The Institution of Engineers, Malaysia

IEM GUIDELINE ON

The Prevention and Control of Dengue

FIRST EDITION, APRIL 2022

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CONTENT

FOREWORD by President Ir. Ong Ching Loon

Dengue has been one of the major threats to the health of tropical and sub-tropical regions, and Malaysia is no exception. Due to global climate change and other factors, the vector of the virus - the aedes aegypti mosquito - has spread considerably over the past decades. While most of the population is aware of it, not all are cognizant of the effective actions to eliminate it from our living environment. Therefore, tens of thousands are infected every year just in Malaysia alone, some even succumbed to it.

As the largest professional learned society, we aspire to promote the science of engineering in all disciplines, with the aim of ensuring sustainability in economic growth and all other endeavors. With this overall goal in mind, IEM aspires to uplift the quality of life of our compatriots by setting up various guidelines and standards where it is currently non-existence. One of my aspirations for IEM is to compile the immense knowledge and expertise of our talented members in all the engineering disciplines for publication as guidelines or handbooks of IEM for adoption by the engineering industry not just in Malaysia but internationally.

I am truly delighted to see the timely publication of the Guideline on the Prevention and Control of Dengue from the engineering perspectives, and I wish to congratulate the Task Force for completing this monumental task. The Task Force has created wonders under the leadership of its chairman, our highly respected Past President YBhg. Dato' Ir. Lim Chow Hock, whose unrivalled wisdom as a former Senior Director in the Department of Irrigation and Drainage Malaysia has helped the Task Force in overcoming a slate of challenges faced during its course of unenviable work.

It is my sincere hope that this Guideline will benefit all stakeholders, including decision makers, regulators, developers, consultants, contractors, system operators, maintenance experts, as well as the residents in ensuring a healthier environment for all. A chain is only as strong as its weakest link. Only when the weakest and most vulnerable among us are well protected against the onslaught of dengue, we can claim that we are truly free from this long-lasting outbreak. Each of us is required to do our part if we want to succeed in this war against dengue. With the publication of this Guideline, it is my fervent hope that it will be widely adopted nationally and regionally.

Once again, congratulations to the Task Force for your unwavering commitment and hard work to prepare this Guideline on the Prevention and Control of Dengue. Your effort to make Malaysia and the world a greater and healthier place is truly appreciated by all of us in IEM.
Thank you.

PREFACE

Dengue is a widespread mosquito-borne tropical disease and dengue cases in Malaysia are among the highest within the Western Pacific Region countries. What is crucial in the fight against dengue is to prevent the breeding of the Aedes mosquito. As the Aedes mosquito breeds in stagnant water, engineers need to ensure that buildings and infrastructures do not create breeding grounds for the mosquitoes.

This Guideline is prepared as a technical reference and planning tool for mosquito breeding control from the various engineering perspectives. It takes a holistic approach in providing considerations for dengue prevention and control in all aspects of engineering works from planning, design, construction, management, operation, and maintenance of buildings and infrastructure.

This Guideline is intended to assist engineers, consultants, developers, construction site operators, site inspectors, local authorities, government agencies, academicians, and other interested parties related to engineering in ensuring buildings and infrastructure are free from Aedes breeding grounds.

The Guideline is structured to highlight the potential breeding grounds and focus on the planning and design considerations as well as the operational and maintenance requirements in the specific topics related to land use planning, stormwater management and associated systems, water supply, sewerage, buildings, and mechanical system (within building), construction sites and waste management. Considerable attention is given to construction sites in this Guideline as construction sites are a major source of dengue transmission. Chemical and biological controls considerations from the engineering perspectives are also provided. The Guideline ends with recommendations in the housekeeping and social aspects as ultimately it is the responsible human behaviour that will ensure the effectiveness and sustainability of any good engineering practices towards the prevention and control of dengue.

IEM will continue with its efforts to play active roles to help the government to eradicate dengue for the good of the community and it is hoped that all engineers will continue to support and contribute to these efforts.

"*Bersama-sama Kami Membanteras Denggi*"

Thank you.
The Editorial Team

ACKNOWLEDGEMENTS

This Guideline is a joint effort of all the members of the IEM Dengue Task Force. Among the pioneers of dengue prevention initiatives in IEM is the Deputy Chairman of the Task Force, Ir. John Cheah Kam Loong, who was a former Public Health Engineer, and the Past District Governor of the Rotary International District 3310. He is a member of the Johor State Dengue Endemic Action Committee. He has been instrumental in pushing for various anti-Dengue campaigns relentlessly at various levels, including conferences, State Governments, Municipal Councils as well as schools and neighbourhoods.

The former Minister of Health Malaysia, Tan Sri Dato' Sri Liow Tiong Lai in 2010 granted a COMBI funding of RM10,000 to the Rotary Club of Johor Bahru to study "Why Dengue". Realising that engineers can play a role in the fight against dengue, the IEM (Southern Branch) under the chairmanship of Associate Professor Ir. Dr. Hayati Abdullah formed a Special Committee on Dengue Control in 2015 with Ir. John Cheah Kam Loong as its chairman and has since worked together with the Rotary Club of Johor Bahru. Prior to the formation of the committee, an International Conference on Dengue Situation and its Control was jointly organised by the IEM (Southern Branch), Rotary International and Universiti Teknologi Malaysia in 2014. The publication of this Guideline is a testament to the continuous commitment of the engineer's fight against dengue.

This Guideline is a culmination of the wisdom and engineering acumen of all Task Force Members over the one and a half years. I would like to thank all the Task Force Members for their commitment and great effort in preparing this Guideline, especially the authors for each chapter. I would also like to specially thank Associate Professor Ir. Dr. Hayati Abdullah and Ir. Dr. Chang Chun Kiat for helping me in the editorial work. Acknowledgement is also due to IEM secretariat staff, Mr. Gabriel Lim and others who have helped coordinated and compiled the preparation of this Guideline. Finally, the comments and inputs from IEM members and representatives from the local authorities, various government agencies and professional associations who participated in the stakeholder engagement are highly appreciated.

I would like to take this opportunity to remember the late Ms. Zainun Rani, the secretariat executive who was earlier attached to the Task Force and had carried out a splendid job but unfortunately succumbed to Covid-19 in mid-August 2021.

Dato' Ir. Lim Chow Hock
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SCOPE

This Guideline provides:

- A detailed description of the potential breeding grounds for Aedes Mosquitoes, including knowledge of this vector which is vital for the prevention and control of dengue.

- A detailed description of the planning and design considerations, which are formulated to bring to the attention of designers in applying the design principles and requirements to buildings and infrastructure. This Guideline covers the entire / selected stages of the constructed buildings and infrastructure life cycle, including planning, execution, construction, operation, maintenance, performance monitoring and decommissioning to prevent mosquito form breeding.

- Some useful guides on the operation, maintenance as well as management actions in preventing or eliminating mosquito breeding grounds.

- Some useful guides on the mosquito control measures, which include chemical control, biological control, and environmental management.

- Some useful guides housekeeping, social planning, and the role of engineers in public engagement in dengue prevention and control.

This Guideline is accompanied by and ended with an Annex and a Checklist.

ABBREVIATIONS

Bs	Bacillus sphaericus
Bti	Bacillus thuringiensis israelensis
BQ	Bill of Quantity
CI	Cytoplasmic incompatibility
CLQ	Centralised labour quarters
COMBI	Communication for Behavioral Impact
DID	Department of Irrigation and Drainage Malaysia
DOE	Department of Environment Malaysia
ESCP	Erosion and sediment control plan
HGL	Hydraulic grade line
IEM	Institution of Engineers, Malaysia
IGR	Insect growth regulator
IMR	Institute for Medical Research
JMB	Joint management body
MOH	Ministry of Health
MIL	Manhole invert level
MSWLF	Municipal solid waste landfill
MWA	Malaysian Water Association
MS	Malaysia Standard
NGOs	Non-governmental organisations
PIL	Pipe invert level
RC	Reinforced concrete
REAM	Road Engineering Association of Malaysia
RIDL	Release of Insects with Dominant Lethality
RWHS	Rainwater harvesting system
SPAN	Suruhanjaya Perkhidmatan Air Negara
SSTS	Small sewerage treatment system
SOP	Standard operating procedures
STP	Sewerage treatment plant
S.O.	Superintendent officer
T&C	Testing and commissioning
ULV	Ultra-low volume
WHO	World Health Organization

1.0 INTRODUCTION

Dengue is a global mosquito-borne viral infection and according to the World Health Organization (WHO), there are an estimated 100 – 400 million infections every year. The disease is endemic in over 100 countries, putting a large number of the world's population at risk. Over the last two decades, the number of dengue cases reported to WHO has increased more than eightfold from 505,430 cases in 2000 to more than 2.4 million in 2010, and 5.2 million in 2019. According to WHO, the America, South-East Asia and Western Pacific regions are the most severely affected areas (World Health Organization 2022).

The number of cases and death due to dengue in Malaysia for the year 2000 until 2021 is as shown in Figure 1.1 below.

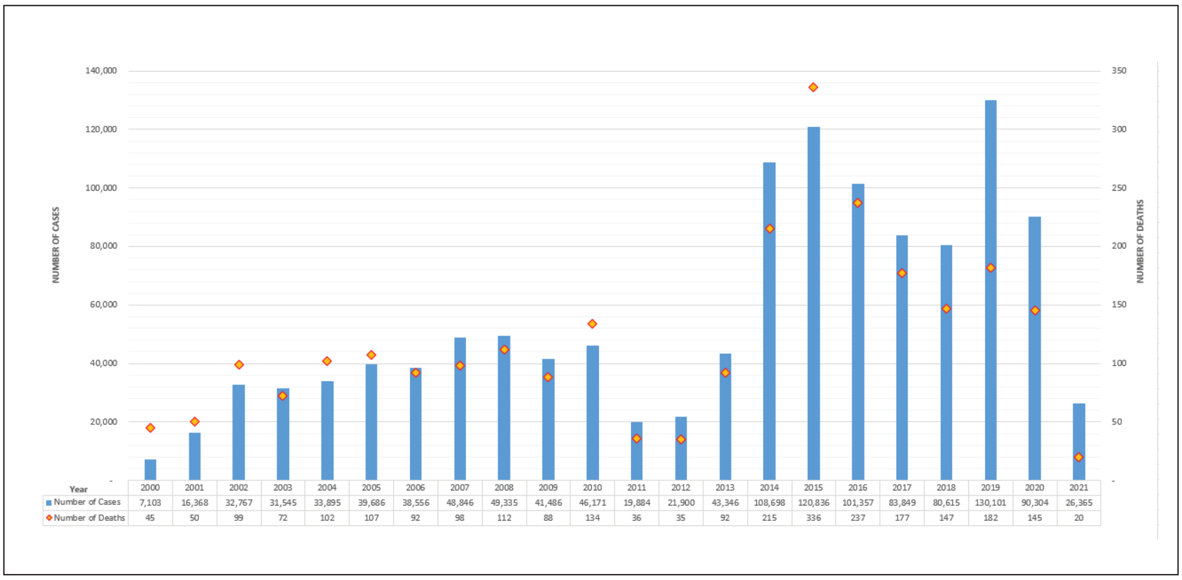

Figure 1.1 Number of Cases and Death due to Dengue in Malaysia, 2000 – 2021 (idengue; Situasi Semasa Deman Denggi, Zika, Chikungunya di Malaysia Tahun 2021)

The dengue endemic in Malaysia is one that cannot be taken lightly as dengue cases in Malaysia are among the highest within the Western Pacific Region countries as reported by WHO in 2020. The average weekly dengue cases reported in Malaysia is over 1,700 in 2020.

Because there is currently no cure for dengue, proper vector control is critical in combating this disease, which is primarily spread by the female Aedes Aegypti mosquito. Controlling mosquito vectors or interrupting human–vector contact is a means to prevent or reduce dengue virus transmission. In the planning and design of engineering infrastructures such as urban drainage system, roadside drains, public parks and sewerage system, engineers from various relevant disciplines play an important role to ensure that the risk of occurrence of stagnant water in any engineering system is adequately addressed. There will be no larva if stagnant water is removed. If the there are no larvae, there will be no adult mosquitoes and thus no vectors to spread the dengue virus. This guideline will be useful to all engineers in their engineering planning, design, operation, and maintenance work to prevent the occurrence of stagnant water in all buildings and engineering systems.

1.1 Dengue Fever

Dengue fever and dengue hemorrhagic fever are among the most prevalent vector-borne diseases in the tropical region. In recent decades, the risk of dengue infection has increased dramatically not only in the tropical region, but also in the sub-tropical regions. Dengue fever is mainly found in the urban and suburban areas. Urban development contributes significantly to the increased risk of dengue infection and transmission. In Malaysia, the construction industry has been identified as a major contributor to creating breeding sites, with a significant number of dengue cases and deaths caused by dengue in the construction site.

The dengue virus is responsible for causing the dengue fever. The dengue virus is transmitted by female mosquitoes mainly of the species Aedes aegypti as well as the Aedes albopictus. Aedes aegypti is a mosquito that can spread dengue fever, chikungunya, Zika fever, Mayaro and yellow fever viruses. The mosquito is distinguished by white markings on its legs and a lyre-shaped marking on the upper surface of its thorax. This mosquito can be found in tropical, subtropical and temperate climates.

Figure 1.2 Adult Aedes Mosquito

These mosquitoes are drawn to chemical compounds such as ammonia, carbon dioxide, lactic acid, and octenol, emitted by mammals in order to find a host. The female mosquito bites in order to obtain blood, which is required to mature the eggs.

1.2 Prevention and Control

As there is currently no effective vaccine against dengue and no specific treatment for the disease, preventing and controlling dengue fever outbreaks are essential steps to fight the disease. Since the disease is transmitted by the Aedes mosquito, it is crucial to prevent its breeding. The Aedes mosquito breeds in stagnant water and both Aedes aegypti and Aedes albopictus are primarily found breeding in containers in areas with a high population density. Aedes albopictus, on the other hand has also been found in natural surroundings (Y.L. Cheong et al., 2014).

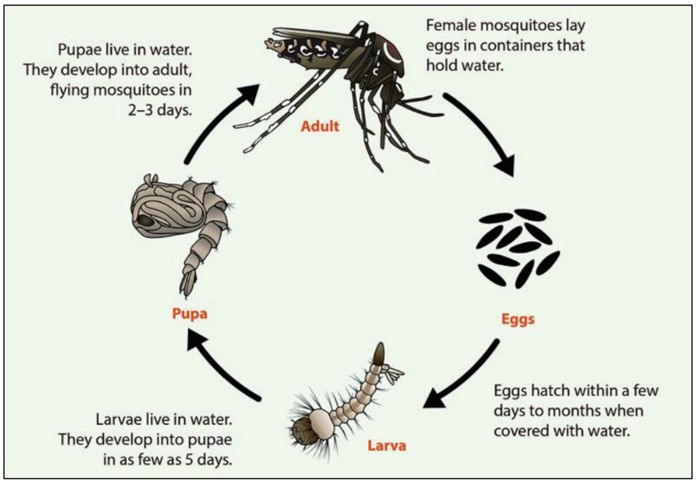

Figure 1.3 Life stages of Aedes aegypti and Aedes albopictus (CDC 2022)

The life cycle of the Aedes mosquitoes is shown in Figure 1.3. In general, the life cycle of the Aedes mosquito could be less than 7 days with the assumption that the process from the eggs to adult flying mosquitoes is undisturbed (Table 1.1). The identified risk is any exposed surface water that stagnates for more than 72 hours has a moderate level of risk that the life cycle gets completed.

Table 1.1 Undisturbed Life Cycle Stages of Aedes Mosquito

Life Cycle Stages	Days	Under Normal Condition
Eggs to Larvae	0	Assumed already inside the water because eggs are hardy and can last up to 6 months.
Larvae to Pupa	5	Water remains stagnant or almost zero water velocity on the sides or insufficient incoming water to interrupt the development of the larvae to pupa.
Pupa to adult	2-3	Water remains stagnant or almost zero water velocity on the sides or insufficient incoming water to interrupt the development of the pupa to adult aedes mosquito

Engineers have a vital role to play in ensuring buildings and infrastructures do not create breeding ground for the Aedes mosquito by eliminating stagnant water. Various elements of the engineering works such as planning, design, operation, and maintenance will need to include considerations for the prevention of mosquito breeding ground. Towards this end, there is a need to provide guidelines from the engineering perspectives for the prevention and control of dengue with respect to land use planning, stormwater management and associated systems, water supply system, sewerage, buildings and mechanical systems, waste management, construction sites, chemical, biological and social aspects.

1.3 Summary of the Guideline on the Prevention and Control of Dengue

This Guideline on the Prevention and Control of Dengue was developed by the Task Force Members under the Institution of Engineers, Malaysia (IEM). The Guideline provides essential aspects of planning, design, construction, management, operation, and maintenance of buildings and infrastructure from the engineering perspectives under the various related disciplines for the prevention and control of dengue. The Guideline is intended as a technical reference and planning tool to engineers, consultants, developers, construction site operators, site inspectors, local authorities, academicians, and government agencies for mosquito control. It is to ensure buildings and infrastructures do not create a breeding ground for the Aedes mosquitoes.

Mosquitoes prefer not only to breed in domestic habitats but also in the natural habitat of varying land use. Land use and land cover change influence mosquito are probably more apparent with vegetation and topographic characteristics. It is a major constituent concerning mosquito-borne diseases by influencing the mosquito's habitat. Hence, land use factors are an important component to be considered in the strategic planning and implementation of vector control.

Mosquitoes are known to breed in stagnant water and controlling them or preventing their egg-laying is challenging in stormwater associated systems, water supply systems, and sewerage treatment facilities. The size and variability of the stormwater associated systems, inconsistent quantity and timing of water flows, and tendency to carry and accumulate sediment, trash, and debris become holding areas of stagnant water, makes these systems highly conducive for mosquitoes breeding ground. Another risk for water supply system can become breeding grounds for mosquitoes is water is supplied to each demand point via reticulation pipes from the water treatment plants and service reservoir, while these structures are essentially water storage and conveyance facilities, stagnant water can always arise upon its construction and prior the commissioning process. Sewerage treatment facilities are designed to collect, treat, and release nutrient-rich highly organic water to remove contaminants from wastewater. Further, the mosquito breeding ground associated with sewage treatment facilities is usually associated with their inadequate design, operation, and maintenance, or faulty methods of effluent disposal or dispersal.

There are many buildings and engineering constructions sites around the country. It is crucial to identify stagnant water within a built environment and in the mechanical systems, which could be a potential breeding ground for mosquitoes. Besides that, for mosquito control around buildings, it is crucial to consider mosquito control integrated into stormwater associated systems, water supply systems, and sewerage treatment facilities. Construction sites are one of the most common breeding grounds for all mosquitoes including the Aedes mosquito. Common issues are identified, and recommendations are provided to eliminate mosquito breeding through effective planning and designs. It is recommended that the bill of quantity (BQ) for contractors to include all preventive and corrective measures, as well as administrative control, shall foresee all stages of construction.

Sustainable solid waste management is crucial to the prevention of breeding grounds for the mosquito. One of the most common problems associated with poorly designed and poorly managed landfills and solid waste (disposal site & transfer station) is that it leads to surface stagnant water.
Therefore, proper waste management must be undertaken to ensure that it does not affect the environment and not cause health hazards to the public.

Vector control strategies have traditionally focused on killing mosquitoes using a variety of insecticides. Chemical control aims to control mosquitoes during different life stages such as larvae, pupae, and adults based on adult control and breeding control. For chemical control, the focus should first be made to prevent mosquito breeding, and the use of chemicals such as fogging (emergency control) can be considered to reduce or control the number of adult mosquitoes within a certain coverage area in a short period. However, chemicals should be used in the correct manner so as not to pollute the environment or consumables for humans or animals.

Biology control strategies aim to be sustainable to reduce the current reliance on insecticide-based mosquito control. Biological control uses predators (mosquitofish and Copepods), pathogens (Wolbachia, bacteria), mosquito repellant plants, as well as genetically modified mosquitoes to reduce populations of mosquitoes and larvae. In particular, biological control is often combined with environmental management to enhance results.

Residential and commercial buildings, schools, public buildings and amenities, land under government control, factories and industrial areas, and vacant lands are all potential sites for mosquito breeding grounds. Good planning, engineering design, and implementations are not complete without responsible human behavior and housekeeping. Every member of the community has an important role to help prevent dengue. At present Communication for Behavioral Impact (COMBI) developed by United Nations World Health Organisation (WHO) is a dynamic approach in the prevention and control of dengue and it was expanded to all other states in Malaysia; COMBI programs demonstrate the success and adaptation of social mobilization and communication strategy to influence behavior change among individuals, families, and communities towards healthy behaviors.

Engineers are largely responsible to ensure that building and infrastructure projects have been built with always considering the vast increase of mosquito breeding grounds, which could be prevented at a reasonable cost. Indeed, engineers should consider the prevention of dengue risk by adapting the general principles of prevention during the planning and design stage and always consider the prevention of dengue risk by adapting the general principles of prevention. It is recommended that building and infrastructure projects, especially those areas that interface with urbanized or public areas, should consider the content of these considerations from the inception to design stage. Finally, the IEM as an engineering organisation plays an important role to guide the community as well as other stakeholders through education, awareness, and technical advice on planning and design of public buildings, infrastructures, and amenities.

Finally, this Guideline has been produced to be made widely available to all practitioners at all levels with best engineering practices in effectively preventing and control of dengue in Malaysia, as well as regional and worldwide. The Guideline is intended for engineers, consultants, developers, construction site operators, site inspectors, local authorities, academicians, government agencies, and other interested parties to review and use when designing and maintaining buildings and infrastructure. Recommendations are made with consideration to eliminate stagnant water and conduct regular housekeeping practices, where possible to ensure all prevention and control activities are carried out completely and effectively.

2.0 LAND USE PLANNING

2.1 Introduction

Mosquitoes prefer not only to breed in domestic habitats, but also in the natural habitats of varying land use (Guzman et al., 2010). Agriculture, which is the greatest driver for change of land use across the earth, and water bodies have been identified as likely risk factors for dengue because of the provision of suitable habitats for the vector. Vegetation and land cover characteristics can influence the risk of land use change and is a major constituent of global environmental change that can potentially affect human health in relation to mosquito-borne diseases by influencing the mosquito's habitat. Hence, land use factors are an important component to be considered in the strategic planning and implementation of vector control.

2.2 Vegetation/Parks

Park management ought to take preventive measures in order to reduce health risk on parks, sports field or playground visitor due to a perception that naturalistic landscapes could possibly become mosquito breeding grounds if not regularly maintained, especially during the wet season.

2.2.1 Potential Breeding Ground

- Shallow waters exposed to direct sunlight will encourage more vibrant growth of emergent and microscopic plants, thus providing necessary food and protection for mosquito larvae.

- Tall grass and thick vegetation provide protective cover for mosquitoes during the heat of the day, mosquitoes will retreat into foliage to avoid dehydrating.

- Areas with low vegetation and the presence of water bodies such as ponds and wetlands are favored dengue infection (Nazri et al., 2011; Araujo et al., 2015).

- Open spaces with shaded vegetation, for instance in car tires and garbage dumps (Malaysia Institute for Medical Research, 2010).

- Low-lying flat lands with insufficient permeability and inadequate natural drainage tend to retain water indefinitely and form marshes and swamps which are suitable habitats for many mosquito species.

- Open spaces with shaded vegetation.

- Rainwater that accumulates in tree holes can provide an ideal place for the mosquito breeding.

2.2.2 Planning and Design Considerations

- Better drainage can result in improvement of the overall benefit to health, safety, and the environment of vegetation in a park, sports field, or playground as a result of reduced maintenance and the need to use insecticides for mosquito control.

- Design drainage systems that promote infiltration or overland flow can help to reduce mosquito breeding habitat and disperse water over a larger vegetated area, as well as potentially reduce irrigation needs.

- Select green infrastructure element that eliminate stagnant water on pavement, in low-lying areas or nuisance flooding in parking areas, walkways, and playing fields at the park.

- Permeable pavement, bio-filtration drainage system, sub-soil drain, infiltration trench and underground storage systems are common stormwater facilities that can be used to mitigate drainage problems.

- Use mosquito-repellent plants for landscaping (Refer Chapter 10). However, still, these plants don’t always emit the unfriendly smells and might be effective in repelling mosquitoes in small areas.

- The overall benefit to health, safety, and the environment of vegetation in a park, sports field or playground can be improved through better drainage to reduce maintenance burden and also the need for parks managers to use insecticides for mosquito control.

2.2.3 Operation and Maintenance

- Keep park lawn free of containers to prevent stagnant water at all times. Water containing medium must be emptied and cleaned every week to eliminate generation of mosquito larvae.

- Remove excess vegetation and organic debris that provide mosquito larvae with food, shelter from the sun, and hiding places from predators.

- Eliminate mud puddles by adding a layer of stone, cover that with topsoil and then reseed if needed.

- Mow the lawn, remove tall weeds, or keep grass short and weed-free.

- Irrigate lawns carefully to prevent water from stagnant for a few days.

- Regularly check for larvae especially during dry periods in park or gardens with lots of plants growing in stagnant water.

2.3 Agriculture Sources

The changes of land use for agricultural purposes and increase in urban agriculture expand habitats for mosquitoes. The creation of urban farms in complex urban built environments may also create breeding ground for mosquitoes. In cases where these agricultural lands interface with urbanised or public areas, mosquitoes would be a public nuisance, and create health problems for humans and livestock. Good agriculture practices result from the efficient use of water will reduce mosquito populations efficiently. As a result, the balance between the economic and agronomic requirements of growers and landowners with the need for effective mosquito control are essential.

2.3.1 Potential Breeding Ground

- Blocked ditches and/or culverts

- Broken or leaky irrigation pipes and/or valve

- Irrigation tail water areas and return sumps.

- Flooding of fallow fields

- Ponds and natural pools that livestock drink from may become major mosquito-breeding ground.

- Animal husbandry, coconut and cocoa plantations, tea plantation, mixed horticulture (mixed cultivation of gardens, orchards and nurseries with flowers, fruits, vegetables and ornamental plants) surrounding the human settlements are among potential habitats for the dengue vector as in Figure 2.1 (Chareonviriyaphap et al., 2004; Rohani et al., 2001; Thavara et al., 2001; Richards et al., 2006; Vanwambeke et al., 2007).

Figure 2.1: Controlled-drainage tail water (Left) and stagnant water (Right) in palm oil plantation adjacent to human settlement

2.3.2 Planning and Design Considerations

- Design drains that properly convey excess water from collects at lower levels of irrigated fields.

- Design irrigation systems that use water efficiently and drain away stagnant water.

- Grade field to achieve efficient use of irrigation water.

2.2.3 Operation and Maintenance

- Inspect and rectify areas with poor drainage. Eliminate unwarranted stagnant water that ponded for more than 72 hours.

- Maintain and keep all ditches and fields clean at all times. Periodically remove accumulated sediment, debris and emergent vegetation.

- Vegetation should be managed regularly to prevent emergent vegetation and barriers to access.

- Do not over-irrigate, as this will create stagnant water. Irrigate only as frequently as is needed to maintain proper soil moisture.

- Do not over-fertilize as excess fertilizers will leach into irrigation tail water, making mosquito breeding more likely in ditches or further downstream (Lawler and Lanzaro, 2005).

3.0 STORMWATER MANAGEMENT AND ASSOCIATED SYSTEMS

3. 1 Introduction

Stormwater management always addresses public health and safety concerns, mainly on the perspective of flood control and water quality control. Unfortunately, the issues of mosquito management are often overlooked. Mosquito control is crucial to prevent disease transmission and maintain quality of life and must be integrated into the management of stormwater.
Stormwater management and associated systems typically include:

- Conveyance system (e.g. drainage systems, pipe drains, swales, road side drains, highway drainage, culverts, drain inlets, outfalls, etc.);
- Quantity control system (e.g. detention ponds and basins, on-site detention, etc.); and
- Quality control system (e.g. infiltration basins, vegetated swales, gross pollutant traps, water quality ponds, constructed wetlands, etc.).

The size and variability of stormwater associated systems, inconsistent quantity and timing of water flows, and tendency to carry and accumulate sediment, trash, and debris, makes these systems highly conducive as holding areas of stagnant water which in turn provide an ideal breeding ground for mosquitoes. To prevent and control mosquito breeding, appropriate best management practices (BMPs) for stormwater management and associated systems have been identified.

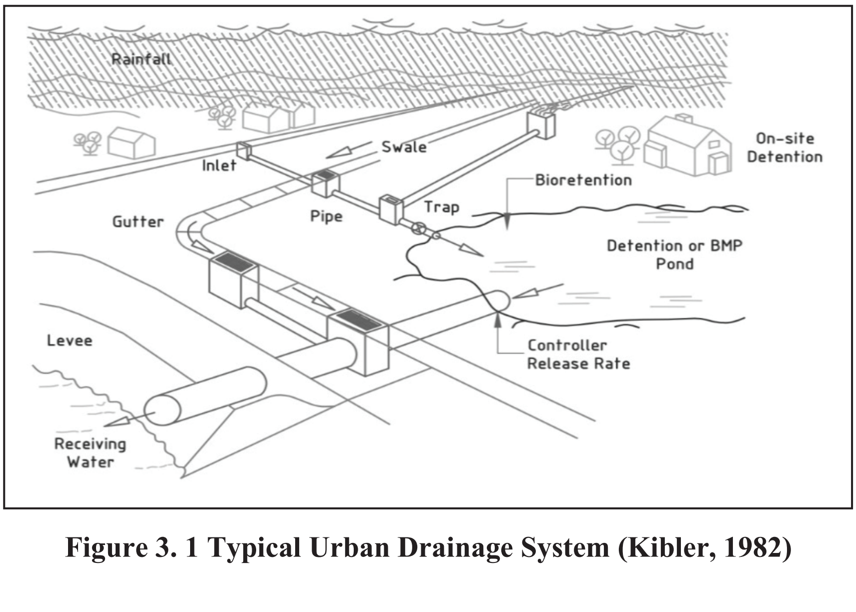

Figure 3. 1 Typical Urban Drainage System (Kibler, 1982)

In the context of stormwater management, wetlands, lakes and ponds render effective stormwater quantity control by providing a significant volume of temporary water storage above the permanent pool elevation. Besides that, wetlands, lakes and ponds reduce stormwater runoff challenges by controlling and slowing the movement of stormwater. They are commonly used for water quality improvement and increase groundwater aquifer recharge. However, mosquitoes are known to breed in stagnant water and there is a need to consider the role of natural and constructed wetlands, lakes and ponds in relation to mosquito populations. Most frequently, mosquito breeding in wetlands, lakes and ponds is a "nuisance" in posting a threat to the health and quality of life of nearby residents.

3.1.1 Potential Breeding Ground

- Stormwater systems encourage mosquitoes breeding if they fail to perform as design due to a lack of awareness and maintenance by the property owner.
- Drain sumps with large quantity of stagnant water have the capacity to be key containers for Aedes aegypti breeding ground (Tun-Lin et al., 1995).
- Design stormwater systems with permanent water sources such as wetlands, ponds, and basins to be supported by flows from urban runoff or water supplies in order to maintain depth, as well as maximise open swathes of deep water to discourage mosquito breeding.

3.1.2 Planning and Design Considerations

- Considering mosquito control in the design, construction, and operation of stormwater systems.
- Design and operate stormwater systems that will discharge accumulated water in 48 hours or less.
- Design and operate stormwater systems to include easy access for maintenance.
- Design stormwater systems to drain all of the water in the event by providing water flow and reduce stagnation

- Design stormwater systems with permanent water sources such as wetlands, ponds, and basins to be supported by flows from urban runoff or water supplies in order to maintain depth, as well as maximise open swaths of deep water to minimise mosquito breeding ground.

3.1.2 Operation and Maintenance

- Eliminate unnecessary stagnant water from stormwater systems.

- Remove emergent vegetation, sediment, trash, and debris from stormwater systems that promote stagnant water.

- Carry out routine inspection and maintenance for stormwater systems to ensure free flow of water without obstruction.

3.2 Stormwater Conveyance System

A stormwater conveyance system includes all natural and engineered components of a drainage system that collect stormwater runoff and convey it away from the systems to reduce the potential of flooding and erosion; thus, it is in principle compatible with mosquito control in eliminating mosquito breeding ground.

Earth drains are the most common and cheapest form of drainage system used everywhere around the world. However, overgrown of semi aquatic or aquatic vegetation which are clogging the drain have constantly been a major challenge associated with this type of drain and therefore regular maintenance is required from relevant local authorities. Smaller concrete drains are easily clogged by fallen leaves, tree branches, garbage, debris, silt from road surface, and overgrown vegetation (Figure 3.2). In addition, broken drains can cause depression and subsequent blockage must be repaired immediately. Typically, mosquito breeding occurs in stormwater conveyance system are usually due to inadequate maintenance of drainage system and ancillary structures.

Figure 3.2 Stagnant water in drain clogged by fallen leaves

3.2.1 Planning and Design Considerations

- Stormwater conveyance system shall be able to drain completely to avoid stagnant water.
- Provide proper grades along stormwater conveyance structures to ensure that water flows freely and no blockage.
- Encourage provision of open drain, covered open drain (removable cover) and swale (Figure 3.3).
- Propose minimum velocity (0.6 m/s) and set minimum gradient for open drain and underground drain to prevent sedimentation and vegetative growth (DID, 2012).

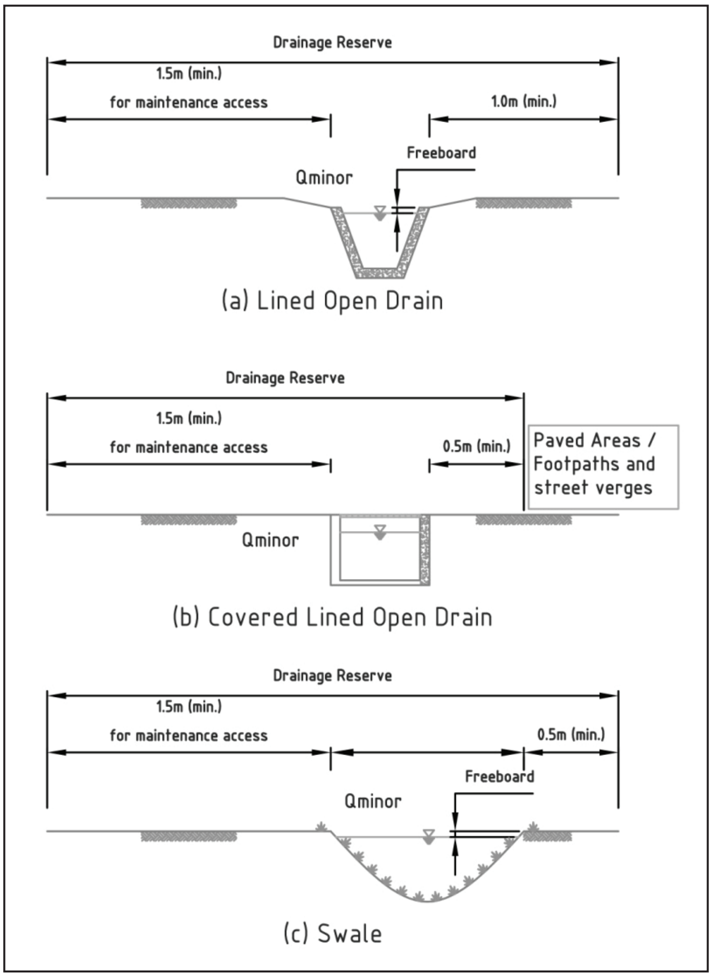

Figure 3.3 Drainage Reserve for Minor Drain and Swale (DID, 2012)

- For major drainage system, where practical, 'U' shape central flow at the drain base slab should be considered to provide dry weather flow.

- The velocity along the swale shall not exceed the recommended maximum scour velocity for various ground covers and values of soil erodibility, or ideally be less than 2 m/s, unless additional erosion protection is provided.

- The reinforced concrete drain should be provided for the lined open drains that exceed 0.9 m in depth.

- Invert level of drainage sump should be equal or same as invert level of outflow drain to ensure no water ponding in drainage sump (Figure 3.4).

Figure 3.4 Stagnant water inside drain sump caused by depressed invert level

- Stormwater pipe systems (Figure 3.5) shall be designed using "Hydraulic Grade Line (HGL) method using appropriate pipe friction (eg Darcy-Weisbach, Manning, Colebrook-White) and drainage structure head loss coefficients.

- Minimum pipe culvert sizes shall be 600mm.

- Stormwater pipe systems should be laid to grade to avoid low areas that may hold water.

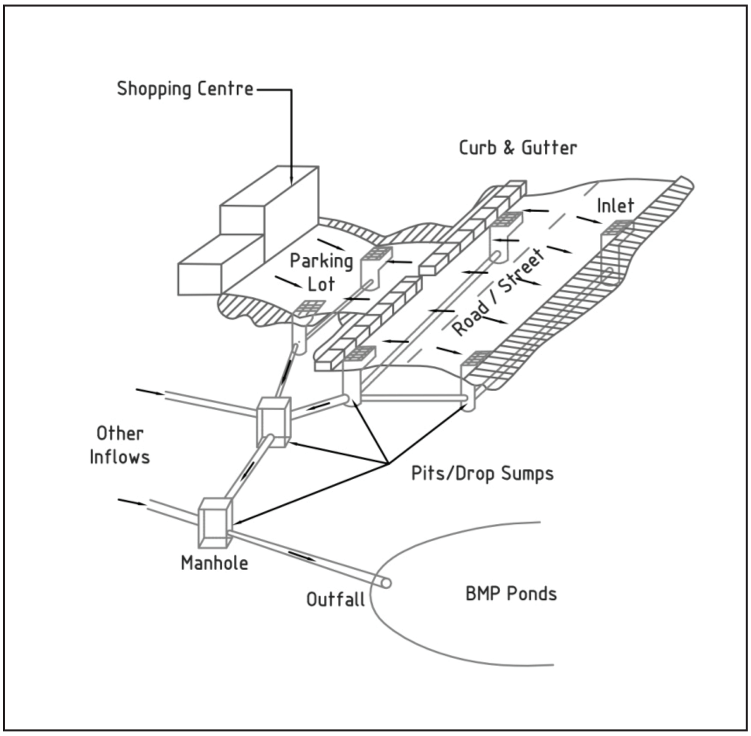

Figure 3.5 Elements of Pipe Drainage System (DID, 2012)

- Access for maintenance / service opening should be considered when determining the size for longer concrete pipe culvert.

- Set minimum spacing and specification for trash screen to prevent easy clogging of trash.

- Design and operate proper outfalls for stormwater conveyance structures to prevent scour depressions that can hold stagnant water. If needed, use concrete slabs to dissipate energy.

3.2.2 Operation and Maintenance

- Inspect and maintain stormwater conveyance structures on a routine basis to ensure the grade function as designed and accumulations of sediment, trash, and debris must be removed regularly.

- Remove emergent vegetation from stormwater conveyance structures that accumulate water to provide rapid discharge.

- Swales can become a nuisance due to mosquito breeding in stagnant water if obstructions develop (e.g. debris accumulation), invasive vegetation or if proper drainage slopes are not implemented and maintained.

- Ensure soils are well compacted to prevent subsidence. Inspect the surface of swale, fill if erosion occurred in natural depressions; or remove and replace soil as needed if sediment accumulation.

3.3 Drainage Inlets

Drainage inlets are used to receive runoff and convey it to a stormwater drainage system (Figure 3.6). They are typically located in gutter sections, paved medians, roadside, and median ditches. There are four types of inlets commonly used, i.e., grated inlets, kerb opening inlets, slotted inlets, and combination inlets. Drainage inlet capacity governs both the rate of water removal from the gutter and the amount of water that can enter the stormwater drainage system. Inadequate inlet capacity or poor inlet location may cause back water and then flood the road. There are many variables involved in designing the number and placement of inlets, and in determining the hydraulic capacity of an inlet. The hydraulic capacity of a stormwater drain inlet depends upon its geometry as well as the characteristics of the gutter flow.

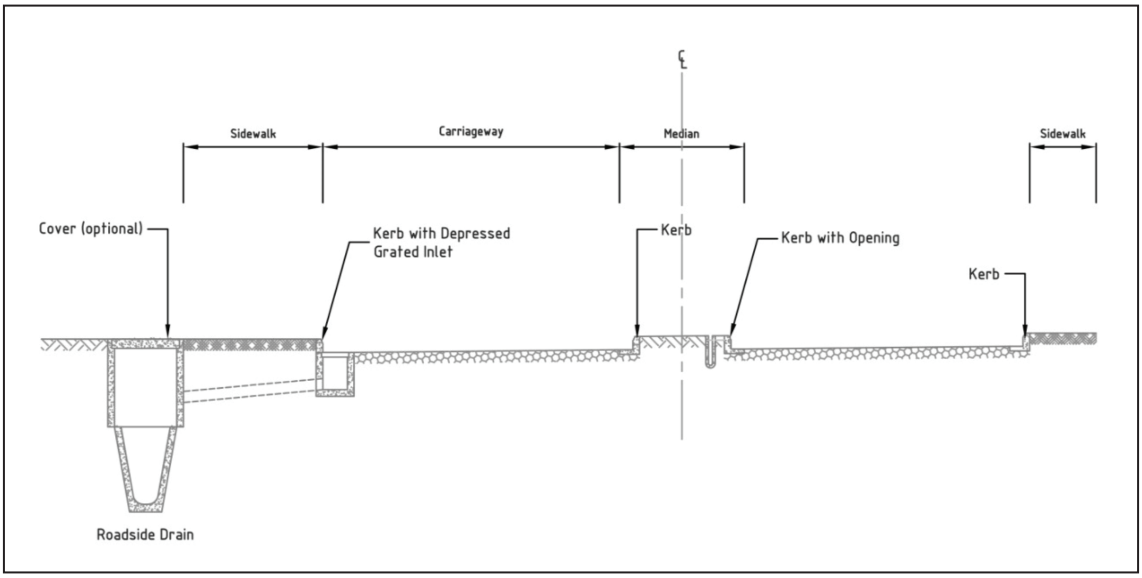

Figure 3.6 Road Drainage System and Stormwater Inlets (REAM, 2002)

3.3.1 Planning and Design Considerations

- The size and slope of gutter shall be carefully designed so that does not cause sedimentation and erosion within gutter.

- Gutters should locate in front of the kerbs when used with kerbs.

- The precast units of the gutter should be provided with a concrete surround from the base to the top of the precast section to ensure continuity of the drain and preventing water seepage and dislocation of the precast units.

- Drainage inlet will be necessary to have at least 1.0m head height between road level and drain invert to ensure the head available to force gutter flow into inlets is sufficient and operate correctly (REAM, 2002).

- The capacity of kerb inlet can be significantly increased by depressing the opening or installation of deflector veins in the gutter adjacent to the opening, which will cause the water to flow into the kerb opening.

- If depressed grated inlet is required, the width of the galvanised steel grating should be limited to 250 mm (Figure 3.7).

- Slotted inlets can be used in areas where it is desirable to intercept sheet flow over a wide section.

- All drain inlets must be sufficiently graded to prevent sediments and debris accumulation and minimize potential for stagnant water.

- Provide proper grades along conveyance structures to ensure that water flows freely.

- Extra inlets must be provided near the low point of sag vertical curve to cater for flow that might have passed the previous inlets to prevent ponding at the 1ow points.

- Drainage inlets should be located just upgrade of pedestrian crossings and just before the change in crossfalls.

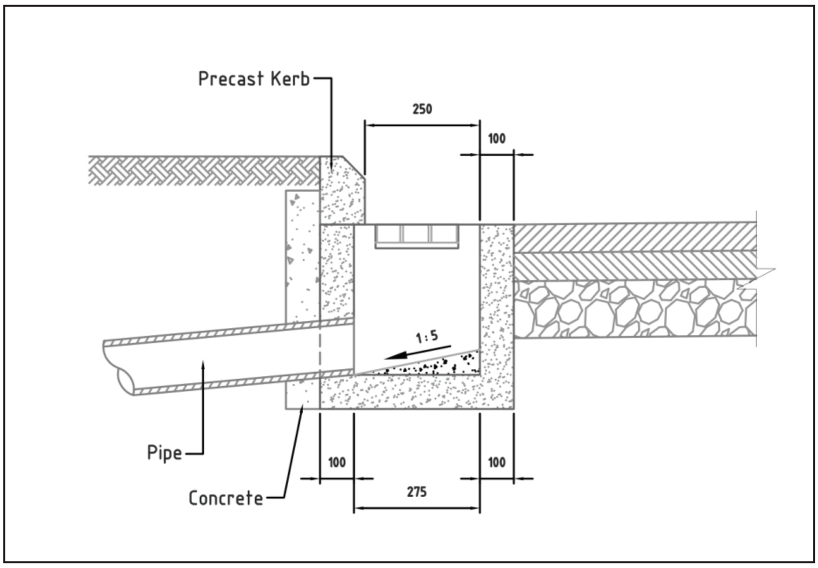

Figure 3.7 Typical Section of Depressed Grated Inlet (REAM, 2002)

3.3.2 Operation and maintenance

- Inspect on a routine basis to ensure the grade great function as designed to discourage accumulations of sediment, trash, and debris.

- Keep inlets free of accumulations of sediment, trash, and debris to prevent blockage that cause back water on the road and gutters.

3.4. Ponds and Lake

Certain types of stormwater management practices that are characterized by ephemeral shallow water habitat and/or dense growth of emergent vegetation will provide excellent mosquito breeding habitat. Ponds that are uniformly deep, with steep side slopes, resident populations of mosquitofish and certain species of aquatic insects will not encourage significant mosquito’s growth. The creation of permanent, stagnant water features is not advised for effective mosquito control.

3.4.1 Planning and Design Considerations

- Ponds can be developed as "Dry" or "Wet" type as shown in Figure 3.8. For wet pond, the catchment area served is greater than 10ha. It is to ensure that the area generates enough baseflow to replenish and maintain the permanent pool level (DID, 2012).

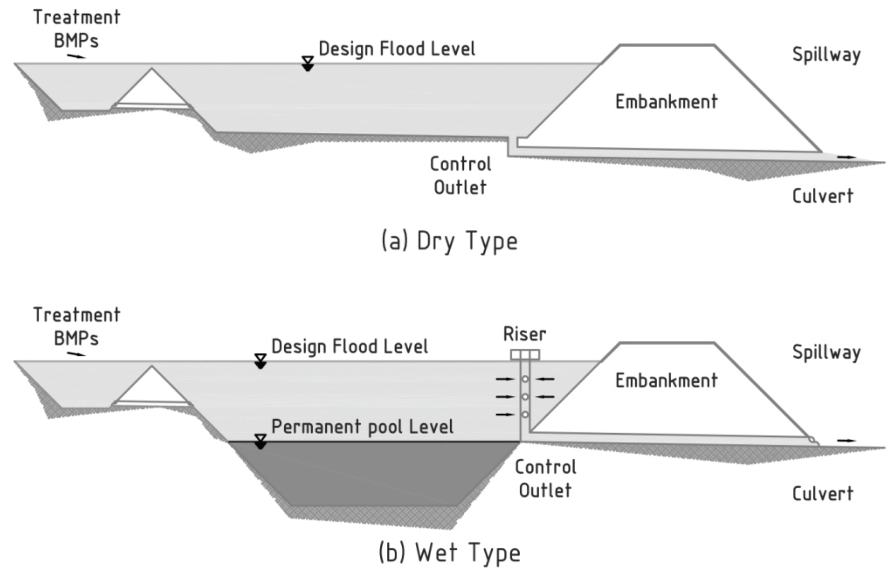

Figure 3.8 Typical Detention Ponds (DID, 2012)

- Design dry ponds to allow for complete draining. Low-flow provision channel should be provided to cater for dry-weather flows.

- Ponds typically will not have mosquito production problems in a central pool that is more than 1.2 m deep, as long as it never dries out or becomes so diminished that water quality is impaired.

- Ponds or features that provide a steep slope or have vertical walls that quickly drop off into deep water will be less favorable to mosquitoes.

- Side slopes above permanent water level should also be gentle. The side slope of ponds should not be steeper than 1(V):4(H). Ponds with steeper slope may require a fence or rail (DID, 2012).

- The slope of the wet side can be made steeper than the slope of the dry side. Design slope angle of at least 2(V):1(H) to minimise invasive emergent vegetation in ponds. Bank slopes of 2:1 and minimum depths of 1.2 to 1.5 m for significantly reduce bottom-rooted aquatic plants.

- Encourage patches of natural vegetation at pond edges to provide beneficial wildlife and insect habitat (Figure 3.9). Emergent plant density is routinely managed so mosquito predators can move throughout the vegetated areas and are not excluded from pond edges.

- Shallow vegetated benches shall be designed accessible for periodic maintenance and/or control of emergent vegetation.

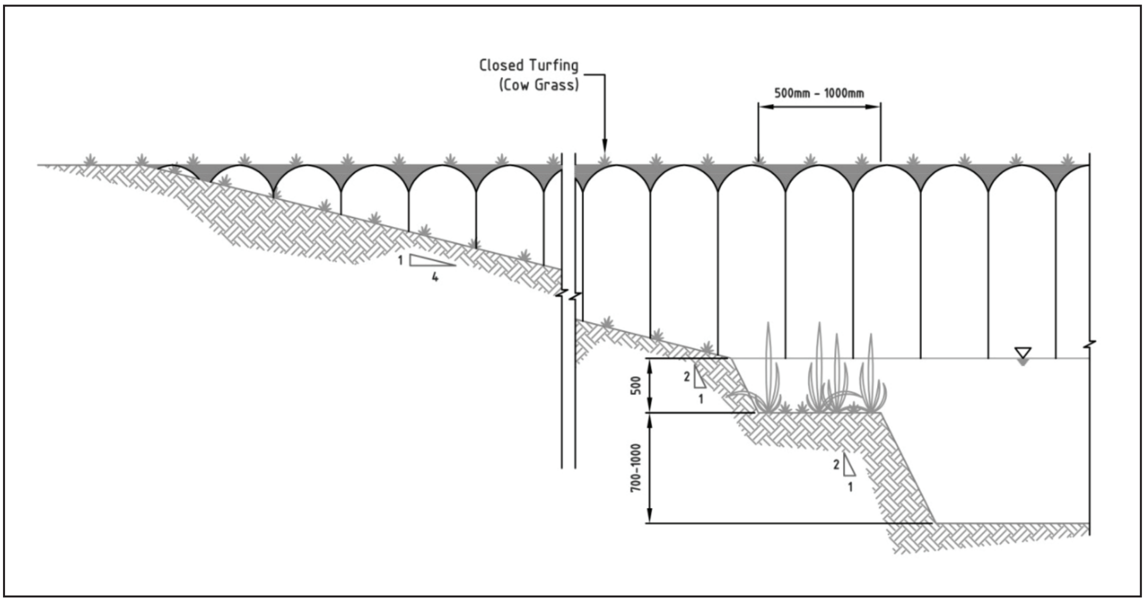

Figure 3.9 Example of Proposed Shallow Vegetated Benches at Pond

- Design stormwater structures so that they do not hold stagnant water for more than 48 hours to prevent mosquito breeding.

- Design stormwater features to prevent or reduce the possibility of blocked discharge orifices (e.g., debris screens) should be incorporated into the design. The use of weep holes is not recommended.

- Pond inlets should be designed to be furthest possible from the outlet structure as possible to provide longest flow path between inlet and outlet. Inlets that are too near the pond outlet may affect its hydraulic efficiency by increasing short-circuiting, reduced particulate and pollutant removal.

- Provide a uniform grade between the inlets and outlets to ensure that all water is discharged within 48 hours or less after storm event.

- Use grouted riprap or concrete blocks instead of loose riprap to prevent stagnant water.

- Design distribution pumping and containment basins with adequate slopes that could be fully drained. The design slope should take into consideration build-up of sediment between maintenance periods.

- Avoid shallow ponds and basins without fish or aeration.

- Adding a fountain, aeration, waterfall, or other devices for stagnant ponds or lakes which lacking water movement or lacking enough oxygen for fish survival by agitating pond water and increases water circulation. However, there is still a possibility for water stagnant at the corner of the pond or fountains that are not circulating

- Avoid the use of electric pumps. They are subject to failure and often require permanent-water sumps.

- Provide ecologically stable ponds that do not produce problem mosquito population as the natural factors of surface wave action tend to eliminate mosquito larvae. Generally, natural ponds, lakes and engineered detention ponds will have adequate surface water movement and do not require artificial aeration.

- Other key factors in lakes and ponds that will reduce and eliminate mosquito larvae and they are as follows:
  a) Fish and aquatic insects
  b) Disturbance from rainfall
  c) Wave action or water movement on the lakes or pond surface is an important factor in reducing mosquito larvae survival rates.

3.4.2 Operation and Maintenance

- Provide routine inspection and maintenance to ensure the grade functions as designed.
- Ponds designed to be dry but remaining wet should be rectified by retrofit, replacement, repair, or more frequent maintenance.
- Inspect and remove accumulated sediment in the forebay.
- Remove accumulated litter and debris at the end of the wet season.
- Maintain high quality vegetative buffers around the pond to assist mosquitofish movements to control mosquitoes.
- Introduce mosquitofish to control or eliminate mosquito larvae (Refer Chapter 10 on Biological Control).
- Prevent excess nutrients and pollutants from entering the pond that causes eutrophication.
- Remove excess vegetation and organic debris that provide mosquito larvae with food, shelter from the sun, and hiding places from predators.

3.5 Constructed Wetlands

Wetland's landscaping provides for diverse flora and fauna, including birds, bats, aquatic insects, fish, and amphibians; all which feed on mosquitoes. Constructed wetlands systems remove pollutants in stormwater through sedimentation, filtration of fines and biological uptake. The main components of wetlands are the inlet zone, macrophyte zone and then open water zone (Figure 3.10).

However, water features in the landscape will invariably attract adult mosquitoes, and efforts in controlling them or prevent their egg-laying is challenging. Due to the long hydraulic residence time and permanent water surface, constructed wetlands will normally breed mosquitoes. Hence, wetlands are also natural producers of mosquitoes and these create conflicts with human neighbors nearby. The potential of constructed wetlands for mosquito nuisance and transmission of mosquito-borne viruses in natural and constructed wetlands in temperate Sweden were evaluated by Schäfer et al. (2004). The study found that that mosquito abundance and species richness were higher in the natural than in the constructed wetlands and it was a positive correlation with the wetlands size. Nevertheless, Aedes albopictus is also found in natural wetlands and has the ability to spread rapidly, as noted by Benedict et al. (2007).

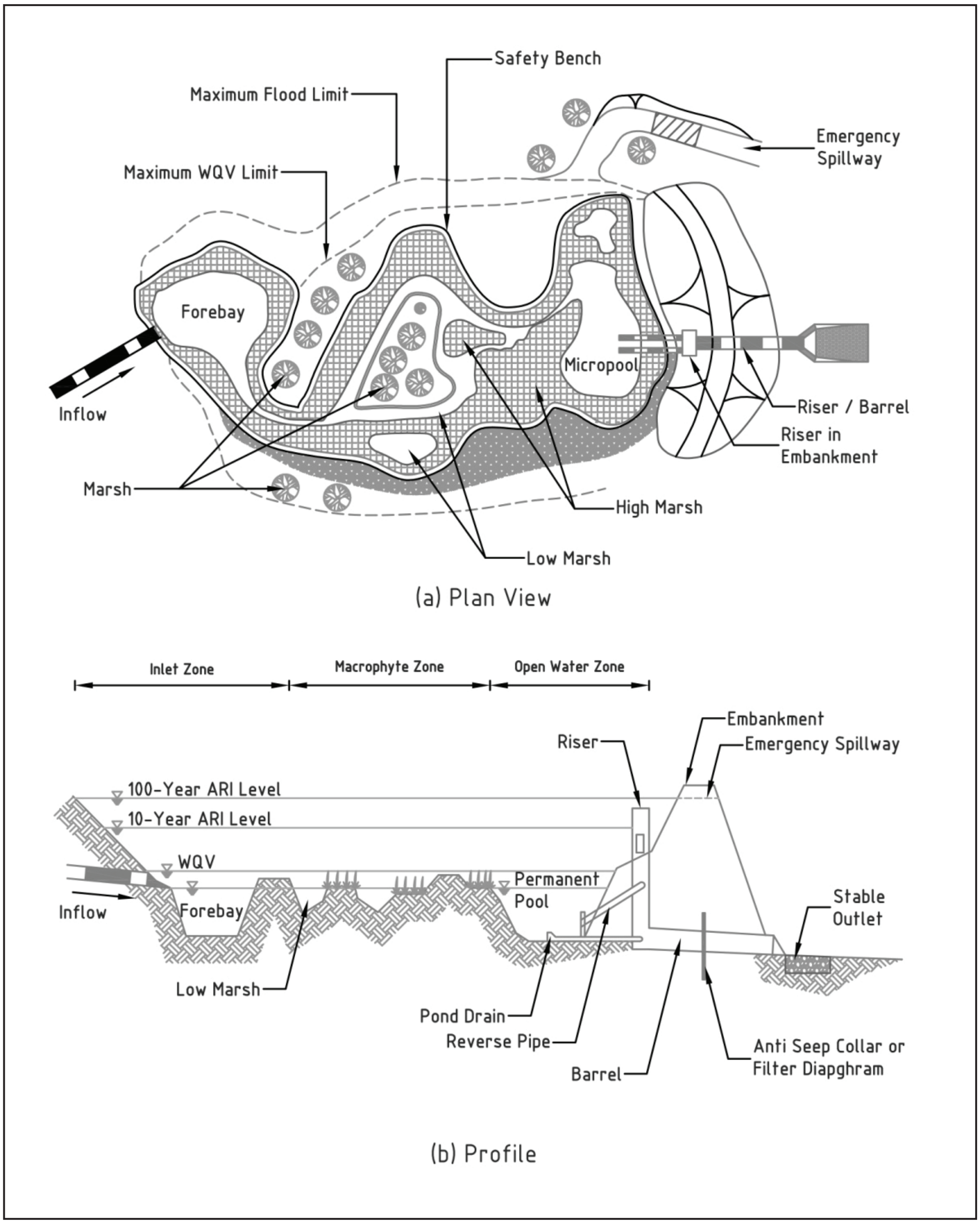

Figure 3.10 Wetlands Component (DID, 2012)

3.5.1 Planning and Design Considerations

- Mosquito control can be a concern for constructed wetlands if they are undersized or have a small contributing drainage area.

- Constructed wetlands design shall include variety of water regimes to foster the development of a variety of plants and animals that will naturally include mosquito predators (e.g. dragonflies, damselflies, water striders, pond skaters, backswimmers, predaceous diving beetles, topminnows, and mosquitofish).

- Improved water flow through the wetland system to minimizes stagnant water and facilitates movement of fish and other natural predators.

- Vegetation management, as it relates to mosquito control, will create open water areas that are unfavorable for mosquito breeding and increase predation pressure on mosquito larvae. This technique is most relevant to constructed wetlands and is particularly important to consider during the design phase of the wetland's creation process.

- Thick vegetation stands may reduce water flow thus reducing physical disturbances such as high currents, eddies, and waves that can negatively impact developing mosquito larvae.

- Water quality and wildlife habitat enhancement in wetlands are dependent upon wetland plants coverage, diversity, and productivity and could suffer with reductions in vegetation cover.

- The example of biological control agents for aquatic and wetland plant species can be found in Malaysia are *Pandanus amaryllifoliusn* (Pandan) and *Chrysopogon zizanioidesj* (Vetiver) (Figure 3.11).

(a) *Pandanus amaryllifoliusn* (Pandan)

(b) *Chrysopogon zizanioidesj* (Vetiver)

Figure 3.11 Wetlands Species

- Use concrete or liners in shallow areas to discourage plant growth where vegetation is not necessary.

- Design maintenance access to allow for periodic inspection and control of emergent and vegetation, and routine monitoring and control of mosquitoes.

3.5.2 Operation and maintenance

- Stock stormwater ponds and constructed wetlands with mosquito-eating fish to enhance natural mosquito control.

- Minimise the density and width of emergent vegetation areas. Emergent plant density should be routinely managed so mosquito predators can move throughout the vegetated areas and are not excluded from pond edges.

- Manage the spread and density of floating and submerged vegetation that encourages mosquito production (i.e., water hyacinth, water primrose, filamentous algal mats, etc.).

3.6 Underground Stormwater Structures

The underground stormwater structures that contain permanent water, like underground chambers have high potential for mosquitoes breeding compared to those stormwater systems designed to drain or infiltrate rapidly. All underground stormwater structures pose significant risk of breeding mosquitoes, which can easily seek out unseen water sources and enter gaps as small as a 2 mm (Metzger, 2004). Mosquitoes gain access to underground stormwater structures through many parts, including inlet and outlet pipes, loose-fitting covers, and vent holes. Consequently, actions and designs consideration to enhance effectiveness of underground stormwater structures in eliminating stagnant water is crucial due to mosquitoes can utilize underground sources of stagnant water as a breeding ground.

3.6.1 Planning and Design Considerations

- Where possible, seal access holes (e.g., pick holes in manhole covers) to underground structures designed to retain water in sumps or basins to prevent access of adult mosquitoes.

- Install rubber gasket for cover to eliminate gaps. The use of gaskets can provide a much more effective barrier when used properly.

- If the sump or basin is completely sealed against mosquitoes, the inlet and outlet should be completely submerged to reduce the available surface area of water for mosquitoes to lay eggs.

- Design bed surface slope towards the outlet for at 1.5% for underground stormwater structures.

- Invert level of primary outlet pipe should be equal or same as invert level of outflow drain to ensure no water ponding in the outlet structure (Figure 3.12).

- Consider underground stormwater structures design with the appropriate pumping, piping, valves, or other necessary equipment to ensure easy dewatering when required.

- Design a sump pump which can drain off during dry season.

- Circulate water to avoid stagnation (e.g., provide a constant influx of water equal to the net loss or discharge of water).

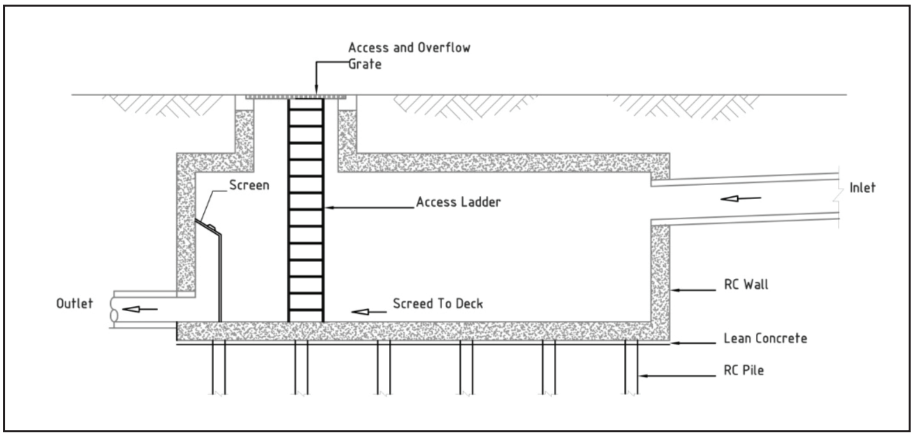

Figure 3.12 Typical Underground Stormwater Structures

3.6.2 Operation and maintenance

- Provide manholes and/or cleanouts to all portions of the system.
- Inspect inflow points for sediment accumulation
- Inspect screens or trash racks, and clear of any accumulated trash, sediment and debris.

3.7 Natural River/Stream/Water Courses

Generally, mosquitoes are not found in moving streams and rivers or in areas with heavy wave action. However, mosquito breeding sites might be found in areas where water stagnant for more than five days on river floodplains along stream and riverbanks.

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3.7.1 Planning and Design Considerations

- Meandering rivers in floodplain with slow flow and much silting but exposed to periodic torrential flows might break through the banks and flood the low-lying areas along the course.
- Low-lying areas may form extensive river swamps where flow is off concern become the breeding places for mosquitoes.

- The natural water courses which dry soon after storm events usually still stagnant along series of ground depressions and "potholes" filled with water and thus produce favourable breeding ground for mosquitoes.

- All "potholes" should be backfilled to grade by filling so that water will drain off.

- Construct levees which serve as flood protection measures and also to prevent the formation of swamps by water overflowing to low-lying areas, backwater pools, marginal pockets and the eroded or fallen stream banks.

3.7.2 Operation and maintenance

- Clear debris, litter from drain and drain outlet periodically.

- Immediately remove noxious weeds and plants, particularly those that are invasive.

- Remove accumulated litter and debris at the middle and end of the wet season.

4.0 WATER SUPPLY SYSTEM

4.1 Introduction

The purpose of water supply system is to deliver water to consumers with appropriate quality, quantity, and pressure. The setting requires an extensive system of pipes, storage reservoirs and tanks, pumps, and related appurtenances. A water supply system may be classified into three types, namely a gravity system (Figure 4.1), a direct pumped system and a gravity and pumped combination system (Figure 4.2). The main purpose of the Service Reservoir is to provide intermediate storage for incoming treated water, providing back-up supply or reserve, especially in times of service interruptions at the upstream Water Treatment Plants, and deliver water into the water reticulation systems. The Service Reservoirs also manage fluctuations in water supply demand. The Suction Tank will receive incoming water supply of low pressure for storage before the water is pumped up to the Service Reservoir via the pumping system within the Pump House. From the service reservoir, water is supplied to each demand point via reticulation pipes. As these structures are essentially water storage and conveyance facilities, stagnant water can arise upon its construction and prior the commissioning process.

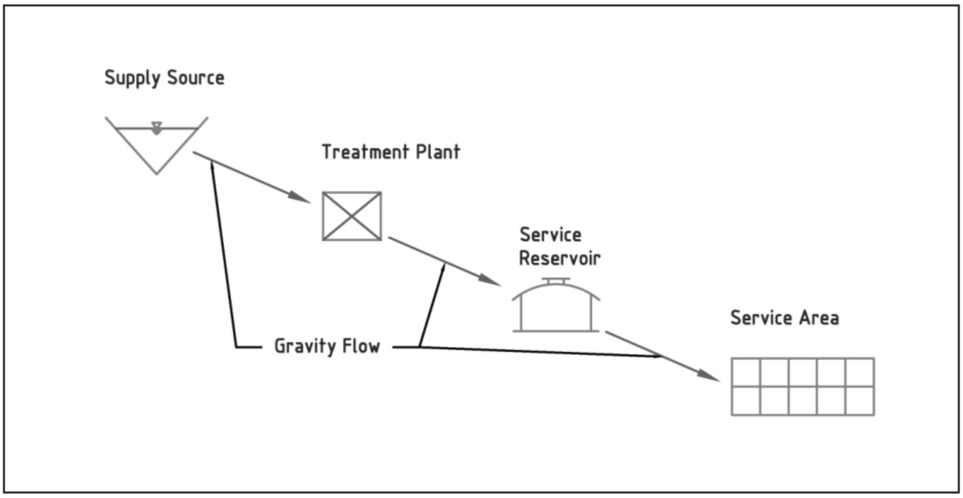


Figure 4.1 Typical Gravity Water Supply System (MWA, 1994)

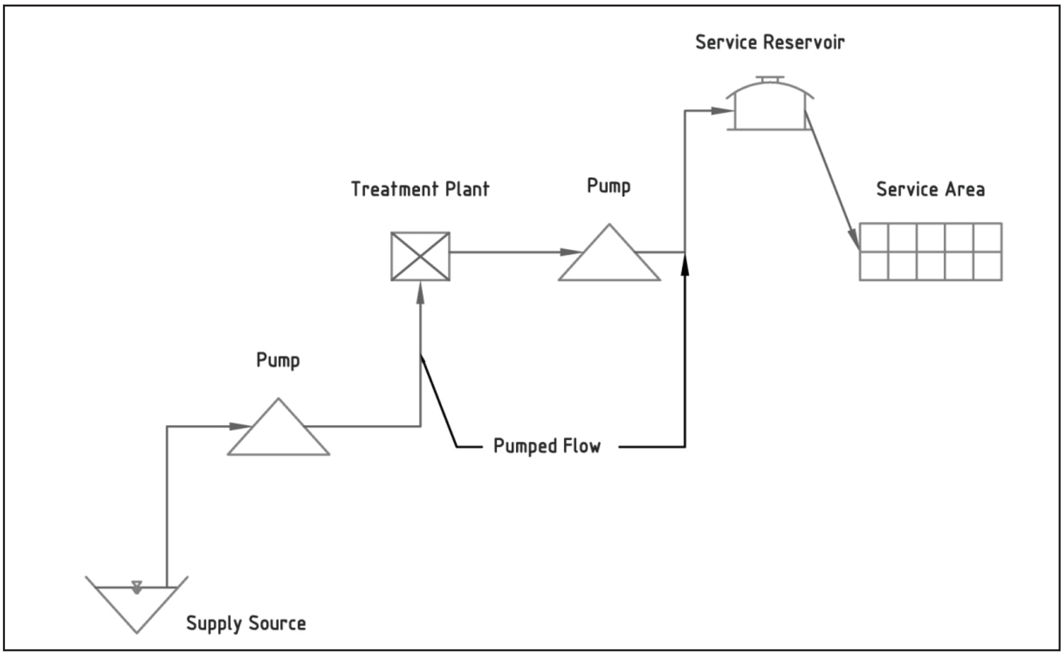


Figure 4.2 Typical Pumped and Gravity Water Supply System (MWA, 1994)

4.2 Potential Breeding Ground

- General Water Supply system: All valve chambers
- Suction Tank Area: Storage cells, Valve chambers, perimeter road and drain system
- Pump House: Internal trench and ponding due to undulating floors
- Service Reservoirs: Storage cells, Valve chambers, perimeter road and drain system.
- Inlet/outlet valve chamber (Figure 4.3) and scour outlet chamber (Figure 4.4) can become mosquitoes breeding ground due to missing/inadequate drainage outlet and lack of maintenance.

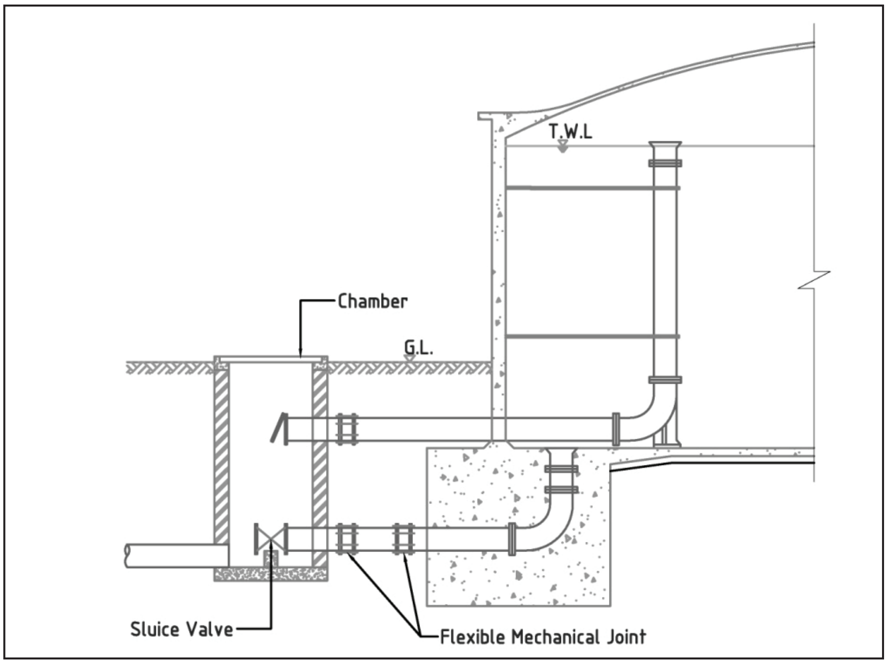


Figure 4.3 Typical Inlet/Outlet Valve Chamber (MWA, 1994)

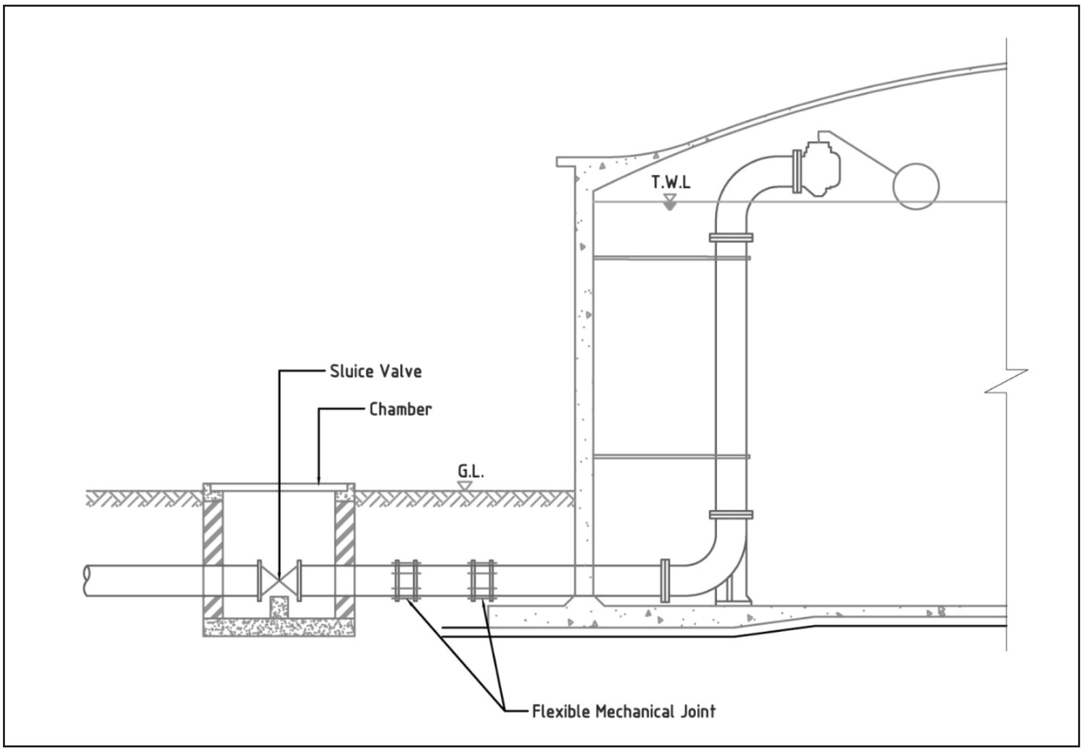


Figure 4.4 Typical Scour Outlet Chamber (MWA, 1994)

4.3 Planning and Design Considerations

- Service reservoir (Figure 4.5) must be watertight and structurally safe. The reservoir could be on the ground type or elevated type, depending on the size and to meet supply requirements. The shape of the reservoir can be circular, rectangular, square, or mushroom shape type.

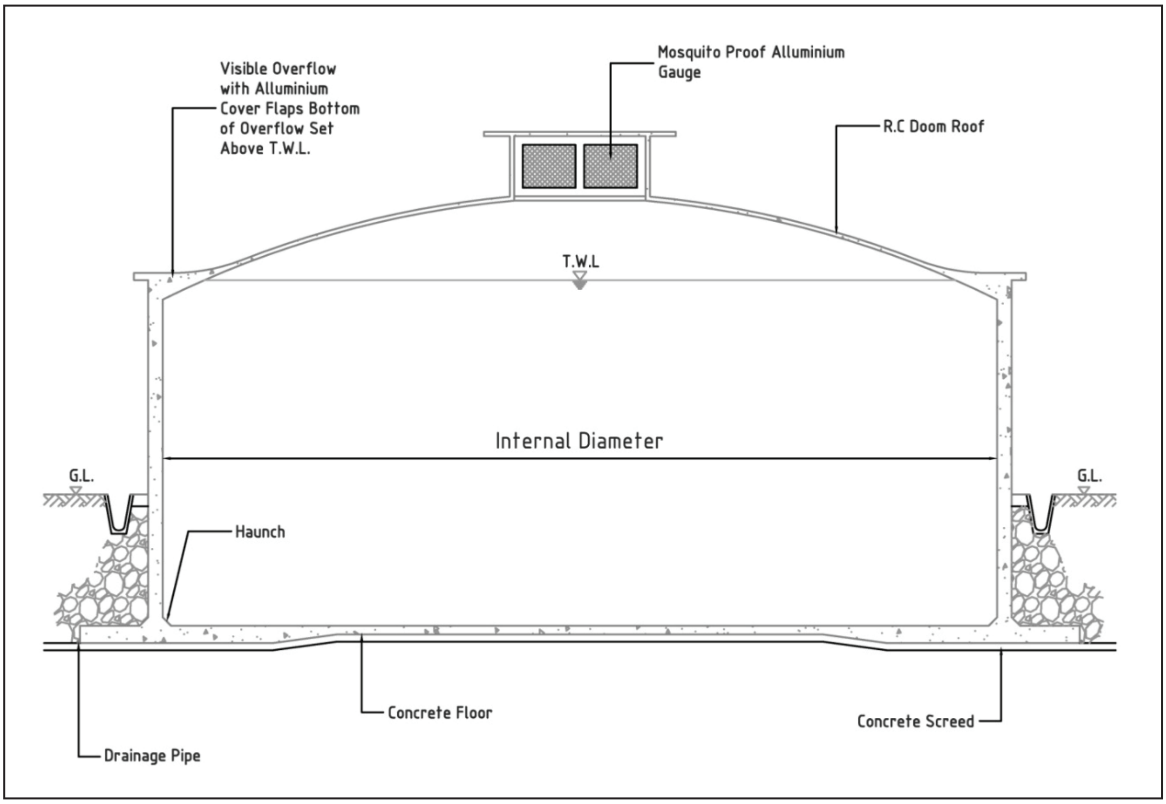


Figure 4.5 Typical Circular Type Service Reservoir (MWA, 1994)

- Valves chambers such as air valves and scour valves along the pipeline route will be typically placed inside reinforced concrete chambers with cover.

- Use heavy-duty reinforced concrete type cover if chamber is situated on the road; or cast-iron cover for those on the road shoulders.

- Covers should be tight fitting with maximum allowable gaps or 2 mm holes. The use of gaskets can provide a much more effective barrier when used properly.

- The chambers along the roadside should be placed higher (at least 50mm) than the road level to prevent stormwater from the road surface from entering the chamber (Figure 4.6).

- For large chambers that are located at low-lying areas, install permanent pumps could be considered as part of the design; or to design the soakaway outlet higher than the drain water level to prevent backflow from the drain during heavy storm events.

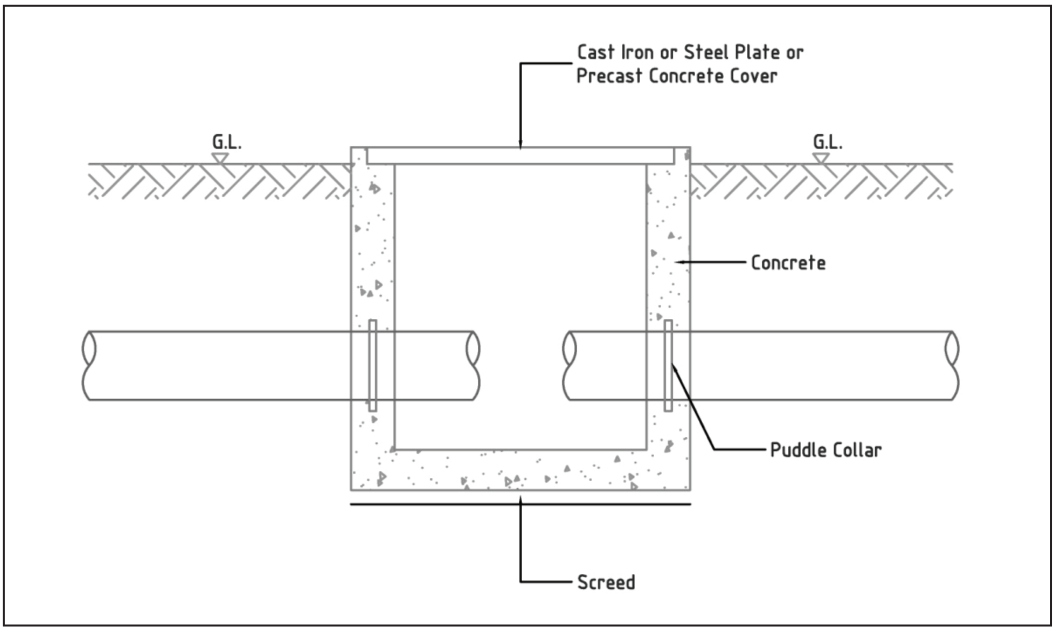


Figure 4.6 Typical chamber by roadside (MWA, 1994)

- Mosquito-proof screening such as vermin screen shall be installed at all ventilators at the suction tanks and service reservoirs.

- The design of access/maintenance road, as well as the drainage needs to ensure that no stagnant water will occur if the reservoirs are located on higher grounds. The typical minimum grade for road should be at least 0.5% (Figure 4.8).

- Provide adequate maintenance access for clearing of debris and vegetation at berm drains.

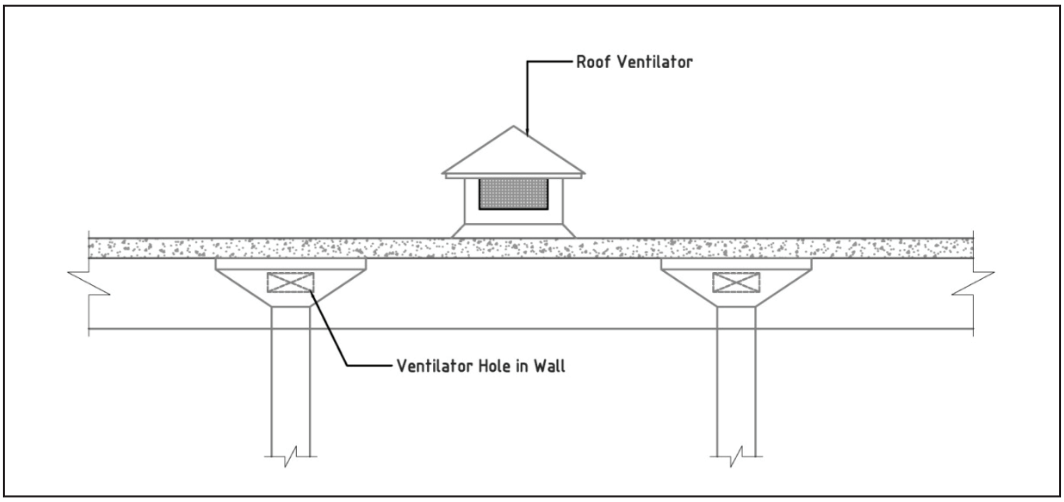


Figure 4.7 Typical Roof Ventilator (MWA, 1994)

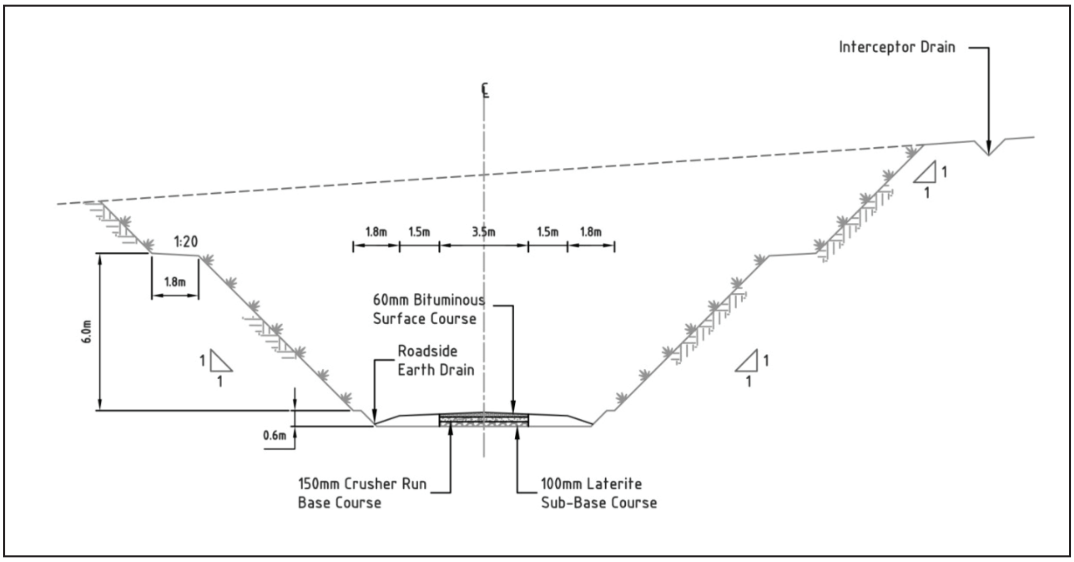


Figure 4.8 Typical Road Section (MWA, 1994)

4.4 Operations and Maintenance

- Contractor should check the chambers after heavy rainfall incidents to ensure water is removed from the chambers either naturally or using pumps during construction of the reservoir.

- Contractor should ensure that the reservoir, chambers, road and drainage does not contribute to permanent stagnant water which can contribute to mosquito breeding before the testing and commissioning and handing over happens.

- Where it is intended for natural drainage, the soak away outlets need to be ensured that it is free from clogging (to prevent stagnant water) and vegetation growth causing obstruction.

- Water supply operator needs to undertake scheduled inspection periodically for the reservoir, chambers, access road and drains to ensure that the facilities mentioned above are not having permanent stagnant water, and if necessary to carry out maintenance and clear the stagnant water to prevent it from becoming a mosquito breeding area.

4.5 Decommissioning of Water Infrastructures

Decommissioning infrastructures typically may cause subsequent maintenance problem particularly when they are located at remote area such as old dams or tailing storage when the monitoring and inspection are less frequent or less attended. Decommissioning water supply infrastructures may not pose such an issue as they are located in residential/habituated area. In such a town re-development/rehabilitation project, land is valuable where the facilities are generally removed, and the land is converted into other type of land use. In these circumstances, there are no abandoned area that would allow stagnant water and mosquito breeding.

However, in the unique cases where such facilities may be decommissioned whereby the structures potentially could be left abandoned for a long time, the following mitigation measures/BMPs should be practiced：

- Potential water containment facilities such as storage tanks, reservoirs should be removed or modified/removed the outlets so that rainwater may not contain in the storage. An effective way to do is to remove the outlet valve which can serve two purposes:
  - prevent water stagnant in the reservoir
  - prevent the theft as valve are normally made of cast iron which can be easily stolen in the abandoned site.

- All the water intakes structures which could allow inflow of water should be plugged off. The containment structures should be infilled with earth to prevent collection of rainwater.

- All the water valves should be removed to prevent the collection of water in the pipeline which may eventually cause water stagnant.

- All the underground sumps shall be properly plugged-off and infilled with earth to prevent the collection of water.

- The tall grasses should be trimmed and cut at regular interval to reduce the risk of mosquito breeding.

- All the drainage outlets should be inspected to prevent clogging and forming of stagnant water.

- The area shall be inspected every 6 months.

5.0 SEWERAGE SYSTEM

5.1 Introduction

Wastewater generated from Residential and Commercial units are wastewater are usually discharged into an external sewage reticulation network system, where it is channeled to the nearest designated Sewerage Treatment Plant (STP) for treatment. However, older developments of residential and commercial units are still known to channel their wastewater into individual septic tanks, due to unavailability of centralized sewerage network reticulation at the time of their development. A typical sewerage reticulation network consists of inspection chamber, manholes and pipelines as shown in Figure 5.1.

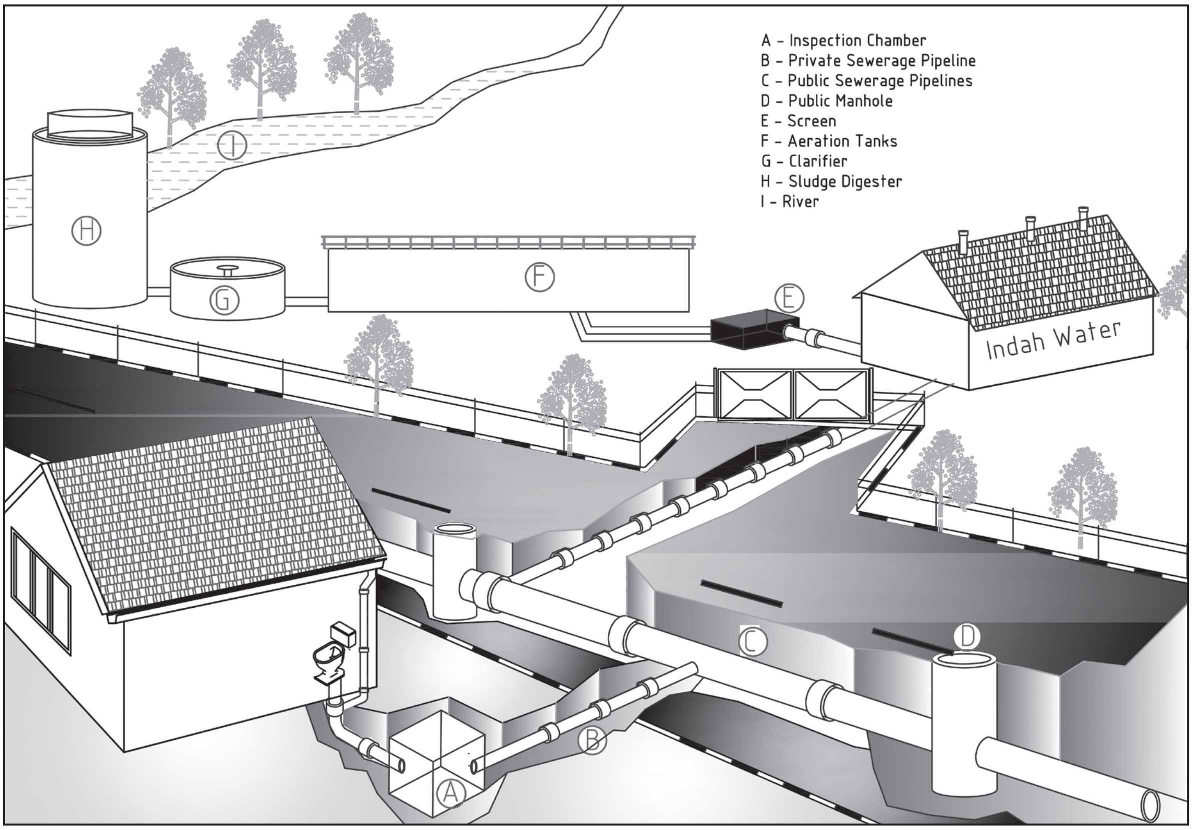


Figure 5.1 Typical sewerage reticulation network (Source: Indah Water Konsortium)

5.2 Potential Breeding Ground

- Common mismatch of manhole or inspection chamber invert level and outgoing pipe invert level that creates ponding issue (Figure 5.2).
- Broken septic tank cover / septic lid that is not sealed properly (Figure 5.3).
- Mosquitoes commonly gain access to septic tanks through the vent pipes.

Figure 5.2 Water ponding issue in manhole or inspection chamber due to mismatch invert level

Figure 5.3 Broken septic tank cover

5.3 Planning and Design Considerations

- To ensure the connection from Inspection Chamber to sewerage manhole have sufficient gradient so the sewage can flow.

- To ensure the connection from sewerage manhole to sewerage manhole have sufficient gradient so the sewage can flow.

- The sewer reticulation shall have hydraulic design in such that the minimum velocity of flow does not fall below 0.8m/s at full bore (Refer to MS1228:1991 - Code of Practice for Design and Installation of Sewerage System) (Figure 5.4).

- In addition, Malaysia Sewerage Industry Guidelines shall also serve as reference for planning and design of sewerage system.

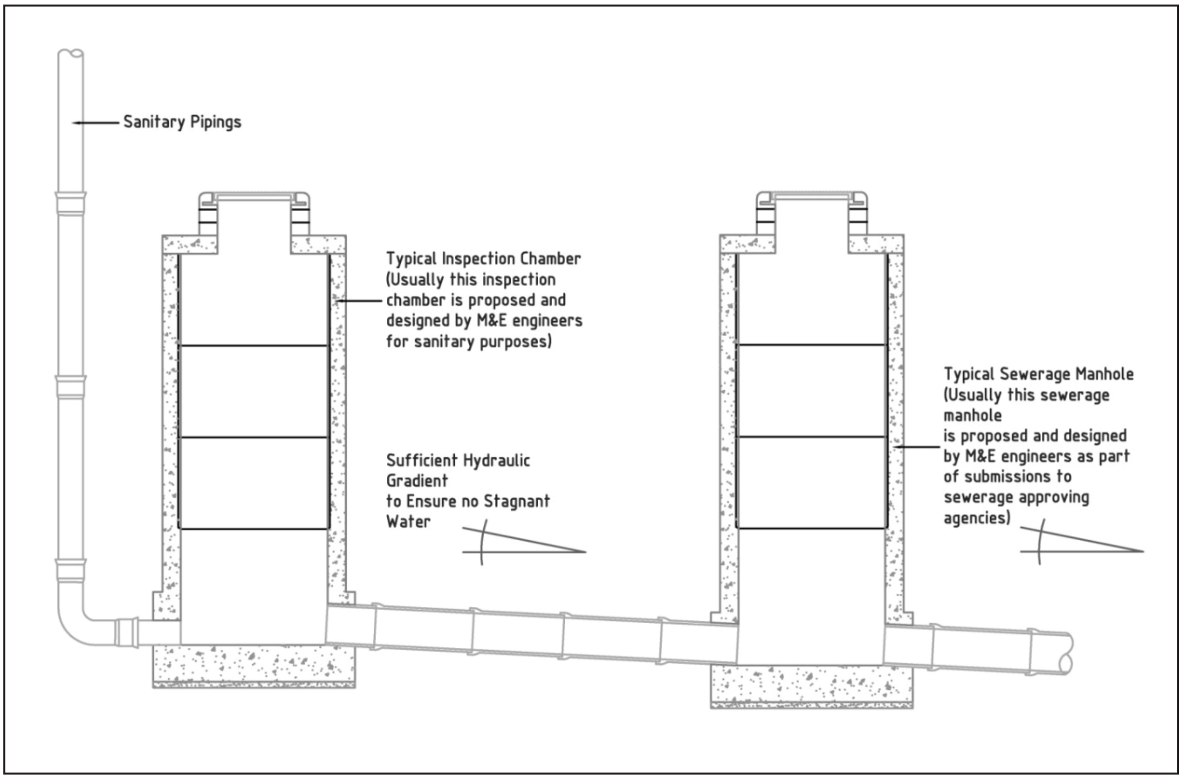


Figure 5.4 Sufficient hydraulic gradient shall be considered for designing sewer reticulation

- Proper consideration shall be adopted to select the sewer pipes material (rigid pipes or flexible piles) to ensure the pipes meet the durability requirement.

- It is advisable to design the outgoing pipe discharge invert level to match the manhole or inspection chamber invert level to avoid water ponding (Figure 5.5).

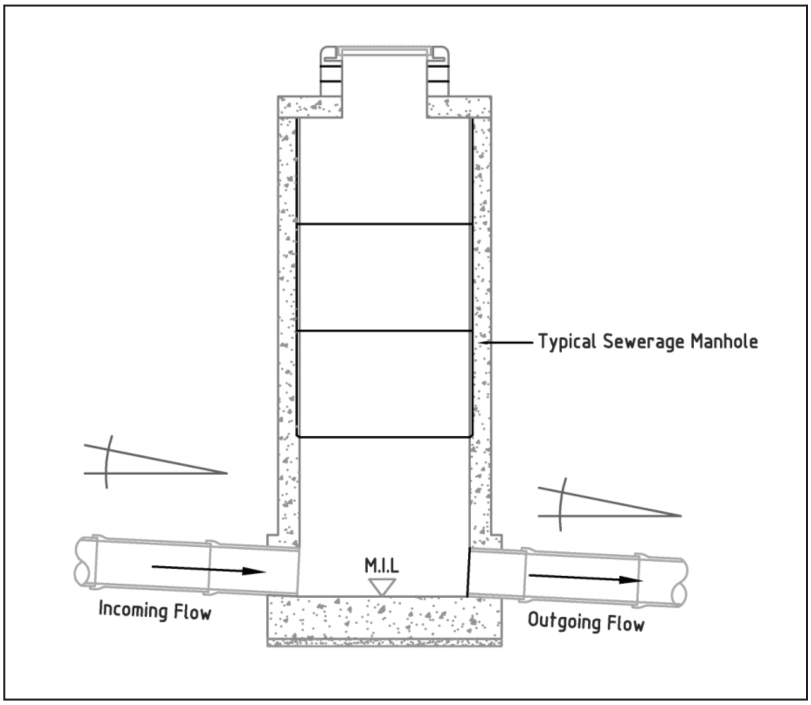


Figure 5.5 A typical connection for outgoing pipe invert level to match manhole/inspection chamber invert level

- A septic tank is a basic form of on-site treatment facility consisting of one or more compartments that provides treatment of sewage by means of sedimentation and anaerobic process. It shall serve a single premise, with capacity not more than 30PE.

- Proper consideration shall be provided during the installation of the septic tanks and its future connection (Figure 5.6). The rubber plug shall ensure watertightness to avoid water trapped during construction. It is also the responsibilities of the contractor to construct according to approved plan and maintain site cleanliness and dry condition. Manhole shall not have any defects that prompt to collect stagnant water.

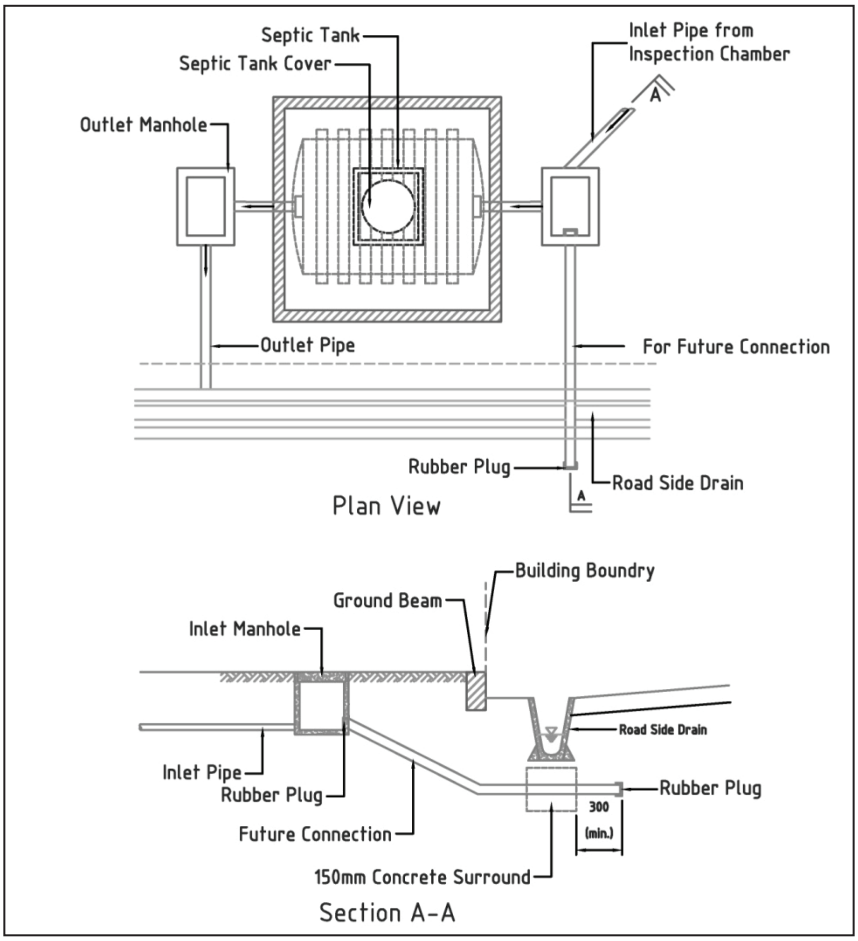


Figure 5.6 A typical connection for individual septic tank with future connection to centralized sewerage reticulation (SPAN, 2009)

- Septic tank (Figure 5.7) or small sewerage treatment system (SSTS) (Figure 5.8) shall be properly sealed during construction and any water trapped shall be pumped out during construction as surface run off will tend to seep into the sewerage reticulation system (Septic tank shall be the type approved by SPAN).

Figure 5.7 Typical septic tank

(Source: Suruhanjaya Perkhidmatan Air Negara, SPAN)

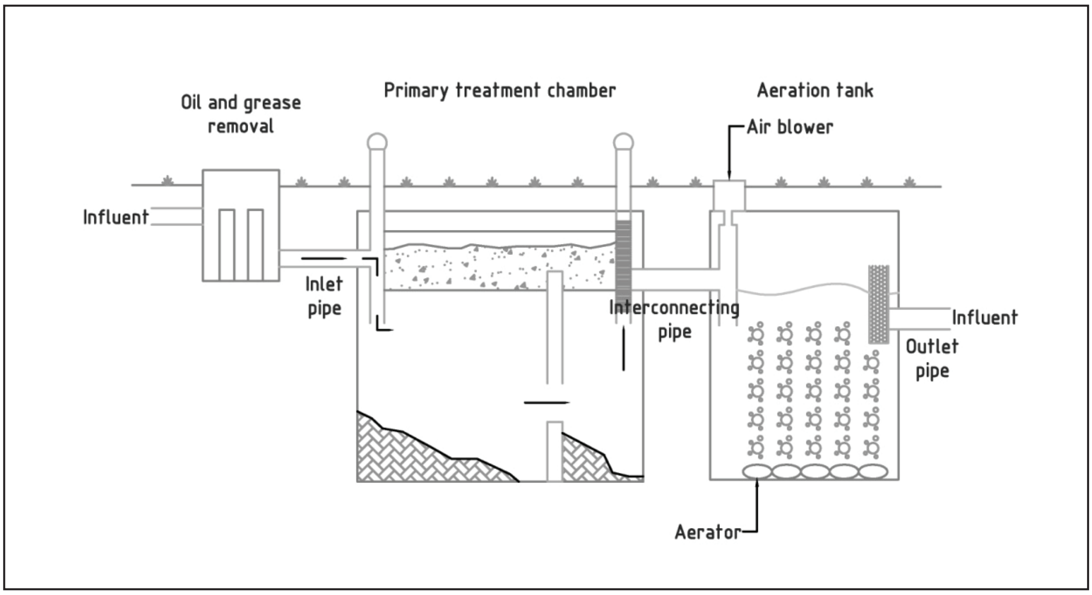


Figure 5.8 Schematic Diagram of SSTS

5.4 Operations and Maintenance

- Manhole shall be properly sealed during construction and any water trapped shall be pumped out during construction as surface runoff will tend to seep into the sewerage reticulation system. It is common during construction the manhole will be plug throughout construction period until testing and commissioning of sewer line and surface run off tends to seep in and fill the manhole. Over a period of time the manhole can be filled with water (Figure 5.9). Butyl rubber sealant can be considered as an option for manhole cover sealant.

Figure 5.9 Manhole or inspection chamber overflow with surface runoff (during construction)

- Seal up keyholes and gaps around manhole or inspection chamber cover (Figure 5.10).
- Broken septic tank cover shall be replaced. However, if there is financial constraints, alternatively providing mosquito mesh cover on top of it provides temporary solution.
- Screen vent pipes or plumbing pipe openings with wire mesh / mosquito-proof screen (Figure 5.11).
- Design of individual septic tank shall allow regular desludging. Desludging shall be at least once every 3 years.
- Fill abandoned or unused septic tanks with dirt, sand or gravel (porous material) to ensure no stagnant water being trapped.
- Any sewerage infrastructures (inspection chambers, manholes, sewer pipes, septic tanks, SSTS) located inside or within the premise boundary are deemed as part of private sewer and it is the obligation of the premise owner to maintain the sewer infrastructures.
- Any sewerage infrastructures located outside the premise boundary are deemed as public sewer and it is the operator's obligation to operate and maintain these infrastructures.
- Premise owner and public sewer operator shall both responsible to ensure the sewerage infrastructures under their responsibilities are not Aedes mosquitoes breeding grounds.

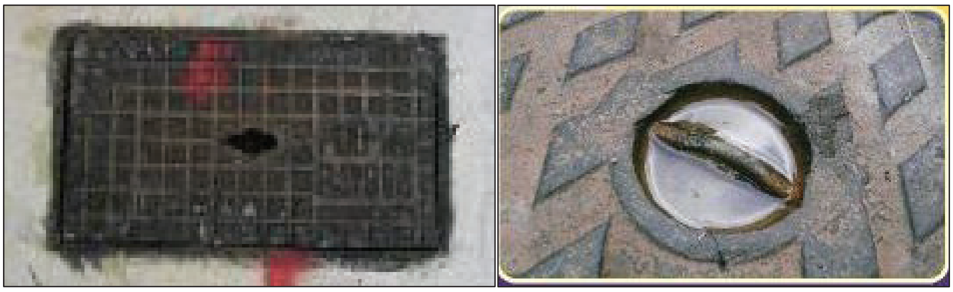


Figure 5.10 Keyholes or lifting hook for manhole or inspection chamber cover will create water ponding

Figure 5.11 Exposed vent pipe shall be properly seal with screen mesh (Source: Department of Health and Human Services-US)

5.5 Decommissioning of Sewerage Infrastructures

- Any sewerage infrastructures will serve and functioned accordingly to the designed life span. However, at times there are certain infrastructures will be decommissioned from time to time.

- These infrastructures are not limited to inspection chambers, manholes, sewer pipes, individual septic tanks, small sewerage treatment systems, sewerage treatment plants and other accessories.

- Once these infrastructures are no longer in use, they will be decommissioned, and proper care shall be attributed to these infrastructures to ensure it will not be Aedes mosquitoes breeding ground once these infrastructures are decommissioned.

- Fill abandoned or unused tanks/ liquid containment structures with dirt, sand, or gravel (porous material) to ensure no stagnant water being trapped.

- Pipe inlet and outlet shall be plugged, or they can be patched with cement or grout.

- Any gap or holes in between sewer manholes covers can be patched with cement or grout.

- Pumps, valves and other accessories shall be removed to avoid theft and the voids / openings left by these accessories' removal shall be properly sealed off by plugging it or cover with mosquitos' proof screen or patch with cement / grout.

- It is recommended to have periodic inspection on these infrastructures to ensures these decommissioned infrastructures does not contribute to mosquitoes breeding ground.

6.0 BUILDINGS AND MECHANICAL SYSTEMS (WITHIN BUILDING)

6.1 Introduction

In the design of the various components of a building, engineers provide the detail aspects of the building in accordance with local authority guidelines, Uniform Building By-Law, and relevant Malaysian Standards. The period from conceptual, construction to handing over to the building owner could take one (1) year to three (3) years or longer. Within the building, there will be many mechanical systems installed for the comfort of the occupants. In general, the timeline can be categorized into several phases namely design, construction, installation, testing and commissioning (T&C) if applicable, handing over and operation and maintenance.

The water within a built environment and in the mechanical systems can be categorised into three (3) types of water:

1. Treated water as potable water in plumbing systems

2. Treated water but non-potable water in firefighting systems, swimming pool and air conditioning systems.

3. Non-treated water namely rainwater, greywater and blackwater as in harvesting systems, drainage systems, and sanitary systems respectively.

Stagnant water in buildings and mechanical systems could be treated or non-treated water. Treated water is supplied from the Water Authority and may contains up to 1000 mg/litre of Total Dissolved Solids which could be a food source for the aedes mosquitoes to complete its life cycle. However, this amount is small in comparison to those in the non-treated water. In this respect the non-treated water will yield a much larger population of aedes mosquito for the same condition. It is crucial to identify stagnant water within the building which is the potential breeding ground of mosquitoes.

To stop the life cycle of the aedes mosquitoes is to remove all stagnant water within the building by either the use of portable pump or manually remove the stagnant water within 4 days of the last rainfall. If inevitably residual water is left behind, the water pH could be enhanced to above 10 (Jasmine, P. and Robin, P.S.V., 2020) or alternatively to dose in larvicide as a form of chemical treatment (Chapter

9). A practical and simple methodology to achieve pH 10 and above is to use a piece of solid soap cut into pieces and placed inside the water in the ratio of 1: 60 by weight. The use of soap which is a common household consumable will not have impact to the environment.

6.2 Potential Breeding Ground

The potential breeding grounds and risks of stagnant water in potable and non-potable water are summarised below.

Facility/System	**Likelihood of Stagnant Water**	**Phase of Construction of Building**
Plumbing Systems are an enclosed system during operation mode (Treated Water as Potable Water)		
• Non-RC Tank	Certain	T&C
• RC Tank	Certain	Erection/T&C
• Swimming Pool	Certain	Erection/ T&C
Firefighting wet systems and air-conditioning systems are enclosed systems during operation mode (Treated Water but Non-Potable)		
• Water tank	Certain	Erection
• Cooling towers	Certain	Erection
Rainwater, Grey water and Black water (Non-Treated Water)		
• Rainwater Harvesting Systems	Certain	Erection/T&C/Hand Over
• Roof Gutter	Certain	Erection/Hand Over
• Lift pits	Certain	Erection
• Internal Drains and Sumps	Certain	Erection
• Sanitary Systems	Certain	Erection

6.3 Plumbing Systems, Swimming Pool and Supporting Services

6.3.1 Planning and Design Considerations

- A typical plumbing system for landed residential premises is shown in Figure 6.1. The cold-water systems are potable water, as such the water if any must remain uncontaminated from erection to operation.

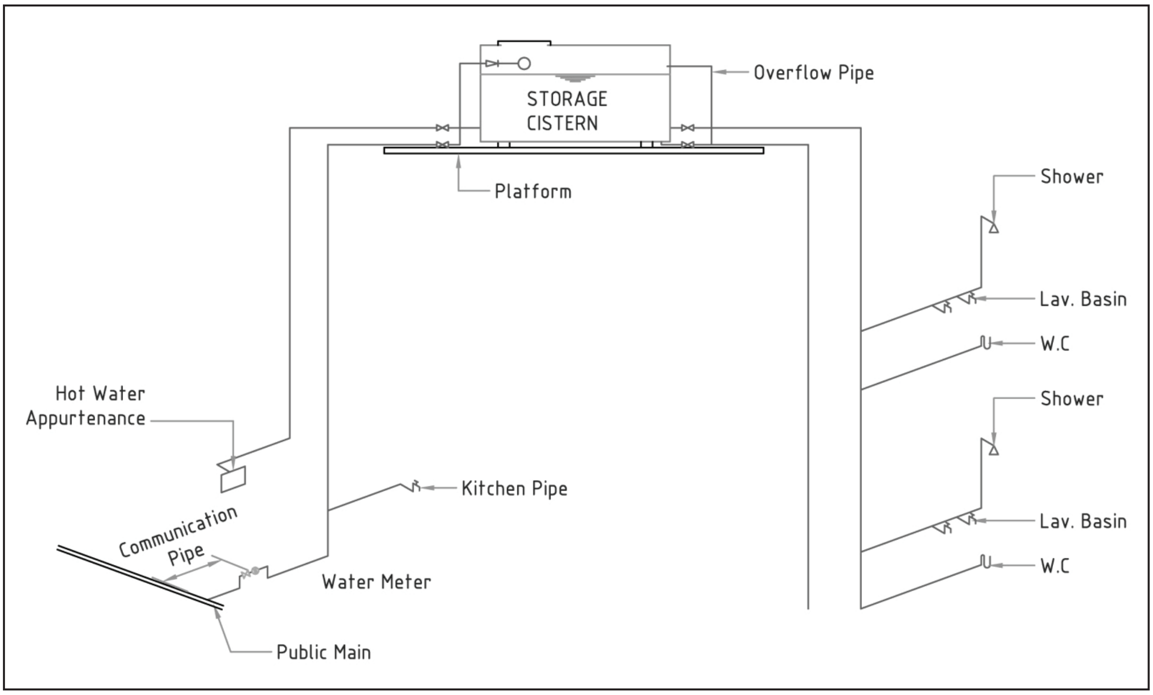


Figure 6.1 Schematic Diagram of a Water Supply Plumbing System for Typical Landed Residential Premises (Source: SPAN Uniform Technical Guide)

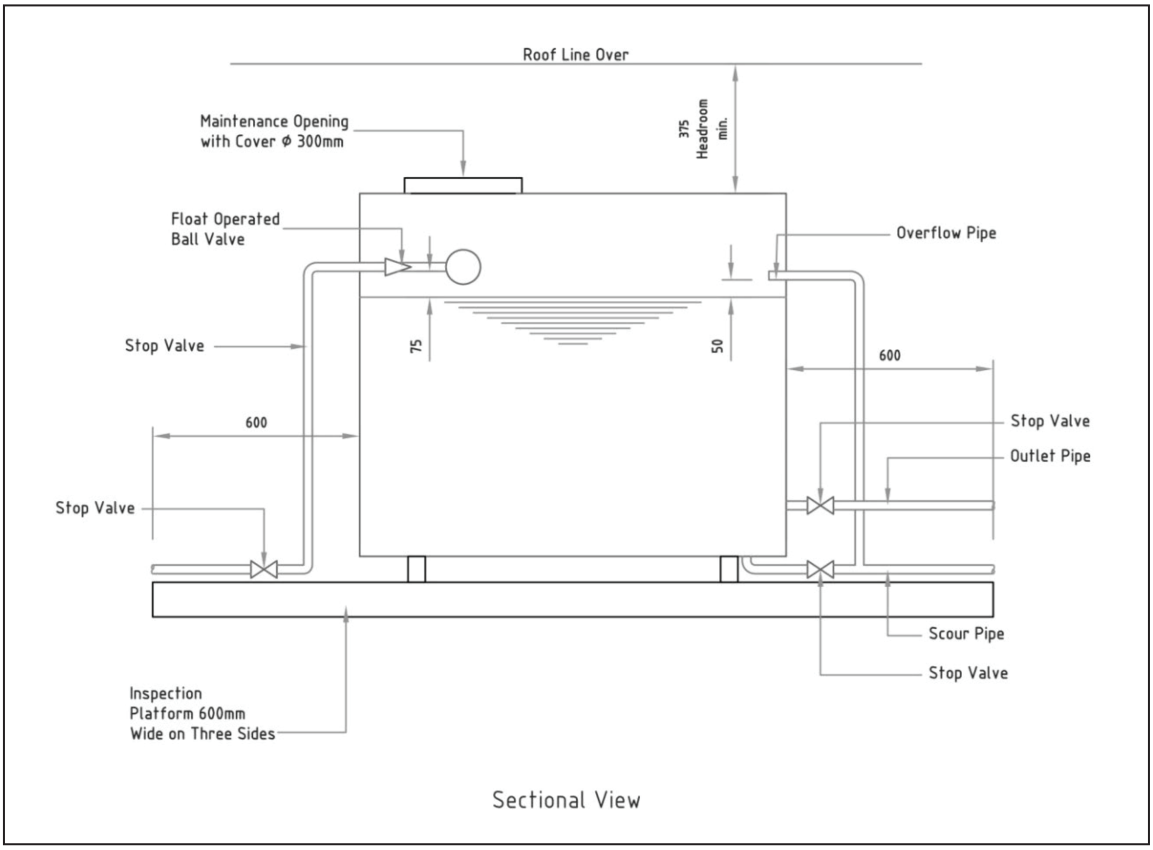


Figure 6.2 Typical Details of a Storage Cistern (Source: SPAN Uniform Technical Guide)

- All openings of the system must be covered with mosquito netting or equivalent to prevent mosquitoes entering the system. Water maybe introduced into the system intentionally or otherwise hence this measure is deemed critical.

- Reinforced Concrete (RC) tank can be used for potable water. As such, the measures taken must be more extensive like installing a temporary cover over the access manhole.

6.3.2 Operations and Maintenance

- Plumbing systems are enclosed systems and during operations there may be minor leaks which will create patches of stagnant water. Immediate steps must be taken to repair all leaks in the facilities room. Likely areas where leaks could occur are at the storage tanks, overflow pipe (unless linked to the scour pipe) and at the pump seal.

- During the construction phase of a swimming pool, rainwater may enter the pool creating an ideal mosquito breeding ground. As such, water inside the pool must be pumped out but not empty and the remaining water pH to be increased to 10 and above.

- Maintenance of swimming pool to be carried out in accordance with the manufacturer recommendations and to ensure that during long non-usage period the pool must retain sufficient water the pool from cracking and water pH to be increased to 10 and above.

6.4 Firefighting Wet Systems and Air-Conditioning Systems (including cooling towers)

6.4.1 Planning and Design Considerations

- Figures 6.3 and 6.4 show typical arrangements for the wet riser system and air-conditioning system. Firefighting Wet Systems and Air Conditioning systems in particular the cooling towers should be emptied of water at all times during long period of non-operation. The chemically treated water would be diluted and become ideal mosquitoes breeding ground.

- If residual water is inevitable, then the water pH must be adjusted to above 10.

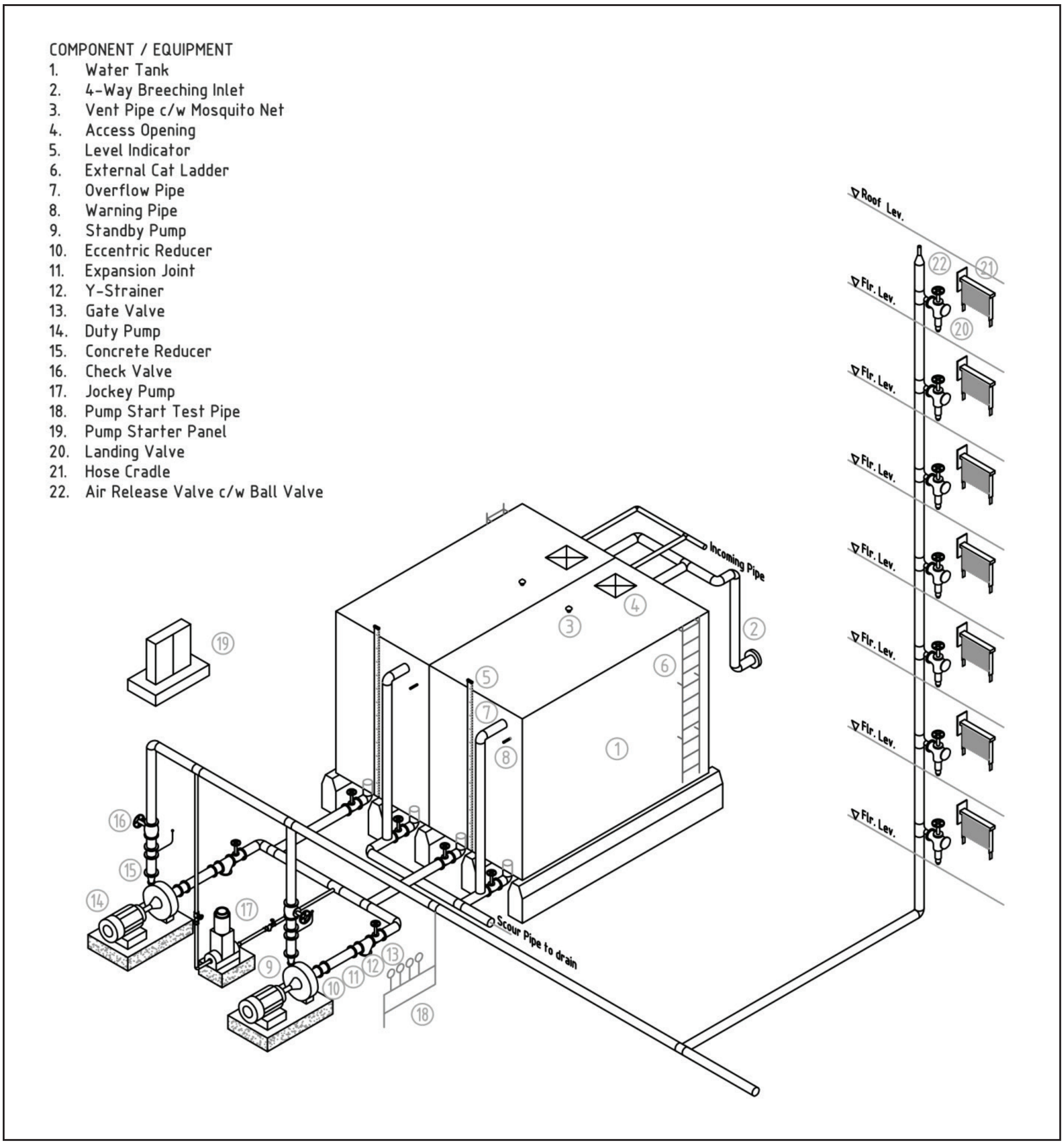


Figure 6.3 Typical Arrangement of Wet Riser System

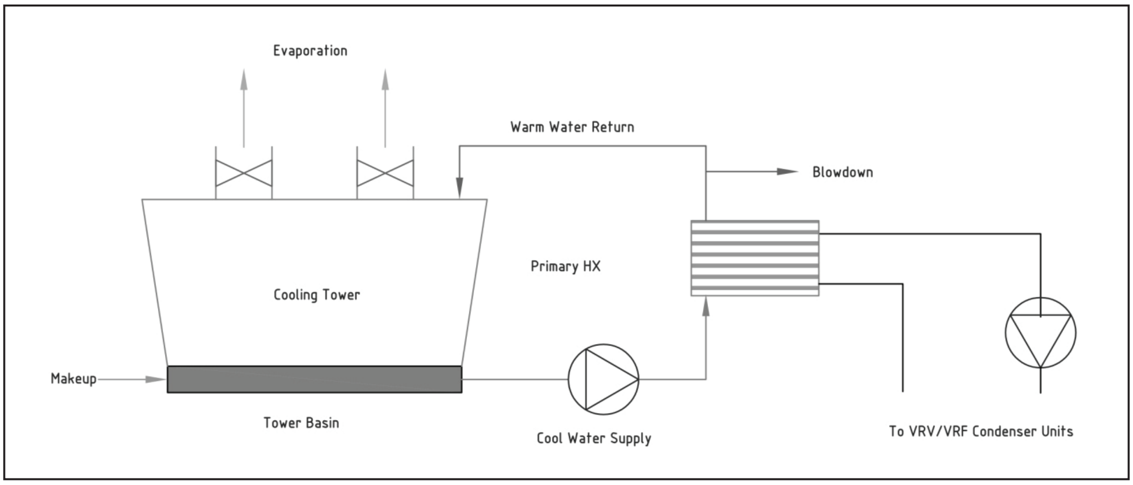


Figure 6.4 Typical Arrangement of Air Conditioning System and Cooling Tower

6.4.2 Operations and Maintenance

- Once these systems are in the operational mode, it is fully enclosed and the tanks openings must have a netting or equivalent to prevent mosquitoes from entering the tanks.
- As for the cooling towers, the standby unit which has a collecting basin must be dose in with larvicide regularly.

6.5 Roof Gutters (including Rainwater Harvesting System – RWHS)

There are 2 types of building roof namely:

1. Reinforced gradient concrete
2. Structured with tiles

6.5.1 Planning and Design Considerations

- Reinforced gradient concrete roof are to be designed with perimeter drain/gutter to channel the water to the downpipes.
- Flat RC roof with insufficient gradient can create ponding. Flat RC roof with up to 10-degree gradient is suggested to ensure water will not stagnate. Ponding if occurs can damage the water proofing membrane installed on the RC roof.

- Roof gutter is to be designed with a gradient to direct rainwater to the downpipes and subsequently discharged to the perimeter drains (without stagnant water). The number of downpipes (n) for the gutter is determined from the roof area. To remove stagnant water in the roof gutter, it is recommended to have (n+1) downpipes. Hence, there is additional outlet. The RWHS if installed receives rainwater from the roof gutter by gravity and will enter a fully enclosed system with the storage tank having mosquito netting at the overflow pipe.

- To eliminate stagnant water, a temporary wire mesh should be installed at all downpipe points to allow rainwater to flow through while preventing debris from blocking the pipes.

- A dome filter is to be installed at the mouth of every downpipe. The perforated slots will stop sizeable debris entering the downpipe which will prevent blocking the downpipe yet sufficient to drain off the stagnate water at the gutter.

- The dome filter is to be installed lower than the gutter vertical height. This will allow rainwater to enter from the top in the event of a blockage at the base. This will effectively drain off all residual water in the gutters.

Figure 6.5 Dome Filter

6.5.2 Operations and Maintenance

- During rainy season, it is necessary to remove the debris accumulated on the temporary wire mesh to ensure flow of water and this should be carried out at least once a month.

- Yearly maintenance for the dome filter is required to remove the accumulated debris.

- During the maintenance liability period, the RC roof must be monitored for ponding and be rectified to avoid stagnant water as a breeding ground for aedes mosquitoes.

6.6 Internal Perimeter Drain, Scupper Drain and Basement Sumps (including lift pits)

The scupper drains and sumps are common at the basement level and will be at the lowest level. Inevitably rainwater will enter the building via the driveways openings and the rainwater will flow to the scupper drains and will be collected at the sumps.

6.6.1 Planning and Design Considerations

- Scupper drain gradient must deviate from the standard and should be made steeper. A steeper gradient of at least 10 degrees will have no impact to the depth at the end because the sump is much deeper. A steeper gradient will ensure that any residual water that stagnates along the drains will evaporate.

- A submersible pump with a float control needs to be used to pump out the water but a portion of the water may remain inside the sump. The residual water pH could be adjusted to be above 10 and remain at this pH until operation.

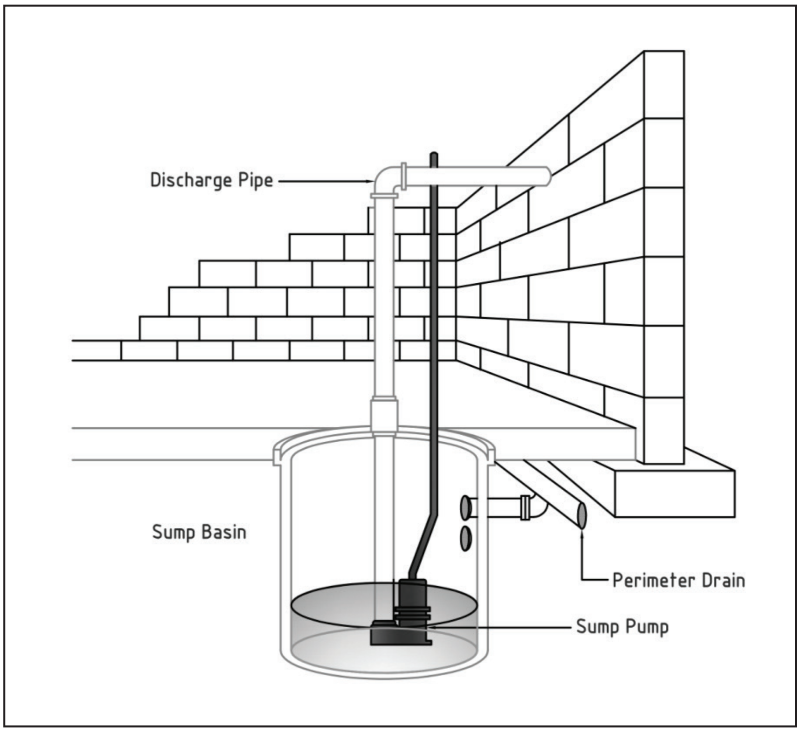


Figure 6.6 Typical Sump Pit at Basement

6.6.2 Operations and Maintenance

- Empty sump pit by sump pump, residual water pH to be adjusted to be above 10.
- Sump pit to be equipped with the appropriate pumping, piping, valves, or other necessary equipment to allow for easy dewatering when necessary.

6.7 Sanitary Systems of the Building

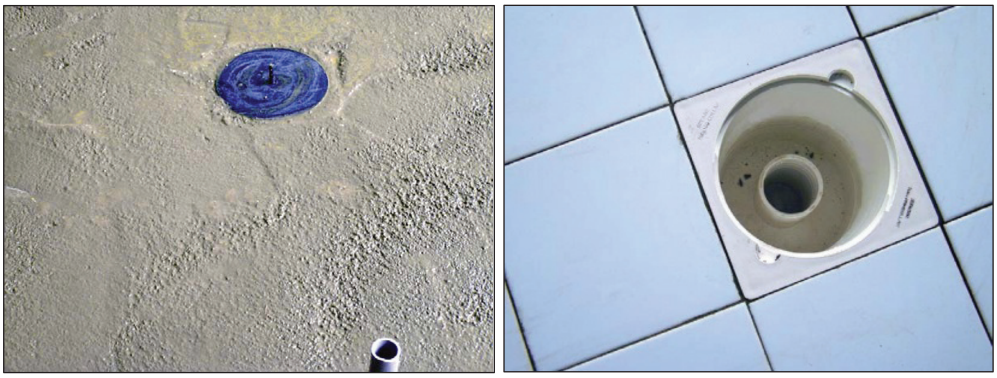
Generally, in sanitary systems, the fluid will flow via gravity from the fixtures to the manhole on the ground floor and again by gravity will flow to the next manhole until it reaches the external manhole. During the construction stage of the sanitary systems, the installed sanitary pipes must be protected from debris falling inside which could cause blockage. In this respect, most sanitary openings are sealed or closed tightly until the fixtures are installed (Figure 6.7).

6.7.1 Planning and Design Considerations

- Floor Traps:

    - Most sanitary fixtures are equipped with a water seal to prevent the foul smell from the sanitary system to enter into the building. In this respect any floor traps which are located in the common areas which usually discharge to the floor drain discharge pipe do not require water seal. Hence, this will eliminate stagnant water in the floor trap.

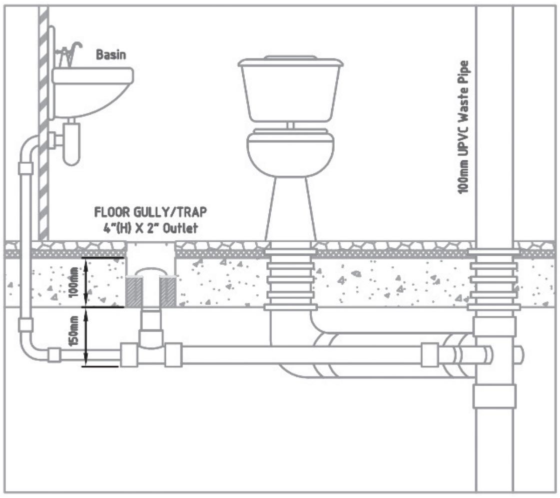
    - It is recommended that the top access floor traps to replace bottom access floor traps for easy of removal of debris and water seal (Figure 6.8).



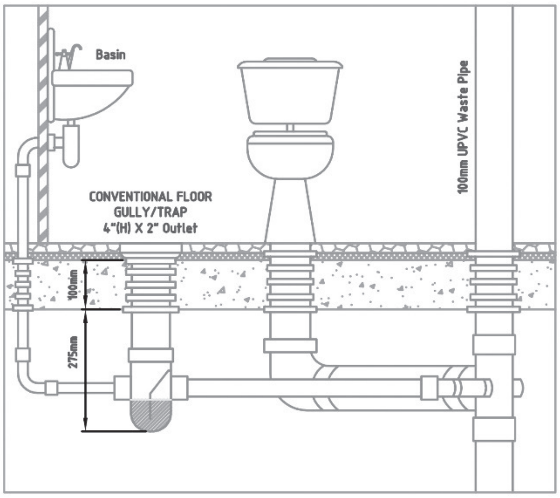
(a) Floor trap cylindrical body cast to the floor slab with a cover.

(b) Floor trap cover removed after tiles installed. Note the water seal.

Figure 6.7 Construction stage to final stage of a floor trap



(a) Top access floor trap with water seal, potential mosquito breeding ground accessible from top to remove the stagnant water if required.



(b) Conventional type floor trap with water seal potential mosquito breeding ground not easily accessible located below the floor to remove the stagnant water.

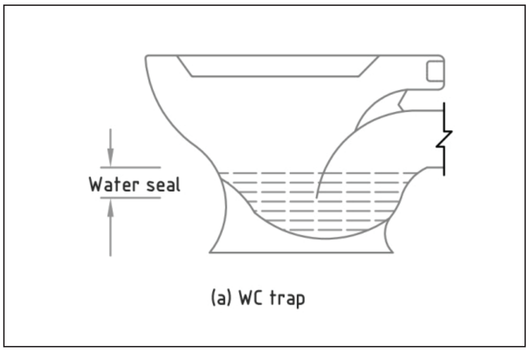
Figure 6.8 Floor trap water seal during operation phase (Courtesy of Spind Malaysia)

- Gully Traps:

  Landed residential houses has an external gully installed. It is recommended that the external gully trap be removed and replaced with direct discharge with a cleaning eye to the sanitary manhole which is located adjacent to it. It is not mandatory in any standard to install an external gully. External gully trap is covered with a grating exposed to atmosphere and water will stagnate if the houses are unoccupied or housing project has been abandoned.

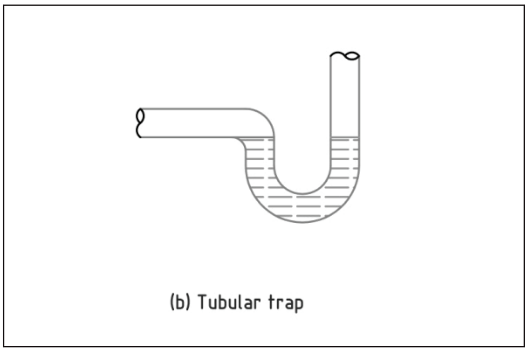
- Fixtures:

  The pH of the water inside the water seal must be adjusted to be above 10.



Toilet Bowl water seal pH of the water inside the cistern to be adjusted to be above 10.

Water Closet (WC)



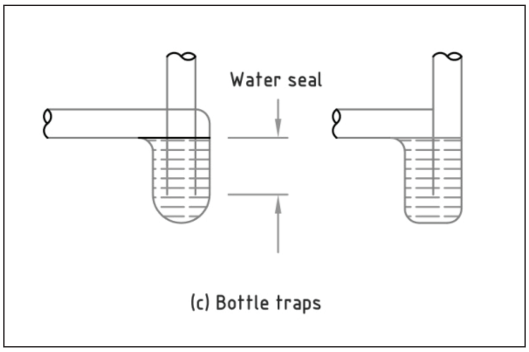


Figure 6.9 Basin water seal during operation phase

- Sanitary Manholes:

  Manholes are to be located on the ground level with the invert level of at least 1 meter deep. For a sizeable project, there will be multiple connecting manholes to direct the soil and waste to the external sanitary pipe. Upon completion of these manholes, rainwater will seep into them and create stagnant water whilst the water could be pumped out, there will be residual water inside. The pH of the residual water must be adjusted at all times to 10 and above.

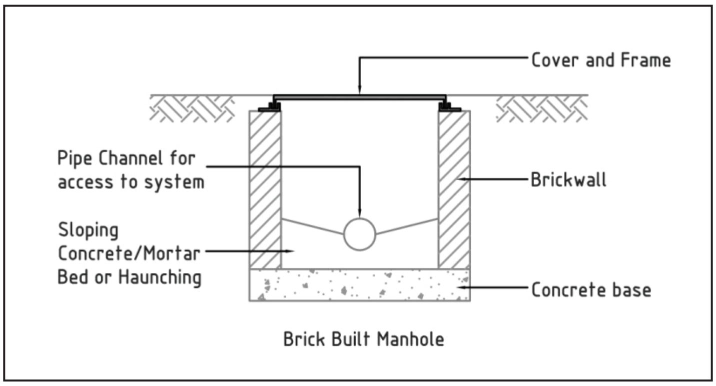


Figure 6.10 Typical Manhole for Sanitary System

7.0 CONSTRUCTION SITES

7.1 Introduction

There are many building and engineering constructions sites around the country. Construction sites are one of the most common breeding grounds for all mosquitoes including aedes mosquito. Different construction sites have different layout and construction methods at various stages of completion. This chapter covers most of the activities at any construction site. Water stagnation or water ponding especially during the monsoon season can lead to breeding grounds for mosquitoes.

7.2 Potential Breeding Grounds

Maintaining good housekeeping at the construction sites is crucial to ensure that there is no stagnant water after rainfall. All ponding areas must be cleared every time after any downpour. Potential breeding grounds include:

- Earthwork Areas and Erosion and Sediment Control Facilities
- Construction Materials Storage
- Plants and Equipment in Open Area
- Right-of-way/Reserve
- Staff Quarters

7.3 Prevention and Control Measures

7.3.1 General Guidelines

Awareness among employees is important to ensure that the constructions site is free from mosquito breeding grounds. There are various methods that can be used to disseminate information to the employees as well as visitors. Listed below are the general guidelines for the control of the spread of dengue fever:

- The whole worksites area must be divided into a few zones to ease the management of dengue control activities with one person-in-charge of one area. Employees must be assigned to perform daily check and inspection around the constructions site based on area zoning. More thorough inspection should be performed in red zone area. Daily search and destroy inspection must be performed at identified areas.

- Workers must be briefed about mosquito breeding grounds, how a person can be infected by the aedes mosquito bite, the health effects of dengue and the countermeasures at the individual levels. This information is to include as the topic for daily toolbox briefing.

- Awareness leaflets, posters or banners can be used as reminders to all workers. To create the awareness of personal hygiene and cleanliness at the Centralised Labour Quarters (CLQ).

- Regular checks using drone to monitor remote areas not easily accessible by foot and over the roof especially after rainfall.

- Mandatory for contractors to ensure all areas are cleaned and tidied up. All disposable food containers, plastic bags and bottles must be cleared from the worksite at all times. All damaged and discarded items must be disposed of on a regular basis. Worksite must be litter free all the time.

- All bulk waste containers, skips and refuse bins must be regularly disposed and apply anti-mosquito oil to the ground below containers.

- Toilet and bathroom floor must be free from water stagnation.

- Hard-to-drain area must be applied with anti-mosquito oil at least once a week and reapply immediately after rain.

- Grass and other vegetation must be cut on a regular basis because this is where the mosquito will stay hiding from the sun.

- A qualified contractor must be appointed to perform fogging once there is a confirmed case of dengue.

7.3.2 Earthwork Plan and Erosion and Sediment Control Plan (ESCP)

- There must be no standing water in all areas under ESCP and any ponding should be immediately cleared (Figure 7.1).
- All depression and unlevel ground caused by machineries must be backfilled, leveled, compacted, and turfed.
- All unused excavator buckets and other accessories shall not be left in the open area. If not, daily check must be performed to ensure there is no stagnant water inside.
- All temporary drainage and emergency spillway must be constructed with gradient that allows for the free flow of water to avoid ponding.
- Ensure all water going to the sediment basin or detention pond is treated with larvicide.
- All rainwater collected in plastic barriers due to missing covers, gaps and cracks must be put off use immediately until it is fully repaired.
- Puddles on the ground and water ponding areas must be backfilled and compacted with soil or sand.
- All trenches must not contain stagnant water.
- Drain and temporary channels shall be dry and if there is stagnant water inside, anti-mosquito oil shall be applied.
- Sump pits and silt traps must be cleaned regularly.

Clogged Drain

Gully During Earthwork

Uneven Backfilling with Water Ponding

Figure 7.1 Areas under ESCP that could cause stagnant water

7.3.3 Storage for Construction Materials

- All construction materials - zinc sheets, form works, steel bars, metal beams, piping, uninstalled toilet bowl and cistern must be free from stagnant water.

- Check for water stagnation on grounds below materials.

- Store all pipes in an inclined or sloping position to prevent water accumulation.

- Hollow metal rods, unused drums and containers shall be free from stagnant water.
- Tools and material storage box must not be exposed to the rain to avoid water accumulation.
- Discarded pail, skip tank, empty chemical and paint cans must not be left in the open where rainwater can accumulate.
- Lid of drums, cans, dust bins and thrash can must be free from water.
- Canvas, sheets, tarpaulin, and plastic covers shall be made straighten to avoid folding which can accumulate rainwater.
- Water stored in tanks, containers, drums, filtration and sedimentation tanks must be treated with larvicide. Cover all water outlet with anti-mosquito netting.
- Bulk waste containers, skips and refuse bins must not contain any stagnant water.
- Remove water stagnation among debris (Figure 7.2).

Construction Debris

Water Ponding on the Floor

Figure 7.2 Construction material areas that could cause stagnant water

7.3.4 Plants and Equipment

- Remove all accumulated water in the sump pit which should be regularly maintained.
- Vehicle washing bays shall not accumulate stagnant water after washing (Figure 7.3).
- Check for water in instrumentation box (e.g. water meters) and other openings (e.g. elevator shafts, piling holes).
- Site office cabin – check on and below roofing and zinc sheet for stagnant water.
- Site office using containers – check in and below containers for stagnant water. Install sloping / pitched roof for all temporary structure on site. The minimum slope for a flat roof is 10%.
- Accumulation of condensed water from outdoor air-conditioned unit must be flushed.
- Ensure all tanks, gully traps and plants do not accumulate water.
- Water in lifts or construction shafts shall be pumped out after rain.
- Check for water accumulation on uneven floor after rain.
- Concrete mixer and wheelbarrow shall not contain any water.
- Concrete test cube tanks must be treated with larvicide or anti mosquito oil.
- Check and flush toilet bowls regularly (pending hand over to developer).

Figure 7.3 Untreated Backfilling and Washing Bay

7.3.5 Right-of-way/Reserve

- All the areas under right of way must be cleared to avoid any stagnant water from accumulating especially after rain.
- Discarded food containers and any other rubbish must be cleared daily.
- Grass and any growth must be cut on a regular basis.
- All puddle and water ponding areas from ground depression must be backfilled.
- Construct and maintain drains to channel water away.

7.3.6 Staff Quarters

- Ensure that there is no water ponding or stagnant water anywhere inside and within the perimeter of the staff quarters especially after heavy downpour.
- All plastic containers, cooking pots, pans and other food containers must be free from stagnant water.
- Uneven floor at toilets and bathrooms must be re-grade to avoid accumulation of standing water.

- All unused water cisterns must be drained out and unused toilet bowls must be covered and sealed.

- Drain out water in bathing tanks and scrub inside the tanks.

- Cover and seal all unused sinks to prevent water stagnation in drain holes.

- Install anti mosquito valve into gully and floor traps and seal traps that are no longer in use.

- Old boots and unused safety helmets must be immediately discarded.

- Refuse bin must be properly covered.

- Search and destroy of mosquito breeding grounds must be carried out after rainfall.

7.4 Provision for Mosquito Control & Prevention in Contract Documents

In all construction contracts, there shall be a provision in the bill of quantity (BQ) for contractors to provide the necessary control measures to prevent mosquito breeding at construction sites. The BQ shall include all preventive and corrective measures as well as administrative control. Party preparing the BQ shall foresee all stages of construction (from Earthwork Plan and Erosion and Sediment Control Plan (ESCP) to the completion and handover of the premise to the owner) that can cause potential breeding ground for aedes mosquito. The contract specifications shall include the followings:

- Keeping Site Dry

  - The Contractor shall be responsible for keeping the whole of the works well drained and free from all water (including rain, storm, spring, running water and water below water table levels, etc.) at all times to ensure that the works is carried out in the "dry".

  - He shall use whatever means necessary to keep the site dry including baling, power pumping and making temporary earth and/or concrete drains or any other means which the Superintendent Officer (S.O.) shall direct.

- The Contractor shall ensure that the water drained from the site shall be kept reasonably free from earth, debris, etc.

- He shall be responsible for finding outlets for the discharge of the water drained from the site and if the water is drained from the site to the public drains, he shall be responsible for including paying all necessary fees and making good damages to the roads, drains etc.

- The Contractor shall be held solely responsible for the sufficiency of the arrangements made for the exclusion of water from the works and for any loss or damage which shall result from the Contractor's negligence.

- Mosquito Prevention

    - All excavations and the site where water stagnates or accumulates shall be kept dry by pumping, baling or other means.

    - The Contractor shall allow for taking such precautions as shall be deemed necessary or desirable by the S.O. to prevent breeding of mosquitoes and he shall pay all charges as required by the Local Authorities concerned for any anti malaria or anti dengue measures taken.

    - The Contractor shall refrain from dumping or depositing rubbish, spoil, used materials, empty bottles, cans and other containers capable of collecting liquid which provide breeding places for mosquito.

    - He shall be held responsible for mosquito nuisance at the site and surroundings arising from non-observance of the provisions of this clause and shall be required to employ whatever mosquito destructive measures directed by the S.O. at the Contractor's own expense.

7.5 Checklist for Control of Mosquito Breeding Grounds in Construction Sites

- Checklist is one of the effective measures that can be used during audit or inspection at the worksite. It should be made available to all parties of concern so that self-inspection and self-audit can be performed.

- The Checklist shown at the end this Guideline is a common checklist that can be applied at any construction sites.

- In general, the vector control activities in the checklist are the responsible of Health, Safety & Environmental (HSE) officers or Site Safety Supervisor (SSS) as per the requirements in the contract.

- Depending on the size of the construction site and the standard operating procedures (SOP), checklist inspection can be performed by the Safety and Health Committee or directly by the contractor working at site.

- Any discrepancy especially if there is a discovery of mosquito larvae shall be reported to the management and immediate corrective action taken.

- Photo of the site must be taken as evidence and display at public areas to avoid recurrence.

8.0 WASTE MANAGEMENT

8.1 Introduction

Municipal solid waste landfills (MSWLFs) or sanitary landfills receive household waste. MSWLFs can also receive non-hazardous sludge, industrial solid waste, and construction and demolition debris. Sustainable solid waste management is crucial to the prevention of breeding grounds for the Aedes mosquitoes. Modern landfills are well-engineered facilities that are located, designed, operated, and monitored to ensure compliance with Malaysian regulations. The landfill siting plan prevents the siting of landfills in environmentally sensitive areas while on-site environmental monitoring systems monitor for any sign of groundwater contamination and landfill gas and provides additional safeguards. In a conventional sanitary landfill, waste is kept effectively dry by using a baseliner and cover. Figure 8.1 shows a cross-sectional view of a conventional sanitary landfill. Such design would prevent rain infiltration and the liquid resulting from biodegradation of waste, termed leachate, is collected at the bottom of the landfill and securely disposed.

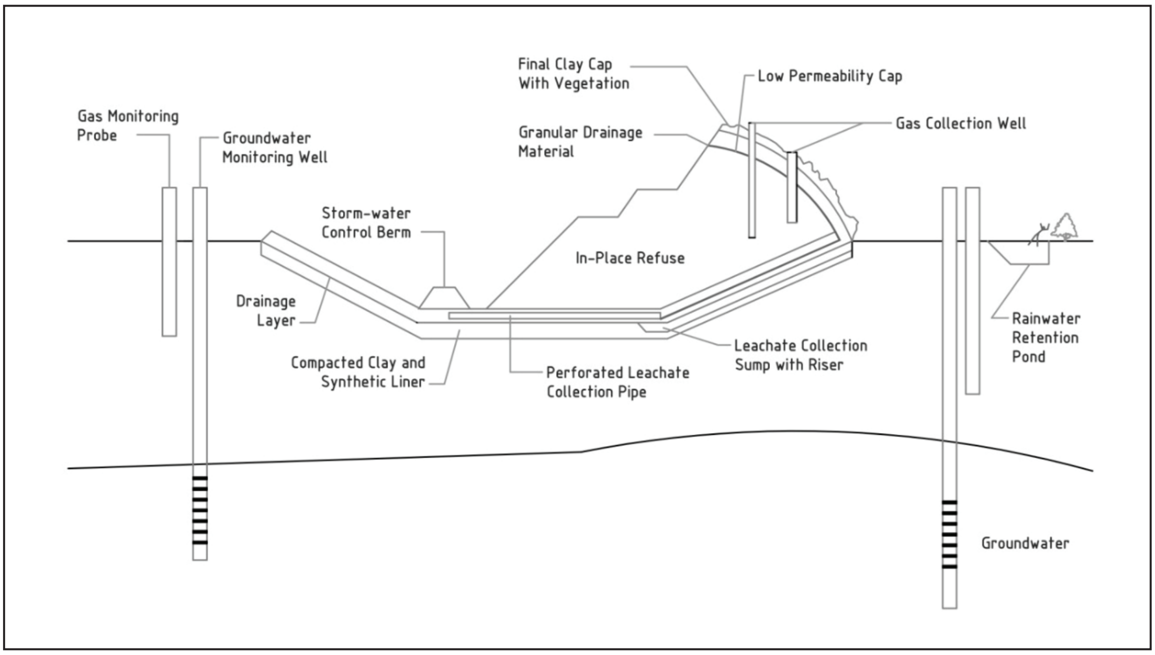


Figure 8.1 Cross section of a typical modern sanitary landfill
(Sharma, H.D. and Reddy, K.R. , 2004)

8.2 Potential Breeding Ground

- Improperly compacted sub-base of landfill that leads to surface stagnant water.

- Water puddles in the landfill that leads to stagnant water.

- Solid waste, object or containers that can hold water – disposal site & transfer station: temporary storage area (open areas)

8.3 Planning and Design Considerations

- The design of sanitary landfill should take into account the flow of water and provides good surface drainage system to avoid stagnant water.

- Landfill Sub-Base

  - It is important to have a properly prepared sub-base as the landfill liner is constructed directly on the sub-base.
  - If the sub-base is not properly compacted, waste compaction in the first few lifts becomes challenging and is possible to cause stagnant water.
  - In sandy soils, the general recommendation is to compact the sub-base to 85–90% of the relative density. During construction, density is usually checked at 30 m grid points (Bagchi, 2004).

- Leachate Management

  - Leachate in excess of 30 m should be removed from the landfill. Leachate can be removed by using gravity flow or by pumping.
  - Leachate collected from the landfill may be stored on site to be treated later or transported for treatment and disposal off site.
  - Surface impoundments and tanks are the typical leachate storage methods. Make sure the tank is always closed to prevent mosquitoes from laying eggs.

Figure 8.2 Leachate Collection Pond

Figure 8.3 Leachate Treatment Plant

- Stormwater Management

  - Stormwater ditch (Figure 8.4) is needed to prevent stormwater from getting into the active phase of the landfill to minimize leachate production and water puddle area.

  - Surface runoff on landfill needs to be routed to natural drainage paths.

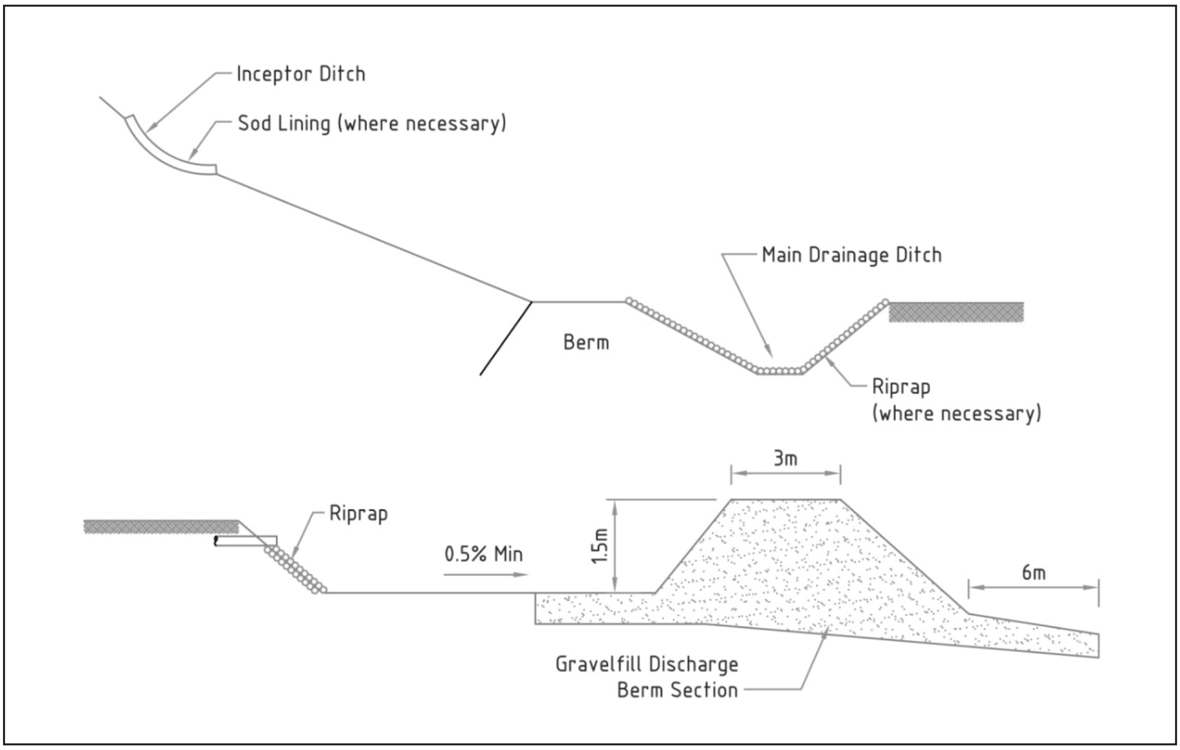


Figure 8.4 Cross sections of a stormwater ditch and a basin used in landfills (Bagchi, 2004)

- Land Shaping/Grading

  - Although land shaping may not produce the even and continuous slopes that result from land grading which is required for good surface irrigation, it generally improves the topography and surface drainage, with the elimination of holes or pockets that may hold water. It is therefore an effective measure for mosquito control.

  - In hilly or rolling country, where proper grading cannot be economically justified, land shaping is therefore a good alternative.

  - Figure 8.5 illustrates the difference between shaping and grading and shows the same original surface profile, as shaped for drainage (top figure) and as graded for surface irrigation (bottom figure).

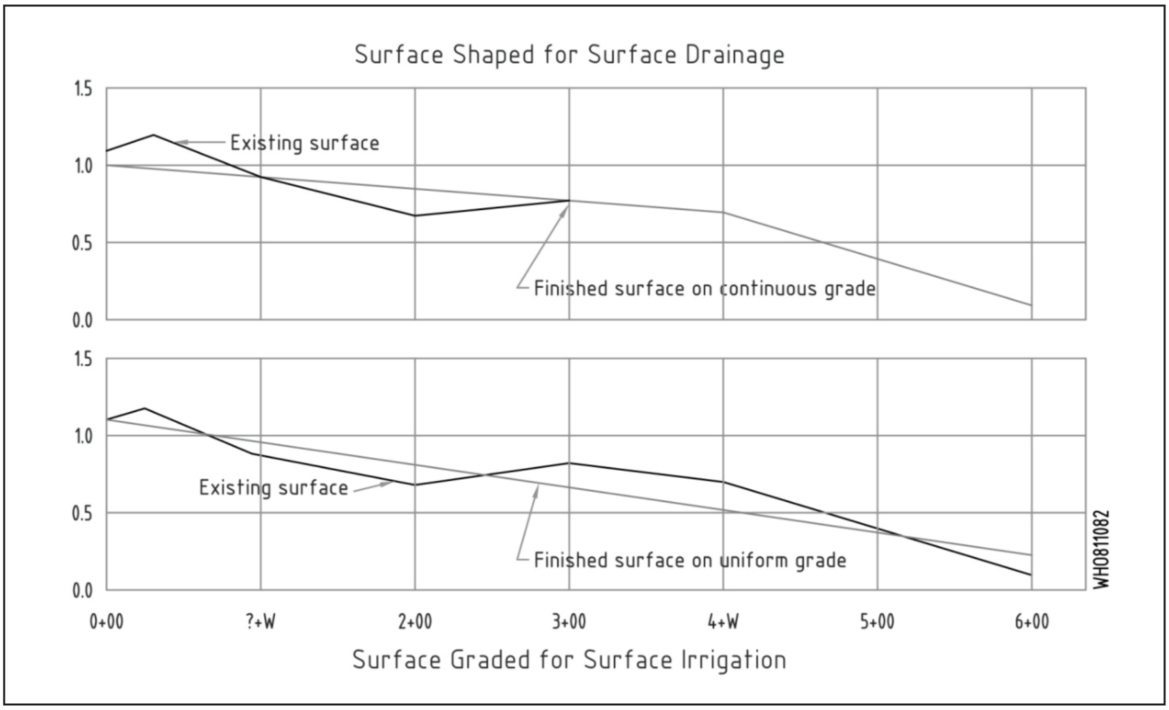


Figure 8.5 Comparative profiles of a land surface, as shaped for drainage (top) and as graded for irrigation (below)

- Land shaping can also be suitable for draining flatlands where a slope is required (Figure 8.6). The spacing and size of the ditches are dictated by the volume of filling required. This shaping is particularly suitable where the groundwater table is not close to the surface, as in that case the ditches might have to be dug deeper than would otherwise be required.

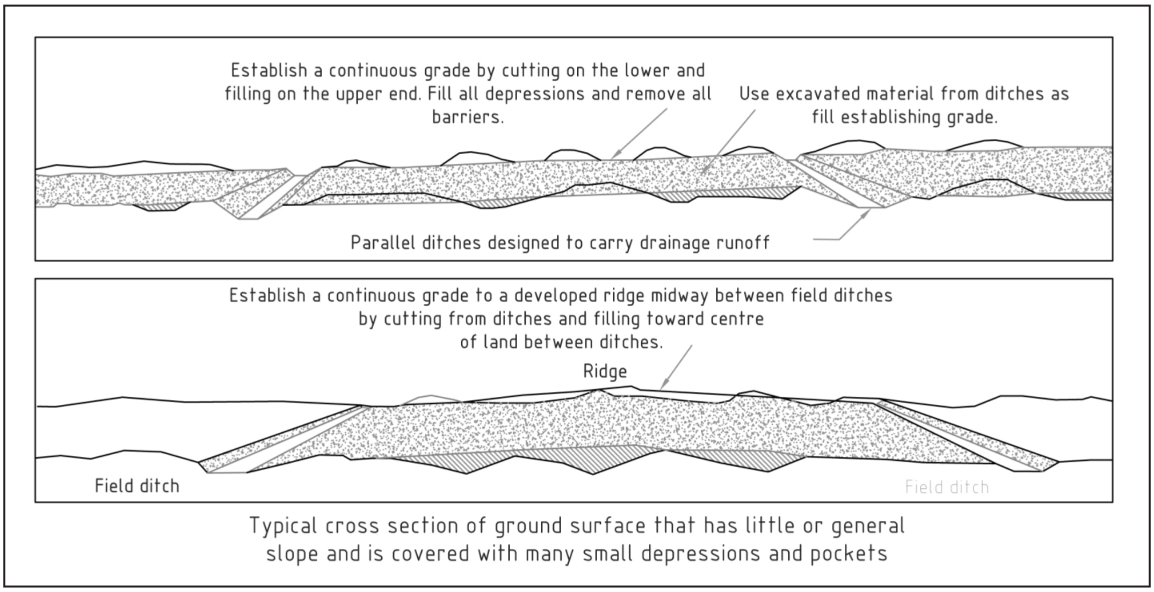


Figure 8.6 Methods of grading land surfaces for drainage

8.4 Operations and Maintenance - Landfill/Disposal Site

Land fill operations and maintenance refer to the standard practices of waste management that have been set by the authorities. Measures need to be taken to prevent stagnant clean water in the event of:

- Waste cans, bottles, containers that can hold rainwater.
- Stormwater management during and after rain.
- Handling of washing water when washing vehicles (compactor).
- Any possible activity that can cause clean water to stagnate and be exposed.

8.5 Sanitary Landfill/Disposal Site Post Closure

- Closure activities of sanitary landfills or disposal sites must begin within 30 days of the last receipt of waste and must be completed within 180 days (Fauziah et al., 2007). Make sure there are no holes that can hold water.

- Critical technical issues that must be addressed regarding closure include the (1) degree and rate of post-closure settlement and stresses imposed on soil liner components and (2) Long-term durability and survivability of cover system to prevent water being compounded.

- The final cover should be the cover soil laid on top of the final landfill waste layer after the landfilling has been completed.

- The purpose of the final cover is to prevent breeding of vectors, such as flies and mosquitoes and scattering of waste (i.e. to ensure the possible water pot waste are not exposed).

- Specification of the final cover:

  - Thickness of the final cover should be at least 500mm or more.

  - Final cover should be laid and compacted properly, i.e. with bulldozers, etc.

  - Final cover should be compacted with an inclined slope of about 2 to 5% gradient to allow for rainwater drainage.

  - Final cover material should be earth or soil material that possesses low permeability, resistance to erosion and suitable for vegetation growth (apply to disposal site & landfill).

9.0 CHEMICAL CONTROL

9.1 Introduction

The use of chemical control may include application of larvicides as routine control strategy or space treatment together with insecticides in conjunction with adequate and competent susceptibility testing. The chemical control aims to control mosquitoes during different life stages such as larvae, pupae, and adult.

The instant effect of the control of mosquitoes by chemical is often temporary in nature, hence chemical control needs to be constantly carried out to maintain adequate control. Moreover, the use of chemicals for mosquitoes control needs to comply with local laws and legislations and in accordance with manufacturer's specifications.

9.2 Adult Control

- In areas where the mosquitoes are endophilic (i.e. tend to rest indoor) or exophilic (i.e. tend to feed and rest indoor briefly), an interior residual house spraying that have a good airborne effect is deemed to be an effective control to eliminate vector transmission. However, for vector that is strongly exophilic or exophagic (i.e. rest and bite outdoors), an exterior space spraying (emergency control) such as fogging can be considered basing on the reported viral cases.

- The adult control falls into two main categories: barrier applications and space treatment applications (Table 9.1).

Table 9.1 Summary of Recommended Adult Control

Item	Adult Control	
	Barrier Application	**Space Treatment**
Description	Target mosquitoes by applying pesticides to structures which cover relatively small areas and to solve specific problem rather than wide adult mosquito	Control adult mosquitoes within a large area during short period of time to reduces number of infective adult mosquitoes
Recommended Method	Residual spraying / Perifocal spraying	Ultra-low volume (ULV), Thermal fogs
Recommended Application	1) Spraying on the inside walls of dwellings where insects meet the treated surface 2) Spraying adjacent surfaces up to 60cm from the potential breeding containers (with or without water holding in the particular area)	1) Apply ULV undiluted or partially diluted insecticide at rate of 0.5-2.01/ha for large area. 2) Apply thermal fogs for indoor or peri domestic area with handheld equipment at a rate of 10-50l/ha.

- The advantages of adult control are:

  i) An immediate solution that able to reduce or control the number of adult mosquitoes within a certain coverage area in a short period of time
  ii) Able to target adult mosquito dwelling within the active period

- The limitations of adult control are:

  i) Requires specific instrument handle by trained & licensed personnel for the application.
  ii) This is a corrective action and only apply after number of infective adult mosquito reach dangerous level
  iii) Adult mosquitoes may spread away from the apply coverage

- Indoor residual spraying is the application of insecticides on the inside walls of dwellings to kill target mosquitoes that meet the treated surface where such insecticidal deposits are intended to remain active for an extended period.

- There are various types of insecticides available for residual treatment (Table 9.2) which can also be used for treatment of potential breeding containers (with or without water holding in that particular area) and for spraying adjacent surfaces up to 60cm from each container, an approach commonly known as perifocal spraying.

Table 9.2 Active ingredient available for residual treatment (Chavesse and Yap, 1997)

Active Ingredient	Chemical Type	Dosage of Active Ingredient (g/m^2)	Duration of Effective Action (month)	Toxicity: oral LD50 of Active Ingredient for Rats (mg/kg of body weight)
Alpha-cypermethrin	Synthetic Pyrethroid	0.02-0.03	4-6	79
Bendiocarb	Carbamate	0.1-0.4	2-6	55
Carbosulfan	Carbamate	1-2	2-3	250
Chlorpyrifos-methyl	Organophosphate	0.33-1	2-3	>3000
Cyfluthrin	Synthetic Pyrethroid	0.02-0.05	3-6	250
Cypermethrin	Synthetic Pyrethroid	0.5	4 or more	250
Deltamethrin	Synthetic Pyrethroid	0.01-0.025	2-3	135
Etofenprox	Synthetic Pyrethroid	0.1-0.3	3-6 or more	>10,000
Fenitrothion	Organophosphate	2	3-6	503
Lambda-cyhalothrin	Synthetic Pyrethroid	0.02-0.03	3-6	56
Malathion	Organophosphate	2	2-3	2100
Permethrin	Synthetic Pyrethroid	0.5	2-3	500
Pirimiphos-methyl	Organophosphate	1-2	2-3 or more	2018
Propoxur	Carbamate	1-2	3-6	95

- Space treatment applications are used in the early stage of the endemic situation to control adult mosquitoes within a large area to reduce the number of infective adult mosquitoes, thus reducing the virus transmission during the short period of time.

- Ultra-low volume (ULV) application is used for target areas such as high-density residential area, schools, and areas where disease cases or vector densities are reported high. The application procedures of ULV consists of undiluted or partially diluted insecticide in the form of a cold aerosol of droplets of controlled size (15-25 microns) at a rate of 0.5-2.0 l/ha (Chavesse and Yap, 1997).

- If the affected area covers less than 1000ha or able to be covered within 10 days, a ground vehicle is applicable for use. Otherwise, an aerial ULV is recommended. ULV application generally should be carried out when air velocities are below 10km/hr and during temperature inversions if possible. The application timing of ULV treatment should usually be made last 3-4 hours of daylight, dusk, or dawn to coincide with the time that mosquitoes are most active, and when non-target insects are least active during the application period. The vehicle-mounted equipment should be driven at speeds between 5 and 15km/h in a crosswind direction so the fog or mist moves at right angles to the line of travel.

- In addition to ULV, thermal fogs (Figure 1) are currently used in small or usually indoor or peri domestic area via handheld equipment at a rate of 10-50 l/ha with less precise droplets size, which is effective against adult mosquitoes due to their resting behaviour and space constraint inside the building.

Figure 9.1 Thermal Fogging

- When a rapid reduction in vector density is required, space treatment using insecticides (Table 9.3) should be carried out every two to three days for 10 days duration. Further applications should be then carried out once or twice a week to sustain suppression of the adult vector population. In addition to insecticide susceptibility, application rate and droplets size, indoor penetration of the insecticides are crucial to the efficacy of the treatment as it depends on the openings of the building during application time.

Table 9.3 Active ingredient available for space spraying treatment (Chavesse and Yap, 1997; Ong S.Q, 2016)

Active Ingredient	Chemical Type	Dosage of Active Ingredient (g/m^2)		Toxicity: oral LD50 of Active Ingredient for Rats (mg/kg of body weight)
		Cold Aerosols	Thermal Fogs	
Cyphenothrin*	Syhthetic Pyrethroid	2-5	-	318
Fenitrothion*	Organophosphate	250-300	270-300	503
Malathion*	Organophosphate	112-693	500-600	2100
Pirimiphos-methyl*	Organophosphate	230-330	180-200	2018

- All insecticides used for adult control must be registered with the Pesticides Board (PB) under Ministry of Agriculture and Food Industries and align with the Department of Environment (DOE) under Ministry of Environment and Water.

9.3 Breeding Control

- An essential component of mosquito control is breeding control (Table 9.4) at domestic breeding sites such as tyres, tin cans, flower pots, or any area with accumulation of stagnant water that can be exposed to mosquito access.

Table 9.4 Summary of Recommended Breeding Control

Item	Breeding Control		
	Larvicide	Surface Agent	Home Remedy
Description	Complementary measure to basic sanitation and feasible to do domestic mosquito species	Can used on water body to prevent mosquito Larvae and pupae from breathing through siphons that extend above water surface	Can reduce or break surface tension of water body to prevent the mosquito to lay egg or lethal to mosquito larvae with sufficient concentration
Type	Bio-rational, insect growth, insect growth regulating (IGRs)	Highly refined mineral oil, monomolecular film (alcohol derivatives)	Soapy water
Remark	Extremely low mammalian toxicity, not change the taste, odour or color of the water	Effective against late-stage larvae or pupae	Not suggested by WHO and lack of scientific research or established research to support this method

- The advantages of adult control are:
  i) An effective preventive action to control the growth of larvae or pupae
  ii) Able to eliminate larvae or pupae more efficiently as they are contained within a certain area

- However, incorrect use of chemical may pollute the environment or consumables for human or animals

- Pesticides that control mosquito larvae are known as larvicides which fall under four categories such as bio-rational, surface oil, insect growth regulating, and chemical products (California Department of Public Health, 2010).

- It is generally agreed that larviciding is more effective than adultciding because the aquatic immature forms are constrained within a water body where they are usually easily accessible, relatively immobile, and unable to escape.

- Larvicide should only be considered as a complementary measure to basic sanitation and only feasible to domestic mosquito species.

- Larvicide must have extremely low mammalian toxicity and not change the taste, odour or colour of the water as many *Aedes* mosquito tend to breed in water storage containers.

- Surface agents such as highly refined mineral oils or monomolecular film (alcohol derivatives) can be used on water body to prevent mosquito larvae and pupae from breathing through tubes known as “siphons” that extend above water surface. The film may remain on the surface from a few hours to a few days depending on the product characteristics and provide effective performance against late-stage larvae or pupae.

- There is an increased interest on home remedy for breeding control such as using soapy water (Tsang, 2015) as an alternative way to use as breeding control for mosquitoes which theoretically work by reduce or break the surface tension of stagnant water for mosquitoes to lay egg and sufficient soap concentration may be lethal to the mosquito larvae. However, there is no established standard on the application of this method and little scientific research to support this method. In addition, there are scientific study that found *Aedes aegypti* larvae to have tolerance ability toward pH changes in the water body and able to survive and develop within the range of pH 4 to 11 (Thomas et al., 2017).

- At present, three compounds are commonly used to control the growth of larvae or pupae: temephos, methoprene and permethrin (Jorge et al., 2012). Chemical pesticides are seldom used to control mosquito larvae in comparison with the others but organophosphate larvicides such as temephos can be used infrequently due to their potential non-target effects and able to treat temporary water or highly polluted water where there are few non-target organisms or livestock are not allowed to access. Methoprene, also known as a type of insect growth regulators (IGRs) is able to disrupt the physiological development of larvae thus preventing adults from emerging.

- The application procedures of larvicide can be through hand-operated compression sprayers for non-potable water and adjacent areas as this produces residue that can destroy existing and subsequent larval infestations. In addition, a syringe or pipette can be applied to treat indoor flow pot within a specific area. The most used formulation of chemical larvicides is liquid (e.g., aqueous suspensions or emulsifiable concentrates) and solid (e.g., solid granules or sand).

- The treatment cycle of larvicide is highly depending on the mosquito species, rainfall pattern and types of breeding site. In general, 2-3 treatments per year between periods of rainfall may deem to be efficient, more frequent treatment may be required on water quality and exposure to sunshine. The used of larvicide must strictly follow the local regulation to understand its acute toxicity, which extreme care must be taken when treating potable water to avoid dosages toxic to human or animals.

9.4 Chemical Control in Hygienic Design Plan

- During the stage of planning and structuring chemical control in hygienic design plan, the following requirements must be taken into consideration:

  i) working procedures

  ii) occupational safety which includes personal hygiene and occupational permit (if needed)

- With regards to building or indoor hygiene, it is best to divide the buildings into several hygienic sections:

  i) undefined section which is clean and dry (e.g. no horizontal surfaces where water may accumulate)

  ii) moderately clean area which is often identify as "grey section" (e.g. corners or edges)

  iii) clean and hygienic which is often identify as "white section" (e.g. even and clear surfaces)

- There is a need to establish critical chemical control onto the breeding ground for mosquito larva, with the aim to act before an infestation occurs.

- Chemical disinfection is an irreversible inactivation of selected or specific living microorganisms which able to reduces to an acceptable level for a defined purpose. If water ponding is unavoidable at location such as fountain, rooftop and any open-air uneven surface, then water disinfecting using chemical is often necessary.

- Common method of chemical disinfecting for water are:

  i) peroxide treatment
  ii) sodium hypochlorite treatment

- Hydrogen peroxide treatment may require the addition of around 40 ppm of peroxide remains in the water ponding with a residence time of 20 to 24 hours to necessary disinfect the water.

- As for sodium hypochlorite, the typical normal concentration is around 0.5 ppm active chlorine.

- Both of these chemical disinfecting treatments have the advantages of reliable elimination of all active organisms in the water ponding and protection of all parts of the water ponding from mosquito larva. However, the disadvantages of this treatment possess the risk of handling with toxic chemical goods and the residue may interact with other material or the surrounding environment.

10.0 BIOLOGICAL CONTROL

10.1 Introduction

Biological control utilises predatory species and pathogenic microorganisms to reduce the population of mosquitoes as disease vectors. Moreover, with the advancement of molecular biology, researchers have discovered ways to manipulate the genetic materials to control the breeding of mosquitoes. Generally, biological control makes use of predators, bacteria, mosquito repellant plants, and genetically modified mosquitoes.

10.2 Predators

10.2.1 Mosquitofish

- The introduction of mosquito predators such as mosquitofish, particularly *Gambusia affinis* (western mosquitofish) and *G. holbrooki* (eastern mosquitofish), is beneficial in combating mosquito-borne diseases. They prey or feed on mosquito larvae thus minimizing the social distress (Tahir et al., 2015).

- The advantages of mosquitofish are:
  i) They grow and reproduce rapidly;
  ii) Feed at the water surface where mosquito larvae are found;
  iii) Tolerate a wide range of temperature and water quality; and
  iv) Effective at controlling permanent-water mosquitoes than floodwater mosquitoes, more effective against larvae of surface-breathing species, and perform better in habitats that lack vegetation (Mazzacano, Celeste; Black, 2013).

- However, mosquitofish do not feed on all types of mosquitoes in all habitats, as they feed at the surface of water. This is because their upward-facing mouth enables them to consume mosquito larvae living on or close to the water surface. Therefore, they are inefficient hunters in dense vegetation and may even cause an increase in mosquitos' numbers as they consume predacious aquatic insects that feed on mosquito larvae. Besides, the density of the mosquitofish also plays an important factor in controlling the effectiveness of biological control, depending on the types of mosquitofish, location, and types of mosquitoes.

- Some of the native mosquitofish and non-native invasive mosquitofish in Malaysia that are not banned by Department of Fisheries, Malaysia as follows:

  i) Hampala Macrolepidota (sebarau)
  ii) Rosbara (seluang)
  iii) Oreochronis (talapia)
  iv) Gambusia (ikan laga)
  v) Poecilia (ikan timah)

- Nevertheless, introducing non-native fish entails a high potential risk of promoting escapes and invasions, impairing ecosystem functioning and biodiversity (Azevedo-Santos et al., 2017). Therefore, it is recommended to use native fish to control the mosquito locally.

10.2.2 Copepods

- Predacious copepods of the genus Mesocyclops (zooplankton) are also used as a biological control agent to reduce the Aedes larvae from container habitats such as water storage vessels and discarded containers (Rey et al., 2012).

- Copepods are small in size (approximately 1-2 mm; 0.04-0.08 in.). They prey on the first and second instar larvae of Ae. aegypti, with preference for first instars, acts as an effective predator for biological control of the transmission system. They are suitable in wells, large cement tanks, ceramic jars, and other domestic containers.

- The advantages of copepods are:
  i) Occurring naturally at high abundance in many wetlands,
  ii) Undergoing diapause when food abundance is low or the habitat dries, and
  iii) Accessible and inexpensive to culture and transport in large numbers.

- It was reported that decrease copepods (Mesocyclops) prevalence coincides with an increase in Aedes larval density (Tran et al., 2015).

- Nevertheless, it is reported that using copepods to control Aedes is risky due to the reasons below (Coelho and Henry, 2017):

    i) Copepods are sensitive to pesticides and tend to be preyed on by mosquitofish even though mosquito larvae were present. For instance, in acute toxicity tests, the LD50 of temephos for freshwater copepods (0.0059 ppm) was lower than the LD50 for Ae. Albopictus (0.0077 ppm);

    ii) Copepods are only effective when present as adults before the mosquito larvae hatch;

    iii) Bodies of copepods can harbor disease-causing bacteria; therefore, treatment of water containing copepods was recommended before consumption;

    iv) Introductions of nonnative species of zooplankton into natural environments may generate negative environmental and economic impacts; and

    v) Cultivating copepods requires facilities with technologies suitable for large-scale, high-cost production with chemical reagents to produce algae.

10.3 Bacteria

10.3.1 Wolbachia

- Another promising biological control method is the use of Wolbachia bacteria strains adapted to infect A. aegypti mosquitoes. Australia exploited Wolbachia-based biocontrol through transinfection of A. aegypti. In such an approach, dengue transmission is suppressed through sabotage of vector breeding via cytoplasmic incompatibility and shortens virus lifespan by blocking viral replication in mosquitoes' salivary gland (Walker et al., 2011).

- Wolbachia pipientis induces sterility specifically in the male mosquito population by using technique like cytoplasmic incompatibility (CI) where on mating with the normal female mosquito the survival rate of offspring is very low (Haikerwal, 2017).

- It is worth mentioning that Malaysia is the second country globally, after Australia, to adopt the Wolbachia approach to prevent and control dengue (Ministry of Health (MOH), 2019).

  The project is initiated by researchers at the medical entomology unit, Institute for Medical Research (IMR), MOH (Nazni et al., 2019). The project is currently in Phase 2 and carried out following WHO-recommended criterion for dengue intervention trial design (Baernighausen et al., 2017).

- Based on passive case monitoring, reduced human dengue incidence was observed in the release sites compared to control areas. Although innovative, this approach still requires evaluation as models have shown varied susceptibility and adaptability of the Aedes mosquitoes to the bacteria, leading to increased viral transmission (King et al., 2018).

10.3.2 Naturally Occurring Bacterial Pesticide

- There are some bacteria that produce mosquito toxins which are considered as the naturally occurring bacterial pesticide against mosquito larvae. These bacteria are produced in artificial cultures namely, Bacillus thuringiensis israelensis (Bti) and Bacillus sphaericus (Bs) (California Department of Public Health and Mosquito and Vector Control Association of California, 2012).

- Manufactured Bti contains dead bacteria and remains effective in the water for 24 to 48 hours; some slow-release formulations provide more extended control.

- Bs products contain spores that in favorable conditions remain effective for more than 30 days. Bs is more suitable in polluted waters and used in alternating applications with Bti to help slow the development of resistance (Mazzacano and Black, 2013).

- Potency is expressed in term of international toxic unit (ITU/mg) by comparing mosquito larval mortality produced by the product under test with the mortality produced by the corresponding reference standard. Prior to control measures, the larval density and the larval stages are checked by dip samples at representative breeding sites to justify actions taken and to establish correct dosages and the appropriate formulations applied. For example, during the most severe floods, usually a third of the area has to be treated with Bti granules which are dispensed with the aid of a helicopter (dosages: 10–20 kg/ha).

- Some commercially available Bti and Bs products used in mosquito and blackfly control programmes and its potency (ITU/mg) is given by (Scarnecchia et al., 2004).

10.4 Mosquito Repellant Plants

10.4.1 Plants

- Plants naturally produce bioactive compounds and many secondary metabolites that serve as defensive chemical against herbivorers including insect pests.

- Most of the mosquito repellant plants have a very strong scent that humans find comfortable which help to hide human scent and thus prevents the bite of neighboring mosquitoes. In addition, planting mosquito repellant plants in the compound will attract other wildlife such as birds as natural predators for mosquitoes enhancing biological control.

  According to the Ministry of Health Malaysia (2016), some of the local plants with mosquito repellent property in Malaysia are Lantana camara (Bunga Tahi Ayam), Cymbopogan nardus (Serai Wangi), Ocimum basilicum (Bunga Selasih), Vetiveria zizaniodes (Akar Wangi), Aloe Barbadensis Miller (Aloe Vera/Lidah Buaya), Fernandoa adenophylla (floramaster), Eurycoma longifolia (Tongkat Ali), Azadirachta indica (Mahagoni/Mambu), and Pelargonium citrosum (Jeremin). Among the mosquito repellant plants, Cymbopogan nardus (Serai Wangi) is the most recommended plant to grow in the landscape and containers. Some photos of the mosquito repellant plants are shown in Figure 10.1.

- The mosquito repellant plants can be planted around patio, deck, or outdoor living space in container or planted in the ground.

- The mosquito repellant plants recommended for indoor are sweet basil (Selasih Manis), lemon balm (Balsem Lemon), and peppermint (Pudina) while for outdoor are lavender, catnip plant, and citronella.

Figure 10.1 Mosquito Repellant Plants

10.4.2 Essential Oils

- Essential oils extracted from mosquito repellant plants are among the most common low-cost products widely used as an alternative to commercialized synthetic insecticides.

- Some of the local mosquito repellant plants with repellant properties of essential oil are Murraya koengii (Curry Leaves), Pelargonium radula (Jeremin), Jasminum officinale (Bunga Melur), and Anthemis nobilis (Roman Chamomile) (Asnawi et al., 2008; Ismail et al., 2014; Muttiah et al., 2019).

10.5 Genetically Modified Mosquitoes

- Advances with genetically modified A. aegypti carrying a dominant lethal gene - Release of Insects with Dominant Lethality (RIDL) and release of these male mosquitoes represent another novel mosquito-targeted intervention (Guzman and Harris, 2015).

- The genetically modified males can cause sterilization when mated with females. Further, its productivity can be increased by simply adding tetracycline to the larval diet. Theoretically, once genetically modified males are released into wild-type populations and mate with normal females, almost 100% of offspring will die in the late larval phase.

- Malaysia government initiated the RIDL in December 2010, releasing 6000 genetically modified mosquitoes into the uninhabited forest of Pahang (Lacroix et al., 2012). A standard ecological method in entomology to evaluate under field conditions the flight distance and longevity of the sterile male Aedes aegypti strain OX513A (My1), a GM strain.

- The biosafety regulatory process before approval of the limited field trial includes notification to biosafety department, establishing lab colony, confined lab study, confined semi-field evaluation, application to Medical Review Ethics Committee and Genetic Modification Advisory Committee, then National Biosafety Board finally open release to the field (Subramaniam et al., 2012).

- The sterile male A. aegypti (OX513A) was manipulated to harbour dominant lethal transgene insertion and compete with wild-type male for mating. High expression of the lethal factor in a positive feedback loop would then limit the survival of transgenics by 95–97% at late-larval or early-pupal stage (Phuc et al., 2007). However, this measure requires much time and continual release of strains for several months. Besides, public engagement is an essential component of field releases to provide information, receive feedback from the public, and gain public trust through transparency.

11.0 HOUSEKEEPING AND SOCIAL

11.1 Introduction

Residential and commercial buildings, schools, public buildings and amenities, land under government control, factories and industrial areas, and vacant lands are all potential sites for Aedes mosquitoes to breed and can create a risk for dengue outbreak. It is therefore everyone's responsibility to eradicate these potential breeding grounds by continuously keeping the areas clean and free from stagnant water.

Apart from government initiatives to combat the spread of dengue, the public should take collective responsibility to improve their own surroundings. Joint effort by the authority with the community can play an important role via regular education and public awareness programmes for the prevention and control of dengue. Improving people's behavior on best hygiene practices and good environmental management to eradicate mosquito breeding grounds has proven to be very effective in the prevention of dengue outbreak.

Good planning, engineering design and implementations are not complete without responsible human behavior and housekeeping. While enforcement activities by relevant authority are still necessary, it is ultimately the responsible human behavior that is required to combat the risk of dengue outbreak. The United Nations World Health Organisation (WHO) has developed the acronym COMBI (Communication for Behavioral Impact) to reach to the public to play its part, because we humans are the ones who have created a conducive environment for the mosquito to breed. As such, it should also be within the control of human behavior to prevent the breeding and hence combat the spread of dengue.

11.2 Principles of Prevention

For the planning and design stage, engineers should consider the prevention of dengue risk by adapting the general principles of prevention. These principles of prevention as listed below should be extended to the execution and operational phase when carrying out any eradication of dengue breeding ground activities.

- Avoid risks
    - As far as practicable, avoid breeding grounds for the Aedes mosquitoes, such as avoiding any potential for the accumulation of stagnant water.

- Evaluate the risks that can't be avoided
    - The risk of dengue may vary depending on various factors such as dengue hotspot area, weather conditions, cleanness of environment, and community attitude. Some areas are prone to a very high risk of dengue outbreak like abandoned construction sites. Thus, evaluating the risk level of dengue risk may urge for better prevention and mitigation measures.

- Combat risks at the source
    - Risks should be addressed, or dealt with, at the source. The source of dengue is coming from vector travel mosquitoes. Fighting these small insects is not effective as compared to eliminating the source of its breeding sites.

- Adapt the residential environment to the sociology factors
    - This may be improved by good town planning and design of residential space for housing development.

- Adapt to technical progress
    - Technology continues to influence modern society, so it's important to keep informed about the latest technical knowledge when selecting prevention methods, equipment, materials and equipment. In general, technical progress leads to improved performance, better ergonomics and reduced risks.

- Replace the dangerous with the non-dangerous or the less dangerous
    - Commonly known as 'substitution', this principle of applying insecticides involves reviewing the choices that are available and then selecting the ones with less toxicity.

- Develop a coherent overall dengue prevention policy
    - With commitment from the organisation or society, having a good policy may reduce environmental risk factors of dengue outbreak.

- Give collective protective measures priority over individual protective measures
  - Collective protective measures control the risks to more than one person and have major advantages over individual protective measures. These measures do not prevent the mosquito bite, however may reduce the chances of getting bitten.

- Give appropriate instructions to the public
  - Instructions should be communicated in a way that is readily understood by the workers or residents. In other words, be both comprehensible and relevant. With nowadays communication advancement through various social media, use of pictorial diagrams or infographics can be more effective to disseminate info and awareness.

11.3 Social Planning

- **Plans to be carried out**
  - Task Force for Occupants of Factories, Buildings, Houses, Landowners, etc to plan the Prevention and Control of Aedes Mosquitoes.
  - Work with Local Authorities, Health Dept, etc. to get their advice of they can be engaged as a partner.
  - Establish a baseline on the impact of Dengue in the area.
  - Train and retrain health staffs and community on the current global efforts on Dengue Eradication.

- **Sites Identification**
  - Occupants of Factories, Buildings, Houses, Landowners, etc. to do in-house specific Aedes surveillance activity as part of health risk assessment, example three monthly audit the sites of potential areas where Aedes mosquitoes breed.

- **Action to be taken:** The areas which has been identified as a potential hazard (Aedes Mosquito Breeding Areas) must be addressed by the followings:
  - Establish task force to clean up the breeding ground.
  - Engage the Occupants as part of the task force
  - Redesign the breeding grounds or environmental modification to avoid a potential hazard for reoccurrence of Aedes mosquito breeding.
  - Raise public awareness by educating the community on the danger of the Dengue fever.

- Many sources of promotional materials such as leaflets, posters on dengue awareness from the ministry of health and local authorities, can be distributed to the community.

11.4 Social Mobilization

- The dengue cases are more prevalent in urban than sub-urban areas. With a dense population, the intensity of spread of dengue is greater.

- As there is no commercially available vaccine, prevention is sought by reducing the habitat and the number of mosquitoes and limiting exposure to bites.

- The way forward is to increase public awareness about dengue, mobilize resources for its prevention and control and, to demonstrate commitment in tackling the disease.

- In controlling Aedes mosquito, the most important aspect is the involvement of the community as a whole in relation to prevention and control. In reducing and preventing the risk of infection, public acceptance of the proposed vector control methods and programs is studied for their effectiveness.

- Among the methods that demonstrate the success and adaptation of a successful community is the COMBI (Communication Behavioural Impact acronym by WHO) program.

- COMBI is a dynamic approach that uses social mobilization and communication strategy to influence behaviour change among individuals, families, and communities towards healthy behaviours.

- To implement the COMBI program, five (5) basic principles of using an integrated Communication strategy should be adopted, namely:
  - Deployment Administration / Public Relations and Advocacy
  - Community mobilization
  - Advertising
  - Presentation Personal / Interpersonal Communication
  - Promotion Service Centre

11.5 Housekeeping in Potential Breeding Grounds

Human settlements and non-agricultural areas largely determine the occurrence of dengue cases. The followings are common public areas that are considered as potential mosquito breeding grounds.

- Low Rise Residential Area
  - For this type of residential environment, the population density is much lower compared to high rise residential areas due to its low capacity to accommodate people.
  - For certain types of residential building, it is in outer residential neighbourhoods. Examples of low-rise buildings are terrace, semi-detached home, cluster-home, bungalow, and town house.
  - For low rise residential areas, the following housekeeping measures can be considered:
    - Storage of material, equipment, asset, vehicles, or any plants to prevent any accumulation of stagnant water, especially those exposed to an open environment.
    - Empty or clean water storage containers, water reserve barrels, pots, or vases, that are not in use on a weekly basis.
    - Keep the surrounding house clean especially drains, tanks, or manholes from rubbish, leaves, or waste. This can avoid the blockage of water flow.
    - House with a mini garden or landscape area, always check if there are any potential spots for mosquitoes breeding sites.
    - Ensure that any outdoor pipe outlet has its proper drainage system, including septic tanks (Figure 11.1).

Figure 11.1 Septic tanks can create mosquito breeding sites

- Disposing of solid waste properly.

- Drink can or disposable food container are some examples of artificial man-made mosquito breeding sites that must be removed from the environment.

- Check for drainage of water collection points around the house whether there are chances of possible mosquitoes' sites.

- Used tires is another source of mosquitoes breeding habitat. It is very popular to be used for landscaping which is mostly in an open environment.

o Suggestions to prevent mosquitoes access to residential area and into homes:
  - Barrier with 3-4 meter height, distance of 2.7 km.

  - Proofing of dwelling and bed nets.

  - House built at ground level is prone to mosquito's bite due to its activity preferable closer to the ground (proof from house built on stilts).

  - Modifications of dwelling.

  - Water container around house: use tight-fitting lids over water containers, depending on size, type and function of the containers.

- High Rise Building
    - High rise buildings like apartments or condominiums are different from other types of housing especially in managing the common area. Typically, the management of apartments and condos is managed by a strata or property management company appointed by the residence's Joint Management Body (JMB) or local authorities.

    - It is necessary to have a joint effort between the management team and residents to keep a sustainable healthy environment. Collective community practices such as the followings have an important role to help prevent dengue:
        - Community program on raising awareness for mosquito control.
        - Communal work programs to clean neighbourhood areas.

    - Examples of common areas that require special attention on housekeeping for high rise residential area are the community hall, playground, swimming pool, religious house, and parking area.

    - For high rise buildings, the following housekeeping measures can be considered:
        - Swimming pool water must be adequately treated on a regular basis with proper chemicals to avoid mosquitoes breeding.
        - Water storage, tanks or container must be covered and sealed if possible.
        - Regularly change water inside a container or water barrel if there are needs to keep reserve water.
        - Use damp sand to keep potted plants or flowers moist.
        - For flowers in vases with water, change it every week.
        - Objects that have potential to accumulate water must be turned over or covered up.
        - Check for mechanical systems with heating or cooling elements which may create stagnant water as a result of thermal processes such as condensation.
        - Check unreachable gutter areas that require special attention like the roof gutter.

- For residents or building occupiers, awareness programs on risk of Aedes mosquitoes and dengue outbreak should continuously be conducted as a part of dengue risk management.

Figure 11.2 Facilities management is duty bound to address water ponding issue

- Industrial Area
  - Establish or adopt proper housekeeping sustainable policy such as the 5S program which can keep the workplace tidy and clean throughout the business operations. This may help the employers, managers, or employees to identify the source that has the potential to become an Aedes mosquitoes breeding site.
  - Proper handling of industrial waste especially when keeping them in an open area before sending to schedule waste management. In the event of rain, the waste may become a source for Aedes mosquitoes breeding site n area where mosquitoes can breed.
  - Any industrial building or installation should avoid any potential of water accumulation via facility management.
  - Mechanical plants with heating or cooling elements should be checked to avoid any potential of water accumulation.
- Abandoned Buildings/Site/Land
  - Duty to manage abandoned building/sites/land should be identified when such area exists.

- Abandoned construction sites are one of the major areas for mosquito's habitat. The developer or landowner should hold responsible to protect nearby neighbourhoods or adjacent occupied areas from being affected by dengue outbreak from such sources.

- Abandoned factories also have potential to become mosquito's habitat and must be managed by the landlord. Some factories may leave machineries or plants that can cause accumulation of water for mosquitoes breeding ground.

- Abandoned lands in particular have been found to be mosquito productive breeding sites due to lack of upkeep, waste accumulation, and legal barriers which stop health officials from entering private property.

- Abandoned land cover types such as neglected grassland. Microhabitats that are shaded and vegetated, as well as wet grassland are favourable habitats for Aedes mosquitoes to breed in.

- Abandoned houses and vacant plots of land turned into unauthorized disposal sites have been identified as dengue-prone hotspots. Many mosquitoes, particularly some Aedes and Culex species can breed in man-made containers and other scrap materials, such as metal, carton, glass, plastic, etc., which (when abandoned on the ground) collect and hold rainwater.

- Schools
  - The risk level for dengue outbreak for schools will increase during the normal school session with high occupancy rate. Thus, it is important for any school management to take necessary action to prevent the risk such as appointing a dedicated staff to coordinate for mosquitoes prevention program.

  - The following housekeeping measures can be considered for schools:
    - Flowers or plants should not be placed in water; if unavoidable, the mouth of the containers should be blocked by sponges.
    - Flowerpot plates should not be allowed to accumulate stagnant water.
    - Gardeners should pay special attention to stagnant water in decorative pots or flowerpot plates that are not found easily.

- Trash such as beverage cans and lunch boxes, etc. should be disposed of properly in trash containers with lids.
- Drains should be kept unclogged.
- Inspection of the entire school area should be conducted once a week in order to eliminate mosquito breeding sources.
- In the hotspot area where the case is high, windows and doors in the classrooms should be installed with mosquito nets.
- Some examples of areas within the school that are possible breeding ground for mosquitoes such as outdoor football grass field with uneven surface, water fountain and landscape area with fish pond will require special attention.

Figure 11.3 Outdoor football grass field with uneven surface can cause stagnant water

- Offices, Office Towers and Government Complexes
  - Most urban offices have their own building facility management to foresee the risk of dengue outbreak and proper environmental management.
  - The periodic housekeeping audit should include water ponding and areas where mosquitoes breed.
  - Dengue awareness must be included in the in-house awareness training

- Community Center & Sport Complexes
    - Community centres and sport complexes which serve as recreational area for the public need to protect the environment from vector-borne diseases through Dengue prevention measures.
    - This would require the involvement and commitment of all parties including the Government, the private sector, NGOs, business entities, communities, and individuals.
- Houses of Worship
    - For houses of worship, usually the risk of being bitten by a mosquito can increase during religious ceremonies.
    - Frequent community housekeeping and cleaning programs can be organized to remove any potential mosquito breeding ground like rubbish or waste after religious events.
    - Religious ceremonies are usually accompanied by banquets to celebrate the participants, and this may result in more waste or rubbish such as paper cups and plastic plates. It needs to be clean up since this waste might create areas of stagnant water especially during the rainy season.
- Wet and Dry Markets
    - Wet market has high tendency for creating mosquito breeding grounds due to the various source of water from storage and transportation of daily consumer needs such as fresh fish, meat, seafoods, chicken, and vegetables.
    - The risk of mosquito related disease is more likely in wet market compared to the dry market. Even though the dry market environment is less likely to accumulate stagnant water, this public area may have similar risk level of getting bitten by mosquitoes if no environmental intervention is in place to prevent this vector-borne disease.
- Areas under local authorities including Drains, Rivers and Vacant Land
    - The local authorities have a great role in the eradication of mosquito breeding grounds.
    - The development of an area requires careful planning including for the prevention of vector-borne diseases.

Figure 11.4 Mosquitoes breed in stagnant water along the drain walls

- Bin Sites
  - Rubbish bin sites has become an environmental and social concerns in Malaysia especially during the raining season. Overloaded rubbish bin can cause the waste to clutter and create stagnant water after it rains before the collection process.

  - Provision of well-drained rubbish bin sites to the excess runoff and removal of the accumulation of stagnant water from the rubbish bin sites are to be considered.

Figure 11.5 Solid waste bin sites can cause stagnant water

- Information on hotspot areas
  - Eliminating dengue breeding ground are more effective by identifying the hotspot area and mitigate the risk of dengue spread in the locality. The identification of the hotspot area in Malaysia could be aid using a dengue early warning system which currently available and can be access through the https://idengue.mysa.gov.my/pageifv2/. This provides a good reference to combat and prevent the dengue outbreak in certain areas rather than randomly put effort to find and destroy mosquitoes breeding ground.

11.6 Engineers' Roles in Dengue Prevention

- Facility Engineers
  - Facility engineers' role include carrying out risk assessment of potential areas for Aedes mosquito breeding.

  - Managing the assessed risk may help them to have an effective risk mitigation and control program.

  - During the operation and maintenance of a certain building or facilities, it is important to include the dengue prevention program as part of facilities inspections.

  - Facility engineers can leverage the requirement in their regular inspection program.

  - Most important thing is to eliminate as far as possible the breeding sites of mosquitoes and the prevention of water accumulation sites.

- Social Engineering
  - Engineers have the responsibility and ethical obligations to hold the safety, health, and welfare of public.

  - The IEM's role as an engineering organisation is to establish Dengue Prevention and Control Committee which can guide the community as well as other stakeholders through education, awareness and technical advice pertaining to planning and design of public infrastructures and amenities.

- Engineering-based controls to prevent dengue outbreak plays an important role in risk management. Engineer's input is important on health-related issue, which may bring huge impact on their work and society.

- IEM through its branches will provide guidance and support for all its members to work together and contribute to the wellbeing of society and the community. IEM will provide training to its members in the following areas:
    - Awareness on Aedes Mosquitoes Behavior.
    - Guideline on the Prevention and Control of Dengue.
    - Interpersonal Relationship when working with the community.
    - Engineers Role towards the health aspect of Society.
    - Working with Government Agencies responsible for the dengue eradication, and
    - Activity Reporting to IEM Branch on Dengue Baseline and the Dengue Trend.

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Chapter 11

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ANNEX

Role of Engineers in Community Engagement Towards the Prevention and Control of Dengue (Example of a Resident Community Approach)

- Location: Majidee Park, Johor Bahru, a resident community with houses build in mid 1960s and comprising about 180 Detached, Semi Detached and Link Houses. The neighbourhood consist of 7 other residential areas which were occupied much later.

- Published dengue data from MOH since 2011 to 2015 for the 8 Residential areas are shown in Table A1. These are actual data on dengue cases obtained from the State Ministry of Health, Dengue Committee for period 2011 to 2015 on reported dengue cases.

Table A1. Dengue Cases 2011 - 2015

Reported Cases of Dengue by Housing Estates (Source Johor State Dengue Committee)	2011	2012	2013	2014	2015
Majidee Park	0	0	0	4	19
Taman Kebun Teh	0	1	1	1	1
Taman Suria	3	5	6	15	19
Kampung Melayu Majidee	7	5	32	16	96
Taman Melodies	2	3	8	14	12
Taman Century	2	5	22	15	29
Taman Sentosa	4	6	24	33	81
Taman Sri Tebrau	1	3	8	8	57
Total	19	28	101	104	314

- This was a serious wake up call for the residents of Majidee Park, the dengue cases suddenly increased with one fatality.

- The resident committee organised a 3-month housekeeping (Gotong Royong) in Sept 2015 to Dec 2015 to eradicate the breeding grounds of the AEDES Mosquitoes. The teamwork from all and the end results were very satisfying.

- The resident committee with the help of IEM Members and Rotary Clubs engaged the stakeholders i.e. Residents, Local Councillor, Member of Parliament, MOH and Southern Waste Holdings.

- There were nine (11) Roads in Majidee Park, the Monsoon Drain and the Playground (the main site for AEDES Mosquitoes Breeding). The neighbourhood schools also got involved in this housekeeping program.

- The organising team met regularly to plan the weekly housekeeping and engaged the authorities and Member of Parliament and the Councillors. The committee weighed the success of the activity and concluded that the approach by the engineers was a key factor in the success.

- The World Health Organisation (WHO), with expert knowledge concluded the community with the local authorities should work hand in hand to eradicate the breeding grounds of the AEDES Mosquitoes.

- Utilises the COMBI (Communication Behavioural Impact an acronym by WHO) program:
    - Mobilize the community to address the issue of dengue in the community
    - Creating a shared responsibility in the community
    - Influence and strengthen decision / behaviour / social norms in the community

- Neighbourhood housekeeping activities and awareness programs:
    - Example of Majidee Park Resident Community and Stakeholders working together to eradicate Aedes mosquito breeding ground is shown in Figure A1.
    - Photos of a community project to eradicate Aedes mosquito breeding ground are shown in Figures A2, A3, A4 and A5.

Figure A1. Initial Condition of the playground and inspection by the resident community with authorities and State Executive Councillor for an action plan

Figure A2. The Resident Association together with the Member of Parliament, Ministry of Health, Local Councillors, Rotary Clubs and IEM (Southern Branch) carrying out a community project to eradicate Aedes mosquito breeding grounds

Figure A3. Support from the Residents, the Local Council with Manpower and Machineries from Southern Waste Holdings

Figure A4. A collaboration between the residents, Member of Parliament, State Executive Councillor, local Councillors, local Authorities, Ministry of Health, IEM (Southern Branch), Resident Association, Rotary Club JB, Rotary Club Pasir Gudang, Rotary Club JB Sentral and UTM BioTech Dept.

- The Majidee Park Dengue Eradication Project:
  - This AEDES Mosquito and Dengue cases were a very serious concern, too many breeding ground and the 5th highest dengue cases amongst the 8 nearby housing areas in 2015.
  - It was a challenge for the residents and a resident association was set up. The Resident Association took this as a challenge to eradicate the Aedes mosquito breeding grounds.
  - This project started in Sept 2015 for 3 months. All parties concerned were mobilised, it was meetings into the late evenings. Almost every Sunday for 3 months, housekeeping was done in the housing estate comprising 250 houses, 2 schools, 20 Shop houses and 11 roads.

- Sharing session with two nearby schools and encouraged these schools to do their own housekeeping was part of this 3 month project.

- Assistance was also given to residents to clean up their septic tanks and surroundings.

- The output on the eradication of Aedes Mosquito breeding ground activity in Majidee Park had multiple benefits: team effort, working with authorities, NGOs, improved fellowship and understanding amongst residents. For three months in a row, there was zero reported dengue cases.

- The teamwork paid off in many ways, Figure A5 shows a transformed housing estate. To sustain, it needs many areas of commitment, from residents to authorities.

- The project is a model for housing estates and NGOs like IEM Branches who can emulate and spin off activities to eradicate dengue.

- Actual data obtained from the State MOH Dengue Committee is shown in Table A2 below.

Table A2. Dengue Cases 2011 - 2021

Reported Cases of Dengue by Housing Estates (Source Johor State Dengue Committee)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021 30th Sept
Majidee Park	0	0	0	4	19	0	0	3	2	2	0
Taman Kebun Teh	0	1	1	1	1	5	1	2	2	3	0
Taman Suria	3	5	6	15	19	16	15	17	29	38	3
Kampung Melayu Majidee	7	5	32	16	96	11	18	14	59	109	3
Taman Melodies	2	3	8	14	12	10	10	3	18	23	0
Taman Century	2	5	22	15	29	6	20	15	16	24	4
Taman Sentosa	4	6	24	33	81	13	12	13	30	86	2
Taman Sri Tebrau	1	3	8	8	57	20	7	4	32	48	1
Total	19	28	101	104	314	81	83	71	188	333	14

Figure A5. A transformed housing estate.

CHECKLIST
FOR CONTROL OF MOSQUITO BREEDING GROUNDS IN CONSTRUCTION SITES

CHECKLIST FOR
MOSQUITO BREEDING GROUNDS
IN CONSTRUCTION SITES

Location :
Date :
Inspection by :

Items	Description	Checked	Findings		Actions Taken		Description of findings	Remarks
			Stagnant water	Mosquito breeding	Clear stagnant water	Apply chemical		
A	**WORKERS QUARTERS**							
1	Water tanks							
	i) Floor under water tanks	☐	☐	☐	☐	☐		
	ii) Check for gaps and openings at covers and ventilation holes	☐						
	iii) Check for torn or detached mosquito nettings	☐						
2	Toilet & Bathroom							
	i) Concrete floor	☐	☐	☐	☐	☐		
	ii) Pails (including rim of overturned pails) / plastic containers	☐	☐	☐	☐	☐		
	iii) Toilet cisterns & unused toilet bowls	☐	☐	☐	☐	☐		
	iv) Bathing tanks	☐	☐	☐	☐	☐		
	v) Drainholes of unused sinks	☐	☐	☐	☐	☐		
	vi) Floor traps	☐	☐	☐	☐	☐		
3	Cooking & Washing Area							
	i) Cooking pots & pans / domestic containers	☐	☐	☐	☐	☐		
	ii) Floor traps	☐	☐	☐	☐	☐		
	iii) Grease traps	☐	☐	☐	☐	☐		
	iv) Refrigerator trays	☐	☐	☐	☐	☐		
	v) Flooring under sinks	☐	☐	☐	☐	☐		
	vi) Discarded items & receptacles	☐	☐	☐	☐	☐		
4	Living Quarters & Common Areas							
	i) Plastic containers / domestic containers	☐	☐	☐	☐	☐		
B	**CONSTRUCTION AREAS**							
1	Grass and vegetation	☐	☐	☐	☐	☐		

2	Puddles on ground and concrete floor at all levels	☐	☐	☐	☐	☐		
3	Building materials - zinc sheets, formwork, pipings, uninstalled toilets, etc including canvas sheets	☐	☐	☐	☐	☐		
4	Drain holes and unused sinks, gully traps	☐	☐	☐	☐	☐		
5	Pails and rim of overturned pails	☐	☐	☐	☐	☐		
6	Wheelbarrows, drums, cans, buckets, tarpaulin sheets	☐	☐	☐	☐	☐		
7	Balconies, swimming pools	☐	☐	☐	☐	☐		
8	Rain gutters, drains and sumps	☐	☐	☐	☐	☐		
9	Yard after rain	☐	☐	☐	☐	☐		
10	Ditches, swales, puddles	☐	☐	☐	☐	☐		
11	Demolition debris	☐	☐	☐	☐	☐		
12	Equipment and machineries	☐	☐	☐	☐	☐		
13	Water storage, drums, containers	☐	☐	☐	☐	☐		
14	Bulk waste containers, skips and refuse bins	☐	☐	☐	☐	☐		
15	Sump pits / silts trap	☐	☐	☐	☐	☐		
16	Drains / temporary channels constructed for drainage	☐	☐	☐	☐	☐		
17	Vehicle washing bay	☐	☐	☐	☐	☐		
18	Lift wells	☐	☐	☐	☐	☐		
19	Planter boxes	☐	☐	☐	☐	☐		
20	Discarded items & receptacles	☐	☐	☐	☐	☐		
21	Toilet							
	i) Concrete floor	☐	☐	☐	☐	☐		
	ii) Pails (including rim of overturned pails) / plastic containers	☐	☐	☐	☐	☐		
	iii) Toilet cisterns & unused toilet bowls	☐	☐	☐	☐	☐		
	iv) Drainholes of unused sinks	☐	☐	☐	☐	☐		
	v) Floor traps	☐	☐	☐	☐	☐		
22	Canteen							
	i) Cooking pots & pans / domestic containers	☐	☐	☐	☐	☐		
	ii) Floor traps	☐	☐	☐	☐	☐		
	iii) Grease traps	☐	☐	☐	☐	☐		
	iv) Refrigerator trays	☐	☐	☐	☐	☐		
	v) Flooring under sinks	☐	☐	☐	☐	☐		
	vi) Discarded items & receptacles	☐	☐	☐	☐	☐		

C	**EARTHWORK PLAN AND EROSION SEDIMENT CONTROL PLAN**							
1	All depression and unlevel grounds	☐	☐	☐	☐	☐		
2	Unused excavator buckets	☐	☐	☐	☐	☐		
3	Temporary drainage	☐	☐	☐	☐	☐		
4	Retention pond	☐	☐	☐	☐	☐		
5	Plastic barrier	☐	☐	☐	☐	☐		
6	Puddles and water ponding areas	☐	☐	☐	☐	☐		
7	Trenches	☐	☐	☐	☐	☐		
8	Drain and temporary channels	☐	☐	☐	☐	☐		
9	Sump pits and silt traps	☐	☐	☐	☐	☐		
D	**STORAGE FOR CONSTRUCTION MATERIALS**							
1	Zinc sheets, form works, steel bars	☐	☐	☐	☐	☐		
2	Metal beams, piping, uninstalled toilet bowl and cistern	☐	☐	☐	☐	☐		
3	Grounds below materials	☐	☐	☐	☐	☐		
4	Pipes in storage	☐	☐	☐	☐	☐		
5	Hollow metal rods, unused drums	☐	☐	☐	☐	☐		
6	Containers	☐	☐	☐	☐	☐		
7	Tools and material storage box	☐	☐	☐	☐	☐		
8	Discarded pail, skip tank, empty chemical and paint cans	☐	☐	☐	☐	☐		
9	Lids of drums, cans, and thrash cans	☐	☐	☐	☐	☐		
10	Water stored in tanks, containers, drums, filtration and sedimentation tanks	☐	☐	☐	☐	☐		
11	Bulk waste containers, skips and refuse bin	☐	☐	☐	☐	☐		
12	Construction debris	☐	☐	☐	☐	☐		
13	Canvas, sheets, tarpaulin and plastic covers	☐	☐	☐	☐	☐		
E	**PLANTS AND EQUIPMENT**							
1	Sump pit	☐	☐	☐	☐	☐		
2	Vehicle washing bays	☐	☐	☐	☐	☐		
3	Instrumentation box	☐	☐	☐	☐	☐		
4	Water meter	☐	☐	☐	☐	☐		
5	Condensed water from A/C unit	☐	☐	☐	☐	☐		

6	Tanks, gully traps and plants							
7	Lifts and construction shafts							
8	Uneven floor							
9	Concrete mixer and wheelbarrow							
F	**SITE CABIN OFFICE**							
1	Site office using container – in and below container							
2	Site office cabin - on and below roofing and zinc sheet							
3	Canvas roof including secondary roof							
4	Ground below cabin							
5	Plastic containers / domestic containers							
6	Discarded items & receptacles							
G	**RIGHT OF WAY RESERVE**							
1	Discarded food containers and rubbish							
2	Grass and undergrowth							
3	Puddle and water ponding areas from ground depression							
4	Drains							

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