Third problem is the inadequacy of the qualified technical manpower for drainage improvement works in the Local Authority. As stated above, the Local Authority is one of the major executive bodies for drainage improvement in the same way as DID. However, the drainage improvement works shared to the Local Authority is hardly implemented due to the lack of the qualified technical manpower.

In due consideration of the above major problems, the following items are proposed so as to promote a consistent drainage policy and ensure smooth implementation of drainage improvement works (refer to Fig. 4-6):

(1) Establishment of Federal and State Interagency Coordinating Council

The following interagency coordinating councils are proposed at both of Federal and State Level to deliberate and coordinate the issues on the drainage improvement works:

(a) National Rivers Council (NRC) at Federal Level

There is recent proposal to establish a National Rivers Council (NRC) with its secretariat at Federal DID to deliberate and formulate the policies and programmes on the nation-wide river management which includes the matters on the flood control and urban drainage. The Council could be regarded and proposed as the most appropriate platform to undertake formulation of the consistent policies on urban drainage improvement for all states.

At present, requests for federal funding mainly originate from three sources, i.e., the Local Authority, the State Authority and the Federal DID. These requests are coordinated by EPU and the Treasury, prioritized through a bidding process and incorporated into the 5-Year Malaysia Plan. Other sources of funding are the State Government and the Local Authority using their own resources. There is an obvious need to coordinate these programmes in tandem with the preparation of local plans, prioritize them before allocating funds. The proposed NRC may again be a suitable forum to address the request before submitting it to EPU and the Treasury for funding approval.

(b) State Planning Committee at State Level

There is a existing coordination body called State Planning Committee (SPC) at State Level. The SPC deliberates the formulation of state policies on the conservation, development and use of all land in the State. The SPC also gives the direction to the Local Authorities on the matters pertaining to physical planning and development. The on-going intensive land development in the study area would cause a rapid increment of peak storm runoff discharge, while the urban drainage improvement may hardly catch up with the rapid increment of discharge. To avoid such unbalance, the SPC should be the forum to coordinate projections on land development and the urban drainage. Moreover, the State Director of DID should be made a permanent member of SPC so as to take technical responsibility on river management and urban drainage.

(c) State Water Management Authority (SWMA) at State Level

The SWMA is recently proposed as the interagency coordination body among the agencies related to the river management and urban drainage at State Level. The objectives of the SWMA proposed in this Study is to coordinate the drainage management plans that emanate from the State DID and/or Local Authority in order to promote a consistent drainage improvement plan. The SWMA is to be chaired by the Menteri Besar with the State Secretary as the Deputy Chairman. The secretary of the Authority is rotationally appointed, and the current secretary is seconded from the DID. At the same time, the SWMA should coordinate with NRC to enhance the consistent drainage improvement policies between Federal and State Levels.

(2) Demarcation of Functional Responsibility for Drainage Improvement

The Ministerial Functions Act of 1969 and the Cabinet Directive of June 1996 provide guidance on the functional demarcation. According to guidance, the DID be responsible for all drainage facilities relative to the proper management of drainage basins, while the Local Authority is to be responsible for facilities necessary at the sub-basin level. With referring to the guidelines and in due consideration of the particular features of the drainage facilities, proposed are the functional responsibilities on planning, design, construction and maintenance of drainage facilities as shown in Tables 4-2 and 4-3. Major drainage facilities directly connected with flood mitigation such as river channel improvement, flood retardation basins, weirs and gates, trunk drains and community detention facilities will be the responsibility of DID. The maintenance of these facilities will also be made by DID except for community detention pond facilities that are normally incorporated with recreational facilities. Since these facilities are to meet the community recreational needs, the Local Authority should preferably maintain them. The Local Authority should also manage and maintain drainage facilities constructed at the sub-basin level. This will include drainage facilities within the housing development sites that are usually built to the appropriate technical specifications by the developers and eventually surrendered to the Local Authority as a public facility.

(3) Capacity Building of Local Authority

The Local Authority is the custodian of the drainage channels in his jurisdiction area, and has to coordinate with all relevant agencies on the drainage infrastructures and their maintenance. Thus, the Local Authority shoulders the extensive responsibilities on the drainage improvement, and the responsibilities will significantly expand as the urbanization progresses very rapidly.

In spite of the extensive responsibility on the drainage improvement, both Local Authorities of Sungai Petani and Melaka are suffered from a lack of qualified technical manpower, and there does not exist even a drainage division within their Engineering Department. In order to retrieve this unfavorable situation, it is required to promote the plan for reinforcement of the present capacity building of Local Authority into more practical programmes through deliberations among the related departments and agencies..

### 4.3.2 Funding and Cost Recovery Measures

In accordance with the current laws and regulations in Malaysia, the available cost recovery measures for drainage improvement could be broadly classified into two (2) categories. The first is the recovery cost secured from government grants such as the "Federal and State Development Grant" and the "State Road Grant". The second is recovery cost obtained from the charges imposed on land developers and the direct beneficiaries of drainage improvement including "Drainage Contribution", "Drainage Improvement Charges", "Drainage Rates" and "Drainage Infrastructure Cost". The proposed sources of funding and cost recover measures for each of drainage improvement work is as described below (refer to Table 4-4):

(1) Federal and State Development Funds

Federal and State Development Funds are the most common sources of funds for drainage projects. Federal Funds are secured from the Federal Treasury and may be initiated by the Local Authority, State DID or the Federal DID. These funds cover master planning studies, as well as design and construction of facilities. These projects are budgeted as part of the 5 year Malaysia Plans and taken under the heading of Drainage and Flood Mitigation in Urban Areas and River Management projects in the case of Federal DID projects.

(2) State Road Grants

These are annual grants provided by the Federal to the state governments. These grants are to cover maintenance cost of State Roads and other roads that meet the required qualification. This budget is usually administered by the State JKR and also includes maintenance of roadside drains and culverts.

(3) Drainage Contribution

Some measures of cost recovery for the provision and maintenance of these facilities is through the imposition of Drainage Contribution by the State Authority for land use conversion. Again, instead of calling it drainage contribution, perhaps a river conservancy charge may be more appropriate as most final discharges are to the river. This will also help differentiate the charges imposed by the Local Authority under the Street Drainage Building Act. Except for the city councils and the Municipality of Penang, it is also suggested that the charges be standardized for municipal areas and another for District Council areas in line with the recommendations of Ministry of Housing and Local Government.

(4) Drainage Improvement Charges

The management of Drainage Facility at the sub-basin level is usually the responsibility of the Local Authority. Most of the infrastructure however is built by the developer and surrendered to the Local Authority as public facility. The Local Authority under s51 Street Drainage Building Act is empowered to impose a Drainage Improvement Charge on developers. This is a potential cost recovery measure for the Local Authority and the fund could be consolidated into the Improvement Services Fund or the Local Authority Fund. These funds could be used to rehabilitate existing detention ponds and construct new storage facilities in open spaces. Under the Act, specific drainage improvement charges may also be imposed on frontagers to recover investment cost including land acquisition cost for the provision of any drainage infrastructure.

(5) Drainage Rates

The Local Authority may also impose Drainage rates to meet the cost of construction of any drainage system (s132 Local Governments Act 1976). These rates will be based on a percentage of the annual value of the holding or the improved value of the holding. The maximum rate imposed is 5% of the annual value or 1% of the improved value. Most Local Authorities have not imposed these charges on ratepayers. However with increased responsibility for providing and maintaining drainage systems including retention ponds, it may be incumbent on Local Authorities to impose these rates to ensure a revenue stream for such works.

(6) Drainage Infrastructure Cost met by Developers

The Local Authority by law may require developers to construct connecting drains and other storm water detention facilities within development areas. There have also been instances where developers have been required to improve drainage channels outside their development areas. These requirements are imposed as conditions for development approval and in most cases complied by the developers. The developers normally construct the facilities and then hand them over to the Local Authority which then has the responsibility to maintain them.

(7) Subsidy

Storage tanks have been successfully applied in Japan as a detention facility in existing built up areas. While storage tanks may be imposed as a condition for building plan approval, it may be difficult to impose this requirement on existing premises. Hence some form of subsidy may be needed to encourage existing property owners to install the facility. Detention storage tanks may be incorporated with the rainwater collection tanks which are promoted by the Ministry of Housing (MHLG). Research in Japan has shown that subsidy provided by the Ministry of Construction for storage tanks offsets the more expensive option of providing wider drains, rivers and detention facilities.

### 4.3.3 Enforcement Capacity

Among others, the following legislation, rules and regulations are newly proposed as major requirements for drainage improvement projects.

(1) Enforcement of Guideline on Construction of Flood Detention Pond by Land Developer

According to the present guideline, the land developer is required to construct a flood detention pond for his land development area of more than 10 ha. In another words, the land developer could avoid construction of a flood detention pond as far as the land is less than 10 ha. Land development is, however, now being intensively made causing drastic increment of peak flood discharge, and the channel flow capacities of the existing drainage channels as well as the downstream river channels are extremely small. In due consideration of such critical conditions, the flood runoff from almost all of the new land development area should be subject to regulation by a flood detention facility. From this viewpoint, one (1) ha instead of 10 ha as currently required is provisionally proposed as the minimum land development scale for which the land developer is obliged to construct a flood detention pond.

(2) Securing of Drainage Reserve Area

In Malaysia, the construction of any building is not permitted within 50 feet from the riverbanks as prescribed in the Water Act of 1920. Based on the prescription, DID proposes the width of 15 m from the riverbanks as river and drainage reserves useful to preserve the natural flood retarding effect. In spite of the flood control effect, the river reserves have not been demarcated, and even the buildings are constructed adjacent to the riverbanks in the study area. To remedy such unfavorable conditions, the reserves should be gazetted, and DID should be designated as the controlling agency. The reserved should be shown in a zoning plan and declared as public land. Any type of land development activity shall be prohibited in the area, except for a specific type of development that could preserve the retarding function, such as piling type of buildings.

(3) Water Pollution Control

The enforcement of water pollution control principally lies with DOE. In the long run, there is a need to establish quality standards for storm water runoff similar to the existing Environmental Quality Regulations for Sewerage and Industrial Effluents established in 1979. The storm water tends to wash the dust, sediment and other water pollution sources and bring them into the flood detention ponds causing deterioration of their water quality. In Malaysia, however, the water quality is currently not monitored during the flood. From this viewpoint, the objectives of existing monitoring by DOE should be extended to the quality of storm runoff in order to ensure water quality standards for the flood detention ponds in particular in order to ensure that the water quality standards are not breached.

(4) Promotion of Public Awareness on Proper Solid Waste Disposal and Water Pollution Control

Garbage and other solid wastes are among the main pollutants of storm water and they often clog drains causing flush floods. Most of the Local Authorities have bylaws to prevent littering of solid wastes, but enforcement is difficult due to difficulties in identifying the polluters. Under this situation, both the DID and the Local Authority should take an active role in educating the public on proper solid waste disposal to prevent water pollution. Table 4-5 shows a summary of the various violations, the enabling laws and the relevant enforcement agency.

## 4.4 Preliminary Study on Prevention of River Overflow

### 4.4.1 General

As described above, the principal objective of this study is to formulate the drainage improvement plan. However, there are the following six (6) major river systems with catchment areas of more than 4 $km^2$ in the study area, and the drainage discharge finally flows into these rivers and influence the river flow condition.

| Sungai Petani | | |
|---|---|---|
| Name of River | Major Tributary | Catchment Area (km2) |
| 1. Lalang | Bakap, Line A | 25 |
| 2. Tukang | | 8 |
| 3. Petani | Line A1 | 38 |
| 4. Pasir | | 23 |

| Sungai Melaka | | |
|---|---|---|
| Name of River | Major Tributary | Catchment Area (km2) |
| 1. Lereh | Udang, Gajah | 35 |
| 2. Malim | Ayer .Salak, Ayer Hitam | 52 |
| 3.. Melaka | Cheng, Putat | 92 |

Among the above rivers, Sg. Malim and Sg. Melaka have already been provided with river channel improvement works including construction of bypass channel, and could prevent the channel overflow of 5 to 50-year return period. On the other hand, the others have remained as natural rivers without any major river improvement works and could not cope with even a 2-year return period flood (refer to Subsection 2.4).

The ongoing intensive land development in the upper reaches will accelerate the increment of the basin runoff discharge, and thereby, highlighted is the basin detention facilities proposed in the drainage improvement plan. That is, should the basin flood detention facility be introduced, the future increment of basin runoff discharge toward the year 2020 could be controlled to be marginally small and, therefore, the present river overflow conditions will not worsen even in the year 2020 due to the flood detention facilities proposed in the drainage improvement plan.

However, the facility could hardly decrease the future runoff discharge below the present level. Thus, the present states of river overflow will continue in the future, unless a particular prevention work for overflow is provided. The present flow capacity is extremely low, while the present intensive urbanization in the study area will certainly require expansion of land development into the present habitual inundation area along the river and not allow overflow from rivers.

### 4.4.2 Standard Design Flood Discharge and Possible Measures for Prevention of River Overflow

The possible countermeasures for river overflow are classified into (1) enlargement of river channel and/or construction of new bypass channel, and (2) construction of flood retarding basins and/or flood control dam. The measures of (1) function to increase the river flow capacity, while the measures of (2) are to store the flood runoff discharge from the catchment and reduce the peak of design flow discharge.

As shown in Fig. 4-7, the standard design discharge of 100-year return period for most rivers will have a large gap as compared with the present river channel flow capacity. It is herein noted that the standard design discharge is defined as the target maximum design river flow capacity, which could be reduced by regulation effect of flood detention facilities such as flood retarding basin and flood control dam.

Among the possible countermeasures, the measures of (1) will require far larger channel cross-sections than the existing sections to meet the big gap between the present river channel flow capacity and the standard design discharge. Accordingly, the measures will require an extensive land space. Moreover, the measures need to be implemented from the downstream toward upstream in order to avoid an excessive discharge flowing into the downstream. A substantial part of the downstream of rivers are located in the existing and/or projected built-up area, and difficulties are foreseeable in acquiring the necessary land space.

Due to the above difficulties in land acquisition, highlighted are the measures of (2), and the possible sites of the measures were scrutinized through field reconnaissance. As the results, it is identified that the possible site for flood control dam is hardly secured due to the rather flat topography in the study area, but there are several possible sites for basin-wide flood retarding basins as shown in Fig. 4-8. The possible retarding basins are presently swamp areas and/or vacant grassland located in the low-lying plain along rivers. Among them, the prominent retarding basins are enumerated as those along Sg. Lalang (Reference No. RSA-1 in Fig. 4-8), Sg. Tukang (RTU-1), Sg. Pasir, (No. RPA-1) and Sg. Cheng (No. RCE-1). These retarding basins are located at the downstream and/or middle stream of rivers covering a substantial part of catchment area, and therefore could have a significant effect on reduction of peak of the flood runoff discharge. As for the rivers other than the above four (4) rivers, the effect of retarding basins could not be expected, and only the measures of river channel improvement and/or construction of bypass channel are applicable to the rivers.

Construction of the above countermeasures for river overflow will be required in parallel with the drainage improvement works so as to get rid of all types of flooding problems. In this connection, a detailed topographic survey for the possible retarding basins need to be undertaken to clarify the hydraulic potential capacity of flood retarding basin and determine the design flood discharge and structural features both for retarding basins as well as the river channels. At the same time, a detailed parcel survey will be required to clarify the contents of land acquisition for construction of retarding basins and river channel improvement.

## 4.5 Preliminary Design of Proposed Drainage Facilities

### 4.5.1 Drainage Channel

The preliminary design of drainage channels is made to cope with the channel design flood discharge with particular attention on the following items:

(1) Route and Alignment

The best route of channel improvement is selected through examination of the route along the existing waterway and in comparison with alternative routes of new drainage channel, if necessary. The alignment is arranged as smooth as possible and determined in due consideration of the project cost which includes construction cost as well as maintenance cost.

(2) Longitudinal Profile

The design gradient of channel bed is in principle set as the average of the existing bed gradient and arranged to gradually change from steep to gentle in the descending course in order to minimize the channel bed fluctuation. The channel construction and maintenance cost is also taken into consideration in determining the channel bed gradients.

(3) Cross Section

The cross-sectional design is made considering the prescribed flow capacity, topographic and soil conditions, environmental condition and construction cost. A single cross-section is adopted as the principal cross-section shape of a drainage channel so as to secure maximum cross-section area under the restricted right-of-way. A concrete flume type with a rectangular single cross-section area is also adopted to a congested area or low-lying area. Given below are the standards applied to the design of proposed cross-sections.

| Type | Structural Characteristics | Applicability for Urban Drainage |
|---|---|---|
| Earth channel (Naked channel) | A trapezoidal cross-section shape is formed and side slope gentler than 45° is required to keep it stable against sliding failure. (Recommended side slope: 1:1.5 to 2.0) | Low cost construction can be expected, but periodical weeding is necessary. A relatively wide area for the right-of-way is necessary. |
| Lined channel | A trapezoidal cross-section shape is formed and side slope steeper than 45° lined with stone pitching, concrete and turfing can be applied. | Relatively easy maintenance can be expected. Compared to earth channel a much narrower area for the right-of-way is required. |
| R.C. channel (Flume type) | A rectangular reinforced concrete cross-section is formed. The type can be constructed under any topographic and geological conditions. | Although the construction is costly, easy maintenance can be expected. The right-of-way can be minimized. |
| Sheet pile channel | A rectangular sheet pile wall cross-section is formed without channel bottom slab. This type is suitable for deep channel. (Recommended channel depth: more than 3m) | In the case of a deep channel and the restricted right-of-way, this type will be applied, although the construction is costly. |
| Vegetated channel | A trapezoidal cross-sectional shape with very gentle side slope is formed with vegetation in view of environmental and ecological circumstances. Infiltration efficiency might be conditional on the soil and geological conditions. | Although the construction is not so costly, periodical maintenance is required. A wide space for securing gentle side slope is also necessary. |

(4) Freeboard

The open drainage channel takes the following freeboard in order to cope with rise of design high water level by wave height, hydraulic jump and drifting materials:

- If 20% of the channel depth is more than 0.3m : 0.3m
- If 20% of the channel depth is less than 0.3m : 20% of the channel depth

(5) Underpass Structure

A box culvert or a pipe culvert is adopted as the structure to pass under the existing roads or other structures. Once culvert structure is constructed, it is virtually difficult to further increase the flow capacity of the culvert unlike open channels, and debris and other drifting materials could possibly close the structure. In order to cope with such unfavorable conditions, the culvert takes 130% of the design flow discharge for open channel, if the culvert is submerged, or take 0.3m of freeboard in height, if the culvert is not submerged. The proposed culverts are designed to be the R.C. structure which could secure sufficient strength to sustain dead and live loads.

### 4.5.2 Flood Detention Pond

The design works are made on the following two types of flood detention ponds:

| Type of Pond | Characteristics |
|---|---|
| (a) Wet Pond | The pond impounds the water even during non-flooding time. Amenity space is provided around the impounding space so as to provide public recreation space and to improve the urban scenery; hence, the pond may also be called as community pond. The pond is placed at the area where a rather extensive vacant land could be allocated to the wet pond. Moreover, the pond is applied only when the catchment area is subject to the new land development area, where less non-treated wastewater is expected to flow into the pond. |
| (b) Dry Pond | A structure is provided to divert the non-flood discharge into the pond so as to prevent polluted wastewater from flowing into the pond. Due to the diversion of non-flood discharge, the pond is dried up during non-flooding time, and the dry space could be temporarily used as public sports space and/or other recreational space. The pond is applied when the catchment area contains a substantial extent of the existing built-up area, where the wastewater is expected to flow into the pond, and the water impounded may cause environmental deterioration. When the pond is placed in a rather extensive vacant space where large-scale amenity facilities could be provided, it could also be called as the community pond. |

The proposed flood detention ponds include those to be newly constructed as well as the existing ponds to be rehabilitated. The new ponds could take either of the above two types. On the other hand, all of the existing ponds are assumed to take the dry pond type instead of their present wet pond type in order to minimize the inflow of wastewater. Major design features for the above flood detention ponds are as described below.

(1) Storm Outfall Structure

The storm outfall structure is designed for the aforesaid dry pond type, and placed immediately before the under-mentioned inlet structure of the pond, as shown in Fig. 4-9. The storm outfall structure functions to divert the non-flood discharge from the inflow to the pond so as to minimize the inflow of polluted wastewater and dry up the pond during the non-flooding time.

(2) Inlet Structure

A channel type inlet structure with steel screen is designed at the entrance of all types of ponds in order to trap influxes of rubbish and sediment and easily remove the trapped matters. Moreover, some protection works such as gabion mat and revetment are provided at the immediate downstream of inlet structure to protect the pond from scouring and erosion. A typical inlet structure is illustrated in Fig. 4-10.

(3) Pond

Both wet type pond and dry type pond are provided with bottom and slope protection by turfing in principle. However, when intensive erosion is expected, the bottom protection is assumed to be made with concrete lining, and the slope protection with stone-pitching. The dry pond is also provided with concrete drains at the bottom to facilitate drying up immediately after flooding. The standard storage capacity of the wet and dry types of pond is assumed as below, referring to the results of the hydrological analysis (refer to Section 3.3).

| Items | Standard Size per Unit Catchment Area of 10ha |
|---|---|
| Storage capacity | 12,800 $m^3$ per of 10ha |
| Storage area<br>(b-1) Non-Community Pond<br>(b-2) Community Pond | <br>4,000$m^2$ per 10ha<br>5,500$m^2$ per 10ha |
| Storage depth of pond | 3.2m<br>(the lower depth of 2.0m used for control of 5-year return period flood, and the upper depth of 1.2m for 100-year return period flood. The upper depth is also used as the amenity space in case of community pond) |
| Height of freeboard | 0.6m |

Note: Items (a) and (b) will increase in proportion to rate of the actual catchment area to the standard value of 10 ha.

(4) Outlet Structure

The outlet structure with two orifices is designed as a channel type of R.C. structure located at the lower end of the pond structure to connect with the downstream channel. A steel screen is also built beside the orifices in order to protect the orifices from clogging by drifting rubbish. Moreover, an inspection hatch and a slide gate for orifices are installed to facilitate easy and sustainable maintenance work. A typical outlet structure is illustrated in Fig. 4-11.

(5) Spillway

When a pond is placed at a valley and its surrounding bank crest level is more than 1.5m high above the ground level, a spillway is designed to safely spill out the flood discharge. The design discharge for the spillway is equivalent to 120% of 100-year return period for a concrete structure pond and 144% of 100-year return period for an embankment pond.

(6) Maintenance Road

There will be a great volume of rubbish and sediment flowing into the existing ponds. In order to ensure the sustainable removal of these materials through regular maintenance, an approach road towards the bottom of the pond and a maintenance road around the pond are designed. A typical arrangement of the roads is shown in the general layout in Figs. 4-11 to 4-12.

### 4.5.3 Storage in Public Open Space

School playgrounds, parks, parking lots and other wide public places may be utilized as temporary storage ponds. These places need to be excavated to a certain depth to ensure a sufficient regulation capacity for storm water without marring their original functions. Storage water will be led to the outlet by the side drains placed at the circumference of excavated pond and released naturally through the orifice of the outlet structure. A preliminary design of typical storage facilities in public open space is prepared, as shown in Fig. 4-13, and its features are summarized below:

(1) Inlet and Outlet

Inlet structure is designed as orifice with interceptor for influx of sediment, rubbish, debris, etc. to protect the orifice from clogging. The facility is subject to natural drainage, and not equipped with outlet control devices such as gate and valve, which require artificial operation.

As stated before, the study area has a low infiltration potential, and therefore the outlet structure is designed as orifice or open channel instead of the infiltration type structure. Side drain or drainage ditch is placed at the perimeter of the public open space in order to drain out the stored water smoothly and decrease the frequency and time of inundation in the space.

(2) Storage Area

Storage area is a surface excavation pond surrounded by R.C. wall. The bottom of the pond is a gentle slope and protected with turfing to facilitate smooth drainage after rainfall. The allowable maximum storage depth is assumed at 0.3 m for the sake of safety of children. Moreover, the allowable maximum time duration of flood storage by the facility is limited to 2hours in due consideration of the original purpose of usage of the public open space. In accordance with results of the hydrological analysis in Subsection 3.3.2, the standard storage capacity is assumed as below:

| Items | Unit Size per Standard Extent of One Lot of Institutional Area (20,000m$^2$) |
|---|---|
| (a) Storage Capacity | 1,200 m$^3$ |
| (b) Storage Area | 4,000 m$^2$ |
| (c) Storage Water Depth | 0.3 m |
| (d) Max. time duration of flood storage | 2 hours |
| (e) RC Wall with Side Drain | 0.6 m high, 260 m in total length |

Note: Items (a) and (b) will increase in proportion to the ratio of actual institutional area to the standard value of 20,000m$^3$.

### 4.5.4 Storage Tank in House Lot

Water storage tanks are installed on the ground to store rainwater from the roofs of house and buildings. It is necessary to scatter the storage facilities in wide areas involving a number of private house lots, because a single unit of facility has a very small capacity. Rainwater will be collected with roofs and rainwater down pipes and stored in a FRP storage tank installed at a house lot. Then, the stored water is naturally released through the outlet orifice of the tank.. It is noted again that the outlet structure of infiltration type is not applied due to the low infiltration capacity of the ground in the study area. One unit of typical storage system at a house lot is illustrated in Fig. 4-14, where the following standard storage capacity for one unit of house lot is assumed, referring to the results of hydrological analysis in Section 3.3:

| Items | Unit Size per Standard Extent of One House Lot (200m$^2$) |
|---|---|
| (a) Storage Capacity | 2 m$^3$ |
| (b) Required Installation Space | 2 m$^2$ |
| (c) Storage Water Depth | 1 m |
| (d) PVC Pipe Plumbing | 40 m in total length |

Note: Items (a) and (b) will increase in proportion to rate of the actual institutional area to the standard value of 200m$^2$.

A part of rainwater stored in the storage tank could also be used as water resources. However, the preliminary design in this drainage structure plan is made only for the sake of cost estimation of flood control function and not extended to the water resources development. Detailed clarification on the aspect of water resources development is made in the following Feasibility Study.

## 4.6 Operation and Maintenance Plan for Proposed Facilities

The drainage facilities are subject to constant wear and tear, and should be well maintained and repaired to sustain their prescribed functions. Thus, maintenance for drainage facilities is indispensable as a part of the drainage improvement and its work plan should be prepared in due consideration of necessary work items/procedures and administrative arrangement (such as budgeting arrangement and manpower arrangement for maintenance).

Major works for maintenance of drainage facilities have no significant difference from those of other infrastructures including removal of sediment, solid waste and other drifting materials and repair/replacement of parts of the facilities. Among the drainage facilities, the flood detention facility placed in a private house lot will take a space which can be used for various purposes other than flood mitigation. Accordingly, maintenance work for those facilities is subject to cooperation from and agreement with owners and/or users of the space. The maintenance works required for the drainage facilities are as described below.

### 4.6.1 Flood Detention Facilities

The following items are given as the major maintenance works for flood detention facilities (refer to Table 4-6):

(1) Securing of Detention Capacity

The maintenance work aims at securing the detention capacity as well as the flow capacity of inlet/outlet structures of the storage facilities. In order to fulfill the storage function, required are the periodical removal of sediment, solid waste and other drifting materials from the inlet/out and flood storage space. Backhoe or other heavy excavation equipment will be required for removal of deposits from a large-scale storage ponds. Moreover, periodical inspection should be made on the damage to inlet/outlet structures and leakage of water from the ponding space, and repair works should be made as required through the inspection.

(2) Safety Control

A signboard nearby and fence around the storage facility should be installed and periodically inspected/repaired in order to prevent persons from falling into the ponding area and trespassing into the inlet/outlet structures and other danger zones of the facility.

(3) Sanitary Control

Periodical inspection of the water quality of the ponding water should be made. In accordance with the inspection, impounding water should be drained and pollution control measures should be taken as required.

### 4.6.2 Drainage Channel

The most critical issue on the maintenance works is to secure the prescribed channel flow capacity. In order to cope with the issue, required is periodical and emergency removal of sediment, sludge and other drifting materials accumulated in the drainage channel. Mowingof grass on the channel slope of an earth drain is also required. A lot of drifting debris tend to accumulate and clog at the hydraulic critical points such as inlets of diversion point and pipe culvert, piers of bridge and drop structure. Therefore, special attention should be paid to those points through the periodical maintenance during non-flooding time as well as the emergency maintenance during and after flooding time. Among others, the inspection of drainage facilities immediately after flooding will facilitate to clarify the trouble points and structurally weak points, and the revision of maintenance program should be made on the basis of the inspection.