JICA Study Team based on PCM workshop held during 17 – 25 Sep. 2008.

APPENDIX – G

COST ESTIMATION FOR MASTER PLAN

APPENDIX - G COST ESTIMATION FOR MASTER PLAN

Table of Contents

G.1 Estimated Unit Construction Cost of Pipeline

Item Description	Unit	L.C. (USD)	F.C. (USD)	Total (USD)
-1 DCI Pipe				
DCIP 1200mm	m	154	2,016	2,170
DCIP 1100mm	m	142	1,727	1,870
DCIP 1000mm	m	131	1,457	1,589
DCIP 900mm	m	120	1,202	1,322
DCIP 800mm	m	110	1,071	1,181
DCIP 700mm	m	100	858	958
DCIP 600mm	m	90	676	766
DCIP 500mm	m	81	506	587
DCIP 450mm	m	76	429	505
DCIP 400mm	m	71	366	437
DCIP 350mm	m	67	296	363
DCIP 300mm	m	62	249	311
DCIP 250mm	m	58	190	247
DCIP 200mm	m	53	152	205
-2 PVC Pipe				
PVC 300mm	m	16	136	152
PVC 250mm	m	14	102	116
PVC 200mm	m	12	74	86
PVC 150mm	m	10	53	63
PVC 100mm	m	8	36	44
PVC 75mm	m	8	30	37

G.2 Estimated Construction Cost of WTP

G.2.1 Expansion of the existing WTP

Item Description		L.C (USD)	F.C (USD)	Total (USD)
-A1	Raw Water Pump Facility			
	Civil and Architecture Works	61,000	170,000	231,000
	Mechanical and Electrical Works	0	603,000	603,000
	Sub Total of -A1	**61,000**	**773,000**	**834,000**
-A2	Receiving Well			
	Civil and Architecture Works	40,000	106,000	146,000
	Mechanical and Electrical Works	0	0	0
	Sub Total of -A2	**40,000**	**106,000**	**146,000**
-A3	Coagulo-sedimentation Basin			
	Civil and Architecture Works	143,000	381,000	524,000
	Mechanical and Electrical Works	0	27,000	27,000
	Sub Total of -A3	**143,000**	**408,000**	**551,000**
-A4	Rapid Sand Filter			
	Civil and Architecture Works	233,000	368,000	601,000
	Mechanical and Electrical Works	0	340,000	340,000
	Sub Total of -A4	**233,000**	**708,000**	**941,000**
-A5	Chemical Facility			
	Civil and Architecture Works	0	0	0
	Mechanical and Electrical Works	0	135,000	135,000
	Sub Total of -A5	**0**	**135,000**	**135,000**
-A6	Clear Water Reservoir			
	Civil and Architecture Works	115,000	357,000	472,000
	Mechanical and Electrical Works	0	30,000	30,000
	Sub Total of -A6	**115,000**	**387,000**	**502,000**
-A7	Transmission Pump Facilities			
	Civil and Architecture Works	0	0	0
	Mechanical and Electrical Works	0	1,569,000	1,569,000
	Sub Total of -A7	**0**	**1,569,000**	**1,569,000**
-A8	Electrical & Generator Facilities			
	Civil and Architecture Works	52,000	121,000	173,000
	Mechanical and Electrical Works	0	107,000	107,000
	Sub Total of -A8	**52,000**	**228,000**	**280,000**
-A9	Piping Works			
	Civil and Architecture Works	104,000	476,000	580,000
	Mechanical and Electrical Works	0	0	0
	Sub Total of -A9	**104,000**	**476,000**	**580,000**
	Total of Construction Cost	**748,000**	**4,790,000**	**5,538,000**
	Civil and Architecture Works	**748,000**	**1,979,000**	**2,727,000**
	Mechanical and Electrical Works	**0**	**2,811,000**	**2,811,000**

G.2.2 New West WTP

Item Description		L.C (USD)	F.C (USD)	Total (USD)
-A1	Intake Facility			
	Civil and Architecture Works	70,000	213,000	283,000
	Mechanical and Electrical Works	0	86,000	86,000
	Sub Total of -A1	**70,000**	**299,000**	**369,000**
-A2	Raw Water Pump Facility			
	Civil and Architecture Works	573,000	1,702,000	2,275,000
	Mechanical and Electrical Works	0	1,830,000	1,830,000
	Sub Total of -A2	**573,000**	**3,532,000**	**4,105,000**
-A3	Chemical Sedimentation Basin			
	Civil and Architecture Works	5,068,000	8,619,000	13,687,000
	Mechanical and Electrical Works	0	3,093,000	3,093,000
	Sub Total of -A3	**5,068,000**	**11,712,000**	**16,780,000**
-A4	Rapid Sand Filter			
	Civil and Architecture Works	2,958,000	3,472,000	6,430,000
	Mechanical and Electrical Works	0	9,459,000	9,459,000
	Sub Total of -A4	**2,958,000**	**12,931,000**	**15,889,000**
-A5	Chemical Facility			
	Civil and Architecture Works	156,000	363,000	519,000
	Mechanical and Electrical Works	0	1,670,000	1,670,000
	Sub Total of -A5	**156,000**	**2,033,000**	**2,189,000**
-A6	Clear Water Reservoir			
	Civil and Architecture Works	914,000	2,889,000	3,803,000
	Mechanical and Electrical Works	0	45,000	45,000
	Sub Total of -A6	**914,000**	**2,934,000**	**3,848,000**
-A7	Transmission Pump Facilities			
	Civil and Architecture Works	542,000	1,453,000	1,995,000
	Mechanical and Electrical Works	0	6,255,000	6,255,000
	Sub Total of -A7	**542,000**	**7,708,000**	**8,250,000**
-A8	Drainage Tank			
	Civil and Architecture Works	166,000	493,000	659,000
	Mechanical and Electrical Works	0	251,000	251,000
	Sub Total of -A8	**166,000**	**744,000**	**910,000**
-A9	Administration Facilities			
	Civil and Architecture Works	311,000	726,000	1,037,000
	Mechanical and Electrical Works	0	3,733,000	3,733,000
	Sub Total of -A9	**311,000**	**4,459,000**	**4,770,000**
-A10	Electrical & Generator Facilities			
	Civil and Architecture Works	207,000	484,000	691,000
	Mechanical and Electrical Works	0	5,064,000	5,064,000
	Sub Total of -A10	**207,000**	**5,548,000**	**5,755,000**
-A11	Piping Works			
	Civil and Architecture Works	341,000	3,458,000	3,799,000
	Mechanical and Electrical Works	0	0	0
	Sub Total of -A11	**341,000**	**3,458,000**	**3,799,000**
-A12	Other Works			
	Civil and Architecture Works	1,138,000	285,000	1,423,000
	Mechanical and Electrical Works	0	0	0
	Sub Total of -A12	**1,138,000**	**285,000**	**1,423,000**
	Total of Construction Cost	**12,444,000**	**55,643,000**	**68,087,000**
	Civil and Architecture Works	**12,444,000**	**24,157,000**	**36,601,000**
	Mechanical and Electrical Works	**0**	**31,486,000**	**31,486,000**

G.2.3 New East WTP

Item Description		L.C. (USD)	F.C. (USD)	Total (USD)
-A1	Intake Facility			
	Civil and Architecture Works	30,000	90,000	120,000
	Mechanical and Electrical Works	0	38,000	38,000
	Sub Total of -A1	**30,000**	**128,000**	**158,000**
-A2	Raw Water Pump Facility			
	Civil and Architecture Works	208,000	589,000	797,000
	Mechanical and Electrical Works	0	703,000	703000
	Sub Total of -A2	**208,000**	**1,292,000**	**1,500,000**
-A3	Chemical Sedimentation Basin			
	Civil and Architecture Works	415,000	1,315,000	1,730,000
	Mechanical and Electrical Works	0	988,000	988,000
	Sub Total of -A3	**415,000**	**2,303,000**	**2,718,000**
-A4	Rapid Sand Filter			
	Civil and Architecture Works	268,000	805,000	1,073,000
	Mechanical and Electrical Works	0	2,238,000	2,238,000
	Sub Total of -A4	**268,000**	**3,043,000**	**3,311,000**
-A5	Chemical Facility			
	Civil and Architecture Works	192,000	448,000	640,000
	Mechanical and Electrical Works	0	969,000	969,000
	Sub Total of -A5	**192,000**	**1,417,000**	**1,609,000**
-A6	Clear Water Reservoir			
	Civil and Architecture Works	425,000	1,501,000	1,926,000
	Mechanical and Electrical Works	0	45,000	45,000
	Sub Total of -A6	**425,000**	**1,546,000**	**1,971,000**
-A7	Transmission Pump Facilities			
	Civil and Architecture Works	472,000	1,226,000	1,698,000
	Mechanical and Electrical Works	0	1,670,000	1,670,000
	Sub Total of -A7	**472,000**	**2,896,000**	**3,368,000**
-A8	Drainage Tank			
	Civil and Architecture Works	71,000	215,000	286,000
	Mechanical and Electrical Works	0	261,000	261,000
	Sub Total of -A8	**71,000**	**476,000**	**547,000**
-A9	Administration Facilities			
	Civil and Architecture Works	480,000	1,120,000	1,600,000
	Mechanical and Electrical Works	0	1,580,000	1,580,000
	Sub Total of -A9	**480,000**	**2,700,000**	**3,180,000**
-A10	Electrical & Generator Facilities			
	Civil and Architecture Works	384,000	896,000	1,280,000
	Mechanical and Electrical Works	0	1,749,000	1,749,000
	Sub Total of -A10	**384,000**	**2,645,000**	**3,029,000**
-A11	Piping Works			
	Civil and Architecture Works	171,000	1,077,000	1,248,000
	Mechanical and Electrical Works	0	0	0
	Sub Total of -A11	**171,000**	**1,077,000**	**1,248,000**
-A12	Other Works			
	Civil and Architecture Works	313,000	194,000	507,000
	Mechanical and Electrical Works	0	0	0
	Sub Total of -A12	**313,000**	**194,000**	**507,000**
	Total of Construction Cost	**3,429,000**	**19,717,000**	**23,146,000**
	Civil and Architecture Works	**3,429,000**	**9,476,000**	**12,905,000**
	Mechanical and Electrical Works	**0**	**10,241,000**	**10,241,000**

G.3 Estimated Construction Cost of Transmission Pipeline

Item Description	Unit	LC/m	FC/m	Quantity	L.C. (USD)	F.C. (USD)	Total (USD)
-B DCIP 1000mm	m	131	1,457	9,100	1,196,377	13,262,249	14,458,626
DCIP 900mm	m	120	1,202	5,857	704,773	7,040,934	7,745,707
DCIP 800mm	m	110	1,071	2,500	275,525	2,678,025	2,953,550
DCIP 700mm	m	100	858	5,293	529,459	4,543,194	5,072,652
DCIP 500mm	m	81	506	4,450	358,848	2,251,344	2,610,192
DCIP 200mm	m	53	152	250	13,310	37,933	51,243
Total of Construction Cost					**3,078,000**	**29,814,000**	**32,892,000**

G.4 Estimated Construction Cost of Transmission Pump Station

G.4.1 Pump Station at North Low SR

Item Description	L.C. (USD)	F.C. (USD)	Total (USD)
-C1 Building Work			
Civil and Architecture Works	222,000	568,000	790,000
Sub Total of -C1	**222,000**	**568,000**	**790,000**
-C2 Pump Equipment Work			
Mechanical and Electrical Works	0	1,455,000	1,455,000
Sub Total of -C2	**0**	**1,455,000**	**1,455,000**
-C3 Electrical Work			
Mechanical and Electrical Works	0	977,000	977,000
Sub Total of -C3	**0**	**977,000**	**977,000**
-C4 Piping Work			
Civil and Architecture Works	20,000	166,000	186,000
Sub Total of -C4	**20,000**	**166,000**	**186,000**
Total of Construction Cost	**242,000**	**3,166,000**	**3,408,000**
Civil and Architecture Works	**242,000**	**734,000**	**976,000**
Mechanical and Electrical Works	**0**	**2,432,000**	**2,432,000**

G.4.2 Pump Station at South Low SR

Item Description	L.C. (USD)	F.C. (USD)	Total (USD)
-C1 Architecture Work			
Civil and Architecture Works	160,000	374,000	534,000
Sub Total of -C1	**160,000**	**374,000**	**534,000**
-C2 Pump Equipment Work			
Mechanical and Electrical Works	0	1,066,000	1,066,000
Sub Total of -C2	**0**	**1,066,000**	**1,066,000**
-C3 Electrical Work			
Mechanical and Electrical Works	0	1,189,000	1,189,000
Sub Total of -C3	**0**	**1,189,000**	**1,189,000**
-C4 Piping Work			
Civil and Architecture Works	11,000	81,000	92,000
Sub Total of -C4	**11,000**	**81,000**	**92,000**
Total of Construction Cost	**171,000**	**2,710,000**	**2,881,000**
Civil and Architecture Works	**171,000**	**455,000**	**626,000**
Mechanical and Electrical Works	**0**	**2,255,000**	**2,255,000**

G.5 Estimated Construction Cost of Distribution Main Facility

G.5.1 North Low SR Facilities (Low Zone)

Item Description	L.C. (USD)	F.C. (USD)	Total (USD)
-D1 Excavation Work			
Civil and Architecture Works	44,000	175,000	219,000
Sub Total of -D1	**44,000**	**175,000**	**219,000**
-D2 Structure Work			
Civil and Architecture Works	1,370,000	3,879,000	5,249,000
Sub Total of -D2	**1,370,000**	**3,879,000**	**5,249,000**
-D3 Painting Work			
Civil and Architecture Works	17,000	329,000	346,000
Sub Total of -D3	**17,000**	**329,000**	**346,000**
-D4 Piping Work			
Civil and Architecture Works	93,000	996,000	1,089,000
Mechanical and Electrical Works	0	169,000	169,000
Sub Total of -D4	**93,000**	**1,165,000**	**1,258,000**
Total of Construction Cost	**1,524,000**	**5,548,000**	**7,072,000**
Civil and Architecture Works	**1,524,000**	**5,379,000**	**6,903,000**
Mechanical and Electrical Works	**0**	**169,000**	**169,000**

G.5.2 North High SR Facilities (High Zone)

Item Description		L.C. (USD)	F.C. (USD)	Total (USD)
-D1	Excavation Work			
	Civil and Architecture Works	33,000	136,000	169,000
	Sub Total of -D1	**33,000**	**136,000**	**169,000**
-D2	Structure Work			
	Civil and Architecture Works	951,000	2,702,000	3,653,000
	Sub Total of -D2	**951,000**	**2,702,000**	**3,653,000**
-D3	Painting Work			
	Civil and Architecture Works	12,000	239,000	251,000
	Sub Total of -D3	**12,000**	**239,000**	**251,000**
-D4	Piping Work			
	Civil and Architecture Works	43,000	347,000	390,000
	Mechanical and Electrical Works	0	140,000	140,000
	Sub Total of -D4	**43,000**	**487,000**	**530,000**
	Total of Construction Cost	**1,039,000**	**3,564,000**	**4,603,000**
	Civil and Architecture Works	**1,039,000**	**3,424,000**	**4,463,000**
	Mechanical and Electrical Works	**0**	**140,000**	**140,000**

G.5.3 South Low SR Facilities (Low Zone)

Item Description		L.C. (USD)	F.C. (USD)	Total (USD)
-D1	Excavation Work			
	Civil and Architecture Works	15,000	57,000	72,000
	Sub Total of -D1	**15,000**	**57,000**	**72,000**
-D2	Structure Work			
	Civil and Architecture Works	516,000	1,457,000	1,973,000
	Sub Total of -D2	**516,000**	**1,457,000**	**1,973,000**
-D3	Painting Work			
	Civil and Architecture Works	6,000	115,000	121,000
	Sub Total of -D3	**6,000**	**115,000**	**121,000**
-D4	Piping Work			
	Civil and Architecture Works	26,000	220,000	246,000
	Mechanical and Electrical Works	0	70,000	70,000
	Sub Total of -D4	**26,000**	**290,000**	**316,000**
	Total of Construction Cost	**563,000**	**1,919,000**	**2,482,000**
	Civil and Architecture Works	**563,000**	**1,849,000**	**2,412,000**
	Mechanical and Electrical Works	**0**	**70,000**	**70,000**

G.5.4 South High SR Facilities (High Zone)

Item Description		L.C. (USD)	F.C. (USD)	Total (USD)
-D1	Excavation Work			
	Civil and Architecture Works	22,000	86,000	108,000
	Sub Total of -D1	**22,000**	**86,000**	**108,000**
-D2	Structure Work			
	Civil and Architecture Works	793,000	2,233,000	3,026,000
	Sub Total of -D2	**793,000**	**2,233,000**	**3,026,000**
-D3	Painting Work			
	Civil and Architecture Works	9,000	173,000	182,000
	Sub Total of -D3	**9,000**	**173,000**	**182,000**
-D4	Piping Work			
	Civil and Architecture Works	36,000	346,000	382,000
	Mechanical and Electrical Works	0	71,000	71,000
	Sub Total of -D4	**36,000**	**417,000**	**453,000**
-D5	OHSR			
	Civil and Architecture Works	87,000	296,000	383,000
	Mechanical and Electrical Works	0	24,000	24,000
	Sub Total of -D5	**87,000**	**320,000**	**407,000**
-D6	Pump Station			
	Civil and Architecture Works	94,000	227,000	321,000
	Mechanical and Electrical Works	0	709,000	709,000
	Sub Total of -D6	**94,000**	**936,000**	**1,030,000**
	Total of Construction Cost	**1,041,000**	**4,165,000**	**5,206,000**
	Civil and Architecture Works	**1,041,000**	**804,000**	**804,000**
	Mechanical and Electrical Works	**0**	**3,361,000**	**4,402,000**

G.5.5 Gumbo (East) ET Facilities (Gumbo Zone)

Item Description		L.C. (USD)	F.C. (USD)	Total (USD)
-D1	Excavation Work			
	Civil and Architecture Works	3,000	12,000	15,000
	Sub Total of -D1	**3,000**	**12,000**	**15,000**
-D2	Structure Work			
	Civil and Architecture Works	242,000	733,000	975,000
	Sub Total of -D2	**242,000**	**733,000**	**975,000**
-D3	Painting Work			
	Civil and Architecture Works	1,000	23,000	24,000
	Sub Total of -D3	**1,000**	**23,000**	**24,000**
-D4	Piping Work			
	Civil and Architecture Works	13,000	108,000	121,000
	Mechanical and Electrical Works	0	24,000	24,000
	Sub Total of -D4	**13,000**	**132,000**	**145,000**
	Total of Construction Cost	**259,000**	**900,000**	**1,159,000**
	Civil and Architecture Works	**259,000**	**876,000**	**1,135,000**
	Mechanical and Electrical Works	**0**	**24,000**	**24,000**

G.6 Estimated Construction Cost of Distribution Main & Sub-main

G.6.1 High Zone

Item Description	Unit	LC/m	FC/m	Quantity	L.C. (USD)	F.C. (USD)	Total (USD)
-E DCIP 900mm	m	120	1,202	382	45,966	459,217	505,184
DCIP 800mm	m	110	1,071	3,542	390,364	3,794,226	4,184,590
DCIP 700mm	m	100	858	1,950	195,059	1,673,763	1,868,822
DCIP 600mm	m	90	676	861	77,731	581,812	659,543
DCIP 500mm	m	81	506	7,311	589,559	3,698,781	4,288,340
DCIP 400mm	m	71	366	12,623	898,631	4,619,639	5,518,271
DCIP 300mm	m	62	249	10,249	636,668	2,548,106	3,184,774
DCIP 200mm	m	53	152	43,084	2,293,792	6,537,135	8,830,927
Total of Construction Cost					**5,128,000**	**23,912,000**	**29,040,000**

G.6.2 Low Zone

Item Description	Unit	LC/m	FC/m	Quantity	L.C. (USD)	F.C. (USD)	Total (USD)
-E DCIP 1000mm	m	131	1,457	611	80,328	890,465	970,793
DCIP 800mm	m	110	1,071	3,808	419,680	4,079,168	4,498,847
DCIP 700mm	m	100	858	4,600	460,138	3,948,364	4,408,502
DCIP 600mm	m	90	676	3,136	283,118	2,119,121	2,402,239
DCIP 500mm	m	81	506	2,315	186,682	1,171,205	1,357,886
DCIP 400mm	m	71	366	21,741	1,547,742	7,956,554	9,504,296
DCIP 300mm	m	62	249	13,250	823,090	3,294,215	4,117,305
DCIP 200mm	m	53	152	25,246	1,344,097	3,830,576	5,174,673
Total of Construction Cost					**5,145,000**	**27,290,000**	**32,435,000**

G.6.3 Gumbo Zone

Item Description	Unit	LC/m	FC/m	Quantity	L.C. (USD)	F.C. (USD)	Total (USD)
-E DCIP 800mm	m	110	1,071	353	38,904	378,137	417,041
DCIP 600mm	m	90	676	1,560	140,837	1,054,154	1,194,991
DCIP 500mm	m	81	506	3,889	313,609	1,967,523	2,281,132
DCIP 400mm	m	71	366	4,135	294,371	1,513,286	1,807,657
DCIP 300mm	m	62	249	2,689	167,041	668,539	835,580
DCIP 200mm	m	53	152	1,368	72,832	207,567	280,399
Total of Construction Cost					**1,028,000**	**5,789,000**	**6,817,000**

G.7 Estimated Construction Cost of Distribution Network

G.7.1 High Zone

Item Description	Unit	LC/m	FC/m	Quantity	L.C. (USD)	F.C. (USD)	Total (USD)
-F PVC 150mm	m	10	53	66,900	660,303	3,543,024	4,203,327
PVC 100mm	m	8	36	378,900	3,171,393	13,572,198	16,743,591
Total of Construction Cost					**3,832,000**	**17,115,000**	**20,947,000**

G.7.2 Low Zone

Item Description	Unit	LC/m	FC/m	Quantity	L.C. (USD)	F.C. (USD)	Total (USD)
-F PVC 150mm	m	10	53	75,900	749,133	4,019,664	4,768,797
PVC 100mm	m	8	36	430,100	3,599,937	15,406,182	19,006,119
Total of Construction Cost					**4,350,000**	**19,426,000**	**23,776,000**

G.7.3 Gumbo Zone

Item Description	Unit	LC/m	FC/m	Quantity	L.C. (USD)	F.C. (USD)	Total (USD)
-F PVC 150mm	m	10	53	19,700	194,439	1,043,312	1,237,751
PVC 100mm	m	8	36	111,600	934,092	3,997,512	4,931,604
Total of Construction Cost					**1,129,000**	**5,041,000**	**6,170,000**

G.7.4 Kiosk/Tank Truck Feeding Station

Item Description	Unit	LC/m	FC/m	Quantity	L.C. (USD)	F.C. (USD)	Total (USD)
-F Kiosuku	m	10,000	0	300	3,000,000	0	3,000,000
Total of Construction Cost					**3,000,000**	**0**	**3,000,000**