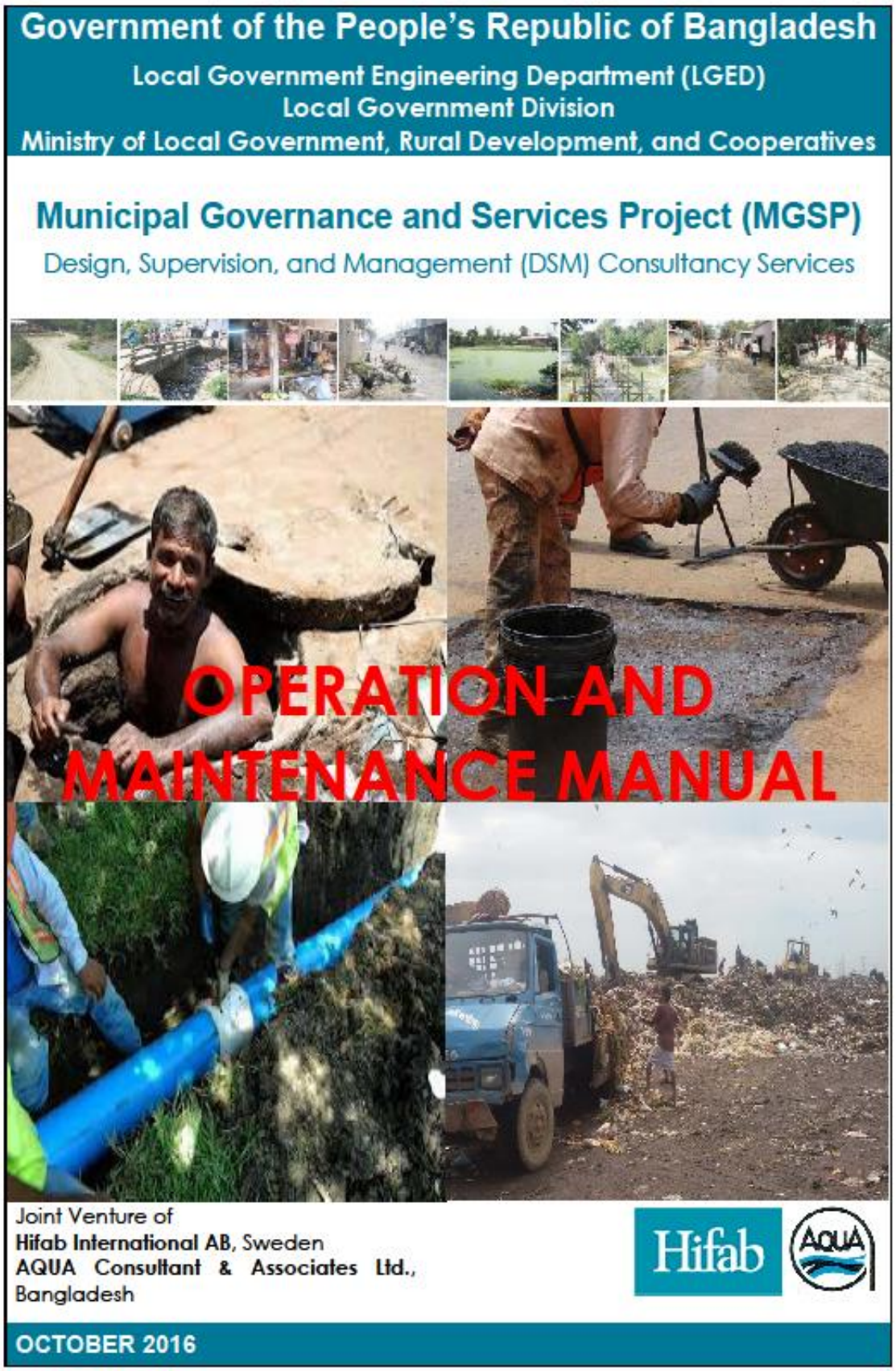

Government of the People's Republic of Bangladesh
Local Government Engineering Department (LGED)
Local Government Division
Ministry of Local Government, Rural Development, and Cooperatives
Municipal Governance and Services Project (MGSP)
Design, Supervision, and Management (DSM) Consultancy Services
OPERATION AND MAINTENANCE MANUAL
Joint Venture of
Hifab International AB, Sweden
AQUA Consultant & Associates Ltd., Bangladesh
OCTOBER 2016

CHAPTER 1

GENERAL

CHAPTER 2

O&M CONCEPT IN THE MGSP

CHAPTER 3

DETAILS OF FRAMING AND IMPLEMENTATION OF O&M PLAN

CHAPTER 4

ROADS

CHAPTER 5

URBAN DRAINAGE

CHAPTER 6

WATER SUPPLY

CHAPTER 7

COLLECTING AND TRANSPORTING SOLID WASTE

CHAPTER 8

LANDFILL OPERATIONS AND MAINTENANCE

APPENDIX A

OPERATION OF STANDING COMMITTEE FOR O&M

APPENDIX B

FUNCTIONING OF WORKING GROUP

APPENDIX C

C 1 INFRSTRUCTURE INVENTORIES

C 2 PRIORITIZATION

C 3 SUBPROJECT O&M PLAN

C 4 ANNUAL O&M PLAN

APPENDIX D

D 1 BUDGET FRAMEWORK FOR O&M (BUDGET ALLOCATION FOR O&M IN ANNUAL BUDGET)

D 2 ASSESSMENT OF FINANCIAL NEED FOR MAINTENANCE (BASED ON PHYSICAL CONDITION)

APPENDIX E

E 1 ANNUAL O&M PLAN IMPLEMENTATION (PROGRESS REVIEW OF PERIODIC MAINTENANCE)

E 2 ANNUAL O&M PLAN IMPLEMENTATION (PROGRESS REVIEW OF ROUTINE MAINTENANCE)

APPENDIX F

PROCESS OF CITIZEN PARTICIPATION IN O&M

APPENDIX G

TECHNICAL CAPACITIY FOR O&M

APPENDIX H

OPERATIONAL GUIDELINES FOR COMPOSTING FACILITY

PREFACE

This Operation and Maintenance Manual has been prepared with the objective of putting in place a comprehensive, consistent, and common system for operation and maintenance (O&M) during the implementation of the *Municipal Governance and Services Project* (IDA Credit No. 5339-BD). The Manual covers the overall O&M systems at the ULB level for different types of assets based on the standard procedures for the Project.

The O&M Manual provides inventory and inspection procedures for different types of assets. The inspections should be conducted in relation to the standard and special specifications as incorporated in the construction and installation procedures. If there are any differences between the tests and other evaluation procedures described in the Manual and those stipulated in the Project's contract documents, procedures, or specifications, the latter shall prevail.

It is suggested that the Manual be kept in a ring binder so that any additions or modifications can be easily incorporated later, if required.

Based on the nature of different ULB assets, the relevant portions can be supplied to contractors, ULBs, and DSM for day-to-day reference.

TABLE OF CONTENTS

TERMS AND ACRONYMS

ADB	Asian Development Bank
AE	Assistant Engineer
BC	Bituminous Carpeting
BDT	Bangladesh Taka
CBO	Community Based Organization
CC	Cubic Centimeters
Consultant	Hifab International AB in association with AQUA Consultant and Associates, Ltd.
CRCP	Continuously Reinforced Concrete Pavement
CWR	Clear Water Reservoir
DI	Ductile Iron (Pipes)
DPHE	Directorate of Public Health Engineering
DSM	Design, Supervision, and Management Consultant
E.coli	Escherichia coli (a type of bacteria)
G	Grams
GI	Galvanized Iron (Pipes)
GOB	Government of Bangladesh
GPS	Global Positioning System
HDPE	High Density Polyethylene (Pipes)
HMA	Hot Mixed Asphalt
HV	High Voltage
ID	Identification
IDB	Islamic Development Bank
IRP	Iron Treatment Plant
JICA	Japan International Cooperation Agency
JPCP	Jointed Plain Concrete Pavement
JRCP	Jointed Reinforced Concrete Pavement
KfW	Kreditanstaltfür Wiederaufbau (German government-owned development bank)
khal	Open channel
kWh	kilowatt-hours
LGED	Local Government Engineering Department
M	Meter
m^2	Square Meters
m^3	Cubic Meters
mg/l	Milligram per liter
MGSP	Municipal Governance and Services Project
mm	Millimeters
MS	Mild Steel

MSU	Municipal Services Unit
MV	Medium Voltage
NGO	Non-Government Organization
O&M	Operation and Maintenance
OHT	Overhead Tank
PCC	Portland Cement Concrete
PDB	Power Development Board
PH	Pump House
pH	A measure of acidity or alkalinity of water soluble substances.
PIU	Project Implementation Unit
PMU	Project Management Unit
PN8/PN10	Pipe pressure classification in accordance with AS/NZS 4130
Pourashava	Municipality
Pozzolan	A siliceous or siliceous and aluminous material arecommonly used as an addition (the technical term is "cement extender") to Portland cement concrete mixtures to increase the long-term strength.
PTW	Production Tube Well
PVC	Poly-Vinyl Chloride (Pipes)
RCC	Reinforced Cement Concrete
REB	Rural Electrification Board
RHD	Roads & Highway Department
Rubblization	It is a construction technique that involves in reducing existing concrete into rubble at its current location rather than hauling it to another location.
SIC	Subproject Implementation Committee
SMA	Stone Matrix Asphalt
TLCC	Town Level Coordinating Committee
TOT	Training of Trainers
ULB	Urban Local Body
Union	Smallest rural administrative unit
Upazila	Sub-District
UPVC	Unplasticized Polyvinyl Chloride (Pipes)
V	Voltage
WB	World Bank
WG	Working Group
WHO	World Health Organization
WLCC	Ward Level Coordinating Committee
XEN	Executive Engineer

CHAPTER 1

GENERAL

1.1 Introduction

Operation and Maintenance (O&M) of assets is one of the main concerns of Urban Local Bodies (ULBs) in delivering services to its citizens. A huge amount of resources has been invested in developing these assets to provide adequate physical facilities to the town dwellers. Proper operation and timely maintenance can only ensure effective return on such expenditure. Rapid growth in urban population due to migration from rural areas and other factors have strained burdened on infrastructure of most of the ULBs causing considerable deterioration of the physical assets and services. On the other hand, availability of resources, adequate manpower and their capacity, in most cases, are undependable. Therefore, it is a big challenge for the ULBs to ensure proper O&M of its assets by establishing an effective and efficient management system.

1.2 Fundamentals of O&M

In an engineering sense, operation refers to hourly and/or daily operation of the components of a system such as plant, machinery, equipment, infrastructure, and facilities. Operation should be considered as routine work.

Maintenance is defined as the art of keeping assets such as plant, equipment, structures, and other facilities in optimum working order. To maintain something is to keep that facility in good and continuous serviceable condition by carrying out repair or remedial works as and when necessary. If these works the delayed for any reason, subsequent rectification costs will inevitably increase as further deterioration takes place. However, maintenance does not include any improvement or reconstruction.

Two most commonly accepted maintenance categories are:

1. Routine Maintenance; and
2. Periodic Maintenance.

Under special circumstances more categories could be included, namely:

1. Urgent Maintenance; and
2. Rehabilitation.

1.2.1 Routine Maintenance

Routine maintenance refers to preventive and corrective maintenance activities carried out continually, largely repetitively, for any kind of infrastructure whatever its engineering characteristics. The intensity may vary with time. In a particular season of the year the requirement may be high. Routine maintenance operations are usually carried out by choosing labor intensive methods. The cost of routine maintenance activities is low compared to periodic maintenance or rehabilitation. Proper attention will have to be given to allocate funds from the maintenance budget for this purpose. Examples of these activities are cleaning, sweeping, cutting grass, clearing drains, etc.

1.2.2 Periodic Maintenance

Periodic maintenance is so called because these activities are undertaken at intervals over a period of time. These maintenance tasks are often programmed in a pre-determined plan or schedule. Periodic maintenance is not upgrading, extending, or changing the infrastructure from one stage to another. Periodic maintenance refers to preventive maintenance activities carried out less often, such as once every two or five years. Examples of periodic maintenance activities are resealing of road surfaces, painting, etc.

There must be a good balance between routine and periodic maintenance in order to gain optimum benefit from the infrastructure. If any one of two remains absent, the system will not be effective and will not be sustained. It is therefore necessary to attend to both of these categories of maintenance while allocating funds and preparing a ULB maintenance program.

1.2.3 Urgent Maintenance

Urgent maintenance is needed to deal with emergencies and problems calling for immediate actions. Emergency maintenance activities cannot be anticipated beforehand like when a road is blocked. Other examples for urgent maintenance are removing debris and obstacles, placing warning signs, executing diversion works, etc.

1.2.4 Rehabilitation

Rehabilitation refers to activities carried out to correct major defects in order to restore a facility to its intended operational status and capacity, without significantly expanding it beyond its originally planned and designed function or extent. Rehabilitation activities are more expensive than other categories of maintenance.

1.3 Linkage between Operation and Maintenance

Operation in this document refers to a set of activities involved in the operation of ULB assets such as transportation, equipment, machinery, infrastructure, and service facilities. Maintenance refers to a set of activities to ensure keeping the existing system in such a state that it can be operated correctly and with cost effectiveness. These two sets of activities are closely linked, since operation will not continue for long without maintenance. These personnel normally conduct operation as well as maintenance.

1.4 Objectives

An efficient O&M system aims to minimize downtime by providing the most effective use of facilities and manpower to secure the desired result at the lowest possible cost. The specific objective of this manual is to assist ULBs prepare and implement their ULB infrastructure O&M plan with a view towards establishing a proper system for:

1. ensuring maximum benefits from the built infrastructure assets by prolonging the life and reducing downtime;
2. minimizing the cost by minimizing the degree of deterioration of the built infrastructure assets;
3. ensuring maximum service from the facilities to meet operational requirements; and
4. improving the service quality and enabling the infrastructure assets and facilities, including plant, equipment, machinery, etc. to provide services at their specified rates.

1.5 Importance of O&M and Scope

Maintenance is an essential follow up that is to be carried out as soon as the facilities are created and should continue throughout the designed life. Its purpose is to reduce the rate of deterioration and operational cost, and provide safety, convenience, and regular services. Proper operation and maintenance provide worthwhile contributions to the economic well-being. In addition, an effective operation and maintenance system is a valuable part of the economy. Hence, there is a prime need to develop a sustainable operation and maintenance system for the physical assets of the ULB.

In addition to the urban infrastructure, there is also a need to establish the effective operation and maintenance system for mechanical equipment and vehicles owned by the ULB. This plays a vital role in the development process. For example, operation of street lighting system, solid waste management, public sanitation, kitchen market, etc. in the ULB draws necessary attention. However, among various kinds of assets owned by the ULB, the following types of infrastructure and other assets (but not limited to) may be taken into account of this operation and maintenance manual.

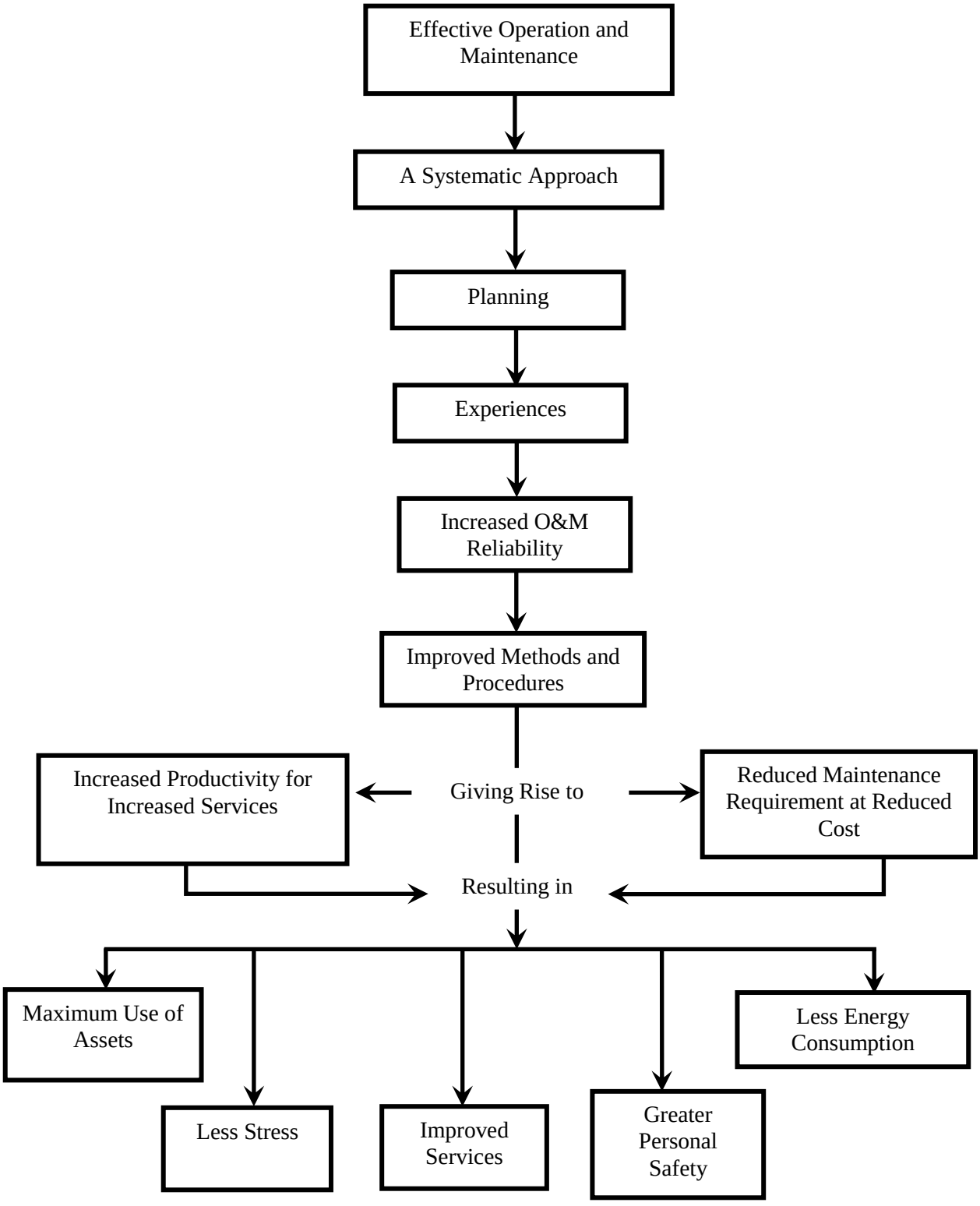
1. Roads, bridges and culverts, and footpaths
2. Multipurpose buildings (office, residences, auditoria, etc.)
3. Drainage infrastructure
4. Bus and truck terminals, including their parking areas
5. Water supply infrastructure (tube-wells, pump houses, overhead tanks, and distribution network)
6. Public toilets
7. Slaughter houses
8. Solid waste management in landfills
9. Street lighting
10. Kitchen markets
11. Multipurpose buildings, supermarkets, rental shops, and commercial complexes
12. Burial grounds, graveyards, and crematoria
13. Beautification and recreational facilities (parks, playgrounds, open space, etc.)
14. Transportation and vehicles
15. Equipment and machinery

The scope of O&M varies among ULBs depending on the type, nature, and volume of existing infrastructure, facilities, and other assets. Therefore, each ULB is required to prepare its own infrastructure O&M plan to meet the objectives of this manual.

1.6 Operation and Maintenance Actions and Benefits

Actions and benefits from systematic operation and maintenance are shown in **Exhibit 1-1**.

Exhibit 1-1
Operation and Maintenance Action and Benefit Diagram



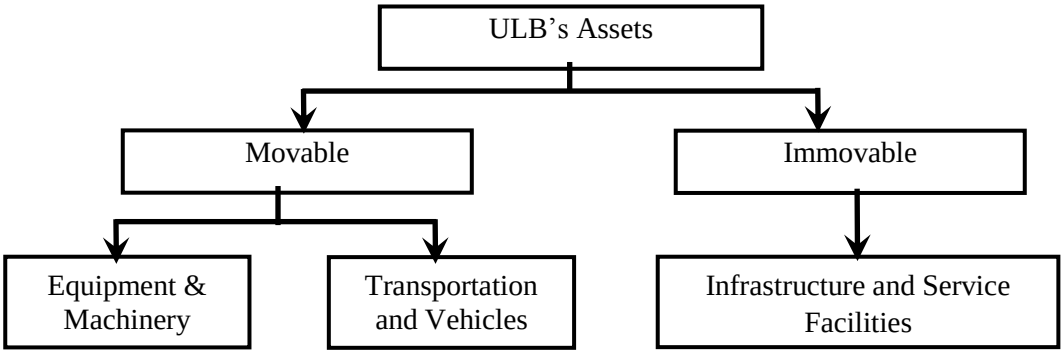
CHAPTER 2

O&M CONCEPT IN THE MGSP

2.1 General

O&M of urban infrastructure has been given due importance in the Municipal Governance and Services Project (MGSP). This manual will cover only O&M for urban ULBs. It addresses both movable and immovable assets that include infrastructure, service facilities, transportation, equipment, machinery, etc. Classification of movable and immovable assets can be easily understood from **Exhibit 2-1**.

Exhibit 2-1
Classification of Movable and Immovable ULB Assets



2.2 Municipal Governance and Services Project (MGSP) and O&M

2.2.1 O&M Grant on a Declining Basis

The MGSP O&M grant support is intended to assist ULBs to maintain a reasonable and affordable level of maintenance of existing infrastructure. The larger objective is to provide a satisfactory of services, prolong life of the assets, and to defer capital expenditure required to replace assets. Project O&M support is provided on a declining basis with the requirement that, starting in the second year, ULBs will maintain the OM level of the first year by topping the corresponding amount of the declining grant amount with their own funds.

2.2.2 Eligibility for Second and Subsequent Years' O&M Grants

O&M grants for the second and subsequent years will be provided only upon (a) the ULB presenting a satisfactory O&M plan and (b) proof that the ULB budget approved by June 30 each year shows that the first years' O&M allocation level (grant plus own funds) has been maintained, with topping up if necessary.

2.2.3 Expenditure Not Eligible for O&M Grant Financing

The following items are not eligible for using the MGSP O&M grant.

1. Surfacing city roads and constructing new drains, except a missing link absolutely necessary for effective functioning of the asset.
2. Funds assigned to the Ward Councilors for implementation; O&M implementation must be done only by authorized ULB staff.
3. O&M for only one sector, such as only roads. O&M needs must be considered and O&M spending must be prioritized across sectors.

2.2.4 Maintenance Works and Goods Eligible for Financing with the O&M Grant

The works and goods eligible for financing using the O&M grant funds are described below.

1. Roads. O&M for roads should include repair of potholes and patches; shoulders or berms; medians; and uneven footbaths that pose a danger to the public.
2. Drains. O&M for drains should include regular drain cleaning including emptying gully pits; repairing soffit and walls of damaged drains; repairing and upgrading for replacing missing or broken cover slabs as well as missing or stolen manhole covers.
3. Water Supply. Repairing leaking water pipes in the distribution system; repairing or replacing tube well pumps; and preventative maintenance of pumps. Adequate spares should be procured for the work that will be done through force account.
4. Street Lights and Traffic Signals. Repairing faulty traffic signals and street lights; and replacing burnt out bulbs.
5. Buildings Maintenance. Routine repairs to public buildings owned by ULBs such as leaking roofs, damp walls, pipe work, painting, etc.
6. Vehicles and Equipment. Preventative maintenance and repairs to vehicles and equipment.
7. Parks and Gardens. Repair of facilities in parks including pay equipment and benches.
8. Sanitation. Maintenance of public toilets and emptying septic tanks linked with public toilets.
9. Procurement of Goods (Stores, Tools, and Equipment). Purchase of annual requirement of material; small tools and equipment including materials, spares, such as hand tools, tar boilers, fuel or wood, gloves, and boots; tamping equipment or small road rollers; street lamps; drain cleaning tools; wheel barrows, etc. It is necessary for the ULB to have a store and storekeeper to maintain the inventory and manage the stores.

2.3 Institutional Arrangements

According to the Local Government (Pourashava) Act 2009, the Pourashava Engineering Division, headed by an Executive Engineer (XEN) or Assistant Engineer (AE), will be responsible for the ULB's infrastructure O&M. However, category B and C ULBs commonly face the shortage of manpower. Thus, the MGSP has assigned one Assistant Municipal Engineer (DSM consultant) to each PIU. They will assist the ULBs prepare and implement the O&M plan. In addition, each Project ULB will form a working group for O&M, consisting of ULB officials. It will also assign a standing committee consisting of ULB councilors that will oversee O&M of the ULB infrastructure working group. The standing committees are already established in the Project ULBs.

Refer to Chapter 3, Section 3.1 for the detailed institutional O&M arrangements.

2.4 O&M Budget for ULBs

ULBs have recently started to earmark funds for O&M. Under the Project, ULBs have to prepare O&M plans for all MGSP subprojects. These plans define the budget, sources of finance, and institutional responsibilities. In addition, for the three categories of revenue-generating subprojects, i.e., bus and truck terminals, municipal markets, and water supply systems, each subproject has to achieve full cost recovery for O&M by collecting user fees and tariffs. In case of construction equipment to be procured under the Project and to be used by the ULB, rental fees are supposed to cover the maintenance cost.

2.5 ULB Infrastructure Operation and Maintenance Action Plan (O&M Plan)

Apart from O&M plans required for individual subprojects, each Project ULB will formulate and implement an Infrastructure Operation and Maintenance Action Plan (O&M plan) under MGSP. This will strengthen their O&M capacity and ensure the sustainability of benefits from infrastructure investment, including construction equipment. The objective of the O&M plan is to enhance the sustainability of ULB infrastructure by strengthening the ULB's capacity for O&M of the infrastructure.

The following are the action areas included in the O&M plan.

1. The institutional arrangements for O&M implementation (working group and standing committee)
2. Planning O&M
   - Inventories of ULB infrastructure
   - Prioritizing infrastructure for O&M
   - Subproject O&M plan
   - Annual O&M plan
3. Budget framework for O&M
4. Budget for O&M allocated in the annual budget
   - Medium-term budgeting framework for O&M
   - Implementation of O&M
5. Citizens' participation in O&M by involving the TLCC and WLCC
6. Technical capacity for O&M (including O&M for construction equipment).

The O&M plan will consist of the following items against the action areas listed above.

1. **Output / Indicator:** Output is the gain resulting from input, which is aimed at a specific action. The output is considered as an O&M plan indicator;
2. **Specific Task:** Tasks to be undertaken from a specified result;
3. **Organization / Person in Charge of Task:** Organization or person in charge to be selected to implement specific tasks; and
4. **Time schedule:** Setting a schedule for completing the respective tasks.

2.5.1 Format of O&M Plan

The format of the O&M plan containing all the items against the action areas is presented in **Exhibit 2-2**.

Exhibit 2-2
Format of the O&M Plan

Name of ULB: _____
ULB Infrastructure O&M Plan

Action	Output / Indicator	Specific Task	Organization / Person in Charge	Time schedule
Institutional Arrangements				
A standing committee and councillors are assigned to the O&M	•			
A working group for O&M consisting of ULB officials is established	•	•		
Planning of O&M				
Inventories of infrastructure under the responsibility of ULB are prepared and updated	•	•		
Priority list of O&M of infrastructure is prepared	•	•		
Subproject O&M plan is prepared	•	•		
Annual O&M Plan is prepared	•	•		
Budget framework of O&M				
Budget for O&M is allocated as part of the annual budget	•	•		
Five-year Budget Plan for O&M is prepared	•	•		
Implementation				
Annual O&M Plan is implemented	•			
Citizens' participation				
TLCC and WLCCs are involved in O&M	•			
Technical capacity for O&M				
Technical skills of concerned persons for O&M are improved	•			

Note: This table is the format of the ULB O&M Action Plan (O&M plan). The contents of the plan should be prepared and determined by the ULB. Actions indicated in this table should be included in the O&M plan of each ULB.

2.5.2 Process for Preparing the O&M Plan

Each ULB will prepare O&M plan with support from the PMU and DSM consultants. As part of this preparation process, the ULB should hold discussions at the TLCC and consultations with concerned persons. The draft O&M plan will be submitted to the PMU for approval.

O&M plans will be prepared annually for all infrastructure assets in each ULB including cost estimates, not only for the O&M financed under MGSP. Information requirements for O&M plan preparation is information on infrastructure assets, ideally, from well-maintained records of assets (asset register); assessment of conditions and state of repair of each type of infrastructure; and prioritization of maintenance needs and frequency of interventions. The O&M plan will describe the following items.

1. Routine maintenance work (e.g. road patching, repairing RC road, repairing leaks in water distribution pipes, cleaning drains) and periodic or phases maintenance (e.g. repairing short sections of failed road, removing accumulated silt deposits in town-wide drainage system, etc.).
2. Maintenance work for each type of asset and the O&M cost estimate for each type of asset.
3. Procurement method, i.e. by force account (materials, tools, and labor) or contract.
4. Contingency allocation for unforeseen emergency repair work.
5. Annual procurement of estimated materials and spares required for the year.
6. Computation of total cost for all O&M activities.

The estimated cost of the O&M will be compared with the total O&M budget and revised as necessary to fit the specified O&M budget.

2.5.3 Budget Preparation Process

Steps in the preparation of the O&M budgets include the following items.

1. Confirmation that the total O&M cost is consistent with the specified budget.
2. Detailed description for allocating the O&M budget for each type of activity (drawn from details in the O&M plan).
3. Submitting the total budget including O&M to the ULB Council for approval.
4. Formal allocation of annual funds annual to finance O&M works.

2.5.4 O&M Implementation

Maintenance works will be carried out using a mix of force account (direct expenditures) procedures and contracts following contracting procedures. Works must be supervised by an engineer. Contracts should be offered only for maintenance work for which there is no in-house capacity or facilities, and for circumstances where the volume of work involved makes it more economical executed through contracting.

The PMU, with support from the DSM Consultant, will provide training courses for each ULB concerning the overall mechanisms and procedures for O&M plan, technical measures for O&M for each type of infrastructure, and so forth. The PMU will also develop training materials and O&M manuals for the ULBs.

2.5.5 Asset Maintenance Recording and Monitoring

ULBs should are required to maintain details of O&M works carried out for all infrastructure. A database will provide details of when assets were created, the cost and frequency of repairs, maintenance, etc. Such records should indicate the increasing cost of maintenance and facilitate the decision to replace the asset when it becomes uneconomical to continue the high maintenance costs.

CHAPTER 3

DETAILS FOR FRAMING AND IMPLEMENTING THE O&M PLAN

3.1 Institutional Arrangements for O&M

Each ULB will establish an additional standing committee or assign any of the existing standing committees to oversee the O&M activities of the ULB and to provide support and assistance to the O&M working group formed for implementation of the ULB specific O&M plan. Details of constitution of the working group and standing committee are described in the following paragraphs.

3.1.1 Formation of O&M Working Group

The Engineering Division of ULB is entrusted with responsibility for O&M of ULB infrastructure and other assets. For City Corporations, the Engineering Division is headed by the Executive Engineer (XEN). For Category A ULBs, the Engineering Division is also headed by an XEN while for Category B and C ULBs, the Engineering Division is headed an Assistant Engineer (AE). Under the MGSP, the O&M Working Group shall consist of ULB officials including the Engineer, Secretary, and Health Officer as well as a few other members. Based on this organization, the constitution and functions of the O&M Working Group are presented below.

City Corporations

1. Executive Engineer - Convener
2. Accounts Officer - Member
3. Health Officer - Member
4. Town Planner - Member
5. Slum Development Officer - Member
6. Sub-Assistant Engineer (Civil) - Member
7. Assistant Engineer (Electrical) - Member
8. Assistant Engineer (Civil) - Member-Secretary

Category A ULBs

1. Executive Engineer - Convener
2. Secretary - Member
3. Health Officer - Member
4. Town Planner - Member
5. Slum Development Officer - Member
6. Superintendent, Water Works (SAE) - Member
7. Sub-Assistant Engineer (Civil) - Member
8. Sub-Assistant Engineer (Elec./Mech.) - Member
9. Assistant Engineer - Member-Secretary

Category B and C ULBs

1. Assistant Engineer - Convener
2. Secretary - Member
3. Health Officer - Member
4. Superintendent, Water Works (SAE) - Member
5. Sub-Assistant Engineer (SAE), Electrical - Member
6. Municipal Engineer (Consultant) - Member
7. Sub-Assistant Engineer (Civil) - Member-Secretary

3.1.2 Functions and Tasks of the O&M Working Group

The O&M Working Group will assume overall responsibility of O&M at the working level. The group members will be the core persons for implementing the O&M plan. The working group will work as per the following TOR.

1. Advise in preparation of infrastructure inventory and database, identifying the physical features (e.g. length, area, material, etc.) of all infrastructures (e.g., buildings, roads, drains, etc.) which require maintenance.
2. Identify O&M tasks defining the type of maintenance (routine, periodic, emergency, or rehabilitation) to be performed on each infrastructure and works to be done (e.g. sweeping road, drain cleaning, road patching, pothole, painting, etc.).
3. Prioritize infrastructure to be undertaken for O&M within available budget considering a set of criteria including social and commercial importance of the infrastructure.
4. Prepare the annual O&M budget, submit it to the standing committee, and pursue full allocation of O&M funds on time.
5. Assign divisions or sections and the persons responsible performing the tasks relevant to them.
6. Support the preparation and implementation of subproject O&M for each type of infrastructure including setting technical specifications, tendering, contracting, supervision of implementation, etc.
7. Estimate time required to complete each tasks including developing an annual work schedule.
8. Hold regular meetings at least once in a month, monitor progress of implementation, and report to the standing committee and Mayor.

3.1.3 Establishing the O&M Standing Committee

The ULB may establish an additional standing committee for O&M, as per the provision of Article 55(2) of the Local Government (Pourashava) Act 2009, or it may assign any of the established standing committees to oversee O&M activities of the ULB. After reviewing the draft by-laws, issued by the LGD vide No. 46.063.022.01.00.001.2012 (Part-3)-7 dated 2 January 2013 related to the establishment of standing committees and their functions, it is understood that the Communication and Physical Infrastructure Standing Committee may be assigned the responsibility of O&M of ULB infrastructure and other assets. The ULB can include O&M responsibility within the proposed functions of the said standing committee, and issue a notification within the provision of the instructions given in the above mentioned letter of the LGD. Accordingly, the constitution and functions or tasks of the standing committee may be as follows.

Constitution of Communication and Physical Infrastructure Standing Committee

Chairman	:	Councilor (General/Reserved)
Member 1	:	Mayor (Ex-office)
Member 2	:	Councilor (General/Reserved)
Member 3	:	Councilor (General/Reserved)
Member 4	:	Councilor (General/Reserved)

Note 1: 40% of the members shall be from Female Ward Councilors
Note 2: An engineer experienced on O&M of ULB infrastructure and assets may be included or co-opted as a member to facilitate activities of the standing committee. The co-opted member shall not have voting power.

3.1.4 Functions and Tasks of the O&M Standing Committee

The ULB Standing Committees have the functions and tasks listed below.

1. Assist the O&M Working Group in performing their overall function and oversee the O&M activities.
2. Assist the O&M Working Group to prepare inventory and databases of ULB infrastructure that require maintenance.
3. Organize awareness campaigns to create the “sense of ownership” among the citizens.
4. Motivate the people through the TLCC and WLCC to participate in planning and implementing O&M activities of ULB infrastructure.
5. Hold standing committee meetings at least once every three months to review and monitor the progress of O&M activities and report to the TLCC and Mayor.

3.2 O&M Planning

Proper O&M planning includes realistic budgeting and efficient management. It plays a very important role in realizing quality services from ULB infrastructure. The Engineering Division has to follow some specific actions in planning the O&M of ULB assets. The four major parts of activities related to O&M plan are as follows:

1. Maintaining inventories of the ULB infrastructure;
2. Prioritizing ULB infrastructure for maintenance;
3. Preparing of O&M plans for each subproject under MGSP; and
4. Preparing Annual ULB O&M Plans.

Timely planning of O&M is the key for starting and finishing implementation on time. Therefore, the O&M plan should be done precisely within a distinct time frame.

3.2.1 ULB Infrastructure Inventories

The foremost condition to identify the maintenance needs is to establish an inventory database of all existing ULB infrastructure. The inventory database shall include an informative description of such infrastructure including 1) type; 2) name of infrastructure with its identification number; 3) location or start and end point; 4) size, length, and capacity; 5) year of construction; and 6) physical condition of each infrastructure. The inventories shall be prepared for the following major types of infrastructure, but not limited to the following items.

1. roads, bridges/culverts, and footpaths;
2. buildings (office, residences, auditoria, etc.);
3. drainage infrastructure;
4. bus and truck terminals, parking area;
5. water supply infrastructure (tube-wells, pump houses, overhead tanks, distribution network);
6. public toilets;
7. slaughter houses;
8. solid waste bins and disposal grounds;
9. street lighting;
10. kitchen markets;
11. supermarkets, rental shops, and commercial complexes;
12. burial grounds, graveyards, and crematoria; and
13. beautification, recreational facilities (parks, playgrounds, open space, etc.).

The infrastructure inventories prepared by the ULBs will be maintained and updated periodically. Each ULB will also be responsible for the preparing inventories of construction plant and equipment it possesses.

3.2.2 Prioritizing ULB Infrastructure for Maintenance

There is always deficit of regular funding compared to the real need for normal maintenance of ULB infrastructure. Therefore, prioritization of significant infrastructure shall be done considering its importance and need for the sake of sustainable maintenance. The prioritization process shall require detail information and technical analysis. A priority list of ULB infrastructure for maintenance shall be prepared based on this information and analysis as well as social and commercial importance. With this aim, the ULB shall consider some indicators, but not limited, to the following points:

1. Routine maintenance for infrastructure shall be emphasized over periodic maintenance;
2. Arterial roads including bridges and culverts shall be emphasized over tertiary roads;
3. Roads linked with Upazila and Union roads shall be prioritized;
4. The infrastructure built by development partners, including MGSP, shall be prioritized;
5. The infrastructure benefitting the most people shall be prioritized;
6. The infrastructure located in the ward which the citizens paid more tax compared to other wards shall be prioritized;
7. Infrastructure having significant environmental conservation and life influences shall be prioritized; and
8. Social and commercial importance of the infrastructure.

3.2.3 Preparation of O&M Plan for Each Subproject under MGSP

Each ULB will prepare an O&M plan for each subproject implemented under MGSP. This plan is aimed at clarifying organizational structure, budget, financial sources, and procedures for O&M of each subproject. ULBs will prepare subproject O&M plans in the process of subproject planning. The plans will be discussed at the TLCC and WLCCs. If the institutional arrangements for O&M implementation involve organizations or persons outside the ULB Council, the ULB should obtain their commitment to O&M of the subprojects prior to the finalization of the plans.

3.2.4 Preparation of the Annual ULB O&M Plan

Each ULB will prepare an Annual O&M Plan that comprises the following items for each infrastructure in the inventory:

1. organizations and persons in charge;
2. necessary manpower to be contracted or hired;
3. schedule of works; and
4. O&M budget required.

The Annual O&M Plan will be discussed at the TLCC and WLCCs. The ULB should prepare the Annual O&M Plan by May of each year. This is because the ULB's annual budget is prepared and approved by May and the required amount for O&M shall be allocated in the ULB's annual budget. The Annual O&M Plan will be prepared for each fiscal year. The ULB's Annual O&M plan shall be prepared following the priority list and a suitable format.

3.3 Budget Framework of O&M

Each ULB will prepare an annual O&M plan and subproject O&M plans. The subproject O&M plan, including budget requirements shall be approved by the TLLC together with subproject application. The ULB shall then earmark the required O&M budget. The ULB shall

allocate adequate funds for O&M from its revenue income and increase O&M budget annually to meet the backlog maintenance. The Project ULBs should keep at least 15-20% of the annual development budget for O&M infrastructure.

3.3.1 Annual O&M Budget

Based on an Annual O&M Plan and subproject O&M plans, each ULB will allocate budget for O&M in the process of annual budgeting that is usually undertaken from May. After the preparation of each Annual O&M Plan, an incremental increase of 5% per annum should be allocated until the financing requirement for sustainable O&M is met.

3.3.2 Medium Term Budgeting Framework

In order to enhance predictability of budget and sustainability of O&M activities, each ULB will prepare a Five-year Budget Plan for O&M as part of its routine MGSP activities. The plan will include estimated cost of O&M, an available amount of the budget earmarked for O&M, and a target amount of budget for O&M in each of the next five years. The cost, available amount, and target amounts will be identified for each type of infrastructure. The TLCC and WLCCs will be involved in the process of this preparation. This Five-Year Plan is aimed to help ULBs understand the gaps between the estimated cost and available budget, and to undertake systematic efforts to increase O&M budgets in ULBs.

3.4 Implementation of O&M Plan

Each ULB will implement respective actions in its O&M plan. It will assign a standing committee and councillors in charge of O&M and establish a working group for O&M. The O&M Working Group in each ULB will monitor and supervise activities of the annual O&M plan to ensure its implementation. The working group will: 1) examine reports on O&M from division or sections and persons in-charge once per month; 2) hold regular a meeting at least once in a month to discuss the progress of the annual O&M plan and results of O&M; and 3) report on O&M to the standing committee and councillors in charge of O&M at least once every three months. The standing committee and councillors will hold a meeting at least once every three months.

3.5 Citizens' Participation in O&M

Each ULB will involve the TLCC and WLCCs in the preparation and implementation of O&M activities. The TLCC and WLCCs will hold discussions on the inventories of infrastructure, subproject O&M plans, Annual O&M Plans, and Five-year O&M Budget Plan. The TLCC and WLCCs will discuss the status of O&M and make suggestions and recommendations for the ULB. The working group for O&M should report O&M issues to the TLCC at least once every three months. The working group may also involve the WLCC and citizens, such as executive committee members of CBOs, SICs, and informal group members (if any) in routine O&M of infrastructures and facilities.

3.6 Technical Capacity for O&M

Each ULB will implement activities to improve technical skills of concerned persons for O&M. Concerned officials of each ULB will participate in training courses on O&M provided by the Project, and disseminate learned knowledge and skills for relevant persons. It may be necessary for each ULB to provide training to its contractual labor as well as to the citizens involved in O&M such as executive committee members of CBOs, SICs and informal group members (if any). Each ULB will also ensure that O&M manuals provided by the Project and other related documents will be properly stored at the ULB office so that every concerned person is able to access them. To this effect, the PMU or MSU of the LGED, with support from the DSM Consultant, will provide training courses for ULBs concerning the overall mechanisms and procedures for preparing and implementing O&M plan. Training will include technical measures for O&M of each type of infrastructure.

3.7 O&M of Construction Equipment

Operation and maintenance of construction equipment is equally important as the O&M of infrastructure assets. Each ULB will be responsible for the proper O&M of construction equipment.

The O&M of construction equipment includes the following issues.

1. Whenever possible, store equipment inside where floor drains has been connected to the sanitary sewer system.
2. When inside storage is not available, equipment will be parked in the approved designated areas.
3. Routinely inspect equipment storage and maintenance areas to determine their effectiveness.
4. Regular cleaning and maintenance of construction equipment, particularly cleaning and maintenance after each time use of such equipment.
5. Provide wash areas for all equipment inside the maintenance building that has a suitable drainage system.

3.8 Specimen O&M Plan

Each ULB under the MGSP is shall prepare and O&M plan during Project implementation. The O&M plan will be submitted to Project Director for consideration. The ULB working group, with assistance and support from the ULB standing committee, will be responsible for preparing and implementing O&M plan, including all the contents so far discussed. Accordingly, a sample O&M plan is framed and attached to this manual as **Appendix C**. However, the actual contents of the action plan shall be determined by the concerned ULB without any change of action indicated in the format.

3.9 Appendices to Support Preparation and Implementation of O&M Plan

Supporting tools for preparing and implementing the O&M plan, such as checklists, formats, questionnaires, etc. are provided as Appendices to this manual.

Name of ULB: ----------
Sample format of ULB's Infrastructure O&M Plan)

Action	Output/ indicator	Specific task	Organization/ person in charge	Time schedule
Institutional arrangements				
A standing committee and councillors are assigned to O&M.	• Standing Committee with specific responsibilities of O&M • List of Councillors involved with O&M • Meeting minutes	• Assist O&M working group in performing their overall function and oversee the O&M activities; • Assist O&M working group in preparing inventory and database of ULB infrastructure that require maintenance; • Organize awareness campaign to create "sense of ownership" among the citizens; • Motivate the people through TLCC and WLCC to participate in planning and implementing O&M activities of ULB infrastructure; • Hold standing committee meetings at least once every three months to review and monitor progress of O&M activities and report to TLCC and Mayor.	• ULB Mayor • Standing Committee	Latest by end of FY
A working group for O&M consisting of ULB officials is established	• WG with specific responsibilities for O&M • List of officials with assigned responsibilities • Type of maintenance • Priority list for O&M • Estimated budget • Meeting minutes	• Advise in the preparation of infrastructure inventory and database, identifying the physical features (e.g. length, area, material, etc.) of all infrastructure (e.g., buildings, roads, drains, etc.) which require maintenance; • Identify O&M tasks defining type of maintenance (routine, periodical, emergency, or rehabilitation) to be performed on each infrastructure and works to be done (e.g. sweeping road, drain cleaning, road patching, potholes, painting, etc.) • Prioritize infrastructure to be undertaken for O&M within the available budget considering a set of criteria including social and commercial importance of the infrastructure; • Prepare the annual O&M budget requirement, submit to the standing committee and pursue full allocation of O&M funds on time; • Assign division or sections and the persons with responsibilities in performing the tasks relevant to them; • Support preparation and implementation of subprojects for O&M of each type of infrastructure including setting technical specifications, tendering, contracting, supervision of implementation, etc.; • Estimate the time required to complete each task including developing an annual work schedule; • Hold regular meetings at least once per month, monitor progress of implementation and report to standing committee and Mayor.	• ULB Mayor • Working Group Members	Latest by end of FY

Action	Output/ indicator	Specific task	Organization/ person in charge	Time schedule
Planning of O&M				
Inventories of infrastructure under the responsibility of ULB are prepared and updated	• Inventories of infrastructure (periodically updated)	Prepare Inventories of infrastructure by ULB using formats designed for the purpose which may include (i) identification number, (ii) type, (iii) name, (iv) location or starting and end point, (v) size, length, and capacity, (vi) year of construction, (vii) present condition, etc. Update the inventories of each infrastructure periodically.	• Engineering Division with support from Working Group for O&M	Prepare each year and update periodically
Priority list of O&M of infrastructure is prepared	• Priority list for O&M	Consider and determine indicators including social and commercial importance for analyzing priority needs. Prepare priority list of ULB infrastructure for O&M based on the predetermined indicator criteria and analysis.	• Engineering Division with support from Working Group for O&M	At least once per year by May during budget exercise
Subproject O&M plan is prepared	• Subproject O&M plan	Prepare an O&M plan for each subproject to be implemented under MGSP clarifying organizational structure, budget, financial sources, and procedures for O&M. Discuss the O&M plans at TLCC and WLCCs to determine status of O&M and to make suggestions and recommendations to ULB.	• Working Group for O&M	At the time of subproject preparation Once in year quarter
Annual O&M Plan is prepared	• Annual O&M Plan	The ULB prepares the Annual O&M Plan by April each year. The Annual O&M Plan for subprojects under MGSP will be prepared. ULB Annual O&M plan will be prepared in each year following the priority list.	• Engineering Division with support from Working Group for O&M	By May each year
Budget framework of O&M				
Budget for O&M is allocated in annual budget	• Amount earmarked for O&M	Allocate budget for O&M in the process of annual budgeting that is usually undertaken from April to May. Keep at least 15-20% of the annual development budget for O&M of infrastructure, with an incremental increase of 5% per annum until the financing requirement for sustainable O&M is met.	• Standing Committee in cooperation and coordination with Mayor	By May each year
Five-year Budget Plan for O&M is prepared	• Five-year budget plan	Prepares a Five-year Budget Plan for O&M. Involved TLCC and WLCCs in the process of this preparation.	• ULB Engineering Division with involvement of TLCC and WLCC	During preparation/ Revision of CIP

Action	Output/ indicator	Specific task	Organization/ person in charge	Time schedule
Implementation				
Annual O&M Plan is implemented	• Monthly O&M implementation reports; • Working group meeting every month; • Standing committee meeting every quarter; • Meeting minutes.	• The working group receives reports on O&M implementation from divisions, sections, and persons in charge at least once every three months; • The working group holds regular meetings at least once in a month to discuss progress of the Annual O&M Plan and results of O&M • Working group follow-up implementation of decision in the subsequent meeting; • WG report on O&M to standing committee and councillors in charge of O&M at least once every three months. • The standing committee and councillors hold meetings and discuss O&M at least once every three months, monitor progress, identify problems, suggest ways and means to move forward • The standing committee follows up implementation of decisions in the subsequent meeting	• Divisional and sectional heads or person in charge • Working group • Standing committee and councillors	Throughout the year
Citizens' participation				
TLCC and WLCCs are involved in O&M	• Citizens participate in O&M planning & implementation process • Meeting minutes • Recommendations for ULB Parishad	• TLCC and WLCCs discuss inventories of infrastructure, annual O&M Plan, subproject O&M plan, and five-year Budget Plan. • TLCC and WLCCs discuss the status of O&M; they suggest and recommend action to the ULBULB Parishad. • WG involves citizens such as members of WLCC, CBOs, SICs and informal groups (if any) in routine O&M of infrastructure and facilities. • WG for O&M reports O&M issues to TLCC at least once in every three months.	• O&M working group**;** • Convenor TLCC and WLCC	Once in every three months
Technical capacity for O&M				
Technical skills of concerned persons for O&M are improved	• O&M manuals • Training Courses • Participation of ULB Officials in O&M training • CBO, SIC members and contractual laborers receive O&M training	• UPMU with support from MSU provides O&M manuals and training courses on O&M • ULB officials participate in training courses on O&M provided by the Project. • The officials disseminate what they learn in the training to relevant persons. • ULB provides training to citizens involved in O&M such as members of CBOs and SICs as well as to contractual laborers. • O&M manuals and other related documents are properly stored at ULB office.	• PMU with support from UMSU and Consultants • ULB Secretary with support from working group	FY 2016/2017 FY 2017/18

Note: This table is proposed as a format of the O&M plan; the contents of the plan should be prepared and determined by ULB. However, it is proposed that actions indicated in this table should be included in the plan.

CHAPTER 4

ROADS

4.1 Introduction

Improved road transport facilities are essential for the economic development and social activities of a nation. Deterioration of a country's transport facilities is a clear indication of the decline of economic growth, which is obviously very undesirable. One of the essential activities required for ensuring that the costly investment in road infrastructure is maximized, is effective maintenance. It should also be kept in mind that neglected or delayed maintenance causes expensive re-constructions and rehabilitation requirements, affecting all sectors of the economy. In addition, effective and timely maintenance will reduce vehicle operating cost, improve road safety and ensure transport punctuality.

Road transport facilities in most of the ULBs (at Pourashava or City Corporation level) are very poor. Uneven road surface, potholes and crack, poor traffic signaling, inadequate street lightening, poor drainage of surface runoff, roadside garbage, lack of proper sweeping, heavy traffic congestion, etc. are the common scenario in most Cities and Pourashavas. Therefore, effective and efficient operation and maintenance is required to:

1. reduce the rate of deterioration (to prolong life of the facility);
2. Lower vehicle operating costs of the users by providing a good running surface; and
3. Enable greater regularity, punctuality and safety.

Appropriate O&M procedure in the form of O&M Guidelines is absolutely necessary for any scheme. This guideline will essentially guide the system operators/workers about its daily and routine tasks. It will serve three basic requirements of the O&M which are: a) operation, b) maintenance and c) monitoring.

Roads and Highways Department (RHD) and the Local Government Engineering Department (LGED) shares responsibilities for development and maintenance of the entire road network of the country except City Corporations and Pourashavas, where ULBs are responsible for the development and maintenance of roads that lie with the respective City Corporations and Pourashavas.

Though the Urban Local Bodies (City Corporation and Pourashava) is responsible for development and maintenance of their roads, major development works are usually done through LGED Projects financed by Donor Agencies like WB, ADB, JICA, KfW, IDB, GoB and ULB own resources.

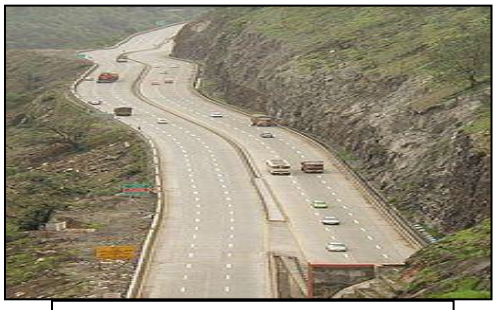
Some useful description and details of equipment, plant operations etc. have been provided in this document. These are not generally meant for the operators/worker but will provide useful information and guidance to the Management.

4.2 Classification of Roads

A Road is a thoroughfare, route, or way on land between two places that has been paved or otherwise improved to allow travel by foot or some form of conveyance, including a motor vehicle, cart, bicycle, or horse.

Road type designations in Waze (GPS-based geographical navigation application program) should be determined by the physical layout and use of the road, not by the name of a road.

Some road type classifications are influenced by city size, traffic density, and regional conventions. For example, in a very large city a primary street may have three or more lanes in each direction on a divided road. While in a town of dirt roads, the only paved single lane street could be a primary street.



Freeway

Based on layout and use, road is classified as follows:

1. **Freeway**. This is a highway or express way with separated lanes and without traffic lights or stop signs. Ramps are used to enter or exit from it.

2. **Highway (Major and Minor)**.Highways are main public roads specially ones connecting towns and cities.

- ***Major highways*** have two lanes in each direction, their access and exits could be a ramp or junction. Whereas ***Minor highways*** are narrow intercity roads, have a single junction. Usually it has one lane on each direction and is not separated. Highways usually have intersections but there are certain cases in which highways have traffic light.

Major Highway

- According to National Road Classification, highways are again classified as National Highway and Regional Highway.

  - ***National Highway*** is one connecting National Capital with Divisional HQ/s or sea port or land port of Asian Highway.

  - ***Regional Highways*** connect District Headquarters or main river or land ports or each other but not connected by National Highway.

Minor Highway

3. **Street (Primary street and Street)** – Streets are defined as public thoroughfares in a city or town, including curbs, gutters and sidewalks on one or both sides.

Primary Streets are usually a two ways roads with more than one lane to each direction; it does not have a separation wall in order to enter or exit that kind of road we use junctions. In the small urban town, a primary street may barely be wide enough for two cars heading opposite directions to pass each other. In dense urban areas primary streets may need to be a divided road with multiple lanes of traffic in each

Primary Street

Street

direction having traffic controls at every intersection. Whereas a s*treet* is a small one or two ways road, small junction is used to enter or exit from it.

4. **Ramps** are used to enter or exit from a freeway or major highway.
5. **Service Roads** are separated slow-speed drivable roads parallel to highway/freeway used as access point to shops/building/gas station, etc.
6. **Dirt Roads** are unpaved roads.

Ramp

4.3 Brief Description of Different Types of Pavement

Road surface or pavement is the durable surface material laid down on an area intended to sustain vehicular or foot traffic. Based on road top, road is named as bituminous/asphalt paved road, cement concrete road, HBB, WBC etc. The construction materials of road are mainly bricks and brick chips, stone chips and gravels, sand, cement concrete and bitumen.

Dirt

Based on surface materials, roads are broadly classified as:

1. Bituminous/Asphalt Paved Road;
2. Concrete Paved (Cement Concrete or Reinforced Cement Concrete) Road;
3. Composite Paved Road;
4. Herringbone Bond Brick (HBB) Road; and
5. Pavers

Generally, two types of surface paving are used in Cities and Pourashavas, flexible (bituminous) and rigid (concrete).

4.3.1 Asphalt Paved Road

Asphalt (specifically, asphalt concrete), sometimes called flexible pavement due to the nature in which it distributes loads, has been widely used since the 1920s. The viscous nature of the bitumen binder allows asphalt concrete to sustain significant plastic deformation, although fatigue from repeated loading over time is the most common failure mechanism. Most asphalt surfaces are laid on a gravel base.

Asphalt Road

Asphalt Road

An asphalt concrete surface will generally be constructed for high-volume primary highways having an average annual daily traffic load greater than 1200 vehicles per day.

Advantages of asphalt roadways include the following items.

1. Relatively low noise;
2. Relatively low cost compared with other paving methods; and
3. Perceived ease of repair.

Disadvantages include the following items

1. less durability than other paving methods;
2. less tensile strength than concrete;
3. the tendency to become slick and soft in hot weather; and
4. a certain amount of hydrocarbon pollution to soil and groundwater or waterways.

Asphalt concrete is usually placed on compacted base course of water bound macadam (WBM) with brick or stone aggregate on well prepared surface. In areas with very soft or expansive sub grades such as clay or peat, thick gravel bases or stabilization of the sub-grade with Portland cement or lime may be required. Generally compacted aggregate (well graded crushed well burnt picked jhama or first class bricks and bats or crushed stone) sand sub-base course is used below the completed base course.

Generally, 25-50mm thick compacted pre-mixed bituminous (well graded stone chips with bitumen) carpeting is made over a bitumen prime coat on base course.

Bituminous surface treatment (BST) or chip seal is used mainly on low-traffic roads, but also as a sealing coat to rejuvenate an asphalt concrete pavement. It generally consists of aggregate spread over a sprayed-on asphalt emulsion or cut-back asphalt cement. The aggregate is then embedded into the asphalt by rolling it, typically with a rubber-tired roller. This type of surface is described by a wide variety of regional terms including "chip seal", "tar and chip", "seal coat", "sprayed seal" or "surface dressing", etc.

4.3.2 Concrete Paved Road

Concrete pavement sometimes called rigid pavement has been extensively used since 1893 for paving highways and airports as well as business and residential streets. Concrete surfaces (specifically, Portland cement concrete) are created using a concrete mix of Portland cement, coarse aggregate, sand and water. Virtually all modern mixes there will also be various admixtures added to increase workability, reduce the required amount of water, mitigate harmful chemical reactions and for other beneficial purposes.

Concrete surfaces have been refined into three common types:

1. Jointed Plain Concrete Pavement (JPCP);
2. Jointed Reinforced Concrete Pavement (JRCP); and
3. Continuously Reinforced Concrete Pavement (CRCP).

The one item that distinguishes each type is the jointing system used to control crack development.

Jointed Plain Concrete Pavement (JPCP)

JPCP is the most common style, made up of slabs with closely spaced contraction joints to control cracking with no steel reinforcement. However, there may be smooth steel bars (dowel bars) at transverse joints and deformed steel bars/connectors (tie bar) at longitudinal joints as well as aggregate interlock. The spacing between transverse joints is typically between 3.7 to 6.1 m. When cracks develop, they should occur in the cracks between slabs, making the road surface easy to repair.

JPCP

Jointed Reinforced Concrete Pavement (JRCP)

This type of rigid pavement contains a steel mesh that reinforces the structure of the concrete slab, although do not improve the structural capacity significantly it allows designers to increase the joint spacing and include reinforcing steel to hold together intermediate cracks in each slab. Transverse joint spacing is longer than that for JPCP and typically ranges from about 7.6 to 15.2 m. The reinforcement prevents some cracks, allowing the larger slabs to be effective. Although, when cracks appear, typically occur between slabs

JRCP

Continuously Reinforced Concrete Pavement (CRCP)

This type contains a high quantity of steel reinforcement and does not require joints, as are not designed to crack at them. The cracks usually form on the pavements at intervals of 1.1 m to 2.4 m. The steel reinforcement constitutes about 0.6% to 0.7% of the cross-sectional pavement area and is located near mid-depth in the slab. The reinforcing steel holds cracks together so closely that they do not cause structural problems within the slab. Continuously reinforced pavements generally cost more than jointed reinforced or jointed plain pavements, due to increased quantities of steel. However, they can present superior long-term performance and cost-effectiveness

CRCP

To prepare for paving, the sub-grade, the native soil on which the pavement is built—must be graded and compacted. Preparation of the sub-grade is often followed by the placing of a sub-base—a layer of material that lies immediately below the concrete. The essential function of the sub-base is to prevent the displacement of soil from underneath the pavement. Sub-bases may be constructed of granular materials, cement-treated materials, lean concrete, etc. In our country, generally compacted aggregate (well graded crushed well burnt picked jhama or first class bricks and bats or crushed stone) - sand sub-base course is used. Once the sub-base has hardened sufficiently to resist marring or distortion by construction traffic, tie bars, or reinforcing steel are placed and properly aligned in preparation for paving.

HBB Road

Advantages of concrete roadways include the following items.

1. They are stronger and more durable than asphalt roadways;
2. They can be grooved to provide a durable skid-resistant surface; and
3. Concrete pavement can be maintained over time utilizing a series of methods known as concrete pavement restoration which include diamond grinding, dowel bar retrofits, joint and crack sealing, cross-stitching, etc. Diamond grinding is also useful in reducing noise and restoring skid resistance in older concrete pavement.

Disadvantages include these topics.

1. They have a higher initial cost; and
2. They take longer to construct.

4.3.3 Composite Pavement

Composite Paved Road

Concrete Composite pavements combine a Portland cement concrete sub-layer with asphalt. They are usually used to rehabilitate existing roadways rather than in new construction.

Asphalt overlays are sometimes laid over distressed concrete to restore a smooth wearing surface. A disadvantage of this method is that movement in the joints between the underlying concrete slabs, whether from thermal expansion and contraction, or from deflection of the concrete slabs from truck axle loads, usually causes reflective cracks in the asphalt. To decrease reflective cracking, concrete pavement is broken apart through a break and seat, crack and seat, or rubblization process. Rubblization is a more complete fracturing of the old, worn-out concrete, effectively converting the old pavement into an aggregate base for a new asphalt road.

4.3.4 Herringbone Bond Brick Road

HBB is a type of road mainly used in rural areas and also in urban areas as local access road. It is also used in School and University Campus, road within Apartment Complex. This type of road is suitable for light and low speed vehicles and walkers.

HBB road is made of mainly well burnt bricks laid on edge in a herringbone pattern placed on a prepared single layer brick flat soling. Usually a sand cushion of minimum 25mm thick sand over the brick flat soling before placing the bricks in herringbone pattern.

The major disadvantages of this type of road are listed below.

1. Noise and vibration;
2. Labor intensive in construction and maintenance; and
3. Moisture infiltration losing base.

4.3.5 Pavers

Pavers (or pervious), generally in the form of pre-cast concrete blocks, are often used for aesthetic purposes, or sometimes at port facilities that see long-duration pavement loading. Pavers are commonly used as local access road with a speed limit of 30 km/h, for the purpose of traffic calming. Due to the high cost of labor required to lay and maintain them, and are typically only kept for historical or aesthetic reasons.

HBB Road

4.4 O&M Activities for the Officers and the Workers

In Cities and Pourashavas, mostly asphalt paved and concrete paved roads are used. Therefore, this O&M Guidelines will be restricted to asphalt and concrete paved road only.

As pavement systems primarily fail due to fatigue(in a manner similar to metals), the damage done to pavement increases with the fourth power of the axle load of the vehicles traveling

on it. According to the AASHO Road Test, heavily loaded trucks can do more than 10,000 times the damage done by a normal passenger car. Passenger cars are considered to have no practical effect on a pavement's service life, from a fatigue perspective.

Other failure modes include aging and surface abrasion. As years go by, the binder in a bituminous wearing course gets stiffer and less flexible. When it gets "old" enough, the surface will start losing aggregates, and macro texture depth increases dramatically. If no maintenance action is done quickly on the wearing course, potholes will form.

4.4.1 Management Tasks

The Officer in charge of maintenance has the responsibility of programming the activities of maintenance work throughout his/her area, with an appropriate allocation of resources provided by the authority concerned. This responsibility involves a sequence of tasks, which can be summarized as follows.

1. Inventory: recording the basic characteristics and components of each section of the road network;
2. Inspection: examining the road and measuring its condition;
3. Determination of maintenance requirements: analyzing why defects are occurring and what maintenance activities are needed to correct them so as to delay further deterioration;
4. Resource estimation: costing the activities of the maintenance program in order to determine the overall budget;
5. Identification of priorities: deciding the work that has to take priority; and
6. Monitoring: checking the quality and effectiveness of the work.

4.4.2 Classification of Maintenance

Road maintenance activities can be classified based on the nature of each activity and the frequency at which they should be carried out.

1. Routine Maintenance;
2. Recurrent Maintenance;
3. Periodic Maintenance; and
4. Urgent Maintenance.

Routine Maintenance

Routine maintenance is required for the general upkeep of the road and road environment. Daily or routine maintenance consists of sweeping, weeding, jungle cleaning, filling eroded area, etc. Defects observed in road surface, shoulders must be expeditiously repaired. No problem should be allowed to continue; otherwise complexity may arise resulting in more damage to the road.

Some routine maintenance items of urban roads are shown in **Exhibit 4-1**.

Instruction No. 4-1: Routine Maintenance of Urban Roads (Action: Officer in Charge and Gang Leader)

Exhibit 4-1
Maintenance Chart of Urban Roads

No.	Maintenance Task	Frequency	Point of Attention
1.	Street sweeping – work should be done in such a way as to leave the streets clean with no dirt, trails or debris.	Daily	Sweeping tools like brooms, brushes, belchas, and garbage hand trolleys are in good condition and properly used. Sweepers attend the works timely and clean the road properly. Sweeping works is completed early in the morning and do not hamper traffic movement. Water spray may be used to reduce dust in air. Surface runoff drainage grid is not blocked by garbage.
2.	Managing garbage generated from sweeping – transportation and safe disposal.	Daily	Garbage collection truck collects the sweeping garbage timely and disposes off in land fill. Garbage collection trucks are in good operating condition.
3.	General upkeep of shoulder and road side – cutting grass, weeds, jungle, branches of road side trees obstructing traffic movement, filling eroded areas.	Monthly	Cleaning tools are in good condition. Funds available for engaging labor. Engaged labors perform the task as directed. Garbage collection truck collects the weeds/cutoff plants, etc. timely and disposes off in landfill. Garbage collection trucks are in good operating condition.
4.	Maintenance of road furniture – painting traffic control and safety sign, repairing/replacing badly oriented/tilted/damaged traffic sign board, painting road line marking, manufacturing and displaying new sign if required, etc.	Quarterly (three months interval) or as required	Funds available for engaging labor/painter and purchasing materials. Engaged laborers and painters perform the task as directed. Only standard signs are used. All the signs are clean and in good visible condition. Standard signs are displayed in standard layout that gives time to understand and respond by the drivers.
5.	Removing standing water from the pavement surface and nearby ground.	As and when required particularly before wet season.	Clean the road side draining grid to drain away the surface runoff. Remove debris from road side obstructing the draining of surface runoff. Make narrow channel on shoulder if necessary to remove standing water from the road surface.

No.	Maintenance Task	Frequency	Point of Attention
6.	Routine inspection of pavement condition.	Monthly	Driving slowly over the road to get an overall impression of its condition. Based on primary impression make a thorough inspection on foot, making notes on the type and extent of distress as one goes along. Rating of pavement distress is made for the management to understand the type of action required like routine maintenance or overlay or reconstruction.

Recurrent Maintenance

These activities may be required at intervals throughout the year depending on the damaging effects of traffic, rain, etc. They include:

1. repairing potholes, ruts, depressions, cracks, etc.; and
2. corrections to the edges of pavements and shoulders

Maintenance of Asphalt Pavement

Asphalt pavements offer incredible value. They are quick and economical to construct, have excellent ride quality and are long lasting. Still they are subject to some distresses, particularly when poor quality materials are used and sloppy construction techniques are followed. By understanding the type of distresses and the causes of these problems, appropriate corrective action can be taken to repair the pavement and continue its service life.

The most common distress of asphalt pavement is fatigue from repeated loading over time. However, preventive Maintenance can improve or extend the functional life of a pavement. It is a strategy of surface treatments and operations intended to retard progressive distress and reduce the need for costly corrective and service activities.

Preventive maintenance activities can include conventional treatments such as crack sealing, chip sealing, fog sealing, rut filling, and thin overlays. They can also include emerging technologies such as ultra-thin wearing courses, very thin overlays, and micro-surfacing applications. Aside from crack treatments, all of these treatments leave the pavement with a new wearing surface. A fog seal provides a new wearing surface, although it generally has a lower friction number than the original surface.

Common pavement distresses with possible causes and maintenance suggestions are in **Exhibit 4-2**.

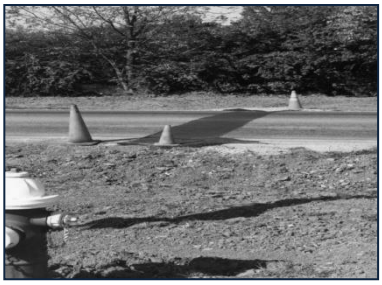
Instruction No. 4-2: Recurrent Maintenance of Asphalt Pavement (Action: Officer in Charge and Gang Leader)

Exhibit 4-2
Maintenance Chart of Asphalt Pavement

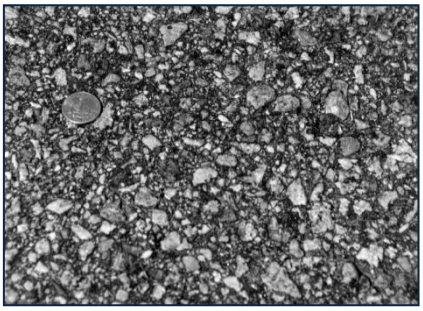
No.	Type of Distress	Possible Causes	Maintenance Suggestions
1.	Fatigue (Alligator) Cracking – *interconnected cracks on pavement surface which resemble an alligator's skin or chicken wire*. 	1. Excessive loading 2. Weak surface, base or subgrade. 3. Thin surface or base 4. Poor drainage 5. Any combination of 1 to 4.	1. Remove all distress area to a depth of firm material. 2. Replace with proper asphalt mix, allowing 25% times depth of patch for compaction.
2.	Block Cracking – *a series of large rectangular cracks on pavement surface* 	1. Old and dried out mix 2. Mix was placed too dry. 3. Fine aggregate mix with low penetration asphalt & absorptive aggregates. 4. Aggravated by low traffic volume.	1. Depending on the severity of the block/multiple crack pattern and dimensions, cracks may be treated by crack sealing, or fog treatment (a light application of a diluted slow-setting asphalt emulsion to the surface). 2. Or surface treatment (thin application of
3.	Edge Cracks – *longitudinal cracks developed within 300-600mm of outer edge of pavement.* 	1. Lack of lateral support 2. Settlement of underlying material. 3. Shrinkage of drying out soil. 4. Weak base or sub-grade layer. 5. Poor drainage 6. Heavy traffic or vegetation along edge.	1. Improve drainage by removing the source that traps the water. 2. Remove trees, shrubs, other vegetation close to edge. 3. Fill crack with asphalt emulsion slurry or emulsified asphalt.

No.	Type of Distress	Possible Causes	Maintenance Suggestions
4.	Longitudinal or transverse Cracks – *longitudinal cracks developed parallel to the centerline while transverse cracks are roughly perpendicular to the centerline*  	1. Poorly constructed paving joint crack. 2. Shrinkage of the asphalt layer. 3. Daily temperature cycling. 4. Cracks in an underlying layer that reflects up through the pavement. 5. Longitudinal segregation caused by the improper operation of the paver.	1. Seal crack or fill with asphalt emulsion slurry or light grade of asphalt mixed with fine sand.
5.	Reflection Cracking – *cracks that formed over joints.* 	1. Differential movement between the asphalt and base or sub-layer or concrete layers in case of composite pavement. 2. Can deteriorate further under heavy traffic.	1. It requires monitoring of the hairline cracks. 2. Crack sealing, or fog treatment with asphalt material. 3. Or surface treatment (thin application of asphalt with or without aggregate) over the entire surface.
6.	Slippage Cracks – *lateral displacement surface layer* 	1. Lack of a good bond between surface layer and the course beneath due to dust, oil, dirt, rubber, water and other non-adhesive material. 2. Tack coat has not been used. 3. Mixture has a high sand content. 4. Vehicular turning or stopping movements in pavements with a low-strength surface mix	1. Remove surface layer from around crack until good bond between layers is found. 2. Patch (partial or full depth) with plant mixed asphalt material. 3. Tuck with an asphalt emulsion.

No.	Type of Distress	Possible Causes	Maintenance Suggestions
7.	Corrugation – *Transverse undulation in surface at regular interval* 	1. Lack of stability in the surface layer. 2. Plastic mixture. 3. Low air voids. 4. Excess asphalt or fines. 5. Unstable base material	1. Mill off the surface to a uniform depth and replace with asphalt. 2. If the asphalt layer is more than 75mm thick, shallow corrugation can be removed with a pavement milling machine followed by a surface treatment. 3. If the base material is responsible, remove pavement, scarify and compact.
8.	Shoving – *Lateral displacement of paving material (bulging of surface) in a localized area.* 	1. Lack of stability in the sub-grade, base or surface layer. 2. Excess asphalt or fine aggregate in mixture. 3. Excess moisture or contamination in the granular base. 4. Smooth or rounded aggregate. 5. Incorrect asphalt grade.	1. Removal of affected area followed by deep patching with asphalt.
9.	Rutting – *Longitudinal surface depression along wheel path*. 	1. Resulting from consolidation or lateral movement of any of the pavement layers or the sub-grade under traffic. 2. Insufficient design thickness. 3. New asphalt pavement with too little compaction during construction. 4. Week asphalt mixture. 5. Weakness in the pavement layers due to moisture infiltration. 6. Use of plastic mixture.	1. Remove plastic mix by milling and replace with stable one. 2. Level pavements by filling with hot plant-mixed asphalt materials followed by thin asphalt overlay. 3. Mill off the surface to a uniform depth followed by overlay or thin surface patch.

No.	Type of Distress	Possible Causes	Maintenance Suggestions
10.	Settlement/ Grade depression – *localized low spots in pavement surface*. 	1. Settlement or failure in the lower pavement layer. 2. Improper construction techniques. 3. Poor drainage.	1. Mill off the surface to a uniform depth followed by overlay or thin surface patch. 2. The area should be string lined for limits of patch.
11.	Uphill or Swell – *localized heave in pavement surface*. 	1. Expansive soil (which swell in the presence of moisture).	1. Excavate the pavement as much necessary and back fill with asphalt mixture.
12.	Utility Cuts or Patch Failure 	1. A portion of a pavement has been removed and replaced. 2. A portion of a pavement where additional material has been added. 3. Poor installation techniques such as inadequate compaction, inferior or improper materials. 4. Failure of the surrounding or underlying pavement.	1. Excavate the patch fully or as required and compact the sub-grade with additional material if required. 2. Replace patch with deep or full depth patch. 3. Allow an extra 25% of volume for compaction.
13.	Pot Hole – *localized disintegration of pavement surface (bowl-shaped holes*) 	1. Resulting from progressive deterioration from other distresses such as alligator cracking, raveling or a failed patch after pieces of original pavement surface have been dislodged. 2. Poor surface mixture (too many or too few fines). 3. Weak spot in base or sub-grade. 4. Severity of the surrounding distress and traffic action accelerate potholes. 5. Insufficient asphalt pavement surface. 6. Poor drainage.	1. Removal of affected area followed by deep patching. 2. Allow an extra 25% of volume for compaction. 3. Use straight edge to restore patch to existing road way. 4. Improve drainage by removing the sources that trap the water. .

No.	Type of Distress	Possible Causes	Maintenance Suggestions
14.	Raveling or Weathering – *wearing out of aggregate particles from asphalt cement* 	1. Lack of compaction. 2. Constructed in wet weather. 3. Dry mix. 4. Dirty aggregate. 5. Overheating mix. 6. Asphalt binder has hardened excessively. 7. Poor-quality mixture. 8. Usually occurs in the presence of both traffic and water.	1. Any surface treatment such as skin patch, spot seal, fog seal or slurry seal. 2. A thin overlay may be required.
15.	Bleeding – *excess bituminous binder occuring on pavement surface(flushed with asphalt)* 	1. Improperly constructed seal coat. 2. Too much asphalt in mix. 3. Too heavy a prime or bond/tack coat. 4. Excessive sealant in the cracks or joints under an overlay. 5. Low air voids. 6. Traffic can contribute to bleeding if the asphalt layers become over-compacted and excess asphalt is forced to the surface. 7. Excessive hot weather	1. Surface treatment such chip seal, sandwich seal. 2. A thin overlay may be required. 3. Spread coarse sand over bleeding area.
16.	Loss of aggregate on surface treatment. 	1. Spreading the chips or aggregate too late in the construction process. 2. Asphalt may have cooled too much. 3. Aggregate too dusty or too wet when spread. 4. Not rolled immediately after placing it may not become seated. 5. Steel-wheeled roller alone was used for compaction. 6. Raining when treatment applied. 7. Applying too little asphalt to embedded the aggregate. 8. Allowing the traffic to use the surface before aggregate is seated and bonded.	1. Spread hot coarse sand over the affected area. 2. Rolled immediately after spreading with a pneumatic-tired roller.

No.	Type of Distress	Possible Causes	Maintenance Suggestions
17.	Polished Aggregate – *aggregate wearing to a smooth finish or texture under traffic*. 	1. Use of naturally smooth, non-crushed gravels and/or soft crushed rock that wears down quickly losing the surface roughness under the action of traffic.	1. Any surface treatment except fog seal (fog seal is a light application of a diluted slow-setting asphalt emulsion to the surface of an aged pavement surface). 2. A thin overlay may be required.
18.	Longitudinal or Transverse Streaking –*presence of alternating stripes aggregates or asphalt.* 	1. Aggregate not spread immediately. 2. Spray bar not set at correct height causing incorrect overlap of the spray fans. 3. Changing spray bar height as the distributor load decreases. 4. Nozzle problems (incorrect angle, incorrect size, different sizes, plugged or restricted nozzles, or ones with imperfections). 5. Nozzle control linkage problem. 6. Inconsistent pump speed or pressure to the nozzles, and varying distributor travel speed. 7. Pump pressure too low. 8. Improper application temperature (allowing the asphalt material to cool); and Improper binder choice (viscosity too high for existing conditions and equipment).	1. Re-seal surface using proper procedure and adjustment of equipment.

Note: Reroute traffic until the sealant material cures. If the pavement must be opened immediately after sealing, protect the sealant against pick-up by tires by lightly covering the sealant material with fine sand or toilet paper.

4.4.3 Repairing Method Details of Asphalt Pavement Distresses

Most common methods of asphalt pavement repair are listed below.

1. Crack repair with sealing;
2. Crack filling;
3. Full-depth crack repair;
4. Fog seal;

5. Seal coat;
6. Double chip seal;
7. Slurry seal;
8. Micro surfacing;
9. Thin hot-mix overlays; and
10. Patches, partial or full depth

Sealant or Filler Materials

There are many crack treatment material products on the market today, each with distinct characteristics. The products essentially comprise three material families and are often grouped by material type, according to their composition and manufacturing process. The principal material families and types are as follows:

1. Cold-applied thermoplastic bituminous materials
   - Liquid asphalt (emulsion)
   - Polymer-modified liquid asphalt

2. Hot-applied thermoplastic bituminous materials
   - Asphalt cement
   - Fiberized asphalt
   - Asphalt rubber
   - Rubberized asphalt
   - Low-modulus rubberized asphalt.

3. Chemically cured thermosetting materials
   - Self-leveling silicone.

Crack Repair with Sealing

It is a localized treatment method used to prevent water and debris from entering a crack, which might include routing to clean the entire crack and to create a reservoir to hold the sealant. It is only effective for a few years and must be repeated. However, this treatment is very effective at prolonging the pavement life. Includes the following three crack repair methods.

Clean and seal

Used on all types of cracks, it involves using a hot air lance or compressed air to blow out the debris in the crack, then filling with a sealant.

Saw and seal

Involves using a pavement saw to create transverse joint sat regular intervals along a newly placed pavement, then filling with a sealant.

Rout and seal

Used on transverse and longitudinal cracks. Involves using a pavement saw or router to create a reservoir centered over existing cracks, then filling with a sealant.

Crack filling

Crack Filling

Normally, cracks less than 19mm wide, which are spaced uniformly along the pavement and have limited edge deterioration, should be sealed. To effectively seal the cracks, the router or saw width must touch both sides

of the crack. Cracks that are greater than 19mm wide and are very numerous are not practical to seal, both because the router or saw will not touch both sides of the crack and because of the number of cracks present. Crack filling differs from crack sealing mainly in the preparation given to the crack prior to treatment and the type of sealant used. Crack filling is most often reserved for more worn pavements with wider, more random cracking.

Asphalt cement and liquid asphalt possess little flexibility and are very temperature susceptible, so they are limited to use as fillers in non-working cracks. Additives such as mineral fillers and fibers provide minimal elasticity to asphalt and do not significantly affect temperature susceptibility. Mineral filled and fiberized asphalt are most appropriate for use in crack-filling operations.

Full-depth Crack Repair

It is a localized treatment method to repair cracks that are too deteriorated to benefit from sealing. Secondary cracking requires there establishment of the underlying base materials.

Fog Seal

A fog seal is an application of diluted asphalt emulsion without a cover aggregate, used to seal and enrich the asphalt pavement surface, seal minor cracks, prevent raveling and provide shoulder delineation. They may be able to temporarily postpone the need for a surface treatment or non-structural overlay.

Fog seal

CSS-I or CSS-Ih diluted with 50 percent water is usually applied at 0.05 to 0.15 gall/sy depending on the pavement texture, weather condition and traffic. A spraying temperature of 125OF to 160°F and surface temperature of at least 50°F are recommended. An asphalt distributor is normally used to apply the fog seal

Seal Coat

It is an application of asphalt followed immediately with an aggregate (typically 19mm chips) cover. Applications with two layers are referred to as a double chipseal. Rapid-setting asphalt emulsions are normally used when placing a sealcoat. Seal coats can waterproof the surface; provide low-severity crack sealing and depressions providing a smooth, attractive and long lasting finish. It will reduce oxidation of the pavement surface, and improve friction.

Seal coat

Double Chip Seal

It is an application of two single seal coats. The second coat is placed immediately after the first. This treatment waterproofs the surface; seals small cracks, reduces oxidation of the pavement surface and improves friction.

Do not place chip seals in cool weather or on days with high humidity. Also do not place them when there is a chance of rain.

Slurry seal

Slurry Seal

Slurry seal is a mixture of fine aggregate, asphalt emulsion, water, and mineral filler (most often used is Portland cement). is used when the primary problem is excessive oxidation and hardening of the existing surface. Slurry seals are used to retard surface raveling, seal minor cracks, and improve surface friction.

Slurry seal should be placed when the air and pavement temperature are both at least $5O^0F$ and there is no chance of freezing within 24 hours after placement. Do not place during rain.

Micro-surfacing

Commonly referred to as a polymer-modified slurry seal; however, the major difference is that the curing process for micro-surfacing isa chemically controlled process, versus the thermal process used by slurry seals and chip seals. Also may be used to fill rutson roads with moderate- to heavy-volume traffic.

Thin Hot-mix Overlays

It is a typical rehabilitation treatment for an aging low volume flexible (hot mix asphalt) pavement. Thin hot mix asphalt (HMA) overlays are plant-mixed combinations of asphalt cement and aggregate placed in depths of 19mm to 40mm over aging pavements as a pavement preservation treatment. The mixes used for thin HMA overlays can be dense-graded, open-graded or stone matrix asphalt (SMA).

For more distressed surfaces, the top 19mm to 40mm of the existing pavement may be removed by cold-milling with carbide-tipped cutting bits to a specified depth followed by the application of the thin HMA overlay.

Thin hot mixed overlay improves ride quality, reduce oxidation of the pavement surface, provide surface drainage and friction, and correct surface irregularities.

Pothole Patching

It includes using cold- and hot-asphalt mixture, spray injection methods, as well as slurry and micro-surfacing materials, to repair distress and improve ride quality.

Pothole patching

4.4.4 Maintenance of Concrete Pavement

Concrete Pavements are costlier to construct as compared to Asphalt Pavement. However, a study conducted in 2002 of concrete (both plain and reinforced) and asphalt pavements with similar traffic and in a similar environment on the Hume Highway over about 100 km between Mittagong and Goulburn in New South Wales, shows that the maintenance costs projected over 20 years' time are significant cost savings in concrete pavements compared to asphalt pavements.

Regardless of quality of pavement material and design, increase in the vehicular traffic and changing environmental conditions will reduce the service life of pavement which ultimately results in its failure.

Cracking is the most common feature of the rigid pavement. Fatigue cracking is considered as the major cause for the failure of rigid pavements. The stress ratio between flexural tensile stress and modulus of rupture of concrete is the primary factor which decides the number of load repetitions to cause fatigue cracking. Pumping, faulting, spelling, shrinkage,

polished aggregates, punch out, deterioration of joint load transfer system, linear cracking, durability cracking, corner break, alkali-aggregate reaction, pop-outs and blow-ups are some the other causes of failure of rigid pavements.

Crack filling, Crack sealing, Stitching, Diamond grinding, Dowel bar retrofitting, Joint repair, Partial-depth repair and Full-depth repairs are the most common preventive maintenance techniques used for restoration of rigid pavements.

Common types of distresses of rigid pavement with possible causes and maintenance suggestions are in **Exhibit 4-3**.

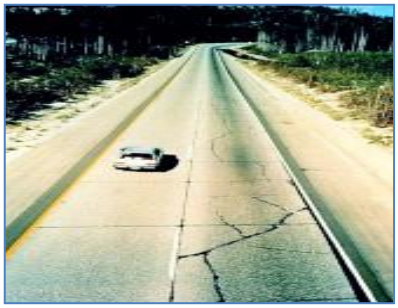
Instruction No. 4-3: Recurrent Maintenance of Concrete Pavement (Action: Officer in Charge and Gang Leader)

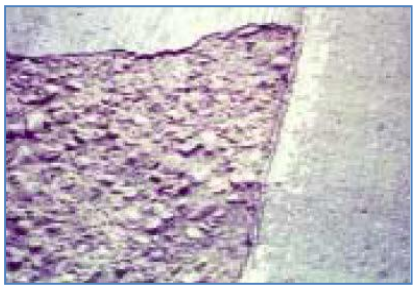
Exhibit 4-3
Maintenance Chart of Concrete Pavement

No.	Type of Distress	Possible Causes	Maintenance Suggestions
1.	Corner Breaks – *A crack that intersects the PCC slab joints near the corner within about 2m or so.* 	1. High corner stress caused by repeated traffic load combined with loss of support. 2. Poor load transfers across the joint, curling stresses and warping stresses.	1. Removal of the affected portion of slab followed by a full-depth patch.
2.	Spelling – *cracking, breaking or chipping of joints/crack edges usually occurs within about 600mm of joints/crack edge*. 	2. Excessive stresses at the joint/crack caused by infiltration of incompressible materials and subsequent expansion (can also cause blowups). 3. Weak PCC at a joint caused by inadequate consolidation during construction. This can sometimes occur at a construction joint if (1) low quality PCC is used to fill in the last bit of slab volume or (2) dowels are improperly inserted. 4. Misalignment or corroded dowel. 5. Heavy traffic loading. 6. Disintegration of the PCC from freeze-thaw action or	1. Apply partial depth patch (Spelling less than 75 mm from the crack face). 2. Apply full depth patch (Spelling greater than about 75 mm from the crack face which indicates possible spelling at the joint bottom).

No.	Type of Distress	Possible Causes	Maintenance Suggestions
3.	Faulting – *a difference in elevation across joint/crack edge*. 	1. Pumping or eroding of material from under the slab. 2. Loss of load transfer device (key, dowel, etc.), or swelling soils. 3. Soft foundation. 4. Curling of the slab edges due to temperature and moisture changes.	1. Faulting heights less than 3mm, do not need to be repaired. 2. Faulting heights within 10 to 20mm, application of a dowel bar retrofit may be considered. 3. Diamond grinding or overlay. 4. Faulting in excess of 20 mm, generally requires total reconstruction. 5.
4.	Polished Aggregate – *aggregate wearing to a smooth finish or texture under traffic*. 	1. Use of naturally smooth, non-crushed gravels and/or soft crushed rock that wears down quickly losing the surface roughness under the action of repeated traffic. 2. As a pavement ages the protruding rough, angular particles become polished.	1. Crushing the naturally polished aggregates creates rough angular faces that provide good skid resistance if the distress is in small area. 2. If polished aggregate distress occurs over an extensive area, consider milling, grooving, or diamond grinding the entire pavement surface.
5.	Shrinkage Cracking – *hairline cracks usually few cm long and not extends the entire depth of the slab. Generally formed during setting and curing of concrete and not located at joint*. 	1. All PCC will shrink as it sets and cures, therefore shrinkage cracks are expected in rigid pavement. Shrinkage cracks are considered a distress if they occur in an uncontrolled manner (e.g., at locations outside of contraction joints in JPCP or too close together in CRCP). 2. In JPCP, if contraction joints are sawed too late the PCC may already have cracked in an undesirable location. 3. Poor reinforcing steel design: In CRCP, proper reinforcing steel design should result in shrinkage cracks every 1.2 to 3 m	1. In mild to moderate severity situations, the shrinkage cracks can be sealed and the slab should perform adequately. 2. In severe situations, the entire slab may need replacement.

No.	Type of Distress	Possible Causes	Maintenance Suggestions
		4. Improper curing technique: If the slab surface is allowed to dry too quickly, it will shrink too quickly and crack. 5. High early strength PCC: In an effort to quickly open a newly constructed or rehabilitated section to traffic, high early-strength PCC may be used. This type of PCC can have a high heat of hydration and shrinks more quickly and to a greater extent than typical PCC made from unmodified Type 1 Portland cement.	3.
6.	Pumping – *movement or ejection of material underneath the slab as result of water pressure*.  	1. Water accumulation underneath the slab can be caused by a high water table, poor drainage, and panel cracks or poor joint seals that allow water to infiltrate the underlying material. 2. Water accumulated underneath a PCC slab ddecreases structural support of the slab, which can lead to linear cracking, corner breaks and faulting.	1. The pumping area should be repaired first with a full depth patch to remove any deteriorated slab areas. 2. Use of dowel bars to increase load transfer across any significant transverse joints created by the repair may be considered. 3. Consideration should be given to stabilizing any slabs adjacent to the pumping area as significant amounts of their underlying base, sub base or sub grade may have been removed by the pumping. 4. Finally, the source of water or cause of poor drainage should be addressed.

No.	Type of Distress	Possible Causes	Maintenance Suggestions
7.	Punch out – *Localized slab portion broken into several pieces typically concern only with CRCP.* 	1. Localized construction defect such as inadequate consolidation. 2. It can be caused by steel corrosion, inadequate amount of steel, excessively wide shrinkage cracks or excessively close shrinkage cracks.	1. Apply full depth patch.
8.	Linear Cracks – *cracks which divide an individual slab into two to four pieces, often referred to as "panel cracking".* 	1. Heavy repeated traffic loading. 2. Inadequate slab thickness. 3. Loss of foundation support. 4. Thermal gradient curling. 5. Moisture stresses. 6. A localized concrete construction deficiency, for example, honeycombs. 7. Or combination of all mentioned above. 8. It can be caused by steel corrosion, inadequate amount of steel, excessively wide shrinkage cracks or	1. Slab with a single, narrow linear crack may be repaired by crack sealing. 2. Slab with more than one linear crack generally require a full-depth patch.
9.	Joint Load Transfer System Cracks – *Transverse crack or corner break developed as joint load transfer dowels fail.*  	1. Corrosion: dowel bars can corrode over time if not properly protected. The corrosion products occupy volume, which creates tensile stresses around the dowel bars, and a severely corroded dowel bar is weaker and may fail after repeated loading. 2. Misalignment: Dowel bars inserted crooked or too close to the slab edge may create localized stresses high enough to break the slab. Misalignment can occur during original construction or during dowel bar retrofits.	1. Removal and replacement of the affected joint load transfer system followed by a full-depth patch for affected area.

No.	Type of Distress	Possible Causes	Maintenance Suggestions
10.	Scaling–*delaminating or disintegration of the slab surface to the depth of the defect usually 6 to 13 mm.* 	1. Construction defects include over-finishing, addition of water to the pavement surface during finishing, lack of curing, attempted surface repairs of fresh concrete with mortar. Generally, this occurs over a portion of a slab. 2. Material defects include: inadequate air entrainment for the climate. Generally, this occurs over several slabs that were affected by the concrete batches.	1. If the distress is severe, remove the immediate surface and provide a thin bonded overlay.
11.	Alkali-Aggregate Reaction – *Map or Pattern cracking.*  	1. In Portland cement concrete, aggregates containing reactive silica interact with alkali (sodium oxide and potassium oxide) present in the cement to form expansive alkali silicate gels which disrupt the concrete by forming pattern cracks. 2. The gel attracts considerable amounts of water and expands. If the expansion is great enough, the resulting stress will crack the now-weakened aggregate and surrounding cement paste. 3. After the gel ingests enough water, the water takes over and the substance becomes an alkali-silica gel disbursed in a water fluid. This fluid then escapes to surrounding cracks and voids and may partake in secondary reactions.	1. May require partial or full depth patch for the affective area depending on severity. 2. Avoiding susceptible aggregates containing reactive silica like siliceous limestone, chart, shale, volcanic glass, synthetic glass, sandstone, praline rocks and quartzite, river rock. 3. Use of low alkali cement and pozzolanas. By reacting with the calcium hydroxide in the cement paste, a pozzolan can lower the alkalinity through lowering pH of the pore solution. Additionally, the silica contained in a pozzolan may react with the alkali in the cement. 4. Pozzolanic admixture. By reacting with the calcium hydroxide in the cement paste, a pozzolan can lower the pH of the pore solution. Additionally, the silica contained in a pozzolan may react with the alkali in the cement

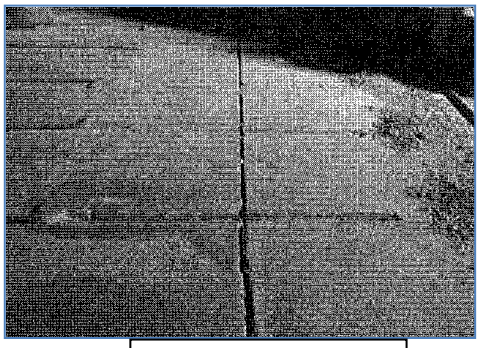
No.	Type of Distress	Possible Causes	Maintenance Suggestions
12.	Blowups– *Localized upward movement or shattering of the pavement slab.*  	1. During winter wide joint openings are created due contraction of concrete slabs. These joint openings are usually filled by materials like rocks or soil which are incompressible. During summer the expansion of joints is prevented by non-availability of space (occupied by incompressible material) and hence compressive stresses are induced at the joints, which may cause the slabs to shatter or move upward. Hence the blow-up is the consequence of compressive joint failure. 2. Material defects include: inadequate air entrainment for the climate. Generally, this occurs over several slabs that were affected by the concrete batches.	1. Require full depth patch.
13.	Pops-outs– *A small piece of concrete that breaks loose from the concrete surface to the depth of usually 13 to 50 mm and 25 to 100mm in dia.* 	1. Poor aggregate freeze-thaw resistance. 2. Expansive aggregates. 3. Alkali-Aggregate Reactions.	1. Pop-outs of greater size need to be repaired by partialdepth patch or filled with the same materials as used for repairing cracks or joints in PCC pavements.

4.4.5 Repairing Method Details of Rigid Pavement Distresses

Most common methods of rigid pavement repair are:

1. Joints and Crack sealing;
2. Stitching;
3. Slab stabilization;
4. Diamond grinding; and
5. Patches – partial depth and full depth

Joint and Crack Sealing



Slots and U-bars

Sealant products are used to fill joints and cracks in order to prevent the entrance of water or other non-compressible substances and also to reduce dowel bar corrosion by reducing the entrance of chemicals. Although, most rigid pavement joints are sealed at the time of new construction.

Usually cracks less than 2 mm require crack filling. Low viscosity epoxy and polymer- modified asphalt are used as crack filler.

Cracks more than 2mm require sealing with sealing with a specialized material. All unsound material near the crack should be chiseled out to form a trapezoidal notch of 30 to 40 mm deep with width at the bottom of the notch slightly more than at top for better interlocking. After thoroughly cleaning, the notch is given a tack coat and then sealed using epoxy resin mortar.

Joint sealing

Hot-pour seal has 3 to 5 years of life after proper installation. PVC (poly-vinyl chloride) coal-tars can perform well past 8 years, silicone sealants for 8 to 10 years and compression seals provide service for periods often exceeding 15 years and sometimes 20 years.

Stitching

It is a repair technique to maintain aggregate interlock at the point of cracking and to provide added reinforcement and strength to the pavement. Stitching is carried out for strengthening longitudinal cracks in slabs. Stitching is also adopted to alleviate the problems of omission of tie bars during construction, to tie roadway lanes and centerline longitudinal joints of pavements. There are three types of stitching used:

1. cross-stitching;
2. slot-stitching; and
3. U-bar stitching.

Cross-stitching is the most widely used method In cross-stitching, holes are drilled at an angle so that they intersect the longitudinal cracks or joints at about mid-depth of the slab. Dusts are removed by compressed air and epoxy is injected into the holes. Tie bars are inserted and excess epoxy is removed.

In slot-stitching, slots with lengths no smaller than 60 cm are cut approximately perpendicular to the longitudinal joints or cracks using a slot cutting machine or walk-behind saw. Slots are prepared by removing the concrete and cleaning the slot. Deformed bars are placed and backfill material is applied, finished, and cured. In slot-stitching, the concrete slabs are held together by the shear stress of deformed bars. It is important to provide high strength backfill material and good consolidation around the bars and concrete surface.

In U-bar stitching, slots are cut using a slot cutting machine and concrete is broken and removed by pneumatic hammer. In this method, anchoring action by the U-bars provides most of the restraining force. Proper backfilling around the ends of the U-bars is important.

Slab Stabilization

Slab stabilization

Slab stabilization seeks to fill voids beneath the slab, corner or joints caused by pumping, consolidation, sub-grade failure or other means. Voids are typically filled by pumping generally Pozzolan-cement grout through holes drilled through the slab.

Diamond Grinding

It refers to a process where "gang-mounted diamond saw blades" are used to shave off a thin, 1.5 to 19 mm top layer of an existing PCC surface in order to restore smoothness and friction characteristics. Most often, it is used to restore roadway friction or remove roughness caused by faulting, studded tire wear, and slab warping and curling. Another very important effect of diamond grinding is the significant increase in surface macro-texture and consequent noise reduction and safety improvement. Safety is improved by a temporary increase in skid friction resistance.

Diamond grinding

Patches

Patches are used to treat localized slab problems such as spelling, scaling, map cracking, joint deterioration, corner breaks or punch outs. If the problem is limited in depth, then a partial depth patch may be appropriate, otherwise a full depth patch is recommended. A high quality patch can be considered a permanent repair, although all patches are treated as a form of pavement distress.

Partial Depth Patch

Partial depth patches are used to restore localized areas of slab damage that are confined to the upper one-third of slab depth. Generally, this includes light to moderate spelling and localized areas of severe scaling. Partial depth patches are usually small, often only 50 – 75 mm deep and covering an area less than 1 m2. The generally partial depth patching process proceeds as follows.

Partial depth patch

1. **Locate the area to be patched**. Extend the patch beyond the damaged area by 75 – 100 mm.
2. **Remove the damaged material**. Removal is usually accomplished by sawing and chipping. Small areas can be removed by sawing around the patch edges and then chipping out the interior. The patch should be deep enough to remove all the damaged material.
3. **Clean the area to be patched**. Sandblasting or water blasting removes loose particles and creates a rough texture to which the bonding agent can adhere.
4. **Apply a bonding agent**. A cementations grout is used to help the patch material bond to the original slab material.
5. **Place, finish and cure the PCC**. The PCC should be placed so that the patch is of the same elevation as the surrounding slab. Finishing the patch from the center to the edges helps push the PCC patch material firmly against the existing slab and increases the potential for a high strength bond.

Full Depth Patch

Full depth patch

Full depth patches are used to restore localized areas of slab damage that extend beyond the upper one-third of slab depth or originate from the slab bottom. Generally, this includes spelling, punch outs, corner breaks, moderate to severe slab cracking and localized areas of severe scaling (e.g., reactive aggregate distress, over-finishing the surface). Corner breaks and punch outs should almost always be patched to full depth. When deciding between a partial and full depth patch for spelling and slab cracking, realize that joint spalls extending more than about 75 to 150 mm from the joint are indicative of possible slab bottom spelling. Corner breaks and slab cracking are indicative of structural inadequacies that cannot be addressed with partial depth patching. These problems should be addressed using a full depth patch.

1. **Locate the area to be patched**: If the area to be patched is too close to an existing joint or crack, the patch area should be extended as follows:
   - Patch boundary within 2 m of an existing unpowered transverse joint. Extend the patch to the transverse joint.
   - Patch boundary on an existing doweled transverse joint. If the other side of the joint does not require repair, extend the patch beyond the transverse joint by about 0.3 m to remove the existing dowels.
   - The patch boundary falls on an existing crack. Extend the patch beyond the crack by about 0.15 m.
2. **Remove the damaged material**: Usually, full depth saw cuts are used to isolate the repair area from the rest of the pavement. Then, the isolated section is lifted out as a whole or broken up and removed.
3. **Prepare the patch area**. The base material and sub-grade is compacted, smoothed and dried. Dowel bars holes are drilled into the adjacent slab transverse sections and dowel bars are inserted to provide load transfer across the patch boundary. Slab replacements longer than about 4.5 m require longitudinal tie bars as well.
4. **Apply a bonding agent**. A cementations grout is used to help the patch material bond to the original slab material.
5. **Place, finish and cure the PCC**. The PCC should be placed so that the patch is of the same elevation as the surrounding slab. Vibratory screeds are often used to strike off and finish full depth patches. Cure the repaired area for at least 14 days by protecting it from traffic movement.

4.4.6 Periodic Maintenance

This is required at periods of several years of frequency depending on the damaging factor as well as the standard of maintenance. They include:

1. Base and surface correction, surface application; and
2. Grading and leveling of shoulders.

These activities are generally treated as major activities and usually done by engaging contractor and not elaborated in these guidelines.

4.4.7 Urgent Maintenance

Urgent maintenance covers the items to be carried out without delay to avoid danger to the traffic. They include:

1. Restoration of flood damage, slides etc.;
2. Road diversions; and
3. Removal of fallen trees and branches.

These activities except removal of fallen trees and branches are generally treated as major activities and usually done by engaging contractor and not elaborated in these guidelines.

4.5 Labor Intensive Maintenance

There will be instances where some ULBs, particularly the smaller ones, might not have all of the heavy maintenance equipment for major maintenance works. In these cases, they will have to use labor intensive maintenance techniques. The following sections describe common labor based methods for routine road works.

4.5.1 Local Sealing

This treatment is used to repair cracks (longitudinal, transverse). The treatment is applied in four stages.

1. Sweep the area by hand. The road surface must be clean and dry following this operation.
2. Mark out the area to be sealed. The surfacing that is to be covered should be outlined in chalk.
3. Distribute the binder. The binder is distributed over the surface using a spray lance or a watering can at either 0.5 kg/m2 for bitumen emulsion or 0.5 kg/m2 for cut back bitumen.
4. Distribution of the aggregate. The aggregate is scattered by shovel from a truck or trailer. The material used is coarse sand up to 5 mm, when dealing with cracks and chippings (6 - 10 mm size) for local surfacing repairs.

It is important not to overheat the cut back bitumen or cationic emulsion because this will affect their durability. A thermometer should be used to check the temperature during heating. Anionic emulsion does not normally require heating. Smoking should not be allowed when handling cut back bitumen. The whole of the surface must be covered.

Repairing Isolated Cracks

In these cases, the cracks are filled in with hot cutback bitumen.

1. Sweeping the area. The crack to be filled must be clean following this operation.
2. Heat the binder. Do not overheat the cutback bitumen because this will affect its durability. Use a bitumen thermometer to check the temperature during heating.
3. Distribute the binder. This is carried out using a spray lance or watering can to follow the line of the crack. The nozzle of the spray

lance or the spout of the watering can must be held close to the road surface. The width of spread should be kept as small as possible.

4. Distribution of the sand. Coarse sand is scattered over the strip of binder using a shovel.

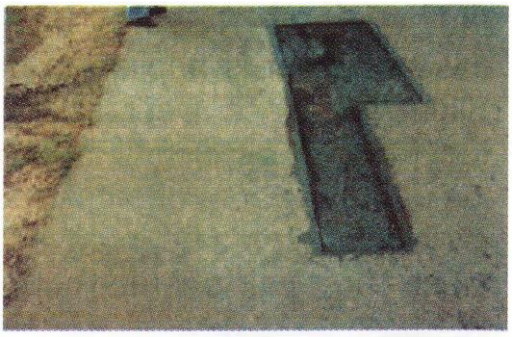
4.5.2 Filling in Depressions

This treatment is applied to deal with subsidence (slight ruts and depressions which are less than 50 mm) and small surface irregularities with no cracks due to shoving. The depressions are filled with cold mix asphalt prepared in advance and stored at the depot.

The repair is carried out in seven steps.

1. Sweep the area. The depressions must be swept out by hand. The surface of the depression must be clean and dry.
2. Mark out the area to be repaired. The surface area of the depression that is to be filled in must be outlined with chalk. Remove any high spots with a pick axe.
3. Obtain the cold mix.
4. Application of a tack coat. Hot cutback bitumen is applied with a spray lance or watering can at a rate of about 0.5 kg/m^2. Do not overheat the cutback bitumen because this will affect its durability. Use a bitumen thermometer to check the temperature during heating.
5. Fill in the depression. The cold mix is placed within the marked outline using a rake and leaving an excess thickness of about one third of the depth of the depression in order to allow for compaction.
6. Compact the material. The material is thoroughly compacted using the small vibrating roller, plate or a rammer, until the level is 3 mm above the surrounding surface.
7. Resealing. This repair must be sealed to prevent water penetration.

4.5.3 Surfacing Patching



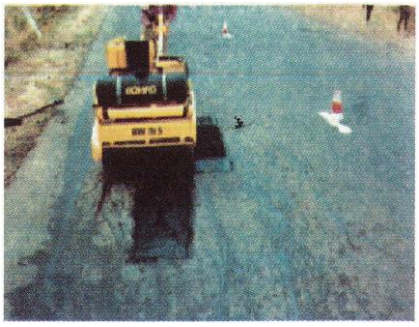
This treatment is used to repair local aggregate loss and is carried out in the following steps.

1. Sweep the area. The area must be swept out by hand. The surface must be clean and dry; and
2. Mark out the area to be repaired. The surfacing that is to be repaired should be outlined in chalk.

Once the area is clearly marked, the ULB has two options.

4.5.4 Option1: Seal

Use cold emulsion or hot cutback bitumen to seal the area to be repaired and provide a tack coat at the rates of 0.5 kg/m^2 for bitumen emulsion and 0.5 kg/m^2 for cut back bitumen.

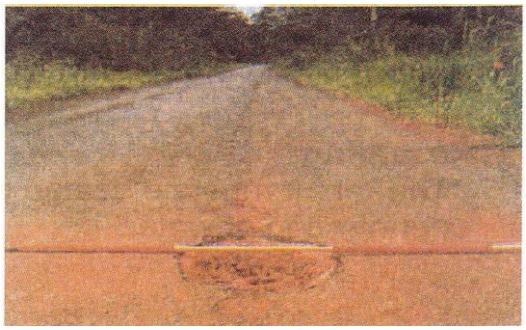


Apply the chippings <6mm size and ensure complete coverage. Lightly roll the chippings into the bitumen using a roller or vehicle tires.

4.5.5 Option 2: Premix

A hot cutback bitumen is applied to the area of the repair with a spray lance or watering can at a rate of about 0.5 kg/m^2 to form a tack coat. Spread fine cold mix (made from material up to 5 mm size) evenly over the area and compact it level with the surrounding surface using the small vibrating roller, or plate, or a rammer.

4.5.6 Base Patching



This is the treatment that is used to repair damage so that the pavement structure can be prolonged. Possible causes are listed below.

1. Mesh cracking; deep ruts and depressions (greater than 50mm);
2. Edge subsidence and rutting (greater than 50mm);
3. Edge surface failure;
4. Potholes; and
5. Shoving large irregularities together with cracks.

Maintenance

1. Mark out the area to be repaired with chalk by drawing a rectangle around the defect;
2. Excavate the area to be repaired. The following tasks are necessary;
   - remove all material from within the marked-out area of the road surface
   - increase the depth of the hole until firm, dry material is found and then trim the walls of the hole so that they are vertical.
   - If water or excessive moisture is present, then arrangements must be made to drain it away from the pavement foundation
   - trim the bottom of the hole such that it is flat, horizontal, and free from loose material then compact it
3. Backfill the hole with selected well graded imported material. This material can consist of the following items.
   - material of the same quality as that of the base layer to be repaired;
   - Cold mix asphalt. Place the material in the hole and compact in one or more layers of regular thickness depending on the depth involved. The last layer prior to compaction must have an excess thickness of about 1/5 the depth of the final layer;
   - Allow for settlement on compaction. Continue compaction depending on the size of the excavation, using the vibrating roller, plate compactor, or with a hammer until the surface is level; and
4. Resealing. Seal the repair to prevent water penetration.

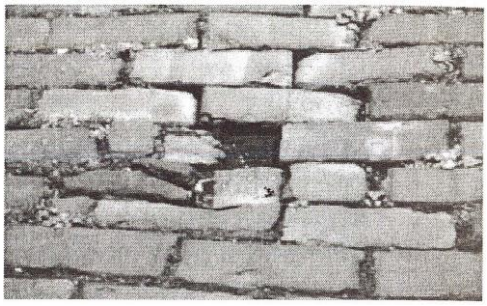
4.5.7 Brick Paved Roads

This section describes typical defects found on brick and block streets. Defects include joint erosion, gaps, breaks or discoloration, settlement, and ride quality. Bricks or blocks sometimes break. Often the breaks are either 1on a corner or edges and the pieces usually become dislodged and are removed from the pavement surface. The type of distress is usually broken and disintegrated bricks. Possible causes are listed below.

1. poor quality materials;
2. poor workmanship;
3. abrasion of vehicular tire; and
4. pavement age.

Maintenance

1. Remove the existing bricks from damaged areas;
2. Check the sand cushion in areas to be repaired. Add sand (FM 0.5), if necessary;
3. Re-lay brick flat soling and herring bone bond bricks. Tamp solidity in place until its top surface matches the surrounding surface; and
4. Spread dry sand (FM 0.8) on the repaired surface and sweep by hand or any other means to fill the new joints completely.



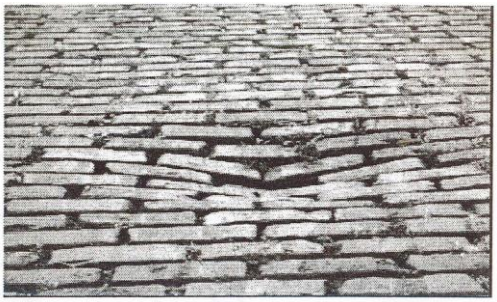
Joints may become eroded, allowing water to collect between the brick or blocks. Open joints may fill with soil and be covered with vegetation in low traffic areas. The main causes that brick and block may be missing are listed below. Missing bricks and eroded brick can have the following causes.

1. Unspecified compaction of improved subgrade layer;
2. Missing bricks on the surface may be caused by theft; and
3. Pavement age.

4.5.8 Settlement

The flow line adjacent to the curb may settle. This creates ponding and often collects debris. Brick or block streets may have sunken or settled areas. These may be isolated areas or they may have adjacent settlements creating a rippled effect. The ULB should take the following steps.

1. Remove the existing bricks from damage areas;
2. Check sand cushion in areas to be repaired. Add sand (FM 0.5), if necessary;
3. Relay Brick flat soling and herringbone born bricks. Tamp solidity in place till its top surface matches with the surrounding surface; and
4. Spread dry sand (FM 0.8) on the repaired surface and sweep by hand/any other means to fill new joints completely.



Possible causes for settlement are listed below.

1. Settlement of the pavement layer due to unspecified compaction;
2. Top surface of shoulder is lower than the surface of the pavement; and
3. Pavement age.

Maintenance

1. Remove the existing bricks surface and soling from damage areas to be repaired;
2. Excavate and remove damaged bricks under laying layers until encountering a sound layer;
3. Replace the layers with suitable filling materials preferably sand (FM 0.5) and ensure proper compaction of the new layer;
4. Replace the brick soling and end edging with good bricks. Joints between the bricks should be filled with sand (FM 0.5) and provide cushion for top surface course;
5. Re-lay herring bone bond with good bricks. Tamp solidity in place till its top surface matches with the surrounding surface; and
6. Spread dry sand (FM 0.8) on the repaired surface and sweep by hand or any other means to fill new joints completely.

4.6 Traffic Control and Safety

A primary consideration of all pavement maintenance operations is safety. Whether maintenance operations must be completed under traffic or with lane closures, traffic control and safety on site must be considered when planning the work. Standard signs should be displayed before start of maintenance activities. Some standard traffic control and safety sign are shown in **Exhibit 4-4**.

Exhibit 4-4
Traffic Control and Safety Signs

CHAPTER 5

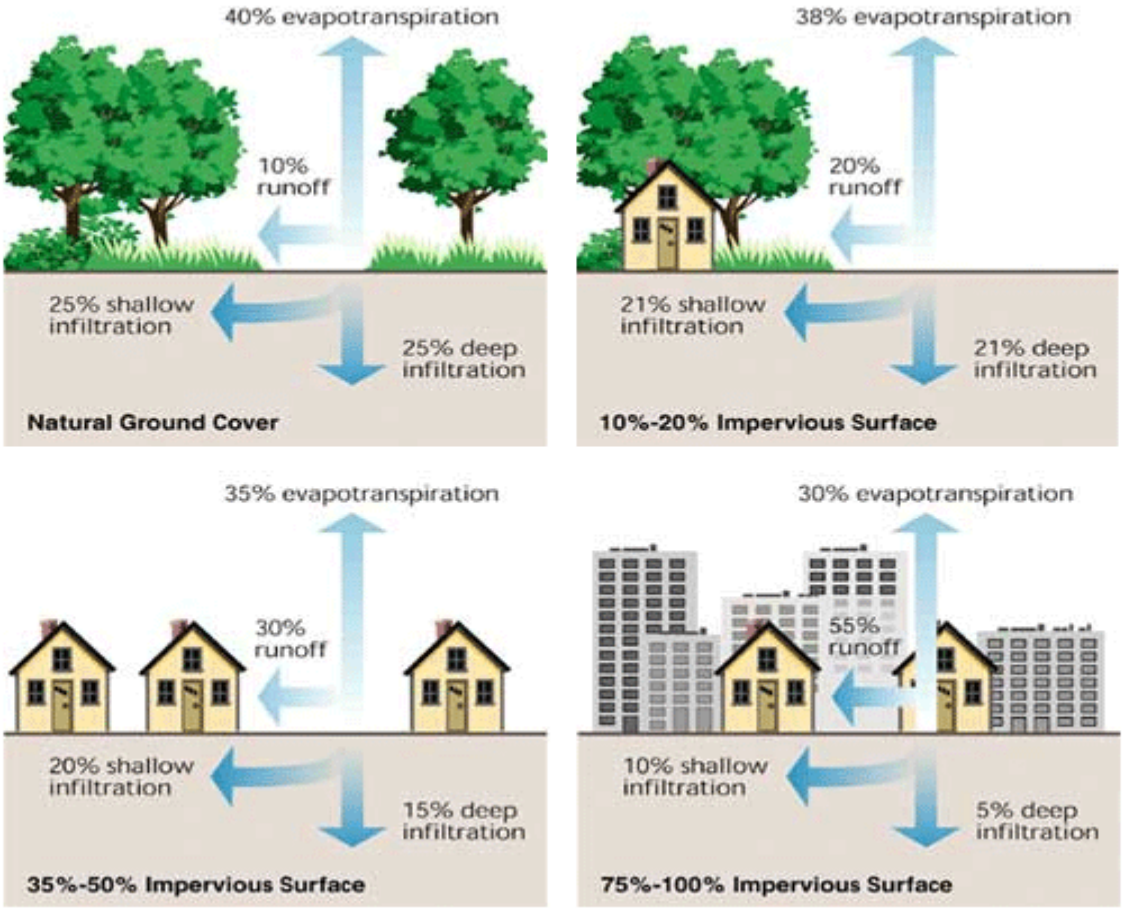
URBAN DRAINAGE

5.1 Introduction

5.1.1 General Drainage

Urbanization, which includes transportation activities, increases storm water volume and velocity by increasing the amount of impervious cover. Improved storm drain systems increase the rate of runoff from a location such as a roadway or land development. Rapid disposal of runoff from developing areas increases the frequency of flooding in downstream areas. The results can increase flooding, soil erosion, sedimentation, stream bank erosion and channel enlargement, and pollution of surface and subsurface waters. **Exhibit 5-1** illustrates different types of runoff rates for different surfaces.

Exhibit 5-1
Runoff Rates for Various Surfaces



Where developed areas that already exist are downstream of more recent development, as is a predominant sequence of development, flooding reduces property values and may lead to abandonment of property. Massive investments of drainage are sometimes required to reduce flood damage. The alternative is to provide flood protection by storm water management in the upstream developing areas. Where pollution abatement as well as flood control is an objective, additional or alternative storm water management measures may be necessary to provide source control of storm water pollution.

5.1.2 Reducing Storm Water Flows

Runoff into drains can be minimized by including sustainable urban drainage systems or low impact development or green infrastructure practices into city and municipal plans. To reduce storm water from rooftops, flows from eaves troughs (rain gutters and downspouts) may be infiltrated into adjacent soil, rather than discharged into the drainage system. Storm water runoff from paved surfaces can be directed to unlined ditches before flowing into the drains, again to allow the runoff to soak into the ground. Permeable paving materials can be used in building sidewalks, driveways, and in some cases, parking lots, to infiltrate a portion of the storm water volume.

5.1.3 Water Quantity

Storm drains are often unable to manage the quantity of rain that falls during heavy rains and storms. When storm drains are inundated, street flooding can occur. Unlike catastrophic flooding events, this type of urban flooding occurs in built-up areas where man-made drainage systems are prevalent. Urban flooding is the primary cause of drain backups which can affect properties year after year.

The first flush from urban runoff can be extremely dirty. Storm water may become contaminated while running down the roads, other impervious surfaces, or from vegetative chemical run-off before entering the drain.

Illicit Inlet with unknown pollutants

Water running off these impervious surfaces tends to pick up gasoline, motor oil, heavy metals, trash, and other pollutants from roadways and parking lots, as well as fertilizers and pesticides. Roof runoff contributes high levels of synthetic organic and zinc (from galvanized roofs). Fertilizer use on residential areas and parks is a significant source of nitrates and phosphorus.

Separation of undesired runoff can be achieved by installing devices within the drainage system. These devices are relatively new and can only be installed with new development or during major upgrades.

Water quality problems in surface waters often stem from nonpoint as well as point sources of pollution. A point source is a single identifiable localized source of pollution while a nonpoint source comes from diffuse sources, such as polluted runoff from agricultural areas draining into a river. Water quality goals for surface waters require abatement of pollution from nonpoint sources as well.

Road construction, operation, and maintenance contribute a variety of pollutants to surface and subsurface water. Solids, nutrients, heavy metals, oil and grease, pesticides, and bacteria all can be associated with road runoff. Although the impacts of highway runoff pollution on receiving waters may not be significant, it is generally recognized that ULBs may be required to apply the BMP available to reduce pollutant loads entering a water body.

Because there was a need to include other important public drainage facilities and to establish guidelines for private drainage facilities, the manual includes guidelines for the inspection, operation and maintenance of public and private storm drainage facilities within a town.

5.1.4 Chapter Contents

This chapter of the O&M Manual describes the inspection, operation, and maintenance requirements for all public and private storm drainage facilities in a ULB. Where possible, the information contained in the manual should be used in conjunction with the recent drawings for each facility as well as the chapter on solid waste management.

As a consequence of its function, the storm water conveyance system collects and transports urban runoff and storm water that may contain certain debris and pollutants. Consequently, these debris and pollutants accumulate in the system and must be removed periodically. In addition, the systems must also be maintained to function properly hydraulically to avoid flooding. Maintaining the system may involve the following activities.

1. Inspection and cleaning of storm water conveyance structures;
2. Controlling illicit connections and discharges; and
3. Controlling illegal dumping.

5.2 Components of Urban Drainage

An urban drainage system consists of many components. The primary physical components are described in this section.

5.2.1 Inlets and Catch Basins

There are two main types of storm water drains inlets, side inlets and grated inlets. Side inlets are located adjacent to the curb and rely on the ability of the opening under the back stone or lintel to capture flow. They are usually depressed at the invert of the channel to improve capture capacity.

Side inlet

Many inlets have gratings or grids to prevent people, vehicles, large objects or debris from falling into the storm drain. Grate bars are spaced so that the flow of water is not impeded, but sediment and many small objects can also fall through. However, if grate bars are too far apart, the openings may present a risk to pedestrians, bicyclists, and others in the vicinity. Grates with long narrow slots parallel to traffic flow are of particular concern to cyclists because the front tire of a bicycle may become stuck, causing the cyclist to lose control and fall. Storm drains in streets and parking areas must be strong enough to support the weight of vehicles and are often made of cast iron or reinforced concrete.

Cover*Horizontal storm Inlet*

Some of the heavier sediment and small objects may settle in a catch basin, or sump, which lies immediately below the outlet. Water from the top of the catch basin reservoir overflows into the sewer proper here. The catch basin serves much the same function of catching objects as the trap in household wastewater plumbing.

Unlike the plumbing trap, the catch basin does not necessarily prevent noxious gases such as hydrogen sulfide and methane from escaping. However, gully pots are designed as true water-filled traps and do block the egress of gases and rodents.

Most catch basins will contain stagnant water during the drier parts of the year and can be used by mosquitoes for breeding. Larvicides or disruptive larval hormones have been used to control mosquito breeding in catch basins. Mosquitoes may be physically prevented from reaching the standing water by the use of an "inverted cone filter". Another method of mosquito control is to spread a thin layer of oil on the surface of stagnant water, interfering with the breathing tubes of mosquito larvae.

The performance of catch basins at removing sediment and other pollutants depends on the design of the catch basin (for example, the size of the sump), and on routine maintenance to retain the storage available in the sump to capture sediment.

Catch basins act as a first-line pretreatment for other treatment practices, such as retention basins, by capturing large sediments and street litter from urban runoff before it enters the storm drainage pipes.

5.2.2 Piping

Concrete pipe culvert under construction

Pipes can come in many different cross-sectional shapes. These include rectangular, square, arch, oval, inverted pear-shaped, egg shaped, and most commonly, circular. Drainage systems may have many different features including falls, stairways, balconies, and pits for catching rubbish, sometimes called gross pollutant traps. Pipes made of different materials can also be used, such as brick, concrete, high-density polyethylene, galvanized steel, or fiber.

5.2.3 Outlets

A drainage outlet is the terminal component of the whole system, which releases the flows into a major natural water body in the vicinity. The location and elevation of the outlet should be suitable for the whole gravity drainage system.

Drain under the main road empties into a bigger channel

Most drains have a single large exit at their point of discharge (often covered by a grating) into a canal, river, lake, reservoir, sea, or ocean. Other than catch basins, there are typically no treatment facilities in the system. Small storm drains may discharge into individual dry wells. Storm drains may also discharge into man-made excavations known as recharge basins or retention ponds.

Flood gates are sometimes required to prevent backwater flow into the land due to high water level in the downstream rivers. On the other hand, the tidal gate could be required to prevent the intrusion of saline water to the land through the drainage network. These gates are closed during periods when theater level downstream of the outlet is higher than the water level in the drainage system within the compartment. The hydraulic design of such tidal gates entails careful consideration to ensure effective performance of the gate.

In many areas, ponds are excavated inside private property and are used to hold rainwater runoff temporarily during heavy rains and to restrict the outlet flow to the town drain. This lessens the risk of the public drain being overburdened during heavy rains.

5.3 Brief Description of the Components

Hydraulic structures are integral components of drainage and used to control water distribution, velocity, directions, depths and the general configuration of a waterway including its stability and maintenance purposes. Many of these structures appear special and are expensive, which require careful and thorough hydraulic engineering design and judgment. Proper application of hydraulic structures can reduce initial and future maintenance costs by changing the character of the flow to fit the needs of a particular subproject, and by reducing the size and cost of related facilities. The hydraulic structures discussed in this chapter are mostly used for surface drainage.

The shape, size, and other features of a hydraulic structure can vary widely for different subprojects, depending upon the functions to be accomplished. Hydraulic design procedures govern the final design of all structures.

The most common hydraulic structures used in urban drainage are for the following items.

1. Inlets;
2. Flow regulators;
3. Conveyance – Drains, culverts, siphons;
4. Energy Dissipation - Stilling basins, drop structures;
5. Water Quality Improvement - Sediment traps, and ponds; and
6. Outlets – Spillways, culverts, gates, and basins.

5.3.1 Inlets

Improper physical connections to the storm drain system can occur in a number of ways, such as overflow cross-connects from households or private property and floor drains from businesses like auto shops and restaurants. Illicit discharges and illegal connections can generally be detected and investigated through a combination of programs and approaches that target a variety of pollutants and sources. The inspectors should be aware of the following situations and take appropriate action.

1. Prohibited discharges such as dumping, paint spills, abandoned oil containers, etc. observed during the course of normal daily activities so they can be investigated, contained, and cleaned up.
2. Detecting and eliminating existing illicit connections and improper disposal of pollutants into the drains, i.e. identify problem areas where discharges or illegal connections may occur and follow upstream to determine the sources.
3. Report all observed illicit connections and discharges to the Head of the Engineering Department or his representative.
4. In addition, ULB staff should encourage public reporting of improper waste disposal by distributing public education materials and advertising the 24-hour water pollution problem reporting hotline.

An illicit discharge is any release of a fluid or other material into the town's drainage system that is not storm water. Examples of such discharges are sump contents pumped out onto the ground, individual sewage, grease that might flow out of a trash dumpster onto a street, or any other number of things pumped or disposed into the drainage system. It is everyone's responsibility to report any suspected illicit discharge to Head of the Engineering Department or his representative.

Inlet Types

Inlets used for the drainage of street surfaces consist four major classes.

1. Curb opening inlets;
2. Grate inlets;
3. Linear drains; and
4. Combination inlets. Combination inlets usually consist of some combination of a curb-opening inlet and a great inlet.

5.3.2 Open Channels

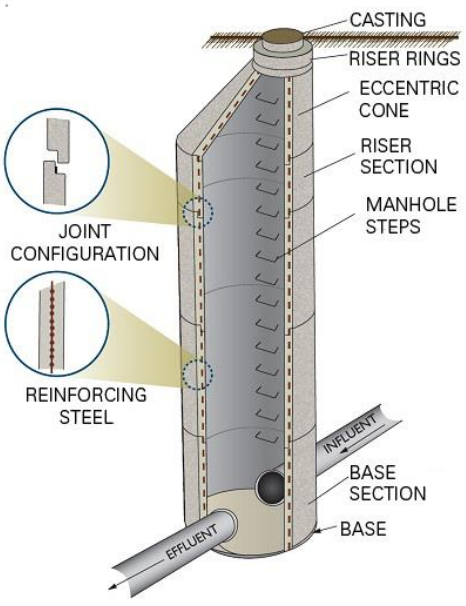
Rectangular urban drain with cover slabs

Surface drains, used in most ULBs are usually open channels. They can be either unlined or lined. The most common ULB surface drains are concrete open channels. The most common are rectangular. They may also be triangular, trapezoidal, or composite. Land forming and grading can be considered as part of open drainage systems too. Lined open channels are necessary to control erosion and scouring of the drainage system in urban areas where the available land is limited. However, pervious types of agricultural open drains and natural waterways are usually trapezoidal.

The roadside ditch group is responsible for grading and regarding roadside ditches throughout the ULB. ULBs have tandem ditching machines is currently used for this purpose. Cleaning roadside ditches helps to remove nutrients which are trapped in the dirt removed during cleaning.

5.3.3 Pipeline Drains

Pipe drains are not common in most of the ULBs. Pipe drains are commonly used for large urban areas. The most common pipe mater inliers in forced concrete although other materials such as clay and plastic may be used. Corrugated flexible pipes are used in some places because they have the advantage of easy transportation and quick installation.



Typical manhole for pipe drain

Pipeline drains are normally equipped with manholes, which are top openings to the under ground drainage system to house an access point for making connections, inspections, valve adjustments or performing maintenance. Manhole closings are protected by a manhole cover, a flat plug designed to prevent accidental or unauthorized access to the manhole. Those plugs are traditionally made of metal, but may be constructed from precast concrete, glass reinforced plastic or other composite material. The access openings are usually circular in to prevent accidental fall of the cover into the manhole.

5.3.4 Types of Culverts

A culverts a structure that allows water to flow under a road, railroad, trail, or similar obstruction from one side to the other side. It is typically embedded so as to be surrounded by soil. A culvert may be made from pipes, reinforced concrete, bricks, or other material.

The size and type of culvert depends on the amount of water flowing, the area that is discharging to it and how deep the culvert is being installed. Some culverts can also serve as roadway surfaces but they will always serve to convey water through a pipe or channel. Generally selection and type of material depends on the comparative cost, location of structure, availability of skilled labor, time limitations and design being proposed.

The culverts can be classified depending on shape (circular, rectangular, arch, etc.), material (concrete, brick, steel, plastic, wood, etc.) and operating conditions such as inlet control or outlet control.

Culverts are commonly used both as cross-drains for ditch relief and to pass water under a road at natural drainage and stream crossings. A culvert may be a bridge-like structure designed to allow vehicle or pedestrian traffic to cross over the waterway while allowing adequate passage for the water. Culverts come in many sizes and shapes including round, elliptical, flat-bottomed, pear-shaped, and box-like constructions. The culvert type and shape selection is based on numerous factors including the requirements for hydraulic performance, limitation on upstream water surface elevation, and roadway embankment height.

Examples of a few common shapes of concrete culverts are described below.

Box Culverts

One of the most used culvert types is a box culvert. Box culverts have a concrete (sometimes other materials can be used too) floor allowing the water to flow smoothly through it. Box culverts are usually made using reinforced concrete. Some box culverts can be built using composite structures and are great when water needs to change direction or when large flow of water is expected. Box culverts can also be installed in such way that the top of culvert is also the roadway surface. The most challenging part of installing these types of culverts is that there is a need to have a dry surface in order to install the culvert, so dewatering or diversion of the water will be needed to complete the installation

Twin concrete box culvert

Arch Culverts

Arch culvert

An arch culvert is normally a low-profile culvert. It can be installed without disturbing the causeway because it will span over the entire drainage width. They are normally made of metal, masonry, or RCC. They are installed easily and you do not need to use expensive water diversion structures to install. Common shapes include semicircular arch, or elliptical arch, and box. Another benefit of these type of structures is that the installation process will not take much time, compared to traditional box culverts.

Pipe Culverts

Pipes culverts are available in different shapes such as circular, elliptical, and pipe arches. Although circular pipes are the most common, other shapes might be used depending on site conditions and constraints at the jobsite. Their prices are very competitive and they are very easy to install. As with other culvert types, the selection of the culvert will depend on hydraulic design and other factors that might affect their performance and suitability. This is the preferred one on urbanized areas and is the one usually used to manage storm drainage systems.

Reinforced concrete pipe culvert

Culvert Materials

Culverts can be constructed from a variety of materials including cast-in-place or precast concrete (reinforced or non-reinforced), galvanized steel, aluminum, or plastic such as high-density polyethylene. In addition, two or more materials may be combined to form composite structures. For example, open-bottom corrugated steel structures are often built on concrete footings.

Corrugated iron culvert

5.3.5 Retention Ponds

Urban retention pond

It is common to see retention ponds in urban areas. Retention ponds capture the diverted storm water runoff from streets. These ponds provide two primary services. First, they retain the runoff before releasing it into streams or other bodies of water. They release the water at flow rates and frequencies similar to those that existed under natural conditions. The flood volume held in a retaining pond reduces the impact on downstream storm water systems. The second benefit of the retaining ponds is that they provide pollutant removal through settling and biological uptake. Ponds remove 30-80% of certain pollutants from water before it enters nearby waterways. Common pollutants reduced are sediments, bacteria, greases, oils, metals, total suspended solids, phosphorous, nitrogen, and trash.

5.3.6 Outfalls

The discharge point or outfall (outlet) from an urban area can be either a field drain,a natural river or stream, an existing or proposed drain, a pond or a wetland area. The procedure for calculating the hydraulic grade line through the drainage system begins at the outfall. Therefore, consideration of the outfall conditions is an important part of the drainage system. The main purpose of an outfall structure is the protection of the receiving body of water from

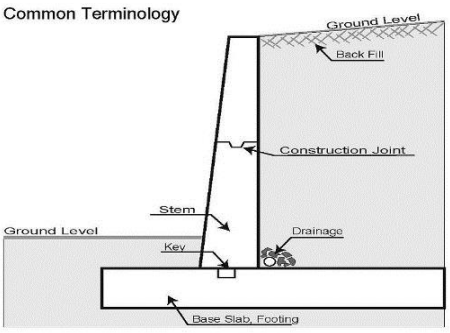
Outfall into a stream

scouring and erosion. A properly designed outlet structure should be stable and can even prevent backwater effect on the drainage system.

Vertical drop structures are controlled transitions for energy dissipation in steep channels where other energy dissipation structures are not cost effective. Drop structures in open channels change the channel slope from mild to steep. Flow velocities should be reduced to non-erosive velocities, while the kinetic energy or flow velocity gained by the water as it drops over the spillway is dissipated by an apron or stilling basin.

5.3.7 Retaining Walls

Retaining walls are structures designed to restrain soil to unnatural slopes. Generally, they are used to hold back earth or water. They are used to bound soils between two different elevations often in areas of terrain possessing undesirable slopes or in areas where the landscape needs to be shaped severely and engineered for more specific purposes. Retaining walls are often constructed along large drains or ponds.



Typical side view of retaining wall

5.4 O&M Activities for the System Manager and Crews

Each ULB has back and side ditch crews assigned to cover routine ditch maintenance and preventive maintenance activities in assigned areas. These crews perform mostly manual type work with weed eaters, shovels, and rakes. Employees in this work group are exposed to extremely variant environmental and natural conditions such as extreme heat and cold as well as other hazards like insect stings. Their work is an integral part of our storm water management program.

The ULB's storm sewer crew construction group implements storm sewer construction. This crew has the responsibility of infrastructure repair and storm drain installation. Many of the more complex storm sewer installation and repair projects are planned and budgeted one year in advance. Projects are prioritized based on either previous flooding problems or repeated infrastructure failure. Longer term capital projects are budgeted in the CIP.

5.4.1 Storm Water Management and Best Management Practices

Storm water consists primarily as rainfall and surface runoff. Storm water includes overland flow as well as flow in ditches and storm drain systems. Storm water management includes non-structural and structural measures such as the following items.

1. Erosion control to minimize erosion and sediment transport;
2. Storm water detention and retention systems to reduce peak runoff rates and improve water quality;
3. Sedimentation and filtration systems remove debris, suspended solids, and insoluble pollutants;
4. Vegetation buffers to reduce transport of pollutants; and
5. Detention and retention ponds which delay storm water flow and trap sediment, silt fences to trap sediment, and vegetation to retard flow and trap sediment.

5.4.2 Prioritizing Maintenance and Repair

As with other infrastructure, surface drainage components also require scheduled and unscheduled maintenance for them to function as per design and construction.

All storm drainage maintenance and repair work shall be prioritized. Major drainage systems will have top priority, especially ones that affect great portions of the town. Work orders for maintenance and repair work generated by inspections will be carried out by drainage maintenance personnel, or private contractors hired by the ULB as early as practical. Given the fact that there is frequently a backlog of work to be accomplished, the drainage maintenance crews will perform the highest priority assignments first, and then make their way down the list according to the priorities and completion dates assigned to the remaining work.

1. Emergency work (where life and safety issues are involved) will be given the highest priority. This work should be initiated as soon as the manpower and equipment are available to perform the needed tasks.
2. The next highest priority will be removing flow obstructions, correcting the underlying cause of these obstructions, and addressing immediate threats to property damage. The goal for completing this work is one or two weeks from the completion of the inspection, depending on the complexity of the work involved.
3. Routine preventative maintenance activities will be given a lower priority but will be carried out as early as practical by drainage maintenance personnel. The goal for completing routine work is within six months or before the monsoon season. Routine work includes but is not limited to removing sediment and debris; spraying, trimming or removing vegetation; and performing minor repairs to earthen slopes, berms, and levies or to the surrounding areas.

5.4.3 Solid Waste and Aquatic Vegetation

Solid waste and vegetation are major problems in large open channels and ponds. The ULB should keep the following points in mind.

1. Store wastes collected from cleaning activities of the drainage facilities in appropriate containers or temporary storage sites in a manner that prevents discharge to the storm drain.
2. Remove the wastes. Water should be treated with an appropriate filtering device to remove the sand and debris prior to discharge to the drain. Dewatering near a storm drain or stream should be avoided.

The ULB shall provide for laboratory analysis of at least one randomly collected sediment (less the debris) sample per year from the storm drain inlet cleaning program to ensure that it does not meet the criteria for hazardous waste. If the sample is determined to be hazardous, the sediment must be disposed of as hazardous waste.

5.4.4 Responsibilities for Drainage Maintenance

An adequate O&M budget is essential for drainage systems. A maintenance budget should be made available according to the existing market costs. The allotted budget should not be used for other purposes anticipating that maintenance might not be required for the fiscal year considered.

Cleaning crew member

Responsibility for the town storm water facilities falls under the Head of the ULB's Engineering Department. He directs the overall maintenance

activities of the town's drainage staff. Operations staffs are responsible for tracking inspections for the ULB drainage facilities for prioritizing and scheduling maintenance, and repair work to be performed by the ULB's drainage maintenance crews. The Head of the Engineering Department usually appoints an operations manager who is in charge of the ULB drainage system maintenance.

The ULB will conduct Individual site inspections in response to citizen complaints and/or drainage service requests. These calls are generally received by the Head of the Engineering Department or his representative. When an inspection identifies the need to maintain, repair, or clean the drainage facilities, a work order shall be generated and the work shall be scheduled and performed acceding to the priority assigned to the work. When an inspection identifies the need to maintain, repair, or clean privately owned on-site drainage facilities, the property owner shall be notified by the Head of the Engineering Department or his representative and requested to take corrective action. If the property owner fails to maintain the facilities adequately, the UBL shall be given the right to enter the property, upon proper notice, for maintenance purposes. All such costs shall be assessed against the owner.

Maintenance during the plant establishment phase is critical because it is during this phase that plants are most vulnerable to damage. Low water level, weed invasion, and damage by animals are possible causes of problems. Plants should be inspected at least weekly during the initial phase in order to detect any damage and allow corrective action.

Aquatic plants should be inspected periodically to control pest species and to promote the desired mix of plants for conservation and landscape purposes. Occasional replanting may be necessary to maintain the desired mix of species.

5.4.5 Inspection Criteria

The inspection of public drainage facilities will consist of a detailed evaluation of the existing condition of each of the components of the system. The following inspection items, while not all inclusive, are typical of most facilities and should be noted.

1. Side slopes and bottom widths emphasizing the amount of erosion or sediment present;
2. Earthen berms and levies;
3. Inlet and outlet structures, grade control structures, and erosion protection;
4. Landscaping, vegetation, and erosion protection measures;
5. Fences (if present) and signs of unnatural erosion or vandalism;
6. Sediment or debris that could obstruct the free flow of water through the conveyance system; and
7. Trash, vegetation, and other rubbish that could obstruct the free flow of water through the conveyance system.

Inspections shall be scheduled and tracked by operations staff using the ULB's maintenance management program. The information collected from these inspections shall be entered into the program and used to generate appropriate work orders.

All drainage facilities that the ULB maintains shall also be inspected after a major storm that could adversely impact the drainage system.

5.5 Operation and Maintenance of Facilities

5.5.1 Operation

Storm water operations and maintenance consists of the day-to-day operation of AIMS (Analysis, Inspection, Maintenance, Support), back and side ditches, major outfall and khal maintenance, storm sewer cleaning, storm sewer construction, and roadside ditch crews working throughout the ULB. Descriptions of each work function are described below.

Routine ULB Operations

Operation problems or possible design flaws discovered during the inspection of the storm drainage facilities will be directed to the Head of the Engineering Department or his representative for analysis and recommendation.

Well maintained urban drain

1. Annually inspect and clean drainage facilities as needed. Maintain appropriate records. This information should be used to determine problem areas that may need to be checked more often.
2. Remove trash and debris as needed from open channels and properly dispose of these materials (at an approved landfill or recycling facility). It should be noted that major debris removal may require other regulatory permits prior to completing the work.
3. Conduct annual visual inspections during the dry season to determine if there are problem inlets where sediment, trash, or other pollutants accumulate.
4. Eliminate any discharges that may occur while maintaining and cleaning any ULB drainage facilities.
5. Train crews in proper maintenance activities, including record keeping and disposal.
6. Provide energy dissipaters below culvert and drain outfalls to minimize potential for erosion.

Illicit Discharges

An illicit discharge is the discharge of pollutants or non-storm water materials to drainage systems via overland flow or direct dumping of materials into a catch basin. Illicit discharges enter the system through either direct or indirect connections.

1. **Direct connection**: wastewater piping either mistakenly or deliberately connected to the drains.
2. **Indirect connection**: infiltration into the municipal drainage system from cracked sanitary systems, spills collected by drain outlets, or paint or used oil dumped directly into a drain.

Illicit discharges contribute to high levels of pollutants such as heavy metals, toxics, oil and grease, solvents, nutrients, viruses, and bacteria entering receiving bodies of water. Pollutant levels from these illicit discharges are high enough to significantly degrade receiving water quality and threaten aquatic, wildlife, and human health. If a ULB staff member witnesses anyone dumping substances into storm drains or any mysterious substances in or around storm drains or in local water bodies, he should contact ULB's Head of the Engineering Department or his representative immediately

5.5.2 Maintenance

The following items should be repaired or replaced if damaged.

1. Rusted, bent, cracked, or chipped pipe will be repaired to design or replaced.
2. Damaged or missing manhole covers or grates will be repaired to design or replaced.
3. Any storm drainage facilities that are deteriorated due to age and/or use will be repaired to design or replaced.
4. An inspection may reveal that important elements of the drainage system are damaged or missing and/or that design flaws or operational problems may be the root cause of the damage that needs to be repaired. In any event, the Head of the Engineering Department or his representative may be required to perform a detailed evaluation of the site prior to implementing a solution. The replacement or type of repairs of these elements will depend upon the results of the engineering evaluation and the recommended course of action.

5.5.3 Monitoring

The ULB should encourage or create a volunteer work force to mark drain inlets. ULB staff must organize, market, and provide training to initiate the volunteer programs by using the following activities.

Local residents clean drain

1. Promote volunteer services through radio, television, and mail-out campaigns;
2. Educate businesses and residents about storm water pollution, the storm drain system, and the watershed; and
3. Provide information on alternatives such as recycling, disposing household hazardous, and using safer products.

5.6 Operation and Maintenance of Open Channel Drains

5.6.1 Operation

The operation of a properly maintained free flowing channel is usually automatic. The main exception is if there are gates or other hydraulic structures integrated in the system that requires periodic adjustment. In some instances, pumps might need to be operated. But these cases are exceptions in most Bangladeshi ULBs and will not be discussed in this manual.

5.6.2 Maintenance

The following items should be addressed annually for streams, open channels, and ditches.

Marinating saucer drain

1. Sand, silt, trash, debris, and any other restrictions to the flow of water will be removed, including excess vegetation.
2. Vegetation will be removed by trimming or cutting, and not by excavating. Trimming or removing mature vegetation will be at the direction of trained personnel. Mowing of native grasses and weeds maybe by either manual or mechanical means.
3. All material removed will be hauled away from the site to an approved landfill or stock pile area, including all grass clippings and cutting from trees and shrubs.
4. All streams, channels, and ditches in the urbanized portion of the ULB are to be cleaned and maintained in accordance with the best management practices adopted

as part of the ULBs plan, including the frequency of cleaning and measureable goals established for this activity.

The following points should be considered for removing sediment and debris.

Trash rack for collecting trash and debris

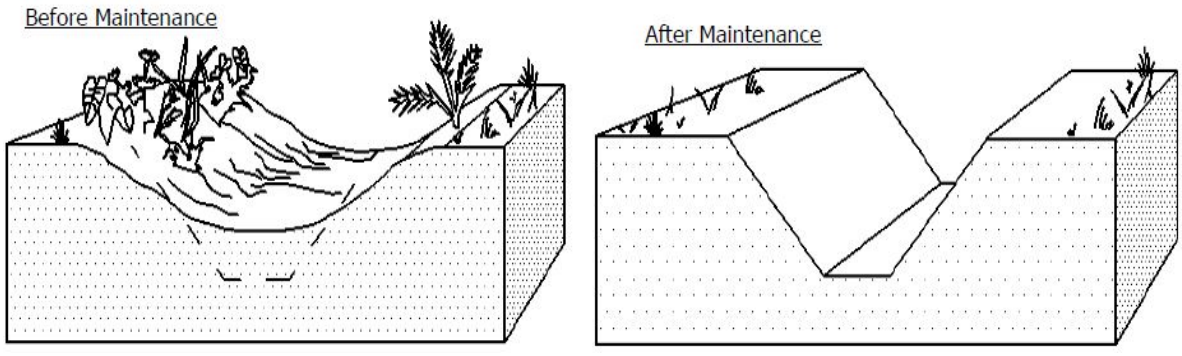
1. Removing sediment and debris consists of excavating and transporting excavated material to an approved of-site landfill, stockpile, or disposal site.
2. Markers may be installed within basins and channels to assist operators in locating the bottom limits of the excavation. Potentially submerged structures may be marked with a staff gauge to prevent damage by heavy equipment.
3. Excavation and removal of sediment material from the basin or channel bottom will be to the original lines and grades indicated on the as-built drawings for these facilities, or to the depth indicated by the monuments or markers.
4. Operators must use caution to avoid undercutting existing erosion or slope protection facilities when excavating near or around the toe of protected slopes.

The following items should be examined for repairing erosion.

1. Remove loose material as well as repair and stabilize eroded surfaces using mechanical compaction
2. Remove slide material and rebuild failed slopes with suitable fill material, keying compacted material into the slope.
3. Replace any soil removed by burrowing rodents using mechanical compaction. Consider removing burrowing animals from sensitive areas.
4. Re-establish vegetation.

Exhibit 5-2 illustrates how an earthen open channel should be restored to its design dimensions after maintenance.

Exhibit 5-2
Restored Open Channel



5.6.3 Trouble Shooting in Drainage Flow

Routine Trouble Shooting

Illegally dumped wastes can cause storm water and receiving water quality problems as well as clog the storm drain system itself. Non-hazardous solid wastes may include garbage, trash, refuse, paper, rubbish, ashes, industrial wastes, demolition and construction wastes,

abandoned vehicles and their parts, discarded home and industrial appliances, manure, vegetable or animal solid and semi-solid wastes, and other discarded solid or semi-solid waste.

That is, provided that such wastes do not contain wastes which must be managed as hazardous wastes, or wastes which contain soluble pollutants in concentration which exceed applicable water quality objectives or could cause degradation of waters of the state.

The ULB maintenance staff should perform the following tasks.

1. Report prohibited discharges such as dumping's observed during the course of normal daily activities so they can be investigated, contained and cleaned up.
2. Conduct field investigations to detect and eliminate improper disposal of pollutants into the storm drain (i.e. identify problem areas where discharges or illegal connections may occur and follow up stream to determine the sources.
3. Report all observed illicit connections and discharges to ULB's Head of the Engineering Department or his representative.

ULBs should encourage residents to maintain cleanliness

4. Encourage public reporting of improper waste disposal by distributing public education materials and advertising the reporting procedures.
5. Post "No Dumping" signs in problem areas with a phone number for reporting dumping and disposal. Signs should also indicate fines and penalties for illegal dumping.

Training, Education, and Outreach

The ULB should conduct regular refresher programs as listed below.

Anti-Illegal dumping campaign

1. Annually remind ULB employees to recognize and report illegal dumping.
2. Encourage public reporting of illegal dumping.
3. Educate the public with public education materials such as a hotline and/or door hangers (door hangers are placed on the front doors in neighborhoods where illegal dumping has occurred to inform the reader why illegal dumping is a problem, and that illegal dumping carries a significant financial penalty).
4. Educate the public through volunteer water quality monitoring programs. Volunteers can be trained to notice and report the presence and suspected source of an observed pollutant to the appropriate public agency.

5.7 Operation and Maintenance of Pipeline Drains

Most pipelines operate as open channel flow. Hence the water will flow automatically if the system is maintained properly. Usually, there is no routine operation activities for pipeline drains.

5.7.1 Operation

Pumps

In some locations, gates and pumps both are required to maintain safe water level in the drainage system. This would allow water to drain by gravity when the tail water level is low, saving on pumping costs, and to be pumped when the tail water level is high.

5.7.2 Maintenance

Cleaning a pipeline

The storm sewer cleaning program has been established to clean catch basins, drainage pipes, and box culverts throughout the ULBs. ULBs possess at least one combination catch basin cleaning truck to perform preventive maintenance throughout the ULB. This program is augmented by a street sweeping program. Both are designed to keep silt and debris from the waterways and other bodies of water.

The following points should be considered for cleaning and maintaining pipes, drainage inlets, and manholes.

1. Remove and dispose of sand, silt, trash, and debris to approved disposal locations.
2. Clean and flush inlets and pipelines by using water hose or by road the lines. All material removed from the drainage system shall be hauled to an approved disposal area.
3. Check for any signs of leakage at pipe joints as well as damage to pipes or structures.
4. All public drains are to be cleaned and maintained in accordance with the best management practices adopted as part of the ULB drainage plan, including the frequency of cleaning and measurable goals established for this activity.

5.8 Operation and Maintenance of Culverts

5.8.1 Operation

Grates help to keep a culvert clean

Culverts are usually designed for open channel flow and not for pressure flow. Normally, they are designed to convey the design flow when they are about 80% full. If the annual peak flow is higher than this, then the ULB should review the original culvert design. There are cases where culverts are gated for controlling flow and maintaining a desired water level. The gates are usually operated to manage water for irrigated field crops. The ULB should therefore coordinate its drainage requirements with irrigation authorities if any gated culverts are within the city or municipal limits.

5.8.2 Maintenance

Proper maintenance is important for maintaining a culvert and getting the best performance out of it. Erosion is a big issue, since the culvert's primary function is to help the movement of water from one place to another. The interior of culverts should always be clean, including the removal of debris and foreign materials from the inlet leading to the culvert. Trees should not be allowed to grow into the area around the culvert, especially on an embankment.

5.9 Major Outfall and Khal Maintenance

This aspect of the storm water management Program was added in the purpose of storm water retention and storm water quality. ULBs are required to perform drainage system and khal maintenance activities. Its efforts are aimed at cleaning khal outfalls that are filled with sediment. Permits from the Department of Environmental Quality (DEQ) are required for many of our khal cleaning efforts. ULBs are in the process of developing a khal enhancement program in cooperation with the Department of Engineering.

5.10 Inspection Checklists

The regular inspection of public storm drainage facilities will consist of observing and notating the condition of each of the components of the system. Checklists were developed to aid in the inspection process located in **Appendix A. Exhibits 5-3 to 5-8** summarize the ULBs' inspection procedures for their urban drainage systems.

Exhibit 5-3
Ponds, Open Detention, and Retention Facilities

Component	Condition	Conditions Requiring Maintenance	Expected Result
Storage Volume	Sediment	Accumulations exceeding 10% of the design flow	Sediment cleaned out
	Trash and debris	Accumulations that are an eyesore	Trash and debris removed
Overflow or Spillway	Missing brick or concrete	Any exposure to original soil	Brick or concrete restored to original lines and grades
Embankments	Settlement	Lowering height (of any part of the facility) by 10 cm or more	Facility restored to design elevation
	Rodent holes	Any evidence of rodent holes or water piping through embankment	Slopes repaired and rodents removed
Vegetation control	Tree growth	Trees interfering with access, silt removal, or mowing	Trees pruned, trimmed, and repaired or removed
	Plant growth	Height of ground cover, grass, or plants interferes with the function of the facility	Grass mowed to 5 cm in height, plants thinned and/or trimmed
	Noxious or poisonous vegetation	Poisonous and/or noxious plants	All undesirable vegetation removed or controlled

Exhibit 5-4
Control Structures and Flow Restrictors

Component	Condition	Conditions Requiring Maintenance	Expected Result
Manholes & catch basins	Damaged or lost parts	Cover or grate missing or only partially in place; frame& grate or manhole cover bent or damaged	Cover, grate and/or frame repaired and reinstalled to design

Component	Condition	Conditions Requiring Maintenance	Expected Result
	Cover or grate difficult to remove	One person cannot remove cover, grate, or frame that is visibly bent	Frame & cover or grate cleaned & repaired or replaced to design
	Cover or lid not working properly	Bolt down cover or self-locking lid cannot be opened by one person with proper tools	All covers & lids repaired or replaced to design
	Joints, cracks, or openings	Any openings allowing material to be transported into the facility	All openings are properly sealed
Cleanout gate	Damaged or missing parts	Gate not watertight and/or parts are damaged or missing	Gate repaired or replaced to design
	Gate rusted and/or stuck	Cleanout gate cannot be operated by one person or is rusted over 50% of its surface area	Gate repaired or replaced to design
Orifice plate	Damaged or missing	Control structure is not working properly due to missing, bent, or out of place orifice plate	Plate repaired or replaced to design
Overflow system	Obstructions	Any sediment, trash, or debris blocking or having the potential to block the overflow system	Overflow system is free of obstructions & works as designed
General	Structural damage & cracking	Cracks in walls, bottom, and/or top slab wider than 1 cm, and longer than 30 cm., or visible deformation	Manhole or catch basin repaired or replaced to design
	Sediment and debris	Accumulations exceed 10% of the volume of the control structure	Sediment, trash, and debris removed

Exhibit 5-5
Drainage Inlets, Manholes, and Junction Structures

Component	Condition	Conditions Requiring Maintenance	Expected Result
Manholes and catch basins	Damaged or lost covers	Cover or grate missing, or only partially in place; frame & grate or manhole cover bent or damaged	Cover, grate and/or frame repaired and reinstalled to design
	Cover or grate difficult to remove	One person cannot remove lift and/or cover, grate or frame visibly bent	Frame & cover or grate cleaned & repaired or replaced to design
	Cover or lid not working properly	Bolt down cover or self-locking lid cannot be opened by one person with proper tools	All covers & lids repaired or replaced to work properly
	Joints, cracks or openings	Any openings allowing material to be transported into the facility	Openings properly connected & sealed
	Settlement or misalignment	Concrete basin or vault has settled more than 2.5 cm. or rotated more than 5 cm. out of alignment	Basin repaired or replaced to design
	Structural damage &	Cracks in walls, bottom, and/or top slab wider than 1 cm, and	Concrete structures repaired or replaced to design

Component	Condition	Conditions Requiring Maintenance	Expected Result
	cracking	longer than 30 cm., or visible deformation	
	Sediment and debris	Accumulations exceed 10% of the design volume	Sediment, trash and debris removed
Vegetation control	Weeks	Vegetation growing across and blocking more than 10% of basin opening; or growing inside basin or pipe inlet	Weeds removed

Exhibit 5-6
Pipes, Culverts, and Storm Drainage Conveyance Systems

Component	Condition	Conditions Requiring Maintenance	Expected Result
Pipes & Culverts	Damage or rust	Protective coating is damaged; rust causes more than 50% deterioration to any part of pipe	Pipe repaired or replaced
	Dents	Any dent that decreases the cross sectional area of the pipe by more than 10%	Pipe repaired or replaced
	Chips or cracks	Cracked or chipped concrete pipe	Pipe sealed & repaired or replaced
	Settlement or deflection	Settlement or deflection resulting in misalignment or sags where pipe is bent out of shape, or deformed more than 10% of its design shape	Pipe or culvert replaced
Open Ditches	Erosion	Erosion features over 5 cm. deep on side slopes	Slopes stabilized and shielded from erosion
	Missing or out of place bricks	Bricks on sides or bottom of ditch is disturbed or removed, exposing the underlying to erosion	Replace brick lining to design standard
General	Sediment, trash, and debris	Accumulated sediment, trash and/or debris exceeding 10% of the volume of the conveyance system	Sediment, trash, and debris removed
	Vegetation	Any vegetation that reduces the free flow of water through the conveyance system	Vegetation removed

Exhibit 5-7
Trash Racks and Debris Barriers

Component	Condition	Conditions Requiring Maintenance	Expected Result
Metal Bars & Frame	Trash & Debris	Accumulations of trash and debris that are plugging more than 20% of the openings	Trash and debris removed
	Damaged or missing bars	Bars are bent out of shape more than 7 cm; loose; or missing	Bars repaired or replaced to design
	Rust	Bars are visibly rusty, and causing	Bars cleaned and repaired or

Component	Condition	Conditions Requiring Maintenance	Expected Result
		50% deterioration to any part of the trash rack or debris barrier	replaced

Exhibit 5-8
Surfaces, Fences, and Gates

Component	Condition	Conditions Requiring Maintenance	Expected Result
Vegetation	Damage	Trees and shrubs that are dead, diseased, badly damaged, broken, blown over or leaning, causing exposure of roots	Dead or diseased trees and shrubs removed, and damaged plants repaired or replaced
	Weeds	Weeds in landscaped areas crowding out plants & shrubs	Weeds removed, and dead plants replaced
General	Missing or broken parts	Any defect in a fence or gate that permits easy entry to a facility, including erosion that creates an opening under a fence or gate	Fence, gate, & grounds repaired and/or parts replace to design
		Broken or missing hinges; posts or gate out of plumb more than 15 cm.; stretcher bar, stretcher bands, and ties are missing; gate is difficult to open and close	Repair fence & gate so that posts are plumb and gate opens and closes freely or replace to design
		Broken or missing locking devices	Devices repaired or replaced to design
		Top rails bent; missing or loose tension wire; barbed wire loose or sagging between posts; or broken or missing parts	Fence properly repaired and aligned, or replaced to design
	Rusting & scaling	Rusting or scaling condition that affects structural adequacy	Rusting and scaling removed or affected parts replaced
	Trash & debris	Excessive accumulations within landscaped areas	Trash and debris removed

CHAPTER 6

WATER SUPPLY

6.1 Introduction

The urban water supply sector in Bangladesh has limited success in terms of both quality and quantity of service. The service condition in most of the ULBs is very poor. Low coverage, low line pressure, frequent leakage in distribution system, high percentage of non-revenue water, weak financial capacity due to low revenue collection, high operating expenses, and inadequate institutional capacity are the main weaknesses of ULB water supply systems. So, operation and maintenance (O&M) problems are major obstacles to overcome in order to provide efficient service from a system built with adequate care, quality control, and supervision. Expected benefits never reach the target groups due to improper operation and lack of timely maintenance. Accumulated O&M problems require costly solutions and often lead to premature abandonment of many schemes.

Appropriate O&M procedures describes as O&M Guidelines are absolutely necessary for any scheme. This chapter will guide the system operators about their daily and routine tasks. It will serve three basic requirements of the O&M which are listed below.

1. operation,
2. maintenance; and
3. monitoring.

Some useful descriptions and details of equipment, plant operations, etc. are provided in this chapter. These are not generally meant for the operators but will provide useful information and guidance to the management.

The need for routine and preventive maintenance is emphasized to ensure longer plant and equipment life. Maintenance charts are included for valuable equipment and units of piped water supply.

6.2 Components of Municipal Water Supply

The major components of municipal water supply are listed below

1. Production Tube well with Pumping Equipment (Submersible pump);
2. Over Head Tank;
3. Distribution Network;
4. Service Connections; and
5. Treatment Plant.

6.3 Brief description of the Chapter

6.3.1 Production Tube Well with Pumping Equipment (Submersible Pump)

Production wells with pumping equipment play an important role in piped water supply systems. The function of production well is to provide water to the treatment plant, reservoirs, or directly to the system depending on raw water quality. The system extracts water from a suitable underground aquifer using suitable pumping equipment.

The size of production well is usually in the range 200-400mm diameter for upper well casing and 100- 200 mm diameter for lower well casing and filter. The main components are

housing pipes as the upper well casing, blank pipes as the lower well casing as well as strainers and sand traps.

The type of pumping equipment for wells utilizing a piped water supply system is restricted to submersible pumps because of their advantages over the turbine pumps. The capacity of the pump depends on the design discharge and head. The main components of the submersible pump are listed below.

1. Pump bowl assembly;
2. Motor assembly;
3. Sleep coupling; and
4. Suction casing.

Typical drawings of Production Tube well, installation of pumping equipment and Circuit diagram are shown in **Exhibits 6-1, 6-2, and 6-3**.

Exhibit 6-1
Typical Drawing of Production Tube Well

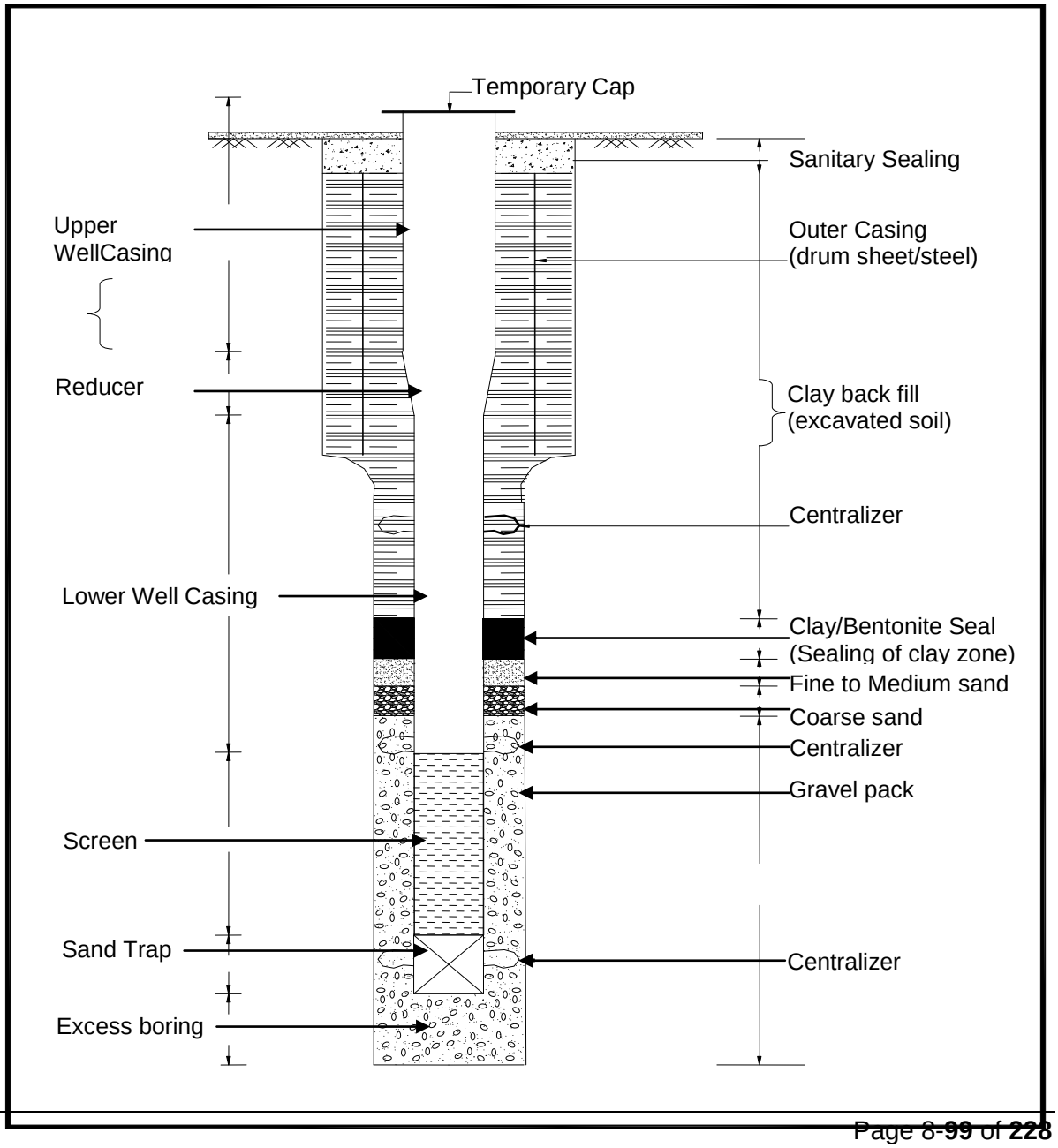


Exhibit 6-2
Typical Installation Diagram of Submersible Pump and Discharge Pipe Assembly

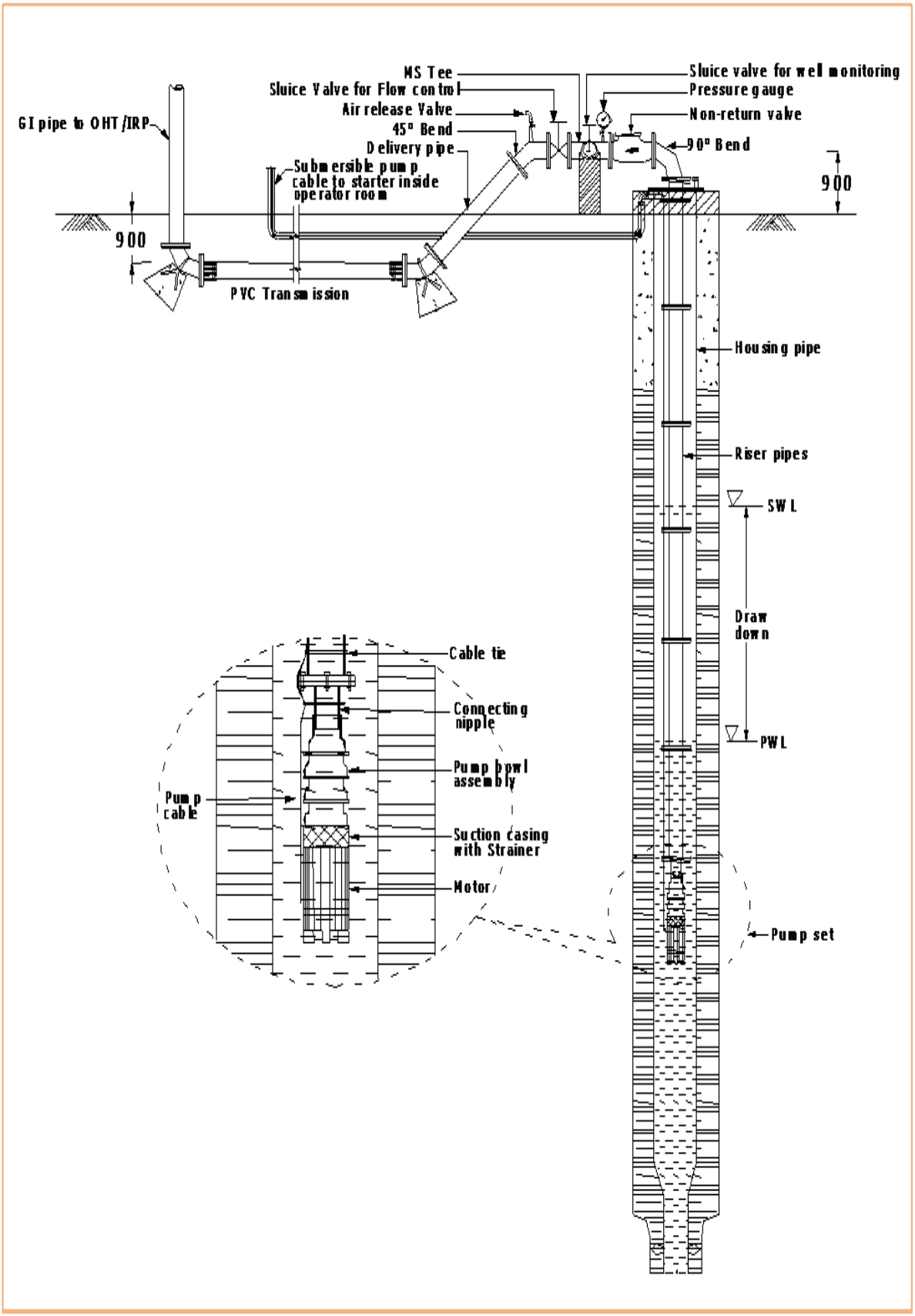
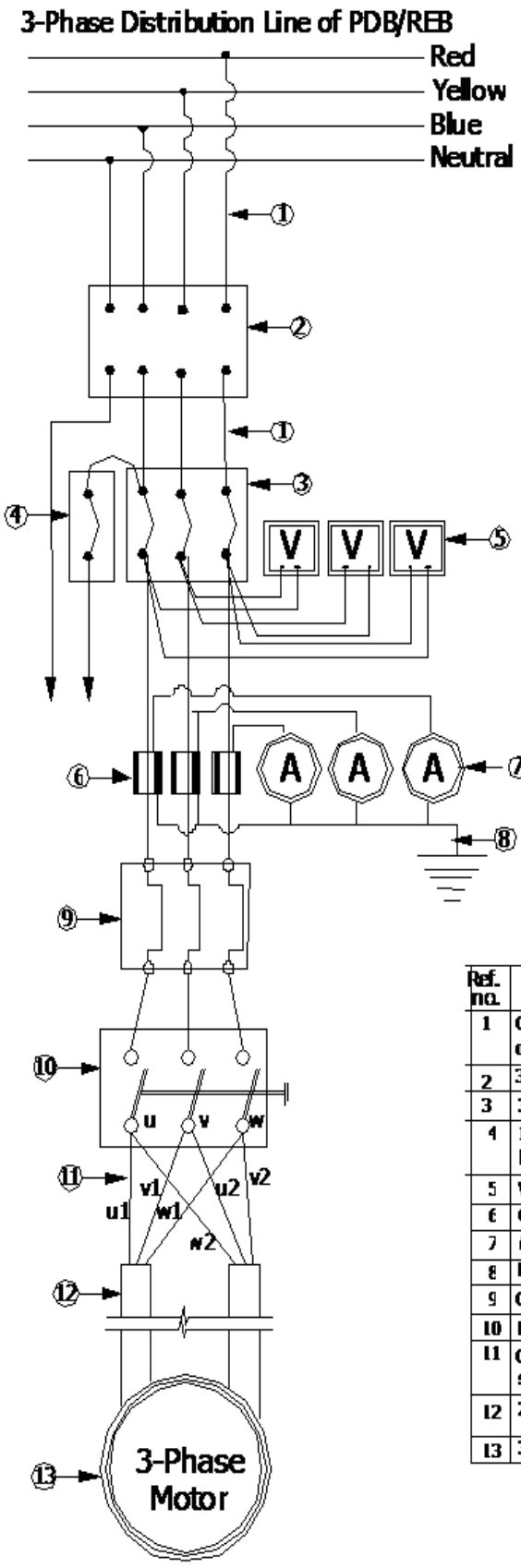


Exhibit 6-3
Typical Circuit Diagram of 3-Phase Submersible Pump Motor Control Unit



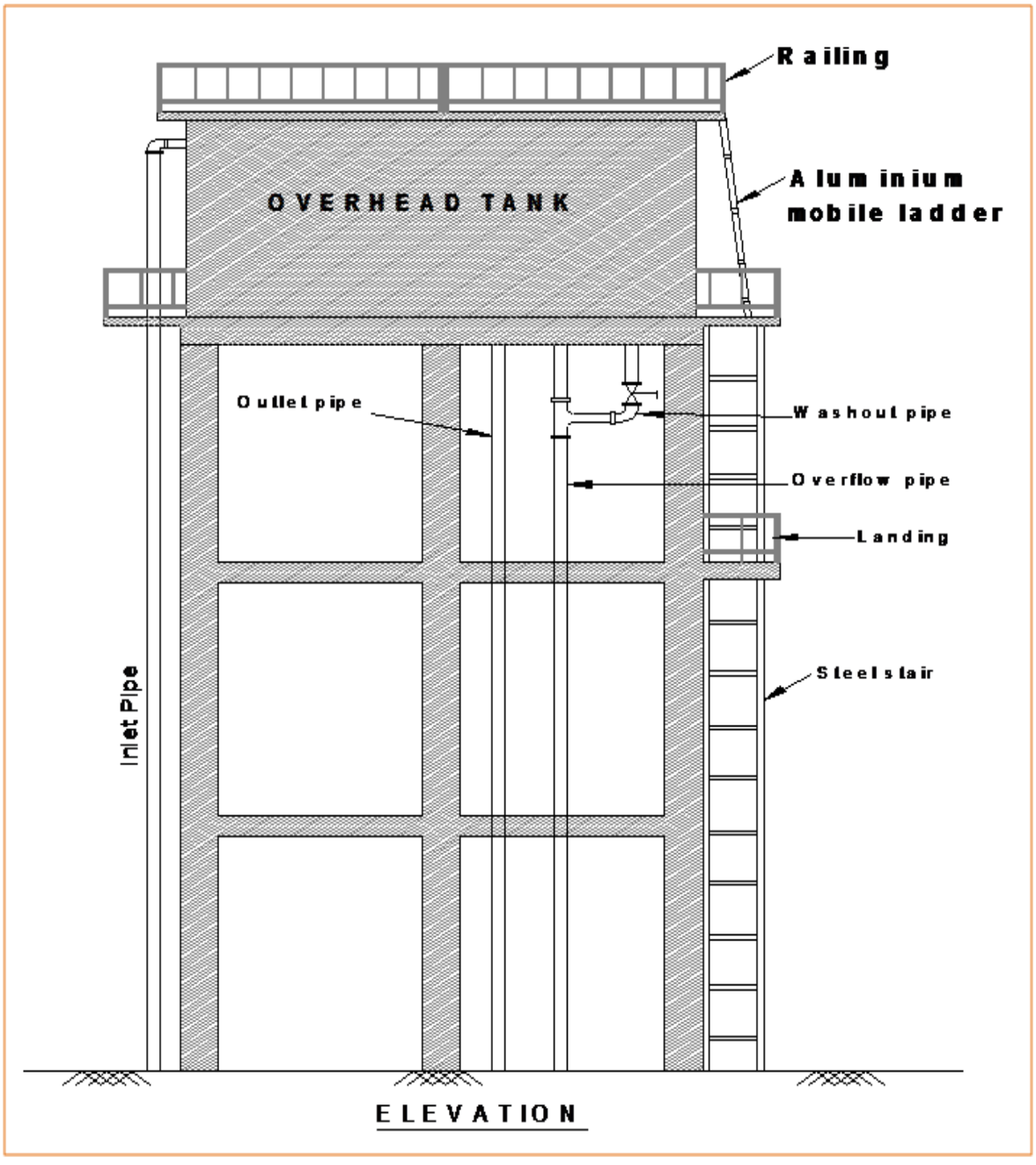
Ref. no.	Description
1	Cable from distibution line/energy meter of REB/PDB to motor control panel
2	3-Phase energy meter
3	3-Phase circuitbreaker
4	1-Phase circuitbreaker to fan, light & control circuit etc.
5	Voltmeters (3 nos.)
6	Current transformer (CT)
7	Ampere-meter (3 nos.)
8	Earthing from CT
9	Over load relay
10	Direct on line (DOL) starter
11	Connection to starter from submersible motor
12	2X3 core cable from submersible motor
13	3-Phase submersible pump motor

6.3.2 Over Head Tank

In piped water supply systems, water is supplied to the distribution network either directly from the PTW or through OHT. Where treatment of raw water is required, water from a Clear Water Reservoir (CWR) or pressure filter is lifted to the OHT. The height of the OHT is usually in the range 15 – 30m depending on the size of the distribution network to maintain a minimum distribution line pressure 10m. The capacity of the OHT is about 15-25% of the day demand. For 24-hour supply, the OHT serves as balancing tank.

The shape of tank will be either rectangular or round and made of Reinforced Cement Concrete (RCC). **Exhibit 6-4** shows a typical overhead tank.

Exhibit 6-4
Typical Drawing of OHT



6.3.3 Supply Pipe Network

In municipal water supply systems, water is supplied to the distribution network either directly from the PTW or through OHT to reach the consumers' taps. Where treatment of raw water is required, water from a Clear Water Reservoir (CWR) or Pressure Filter is lifted to the OHT for supplying the network. In municipal water supply systems, the distribution lines are generally constructed with water grade UPVC or HDPE pipes except in bridges, culverts, or road crossings, where metal pipes like GI, MS, or DI are used.

The main components of the pipelines are listed below.

1. Transmission line;
2. Distribution line;
3. Reticulation line;
4. Sluice valve;
5. Washout arrangement; and
6. Flexible joints (dresser coupling, flange adopter).

A typical drawing of Pipeline installation trench, Sluice valve and Washout arrangement are shown in **Exhibits 6-5, 6-6, and 6-7**.

Exhibit 6-5
Pipe Installation Trench

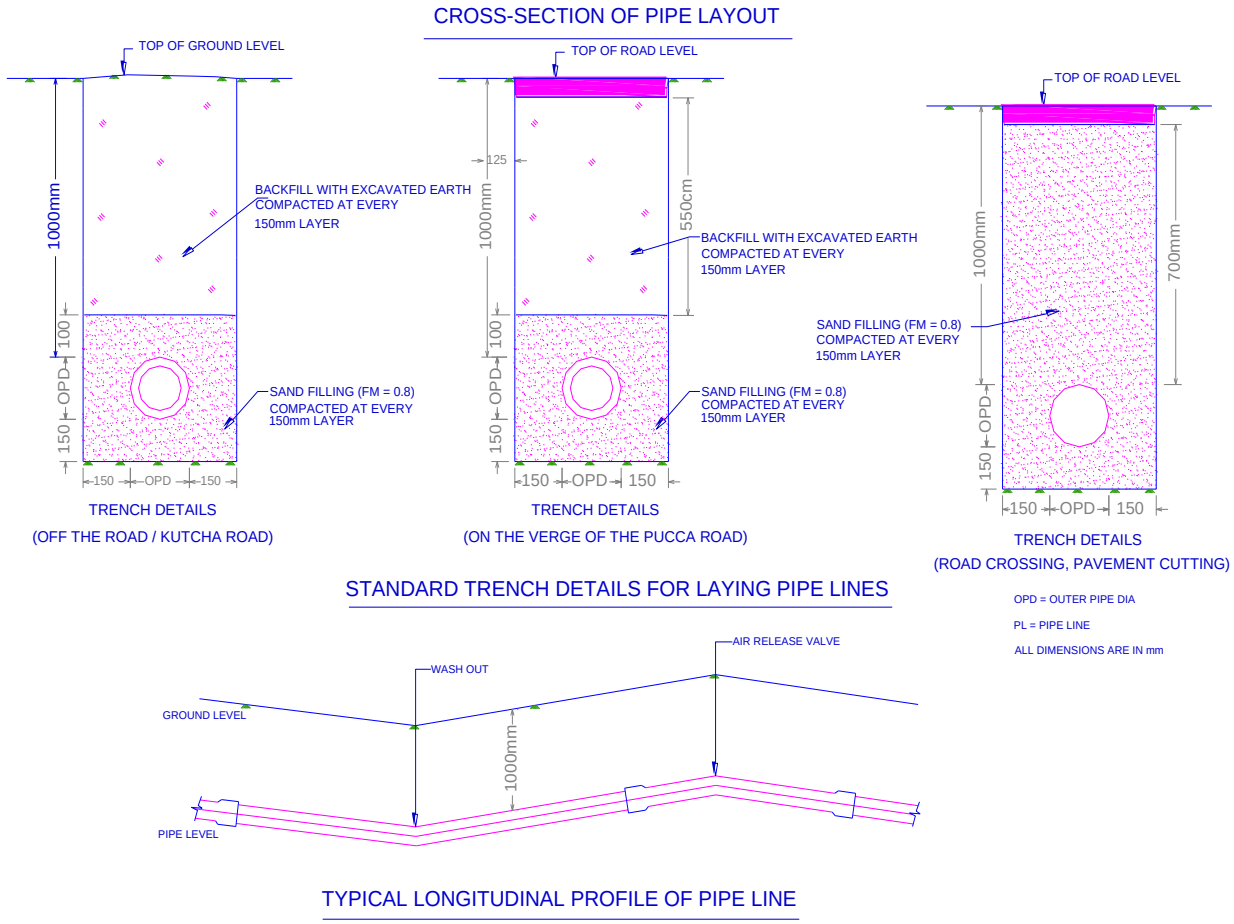
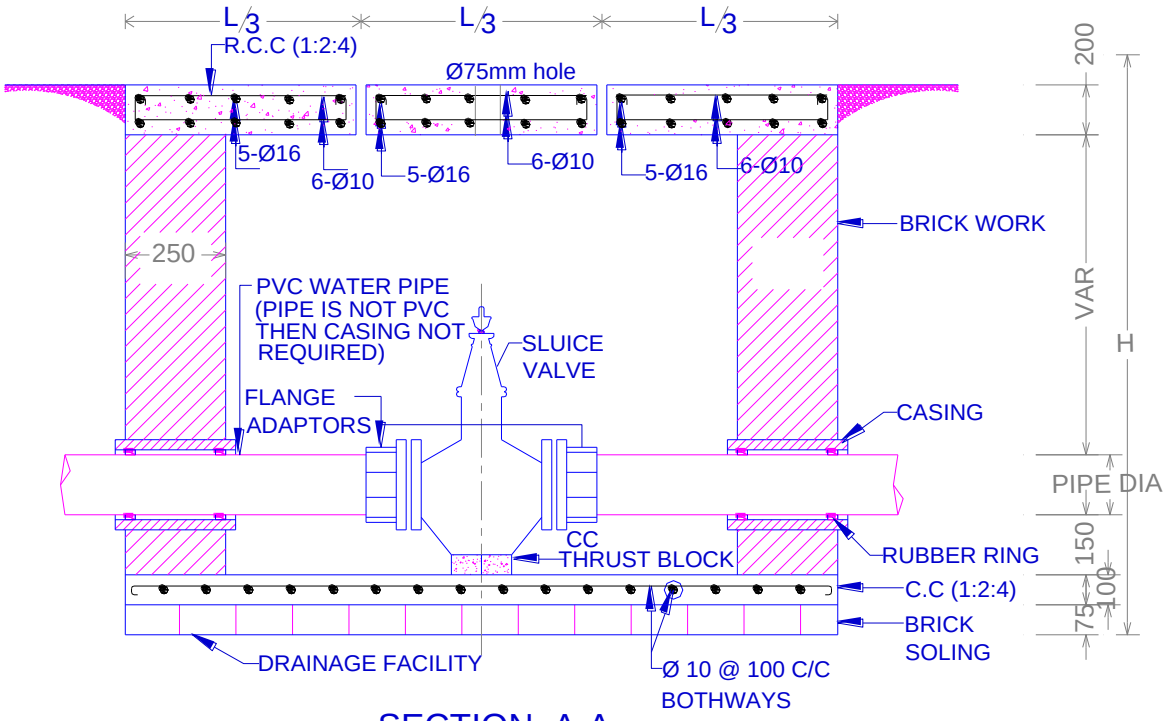
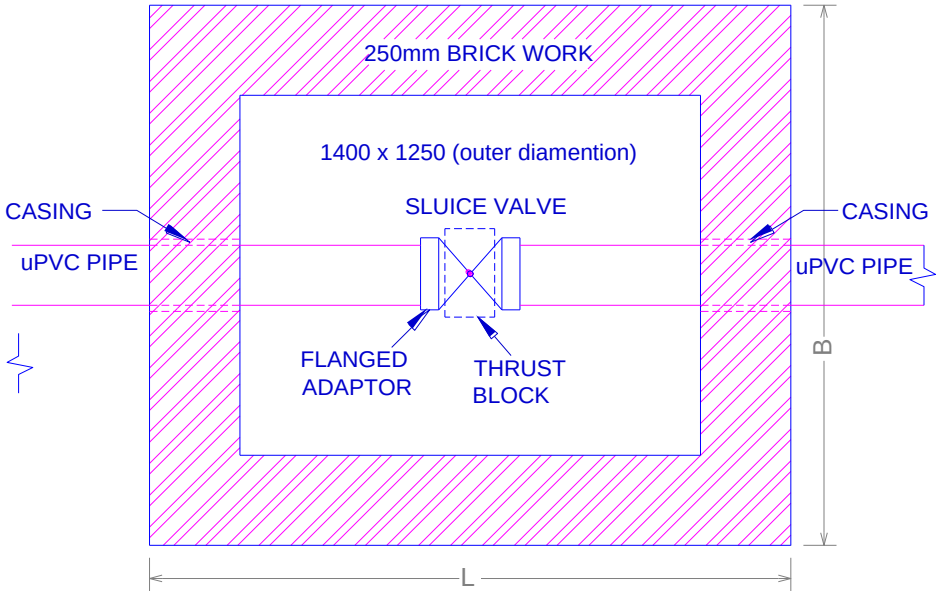


Exhibit 6-6
Sluice Valve Chamber

DETAILS OF SLUICE VALVE CHAMBER

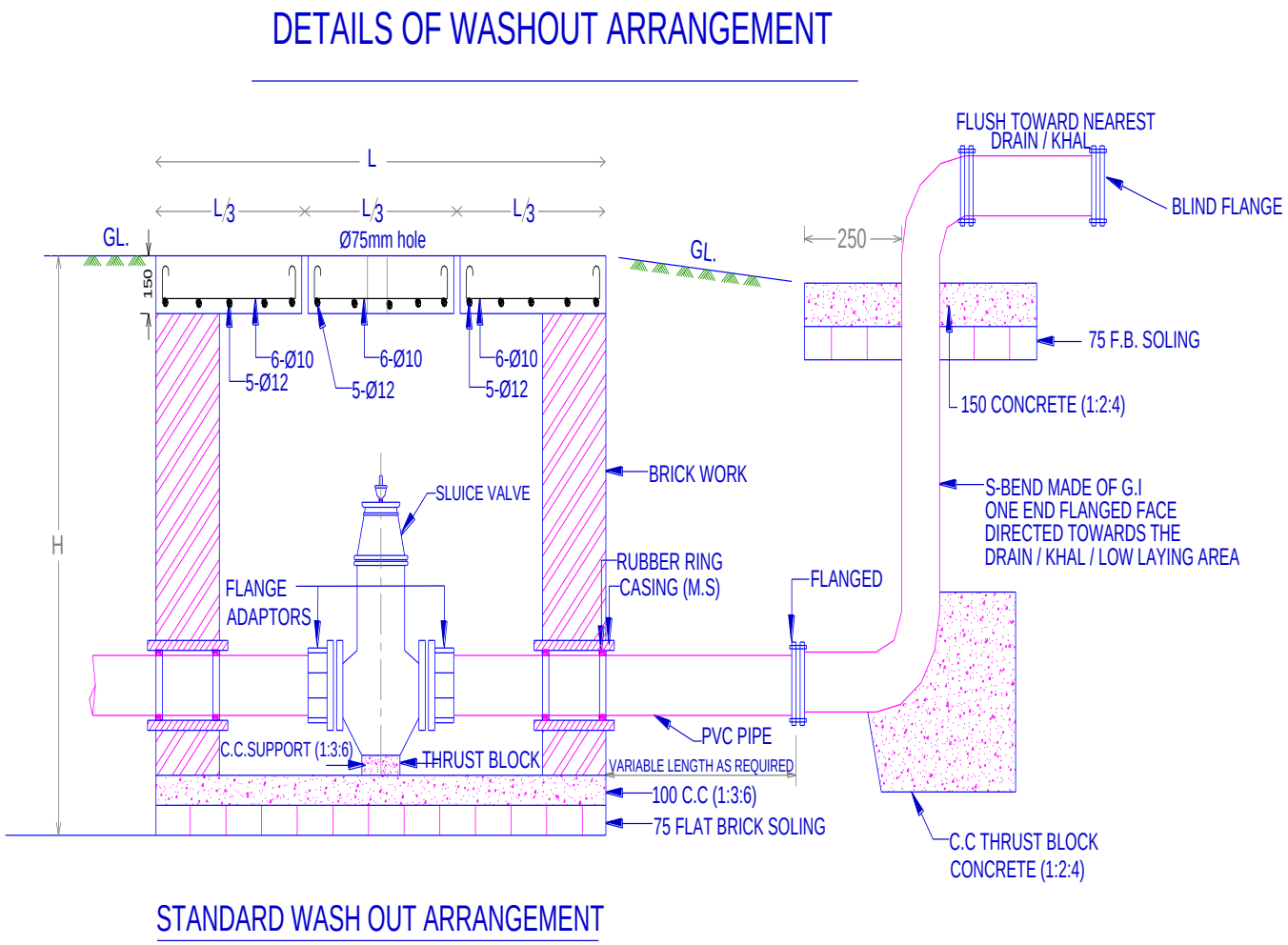


SECTION A-A



PLAN OF SV CHAMBER

Exhibit 6-7
Washout Arrangement



6.3.4 Service Connection

A service connection is a connection from the distribution or reticulation pipeline to the premises of the customers up to a reasonable distance for tapping supply water.

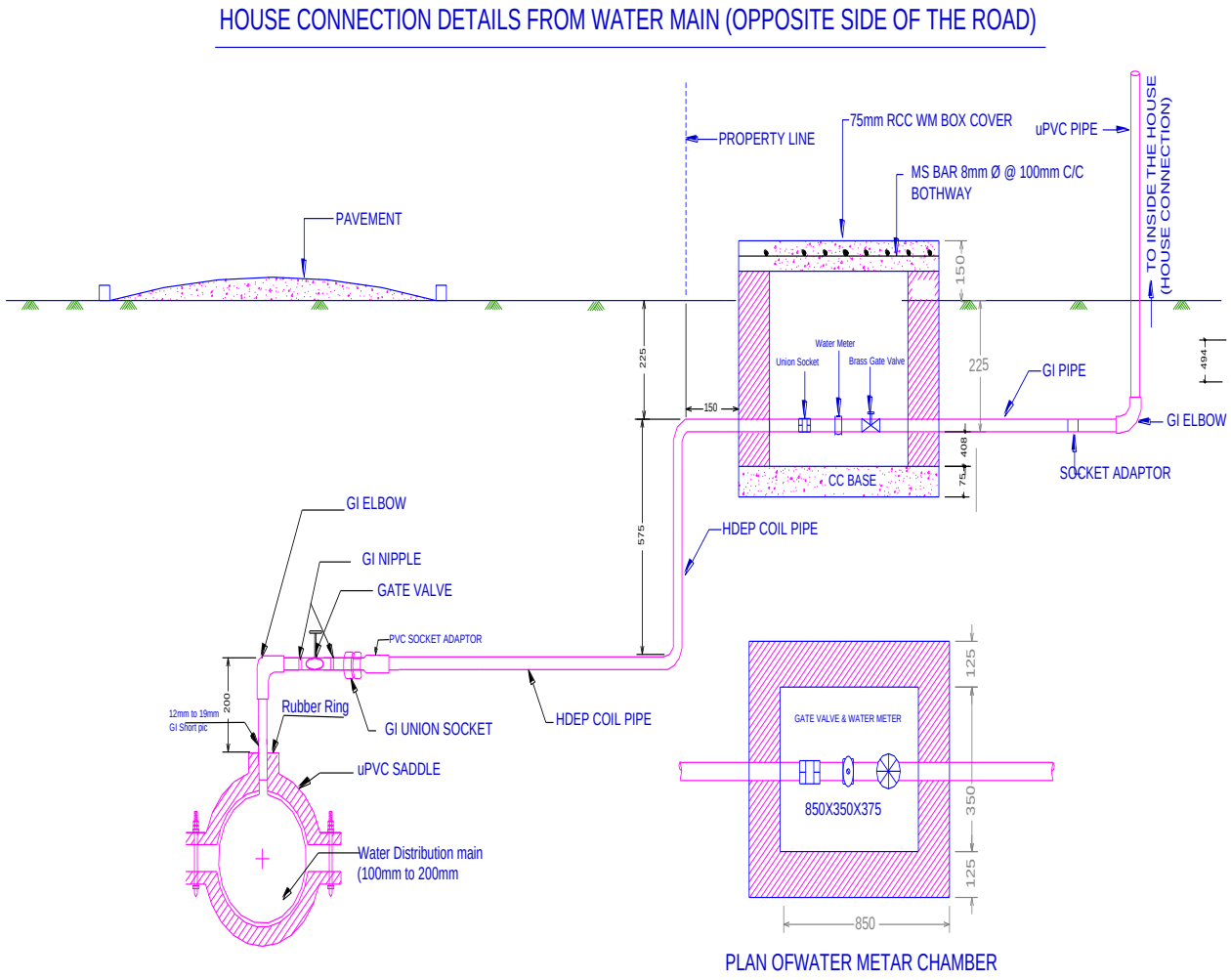
Good quality materials and tools should be used in for service connections. Using bad quality materials and poor plumbing in service connection will cause serious maintenance problems and loss of water. Generally, 12mm-19mm diameter domestic connections are used. For commercial services, the size of connection is in the range 25mm – 40mm. The connection material is usually “E” class UPVC or HDPE (either PN8 or PN10) or GI pipes.

In municipalities, the types of service connections are of the following types.

1. House connection;
2. Yard or Street faucet; and
3. Commercial connection.

A typical drawing of house connection is shown in **Exhibit 6-8**.

Exhibit 6-8
House Connection



6.3.5 Treatment Plant

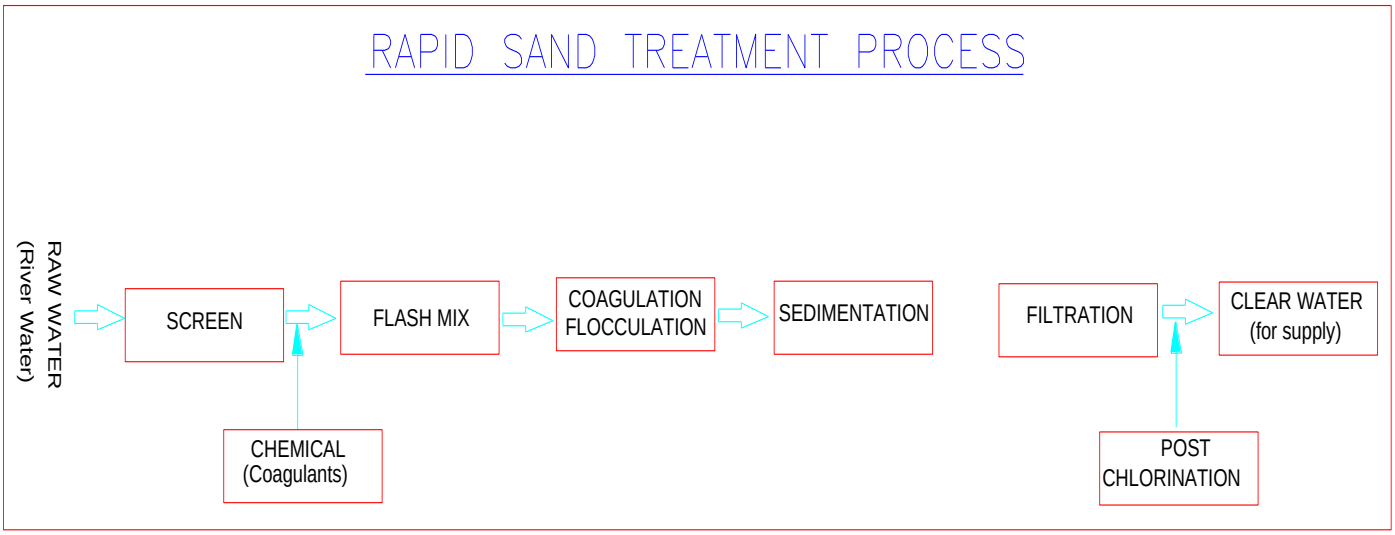
Bangladesh has abundant sources of groundwater and public water supply in most of the Project ULBs. Water supply comes from on groundwater source except few locations. In most places groundwater from deep aquifers needs no treatment and is directly supplied to the network from production wells. In the Project ULBs, Gopalganj public water supply is from surface water due to high concentration of iron in the groundwater.

Drinking water should preferably be obtained from an unpolluted source. The raw water normally available from surface water sources is, however, not directly suitable for drinking purposes. The objective of water treatment is to produce safe and potable drinking water.

Some of the treatment processes commonly used in municipal water supply includes plain sedimentation, rapid sand filtration with coagulation-flocculation units as essential pretreatment units. Roughing filters are also used under certain circumstances as pretreatment units for the conventional filters.

A flow chart of surface water treatment process is shown in **Exhibit 6-9**.

Exhibit 6-9
House Connection



6.4 Operation and Maintenance Activities for the System Manager and Operator

6.4.1 Operation and Maintenance of PTW and Pumping Equipment

Operation

Daily operation consists of starting, running and closing of submersible pump, associated equipment and instrumentation controls. The operation of each must be conducted following some preset instructions and also complying with the emergency measures, precautions and manufacturer's special instruction if any. Operation instructions with step by step action by operator are given below

Instruction No. 6-1: Operation of Submersible Pump (Action: Pump Operator)

Pre-start Check

1. Check if there is any loose connection in the main electrical wiring inside operator's room or loose nuts and bolts in the pump assembly and correct the defects.
2. Check the voltage of each of three phases. Do not start the pump if:
   - Voltage of any phase is out of operating range (380-440V);
   - Voltage difference between any two phases exceeds 10V.
   - If the voltage is out of operating range, record the voltage in the log book and, inform the power supply office (PDB/REB) for immediate measure. Also bring it to the notice of the Manager/Water Works Superintendent.

3. Check if the overload relay is correctly set (It should be set to rated current recommended by manufacturer (as inscribed on motor body);
4. Check and record the energy meter (kwh) and flow meter reading (if any) and record in log book.

Pump Starting

1. Regulate the delivery sluice valve to about 90% closed position (Operator should know the number of turns for fully opening or closing) before starting the pump;
2. Switch on the circuit breaker or main switch if it is in closed position;
3. Start the motor pushing the start button;
4. Check that the pump has started delivering water by opening sampling tap;
5. Open the delivery sluice valve gradually for designed flow (appropriate regulation or turning of the valve should be determined from prior trials);
6. Record starting time in log book.

Supervision and Monitoring During Operation

1. Watch time to time if there is any abnormal sound or noise or vibration from the pump. In case of any such abnormality, stop the pump operation and report to Manager for urgent action;
2. Check the direction of rotation of the pump. Rotation in reverse direction may be identified from the minimum flow through the sampling tap. Ampere reading will also be higher than normal;
    - If reverse rotation is noticed, stop operation and contract the power supply office to confirm regarding change of power phase;
    - In case of rotation in reverse direction, interchange of any two phase of connection cable before restart the pump;
3. Operator should remain vigilant that pump never runs dry. However submersible pumps are presently with built in water guard against dry run;
4. Record the readings of ammeter, voltmeter and pressure gauge in the logbook after half an hour of each operation; and
5. In case of shut down of pump due to power failure, overload tripping or for any other cause.
    - Close the circuit breaker for safety;
    - Record the time of shutdown in log book;
    - Detect the cause of shutdown; and
    - Clear the fault and restart the pump.

Stopping the Pump

1. Close the delivery valve gradually up to about 90% closed position;
2. Switch off the starter by pushing Stop button;
3. Close the delivery valve fully;
4. Record pump shut down time in logbook.

Emergency Stopping of Pump

1. Ammeter reading shows operating current reading much above the rated current;
2. Supply voltage exceeds 440 Volts for three phase supply;
3. Supply voltage exceeds 250V for single phase supply;

4. Delivery pressure rises abnormally high;
5. Abnormal sound or vibration is produced.

Precaution

Do not run a pump against a closed discharge valve for more than 5 minutes.

Energy meter reading

Record energy meter reading on termination of day's operation of the entire system.

Maintenance

Daily or routine maintenance consists of cleaning, oiling, painting, changing of spares, equipment, materials, etc. of well and pumping equipment. Defects observed in pumping unit, riser pipes, well head components, starter, instrumentation controls, cables, etc., must be expeditiously repaired. No problem should be allowed to continue; otherwise complexity may arise resulting in more damage to plant and equipment. See **Exhibits 6-10 and 6-11.**

Instruction No. 6-2: Maintenance of PTW, pH, Valves, and Fittings (Action: Manager and Operator)

Exhibit 6-10
Maintenance Chart of Well, pH, Valves, and Fittings

No.	Monthly Inspection	Action	Points of Attention
1.	Check well and operator's room surroundings for submergence.	Take necessary step in case of submergence.	Provide drains if needed.
2.	Check if surroundings of well and pump room are adequately clean and nothing objectionable is noticed endangering sanitation and environmental safety.	Take remedial measures if any heath and sanitation hazard is noticed	Follow sanitary inspection.
3.	Check operator's room if doors, windows, floor, ceiling, wall plaster, painting, etc. are in order.	Repair if necessary.	Comply with the "Technical Specifications for Construction of Municipal or Urban Center Piped Water Supply Component".
4.	Check electrical wirings for domestic use, inside and outside lights, switches, sockets, plug points, etc.	Repair defects and ensure that they are safe.	Comply with electrical safety regulations.
5.	Check loose connections, nuts and bolts of valves, fittings and discharge pipe assembly.	Securely tighten loose connections.	Use appropriate tools.
6.	Check if exposed joints or connections of pump discharge assembly including sluice valves, non-return valve, pressure gauge, etc. are leaking.	Repair leakages.	Use appropriate tools.

No.	Monthly Inspection	Action	Points of Attention
7.	Check if non-return valve, sluice valves, pressure gauge are properly functioning.	Repair or replace if unserviceable.	Replacement by equipment of acceptable quality.
8.	Check the painting of the discharge pipe assembly, valves and fittings.	Repaint the surfaces if necessary.	Repainting to be done with prior application of an anticorrosive primer.
9.	Check the pipe support.	Repair and ensure stable and firm support.	Stop supply through pipe while repairing the support.

Instruction No. 6-3: Maintenance of Electrical Equipment and Wiring (Action: Manager and Operator)

Exhibit 6-11
Maintenance of Electrical Equipment and Wiring

No.	Inspection	Action	Points of Attention
A	Monthly Inspection		
1.	Check if the motor control panel door is in order and can be securely closed to prevent entrance of dust from outside.	1. Repair the panel door if found defective. 2. Remove accumulation of dust if noticed inside control panel. Also, clean the outer surface. 3. The panel door must remain closed during	Stop electric supply to control panel while cleaning and repairing defects.
2.	Check if any damage occurred to cables, cable supports, accessories, etc.	Replace damaged cables and supports.	Comply with electric safety regulations.
3.	Check discolored and loose cables which are causes of overheating and also check if any cables or accessories are overheating.	1. Tighten the loose cable joints and replace burnt cables. 2. Close the main switch when there is overheating or something is abnormal or wrong and takes	Comply with electric safety regulations.
4.	Check if circuit breaker, fuse, over load relay, voltmeters, ammeters, etc. are properly functioning.	Repair or replace component that are not working.	Replace component with acceptable quality and specifications.
B	Yearly Inspection		

No.	Inspection	Action	Points of Attention
1.	Measure insulation resistance of motor.	Repair motor if insulation resistance falls below 1 mega-ohm.	Disconnect pump cables from control panel and it is to be done by experienced electrician.

Monitoring of PTW

Routing monitoring of the PTW is essential for a better functioning well.

Instruction No. 6-4: Quarterly monitoring of well (Action: Manager and Operator)

1. **Water Level**
   - Record static water level after minimum 6 hours of pump shut down and pumping water level after 1 hour of pump starting. Record levels with date and time;
   - Send a copy of record to local DPHE engineer, as DPHE is playing role as technical adviser of public water supply system; and
   - Compare the result with past records and in case of abnormal fall of water level inform local DPHE engineer.

2. **Discharge**
   - Measure the well's discharge rate by filling a 200-liter drum from the discharge measuring outlet pipe installed with tee and valves on discharge pipe assembly;
   - Record time of filling with stop watch;
   - Compute discharge rate and record with date and time;
   - Compare result with past records and in case of abnormal reduction of discharge, seek local DPHE engineer's advice; and
   - In case of discharge reduces by more than 30% from the initial discharge, the tube well should be regenerated to prevent decrease of the well's life. DPHE has a well-equipped well regeneration team and regenerates wells on payment of scheduled charge.

Trouble Shooting in the Pump Operation

The faults commonly found in the pump operation, probable causes and remedies are summarized in **Exhibits 6-12 and 6-13**.

Instruction No. 6-5: Trouble Shouting of Submersible Pump and Its Remedy (Action: Manager and Operator)

Exhibit 6-12
Faults, Probable Causes and Remedy of Submersible Pump

No.	Problem	Probable causes	Remedy
1.	Pump refuses to start	No power supply from main line	Inform power supply authority
		Defective circuit breaker refusing flow of current	Repair or replace circuit breaker
		Disconnected cable	Securely connect cable

No.	Problem	Probable causes	Remedy
		Pump motor burnt	Rewind or replace motor
		Fallen pump with disconnected cables	Arrange fishing out of fallen pump and reinstallation
2.	Pump trips immediately after start	Overload protection relay set below rated current	Correctly set relay
		Short circuiting due to electrical fault	Identify and clear fault
		Abnormal low voltage	Wait till proper voltage is restored/ inform power supply authority
		Overheating because of loose joint	Securely tighten joint
		Weak motor insulation	Test motor insulation by an experienced electrician and take further action
3.	Pump delivers insufficient water	Rotation in reverse direction	Interchange any two phases
		Profusely leaking rising pipes	Repair riser pipes or joints
		Discharge valve carelessly throttled	Open discharge valve to right position
4.	Suction cut-off during operation	Pumping water level has gone below pump suction level	Add riser pipe(s)
			Throttle discharge valve
			Replace existing pump with a smaller pump
5.	Excessive current (ampere) reading	Defective ammeter	Replace ammeter
6.	Abnormal noise and vibration	Loose riser pipe joint or improper installation	Remove riser pipes and reinstall with secured jointing

Instruction No. 6-6: Trouble Shouting of Electrical Equipment and Wiring and Its Remedy (Action: Manager and Operator)

Exhibit 6-13
Faults, Probable Causes, and Remedy of Electrical Equipment and Wiring

No.	Problem	Cause	Remedy
1.	Showing no power in panel board	Power supply interrupted	Close main switch and carefully investigate reasons for power interruption
		Loose connection	Ensure secured connection replacing defective wire, if required
		Fuse blown out	Replace fuse wire
2.	Voltage out of operating range	Voltage of main supply line is inappropriate	Inform local power supply office and wait till correct voltage is available

No.	Problem	Cause	Remedy
		Defective volt meter	Change or repair the voltmeter
3.	Pilot lamp not working	Fuse blown out	Replace blown out fuse
		No power in that phase	Inform local power supply office and wait till supply is available in that phase with correct voltage
		Pilot lamp is out of order	Replace pilot lamp
4.	Panel gives abnormal noise or shows discolored wiring	It is overloading due to wrong or loose connection	Tighten loose connection or repair faulty connection as required. Also replace discolored wiring if partially burnt
		Faulty magnetic contactor	Repair or replace magnetic contactor
5.	The panel gives burning smell	Electric wire, fittings or instruments burning	Check wiring, connections and fittings, detect fault and carry out repairs

6.4.2 Operation and Maintenance of OHT

Operation

The operation schedule of an OHT will be prepared depending on demand and supply hours. It depends as how the service provider intends to make best use the OHT. Supply to network may be solely provided through the OHT or it may be used as balancing tank.

Instruction No. 6-7: Operation of OHT (Action: Operator)

1. During OHT filling, level indicator should be watched and if there is no level indicator, filling of OHT may be ascertained from previously tested time of filling;
2. Pump should be stopped just before water reaches overflow level; and
3. During maintenance of tanks, water should be delivered directly to distribution system through a bypass arrangement;

Maintenance

Routine maintenance with inspection carried out at specific interval will increase the effective life of the tank. Visible leakages in pipes, water retaining structure, valves and fittings must be repaired without time loss. The operator will report to the manager if he is unable to carry out any repair. See **Exhibit 6-14**.

Instruction No. 6-8: Maintenance of OHT- Quarterly Inspection (Action: Manager and Operator)

1. Check visible leakages in water retaining structure, pipe works, valves and fittings, and take prompt action as per finding;
2. Check surrounding of plant site and ensure that there is no water logging;
3. Check tank site and take immediate measures if environment and sanitation safety standard is violated; and
4. Check and repair unstable or loose pipe supports and clamps.

Instruction No. 6-9: Maintenance of OHT- Yearly Cleaning (Action: Manager and Operator)

Exhibit 6-14
Yearly Cleaning of OHT

No.	Yearly Cleaning of OHT	Points of Attention
1	Preliminary steps	
a	Stop plant operation and close OHT inlet valve.	
b	Continue supply from OHT and when minimum water level is reached inside OHT, close OHT outlet valve.	
c	Continue direct supply from PTW to distribution system.	Switch on plant operation, open bypass valve and regulate, if necessary.
2	Cleaning	
a	Drain out remaining water and during this process brush and flush out deposits as much as possible from tank floor.	Open washout valve.
b	Inspect inside structure of OHT and repair any damage, if located.	Cleaners will step down inside OHT with protective measures to avoid accident due to gases or suffocation. Temporary ladder and flash light will be used.
c	Clean ceiling, walls and bottom floor thoroughly and remove all dirt, deposits and sediments.	Cleaning tools like brush, hosepipe, bucket, etc. and flash light for better visibility inside should be used.
d	Fill OHT up to about 400 mm height.	Close washout valve, open inlet valve and close bypass valve.
e	Thoroughly clean wall and ceiling splashing water by buckets.	Close inlet valve and open bypass valve to restore direct operation from PTW/CWR.
f	Open washout valve and start brushing and cleaning floor when water level is slightly higher than floor level.	Start brushing from distant end and gradually proceed towards washout engaging adequate cleaners.
3	Disinfection	
a	Fill OHT pumping water from PTW/CWR	Close washout valve, open inlet valve and close bypass valve.
b	Restore direct supply from PTW/CWR to distribution, if required.	Open bypass valve and close OHT inlet valve.
c	Prepare bleaching powder solution to dose at 20-25 mg/l.	Wear protective goggles, mask, gloves, boots and apron while handling bleaching powder.
d	Add solution to OHT and retain for 24 hours.	To be done manually.
e	Test residual chlorine and if it is not more than 2 mg/l repeat disinfection process.	Use field test kit for residual chlorine test.
f	Drain out chlorinated water to waste opening washout valve.	Take care that chlorinated water is not drained to agricultural land or pond, and it should not be consumed by human being or livestock.
4	Refilling OHT and restoration of supply	

No.	Yearly Cleaning of OHT	Points of Attention
a	Start filling OHT from PTW/CWR.	Close washout valve, open inlet valve and close bypass valve.
b	Restore normal operation.	Open OHT out let valve.
5	Record cleaning.	Enter in logbook with date and time.

Operation

Service delivery should be such that both quantitative and qualitative water reaches the consumers' end. It means during transportation, water must not be contaminated from any leakage in pipes, valves, or fittings and desirable pressure is maintained.

The public water supply shall be up to the consumers' expectation of clean water in sufficient quantity. Therefore, the flow of water in the distribution lines shall be without any hindrance e.g. blockage in pipes. All the sluice valves on the pipelines shall be fully open. Unless otherwise indicated, sluice valves are opened by tuning the spindle very slowly counter clockwise (opening time about 1 minute) and closed by slowly turning the spindle clock wise (closing time about 1 minute).

Water Pressure in Supply Network

Adequate pressure should be maintained in the supply network otherwise an adequate quantity of water will not reach at consumers' end. The Project recommends a minimum pressure 10m of water column at any point of a new network and 5m for old ones. If that pressure cannot be maintained in the existing system by opening all the distribution valves, then the supply should be closed zone-wise so that certain valves attain the desired line pressure.

Chlorination of Supply Water

Chlorination is the process of adding chlorine to drinking water to disinfect it. Different processes can be used to achieve safe levels of residual chlorine in drinking water. Chlorine is available as compressed elemental gas, sodium hypochlorite solution (NaOCl), or solid calcium hypochlorite ($CaOCl)_2$. These chemicals could be harmful in high doses. When they are added to water, they all mix in and are diluted, resulting in low levels that kill pathogens but the water still safe to drink.

Generally, chlorinating the supply water is done by injecting chlorine gas or liquid sodium hypochlorite to the delivery line of the production well. Doses of the chemicals should be fixed in such a way that there exists a minimum chlorine residual of about 0.2 mg/l at any point of the supply network. Doses of chemicals are fixed by the system designer. However, they may need to readjust which is done by checking the residual chlorine at several points.

Maintenance

Water supply systems are designed to supply water to the consumers 24 hrs. or 12-16 hrs. daily. Therefore, the condition of the pipes and fittings should be optimum to function all day.

For this reason, the entire system must be supervised regularly and any irregularities observed must be addresses promptly. If damage or leakage in pipes or fittings is observed, repair should take place immediately. See **Exhibit 6-15**.

Instruction No. 7-10: Maintenance Chart for Pipelines & Fittings (Action: Manager and Plumber)

Exhibit 6-15
Maintenance Chart for Pipelines and Fittings

Monthly Maintenance	Points of Attention
A. Pipeline and valve chamber	
Inspect pipeline routes particularly for unnatural wet areas and pool of water. Record the possible locations of leakage in a note book	Information should come from plumber/valve operator, who should complete inspection of predetermined area within a week covering at least 2 km a day. He should also collect information from the consumers and the community.
Carry out repairs to leakages	Use proper tools and fittings for repair.
Check valve chamber and leakages in valve and water logging in and around.	Tighten bolts and nuts and replace gland packing. Grease the spindle if necessary. Clean the chamber if there is debris or/and water logging inside. Drain out the outside water logging.
Yearly Maintenance	Points of Attention
B. Valves, Valve Chambers and Boxes	
Fully close and open each valve and repair if there is problem.	Valves not properly closing or opening should be repaired or replaced if necessary.
Replace sluice valves that are not working	Close upstream and downstream sluice valves before replacing the defective one. After replacing defective valve, disinfect the pipe section injecting 30ppm bleaching powder solution. Retain the solution for 30 minutes and flush the pipe. When handing bleaching powder solution wear protective goggles, gloves and rubber apron.
Check the structure of valve chambers and boxes.	Ensure that the valve chamber cover slab is not broken and properly placed. Repair damages.
C. Washouts	
Check washout valves for repairs.	Repair the leakages of washout valves following same method for network valves as stated above. Also check washout pipe and repair if necessary.
Flush out deposits and impurities in pipeline.	Open wash out valve and keep it open for 10 minutes or until clear water comes out from washout pipe. Close valve and make sure that it is not leaking through the discharge end.

Procedures for repairing burst pipes (Action: Manager and Plumber) are listed below.

1. Isolate burst pipe closing the nearest valves promptly;
2. Dig out the burst pipe;
3. Drain out water from the isolated portion of pipeline;
4. Inject bleaching powder solution having 50mg/l free chlorine through removed end and replace the burst pipe using appropriate joints;
5. Retain chlorine solution in isolated pipe section for minimum half an hour;
6. Flush out water through the nearest washout until clear water comes out of washout pipe and smell of chlorine has nearly disappeared; and

7. Restore normal operation opening the closed valves.

Monitoring of Line Pressure

Routing monitoring of line pressure is essential to ensure better service delivery.

Instruction No. 6-11: Monthly monitoring of Water Pressure in Supply Network (Action: Manager and Plumber)

Line Pressure

1 Check water pressure at pre-selected points (street hydrant and consumers' taps) using pressure meter and record. The number of tests should be average one per 500 house connections. Isolate burst pipe closing the nearest valves promptly.

2 Compare with the previous result, if any abnormal fall then tries to find out the reasons and take action accordingly.

Monitoring of Water Quality

The principal risk to human health associated with community water supply is microbiological contamination. The risk of waterborne disease increases with the level of pathogenic micro-organism contamination. According to WHO Guideline Value, E-coli or thermo tolerant coli form bacteria in drinking water must not be detectable in a 100 ml sample. An immediate re-sampling and conformity test must be done if either E. coli or total coli form is detected. The Project recommends zero E. coli or thermo tolerant coli form count per 100ml sample. See **Exhibit 6-16.**

To protect from bacteriological contamination of supply water, a minimum chlorine residual of about 0.2 mg/l at the selected monitoring point should be maintained to ensure that even a little contamination is destroyed by the chlorine. Hence, absence of residual chlorine could indicate potential presence of heavy contamination. If routine checks for residual chlorine using field test kit at few monitoring points are carried out, required chlorine residuals and any sudden absence of residual chlorine should alert the operating staff to take up prompt investigation and remedial measure. Immediate steps to be taken are listed below.

1. Re-testing for residual chlorine;
2. Testing for e-coli content;
3. Checking chlorination equipment;
4. Searching for source of contamination, which has caused the increased chlorine; and
5. Immediate stoppage of supplies from the contaminated pipelines.

Instruction No. 6-12: Water Quality Monitoring (Action: Manager)

Exhibit 6-16
Water Quality Monitoring at Operation Stage

No.	Water Quality Parameter	Test Frequency	No. of Samples	Sampling Point	Testing Equipment or Facility
A.	Ground Water without Treatment				
1	Arsenic	6 month	1	Pumping station	Field kit/laboratory
2	Iron	6 month	1	Pumping station	Field kit/laboratory

No.	Water Quality Parameter	Test Frequency	No. of Samples	Sampling Point	Testing Equipment or Facility
3	Manganese	6 month	1	Pumping station	Field kit/laboratory
4	pH	6 month	1	Pumping station	Field kit/laboratory
5	E. Coli	3 month	3	Consumers' Tap/Reservoir	Field kit/laboratory
6	Sanitary Inspection	3 month		Consumers' Tap/Reservoir	Consumers' Tap/Reservoir
B.	Ground Water with Treatment				
1	Arsenic	6 month	1	Treatment Plant Effluent	Field kit/laboratory
2	Iron	6 month	1	Treatment Plant Effluent	Field kit/laboratory
3	Manganese	6 month	1	Treatment Plant Effluent	Field kit/laboratory
4	pH	3 month	1	Treatment Plant Effluent	Field kit/laboratory
5	Residual Chlorine	1 month	3	Consumers' Tap	Field kit/laboratory
6	E. Coli	3 month	3	Consumers' Tap/Reservoir	Field kit/laboratory
7	Sanitary Inspection	3 month		Consumers' Tap/Reservoir	Consumers' Tap/Reservoir
C.	Surface Water with Treatment				
1	Turbidity	3 month	1	Treatment Plant Influent and Effluent	Field kit/laboratory
2	pH	3 month	1	Treatment Plant Effluent	Field kit/laboratory
3	Residual Chlorine	3 month	1	Consumers' Tap	Field kit/laboratory
4	Colour	3 month	1	Treatment Plant Influent/Effluent /Consumers' Tap	Visual
5	Residual Chlorine	1 month	3	Consumers' Tap	Field kit/laboratory
6	E. Coli	3 month	3	Consumers' Tap/Reservoir	Field kit/laboratory
7	Sanitary Inspection	3 month		Consumers' Tap/Reservoir	Visual and field kit

6.4.3 Operation and Maintenance of Service Connections

Maintenance

The leak proof service connection system should be maintained. Apart from structural soundness of the system, a leak proof condition is of utmost important not only to check the water losses but also to avoid water from being contaminated by polluted water entering the pipe through leakage. Leakage very often occurs in the connection clamps between the main pipe and the service line. Furthermore, there will be a substantial drop in line pressure

due to leakage in service connection pipe. In short, a leaky system is a public nuisance and health hazard.

Routine inspection of service connections should be carried out to ensure that there are no water losses through leakage in clamps, joints in connection pipe, and defective house taps or floating valves in ground and roof tanks.

Instruction No. 6-13: Maintenance Chart for House Connections (Action: Manager and Plumber)

Exhibit 6-17 describes the quarterly maintenance procedures.

Exhibit 6-17
Maintenance Chart for House Connections (In House Connection and Shared Tap)

Quarterly Maintenance	Points of Attention
Check the service gate valve	1. The service valve must be kept fully open. 2. Make sure that the service valve is properly functioning by closing and opening the valve. 3. Ensure that the valve is water tight i.e. no water flows through house taps when valve is closed. 4. Also, ensure that no leakage in gate valve joints with the connection pipe and gate valve spindle.
Check the service gate valve chamber	1. The chamber must be kept clean and without any damage and crack. 2. There must not be any water logging inside and around the valve. 3. Also ensure that the cover slab is not broken and placed properly over the chamber to protect the service valve installation.
Check the house installations	1. Inspect the house installation along the house owner. 2. Make sure that all the taps are fully water tight when closed and no leakage of water through any joints. 3. Make sure that ground/roof tank is provided with float valve functioning properly. 4. Make sure that all the water pipes are well supported and without corrosion and leakage.
Check the shared stand tap installation	1. Make sure that the stand tap platform is in good condition and no crack or damage. 2. Make sure that the waste water drain out properly. 3. Make sure that the taps are fully water tight when closed. 4. Make sure that all the user households keep the tap closed after use every time and do not waste water.
During inspection of household compound, also check if there is abnormal water use by any household due to gardening, watering plants, bathing of domestic animals and storage of water in huge underground reservoir causing water shortage to neighboring houses	In case of abnormal use of water or abnormal storage is detected, 1. the household shall be served by the system Management Committee with a notice to immediately abolish the unacceptable practice. 2. If the household fails to comply with the notice, service line must be disconnected and other action may be taken as deemed appropriate by the Management Committee.
Inspect service connection pipe route and location of saddle joint to locate unnatural wet areas and pool of water.	The plumber will conduct the inspection house to house. He should also collect information from the consumers and the community
Repair of leakages and replacement defective taps.	1. Ensure prompt repairing. 2. Ensure use of proper tools and good quality materials.

Quarterly Maintenance	Points of Attention
Report	Every time inspection of house connections to be recorded in log book and reported.

6.4.4 Operation and Maintenance of Treatment Plant

Operation

The pretreatment units which form essential parts of a Rapid sand filtration unit include (a) Coagulation and flocculation with rapid mixing facilities and (b) Sedimentation units. Effluent quality depends on proper operation of each unit.

Coagulation and Flocculation

The purpose of coagulation and flocculation is to remove particulate impurities, especially non-settle able solids (particularly colloids) and color from the water being treated. Non-settle able particles in water are removed by the use of coagulating chemicals.

Coagulant

The most commonly used coagulant is ferric alum ($Fe_2(SO4)_3Al_2(SO_4)_324H_2O$). However, Poly Aluminum Chloride (PAC) is also used as a coagulant. The advantages of PAC($\{Al_2(OH)_27Cl_{3.3}\}_{15}$) are i) it gets properly dispersed, ii) it does not have any insoluble residue, iii) it does not affect the settling tanks, iv) it is more effective than alum v) it requires less space (may be about 50%). The disadvantage of PAC is that it is less effective in removing color. CaO and Ca $(OH)_2$ are also used as primary aids.

The most important consideration is selecting the proper type and amount of coagulant chemical to be added to the water to be treated. Overdosing as well as under dosing of coagulants may lead to reduced solid removal efficiency. The type of coagulant and doses are selected by plant designer. The operator will follow the preselected doses of chemicals. However, the doses may need to readjust if there is any change of mainly turbidity, pH, alkaline, and temperature. This may be done by carefully performing Jar tests and verifying process performance.

Mixing of Coagulant

Coagulation is a physical and chemical reaction occurring between the alkalinity of the water and the coagulant added to the water, which results in the formation of insoluble flocks. The main requirement of the mix is that all the coagulant be rapidly mixed with all the water instantly to achieve complete homogenization of a coagulant chemical in the stream to be treated. The reason is that the chemical reaction is extremely rapid, practically instantaneous, especially in waters with high alkalinity.

Mixing of the chemical coagulant is usually accomplished in a special coagulant tank with mixing devices (Hydraulic and mechanical). Mixing may also occur in the influent channel or a pipeline to the flocculation basin if the flow velocity is high enough to produce the necessary turbulence. The operator will ensure proper functioning of mixing devises.

Flocculent basin – Operation

The objective of a flocculation basin is to produce a settled water of low turbidity which in turn will allow reasonably long filter runs. The following points should be considered during the operation of the flocculation basins.

Typical jobs performed by an operator in the normal operation of the coagulation flocculation process include the following items.

1 Monitor process performance;
2 Evaluate water quality conditions (raw and treated water);
3 Check and adjust process controls and equipment, and
4 Visually inspect facilities.

Record Keeping

Record keeping of the following items should be maintained.

1. Source water quality (pH, turbidity, temperature, alkalinity, chlorine demand and color);
2. Process water quality (pH, turbidity, and alkalinity);
3. Process production inventories (chemicals used, chemical feed rates, amount of water processed, and amount of chemicals in storage);
4. Process equipment performance (types of equipment in operation, maintenance procedures performed, equipment calibration, and adjustments);
5. A plot of key process variables should be maintained. A plot of source water turbidity vs. coagulant dosage should be maintained. If other process variables such as alkalinity or pH vary significantly, these should also be plotted.

Instruction No. 6-12: Operation Chart for Treatment Plant (Action: Manager and Operator)

Exhibit 6-18 summarizes the coagulation and flocculation trouble shooting procedures.

Exhibit 6-18
Trouble Shooting in Coagulation and Flocculation Process

No.	Problems	Operator's Actions	Possible Process Changes
1.	Water quality changes – source water		
	- Turbidity - Temperature	1. Perform necessary analysis to determine extent of change. 2. Evaluate overall process performance. 3. Perform Jar Test. 4. Make appropriate process change. 5. Increase frequency of process monitoring.	1. Adjust coagulant dosages. 2. Adjust flash mixer mixing intensity. 3. Add coagulant aid. 4. Adjust alkalinity or pH. 5. Change coagulant.
2.	Effluent quality changes – Coagulation process		
	- Turbidity - Alkalinity - pH	1. Evaluate source water quality. 2. Perform Jar Test. 3. Verify process performance – coagulant feed rate & flash mixer operation. 4. Make appropriate process change.	1. Adjust coagulant dosages. 2. Adjust flash mixer mixing intensity. 3. Adjust alkalinity or pH. 4. Change coagulant.
3.	Floc quality changes – Flocculation basin		

No.	Problems	Operator's Actions	Possible Process Changes
	- Floc formation	1. Observe floc condition in basin – dispersion, size and flock strength (break up). 2. Evaluate overall process performance. 3. Perform Jar Test – size, settling rate. 4. Make appropriate process change.	1. Adjust coagulant dosages. 2. Adjust flash mixer mixing intensity. 3. Adjust alkalinity or pH. 4. Change coagulant.

Note: All major problems should be reported to authorities and feedback duly followed up.

Sedimentation

The purpose of sedimentation process is to remove suspended particles so as to reduce load on Filters. If adequate detention time and basin surface area are provided in the sedimentation basins, solids removal efficiencies greater than 95% can be achieved. However, high sedimentation basin removal efficiencies may not always be the most cost effective way to remove suspended solids.

Sedimentation Basin

The sedimentation basin can be divided into 4 zones –

1. inlet zone;
2. settling zone;
3. sludge zone; and
4. outlet zone.

The types of basin generally are rectangular or circular type.

Sludge Handling

Water treatment sludges are typically alum sludges, with solid concentrations varying from 0.25 to 10% when removed from a basin. In gravity flow sludge removal systems, the solid concentration should be limited to about 3%. If the sludges are to be pumped out, solids concentrations as high as 10% can be readily transported. In horizontal flow sedimentation basins preceded by coagulation and flocculation, over 50% of the floc will settle out in the first third of the basin length. Operationally, this must be considered when establishing the frequency of operating sludge removal equipment.

Sludge which accumulates on the bottom of the sedimentation basins must be removed periodically for the following reasons.

1. To prevent interference with the settling process (such as re-suspension of solids due to scouring);
2. To prevent the sludge from becoming septic or providing an environment for the growth of microorganisms that create taste and odor problems; and
3. To prevent excessive reduction in the cross-sectional area of the basin (reduction of detention time);

In large-scale plants, sludge is normally removed intermittently with the aid of mechanical sludge removal equipment. However, in smaller plants with low solid loading, sludge is removed manually.

In manually cleaned basins, the sludge is allowed to accumulate until it reduces settled water quality. High levels of sludge reduce the detention time and floc carries over to the filters. The basin is then dewatered (drained). Most of the sludge is removed by stationary or portable pumps and the remaining sludge is removed with squeegees and hoses. Basin floors are usually sloped towards a drain to help sludge removal. The frequency of shutdown for cleaning will vary from several months to a year or more, depending on source water quality.

Operating Procedure

From a water quality standpoint, filter effluent turbidity is a good indication of overall process performance. However, one must monitor the performance of each of the individual water treatment processes, including sedimentation, in order to anticipate quality or performance changes. Normal operating conditions are considered to be continuous within the operating ranges of the plant, while abnormal conditions are unusual or difficult to handle conditions.
In normal operation of the sedimentation process operator must monitor these items.

1. Turbidity of the water entering and leaving the sedimentation basin and temperature of the entering water are important factors. Turbidity of the entering water indicates the floc or solids loading on the sedimentation process. Turbidity of the water leaving the basin reveals the effectiveness or efficiency of the sedimentation process. Low levels of turbidity are desirable to minimize the floc loading on the filter.

2. Temperature of the water entering the sedimentation basin is important. As the water becomes colder, the particles will settle more slowly. To compensate for this change, the operator should perform jar tests and adjust the coagulant dosage to produce a heavier and thus a settling floc. Another possibility is to enforce longer detention times when water demand decreases.

Record Keeping

Accurate recording of the following items should be maintained.

1. Turbidity of the water entering and leaving the sedimentation basin and temperature of the entering water.
2. Process production inventory (amount of water processed and amount of sludge produced.
3. Process equipment performance (type of equipment, maintenance procedure performed, and equipment calibration)

Instruction No. 6-15: Operation Chart for Treatment Plant (Action: Manager and Operator)

Exhibit 6-19 summarizes the maintenance procedures for sedimentation control.

Exhibit 6-19
Summary of Routine Sedimentation Process Actions (Sedimentation Basin)

No.	Monitoring Indicators	Location	Frequency	Possible Operator Actions
1.	Monitor Process Performance and Evaluate Water Quality Conditions.			
	Turbidity Temperature	Influent/Effluent Influent	At least once every 8- hour shift. Occasionally .	1. Increase sampling frequency when process water quality variable. 2. Perform Jar Test. 3. Make necessary process change. a) Change coagulant dose. b) Adjust flash mixer mixing intensity. c) Change frequency of sludge removal. d) Change coagulant.
2.	Make visual observations			
	Floc settling characteristics Floc distribution Turbidity (clarity) of settled water	First half of basin inlet Launders of settled water conduit	At least once every 8- hour shift. At least once every 8- hour shift. .	1. Perform Jar Test. 2. Make necessary process change. a) Change coagulant dose. b) Adjust flash mixer mixing intensity. c) Change frequency of sludge removal. d) Change coagulant.
3.	Check sludge removal equipment			
	Noise, vibration, leakage, overheating	Various	Once every 8- hour shift.	1. Correct minor problems. 2. Notify others of major problems.
4.	Operate sludge removal equipment			
	Perform normal operations sequence Observe condition of sludge being removed	Sedimentation basin	Once per day to several days or more depending on process conditions. . .	1. Change frequency of operation. a) Change frequency of operation and/or pumping rate if sludge is too watery. b) Increase frequency of operation and/or pumping rate if sludge is too dense, bulk or clog discharge lines. c) Increase frequency of operation and/or pumping rate if sludge is septic.
5.	Inspect Facilities			
	Check sedimentation basins Check basin water over launder weirs	Various Various	Once every 8- hour shift. Once every 8- hour shift. Once every 8- hour shift. Occasionally. .	1Report abnormal condition. 2. Make flow change or adjust launder weirs. 3. Remove debris from basin water surface. a) Change coagulant dose. b) Adjust flash mixer mixing intensity.

No.	Monitoring Indicators	Location	Frequency	Possible Operator Actions
	Observe basin water surface	Various		c) Change frequency of sludge removal. d) Change coagulant.
	Check algae buildup on basin walls launders	Various		
	Observe condition of sludge being removed	Various		

Instruction No. 6-16: Operation Chart for Treatment Plant (Action: Manager and Operator)

Exhibit 6-20 shows the actions concerning the treatment plant operation.

Exhibit 6-20
Troubleshooting in Sedimentation Process

No.	Problems	Operator's actions	Possible process changes
1.	Water quality changes – source water		
	Turbidity Temperature Alkalinity pH Color	1. Perform necessary analysis to determine extent of change. 2. Evaluate overall process performance. 3. Perform Jar Test. 4. Make appropriate process change. 5. Increase frequency of process monitoring.	1. Adjust coagulant dosages. 2. Adjust flash mixer mixing intensity. 3.Change frequency of sludge removal (increase or decrease). 4.Increase alkalinity by adding lime, caustic soda o soda ash. 5. Change coagulant.
2.	Effluent quality changes – Flocculation process		
	Turbidity Alkalinity pH	1. Evaluate over all process performance. 2. Perform Jar Test. 3. Verify performance of coagulation and flocculation process. 4. Make appropriate process changes.	1. Adjust coagulant dosages. 2. Adjust flash mixer mixing intensity. 3. Adjust improperly working chemical feeder. 4. Change coagulant.
3.	Sedimentation basin changes		
	Floc settling Rising or floating sludge	1. Observe floc setting characteristics – dispersion, size and settling rate. 2. Evaluate overall process performance. 3. Perform Jar Test a. Assess floc size and settling rate. b. Assess quality of settled water(clarity and color) 4. Make appropriate process change.	1. Adjust coagulant dosages. 2. Adjust flash mixer mixing intensity. 3.Change frequency of sludge removal (increase or decrease). 4.Remove sludge from basin. 5. Remove broken sludge racks. 6. Change coagulant.
4.	Sedimentation process effluent quality changes		
	Turbidity Color	1. Evaluate overall process performance. 2. Perform Jar Test. 3. Verify performance of coagulation and flocculation process. 4. Make appropriate process change.	1.Change coagulant. 2. Adjust flash mixer mixing intensity. 3. Change frequency of sludge removal (increase or decrease). 4.Adjust coagulant dosages.

Note: All major problems should be reported to authorities and feedback duly followed up.

Startup and Shout Down Process

In the event of requirement for shut down or startup of processes on account of maintenance or a major equipment failure, proper procedures must be followed as per recommendations of the manufacturer of the plant and equipment. The procedures are given below.

Startup Procedure

1. Check operational status and mode of operation of equipment and physical facilities.
   - Check that basin valves are closed. Check that basin isolation gates are closed.

- Check that launder weir plates are set at equal elevations.
- Check to ensure that all trash, debris and tools have been removed from basin

2. Test sludge removal equipment.
   - Check that mechanical equipment is properly lubricated and ready for operation.
   - Observe operation of sludge removal equipment.
3. Fill sedimentation basin with water.
   - Observe proper depth of water in basin.
   - Remove floating debris from basin water surface.
4. Start sample pumps.
5. Perform water quality analyses.
6. Operate sludge removal equipment. Be sure that all valves are in the proper position.

Shut down Procedures

1. Stop flow to sedimentation basin. Install basin isolation gates.
2. Turn off sample pump.
3. Turn off sludge removal equipment.
4. Lock out electrical switches and equipment.
5. Dewater basin if necessary.
   - Be sure that the water level is not high enough to float the empty basin.
   - Open basin drain valves.

B. Grease and lubricate all gears, sprockets and mechanical moving parts which have been submerged immediately following dewatering to avoid seize up.

Filtration (Rapid Sand Filter)

The purpose of filtration is the removal of particulate impurities and floc from the water being treated. In this regard, the filtration process is the final step in the solids removal process which usually includes the pretreatment processes of coagulation, flocculation and sedimentation.

Operation

Filter Operation: A filter is usually operated until just before clogging or breakthrough occurs or a specified time period has passed, generally 24 hours.

Backwashing: After a filter clogs or breakthrough occurs or a specified time has passed, the filtration process is stopped and the filter is taken out of service for cleaning or backwashing.

Surface Wash: In order to produce optimum cleaning of the filter media during backwashing and to prevent mud balls, surface wash (supplemental scouring) is usually required. Surface wash systems provide additional scrubbing action to remove attached floc and other suspended solids from the filter media.

Operation Procedure

The filter influent and effluent turbidities should be closely watched with a turbid meter. Filter Influent turbidity levels (settled turbidity) can be checked periodically at the filter or from the laboratory sample tap. However, the filter effluent turbidity is best monitored and recorded continuously by an online turbid meter.

Important process activities and Precautions are as follows.

1. Monitoring process performance is an ongoing activity. Any treatment process changes or other problems that might affect filtered water quality, such as a chemical feed system failure should be carefully observed.

2. Measuring head loss built up in the filter media gives a good indication of how well the solids removal process is performing. The total designed head loss from the filter influent to the effluent in a gravity filter is usually about 3 meters. At the beginning of the filtration cycle the actual measured head loss due to clean media and other hydraulic losses is about 0.9 m. This permits an additional head loss of about 2.1 m due to solids accumulating in the filter.

3. The rate of head loss build-up is an important indication of process performance. Sudden increase in head loss might be an indication of surface sealing of the filter media (lack of depth penetration). Early detection of this condition permits making appropriate process changes such as adjusting the chemical filter aid feed rate or adjusting the filtration rate.

4. Monitoring of filter turbidity on a continuous basis with an on-line turbid meter is highly recommended. This provides continuous feedback on the performance of the filtration process. In most instances, it is desirable to cut off (terminate) filter at a predetermined effluent turbidity level.

5. In the normal operation of the filter process, it is best to calculate when the filter cycle will be completed on the basis of the following guidelines.

    - Head loss.
    - Effluent turbidity level.
    - Elapsed run time.
    - A predetermined value is established for each guideline as a cutoff point for filter operation. When any of these levels is reached, the filter is removed from service and backwashed.

6. At least once a year one must examine the filter media and evaluate its overall condition. Measure the filter media thickness for an indication of media loss during the backwashing process. Measure mud ball accumulation in the filter media to evaluate the effectiveness of the overall backwashing operation.

7. Routinely observe the backwash process to qualitatively assess process performance. Watch for media boils (uneven flow distribution) during backwashing, media carry over into the wash water trough, and clarity of the waste wash-water near the end of the backwash cycle.

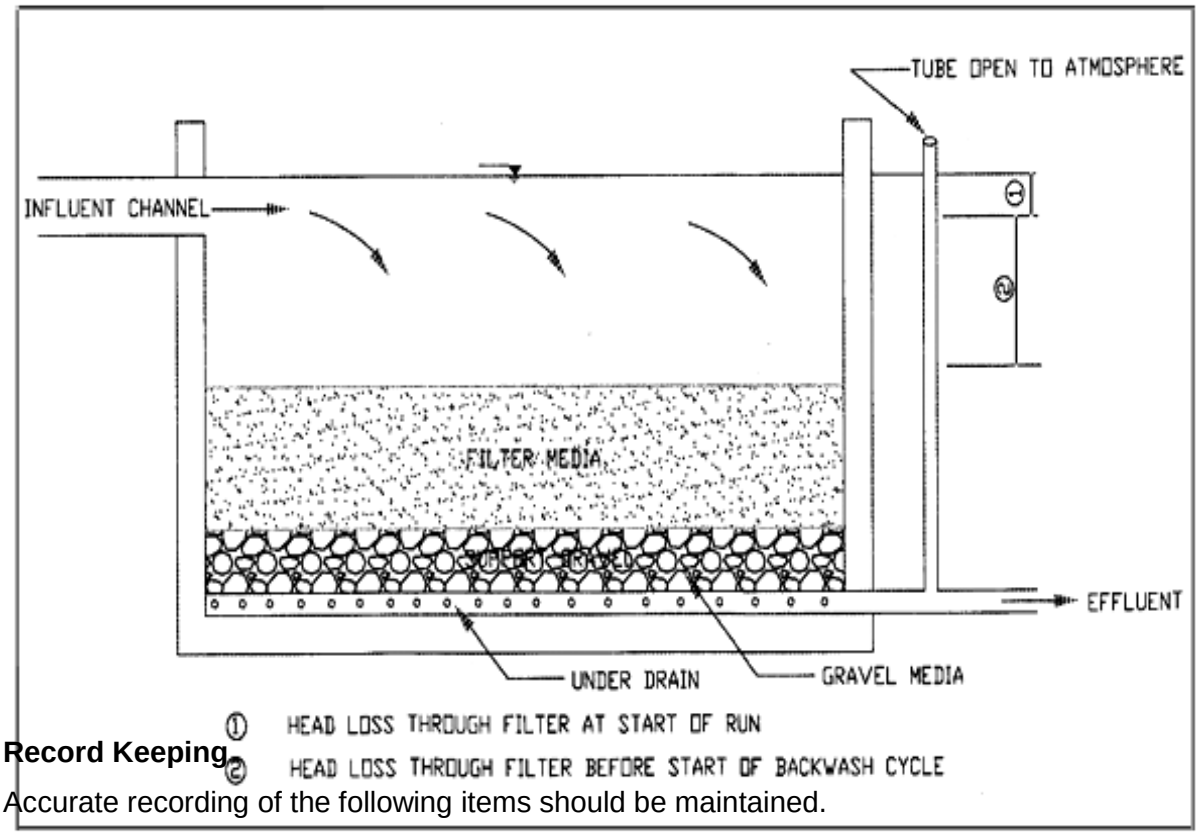
8. Upon completion of the backwash cycle, observe the condition of the media surface and check for filter sidewall or media surface cracks. Correct or report the abnormal equipment conditions to the appropriate maintenance personnel.

9. Never bump up a filter to avoid backwashing. Bumping is the act of opening the backwash valve during the course of a filter run to dislodge the trapped solids and increase the length of filter run. This is not a good practice.

10. Shortened filter runs can occur because of air bound filters. Air binding will occur more frequently when large head losses are allowed to develop in the filter. Precautions should be taken to minimize air binding to avoid damage to the filter media.

Exhibit 6-21 illustrates the filtration process.

Exhibit 6-21
Head Loss in Filtration Process



Record Keeping

Accurate recording of the following items should be maintained.

1 Process water quality (turbidity and color);
2 Process operation (filters in service, filtration rates, loss of head, length of filter runs, frequency of backwash rates, and unit filter run volume);
3 Process water production (water processed, amount of backwash water used, and chemicals used);
4 Percentage of water production used to backwash filters; and
5 Equipment performance (types of equipment in operation, equipment adjustments, maintenance procedures performed, and equipment calibration).

A summary of routine filtration process action is given in **Exhibit 6-22**.

Instruction No. 6-17: Operation Chart for Treatment Plant (Action: Manager and Operator)

Exhibit 6-22
Summary of Routine Filtration Process Actions (Sedimentation Basin)

No.	Monitoring Indicators	Location	Frequency	Possible Operator Actions
1.	Monitor Process Performance and Evaluate Water Quality Conditions.			

No.	Monitoring Indicators	Location	Frequency	Possible Operator Actions
	Turbidity Color Head loss	Influent/Effluent Influent /Effluent	At least once every 8- hour shift. At least once every 8- hour shift At least two times every 8- hour shift.	1. Increase sampling frequency when process water quality variable. 2. Perform Jar Test. 3. Make necessary process change. a) Change coagulant dose. b) Adjust flash mixer mixing intensity. c) Change filtration rate. d) Change coagulant. e) Back wash filter
2.	Operate filter and backwash			
	Put filter into service Change filtration rate Remove filter from service Backwash filter Change backwash rate	Filter module	Depends on process condition	See operating procedure.
3.	Check filter media condition			
	Media depth evaluation Media cleanliness Cracks or shrinkage	Filter module	At least monthly.	1. Replace lost filter media. 2. Change backwash procedure. 3. Change chemical coagulants.
4.	Make visual observation of backwash operation			
	Check for media boils and media expansion Check for media carry over into backwash trough Observe clarity of wastewater	Filter module	At least once per day or whenever backwashing occurs.	1. Make necessary process change. a) Change backwash rate. b) Change backwash cycle time. c) Adjust surface wash rate or cycle time. d) Inspect filter media or support gravel for disturbance.
5.	Check filtration process and backwash equipment condition			
	Noise, vibration, leakage, overheating	Various	Once every 8-hour shift. .	1. Correct minor problems.
6.	Inspect facilities			

No.	Monitoring Indicators	Location	Frequency	Possible Operator Actions
	Check physical facilities an alga on sidewalls and troughs.	Various	Once a day .	1. Remove debris from filter media surface. 2. Adjust chlorine dose to control algae.

Instruction No. 6-18: Operation Chart for Treatment Plant (Action: Manager and Operator)

Exhibit 6-23 summarizes the filtration process.

Exhibit 6-23
Troubles Shooting in Filtration Process

No.	Problems	Operator's Actions	Possible Process Changes
1.	Water quality changes – source water		
	Turbidity Temperature Alkalinity pH Color Chlorine demand	1. Perform necessary analysis to determine extent of change. 2. Evaluate overall process performance. 3. Perform Jar Test. 4) Make appropriate process change. 5. Increase frequency of process monitoring. 6. Verify response to process change. 7. Add lime or caustic soda if alkalinity is low	1. Adjust coagulant dosages. 2. Adjust flash mixer mixing intensity. 3. Change frequency of sludge removal (increase or decrease). 4.Adjust backwash cycle rate/duration. 5.Change filtration rate. 6. Start filter aid feed. 7. Change coagulant.
2.	Effluent quality changes – Sedimentation process.		
	Turbidity Floc carryover	1. Evaluate over all process performance. 2. Perform Jar Test. 3. Make appropriate process changes.	Same as source water quality changes.
3.	Filtration process changes and problems.		

No.	Problems	Operator's Actions	Possible Process Changes
	Head loss increase Short filter run Media surface sealing mud balls Filter media cracks, shrinkage. Media boils Media loss Filter not clean	1. Evaluate overall process performance. 2. Perform Jar Test 3. Make appropriate process change.	1. Adjust coagulant dosages. 2. Adjust flash mixer mixing intensity. 3. Change frequency of sludge removal (increase or decrease). 4.Adjust backwash cycle rate and duration. 5.Manually remove mud balls. 6.Change filtration rate. 7. Decrease or terminate filter aid 8. Replenish lost media. 9. Clear under drain openings of media, corrosion or chemical deposit 10. Change coagulant
4.	Filter effluent quality changes.		
	Turbidity Color pH Chlorine	1. Evaluate overall process performance. 2. Perform Jar Test. 3.Verify process performance. a) Coagulation and flocculation. b) Sedimentation process. c) Filtration process. 4. Make appropriate process change.	1. Adjust coagulant dose. 2. Adjust flash mixer mixing intensity. 3. Change frequency of sludge removal (increase or decrease). 4.Start filter aid feed. 5. Change chlorine dosage 6. Change coagulant 7. Decrease filtration rate

Note: All major problems should be reported to authorities and feedback duly followed up.

Start Up and Shout Down Process

Most plants keep all filters online except for backwash and in service except for maintenance. Filters are routinely taken offline for backwashing when the media becomes clogged with particulates, turbidity breakthrough occurs, or demands for water are reduced. The procedures, in general, are given below.

Filter Check out Procedure

1. Check operational status of filter.
2. Be sure that the filter media and wash water troughs are clean of all debris such as leaves, twigs, and tools.
3. Check and be sure that all access covers and walkway gratings are in place.
4. Make sure that the process monitoring equipment such as head loss and turbidity systems are operational.
5. Check the source of backwash to ensure that it is ready to go.

Backwash Procedures

Filters should be washed before placing them into service. The surface wash system should be activated just before the backwash cycle starts to aid in removing and breaking up solids on the filter media and to prevent the development of mud balls. The surface wash system should be stopped before completing the backwash cycle to permit proper settling of the filter media.

Filter wash should begin slowly for about one minute to permit purging (removing) of entrapped air from the filter media and also to provide uniform expansion of the filter bed. After this period, the full backwash rate can be applied.

Sufficient time should be allowed for cleaning of the filter media. Usually when the backwash water coming up through the filter becomes clear, the media is washed. This generally takes from 3 to 8 minutes. If flooding of wash water troughs or carryover of filter media is a problem, the backwash rate must be reduced.

Opening and closing of valve procedures are listed below.

1. Log length of filter run since last backwash.
2. Close filter influent valve.
3. Open drain valve.
4. Close filter effluent valve.
5. Start surface wash system.
6. Slowly start backwash system.
7. Observe filter during washing process.
8. When wash water from filter becomes clear (filter media is clean), close surface wash system Valve.
9. Slowly turn off backwash system.
10. Close drain valve.
11. Log length of wash and the quantity of water used to clean filter.

Filter Startup Procedure

1. Start filter.
2. Slowly open influent valve.
3. When proper elevation of water is reached on top of filter, filter effluent valve should be gradually opened. This effluent control valve should be adjusted itself to maintain a constant level of water over the filter media.
4. Waste some of the initial filtered water if such a provision exists.
5. Perform turbidity analysis of filtered water and make process adjustments as necessary.

Filter Shutdown Procedures

1. Remove filter from service by closing influent valve and effluent valve.
2. Backwash filter.
3. If filter is to be out of service for a prolonged period, drain water from filter to avoid algal growth.
4. Note status of filter in operations log.

Preventive Maintenance Procedures

Preventive maintenance programs are to assure the continued satisfactory operation of treatment plant facilities by reducing the frequency of breakdown failures. Routine maintenance functions include the following items.

1. Keeping electric motors free of dirt, moisture and pests (rodents and birds).
2. Assuming good ventilation (air circulation) in equipment work areas.
3. Checking pumps and motors for leaks, unusual noise and vibrations or overheating.

4. Maintaining proper lubrication and oil levels.
5. Inspecting for alignment of shafts and couplings.
6. Checking bearings for overheating and proper lubrication.
7. Checking the proper valve operation (leakage or jamming).
8. Checking automatic control systems for proper operation.
9. Checking air/vacuum relief systems for proper functioning, dirt and moisture.
10. Verifying correct operation of filters and backwashing cycles by observation.
11. Inspecting filter media conditions (look for algae and mud balls and examine gravel and media for proper gradation).
12. Inspecting filter under drain system (be sure that the under-drain openings are not becoming clogged due to media, corrosion or chemical deposits).

6.4.5 Summary of O&M Activities

Summary of O&M activities and sample logbook formats to record daily operation and routine maintenance of different components of piped water supply system are included in this section. The summary table of O&M activities contains a brief description of activities, frequency, responsible staff, and reference to the relevant clause for each activity. Sample formats have been developed to record daily operation and routine maintenance in log books.

The summarized activity schedule will enable the water supply staff to review at a glance if the required tasks have been performed as per activity schedule. It will also help management to evaluate the efficiency of the system.

The summarized activity schedule is shown in **Exhibit 6-24** below.

Exhibit 6-24
Summary of O&M Activities

No.	Water Supply Unit	O & M Activity	Frequency of Activity	Water Supply Staff Responsible for the Activity	Reference & Instruction No.	Logbook Entry Required=R Not Required= NR
1	Production well and pumping equipment	▪ Operation of submersible pump	Daily	Operator	7.4.1 Inst. 7-1	R
		▪ Maintenance of PTW, PH, Valves and fittings	Monthly	Manager & operator	7.4.1 Inst. 7-2	R
		▪ Maintenance of Electrical Equipment	Monthly/ Yearly	Manager & operator	7.4.1 Inst. 7-3	R
		▪ Monitoring of PTW	Quarterly	Manager & operator	7.4.1 Inst. 7-4	R
		▪ Trouble shooting of Submersible Pump	As required	Manager & operator	7.4.1 Inst. 7-5	R
		▪ Trouble shooting of electrical equipment & wiring	As required	Manager & operator	7.4.1 Inst. 7-6	R

No.	Water Supply Unit	O & M Activity	Frequency of Activity	Water Supply Staff Responsible for the Activity	Reference & Instruction No.	Logbook Entry Required=R Not Required= NR
2	Overhead tank	Operation of OHT	Daily	Operator	7.4.2 Inst. 7-7	NR
		Routine inspection of OHT	Quarterly	Manager & Operator	7.4.2 Inst. 7-8	R
		Cleaning of OHT	Yearly	Manager & Operator.	7.4.2 Inst. 7-9	R
3	Distribution pipeline	Routine inspection & maintenance of pipelines and fittings	Monthly/ yearly	Manager & Plumber	7.4.2 Inst. 7-10	R
		Repairing of burst pipes	As required	Plumber	7.4.2 Inst. 7-11	R
		Monitoring of water pressure	Monthly	Manager & Plumber	7.4.2 Inst. 7-11	R
		Water quality monitoring	1-6 months	Manager	7.4.2 Inst. 7-12	R
4	Service Connection	Routine inspection & maintenance of service connections	Quarterly	Manager & Plumber	7.4.3 Inst. 7-13	R
5	Treatment Plant	Trouble shooting in coagulation and flocculation process	As required	Manager & Plant Operator	7.4.4 Inst. 7-14	R
		Routine sedimentation process actions	Once in 8-hour shift to once per day	Manager & Plant Operator	7.4.4 Inst. 4-15	R
		Trouble shooting in sedimentation process	As required	Manager & Plant Operator	7.4.4 Inst. 7-16	R
		Routine filtration process actions	At least once to two times in 8-hour	Manager & Plant Operator	7.4.4 Inst. 4-17	R
		Trouble shooting in filtration process	As required	Manager & Plant Operator	7.4.4 Inst. 4-18	R

6.4.6 Proposed Water Quality Testing Facility

The Project recommends developing a water quality testing facility at ULB level with a mini lab or at least with a set of potable field test kits. Since DPHE has water a testing laboratory in each old district level and some mini lab in new district level, laboratory test requirements could be met up there. A list of potable field test kits for the ULBs is given below.

1. Arsenic test kit

2. Iron test kit
3. Manganese test kit
4. pH meter (digital)
5. Residual chlorine meter (digital)
6. Turbidity meter (digital)
7. Electro –conductivity (EC) meter (digital)
8. E. coli count potable kit.

DPHE water testing laboratory facilities with location are given in **Exhibit 6-25.**

Exhibit 6-25
DPHE Laboratory Facility for Water Quality Testing.

No.	DPHE Laboratory	Laboratory Location
1	Central laboratory, Dhaka	36-37 Mohakhali Wireless Gate, Mohakhali C/A, Dhaka-1212 Phone: 9861767
2	DPHE laboratory, Mymensingh	Naomahal Water Tank, Mymensingh; Phone: 091-55489
3	DPHE laboratory, Comilla	Ranirbazar, Comilla Ph. 081-76167
4	DPHE laboratory, Khulna	Khan Jahan Ali Road, Rupsha, Khulna; Phone: 041-721348
5	DPHE laboratory, Rajshahi	Laxmipur, Rajshahi Phone: 0721-771072
6	DPHE laboratory, Barisal	C&B Road, Kazipara, Barisal; Phone: 0431-2174346
7	DPHE laboratory, Jhenaidah	DPHE Divisional Office, Jhenaidah; Phone: 0451-62357
8	DPHE laboratory, Rangpur	Radhaballav, Rangpur Phone: 0521-62907
9	DPHE laboratory, Bogra	Saizgari, Bogra Phone: 051-66408
10	DPHE laboratory, Sylhet	Topkhana road, Sylhet Phone: 0821-716863
11	DPHE laboratory, Noakhali	Maizdi Court, Noakhali Phone: 0321-61497
12	DPHE laboratory, Tongi	DPHE Tongi Store, Mill Gate, Tongi; Phone: 02-9801328
13	DPHE Mini Laboratories at Dist level	Panchagarh, Thakurgaon, Lalmonirhat, Nilphamary, Joypurhat, Naogaon, Satkhira, Meherpur, Magura, Narail, Bhola, Barguna, Shariatpur, Jhalakathi, Manikgonj, Sherpur, Netrakona & Moulavibazar

CHAPTER 7

COLLECTING AND TRANSPORTING SOLID WASTE

7.1 Introduction

Several policy documents of the government of Bangladesh such as Local Government Act 2009, 7th Five Year Plan, Perspective Plan-Vision 2021, Poverty Reduction Strategy Paper, and National Strategy for Safe Water and Sanitation 2011 highlight the importance of waste management. Solid Waste Management (SWM) is one of the most intractable problems causing severe degradation of urban environments of the developing countries. The service absorbs a considerable proportion of municipal effort, budget and work force. SWM services have consistently failed to keep pace with the vast amount of solid waste produced in the ULBs. The developing counties spend 20-40% of their municipal revenues, employing 3-6 workers per 1000 of population on SWM. Many cities face serious environmental degradation and health risks due to uncollected domestic refuse on streets and in public areas, clogged urban drainage systems by indiscriminately dumped wastes and by contamination of water resources near uncontrolled dumping sites. The waste collection and transportation efficiency governs to a large extent, the efficiency of SWM.

Waste Collection includes various activities related to picking waste at different sources, loading the waste onto collection vehicles, and unloading this waste from collection vehicles at communal collection points, processing places, transfer stations, and final disposal sites.

Choosing the most appropriate waste collection system together with other determining factors concerning the overall efficiency and financial performance of SWM are crucial for ULBs of Bangladesh. ULB staff are encouraged to visit the Waste Management Departments of Dhaka North and South City Corporations to observe good practices and systems developed with JICA technical cooperation to get ideas for managing collection and transportation.

7.1.1 Existing Waste Collection Problem and Development Need

Rapid urbanization of Bangladesh, particularly in ULBs, and their rapidly increasing population have created much pressure on the urban services. The existing services are inadequate to serve the inhabitants and solid waste management is one of the major problems faced by the authorities and the inhabitants. The existing officials, working staff, cleaners, drivers, vehicles and other operational logistics are not sufficient to deal with waste generated each day in a ULB. The ULBs need to understand how effectively and efficiently the existing recourses are working in addition to understanding the deficiencies and their reasons. The ULBs staff working in SWM should have clear understanding on SWM performance indicators related to collection and transportation, system design techniques, system assessment tools, resource mobilization strategies, and stakeholder participation. Otherwise, it will be difficult to improve the waste collection and transportation management and its planning.

Unplanned and inadequate collection of solid wastes contributes greatly to an unhealthy environment. It is estimated that 60-80% of the total cost of SWM is spent on the collection phase alone in developing countries. The MGSP ULBs are no exception. Therefore, it is very important to analyze how efficiently and effectively collection systems are working with the aim of improving efficiency, reducing operational costs, and ensuring better use of public taxes.

Lack of community participation, inefficient primary collection service, insufficient secondary collection equipment, and deficiency of staff for vehicle management are associated with

poor waste collection service. ULBs need to overcome such conditions to ensure better SWM.

The Seventh Five Year Plan (2016-20) mentions the need to improve waste collection service and it has set the benchmark indication as “Percentage of urban solid waste regularly collected”. The target value is set as 65.5%, 68%, 70.2%, 72.6%, and 75% corresponding to 2016, 2017, 2018, 2019 and 2020, respectively. ULBs should keep these targets in mind as development requirements when they design and improve their collection capacity.

7.2 Institutional Arrangement for Efficient Waste Collection and Transport Operations

One of the basic requirement or precondition to ensure an efficient waste collection management system is to have sufficient staff and to allocate budget for procuring, repairing, and maintaining vehicles and other equipment. Changing the traditional mindset is also very important because municipalities are not only responsible for street sweeping and cleaners’ management but also for SWM master planning, system designing, and modernizing.

ULBs must consider their capacity development needs and strategies. All staff, engineers, and officers must take initiatives for SWM improvement rather than waiting for top level management decisions. ULB development should consider the legal, technical, and governance aspects. SWM capacity development should also review the institutional, organizational, and social levels.

ULBs must have to have a solid waste management cell or waste management department that is equipped with following staff.

1. Chief Waste Management Officer / Conservancy Officer
2. Superintending Engineer (Civil /Mechanical)
3. Executive Engineer (Civil and Mechanical)
4. Assistant Engineer (Civil and Mechanical)
5. Sub- Assistant Engineer (Civil and Mechanical)
6. Waste Management Inspector or Conservancy Inspector
7. Waste Management Officer

Collection and transportation management is a key element for ULB SWM and they are directly connected with community participation, social mobilization, primary collection management, dustbins and container management, and workshop management for vehicle maintenance.

All ULBs should have a workshop for SWM the equipment’s routine and periodic maintenance. A good workshop is should include mechanics. Spare parts should be available so that vehicles get immediate service to ensure daily waste collection and transportation service. The workshop unit may consist of AE, SAE, head mechanic, several assistant mechanics, storekeeper, and MLSS. Depending on the work volume or expenses the SE or EE may be assigned for look after workshop and procuring waste collection equipment.

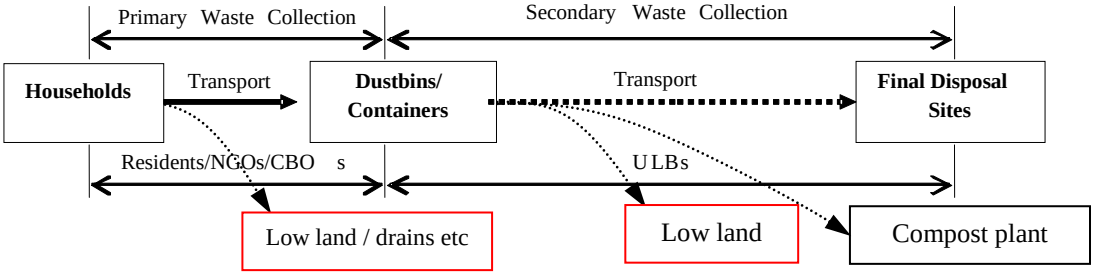
7.3 Classification of Collection System

Many techniques can be used to collect and transport waste from point of generation to communal collection points and transfer stations and to the final disposal site. Transport services include hand carts, rickshaw vans, auto rickshaws, compactor trucks, container carriers, and open trucks. Solid waste collection systems may be classified from several points of view such as the mode of operation, the equipment used, and types of waste collection or based on ULBs own naming. Based on the stages of collection, the collection system is generally categorized as primary collection and secondary collection systems. They can also be categorized as communal, block, curbside, alley, and door-to-door collections. The collection system may vary from one ULB to another based on the traditional pattern of service delivery. However, primary collection and secondary collection are common in all ULBs though their patterns might differ slightly.

7.3.1 Primary Collection and Secondary Collection

Typically, waste collection consists of two parts, namely primary collection and secondary collection as illustrated in **Exhibit 7-1**. ULBs are responsible for secondary waste collection to remove waste from its dustbins and containers, and transport the waste to the final disposal sites. Residents are responsible for bringing their waste to ULB's waste collection points where dustbins or containers are located. NGOs, CBOs, and the private sector can provide primary collection services to collect waste door-to-door and transport the waste to dustbins or other containers. They sometimes convey it to vacant lands by rickshaw vans. At present, NGOs, CBOs, and the private sector usually initiate primary collection services in many ULBs.

Exhibit 7-1
Typical Waste Management System of ULB



7.3.2 Primary Collection Management

Primary collection is the first stage of for collecting solid waste from or near the source of generation by external stakeholders. This involves collecting solid waste from the source of generation and transport the waste to the final disposal site. But it often involves transportation to communal collection bins or points as well as to processing or transfer stations. ULBs need to have clear data base of all primary collection service providers who are mostly CBOs, NGOs, and neighborhood associations.

Primary collection by rickshaw van

Primary collection is a labor-intensive work that uses rickshaw vans. They are usually manned with one van driver and one to two helpers with hand trolleys. They go to each house, collect waste from residents, and put the waste into the rickshaw van. In some areas, residents bring their waste to rickshaw vans using buckets or bags. After collecting waste

from the houses, the rickshaw drivers and helpers dispose the waste in the ULB dustbins, containers, trucks, or at vacant lands.

Container receives waste from primary collection rickshaw van rickshaw van

ULBs should have regular meetings with primary waste collection service providers to improve the quality of collection and reduce open dumping. It is necessary to have community meetings with the presence of community, waste collector (CBO or NGO) and ULB staff frequently. It should be keep in mind the better the primary collection, the cleaner the community areas will be.

Only primary collection may not ensure the cleanness of the locality because of waste generation by floating people and pedestrians. Therefore, street bins are necessary. The example of street bins of Dhaka and Sylhet City Corporations are shown below for the reference of all ULBs.

Secondary Collection

Street bins of Sylhet and Dhaka

Secondary collection is the collection of waste from communal bins, storage points, or transfer stations, and transporting it to the final disposal site. ULBs typically use open trucks or container carriers using container box (demountable container). A ULB needs a proper monitoring and allocation system of waste collection logistics such as a distribution plan for trucks and container boxes to ensure maximum coverage.

Hand Trolley for Primary Collection

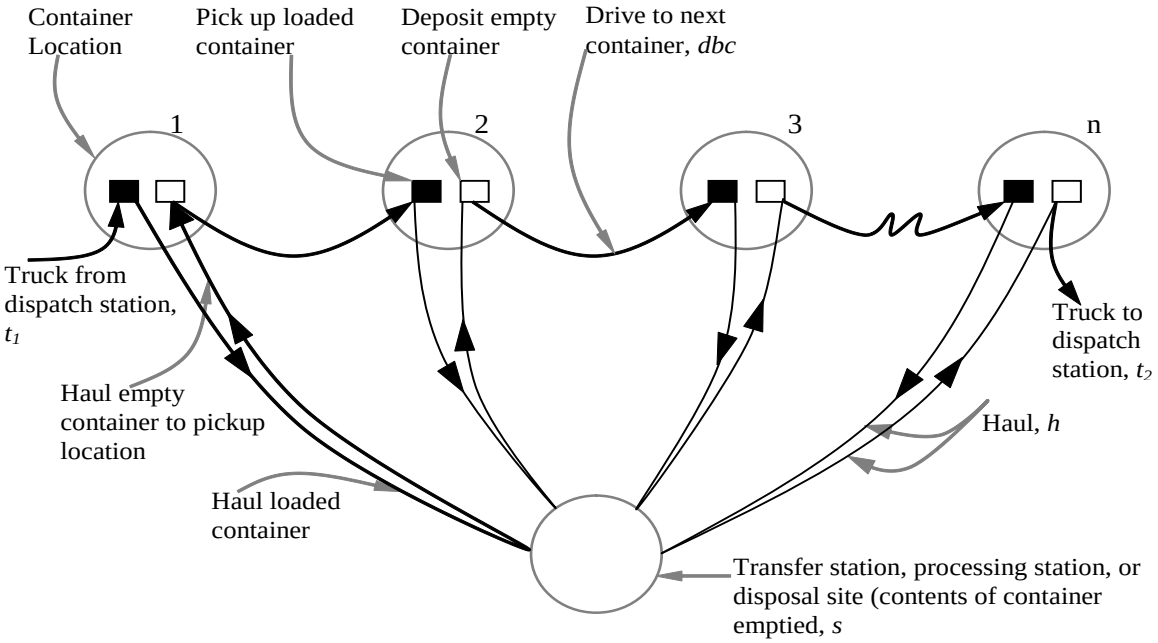
Secondary collection can be differ based on the type of vehicles or collection pattern. An open truck or dump truck based collection is common in Bangladeshi ULBs. However, there are few ULBs that operate container based collection system.

The most common container based collection systems are the hauled stationary container system and stationary container system. The hauled container system is common in some Bangladeshi ULBs. In this collection system, the containers used for the storing wastes are hauled to the processing, transfer, or disposal site to be emptied and returned to either their original location or some other location. See **Exhibit 7-2.**

Secondary collection truck

Exhibit 7-2

Hauled Container System of Waste Collection



Aiming to improve system's performance efficiency the time fractions of the system should be checked carefully and regularly by ULB conservancy and engineering staff. **Exhibit 7-3** shows general monitoring times. The labor productivity can be increased by monitoring the following parameters.

Exhibit 7-3
Time for Secondary Collection

Term	ULB staff should check and monitor the following components
Pickup time, P_{hcs}	The time spent picking up the loaded container, time required to redeposit the containers after their contents have been emptied, and the time spent driving to the next container.
Haul time, h	The time required to reach the disposal site starting after a container whose contents are to be emptied, has been loaded on truck, plus the time leaving after disposal site until the truck arrives at the location where empty container is to be redeposit. Time spent at the disposal site is not included.

Term	ULB staff should check and monitor the following components
At-site time, s	The time spent at the disposal site, including the time spent waiting to unload as well as the time spent unloading.
Off-route factor, W	All the time spent on the activities that are non-productive from the point of view of the overall collection operation. Necessary off-route time includes the following items. 1. time spent checking in and out in the morning and at the end of the day; 2. time spent driving to the first pickup point and/or from the location of the last pickup point to the dispatch station at the end of the day; 3. time lost due to unavoidable congestion; 4. time spent on equipment repairs and maintenance; and 5. Unnecessary off-route time includes time spent for lunch in excess of the stated lunch period and time spent on the unauthorized coffee breaks, talking to friends, etc.

7.4 Harmonizing Primary and Secondary Collection

To avoid mismatching of waste discharge and collection time or place, a common understanding among the community people, primary waste collector or rickshaw van driver, and ULB is necessary.

The time, place, and method of waste shifting from primary to secondary collection phase is still a big challenge in many cities including Dhaka, Chittagong, and cities of other developing counties. However, the local situation, culture, management should always think about efficient harmonization or coordination between primary and secondary collection. ULBs my follow secondary transfer stations of Dhaka North and South City Corporations.

Secondary transfer station using lifting system of primary collection rickshaw vans

Proper harmonization can reduce scattering of waste in and around the ULB. Ward level community meetings or more grass-roots level community meetings on collection management can help solve the problem. However, all the meetings at the community, ward level or headquarters levels should include three important entities 1. community people or community leaders, 2. primary waste collection service providers such as CBOs or NGO and 3. ULB's waste collection and transportation staff along with field level inspectors and supervisors.

Secondary transfer station using traditional system of primary collection rickshaw van unloading and then loading to

7.5 Resource Mobilization

ULBs are suffering from the scarcity of financial and technical resources to meet the service demand of the citizens. There is a huge amount of waste generated every day. But accordingly, ULBs cannot

provide operational logistics and staff. Operation logistics includes primary collection rickshaw vans, open trucks, dump trucks, heavy equipment, and hand trolleys. Scarcity of staff means limited numbers of engineers, conservancy inspectors, supervisors, and cleaners. To overcome this adverse situation, ULB staff need to cooperate with various development partners. This could be done through LGED and LGD. There are many local and international NGOs in ULBs, ULB staff should establish business relationship them and try to include waste management with their projects and programs. For example, where an NGO is working on slum improvement, ULB staff can suggest including waste management in the slums where NGOs are present. There are many projects of various bilateral development partners, international cooperation agencies, commissions, and the United Nations. ULBs should try to link waste management with these programs or projects.

7.6 Examples of Waste Collection Equipment

There are several types of waste collection equipment being used in Bangladeshi ULBs. MGSP should determine the equipment in line with original management processes or ULB capacity. Examples waste collection equipment is summarized in **Exhibit 7-4.** ULBs should try to procure and promote them as much as possible.

Exhibit 7-4
Examples of Operational Equipment for Municipal SWM

Waste Management Equipment / Facility	Picture
A household bin for wet (e.g., organic) and dry (i.e., inorganic) waste. Separation of waste at source to be promoted with various awareness raising and environmental education programs. NGO support is advised.	
Hand trolleys for street sweeping. The wheels are easily breakable unless carefully selected quality cast iron *(dhalailoha)* wheel with firmly pasted rubber at top	

Waste Management Equipment / Facility	Picture
Primary Collection Rickshaw Van with volumetric capacity about 1 m^3.To avoid frequent repair, double rims and high quality tires are suggested. GI sheets of the box should have adequate thickness of about 1 mm.	
Dustbins. ULBs should allocate open trucks to cover all the dustbins every day. Dustbin should be plastered and painted periodically to maintain a decent living environment. Street sweepers should be instructed to keep the dustbins neat and organized without any scattering of waste.	
Open trucks should cover all the dustbins every day and all accumulated waste in the communities (e.g., illegal dumping points, accumulated waste by the municipal cleaners).	

Waste Management Equipment / Facility	Picture
Compactor Truck. It is one of the cleanest systems of waste collection but currently not common in ULBs. Only DNCC, DSCC, and Chittagong CC have compactor trucks. ULBs are encouraged to promote compactor truck based waste collection systems.	
Tire dozer. Tire dozers and dump trucks should work together to clear uncollected waste or long time uncollected open dumping points. Typically, several dump trucks should be assigned for each tire dozer.	

7.7 Operational and Management Plan for Collection System

An operational and management plan for waste collection and transport is important for the ULBs so they are prepared for any unforeseen event. ULB SWM personnel should have a clear data base of existing vehicles and their projected operation life. ULBs should be able to anticipate the existing and future several yearly collection volumes from the plan. For example, assume a ULB has 40 collection trucks and all are of 3-ton capacity. If all vehicles have to make 2 trips per day and after 6 months 5 vehicles will be off route, 10 new vehicles will be procured of 5-ton capacities. So, this projection can be made because the existing collection capacity is 40x3x 2 =240 ton/day. After 6 months, the capacity with existing vehicles will be 35x3x2 =210 ton/day and 10 x 5 x 2 = 100 ton/day additional capacity will be added for new vehicles. Therefore, the total capacity will be 100+210 = 310 ton/day. However, ULBs should keep some vehicles as backups for emergency duties.

ULBs staff working in SWM should not understate its urban growth rate or population growth rate so that the future waste amount can be predicted. Accordingly, future collection rates should be set (e.g., 60%, 70% collection rates should apply for 2017 and 2018, respectively).

ULBs should have strong relationships or partnerships with other organizations working in the same ULB such as the Development Authority, Public Works Department, department of Environment, etc. It is very urgent for system planning and helpful for solving many problems

such finding lands for transfer stations, ward level SWM office construction, or landfill area selection.

7.8 Community SWM

7.8.1 Concept of Community SWM

The idea of community SWM is decentralization of SWM and sharing the roles of SWM among the stakeholders. The main concept is the community taking responsibility in managing SWM of the community area. Community SWM is locally led and based participatory SWM. The notion is that the community takes leadership or initiatives as an important pillar of success of SWM system or service.

Illegal dumping in a body of water

Though the ULB, CBOs, NGOs and communities are working to improve the SWM. However, the following three problems are still persistent in all the ULBs.

1. Dumping of solid waste in open spaces, roads, drains, and canals causing water logging;
2. Scattering of waste around containers and/or dustbins; and
3. Mixing of various types of wastes together (e.g., construction waste, hazardous waste).

These three problems are hindering the well-functioning of urban drainage systems as well as intensifying water logging and urban flooding in the ULBs. To solve the problems, it is essential that ULBs, NGOs, and CBOs collaborate with community people and primary collection service providers (PCSP) to develop a community SWM system. They can establish a mechanism for promoting participation of community people in SWM and to deal with the following key issues:

1. How to increase people's awareness and cooperation in SWM;
2. How to improve the secondary collection;
3. How to encourage primary collection service providers to make their activity more environmental friendly;
4. How to expand the coverage of primary collection service, especially in slum areas, small shops and congested areas;

Water logging due to blocked drains with solid waste

5. How to make good coordination among ULB, primary collection service providers, and citizens and
6. How to cooperate and collaborate with waste pickers.

7.8.2 Objectives of Community SWM

Community SWM aims at attainingimproved SWM by the public in good coordination with SWM services by ULBs and PCSP. The ULBs should be involved in the following activities to achieve the objective of the community SWM.

1. To empower community people to participate in the process of planning and taking actions to improve SWM;
2. To improve quality and efficiency of primary collection in well-coordinated and transparent conditions;
3. To expand service coverage of primary collection including small shops, slum areas, and congested areas with narrow roads;
4. To raise people's awareness of SWM and urban drainage in their community; and
5. To develop good coordination among ULB primary collection service providers and community people.

7.8.3 Principles of Community SWM

The following principles shall guide the implementation of community SWM in MGSP ULBs.

1. Community-led planning and decision making process;
2. Participation of almost equal men and women, disabled, youths; and girls considering gender inclusiveness with higher degree of importance;
3. Flexibility in approaches according to the local situations and lessons learned for sustainability; and
4. Coordination and collaboration among stakeholders particularly ULB, NGOs, and others.

7.8.4 Stakeholders' Mobilization of Community SWM

The following stakeholders are to be engaged in community SWM of ULBs.

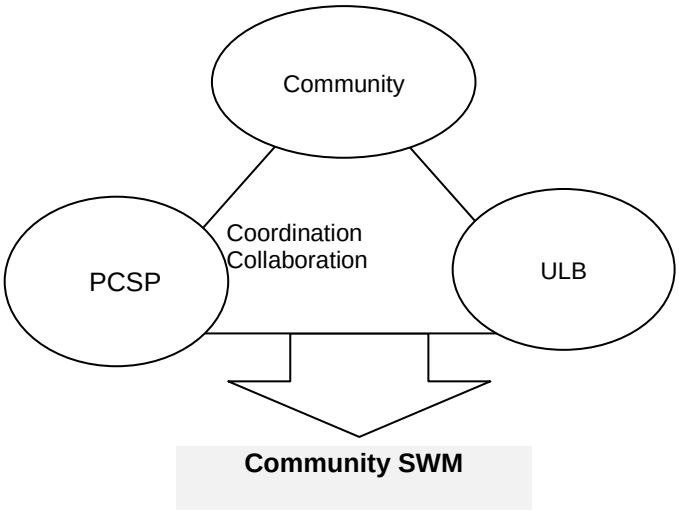
1. Community associations (House Owners Associations, Neighbourhood Associations, Sports Clubs, Local Committees, Youth Groups, etc.);
2. Primary Waste Collection Service Providers (PCSP) or van service
3. ULB (ward councillor, staff and cleaners etc.);
4. Waste pickers;
5. Junk shops;

6. Other CBOs, NGOs, and projects;
7. Local politicians, decision makers, and opinion leaders in the target areas; and
8. Existing private sector initiatives related to SWM.

Including a wide range of target groups and stakeholders is a key consideration for the community SWM. A facilitating body or group or citizen organizations is inevitable for ensuring inclusion of the target group that may be recognized as the Community Group.

Success of community SWM may be rooted in the engagement of the three main stakeholders. These are the community people, ULB, and the primary waste collection service providers (PCSP) as shown in the following **Exhibit 7-5.**

Exhibit 7-5
Coordination of Key Stakeholders for Successful Community SWM



7.8.5 Activities of Community SWM to be Done by the ULB and Community Together

Examples of community SWM activities that ULBs and Community groups might perform together are listed below.

munity and primary collectors meeting in a Dhaka ward

1. Preparing a Community Action Plan and facilitate its implementation (e.g., list of activities to solve SWM problems and to improve SWM, including the timeframe and responsible community members);
2. Coordinating and cooperating with primary collection service providers (e.g., increase regularity of collection, service standards, coverage expansion, reduce illegal disposal);
3. Monitoring and supporting primary collection activities and cleaning work of the DNCC and DSCC (e.g., enhanced street sweeping, recognized street sweepers, municipal staff, etc.);

ULB Street Sweeping

Community meets municipal cleaning workers

4. Distributing Information to all households (e.g., door to door visit, leaflet distribution, making, mosque announcement etc.);

Door to door visit

Miking

Leaflet distribution

5. Promoting people's awareness and participation in SWM (e.g., rally, banner or sign posts, school environmental education, etc.);
6. Reporting local issues and people's opinion to DNCC and DSCC or their zone offices (e.g., monthly meeting in councilor office, women group meeting, CEDC monthly meeting etc.);

Female group meeting

Regular meeting with ward councilor

7. Collaborating and linking with other organizations (CBO or NGOs) to support their

activities and find local sponsors to sustain their activities (e.g., find financial, time, labor, etc. contribution from locality, get sponsors from business entities, etc.);

8. ULB staff facilitating community groups for community contribution in community cleanliness, awareness raising, rallies, and regular meeting; and

Citizen contributions to community cleaning

Regular consultation meeting for community SWM

Raising SWM and community cleanliness awareness

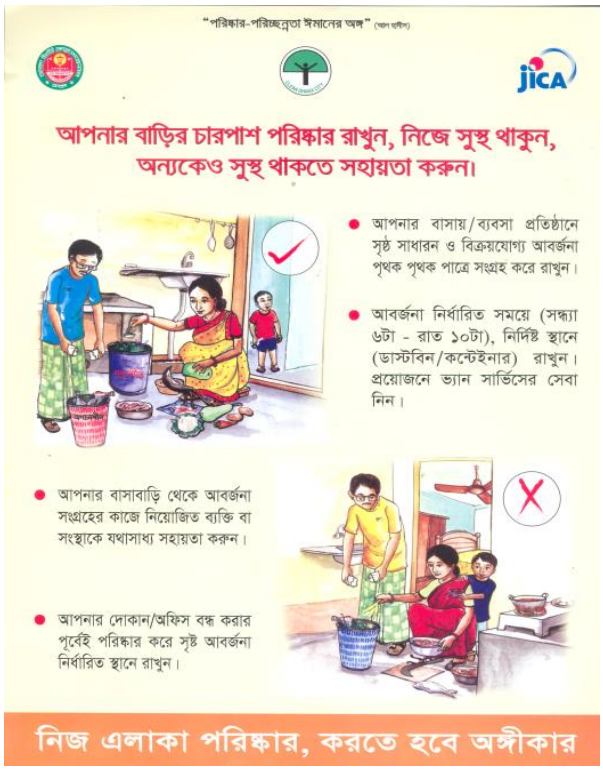
9. Organizing training for community people and primary collection service providers.

7.8.6 Promoting and Raising ULB Social Awareness Tools

ULBs need to keep budget for community solid waste management to be spent in the activities of making, rallies, training, door to door campaigns, leaflet distribution, environmental education in the schools, community level meetings, procurement of rickshaw vans, hand trolleys, community SWM offices, etc. Examples of social mobilization tools are shown in **Exhibit 7-6**.

SWM training for community groups

Exhibit 7-6
Examples Social Mobilizing Tools for ULBs



Leaflet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CHAPTER 8

LANDFILL OPERATIONS AND MAINTENANCE

8.1 Introduction

This guideline is made based on the context of Bangladesh, particularly, based on the successful case of Dhaka South City Corporation, Matuail Landfill Site (LFS). The Project recommends that interested ULB management should arrange a site inspection to observe the practice of landfill operation and maintenance management at Matuail LFS. It will be very helpful to grasp the concept quickly if all levels of staff such as engineers, drivers, heavy equipment operators, and other management and administrative staff participate in the site inspection.

However, The ULBs should have a clear understanding of the landfill O&M guidelines. The main roles of landfill sites are to receive waste, place the waste in systematically arranged cells, protect the environment, and stabilize the waste and return the waste to the soil. Landfill sites should be managed and operated in a sound manner to fulfill these roles. It is, therefore, vital to have an intimate knowledge of the available facilities in the landfill sites including their structures, objectives, and functions. Knowledge of dump truck control, disposal operations, environmental management, emergency management, and post closure operations is also essential for the proper management of landfill sites. The major activities of landfill operations and management are described in the following broad sections.

8.2 Components to Consider for Landfill O&M

1. Vehicle Operations: Control of incoming and leaving vehicles;
2. Disposal Operation: Control of dumping, compaction, and daily cover;
3. Emergency Management: Management under adverse conditions;
4. Post-closure Management: Management after closure of the landfill; and
5. Environmental Management: Control of environmental pollution.

8.3 O & M Activities under Vehicle Operations

8.3.1 Traffic Flow management

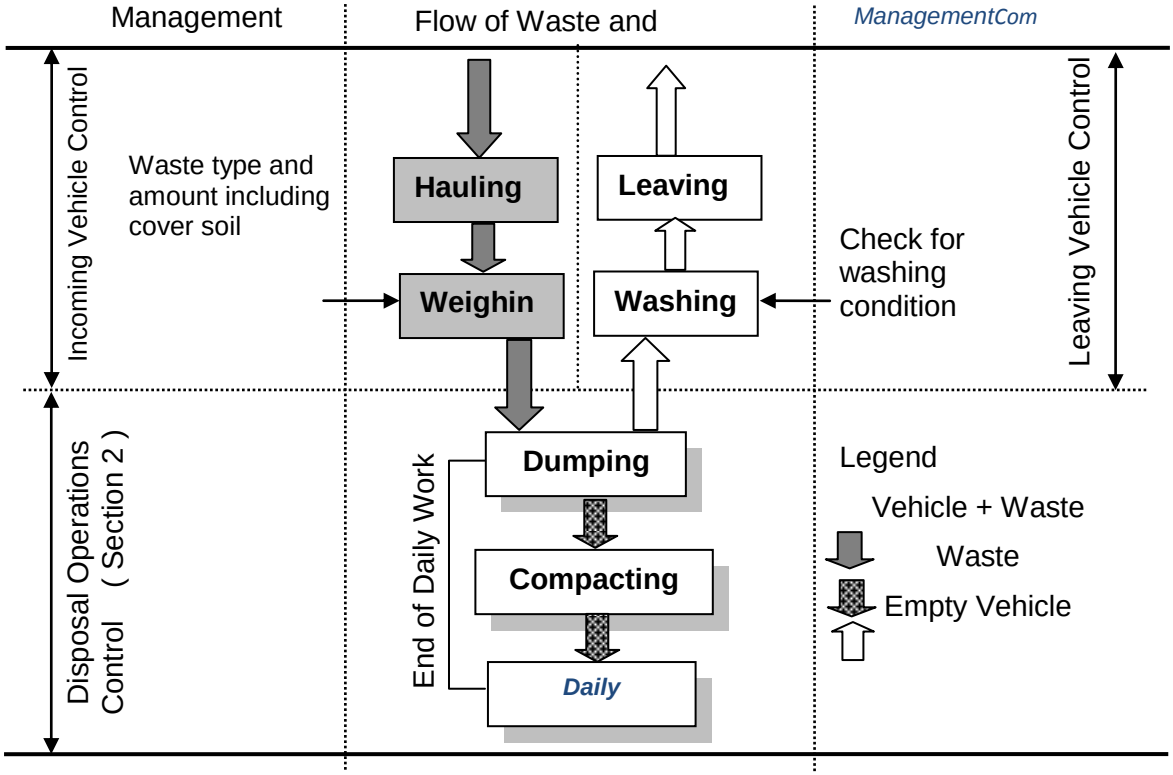
Systematic movement of waste dump trucks, trailers, and heavy equipment engaged in disposal operations within the landfill is required for uninterrupted operation of the landfill. The systematic flow of traffic in a definite route is also important for efficient operation of the landfill. The traffic flow in the landfill site is shown in **Exhibit 8-1**.

The incoming vehicles will follow the specified route via the weighing bridge. The vehicles will then discharge the waste load in a definite location demarcated by the platform supervisors. The outgoing vehicles will leave the landfill site via the vehicle washing facility and leave the landfill site. The landfill heavy equipment will then push the waste to the final disposal area and compact it. The final cover by soil or stabilized soil will be made after a day's work is over.

The site manager may change these conditions in order to improve the operation or meet unforeseen circumstances. In such cases, the modified information should be made available to all landfill operating staff.

Exhibit 8-1
Traffic Flow in the Landfill Site

8.3.1 Weigh Bridge Operation



The weigh bridge operation will have two main functions.

1. Inspection of the vehicle at the point of entry to assess the suitability of its load for acceptance at the site; and

2. Recording of the quantity of waste and particulars of the vehicle and the trip.

Waste Inspection

The ULB's landfill shall accept all types of non-hazardous municipal solid waste types, including domestic and market wastes, road sweepings, and sludge from cleaning the sewers. Hazardous waste, toxic wastes, infectious hospital waste, radioactive waste, liquid waste, and other waste not considered as municipal waste shall not be accepted at the ULB's landfill site. The inspection of the incoming waste will be as follows.

1. The weigh bridge operator may demand a visual inspection. In this case, the vehicle will be directed to a separate location for inspection. This could be just a visual inspection or detailed inspection by dropping waste at designated location.

2. Regardless of initial acceptance at the weighbridge, the waste may be rejected during unloading at the active cell if it contains unacceptable materials. In this case, the rejected waste will be reloaded in the vehicle and returned away from the landfill

site.

3. Should a vehicle not be permitted to discharge its load at the landfill based on the inspection, the vehicle number, driver's name, date and time of arrival, and reasons for rejection shall be reported to the ULB.

Weigh Bridge Record

A form shall be prepared for the purpose of storing information. It may be revised from time to time based on the requirements. A coding system shall be prepared for inputting the collected information into the computer. The data to be recorded should be as shown in **Exhibit 8-2**.

Exhibit 8-2
Weigh Bridge Data

No.	Data for Recording	Provider / Recorder of Data
1	Vehicle number	Weigh Bridge Operator
2	Weight of empty vehicle	Should be retrieved from computer, if recorded once against the vehicle number
3	Arrival time	Weighbridge Operator
4	Weight of the vehicle	Weighbridge Operator (automatically recorded if weighbridge output is connected to computer)
5	Trip origin	Driver (station's name for transfer haul, collection zone for direct haul)
6	Departure time	Weigh Bridge Operator

The recorded data shall be given as input into the computer using the coded format for analysis on daily basis. A computer program may be developed for the analysis of this information as required.

8.3.2 Washing Vehicles

The body and wheels of the vehicles may be contaminated by the waste and leachate from the landfill. To avoid pollution of the roadways by the vehicles, the collection vehicles should be washed before leaving the landfill site. When a vehicle makes several trips during working period, the wheels of the vehicle need washing while leaving the landfill but the body of the vehicle needs washing only after the final trip. The water used for washing vehicle may be considered as leachate depending on the level of contamination of the wash water. The wash water should pass through a skimming tank to trap oil and grease.

8.4 Disposal Operation

8.4.1 General

Landfills need proper operations to make best use of landfill capacity, stabilize waste, and to ensure sound management of leachate and landfill gases. It is also necessary to record the landfill work description so that the data can be utilized as basic information to establish a post closure plan.

It is required to make a landfill plan and to dispose waste systematically according to the plan and record actual amount of haulage and disposal of wastes. Time and place of land filling should also be recorded to grasp the remaining landfill capacity. These data will also be utilized as basic information to determine the cause and measures in an emergency.

The ULB's landfill site should be planned to operate by the "cell construction method" as described in the following sections. The unloaded wastes should be moved and placed by chain dozers and compacted sufficiently by the compacting equipment to form a waste cell. At the close of daily operation soil and stabilized wastes should be placed over the waste to finish the cell.

8.4.2 Waste Unloading

Landfill staff will direct the vehicle drivers to the active waste disposal areas. The platform operators at the active fill areas will direct the vehicle to the appropriate disposal area along the working face as required. No vehicles will be permitted to unload their waste at any location other than the area designated by the platform operators.

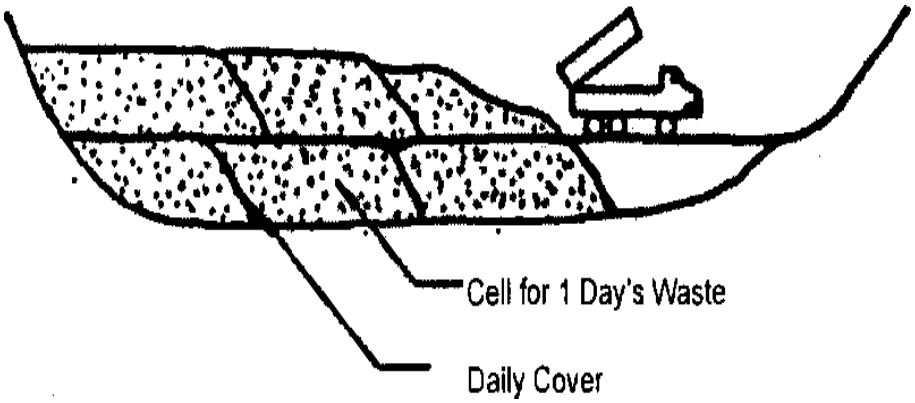
The operators will maintain control of the waste unloading within the active disposal area in order to minimize the width of the working face as well as to decrease the unloading and waiting times. The drivers may be instructed to unload the waste in two or three different waste cells.

8.4.3 Landfill Work

Landfill Method

The landfill method to be adopted is suggested to be cell method. This method, as shown in **Exhibit 8-3**, is widely used as the landfill method of sanitary landfill systems. This has a cell of solid waste covered with a layer of soil or stabilized waste. The size of each cell is determined by the amount of solid waste filled per day. Since each cell is thought to be an independent landfill area, it acts as a fire-breaker. Each cell with soil cover also prevents the waste from being scattered, the emission of bad odors, and breeding of harmful vectors.

Exhibit 8-3
Waste Disposal by Cell Method



Cell Configuration

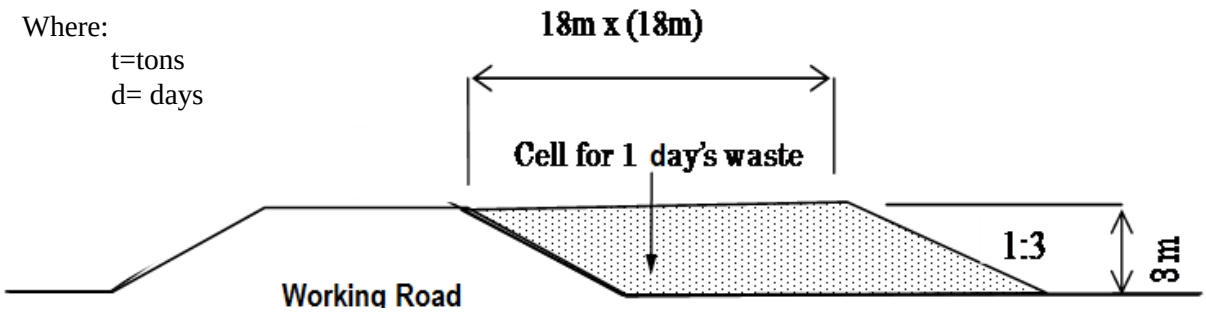
A cell shall be prepared to accommodate one day's waste. The cell area should not be too large to limit the leachate production. The cell may have a height of 3 m and the waste shall be deposited in layers varying from 30-50cm to allow for more uniform compaction. The width shall be sufficient to allow for 4-5 vehicles to discharge the waste at the same time (i.e. minimum 15 m). **Exhibit 8-4** shows how to calculate cell size.

Exhibit 8-4
Calculation of Cell Size

Example for Cell Size Cal culation:

- The waste amount hauled to the site shall be around 1,440 t/d.
- The number of cells : 2
- Accordingly the cell area = (1,440t/d) / (2 cells x 0.8t/m^3 x 3.0m) = 300m^2 with dimensions of 18 m x 18 m.

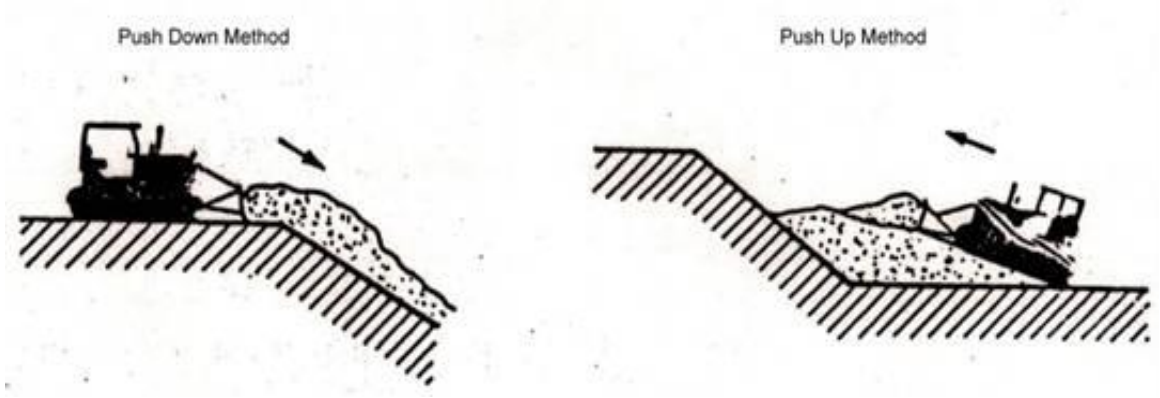
Where:
t=tons
d= days



Spreading and Compaction

The spreading and compaction of the solid waste dumped from the collection vehicles are done by "Push Down" or "Push Up" methods on a slope by a chain dozer as shown in **Exhibit 8-5**.

Exhibit 8-5
Spreading and Compaction by Push Down and Push Up Method



In the case of pushing the solid waste down the slope, it is difficult to spread the waste to a uniform thickness. The bottom part of the slope tends to be thicker. Mixing and compaction is also difficult. On the other hand, it is easier to make uniform landfill layers when pushed up on the slope. Compaction is easier in “Push Up” method.

Therefore, when the compaction has to be done quickly, the "Push Up" method is preferable. As the landfill will be soaked with leachate during the rainy season, the "Push up" method will be difficult at that time. Therefore, in the rainy season "Push Down" method is preferred over the“Push Up” method.

The spreading and compaction of the solid waste delivered to the landfill site will largely influence the capacity of the landfill, stabilization of the landfill layer, post-closure land use, and environmental conservation. The method of the spreading and compaction of the solid waste to be adopted is mentioned below.

1. In general, the “Push Down” method of the spreading and compaction shall be adopted when the platform or temporary road is higher. The “Push Up” method will be adopted when the platform or temporary road is lower lower than the filling area.
2. The “Push Down” method shall be adopted during rainy season.
3. The thickness of layers shall be about 30 to 50 cm.
4. At the boundary of the waste cell, a side slope of 1(vertical) to 3 (horizontal), about 18.5 degrees, is to be maintained.
5. The number of passes of the chain dozer shall be 3 to 5 for compaction of spread waste layer.

The typical operation of spreading and compaction by “Push Up” and “Push Down” methods are shown in **Exhibits 8-6 and 8-7,** respectively.

The landfill platform shall be used for the disposing solid wastes. Particularly,tipper type dump trucks can dispose off the waste. The chain dozers will spread and compact the waste by the push-down method upto the level of the embankments. Later both push-up and push-down method as appropriate can be adopted. A temporary road network will have to be established so the dump trucks can reach on the waste dump higher levels.

Exhibit 8-6
Operation of Spreading and Compaction ("Push Up" Method)

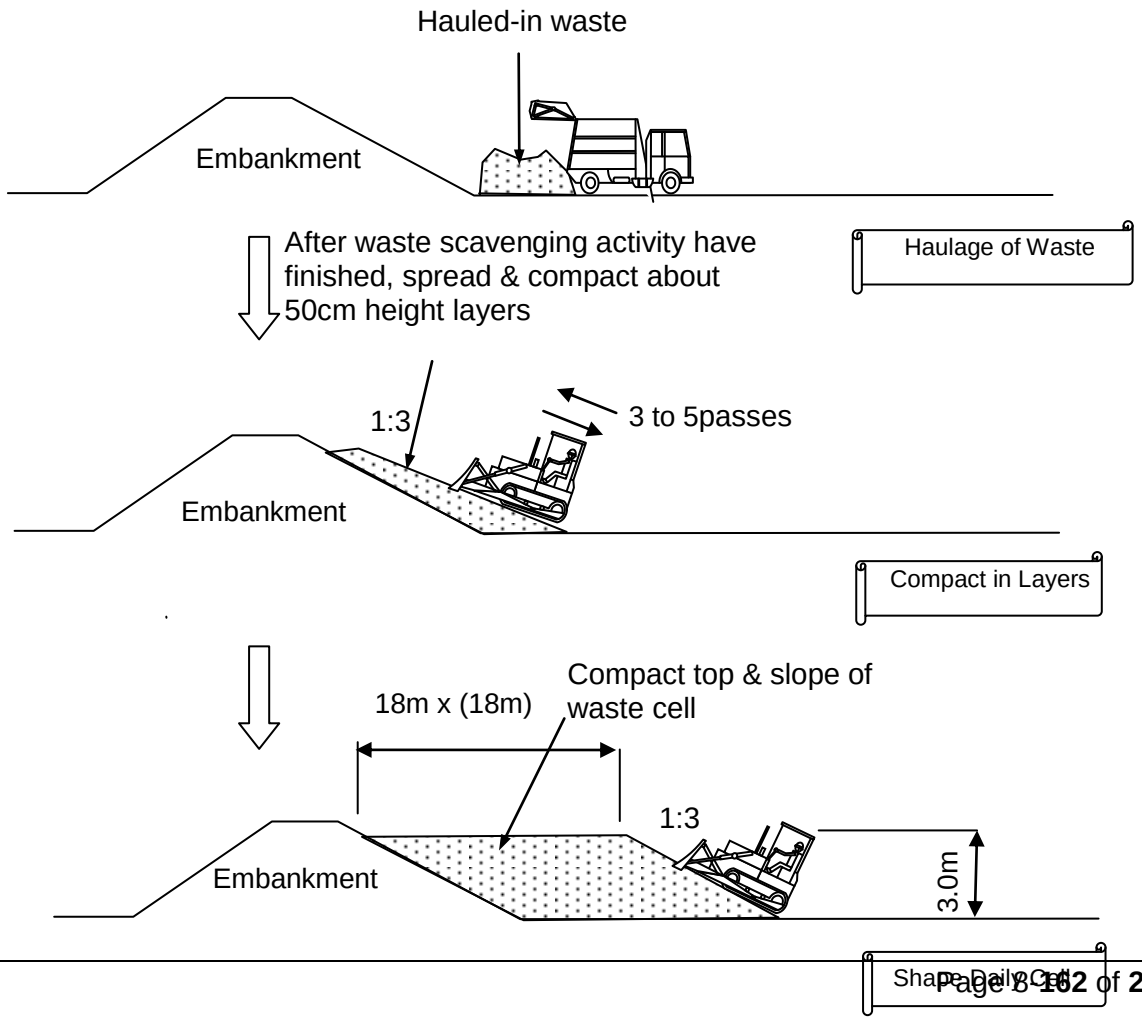
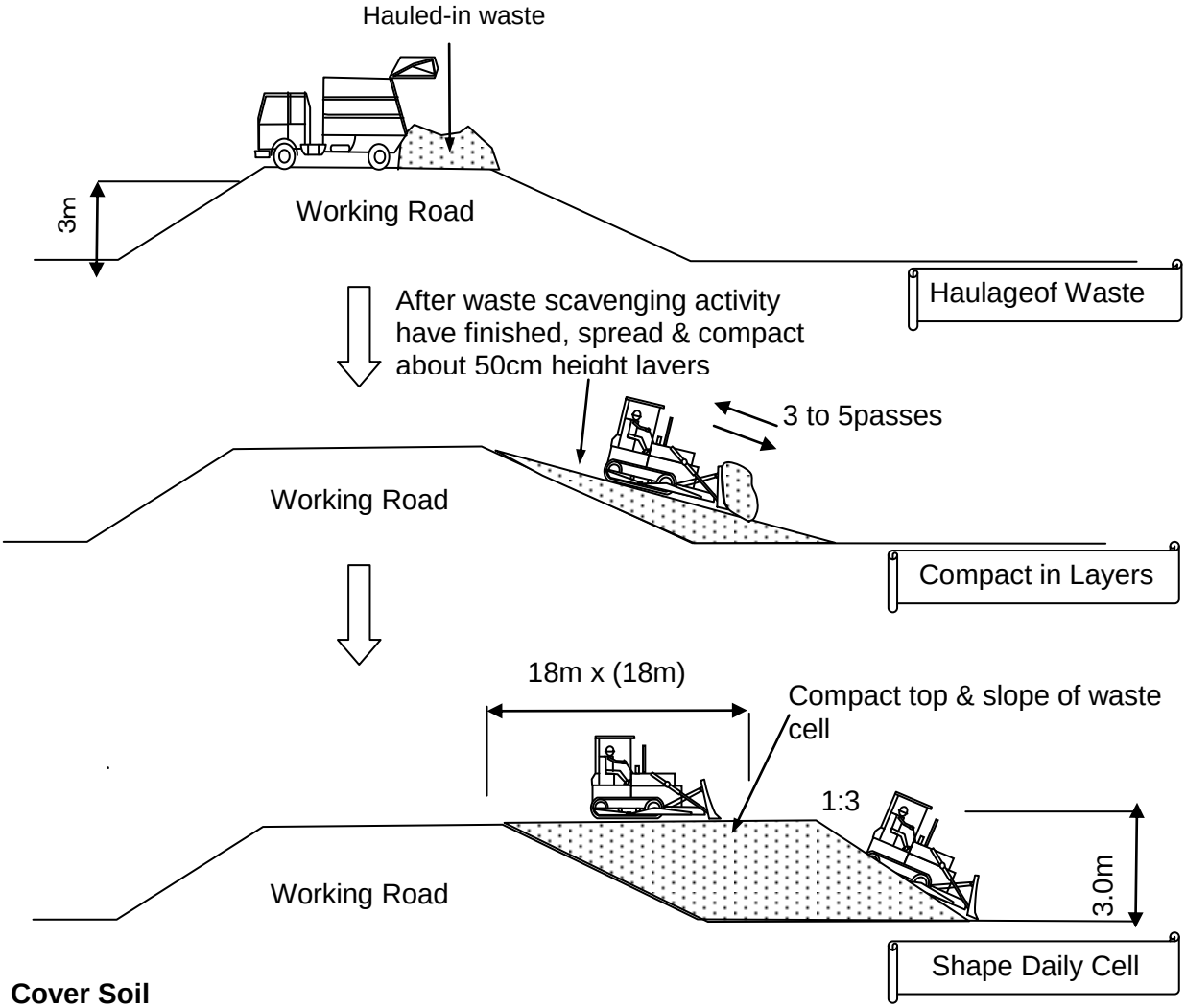


Exhibit 8-7
Operation of Spreading and Compaction ("Push Down" Method)



Cover Soil

Effectiveness and Necessity of Cover Soil

In the sanitary landfill system, the cover soil is indispensable for conserving the surrounding environment. The cover soil prevents the spreading of bad odors, scattering of waste, and breeding of vectors and harmful insects. It also preventsthe lighting and spreading of fires at the site. In addition, it providesa good appearance for the neighborhood. Further, from an operation and management point of view, it eases solid waste spreading and compaction work, and prevents rainwater from seeping into the inner layers of the landfill site. Thus, the leachate volume is reduced.

Type of Cover Soil

Depending on the purpose, cover soil can be classified into daily and final cover soil.

Daily Cover Soil

When the landfill layer reaches the thickness specified in the design or when a one-day portion of the landfill work is completed, soil cover should be provided on the layer. The purposes of the daily cover soil are listed below.

1. To prevent the scattering of waste;

2. To control bad odors; and

3. To stop the breeding of harmful vectors like flies.

In case soil is not available, old stabilized solid waste, dirt, and construction debris can be used as daily cover instead of soil.

Final Cover Soil

The landfill has been designed as a multi-stage landfill with a 5-m stage height. The final cover should be applied as the side slope of a stage progresses. Eventually, when all the landfill work is finished, final cover soil should be placed on top of the last layer. The purposes of the final cover soil are listed below.

1. To provide good appearance for the neighborhood;
2. To enhance usability of the post-closure land;
3. To reduce leachate volume; and
4. To promote growth of vegetation on the slope, berm and top surfaces.

Selection of Cover Soil

Daily Cover Soil

Construction debris and old stabilized waste in the site are to be used as daily cover soil. Old waste to be used as daily cover soil should be 3 or more years old. Construction debris shall be pieces of brick, broken concrete, plaster, and excavated soil from construction sites. They should be checked carefully for toxic substances.

Final Cover Soil

The final cover soil should be resistant to erosion by rainwater, of low permeability, and suitable for plant and vegetation growth. Thus, a loam type of soil, which contains some humus, is recommended. When soils from other construction sites are used, they should be checked carefully for toxic substances.

Determination of Thickness of Soil Cover

The thickness of cover soil depends on the purpose of cover soil, composition, type and shape of solid waste to be covered, and the surrounding environmental condition. According to the type of cover soil, the thickness is generally set up as stated below.

1. Daily Cover Soil
    - Debris: 30 to 50 cm
    - Old waste at the site: 15 to 20 cm
2. Final Cover Soil
    - Grass or low height plants and bushes are planted: more than 50 cm
    - Medium height to tall trees are planted : more than 1.0 m

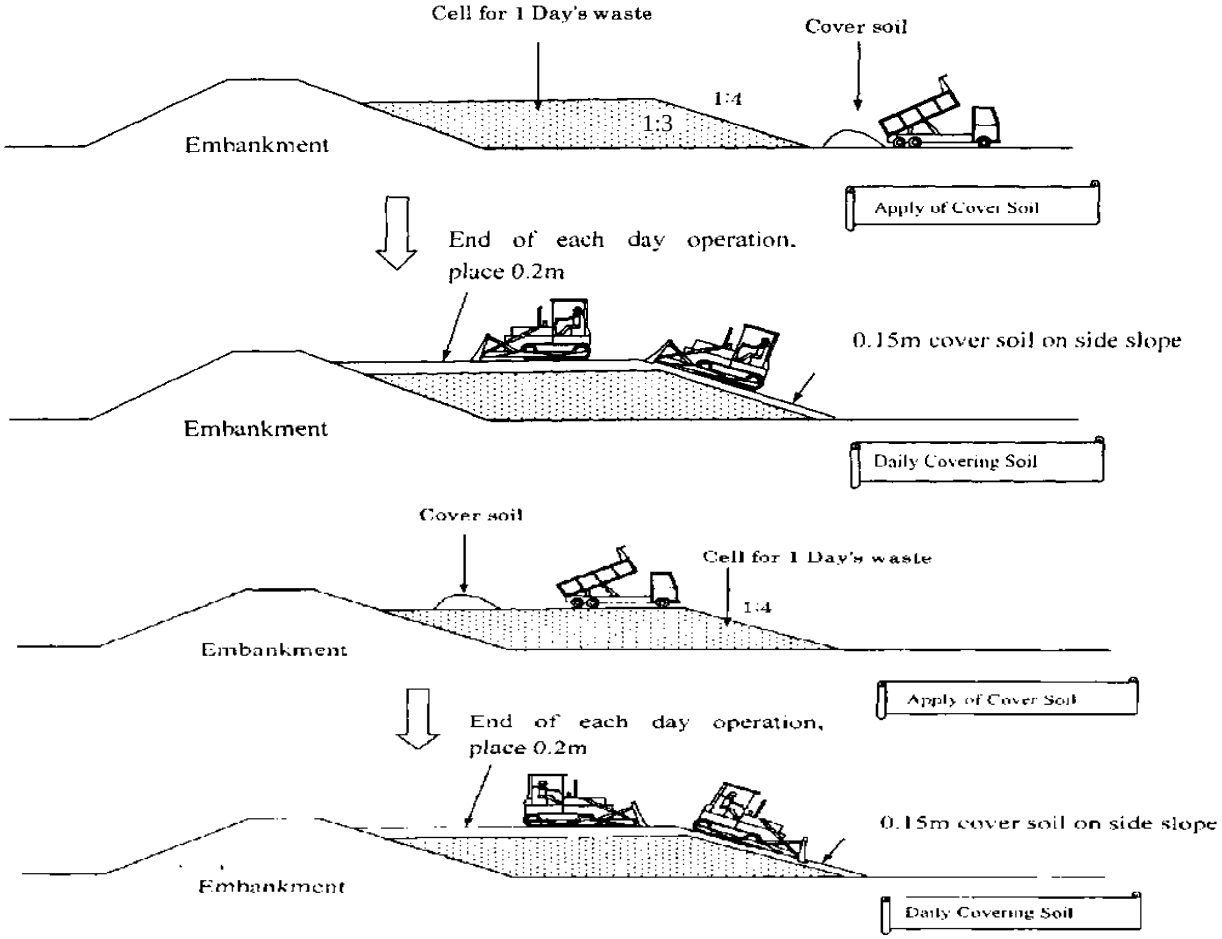
Operation and Maintenance of the Cover Soil

The cover soil should be spread uniformly and compacted by using appropriate landfill equipment. This will depend on the thickness, area, and type of the cover soil.

In particular, since it takes time for the final cover soil on a slope to stabilize, care must be taken to prevent this final layer from being eroded by rainwater. Therefore, the recommended slope should be about 15 degrees.

The typical operation of spreading and compaction is shown in **Exhibit 8-8**.

Exhibit 8-8
Operation Procedure of Daily Covering Soil (Push-down Method)



Maintaining the cover soil is an integral part of the maintenance of post-closure landfill, in addition to leachate and gas treatment. The surface of the final cover soil will sink, crack, and form potholes due to decomposition and consolidation of the filled waste. This may result in percolation of rainwater, water logging, increase of leachate volume, leakage of gas, erosion of the cover soil, landslides, and fires. A survey concerning the subsidence of the post-closure landfill resulted in the following findings.

1. The landfill site subsides deeper when combustible waste is disposed and shallower when incombustible waste, refuse, such as construction debris is disposed;

2. The deeper the landfill, the deeper the site subsides; and

3. The site subsidence continues for several years.

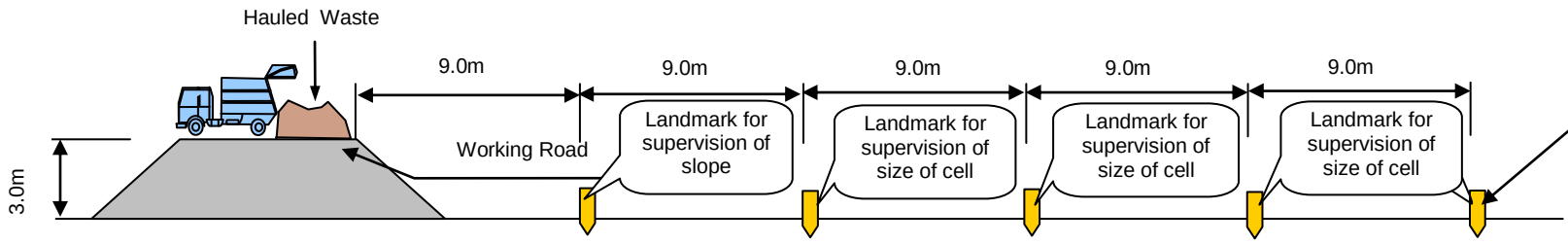
In particular, if the surface of the landfill area depresses or cracks, rainwater will seep into the inner layers via these cracks. This will thus result in increasing the amount of estimated leachate volume. Additionally, these areas will also become points for gas release. Therefore, the surface of the final cover soil and condition of plants should be checked and maintained periodically.

Example of Dhaka South City Corporation LFS (Matuail): as push down method is more effective than push up method for land filling of the organic waste, the working road should be 3 meters high and the waste should be filled by pushing down from the working road. As mentioned earlier, the size of each cell should be 18 meters in width, 18 meters in length,

and 3 meters in height. Waste filling should be done after establishing the landmark of the slope and the cell size as mentioned in **Exhibit 8-9**.

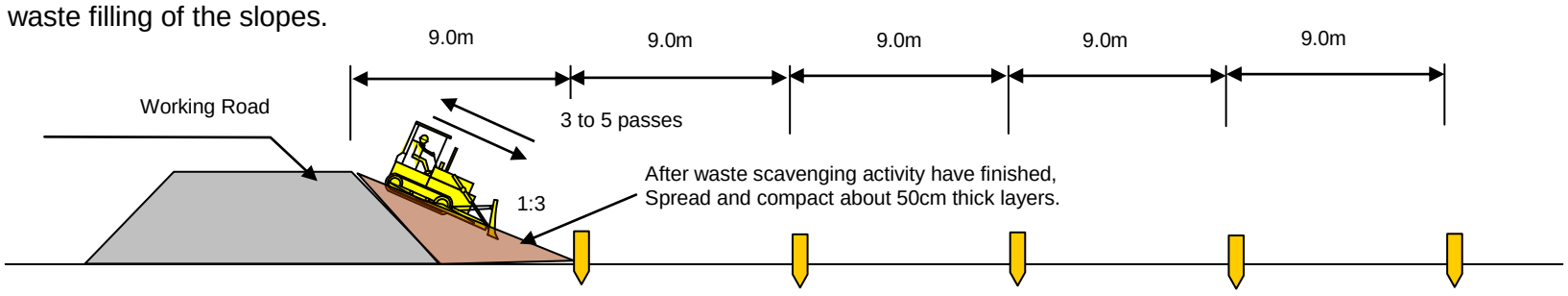
Exhibit 8-9
Operation Procedure for Daily Covering Soil (Push-down Method)

1) Haulage of Waste



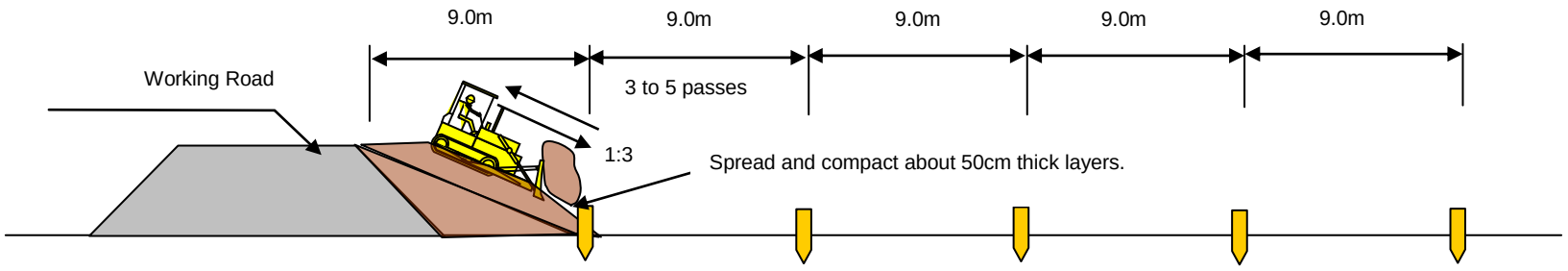
2) Build 1:3 slope for waste filling

Waste filling slope 1:3 would be secured using the landmark that established for the supervision of the waste filling of the slopes.



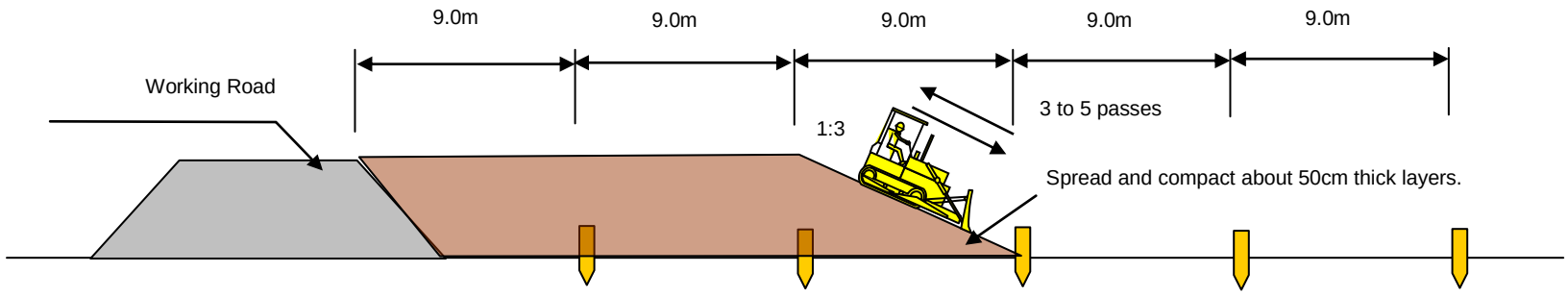
3) Spreading and Compaction of Waste

Waste should be filled maintaining 1:3 slope that build in number 2). For compaction thickness per layer should below 0.5 meter and compaction work should be sufficient.



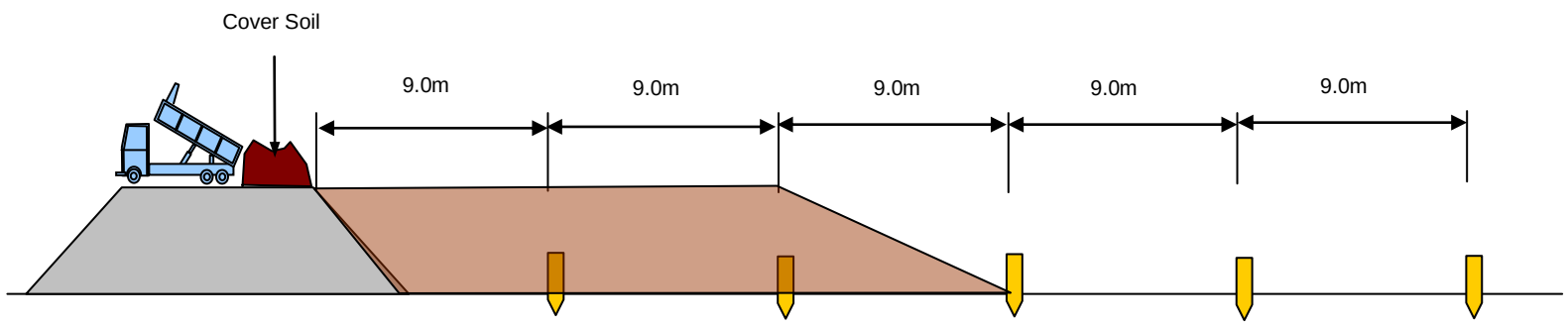
4) Secure the size of Cell

Using the landmark that established for the supervision of the size of the cell and repeating the activities that mentioned in number 3), cell for 1 day should be completed.



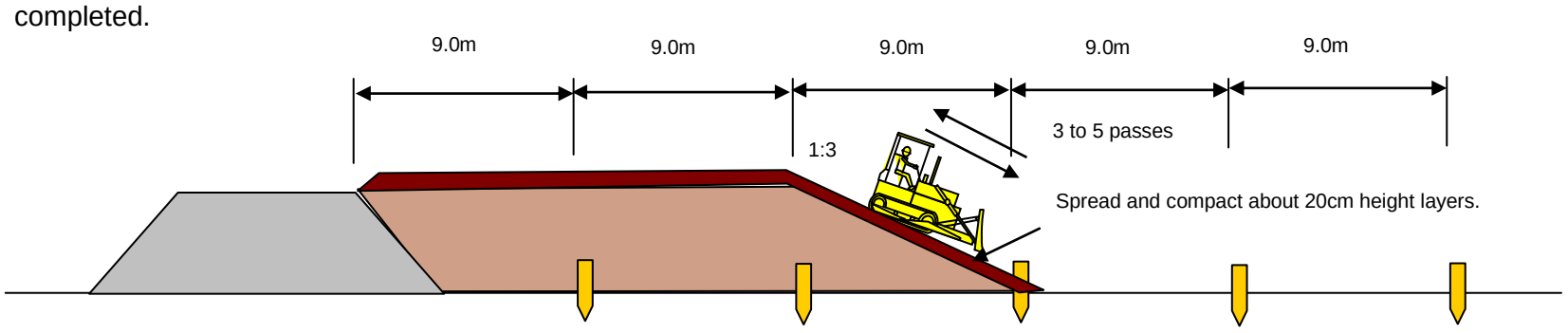
Construction of Cell for 1 Day's waste

5) Apply of cover Soil



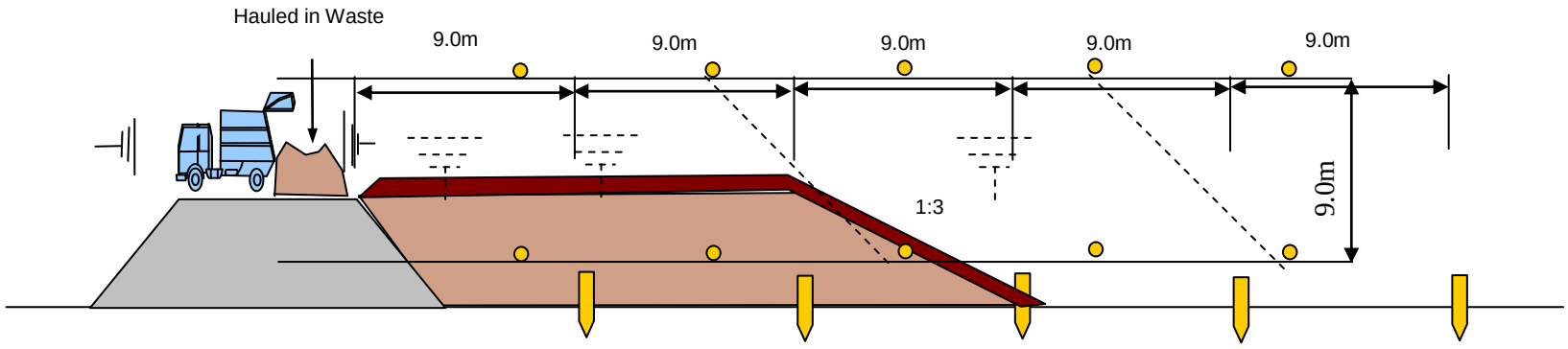
6) Providing Daily Soil Cover

Daily soil covering should be done after the activities that mentioned in number 5). Thickness of compaction of daily soil cover would be minimum 0.2 meter with proper compaction. After that operation for 1 day would be completed.

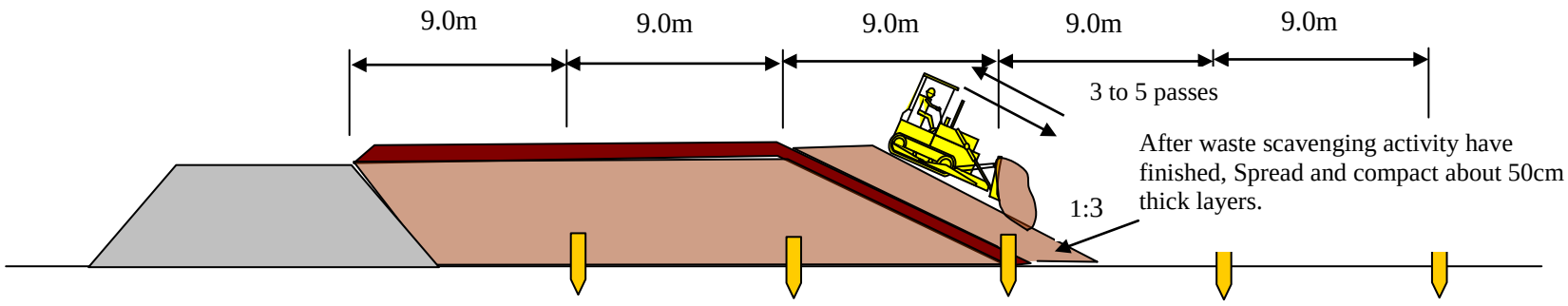


Covering soil for 1st Cell

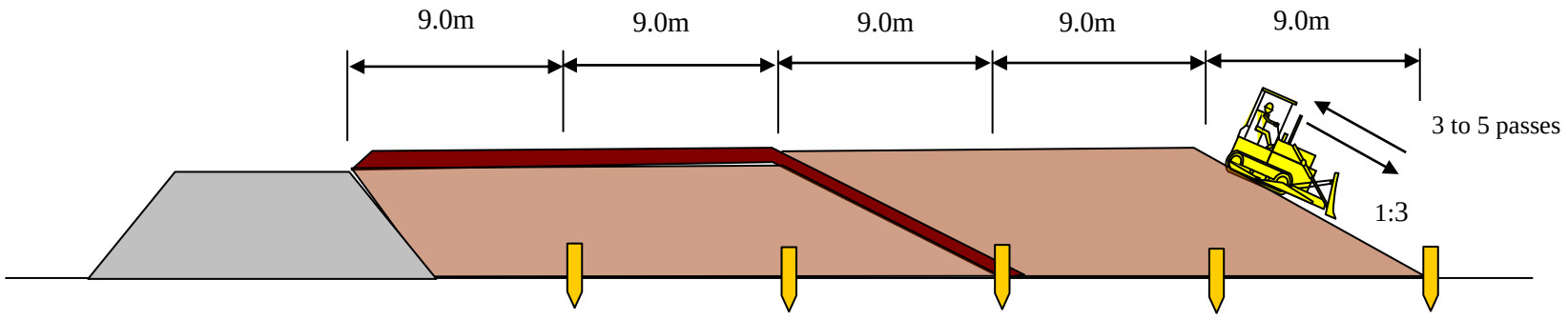
7) Haulage of Waste



8) Spreading and Compaction of Waste Same operation as number 3.

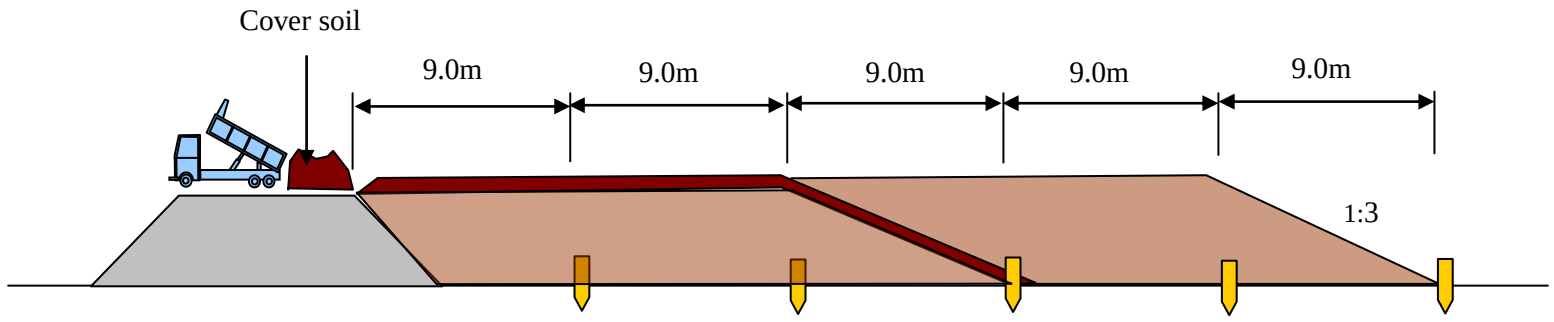


9) Secure the size of the Cell Same operation as number 4.

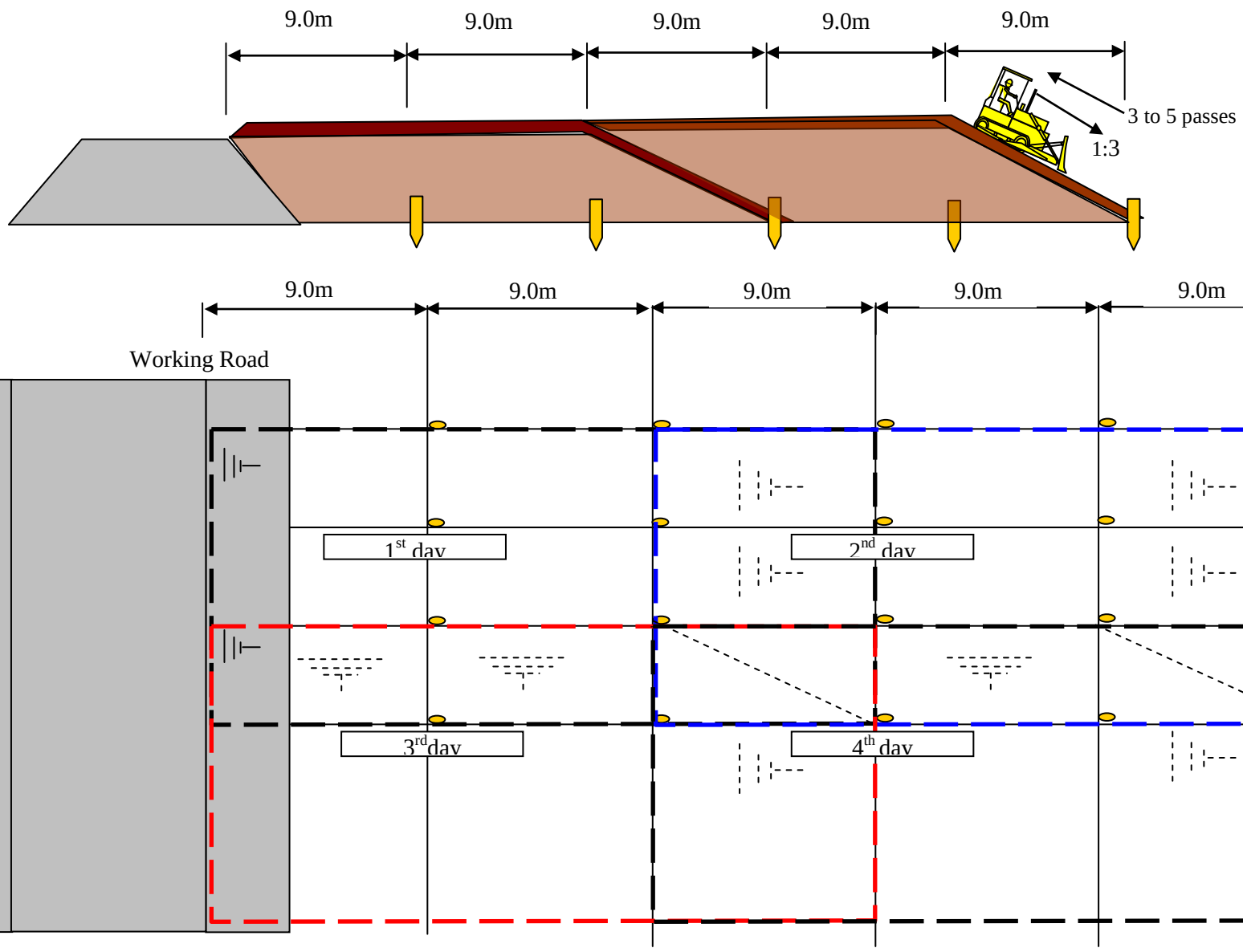


Construction of Cell for 2 Day's waste

10) Application of cover Soil



11) Providing Daily Soil Cover Same operation as number 6.



Covering soil for 2nd Cell

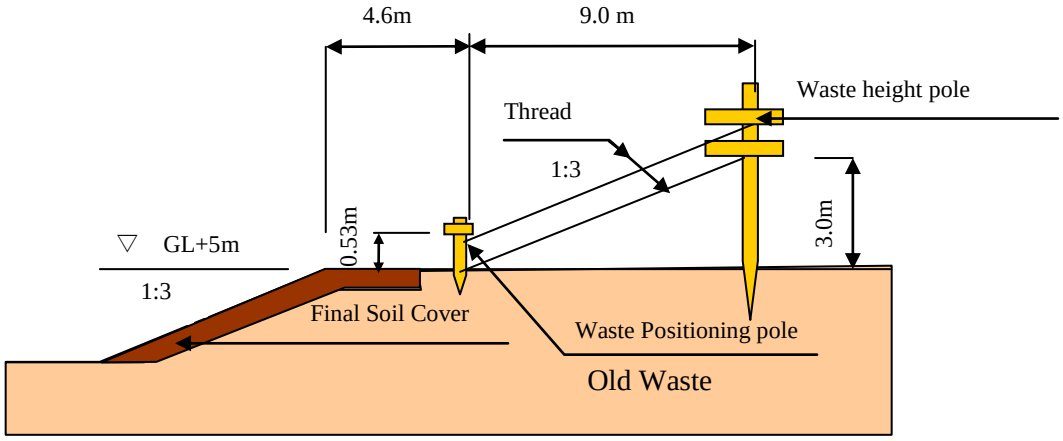
8.4.4 Waste Filling and Soil Cover at Side Slopes

Establishing the side slope at the periphery of a landfill is a difficult job. The height of landfill in the periphery and the slope shall be constructed with the help of height poles and rope as shown in **Exhibits 8-10**. Supervision of the landfilling at the side slope shall be done accordingly. The height of the waste filling per stage is 5 m. It should be filled in two layers of 3m and 2 m in lifts. The steps shall be followed are described below.

***Step 1**: Demarcation of landfilling height of first 3m lift (0 – 3 m)*

Two ropes shall be stretched between waste positioning pole and waste height pole as shown in **Exhibit 8-10** to demarcate the height of the wastes filling and final soil cover at the slope, respectively. Thus the waste filling, thickness of the final soil cover, and the landmark of the slope should be fixed **Exhibit 8-10**.

Exhibit 8-10
Landmark of Slope of the First Layer Landfill

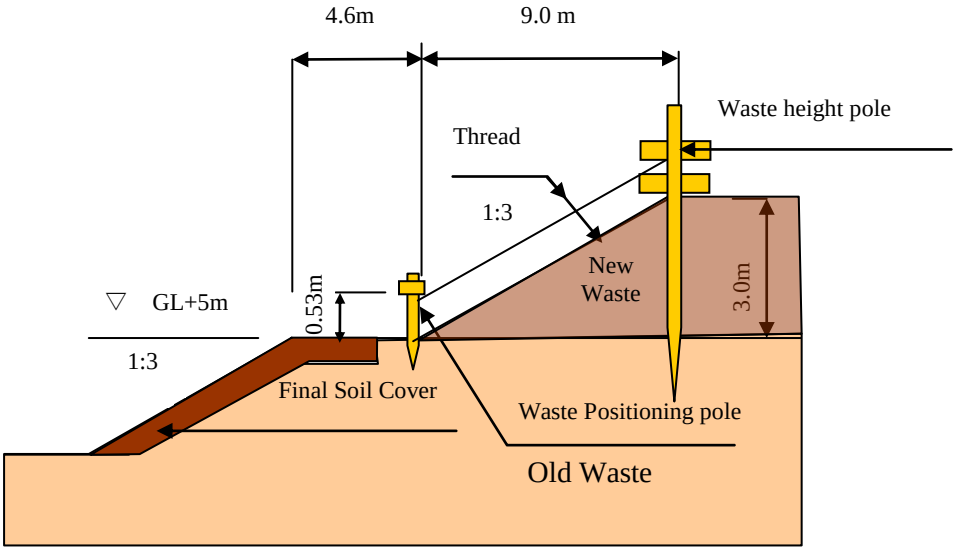



Waste Positioning Pole


Waste Height Pole

***Step 2**: Waste Filling at the 1st layer (0 - 3m).* The waste filling and compaction shall done considering the landmark points mentioned in Step 1. The finished level of the waste shall just touch the rope indicated waste height as per **Exhibit 8-11**.

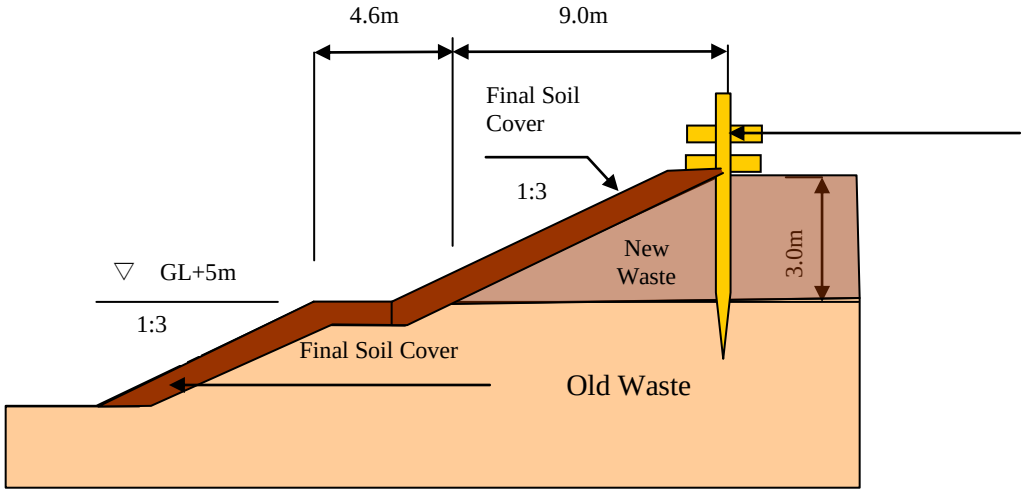
Exhibit 8-11
Waste Filling of First Layer



***Step 3**: Establishment of Final Soil Cover at the 1st layer (0 – 3m)*

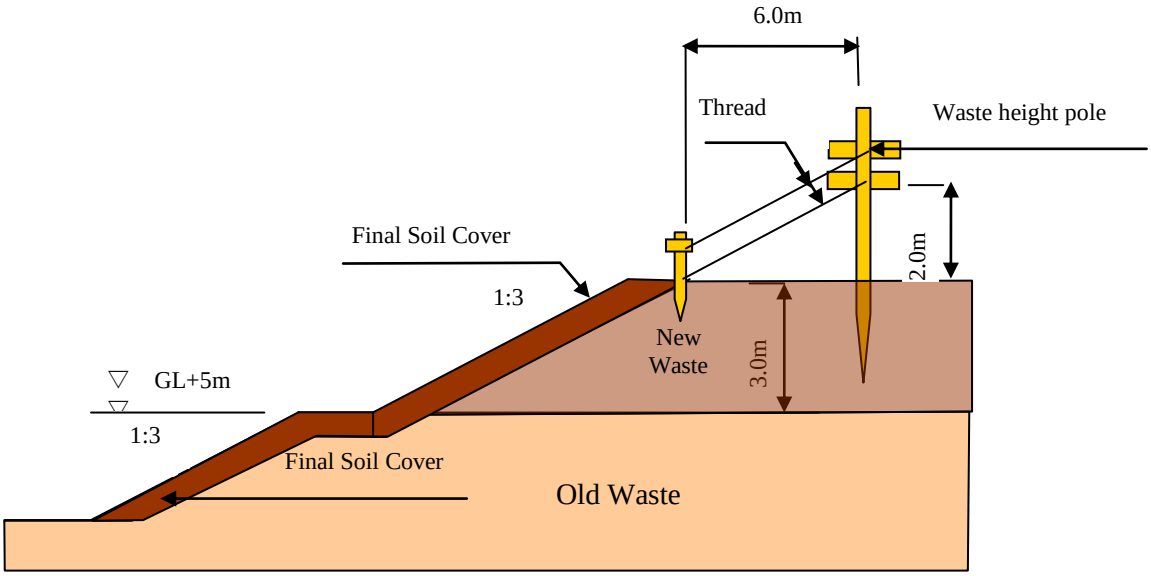
The final soil cover shall be established following the landmark points mentioned in Step 1, **Exhibit 8-11**. The finished soil cover shall be aligned with the rope stretched between the poles to demarcate the alignment of the final soil cover as shown in **Exhibit 8-12**.

Exhibit 8-12
First Layer of Final Soil Cover



***Step 4:** Demarcation of the landfill height of 2nd 2 m lift (3-5m).* Demarcation of the waste filling and final soil cover heights by poles and ropes as discussed in step 1. and shown in **Exhibit 8-13.**

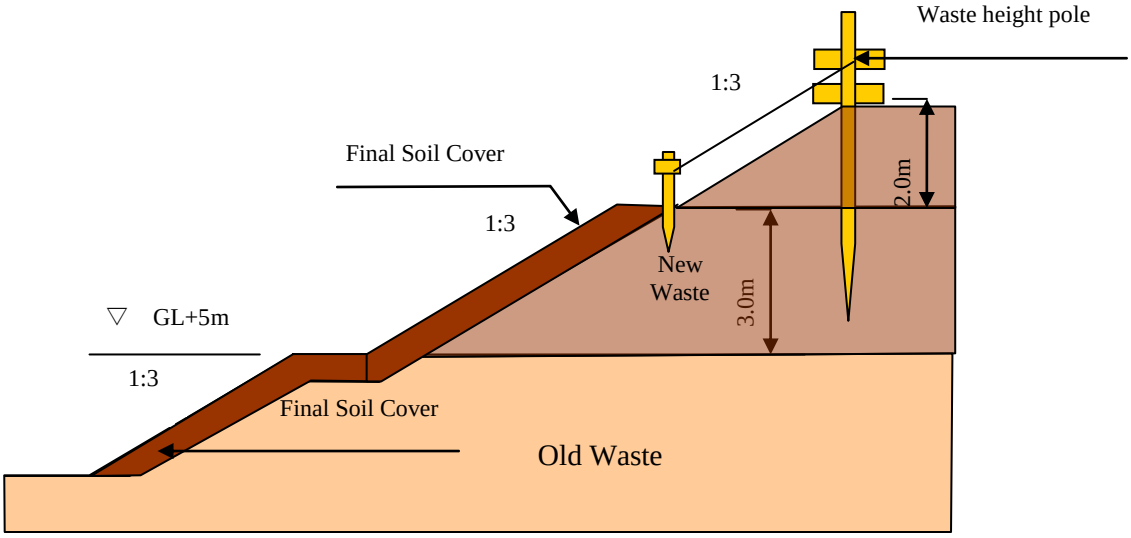
Exhibit 8-13
Demarcation of Second Layer of Land filling



***Step 5**: Waste filling at second Layer (3 – 5m)*

The waste filling and compaction shall done considering the landmark points established in step 4. The finished level of the waste shall just touch the rope indication waste height as shown in **Exhibit 8-14**.

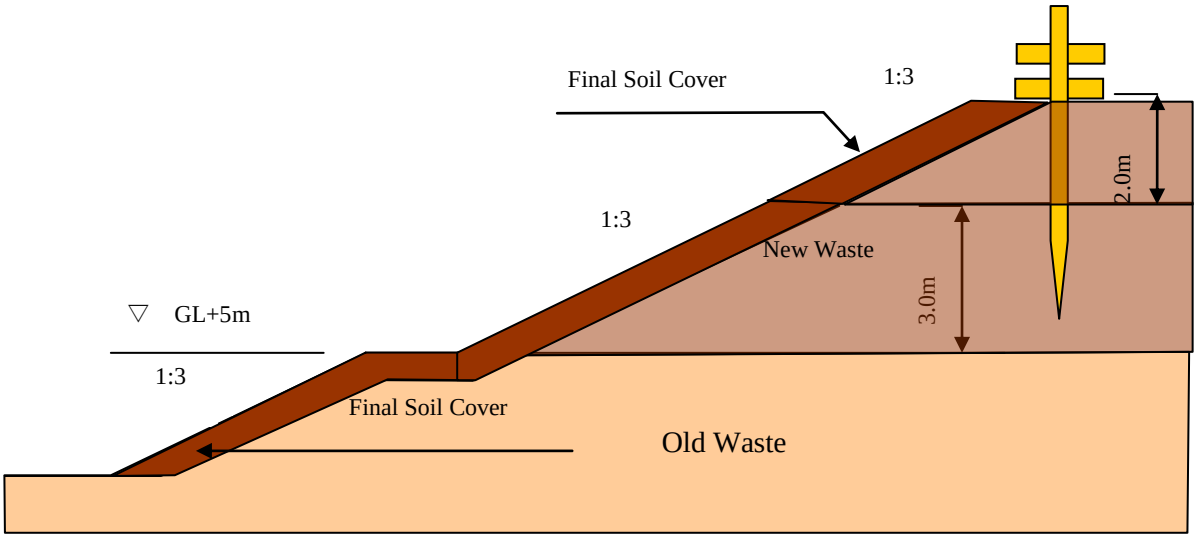
Exhibit 8-14
Second Layer



***Step 6:** Eastablishment of Final Soil Cover at the Second layer (3 – 5m)*

The final soil cover of the second layer shall be done considering the landmark mentioned in Step 4 and following the alignment established by poles and ropes. The establishment of final soil cover is shown in **Exhibit 8-15**.

Exhibit 8-15
Final Soil Cover

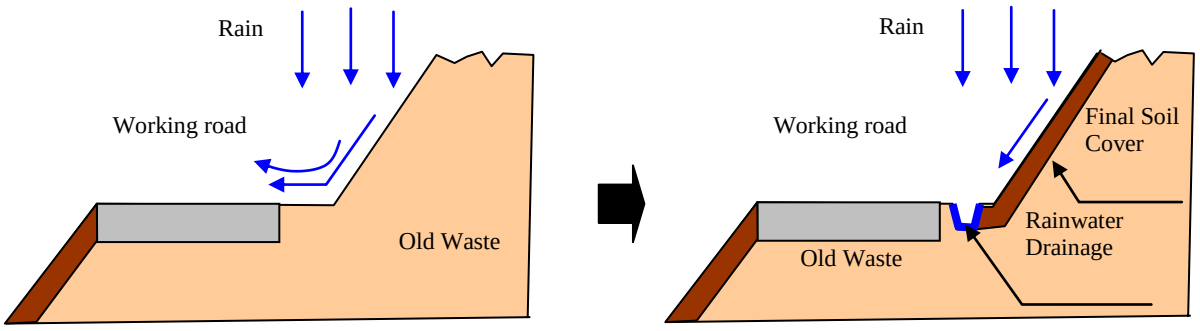


8.4.5 Drainage of Working Road

The working road is constructed on the waste is used by the waste-loaded vehicle to climb up the landfill for disposing waste at designated areas. Drainage congestion on the working road constructed by construction debris on old waste can make the road unstable and be the cause of failure. Hence, proper drainage of the working road and its surrounding area is very important for uninterrupted landfill operations.

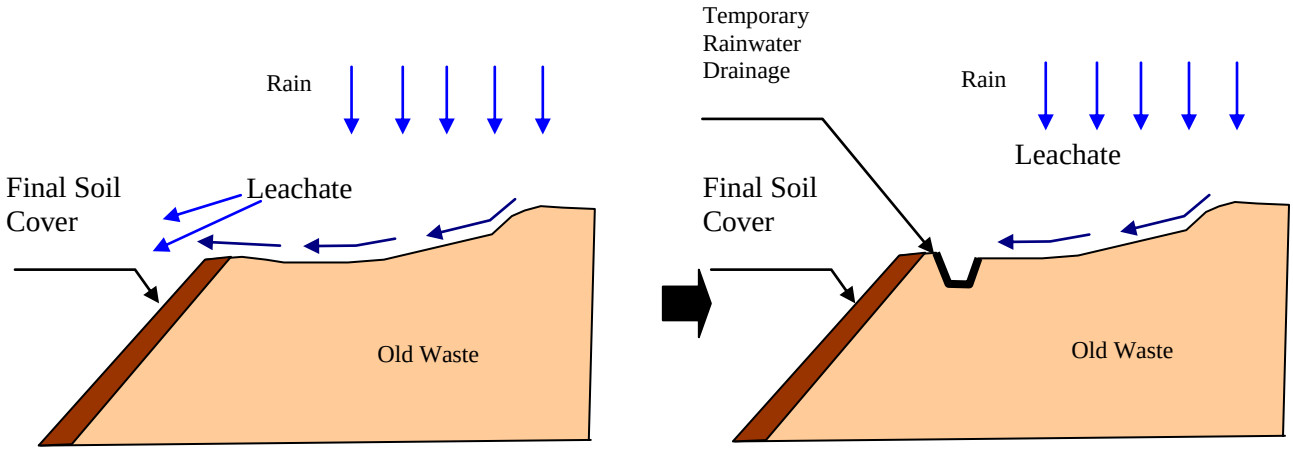
It is necessary to make properly sloped drains at the edge of the working road between the road and slope of waste with soil cover as shown in **Exhibit 8-16** before the rainy season so that rainwater cannot enter into or under the working road and make it unstable. If there is a possibility of producing leachate by mixing of rain water and waste, then the drain is to be connected to the nearby gas vent pipe. If rainwater or leachate accumulation occurs in any location of the landfill, a drain should be constructed and connected to the nearest gas vent pipe. The final soil cover at the periphery of the landfill should be completed before the rainy season to minimize the generation of leachate.

Exhibit 8-16
Drainage at the Edge of Temporary / Working Road



If rainwater flows over the soil cover at slope, it will make rain cuts on the slope. Part of the rain water may also enter into the waste and push the soil cover as shown in **Exhibit 8-16** and make it unstable. In this case, the soil cover will be washed out. To prevent rain cuts and washing out of soil cover, temporary drains as shown in **Exhibit 8-17** should be constructed.

Exhibit 8-17
Construction of Temporary Drains at the Slopes

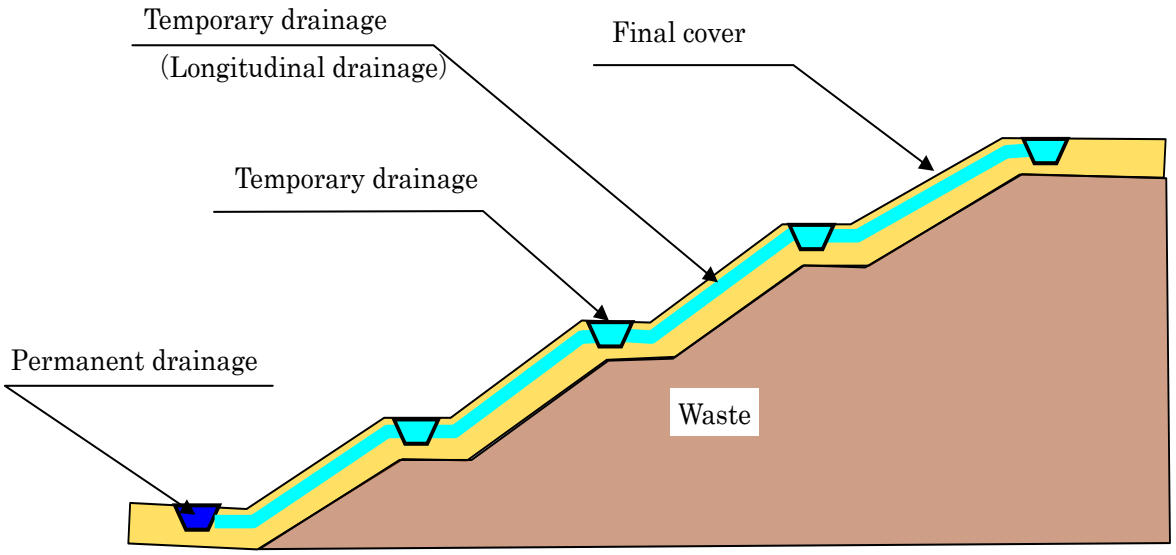


8.4.6 Temporary Drains

Temporary drains, in combination with earth bunds, may be constructed during the operation period to divert storm water from entering into active waste disposal area. The operators shall ensure that these drains do not convey water outside the site. The water collected in these temporary drains shall ultimately seep into the disposed waste and enter into the leachate collection system to be conveyed to the leachate ponds. Once the temporary drains have served their purpose they should be reclaimed properly. No standing water shall be allowed in any part of the landfill.

Proper drainage of the side slopes shall be ensured in accordance with the progress of landfill through construction of longitudinal and traverse drain as shown in the **Exhibit 8-18** in order to protect the slopes.

Exhibit 8-18
Drainage Plan at the Slope

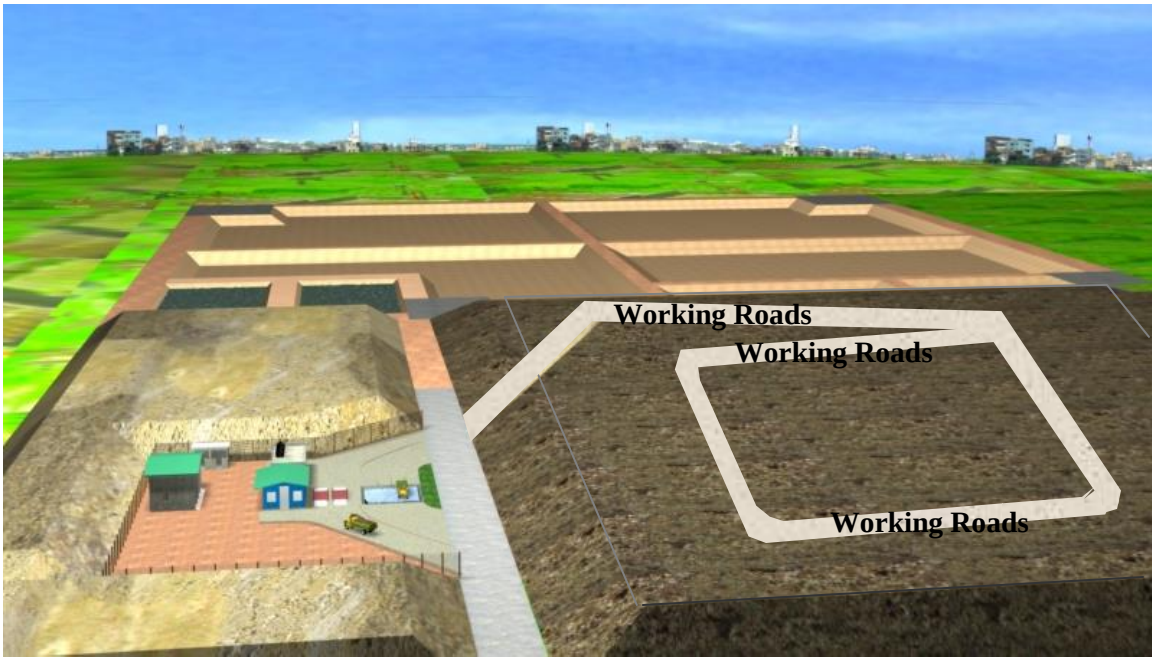


8.4.7 Construction and Operation of Working Road

Constructing and operating a working road are of great importance to keep the landfill operational in all seasons. In the rainy season, rainwater and leachate may accumulate on the working road. This will damage the road and make the waste carrying vehicle difficult to operate. It is necessary to raise the working road above the level of waste and land filling is conducted by push-down method from the working road.

Since construction work for raising the level of working road by increasing the height of landfill is a continuous process, the ULB shall ensure availability of enough construction debris at site for use as and when required. For this purpose, the ULB shall set aside a site for storing construction debris at a suitable area. In order to ensure movement of the waste carrying vehicle at all times, steel plates may be used in the upper parts of the working road in the rainy season. Steel plates are welded with steel bars to avoid sliding. The width of the working road shall be 12m and built by construction debris by in 1-m thick layers over compacted old waste. The arrangement of the working roads is shown in **Exhibit 8-19**.

Exhibit 8-19
Working Roads



8.4.8 Leachate Pond Aeration

Aeration of the leachate in the leachate ponds by operating an air blower is important for biological treatment of the leachate. Aeration keeps the leachate aerobic and prevents odor emission from the leachate being discharged into the pond. The Operation Manual provided by the aerator manufacturer is to be followed for operation and maintenance issues.

8.4.9 Leachate Recirculation and Sludge Disposal

Leachate recirculation shall be performed to allow to increase the decomposition rate of waste and provide further treatment of the leachate by exposing it to anaerobic conditions.

During the dry seasons the leachate recirculation shall be done regularly to reduce the cost of operating the treatment plant and to moisten the disposed waste. This hastens the decomposition process. However, during the rainy season the recirculation shall be done as required to prevent overflow of the leachate pond. Crushed brick or stone bed connected to

stone jacket around the gas vent pipes should be installed for receiving recalculated leachate. Crushed stone or bricks will work as a trickling filter and enhance treatment of leachate.

The accumulated sludge in the sedimentation pond and at the bottom of aeration pond shall be pumped as and when required and deposited over the disposed waste in the landfill.

8.4.10 Gas Vents Extensions

As the waste height increases it will be necessary to increase the height of the gas vents. This will be necessary in order that the gas vents continue to passively expel the generated landfill gas and introduce air into the disposed waste layers. The operator shall use perforated PVC vent pipes surrounded by aggregate in a cage built by wire mesh or mesh made of bamboo slices. The landfill staff shall ensure to maintain the vents free of any foreign materials.

8.4.11 Special Waste Handling

The ULB's landfill site is not designed to handle special waste (e.g. liquid waste, chemical waste, hazardous waste, etc.). Should such waste be delivered to the site, the truck hauling these wastes shall be refused access when detected at the entrance of the site or control area. Trucks may or be directed to re-load and remove the waste should the nature of the waste be detected during the unloading operation.

8.4.12 Landfill Equipment Maintenance

In principle, simple repairs and daily inspection of the heavy equipment shall be carried out at the site. For this purpose, the landfill staff shall include a mechanic with an assistant. The site shall also have some spare parts, and required equipment for the maintenance.

For larger maintenance work the equipment will be transported to the ULB central workshop or a qualified workshop in the ULB. All equipment will have a maintenance record identifying the dates of inspections, repairs, and maintenance. The contents of each input data will be described in detail. For light equipment, such as an aerator, pump, and generator there shall be daily maintenance checks for oil and lubricants. The operator stationed at the site should also be capable of providing simple repairs for these equipment.

8.5 Emergency Management

8.5.1 Types of Emergencies

Managing crises at the landfill requires a contingency plan. The contingency plan should include the following types of emergencies.

1. Failure of embankment;
2. Fires;
3. Release of methane or other noxious fumes;
4. Chemicals or fuel spills;
5. Earthquakes;
6. Flooding and heavy rains;

7. Accident with vehicles or heavy equipment;
8. Landslides or massive settlement; and
9. Explosion, etc.

There might be other emergencies such as a blockage of the access road to the site by the surrounding residents, collapse of road, vehicle failure, injuries of the operating staff, utilities failure or shortages, unauthorized scavenging and waste picking activities in and around the landfill, etc.

8.5.2 Emergency Management and Contingency Plan

The intent of this section is to provide a guideline to identify the potential emergencies at the landfill site. A separate Emergency Management and Contingency Plan (EMCP) needs to be prepared and distributed to the staff at the site in order to make them aware and train them on the emergency response procedures. The landfill management unit of ULBs should visit the Dhaka South City Corporation landfill in this regard.

8.5.3 Emergency Response

Hazardous, Toxic, and Infectious Waste

In the event of any hazardous, toxic, or infectious waste found at the active waste disposal area, site personnel should not attempt to cleanup such materials. The personnel will inform the management and a specialized person or company should be immediately contacted to identify the waste and its clean-up. The following procedure should be followed.

1. Immediately cordon off area where suspected materials are found;
2. Inform the management about the incident;
3. Relocate the working force as required;
4. If possible, identify the materials;
5. Contact a person or company specializing in hazardous and toxic materials management and assist them to identify and remove the suspected materials as required;
6. Prepare a full report with supporting documentation for submission to the relevant authorities.

Fire

Fires that may occur in the landfill waste should be controlled by using fire extinguishers and then covering the burning materials with additional soil or sand. Once the fire is extinguished, the cell containing the burned materials will be excavated, removed, and spread out in an isolated area of the site. Following confirmation that all burning materials have been extinguished, the waste will be covered with a minimum of 15 cm of soil. Special care shall be given in case the leachate pipe or gas pipe catches fire. Replacing the pipe may be necessary. The following actions will be taken if a fire occurs in the refuse fill area.

1. Burning refuse will be buried immediately with cover soil;

2. If the fire is within the reach of the leachate recirculation system, leachate may be pumped on the fire.

3. The Fire Department will be summoned if the site personnel and equipment cannot extinguish the fire. The contact information of the closest fire department should be available at the site.

4. If the fire occurs at areas outside the active waste disposal areas, maximum effort shall be made to prevent the fire from spreading to the waste areas. One method may be to excavate a fire break between the active waste disposal areas and the oncoming fire.

Earthquake

Should a strong earthquake occur, the ULB should suspend the landfill operation in order to assess the damage of the site facilities. These facilities include, but are not limited to the embankment, roads, administration buildings, gas vents, leachate collection and treatment facilities, and utilities supply networks. The damages shall be repaired after this assessment.

Severe Wet Weather Conditions

If there is severe rainfall and fear exists of the collapse of the landfill slopes or the disposed waste, then it is necessary to suspend operation and take necessary actions such as applying cover materials and compacting the affected areas once the storm has abated.

1. If the side slopes collapse, urgent repair will be made and side slopes are to be brought to their original shape by excavator. Soil covers are to be provided and properly compacted.

2. Drainage congestion, if found in some area, shall be urgently drained by excavating drainage channel.

3. The temporary roads are to be checked and repaired, if required.

Access Road Problems

Should there be any transportation disruption to and from the site due to the collapse of the access road or parts of the access road, the landfill operator should notify the relevant officers of the ULB or the Department of Roads and Highways for them to take appropriate and prompt action.

When the road within the landfill collapses, immediate repair work is to be done or a by-pass arrangement should be made to keep the landfill operational. A temporary road may be constructed if the situation requires it. In such cases, temporary roads with steel plates may be constructed for time being used.

In case of collapse of the temporary road used by the vehicles to climb up on the landfill for disposal of wastes, repair should be immediately started using construction debris. Adequate quantities of construction debris are to be stored in area of the landfill for this purpose. An alternative temporary arrangement shall be made to store the incoming wastes at the site until the temporary road is made operational. The permanent platforms may be such sites.

Should the access road problem remain unresolved, then it may be necessary to suspend land fill operation.

8.6 Post Closure Plan

8.6.1 Introduction

Closure of the site shall be accompanied by restoration to prepare the final landform by spreading the soil and site maintenance during a post closure period. The aftercare will include taking steps during and after restoration to bring the land up to the required standard for after use by cultivating, fertilizing, and draining the land to sustain vegetative growth.

The potential for environmental problems such as grounwater contamination by leachate, waste washout due to flooding, slope failures and landslides, landfill gas migration, odor problems, and uncontrolled fires can still exist after site closure. Thus, upon cessation of activities (i.e. waste disposal), necessary measures are to be taken to avoid any pollution risk and to develop the site to a satisfactory state. The activities to be carried out during post-closure period are discussed in the following sections.

8.6.2 Capping of the Site

The capping system is the final component for constructing the landform. It consists of engineering and restoration of surface layers. The restoration layer is layer of earthen material of at least 1.0 m thick which will support native plant growth and thus enable the site for its planned use. If the ULB prepares a specific plan such as grass turfing, forestry, golf course etc. in the top land surface, it should consult an agricultulturist to maintain soil nutrient level for specific plants.

The engineered layers of the cap will comprise, as a minimum of the following itemsl

1. A barrier layer that may be of compacted clay, geo-membranes, or geo-synthetic clay to reduce infiltration of water into the waste and escape of gas from the waste;

2. The top surface must be finished on a slope towards the edge of the landfill so that the rainwater quickly flows to the edges gutters to join the drainage system;

3. A gas collection layer may be composed of gravel, sand, geo-textiles, or geo-nets to transmit gas to collection points; and

4. If gas collection is planned, the existing gas vents are to be used as wells for gas collection after the closure of the landfill.

8.6.3 Management of Leachate and Gas

The equipment used for leachate collection and gas venting and control are to be maintained in good condition in the post-closure period. Treatment of leachate shall cintinue as long as leachte is collected through the leachate collection system. The ULB may plan to collect methane gas for use as a source of energy if the amount of gas produced in the landfill is sufficient for cost-effective power generation.

8.6.4 Settlement Monitoring and Maintenance of Final Soil Cover

During the aftercare period, the site operator shall consider two types of settlement for monitoring.

1. Settlement of the wates due to decomposition and stabilization of the waste in the landfill;

2. Settlement associated with stability of the site including slopes and associated structures.

Investigation of the settlement potential and physical stability of the site are to be undertaken using theoretical and practical investigations. The investigation will consider the composition and density of the waste deposited. Assessing the magnitude of settlement and settlement trends, and identifying and assing the stability slopes and structures are required.

The soil cover constituting the final cap must remain stable and checks must be made to identify cracking of the capping layer. Regular maintenance is required to repair the effects of settlement, subsidence, or erosion.

8.6.5 Surface Run-off Control

In order to maintain effective surface run-off, the integrity of the final cover must be maintained after closure. The cracks, depressions, rain cuts, and erosion appearing on the capping layer need regular repair and maintenance. Monitoring for surface water should continue during the post closure period.

The surface drains in the landfill area must remain operational and well maintained for quick and efficient drainage of the whole landfill area. Where pipes or drainage systems have been laid during the land fill construction, they are to be checked and repaired if necessary. In the event that modifications are necessary in order to maintain effective surface drainage controls, such changes are to be undertaken as long as practicable.

8.6.6 Monitoring of Other Facilities

Roads and other site infrastructure are to be maintained in accordance with the post-closure plan. It will also be necessary to maintain site security and keep the site free from vectors.

8.7 Environmental Management

Many types of pollution may occur unless proper protection measures are taken very seriously. The major adverse impacts during the operational phase of the landfill include possible pollution of surface water bodies affecting fisheries and agriculture; groundwater contamination, drainage congestion, leachate flooding, increased air, odor and noise pollution; and occupational health and safety issues for waste pickers and people involved in landfill operation. Leachate generated in the landfill has extremely high potential for polluting groundwater and surface water sources in the area. Although dikes have been constructed around the landfills to confine the waste and its degraded products, oozing of leachate is common during high rainfall. This can cause severe surface water pollution around the landfill site damaging the fishery, agriculture, and aquatic environments. The clay layer under the landfill is considered as an adequate barrier against groundwater pollution but short circuiting of leachate through an undetected permeable layer poses a threat to groundwater pollution.

Local drainage congestion, filthy environment, breeding of flies and mosquito, obnoxious odor in the surrounding, and fire hazards as well as air and noise pollution are some of the potential adverse environment impacts during construction and operation phases of landfill. These are common adverse effects of improper design and operation of landfill facilities. Occupational health and safety of the workers at landfill site including the waste pickers are

of great concern. These vulnerable groups of people risk their health primarily from increased exposure to hazardous materials, pathogens, and unhealthy environment. The ULB and the contractor workforces involved in landfill operation are exposed to higher risks at the landfill site. Obstructing the regional drainage system may also cause environmental problems in the area.

ULBs should consider hiring external consultants and contractors support for environmental management of landfill that includes pollution control measures, monitoring, and reporting regularly. Nearby universities may be contacted so that the ULB can use the quick monitoring results from the university laboratory.

Appendix A

Operation of Standing Committee for O&M

Step 1. The ULB Mayor will establish a standing committee for O&M as per provision of Article 55(2) of ULB, Act, 2009 or assign the Standing Committee on Transportation and Infrastructure with overall responsibility of O&M of ULB infrastructure (see 3.1.3). An official notification shall be issued in this context.

Step 2.The chairman will hold a standing committee meeting at least once every 3 months. In the first of such meetings, the standing committee can review its Terms of Reference (TOR) and existing situation of O&M activities including setting the agenda for the subsequent meeting.

Step 3. The agenda of standing committee meeting will be decided by analyzing the assigned functions and tasks of standing committee for O&M as listed below.

1. decide process of analysis of the assigned function of WG in performing their activities;
2. determine ways and means to oversee ULB O&M activities;
3. decide how to organize an awareness campaign to create sense of ownership among the citizens;
4. determine the process of involving TLCC and WLCC in O&M activities; and
5. monitor O&M progress activities performed by the WG.

O&M monitoring formats for standing committee are given below.

Asset Type: Road or Streets

Year: _____

Road Name: _____

Road Code: _____ Road Length: _____ (km)

Type of Road: _____ Location: _____

Item No.	O&M Indicators	Yes (Y)	No (N)	Not Applicable (N/A)
1.	Are the roads swept daily to dispose debris and dirt?			
2.	Are the roads properly crowned and super-elevated?			
3.	Are the unpaved parts of the roads (shoulders) well maintained with proper slope?			
4.	Are the footpaths and drain covers in good condition?			
5.	Are paved roads free of unacceptable potholes, cracks, or others damage?			
6.	Are the culverts generally unblocked and free running?			
7.	Are side drains generally free of significant standing water?			
8.	Are side drains generally clean (without vegetation, debris, etc.?			
9.	Are there any other indicators set by the committee addressed and solved?			

All applicable items must be marked “Y” in order to be classified as satisfactory. Based on this inspection, some details of which are shown above, it appears that O&M efforts for this particular ULB asset is (mark the appropriate item):

( ) Satisfactory ( )Not Satisfactory

Asset Type: Drainage Systems

Year: _____

Road Name (if applicable): _____

Road Code (if applicable: _____ Drain Length: _____ (km)

Type of Drain: _____ Location: _____

Item No.	O&M Indicators	Yes (Y)	No (N)	Not Applicable (N/A)
1.	Are the drains cleaned frequently and is sediment and debris removed?			
2.	Are the drains generally unblocked and free running?			
3.	Are side drains free of significant standing water?			
4.	Are the bottoms and sides of the drains free from erosion?			
5.	Are drain linings free of unacceptable damage?			
6.	Are all manhole covers and gratings intact and unbroken?			
7.	Are all connections from latrines to the drains removed?			
8.	Are the drain covers and slabs fixed and leveled properly?			
9.	Are the drain covers and slabs undamaged?			
10.	Are all utility lines (e.g. water supply, gas pipe, etc.) away from the drain so they do not block the flow of water?			
11.	Are there any other indicators set by the committee addressed and solved?			

All applicable items must be marked “Y” in order to be classified as satisfactory. Based on this inspection, some details of which are shown above, it appears that O&M efforts for this particular ULB asset is (mark the appropriate item):

( ) Satisfactory ( ) Not Satisfactory

Asset Type: Water Supply

Year: _____

Component Name: _____

Component Code: _____ Location: _____

Pump House

Item No.	O&M Indicators	Yes (Y)	No (N)	Not Applicable (N/A)
1.	Is the pump house clean and generally in good condition?			
2.	Is the pump operational (no abnormal sound/vibration during operation) and operation and shut down time recorded in log book regularly?			
3.	Is the panel board in good condition (pilot lamp, AV meter, fuse, phase detector, starter, etc in good condition)?			
4.	Is adequate voltage (380~440) for pump operation available for 24 hours?			
5.	Is bulk water meter operational and production and supply quantity is recorded in log book regularly?			
6.	Is the sluice valve in good operating condition (no water leakage through gland packing)?			
7.	Is the pressure gauze functional?			
8.	Is the static and pumped water level is recorded regularly?			
9.	Is the non-return valve in good operating condition?			

All applicable items must be marked “Y” in order to be classified as satisfactory. Based on this inspection, some details of which are shown above, it appears that O&M efforts for this particular ULB asset is (mark the appropriate item):

( ) Satisfactory ( ) Not Satisfactory

Asset Type: Water Supply

Year: _____

Component Name: _____

Component Code: _____ Location: _____

Overhead Tank

Item No.	O&M Indicators	Yes (Y)	No (N)	Not Applicable (N/A)
1.	Is the OHT in good condition and no leakage/soaking of water?			
2.	Is bulk water meter functioning and supply quantity is recorded in log book regularly?			
3.	Is the sluice valve in good operating condition (no water leakage through gland packing)?			
4.	Is the water level indicator functional?			
5.	Is the OHT cleaned regularly and recorded in log book?			

All applicable items must be marked “Y” in order to be classified as satisfactory. Based on this inspection, some details of which are shown above, it appears that O&M efforts for this particular ULB asset is (mark the appropriate item):

( ) Satisfactory ( ) Not Satisfactory

Asset Type: Water Supply

Year: _____

Component Name: _____

Component Code: _____ Location: _____

Water Supply Network

Item No.	O&M Indicators	Yes (Y)	No (N)	Not Applicable (N/A)
1.	Is the water pressure at consumers' end satisfactory?			
2.	Is the transmission/distribution pipe line in good condition and no water leakage or breaking of pipe?			
3.	Is the regulating sluice valve in good operating condition (no water leakage through gland packing)?			
4.	Is the supply water clean, without turbidity, and no bad smell?			

All applicable items must be marked "Y" in order to be classified as satisfactory. Based on this inspection, some details of which are shown above, it appears that O&M efforts for this particular ULB asset is (mark the appropriate item):

( ) Satisfactory ( ) Not Satisfactory

Asset Type: Water Supply

Year: _____

Component Name: _____

Component Code: _____ Location: _____

Service Connections

Item No.	O&M Indicators	Yes (Y)	No (N)	Not Applicable (N/A)
1.	Is the service connection in good condition and no leakage or breaking of connection pipe?			
2.	Is the water consumption meter functioning?			
3.	Is the consumer reservoir (roof tank or ground reservoir) in good condition, no leakage or overflow of water (overflow check valve functioning), and cleaned regularly?			
4.	Are all of the yard and in house taps water tight with no wastage of water?			
5.	Are the consumers satisfied with the quantity and quality of water?			
6.	Is the supply water bacteriological safe (routine residual chlorine and e-coli test of water sample from consumers' taps and recorded in register?			

All applicable items must be marked "Y" in order to be classified as satisfactory. Based on this inspection, some details of which are shown above, it appears that O&M efforts for this particular ULB asset is (mark the appropriate item):

( ) Satisfactory ( ) Not Satisfactory

Asset Type: Water Supply

Year: _____

Component Name: _____

Component Code: _____ Location: _____

Treatment Plant

Item No.	O&M Indicators	Yes (Y)	No (N)	Not Applicable (N/A)
1.	Is the treatment plant clean and generally in good condition?			
2.	Is the effluent clear and turbidity free?			
3.	Is the specified quantity of chemicals used in coagulation of raw water?			
4.	Is the sedimentation chamber clean (no floating particles like leaves, grass, etc)?			
5.	Is the filter bed clean and filter run between two backwash and rate of filtration satisfactory (no clog in filter bed)?			
6.	Is the backwash done at regular interval and backwash duration and expansion of filter bed during backwash satisfactory?			
7.	Is the clear water reservoir clean and required chlorination is made regularly?			
8.	Is the high lift or low lift pump operational (no abnormal noise during operation)?			
9.	Is the panel board in good condition (signal lamp, AV meter, fuse, phase detector, starter, etc. in good condition)?			
10	Is adequate voltage for pump operation available for 24 hours?			
11.	Is the bulk water meter operational and production and supply quantity is recorded in log book regularly?			
12.	Are the sluice valves in good operating condition (no water leakage through gland packing)?			

All applicable items must be marked “Y” in order to be classified as satisfactory. Based on this inspection, some details of which are shown above, it appears that O&M efforts for this particular ULB asset is (mark the appropriate item):

( ) Satisfactory ( ) Not Satisfactory

Asset Type: Public Buildings

Year: _____

Asset Name: _____

Asset Code: _____ Location: _____

Item No.	O&M Indicators	Yes (Y)	No (N)	Not Applicable (N/A)
1.	Are there "Exit" signs where required and are they illuminated?			
2.	Are fire extinguishers and fire hoses in place?			
3.	Have fire extinguishers been checked and tested as required?			
4.	Does the fire alarm system work?			
5.	Do doors open and close smoothly and lock security ?			
6.	Is there any emergency door where needed and does it function properly?			
7.	Are plumbing fixtures in good condition without rips or leaks?			
8.	Are the floors clean?			
9.	Are any stairways (treads, hand rail) in good condition ?			
10.	Is the roof in satisfactory condition with no evidence of leakage?			
11.	Are all windows intact and not broken?			
12.	Are all lights operating?			
13.	Are any air filters clean?			
14.	Are exterior walkways and steps in good condition?			
15.	Is the building generally (interior and exterior walls, floors, etc.) in good condition?			
16.	Are there adequate supplies (light bulbs, filters, cleaning supplies, etc.) on hand?			
17.	Are the open yards free from standing water, debris, grease, oil, etc.?			
18.	Are there any other indicators set by the committee addressed and solved?			

All applicable items must be marked "Y" in order to be classified as satisfactory. Based on this inspection, some details of which are shown above, it appears that O&M efforts for this particular ULB asset is (mark the appropriate item):

( ) Satisfactory ( ) Not Satisfactory

Asset Type: Kitchen Markets

Year: _____

Asset Name: _____

Asset Code: _____ Location: _____

Item No.	O&M Indicators	Yes (Y)	No (N)	Not Applicable (N/A)
1.	Is there daily garbage collection service?			
2.	Are the floors of all platform and shades clean?			
3.	Are the buildings generally (interior and exterior walls, floors) in good condition?			
4.	Are the internal walkways in good condition?			
5.	Are any open yards free from standing water, debris etc.?			
6.	Are the drains cleaned frequently?			
7.	Are sediment and debris removed?			
8.	Are there any other indicators set by the committee addressed and solved?			

All applicable items must be marked “Y” in order to be classified as satisfactory. Based on this inspection, some details of which are shown above, it appears that O&M efforts for this particular ULB asset is (mark the appropriate item):

( ) Satisfactory ( ) Not Satisfactory

Asset Type: Parks and Recreational Centers

Year: _____

Asset Name: _____

Asset Code: _____ Location: _____

Item No.	O&M Indicators	Yes (Y)	No (N)	Not Applicable (N/A)
1.	Are the park lawns mowed?			
2.	Are the turf areas without erosion and depressions?			
3.	Is the turf without weeds?			
4.	Is the turf aerated?			
5.	Is the playground mulch raked?			
6.	Are the plants and shrubs in planters healthy?			
7.	Are the planters without weeds?			
8.	Are the sidewalks without weeds?			
9.	Are the parking lots without weeds?			
10.	Are the parking lot curbs without weeds?			
11.	Are the men's restroom toilets working?			
12.	Are the men's restroom toilets clean?			
13.	Are the men's restroom urinals working?			
14.	Are the men's restroom urinals clean?			
15.	Are the men's restroom lights working?			
16.	Are the ladies' restroom toilets working?			
17.	Are the ladies' restroom toilets clean?			
18.	Are the ladies' restroom floors clean?			
19.	Are the ladies' restroom lights working?			
20.	Is the outdoor lighting working?			
21.	Are there any other indicators set by the committee addressed and solved?			

All applicable items must be marked "Y" in order to be classified as satisfactory. Based on this inspection, some details of which are shown above, it appears that O&M efforts for this particular ULB asset is (mark the appropriate item):

( ) Satisfactory ( ) Not Satisfactory

Asset Type: Street Lights

Year: _____

Asset Name: _____

Asset Code: _____ Location: _____

No.	O&M Indicators	Yes (Y)	No (N)	Not Applicable (N/A)
1.	Is the rating of the fuse and circuit breaker is correct?			
2.	Is the electrical equipment correctly installed properly earthed?			
3.	Are the columns and poles free from cracks, corrosion, defective welds, and insect infestation?			
4.	Are all bulbs intact and functional bulbs?			
5.	Do all bulbs operate every night?			
6.	Do billing meters give correct information and are they sealed?			
7.	Has the connection between the main distribution board and the sub-distribution board been checked in the past 15 days?			
8.	Are there any other indicators set by the committee addressed and solved?			

All applicable items must be marked “Y” in order to be classified as satisfactory. Based on this inspection, some details of which are shown above, it appears that O&M efforts for this particular ULB asset is (mark the appropriate item):

( ) Satisfactory ( ) Not Satisfactory

Asset Type: Collection and Transport

Date: _____, ULB Name: _____, Section Name: _____,

No.	O&M Indicator	Yes (Y)	No (N)	If no, then mention the fault	Not Applicable (N/A)
1.	Are the wastes collection vehicles being operated regularly and efficiently?				
2.	Are there any performance assessment indicators or benchmark indicators set by the ULBs for waste collection and transportation?				
3.	Is there any workshop for the ULB to repair and maintain the vehicles?				
4.	Is there SWM cell with sufficient personnel in ULB?				
5.	Are all the collection points (dustbins, container) served daily?				
6.	Does the ULB arrange meetings to set collection points or times with community?				
7.	Do the inspectors monitor the cleaners' (sweeper, scavenger) work regularly?				
8.	Is time harmonization made between primary and secondary collection to have better coordination ensuring smooth waste flow?				
9.	Is there any standing or monitoring committee for SWM in the ULB?				
10.	Is there any registration system or recognition system in the ULBs for the Primary Collection Service Provider?				
12	Is there any clear data base for ward wise waste amount and operational logistics allocated?				
11	Is there any data base for ward wise primary collection service providers?				
12	Is there any collection improvement plan?				
13	Are the waste collection timing known to the communities?				
14	A the open trucks equipped with sufficient cleaners and equipment?				
15	Are there any occupational health and safety guidelines or instructions for waste workers?				
16	Is there any waste collection monitoring system established?				
17	Is the street sweeping standardized by the ULBs (e.g., number of cleaners per given area)				

All applicable items must be marked "Y" in order to be classified as satisfactory. Based on this inspection, some detail of which are shown above, it appears that O&M for this particular ULB asset is (mark the appropriate item):

( ) satisfactory ( ) Not Satisfactory

Asset Type: Landfill

Date: _____, ULB Name: _____, Landfill Name: _____,

Landfill Area (acre): _____ Location: _____

No.	O&M Indicator	Yes (Y)	No (N)	If no, then mention the fault	Not Applicable (N/A)
1.	Do the vehicles follow directions of the landfill inspectors?				
2.	Are vehicles using the dumping platforms and designated places for disposal?				
3.	Is the compaction of waste by heavy equipment enough?				
4.	Are the landfill staff aware of occupational health and safety?				
5.	Is the landfill management providing safety gear regularly?				
6.	Do they keep a record of vehicle, trips/day?				
7.	Do they keep a record of waste amount disposed in the landfill daily as ton/day?				
8.	Is there any weighbridge established in the landfill site?				
9.	Is there any facility for vehicle washing?				
10.	Is car washing done regularly for each vehicle by the facility using spray nozzle?				
11	Is the cell management system established and informed to all the landfill staff?				
12	Is there adequate budget for daily and final soil cover and other daily operational costs?				
12	Are there sufficient of staff to operate and maintain the landfill operation and facility service?				
13	Is the slope management is done properly to drain water and to reduce leachate?				
14	Is environmental monitoring done regularly?				
15	Is there an Environmental Management Plan?				
16	Is the staff aware of working and temporary roads, temporary drains and can they construct them?				
17	Does the ULB have emergency plan for the landfill?				
18	Can ULB staff operate the landfill in severe weather condition?				
19	Is the leachate treatment done properly and regularly?				
22	Is there storage of adequate quantities of construction debris in the area of the landfill?				
23	Is there a signboard, markings and flood lights in the landfill?				
24	Are there fencing, gates and guards for the landfill?				

All applicable items must be marked “Y” in order to be classified as satisfactory. Based on this inspection, some detail of which are shown above, it appears that O&M for this particular ULB asset is (mark the appropriate item):

( ) satisfactory ( ) Not Satisfactory

Step 4. The standing committee will summarize findings from inspections and monitoring all infrastructure, discuss issues as agenda in meetings, give feedback to the working group, and follow-up actions in the subsequent meeting.

Step 5. The Standing Committee will prepare the notice of invitation for the standing committee meeting with predetermined and miscellaneous agenda for discussion and decision. WG members should also be invited to attend the meeting.

Step 6. It is mandatory to hold a meeting of the standing committee at least once in 3 months, writing the meeting minutes, distributing the minutes among members of standing committee, Mayor, and WG members for implementation of decisions and follow up action. The following formats can be used for preparing the minutes of Standing Committee meetings.

ULB Name: _____

O&M Working Group's Meeting Minutes

Date: _____ Time: _____ Attendance: (Annex)_____

Chairperson of Meeting: _____

Agenda 1
Read & Confirm Last Meeting Minutes

Read by	Discussion on Proper Recording of Meeting Minutes	Necessary Correction or Changes (if any)	Discussion

Agenda 2
Review of Progress of Implementation of Last Meetings Discussion

No.	Decision and Recommendations from Last Meeting	Review of Progress and Present Condition	Next Decision or Recommendation	Person Responsible
1.				
2.				
3.				
4.				
5.				

Agenda 3
Pre-selected Agenda Issues

No.	Agenda Issues	Detail Discussion	Decision and Recommendation (with time schedule)	Responsible Person
1.				
2.				
3.				
4.				
5.				

Agenda 4
Miscellaneous

No.	Agenda Issues	Detail Discussion	Decision and Recommendation	Person Responsible
1.				
2.				
3.				
4.				
5.				

Prepared by: _____ Signature: _____

Appendix B

Functioning of Working Group

Step 1. The Mayor will form a Working Group (WG) with the head of the engineering division as convener. Other members will be the Secretary, Health Officer, Town Planner, and SDO for A-Category Municipalities and the relevant section heads. To this effect an official notification will be issued stating its formation, functions, and responsibilities.

Step 2. The Convener will hold a WG meeting at least once every month. In the first meeting, the WG will review existing O&M practices and decide issues to be included as agenda of the meeting.

Step 3. The WG members will attend ward level general meetings to collect information about the maintenance requirements of the concerned Ward.

Step 4. The agenda of the WG meeting will be decided based on analysis of the existing O&M practices and the tasks as delineated in the IOMAP.

Following are some examples of agenda.

1. Analysis and deciding process for updating existing O&M practices.
2. Preparing a list of infrastructure requiring O&M and assigning responsibilities to the division or person in charge.
3. Advising for preparing inventories databases for each type of infrastructure for O&M.
4. Prioritizing infrastructure and type (routine, periodic, etc.) to be undertaken for O&M within the budget.
5. Support preparation of O&M schemes, tendering, contracting, implementation, and payment.
6. Support preparation of subproject O&M plan (e.g. subproject under MGSP), annual O&M plan, and their implementation.
7. Prepare annual O&M budget and pursue budget allocation.
8. Receive progress of O&M implementation from divisions, sections and persons in charge.

Step 4. Preparing a notice of invitation for WG meeting with predetermined and miscellaneous agenda for discussion and decision.

Step 5. Holding a WG meeting at least once every month, writing meeting minutes, and distributing them among its members. The Mayor and the convener of standing committee for O&M, will review progress of implementation in the subsequent meetings. A specimen format for preparing the minutes of the WG meetings is given below.

ULB Name: _____

O&M Working Group's Meeting Minutes

Date: _____ Time: _____ Attendance: _(Annex--____)_____

Chairperson of Meeting: _____

Agenda 1
Read & Confirm Last Meeting Minutes

Read by	Discussion on Proper Recording of Meeting Minutes	Necessary Correction or Changes (if any)	Discussion

Agenda 2
Review of Progress of Implementation of Last Meetings Discussion

No.	Decision and Recommendations from Last Meeting	Review of Progress and Present Condition	Next Decision or Recommendation	Person Responsible
1.				
2.				
3.				
4.				
5.				

Agenda 3
Pre-selected Agenda Issues

No.	Agenda Issues	Detail Discussion	Decision and Recommendation (with time schedule)	Responsible Person
1.				
2.				
3.				
4.				
5.				

Agenda 4
Miscellaneous

No.	Agenda Issues	Detail Discussion	Decision and Recommendation	Person Responsible
1.				
2.				
3.				
4.				
5.				

Prepared by: _____Signature: _____

Appendix C1

Infrastructure Inventories

Inventories may include information such as (i) Identification number, (ii) Type, (iii) Name, (iv) Location, (v) Size or Capacity, (vi) Year of Construction, (vii) Design Life, (viii) Present Condition, etc. However, required details of information vary from component to component.

A few specimen formats are given below for preparing inventories.

Road Inventory

Name of ULB: _____ Name of Surveyor: _____

Ward No: _____ Designation: _____

Road ID	Name	Location	Type	Size	Year of Construction	Design Life	Present Condition

Notes:

1. **Road ID**: Identification number used in the ULB road inventory Map
2. **Name:** Name of Road under inventory
3. **Location**: Ward number, start, and end point
4. **Type**: Construction Material type such as CC, RCC, BC, WBM, HBB, earth, etc.
5. **Size**: Right of way (m), width of pavement (m), width of footpath (m), width of shoulder (m), etc.
6. **Year of Construction**: The year in which the road was constructed.
7. **Design Life**: Expected design life of road
8. **Present Condition:**
   Good: The road section in question is in a satisfactory condition. No maintenance is needed in the short term. Normal routine maintenance to continue as planned.
   Fair: The pavement condition is such that a maintenance scheme is required.
   Poor: Certain repairs must be undertaken immediately to avoid an unusable or extremely dangerous road. A comprehensive maintenance scheme for repairs and overlays in the short terms is required.
   Critical: Maintenance cannot restore the pavement. The road qualifies as part of a road rehabilitation subproject.

Surface Drain Inventory

Name of ULB: _____ Name of Surveyor: _____

Ward No: _____ Designation: _____

Drain ID	Name	Location	Type	Size	Year of Construction	Design Life	Present Condition

Notes:

1. **Drain ID**: Identification number used in the ULB Drainage Map
2. **Name:** Name of drain under inventory
3. **Location**: Ward number, start, and end point
4. **Type: Construction Material:** Cement Concrete (CC), Reinforced Cement Concrete (RCC), Brick or Earthen with or without outfall in river, canal or ditches, etc.
5. **Size**: Drain section (width x depth) in meters if it is a rectangular section. If not, describe.
6. **Year of Construction**: The year in which the drain was constructed. If a natural waterway, state this.
7. **Design Life**: Expected design life of drain
8. **Present Condition:**
   Good: Smooth water flow, intact structures and surface with connection to clear outfall;
   Fair: Smooth water flow, nominal damage of structures with clear outfall
   Poor: Interrupted water flow, damaged structures, possibility of over-flooding with or without outfall
   Critical: Severe damage of structure, blockage, and flooding without defined outfall.

Street Light Inventory

Name of ULB: _____ Name of Surveyor: _____

Ward No: _____ Designation: _____

Street Light ID	Name	Location	Type	Size	Year of Installation	Design Life	Present Condition

Notes:

1. **Street Light ID**: Identification number used in the ULB Map
2. **Name**: Name of Road (street light) under inventory
3. **Location**: Ward number., start, and end point
4. **Type**:
   Bulb: Solar light, energy saving bulb, tube-light, florescent lamp, etc.
   Light Post: Steel, concrete, wooden, etc.
5. **Capacity**: Watts
6. **Year of Installation**: The year in which the street light installed
7. **Design Life**: Designed life of poles and wires
8. **Present Condition:**
   Good: Light posts are in good condition and fitting and fixtures are fully operational.
   Fair: Light posts are in good condition but fitting and fixtures are not fully operational or vice-versa.
   Poor: Light posts, fittings, and fixtures are not fully operational
   Critical: Beyond repairable stage.

Movable Asset Inventory: Road Rollers

Name of ULB: _____ Name of Surveyor: _____

Ward No: _____ Designation: _____

ID No.	Type	Source of Fund	Road Roller (equipment)	Condition	Buying Date	Last Repair Date

Notes:

1. **Type**: Plate Compactor, two-wheel road roller, three-wheel road roller, etc.
2. **Source of Fund**: Own, GOB, Project (mention project name if relevant)
3. **Road Roller**: Model No., Engine Capacity (cc), Capacity without Vibration (ton), Capacity with Vibration (tons)
4. **Roller Condition:**
   Good: Good engine condition and compaction capacity
   Fair: Fair engine condition and moderate compaction capacity
   Poor: Poor engine condition and poor compaction capacity
   Critical: Poor engine condition and no compaction capacity

Appendix C2

Prioritization

The following points shall be considered as indicators for prioritizing infrastructure and facility O&M.

- Routine maintenance of the infrastructure shall be emphasized over periodic maintenance;
- Arterial roads including bridges and culverts shall be emphasized over tertiary roads;
- Roads linked with Upazila and Union roads shall be prioritized;
- The infrastructure built by development partners including MGSP shall be prioritized;
- The infrastructure benefitting more people shall be prioritized;
- The infrastructure located in the ward in which the citizens paid more tax compared to other ward shall be prioritized;
- Infrastructure having significant environmental conservation and life influences shall be prioritized; and
- Social and commercial importance of the infrastructure.

Appendix C3

Subproject O&M Plan

Operation & Maintenance of subproject after construction, improvement, or rehabilitation shall be conducted in 3-year cycles. The first 2 years will cover routine maintenance (e.g., cleaning and repairing shoulders as well as pothole repair for road subjects, etc.) and the third year for sealing and overlay. This cycle requires the ULB to set aside one percent of the subproject cost for each of first and second year and 5% for the third year. The ULB is required to commit this allocated amount for implementingthe O&M subproject plan as part of subproject planning under MGSP. This O&M cycle should be conducted during the design life of the facility by the ULB engineering division. The format given below may also be used for preparing the Subproject O&M plan for each cycle.

Subproject ID No.	Facility	Name	Design Life	Implementation Cost (BDT)	Three Year Cycle			Source of Fund	Organization
					Year	Type	% (fund)		
					1	Routine	1%		
					2	Routine	1%		
					3	Periodic	5%		

Appendix C4

Annual O&M Plan

The annual O&M plan comprises the items such as organization, responsible people, necessary manpower to be contracted, hiring, schedule of works, O&M budget requirements, implementation schedule, etc. The format given below may be used for preparing of the annual O&M plans.

Annual ULB O&M Plan

Name of ULB: …… Financial Year: …. / ….

Type or Subproject ID No. (from inventory list)	Type of Infrastructure	Name of Infrastructure with Specification (location, length, capacity)	Type of Required Maintenance	Approved Estimated Cost (BDT)	Timeframe and Schedule		Responsible person
					Planned Start date	Planned End date	

Appendix D1

Budget Framework for O&M (Budget Allocation for O&M in Annual Budget)

Step 1. Review inventory of infrastructure and understand present situation.

Step 2. Conduct regular field visit to infrastructure by the persons in charge and update inventories.

Step 3. Assess O&M needs for routine maintenance and prepare fund requirement as fixed cost O&M item in the annual budget.

Step 4.Conduct survey for defect analysis and to specify required maintenance work. A specimen format for such survey may be seen in **Annex D1**.

Step 5. Assess financial needs for maintenance based on physical condition from field visit and survey reports (a format given in **Annex D2** may be used for such assessment).

Step 6. Review and discuss all such assessments received from different persons in charge of O&M as well as in the working group meeting. Compile and submit total O&M needs to the standing committee including the proposal for budget allocation by the end March every year. The standing committee can discuss it with the TLCC held in the 4th quarter of financial year.

Step 7. Review and discuss O&M the budget proposal in the standing committee, arrange a discussion in the TLCC meeting, and pursue allocation as clearly defined item for O&M in the annual budget (at least 25% of total budget).

Annex D1

Defect Analysis to Specify Required Maintenance Work

Name of Scheme: _____
ID Number: _____
Financial Year: _____

Inspected by: _____
Designation: _____
Date of Inspection: _____

No.	Infrastructure Element or Component	Defect, Damage, or Fault	Cause of Defect	Required Maintenance Work

Signature
Prepare by (Name and Designation)

Signature
Checked by (Name and Designation)

Annex D2

Assessment of Financial Need for Maintenance (Based on Physical Condition)

Name of ULB: _____ Financial Year: _____

Type of Infrastructure	No.	ID No.	Name	Length (km/m)	Width (m/mm)	Year of Construction	Proposed Maintenance Need			Ward No.
							Effective Length or Area	Treatment	Approx. Cost (BDT)	
Total Estimated Cost										

Signature
Prepare by (Name and Designation)

Signature
Checked by (Name and Designation)

Appendix D2

Budget Framework for O&M (5-Year Budget Plan for O&M)

The 5-year O&M budget Plan will include:

- Estimated O&M cost;
- Available amount of budget earmarked for O&M; and
- A target amount of budget for O&M in each of the next 5 years.

The table below may be used for 5-year O&M budget plan.

Estimated O&M Cost

Name of Scheme	Estimated Cost of Construction	Year of Construction	Estimated Cost				
			Year 1 (0%)*	Year 2 (1%)*	Year 3 (2%)*	Year 4 (5%)*	Year 5 (5% +5% **) +inflation #

Available Amount of Budget

Year 1 (BDT)	Year 2 (BDT)	Year 3 (BDT)	Year 4 (BDT)	Year 5 (BDT)

Target Amount of Budget

Year 1 (BDT)	Year 2 (BDT)	Year 3 (BDT)	Year 4 (BDT)	Year 5 (BDT)

Note:
***** **5% for O&M of the construction cost;**
****** **5% increase over the 5% of construction cost;**
# **8-10% inflation over estimated O&M cost.**

Appendix E1

Annual O&M Plan Implementation (Progress Review of Periodic Maintenance)

Divisions, sections, or persons in charge will implement the Annual O&M Plan following the rules and procedure applicable for the purpose and will report to the working group. Usually maintenance of civil works (infrastructure) falls under periodic maintenance and implemented by engaging contractors. Repair and maintenance of roads, bridges and culverts, and buildings (office, auditorium, market, public toilet, drain, park, etc.) are the major civil works. A format for reporting process of periodic maintenance of infrastructure is given below.

Physical and Financial Progress of Periodic Maintenance

Financial Year: _____

No.	Name of Scheme	Quantity	Unit	Established Cost (BDT)	Contract Amount (BDT)	Name of Contractor	Contract Signed Date	Work Completion Date	Actual Start Date	Physical Progress Up To Previous Month (%)	Physical Progress Up To Report Month	Fin. Progress Up To Previous Month (%)	Fin. Progress Up To Report Month (%)

Signature: _____
Prepared by (Name and Designation)

Date: _____

Signature: _____
Checked by (Name and Designation)

Date**:** _____

Appendix E2

Annual O&M Plan Implementation (Progress Review of Routine Maintenance)

The other type of maintenance activities implemented regularly by ULBs, mainly by in-house arrangement, is routine maintenance. Road sweeping, cleaning drains, handling solid waste, operating public toilets and slaughterhouses, O&M of street lights, graveyards, parks, etc. fall under the category of routine maintenance. The working group members will monitor progress of routine maintenance, discuss it in the working group meetings, undertake remedial action, prepare a status report and submit it to the standing committee with recommendations. For this purpose, the working group can use the following format for collecting information from the person in charge.

Status of Routine Maintenance Report

Name of Facility: (e.g., kitchen markets) _____ Annual Budget (BDT): _____

Expenditure so far (BDT): _____ Financial Year: _____

No.	Description of Planned Routine Maintenance Work	Status of Compliance	Reasons for Non-compliance	Suggestions for Improvement	Remedial Action Undertaken

Appendix F

Process of Citizen Participation in O&M

Each ULB will design its own process and mechanism to ensure citizen participation in O&M planning and implementation. The standard settings, citizen participation fora in ULBs, are the TLCC, WLCC, CBOs, and SICs. TLCC at central level, WLCCs at ward level and CBOs & SICs are the community level citizen fora. The process of involvement of these fora in ULB O&M activities will depend on its social, economic, political, and other local conditions. However, the following steps may be helpful for citizen participation in O&M at the ULB level.

Step 1. The WG will prepare an inventory of infrastructure with involvement of members of WLCCs and CBOs and SICs.

Step 2. The WG will prepare draft annual O&M plan, subproject O&M plan, and 5-year O&M budget plan and inform WLCC members in WLCC for incorporating suggestions and recommendations.

Step 3. The WG will submit the draft to the TLCC for holding discussing the draft inventories, annual O&M plan, subproject O&M plan and 5-year budget plan. It will finalize these documents based on suggestions and recommendations of the TLCC.

Step 4. The WG will examine possible activities suitable for involvement of CBOs and SICs members at the O&M implementation level, particularly, for routine maintenance.

Step 5.The WG will also assist the WLCC to oversee implementation of both routine and periodic O&M activities within the ward boundary.

Step 6.The WG shall report O&M issues to the TLCC at least once every quarter.

Step 7. The TLCC will discuss the O&M report received from the WG in the quarterly meetings and document recommendations in the meeting minutes. It will also suggest action for consideration of the ULB authorities concerning implementation.

Appendix G

Technical Capacity for O&M

1. Technical capacity development efforts for O&M under MGSP shall be considered as the joint responsibility of project authorities (PMU, MSU of LGED) and project ULBs. The PMU, with assistance and cooperation from MSU will prepare O&M manuals and provide training courses on O&M. Training of Trainers (TOT) Courses for the senior officials responsible for O&M are very important.

2. It is the responsibility of ULB to make sure that all the relevant officials participate in the training courses on O&M and disseminate what they learned to relevant persons.

3. Project ULBs can constitute a training pool consisting of senior officials. ULBs should establish a Resource Corneras a part of the sustainable capacity development efforts.

4. All the manuals and other related documents are to be properly stored at the ULB (in the proposed Resource Corner) for study and conducting training courses.

5. The WG for O&M should organize training programs for CBOs and SICs members as well as for the contractual laborers engaged for routine maintenance. A training plan will be prepared at the beginning of the financial year and implemented as planned. On-the-job training procedure is preferred in this case.

APPENDIX H

OPERATIONAL GUIDELINES FOR COMPOSTING FACILITY

1. COMPOSTING

Composting is the process of bacterial conversion of organic solid and semi-solid wastes into compost which can be handled, stored and transported without any environmental risk and can be used as organic manure for improvement of soil quality and fertility.

1.1 Characteristics of Compost

Compost is a stable human-like product and a very good soil conditioner. It also supplements nutrients to soils. The important chemical characteristics of compost are shown in table below:

No.	Chemical constituents	Percentage by weight
1.	Organic matter	25~50
2.	Carbon	8~50
3.	Nitrogen (as N)	0.4~3.5
4.	Phosphorous (as P_2O_5)	0.3~3.5
5.	Potassium (as K_2O)	0.5~1.5
6.	Ash	20~60
7.	Calcium (as CaO)	1.5~7.0

The application of compost to agricultural lands brings significant favorable changes in the soil properties like:

1. increase organic contents of the soil;
2. increase moisture retention capacity;
3. improve aeration at root zone;
4. improve soil texture;
5. increase soil fertility;
6. replenish micro-nutrients in soil.

1.2 Basic Factors of Composting Process

Composting is a basically a biological process and dependent on several important factors. Some of the basic factors are listed below:

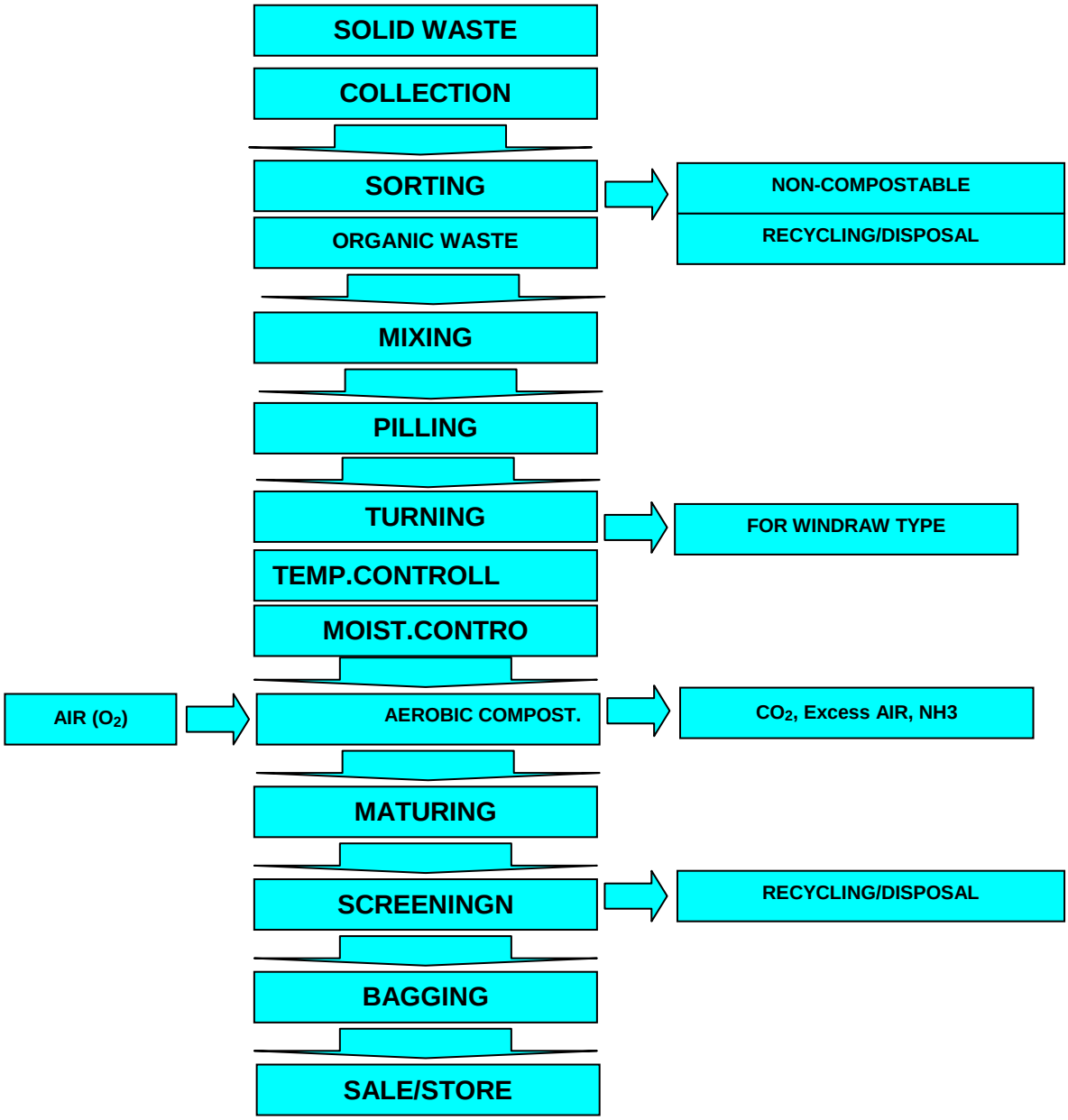
1. The waste material subject to composting must be bio-degradable.
2. Suitable numbers of and types of micro-organisms must be present.
3. The rate and efficiency of composting are dependent on the activity of the micro-organisms.
4. Environmental factors like pH, temperature and presence of oxygen control the composting process.
5. The waste must be nutritionally balanced.
6. The presence of toxic substances has adverse effects on the process.

Composting comprises of various steps starting from waste sorting until final bagging of composed product.

Composting process can be divided into nine steps as shown in fig.1. Waste from households arriving at the compost plant is sorted into several fractions. The organic fraction enters the composting process. It is mixed with additives if necessary and piled into composting system. The composting process has to be monitored by different parameters, of which temperature and moisture are most important. Finally, the matured compost is screened and prepared for selling. Residues from sorting and screening are recycled or disposed of. **Exhibit H-1** Flow diagram showing the basic process of Aerobic Composting.

Exhibit H-1

COMPOSTING STEPS



2. SELECTION OF WASTE FOR COMPOSTING:

All biodegradable waste can be used for composting. But the suitable wastes are:

Garden waste

- Leaves and grass
- Twigs

Food waste
- Vegetable and fruit waste
- Left over bread

Other waste
- Scrap paper/Card board
- Straw
- Meat

Wastes not suitable for composting are:
All sorts of hazardous waste

Residues
- Polythene
- Hard leaves
- Tree branches
- Bones
- Painted card board

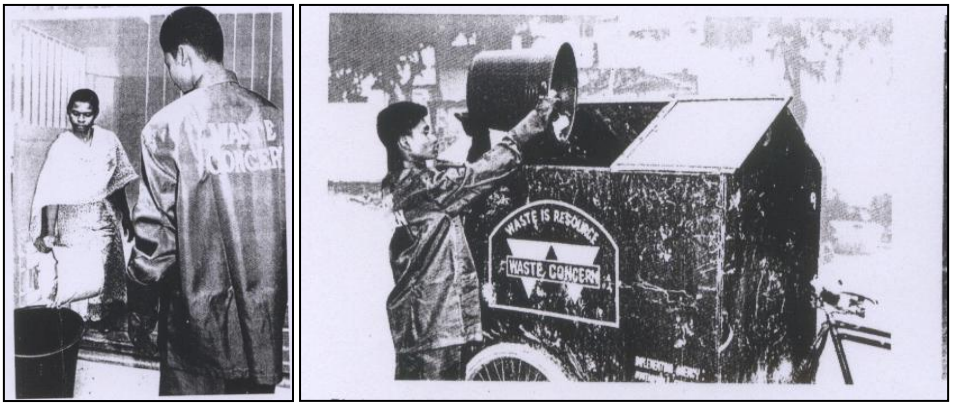
Recyclables
- Metal
- Paper
- Plastic scraps
- Glass
- Card board

3. COMPOSTING STEPS

5 Step-1: Collection

Waste preferably biodegradable from households and kitchen markets will be collected for composting. Kitchen waste should not be older than 2 days. Community may be motivated for segregation of waste at source.

Exhibit H-2
Door to door collection



If the household are willing to segregate their waste i.e. keeping organic and inorganic waste in separate container for collection by the community workers, It will save considerable labor for sorting of waste at plant and will be a plus point for a composting scheme. More over it will increase the quality of both biodegradable waste and recyclables.

Two to three rickshaw-vans may be employed for collection of biodegradable waste from households and kitchen markets closed to the compost plant for composting. Photograph 3.1 shows the collection of waste from household.

6 Step-2: Sorting

Compost quality mainly depends on the quality of the input materials. Hence sorting of waste plays a vital role. Waste not biodegradable need to be separated from the biodegradable fraction. Sorting is essentially required with regard to hazardous materials. To avoid contamination, they must be removed before the composting piles are formed.

Exhibit H-3
Sorting of waste

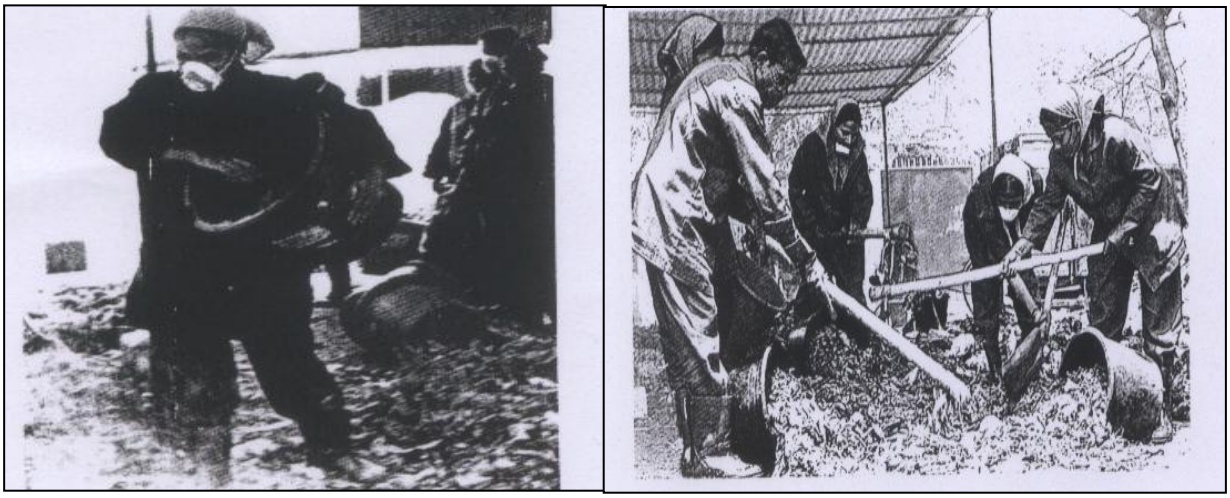
As soon as the mixed household / kitchen market waste arrives at the compost plant, it is separated manually into biodegradable materials, recyclables and rejects. Sorting of waste will be carried out on plant sorting platform. Rejects and recyclables are sorted into buckets and/or baskets. Recyclables are sorted for sale and rejects for disposal to landfill. After having finished the sorting process, the sorting platform is cleaned by water. No waste should remain overnight on the platform, as it will attract vermin and cause bad smell. In all cases handling of waste should be done wearing health protective clothing (gum-boot, hand gloves, musk, apron etc.). Photograph 3.2 shows the sorting of waste.

7 Step-3: Mixing (controlling parameter carbon-nitrogen ratio)

In composting process, the Carbon (C) Nitrogen (N) ratio called as C/N ratio is very important, as the biological degradation of waste largely depends on it. An optimum balance between carbon and nitrogen content is necessary the bacteria need a minimum supply of nutrients to survive. Bacteria use carbon as energy source and nitrogen for cell building. The initial C/N ratio is a deciding factor in the speed at which decomposition takes place. The ideal initial ratio is in the range 30:1~35:1. If the ratio exceeds 50, the time required increases considerably. At lower ratio ammonia is given off. Biological activity is also impeded at lower ratio. Generally, “green” material is high in nitrogen and “brown” material is high in carbon. In solid waste the main source of nitrogen is the vegetables/putrescible matter which has a C/N ratio of about 24:1, and paper is the main source of carbon. Thus, higher the ratio of paper to vegetable/putrescible matters, higher the C/N ratio. Fresh kitchen waste is reach in Nitrogen and paper, dried leaves, straw, sawdust etc. reach in Carbon.

It is recommended to keep the “brown” waste (mainly from park) separate from “green’ household waste and to add it later depending on the composition of household waste. If the Waste is very wet, then the fraction of brown materials is to be increased not only to correct C:N ratio but to reduce the moisture content and to increase air circulation, by adding saw dust, wood chips, etc.

Exhibit: H-4
Mixing of wood chips and thoroughly mixing and sawdust

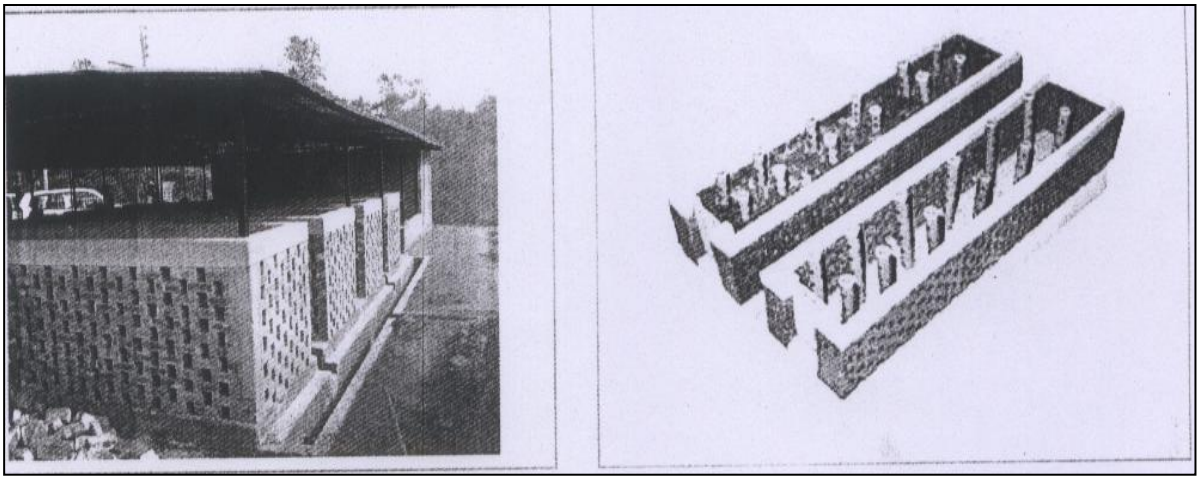


In practice, the ideal combination of wastes for composting must be determined by trials. It will take some time to learn the specifics of local waste. The plant manager should have keen sense of how to mix the different incoming waste and when to add sawdust, wood chips or animal manure. Organic screening residue from previous piles can be added to fresh piles as carbon source.

8 Step-4: Filling the Compost Box

Sorted organic waste is spread daily into the composting boxes loosely in layers of 200 mm thick. Typically, a box is filled within 5~7 days and the waste is rest there for about 40 days for aerobic decomposition before it is removed from the box.

Exhibit: H-5
Boxed type compost plant- box with perforated side wall and vertical ventilation pipe



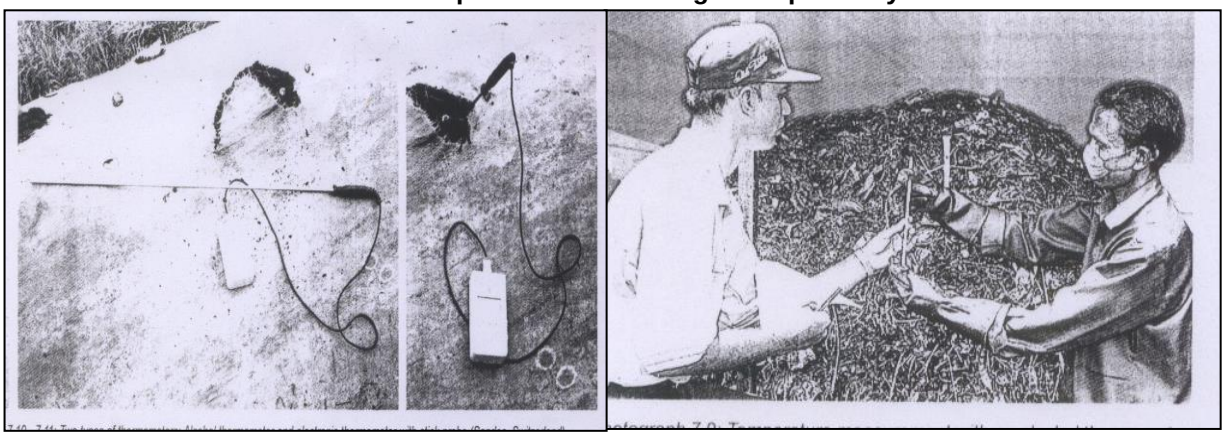
9 Step-5: Temperature Control

Temperature is a key factor affecting biological activity. Temperature and moisture of pile should be measured daily and adjusted for favorable composting process (favorable temperature is 45^0C~ 65^0C and moisture 40%~60%).

The microorganisms in the pile multiply exponentially provided that the C:N ratio, moisture content and the aeration are essentially within the optimal range. The optimum temperature (45^0C~ 65^0C) helps a large Varity of micro-organism to participate in the process. the

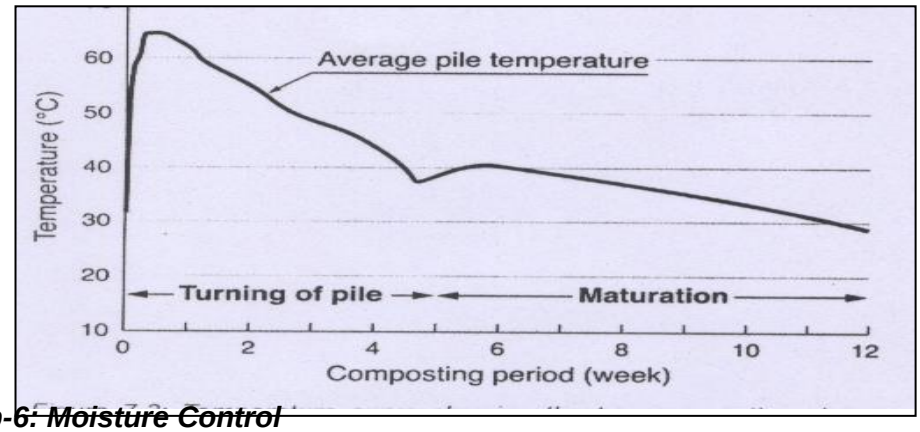
temperature generated (65^{0}C~ 75^{0}C within 1-2 days) by the thermophilic bacterial activity lead to the destruction of disease-causing organism. Higher temperature in the range 60^{0}C~ 70^{0}C should be maintained fo 24 hrs. for destruction of pathogen (disease-causing bacteria). Temperature above 70^{0}C need to be avoided, as they are high even for thermophilic bacteria and inhibit the microbial activity. Temperature above 80^{0}C is lethal to most soil microorganisms and the composting process comes to halt. Temperature around 65^{0}C is favorable for rapid composting and destruction of weed seeds, insect larvae and potential plant / human pathogen. So it is essential to maintain the temperature of the pile at around 65^{0}C for at least 3 days. After the first week, the temperature gradually decreases and the decomposition process slows down. The process that moves into mesophilic phase (45^{0}C~ 50^{0}C) and other microorganisms take over the transformation until the waste material is transformed into fresh compost.

Exhibit: H-6
Electronic thermometer with Temperature monitoring Stick probe by alcohol thermometer



The temperature of the pile is usually measured by thermometer. Alcohol or electronic centigrade thermometer may be used in temperature monitoring. It is advised not to use mercury thermometer as the mercury can pollute the entire compost if it brakes during taking measurement. To use alcohol thermometer, a hole within the pile up to the required depth is made first, then the thermometer is lower in to the hole carefully with a string. Thermometer is left there for 1 minute before pulling out by the string for temperature recording. The “temperature trends” should be recorded twice a day at three points (top, middle and bottom) within the pile. Ambient air temperature should also be recorded. If the temperature of the pile is too high, the pile is to be turned and sufficient water to be sprinkled to lower down the temperature.

Exhibit: H-7
Curve showing av. Pile temperature at ideal condition



10 Step-6: Moisture Control

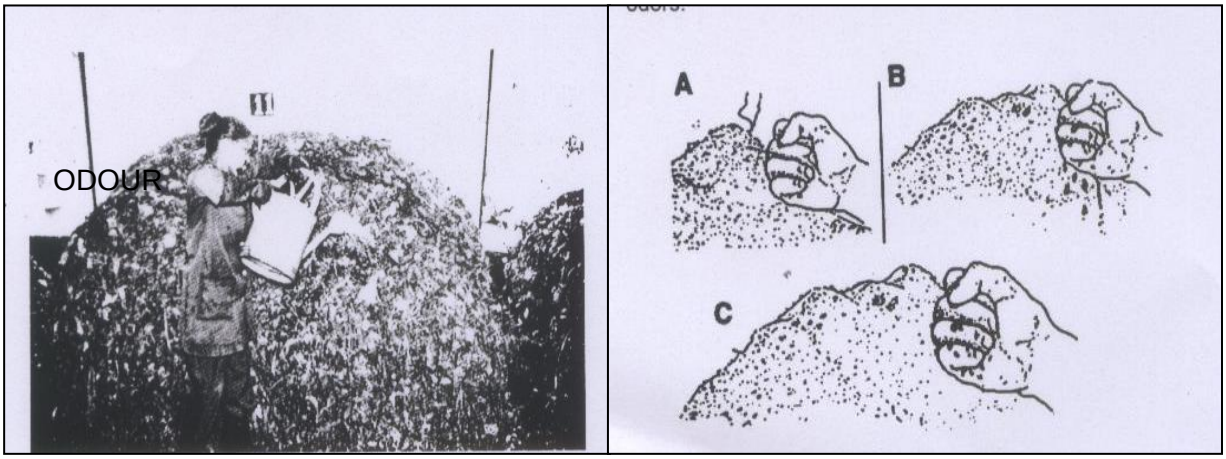
Moisture control of a composting pile is equally important as temperature control. Microbes take up nutrient only as dissolved ions in a film of water. Thus, the moisture content of a pile

plays as important role. For rapid decomposition, the moisture content level of a composting pile should be maintained in the range of 40%~60%, the being about 55%. A moisture level above 65%, water begins to fill the interstices between the particles of the waste reducing the interstitial oxygen and causing anaerobic conditions. This results in a rapid fall in temperature and starts producing offensive odor. When the moisture content drops much below 50%, the composting process becomes slow.

If the pile is too much dry, it is turned with sprinkle of water until optimal moisture content is reached. If the moisture content is too high, the pile needs to be turned and spread and left for dry before reforming. Sawdust or wood chips may be added to absorb excess moisture.

For quick and simple test of moisture content, take a handful of compost and squeeze it hard. If no drops emerge, the moisture content is bellow 40% indicating the nutrient process is hampered resulting in slow down the composting process (Fig. A). If many drops come out, the moisture content is too high (above 60%) and the pile tends to become anaerobic producing bad odor (Fig. B). If only a few drops of water appear, the moisture content is in the optimal stage (in the range 40%~60%, Fig. C).

Exhibit H-8
Watering of pile and Checking moisture content



In the composting process, two other parameters are also to be monitored. These are pH and Oxygen.

Oxygen Requirement:

The availability of air is the key to the aerobic process of composting. It is, however, very difficult to determine the exact requirement of Oxygen because it depends on many variables such as temperature, moisture content and availability of nutrients. An approximate method of monitoring of sufficient oxygen supply is to check the compost for foul odors. Presence of foul odors indicates insufficient supply of oxygen. Turning of pile and leave to dry, adding wood chips, saw-dust will increase the oxygen supply.

pH control:

Parameter which is important in evaluating the microbial environment is the pH of waste. The pH varies with time during the composting process and a good indicator of the extent of decomposition within the compost mass. The optimum pH range for the most bacteria is 6.0~7.5. During the initial period for first 2 to 3 days, pH drops to 5.0 or less and then begins to rise to about 8.5 for the remainder of the aerobic process. If the digestion is allowed to become anaerobic, the pH will drop to about 4.5. To minimize the loss of nitrogen in the form of ammonia gas, pH should rise above 8.5.

Step-7: Maturing / Curing

After 40 days, the material in the piles has a color like soil and the temperature has fallen bellow 50^0C indicating the process has entered the maturing or curing phase. At this stage the fresh compost is removed from the box and pile in the maturing area. To save the space, the piles are made closer and to the height of maximum 1500 mm. It is left there for another 15-20 days for maturing. Turning of pile is not needed, only little water is to be added if the pile gets too dry.

Exhibit H-9
Composed pile in maturing chamber

During maturing phase, other microorganism and small insects like caterpillars and bugs re-colonize in the still immature compost. They further decompose the more complex organic materials like cellulose while producing substance somewhat like topsoil. Additional three weeks are necessary to ensure that the compost is matured and suitable for direct application to plants. During this phase the compost needs less oxygen and less water and the temperature constantly goes down to the ambient temperature.

Temperature of the pile should be monitored daily until it is at the ambient temperature. If temperature rises while water is added, it indicates that the compost is still not matured and needs additional days for final curing.

The presence of white and gray color indicates the presence of fungi, which is important microorganism for composting process. Their appearance also indicates that the piles are still in the mesophilic phase and not matured.

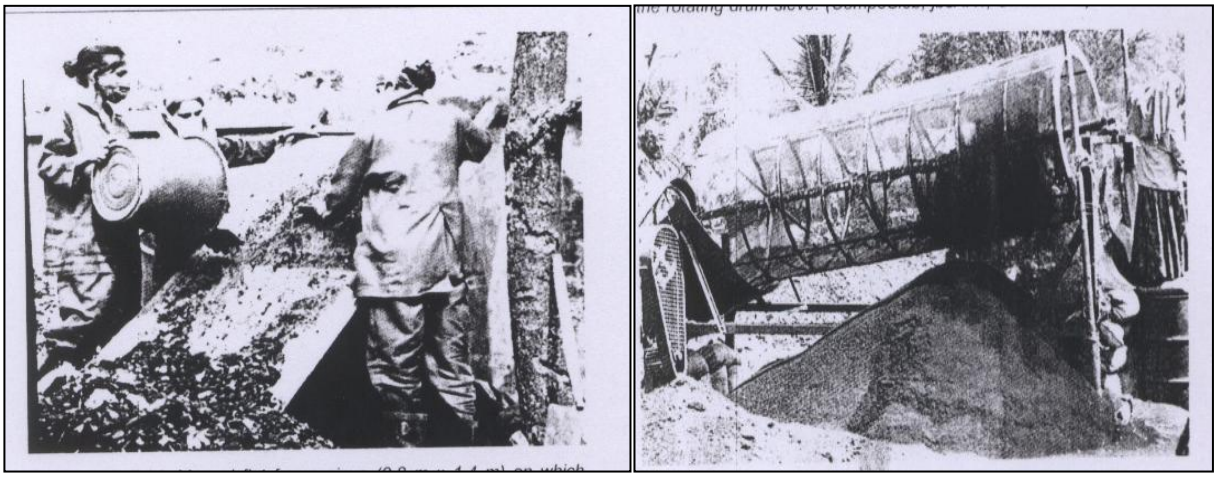
During rainy season, care should be taken to prevent the compost from getting socked. Rain might leach valuable nutrients from the compost.

Matured compost appears dark brown and has an earthy smell and a crumbly texture.

Step-8: Screening

Matured compost has a rather coarse texture. The particle size of the compost mainly depends on the size and composition of the input materials and turning frequency. Turning is needed for windrow type only, not for box type. In many cases finer compost is needed and thereby screening is necessary. Screening is done either by flat frame screen (mesh size 8mm~16mm) or a rotating drum Screen for fine, medium and coarse compost. Size of mesh (screen opening size) is suited for particular type throughput and application. In any case they need to be adjusted to the local condition and structure of compost.

Exhibit H-10
Screening in flat frame screen and Screening in drum screen



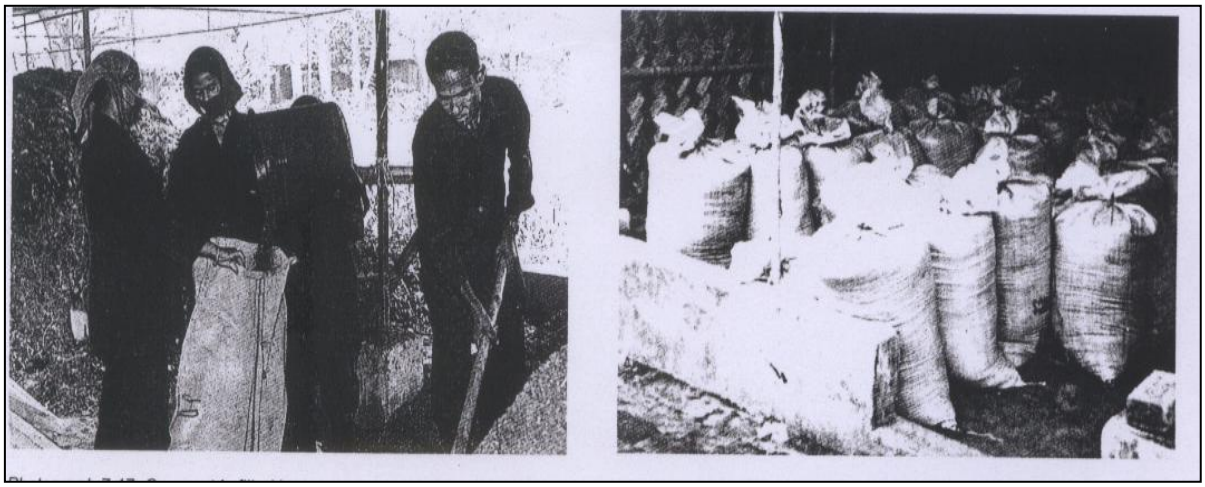
The screening process generates two fractions: the compost and the screening residue. The particle size and amount of composed depends on the mesh size. Coarse organic material, which has not been fully composed, normally remains in the screening residue. This material is a valuable carbon source and should be mixed with fresh incoming waste. As activated carbon, it accelerates the decomposition of the incoming materials.

11 Step-9: Storage and bagging

Depending on the demand of consumers, composed is stored in bulk (for loose delivery) or is packed in bags of different size. If the composed reheats above ambient temperature after screening process, it still is not completely matured. In this case, little water is sprinkle to the composed and is left for a week. Temperature should be checked before bagging starts. Compost should be relatively dry when it is bagged (moisture content <40%).

Compost should be stored in dry and covered place but should not be stored more than two years as its nutrient value slowly goes down. Compost should be bagged in waterproof but permeable to air as the compost is still a ‘living” material requiring air. Woven polypropylene bags are permeable to air and better for bagging compost. It is advised to pack the compost just before selling.

Exhibit H-11
Bagging of compost and Storing and ready for sale



4. PROBLEMS AND MEASURES IN COMPOSTING PROCESS:

No.	Situation	Possible measure
Raw materials		
1.	Large amount of sand and stone and household hazardous	• Improve possible awareness to reduce the production of inert materials. • Improve public awareness to initiate source segregation. • Remove organic fraction instead of residues.
Composting process		
1.	High C/N value after sorting (>40:1)	• Add manure (cow, chicken).
2.	Low C/N value after sorting (<25:1)	• Add wood, dry leaves or
3.	Too high temperature in waste pile in compost box (>70%)	• Turn pile • Sprinkle water if necessary
4.	Too low temperature in waste pile in compost box (<30^{0}C)	• Check moisture content, if necessary add water. • Check C/N ratio, add green material if necessary
5.	High moisture content in waste pile in compost box (>70%)	• Turn pile/spread out pile before reforming and leave to dry. • Add sawdust or wood chips to absorb moisture.
6.	Low moisture content in waste pile in compost box (<40%)	• Spread waste and sprinkle sufficient water

No.	Situation	Possible measure
7.	Odor development in waste pile in compost box (anaerobic condition)	• Insufficient oxygen, turn the pile more often. • If the waste is very sticky and compact, add course material like wood chips to increase aeration. • If the heap is too wet, turn it and leave to dry before re-pilling. • Avoid composting meat or fish
Climatic condition		
1.	Hot and humid climate or high rainfall	• Protect waste from getting socked. • Cover pile with tarpaulin.
2.	Hot and arid climate or extended dry season	• Protect compost from direct sunlight. • Cover pile with tarpaulin. • Water more frequently
Vector		
1	Excessive flies and insects	• Cover heap with 50mm layer of coarse compost. • Make sure to receive fresh domestic waste (not older than 2 days).
2.	Rodents and other animals	• Protect waste/compost piles with barrier and fence (fine meshed chicken wire). • Cover with tarpaulin and held down with stone/bricks.

5. REQUIREMENTS OF A 3-TON CAPACITY COMPOSTING FACILITY:

Land space

1) Total area required: 360 sq.m = 8.89 decimal
2) Compost Plant shade: 176.60 sq.m
3) Compost Chamber: 96.00 sq.m
4) Sorting, screening & packaging area: 30.00 sq.m
5) Maturing Chamber: 10.50 sq.m
6) Compost storing space: 16.50 sq.m
7) Care taker's room, equipment stores: 13.60 sq.m
8) Passage: 10.00 sq.m
9) Open space (access road, wastewater pond, latrine pit, etc) 183.40 sq.m

Equipment

10) Purchase of hand trolley: 2 nos.
11) Tools & plant (shovel, bucket, rack, basket, drum (revolving)/flat plate: 2 sets
Sieve (10~16 mm mesh) for screening, water pot, broom,etc)
12) Thermometer (alcohol): 2 nos.

Health protection

13) Health protective clothing (Mask, apron, gumboot, hand gloves, etc): 2 sets
14) First-Aid box: 1 box

Selling of compost

15) Bags (plastic): As required.
16) Balance: 1 set
17) Sealing equipment: 2 sets
18) Rickshaw van: 2 no.

Manpower requirements

19) Worker: 6 persons
20) Plant manager: 1 person

6. CO-COMPOSTING URBAN SOLID WASTES AND HUMAN/ANIMAL WASTES:

Like urban solid waste, human and animal waste can also be composted. But composting of human and animal waste alone is difficult as they tend to have high nitrogen and moister contents. They are therefore needed to have mixed up with carbonaceous waste such as vegetable and crop waste or compost of urban solid waste to achieve an optimum C/N ratio.