Overview of Urban Road Drainage Systems in Hong Kong

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Abstract

Presented in this paper is an overview of urban road drainage system in Hong Kong. The hydrological process, catchment characteristics and stormwater drainage system in the urban areas are briefly discussed. Gully inlets, as an integral part of the stormwater drainage system hydraulically, are discussed in more details in aspects of design and maintenance.

Introduction

Most urban areas in Hong Kong fall within strips of reclaimed land along the water front. They have the common characteristics of steep and undeveloped upstream with flat and highly urbanised downstream. To prevent flooding, we have to convey the stormwater to the sea by means of drainage system, which consists of underground pipeline networks and river channels. Drainage is a closely linked system and every component is inter-related. To ensure that the drainage system performs satisfactorily, it is prudent that every component of the system can function to the required serviceability level.

How a Drop of Rain Reaches the Sea

Starting from May every year until the end of the wet season in October, Hong Kong will be subject to rainstorms. The rainfall will generate surface runoff and if the runoff is above the capacity of the drainage system, flooding will occur.

Let us look more closely to the above hydrological process. Before the rain drop reaches the ground, it may be held up by the leaves of the trees or on the surface of the buildings. When the rain hits the ground, some of it will be absorbed into the soil and becomes ground water. It may also be absorbed into the trees and release back to the air later. However, if the ground is paved up by concrete, this absorption will be reduced. The rain water will either stay in the small ponds on the ground surface or flow along the road until reaching a nearby road gully. This portion of rain water running on ground surface is called surface runoff.

Road gully is the inlet of road drainage system and is the first drainage component in collecting surface runoff into the system. After getting through the gully grating into the gully sump, the collected water will pass through a connection pipe into the underground pipeline system. Through the pipeline networks, the stormwater will be discharged to suitable outlets, such as the sea or rivers. Figure 1 shows the typical arrangement of gully inlets and the pipe drains.

Catchment Characteristics of Hong Kong Urban Areas

From the drainage point of view, the upper part of most Hong Kong catchments has a steep gradient and is generally not subject to flooding. The stormwater runoff can easily flow to the downstream by natural over-land flow or through the man-made drainage conduits. Meanwhile, drainage systems in the downstream urban areas are flatter and are susceptible to tidal influence. The extreme sea level criterion will then become a controlling factor and must be catered for in the design of downstream drainage systems.

The upper catchments in Hong Kong are usually not developed. Urbanisation of them will increase the peak flow of surface runoff to the downstream. When the undeveloped area is paved for buildings and roads, there will be no absorption of rain into the ground, nor there be any interception of rain by trees or vegetation. More surface runoff will be generated and the flood flow can reach the downstream faster through the man-made conduits. As a result, there will be an increase in the total volume of runoff and an increase in the peak flow rate to the downstream drains.

The catchment sizes in Hong Kong are small. Together with the steep topography in the upper part of the catchment, the stormwater runoff can reach the downstream in a relatively short time. We call the time for the peak flood to reach the downstream outlet as the Catchment Response Time. In general, the response time for most urban catchments is around 1 - 2 hours, meanwhile, the response time for the larger rural catchments like Kam Tin is around 3 - 4 hours.

Since the catchment response time in Hong Kong is short, there is not much emergency arrangement we can make in reducing flood damage when the rain starts to fall. We should therefore design and maintain the drainage system to meet any rainstorms whenever they come.

Drainage Systems in Hong Kong

Hong Kong is a hilly area. Except for the Yuen Long and the North districts, most catchments have appreciable natural drainage gradients. The drainage paths from the upstream to the sea are also relatively short. Under this topography, drainage by conveyance is generally more economic as compared with flood storage or infiltration approaches. Construction of drainage pipeline networks should first be considered among all flood improvement measures.

Flood protection standard of drainage system is represented by its capacity in handling floods of defined severity. The severity of a flood is in turn measured by its Return

Period, i.e. the average or expected period between recurrence of such a flood. So, extreme and infrequent floods will have large return periods, and vice versa. The design standard of DSD is listed in the Stormwater Drainage Manual (1994) which requires the flood protection level for trunk drains in urban area to be 200 years return period. In other words, the average or expected period between flooding of the system is 200 years. Meanwhile for small branch drains serving localised areas, the protection level is set as 50 years return period.

The above standard is introduced in 1994 and not all the drainage systems in Hong Kong can meet them. DSD is carrying out a series of 7 Drainage Master Plan (DMP) Studies to evaluate the existing drainage condition of the stormwater systems and recommend improvement measures. The coverage of each Drainage Master Plan Study is shown in Figure 2.

The first study of the programme has started in January 96 and the last one is expected to start in September 98. The first study for the Yuen Long areas is about complete and the recommended measures will proceed to the detailed design stage and construction is expected to commence in March 02.

Inlets of the Stormwater Drains

Satisfactory performance of the complete drainage system requires the proper functioning of each component. The first drainage component in the conveyance of stormwater is the inlets where the surface runoff is collected into the underground pipeline. If this inlet is blocked by debris or silt, it will affect the overall performance of the system.

There are two basic types of drainage inlets, namely, catchpits and road gullies. Catchpits are usually constructed to receive stormwater from stream courses or from slopes. Catchpits can take different shapes and forms to suit the individual site situations. There are no typical design and they can be combined with rock traps or sand traps to improve the quality of collected stormwater and to prevent blockage of the pipelines. See Figures 3 & 4. DSD has recently prepared some General Guidelines for Design of Catchpits with a view to better facilitate the maintenance operations.

Road gullies are constructed to capture stormwater from the road surface. There are generally three types of gully inlets, namely,

1. kerb or side entry opening (i.e. the kerb overflow weir)
2. grate inlet
3. combination of kerb opening and grate inlet

A gully inlet also includes sump pit, air trap and connection pipe. A typical combined gully inlet is shown in Figure 5. The grating provides a running surface for traffic yet can prevent debris from entering the drainage pipeline. The standard gully grating used in Hong Kong is a double triangular grating of dimension 432 mm x 517 mm and is adopted from the British Standard 497 : 1976.

The kerb overflow weir can provide an additional drainage path for the surface runoff. The sump pit provides a deposition point for silt and heavy debris carried in the stormwater. The air trap can seal up the foul air in the drainage pipeline and can also screen off the floating debris in the surface runoff. The connection pipe connects the gully to the underground drainage pipeline for discharge of the captured stormwater.

Design of Road Gullies

Design of road gullies in HK is detailed in "Road Note 6 - Road Pavement Drainage" (1994). This Road Note is based on the research reports from UK with modification to suit the local condition. In particular the rainfall in HK is much heavier than in UK and the design spacing of the gullies has been adjusted accordingly.

To find out the entry capacity of gullies, we must find out whether the gully pit is a Sag Gully or an On-grade Gully. A sag gully is one at a low point where the water will pond up above the gully and the longitudinal flow of water is not significant. An on-grade gully is one on a sloping road, from which any flows bypassing the inlet can flow to the one downstream.

A sag gully can operate under weir control or orifice control and the entry capacity can be estimated from hydraulic calculations. Meanwhile for on-grade gully, the hydraulic behaviour is much more complicated and cannot be predicted accurately with calculations. The entry capacity of a gully grating must be determined by carrying out tests, either in the field by using water from hydrants or water tanker, or on scaled models in a laboratory. The standard gully that we use in Hong Kong has been tested in UK in 1984 and the results are published in Contractor Report 2 by the Transport and Road Research Laboratory.

Kerb overflow weirs are installed to provide an additional drainage path in roads with moderate or steep gradients where the flow velocity is high and the efficiency of the gully is low. Another application of the kerb overflow weir is at the sag points or the flat roads where the grating can easily be blocked by debris. The weir will then become a reserve inlet in case the gully is obstructed. Therefore, kerb overflow weirs are provided for roads with gradients larger than 5% or smaller than 0.5%.

To prevent debris from being washed into the gully pits, screening bars are installed in the overflow weirs. Vertical bars are installed in gullies on flat roads or sag points. Meanwhile, horizontal bars are installed in gullies on moderate or steep roads. See Figure 6.

According to the Road Note 6, under rainfall with probability of 10 times a year, a design flooded width of 0.75 m is generally permitted for flat or near flat roads. For roads with steeper gradients, a smaller flooded width is desirable. If the rainfall is heavier, i.e. more rare in terms of probability, a larger flood width will be permitted. Some information is extracted below :

Storm Occurrence	Rainfall Intensity	Max. Flooded Width for Normal Roads
10 times/year	80 mm/h	0.75 m
5 times/year	100 mm/h	0.83 m
once per year	140 mm/h	0.95 m
once per 50 years	240 mm/h	1.20 m
once per 200 years	280 mm/h	1.28 m

The flooded width has been designed to cause a minimum inconvenience to the public. For example, the flooded width for the more frequent rainfall of 10 times per year is 0.75 m and splashing over the pedestrians on the footpath is quite minimal. Even under more extreme rainstorms of once per 50 years, the flood depth should still be confined below the kerb height to avoid flooding to the adjoining land or properties.

Maintenance of Road Drainage Systems

The maintenance of road drainage systems are defined under the Lands and Works Branch Technical Circular No. 10/88. Relevant part of the Circular is extracted below :

Category of Stormwater Drainage System of Natural Stream Course	Routine Inspection	Clearance	Minor Repair Work	Remarks
Exclusive Road Drainage Installations :				
(a) Gully pits	HyD	RSD/USD HyD	HyD	See Note (1)
(b) Gully connections, down pipes from elevated highway structures	HyD	DSD HyD	HyD	See Notes (1) & (2)
(c) Roadside slope drainage, roadside open channels, catchpit open connections	HyD	HyD	HyD	See Note (3)
(d) Roadside catchpit piped connections, cross road drains connecting open channels	HyD	DSD HyD	HyD	See Notes (1) & (2)

Notes : (1) Clearance of pump sumps, gully pits and connections within the boundary of high speed roads shall be carried out by HyD.

(2) Overall responsibility for exclusive road drainage lies with HyD. DSD shall provide service for clearance on request.

(3) HyD is only responsible for the maintenance of surface channels and catchpits on roadside slopes where the slope itself is maintained by HyD.

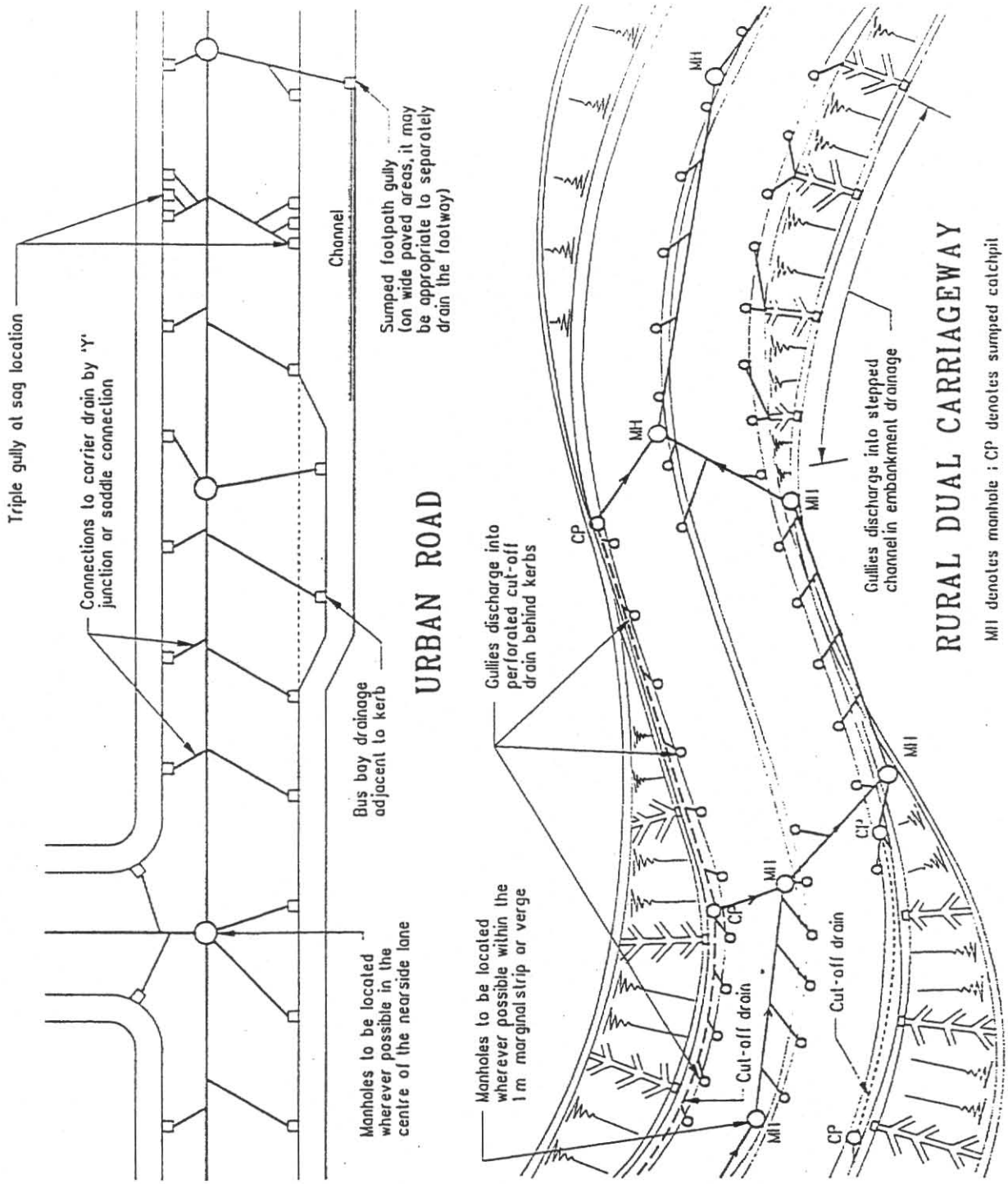
From the above, you may notice that the maintenance of common road drainage systems are carried out by a number of offices, each office being responsible for part of the whole system. To achieve success in the upkeep the serviceability of the road drainage system, it would demand for high degree of understanding and cooperation of the individual offices.

Discussion

The current practice and guidelines on design of stormwater drainage systems and gully intakes are covered under the Stormwater Drainage Manual (DSD, 1994) and the Road Note 6 (HyD, 1994). Despite the fact that some specific technical particulars might need improvement or further deliberation, these documents nevertheless serve a good standard in protecting Hong Kong from flooding.

Gully inlet is an integral part of the stormwater drainage system. It is the entry point of road surface runoff and its performance is in line with the overall services provided by the system. Every component in the system is equally important and must receive the same concern. It is a matter of fact that not all the existing stormwater drainage systems and inlets can meet the current design standard as our standards are very contemporary. There is a need to upgrade the systems. This upgrading should apply to every component including the inlets and pipelines such that an overall improvement of performance is achieved.

Last, but most important of all, is the maintenance aspects of the road drainage system. Only under good maintenance that our road drainage systems can perform to the design standard and maintain our community free from flooding.



Note :

These layouts are not definitive, they are intended to illustrate the type of solutions that can be adopted to achieve an economic drainage system, gullies should be untrapped, unless carrier drain is combined drain.

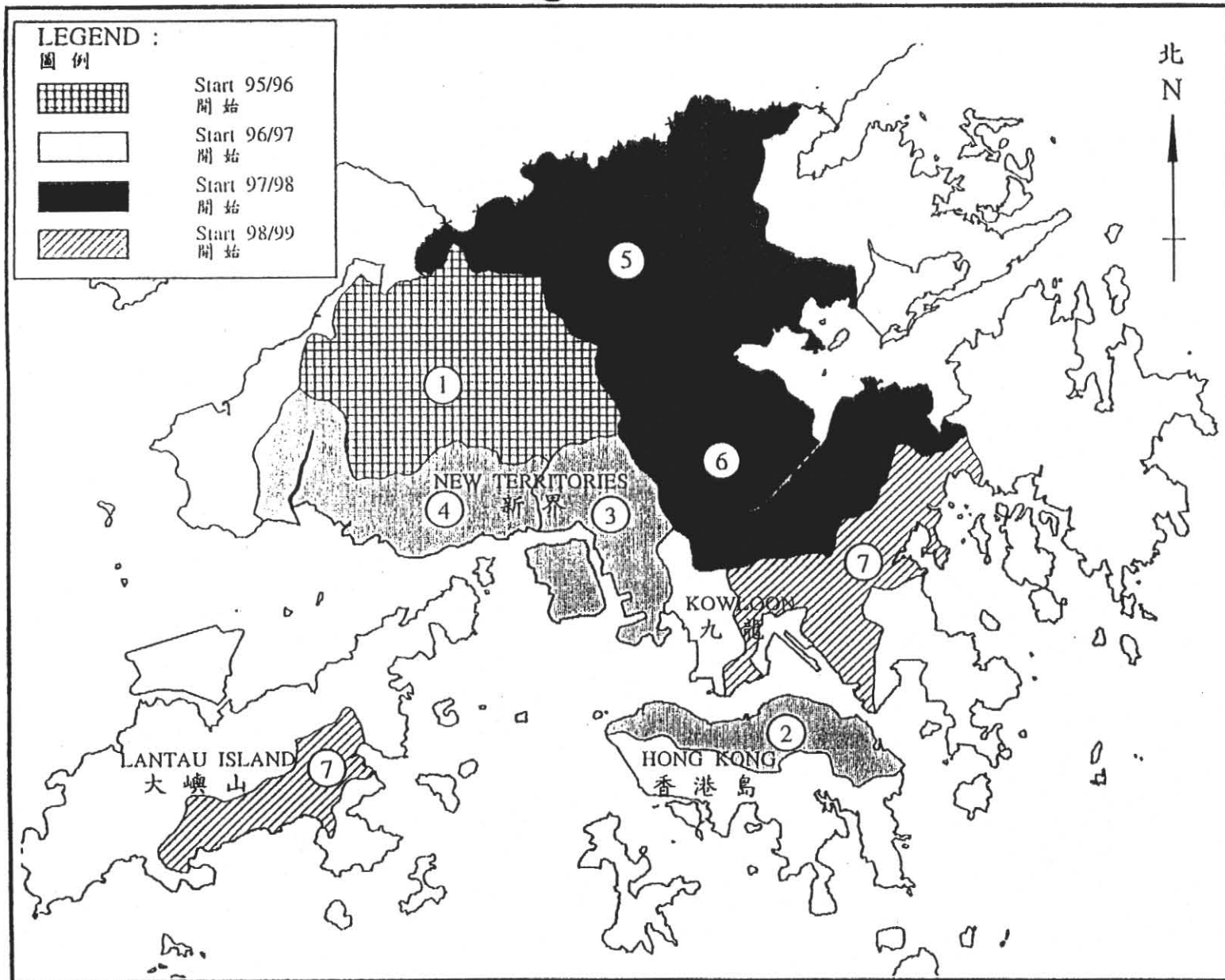
FIG 1

REF.	REVISION	SIGNATURE	DATE
	Former drg. no. H3001/1 with general revision		June 94

ROAD PAVEMENT DRAINAGE - TYPICAL INSTALLATION

HIGHWAYS DEPARTMENT

REFERENCE	DRAWING No. CAD
SCALE Diagrammatic	H 3101



MASTER PLAN AREAS 整體計劃地區	START DATE 開始	COMP. DATE 完結
1. Yuen Long, Kam Tin, Ngau Tam Mei & Tin Shui Wai 元朗，錦田，牛潭尾及天水圍	1/96	1/98
2. Northern Hong Kong Island 香港島北部	5/96	5/98
3. Tsuen Wan, Kwai Chung & Tsing Yi 荃灣，葵涌及青衣	9/96	9/98
4. Tuen Mun, Sham Tseng 屯門及深井	3/97	9/98
5. Northern New Territories 新界北部	10/97	10/99
6. Sha Tin & Tai Po 沙田及大埔	1/98	10/99
7. Sai Kung, East Kowloon & Southern Lantau 西貢，九龍東部及南大嶼山	7/98	12/99

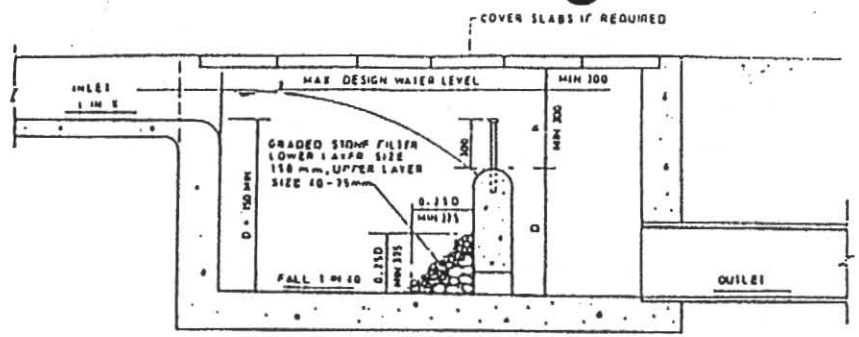
drawing title :
圖則標題

FIG. 2 DRAINAGE MASTER PLAN AREAS
雨水排放整體計劃區

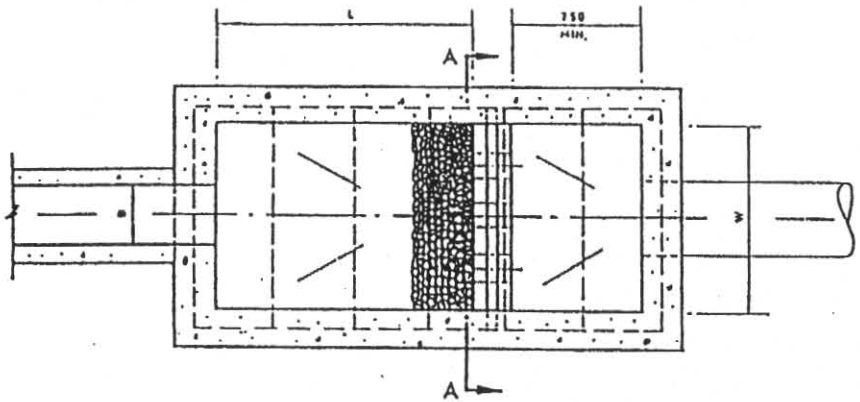
drawing no.
圖號 DLD 1051L

scale
比例 1 : 300 000

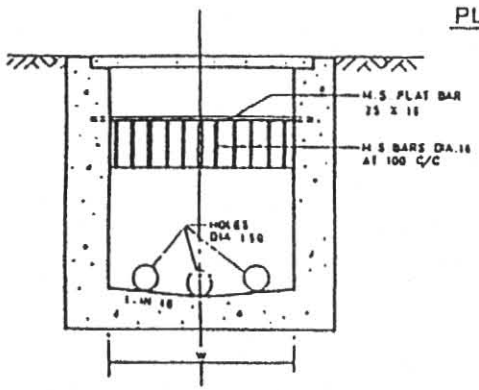
DRAINAGE SERVICES DEPARTMENT
HONG KONG
香港渠務署



LONGITUDINAL SECTION



PLAN



SECTION A – A

NOTES :-

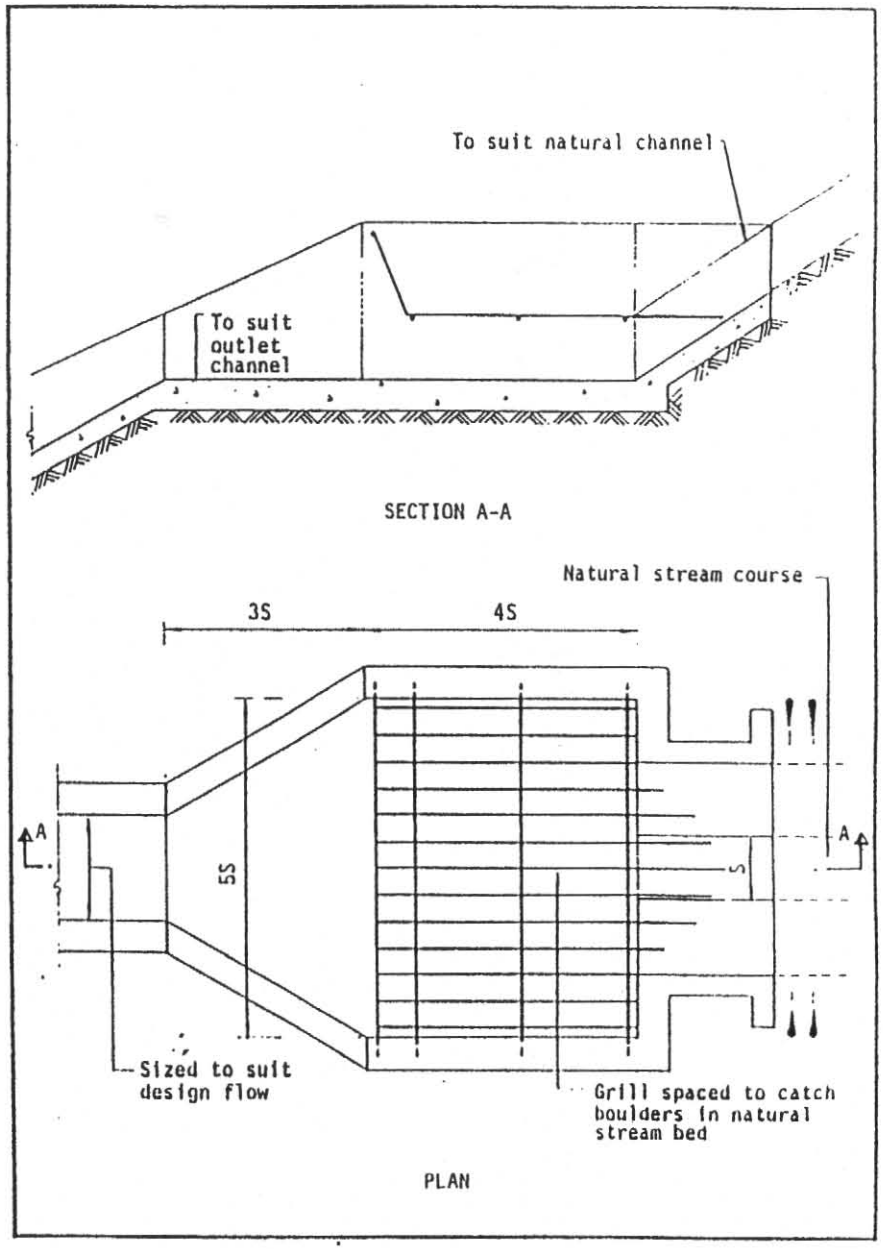
1. ALL DIMENSIONS IN MILLIMETRES.
2. NORMALLY FOR DRAINS OF 300mm DIA. AND BELOW. FOR BIGGER DRAINS AND STEEP TERRAIN, SAND TRAP SHOULD BE SPECIALLY DESIGNED.
3. SIZE
   DEPTH : D ≤ 750
   WIDTH : W ≥ 1.5D
   LENGTH : L = 4.60 $Q^{0.4}$ $A^{0.6}$ $S^{-0.3}$ ≥ 4.0
4. GRADED STONE FILTER SHALL BE CRUSHER RUN GRANITE AGGREGATE.
5. CAPACITY D.W.L TO BE ACCORDING TO SIZE AND NATURE OF CATCHMENT, PROVIDING DETENTION TIME NOT LESS THAN 5 MINUTES FOR MAX DESIGN FLOW OF INLET.

SAND TRAP

DRAINAGE SERVICES DEPARTMENT

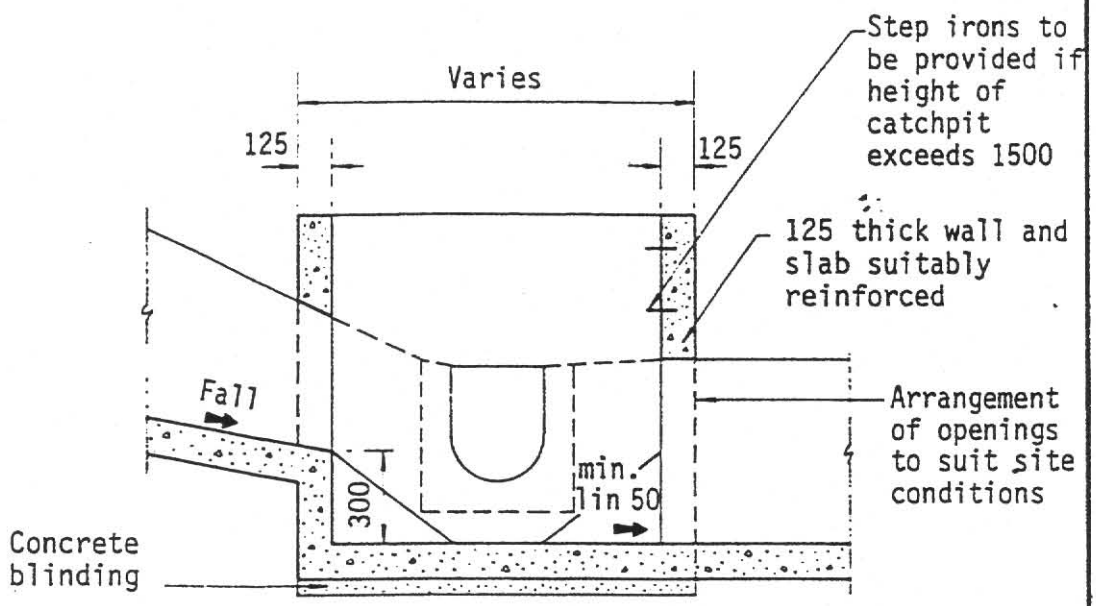
DRAWING No

DS 1025

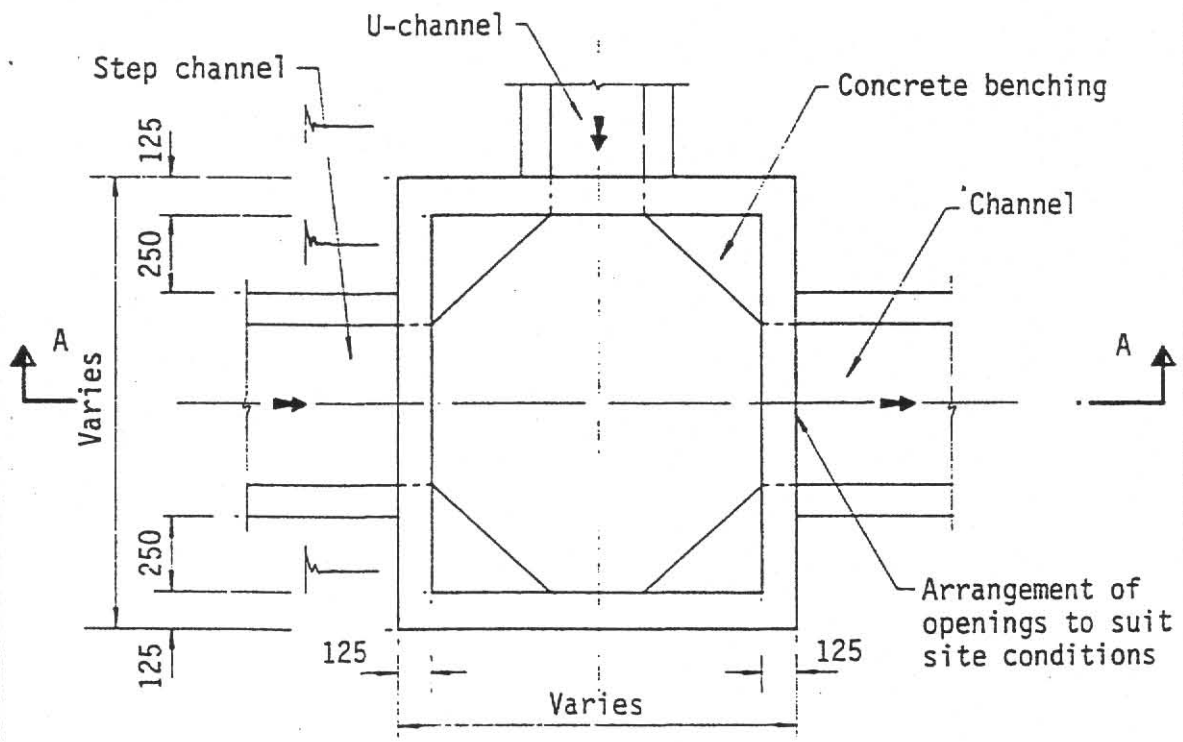


Typical Rock Trap Detail

FIG 3 SAND TRAP & ROCK TRAP



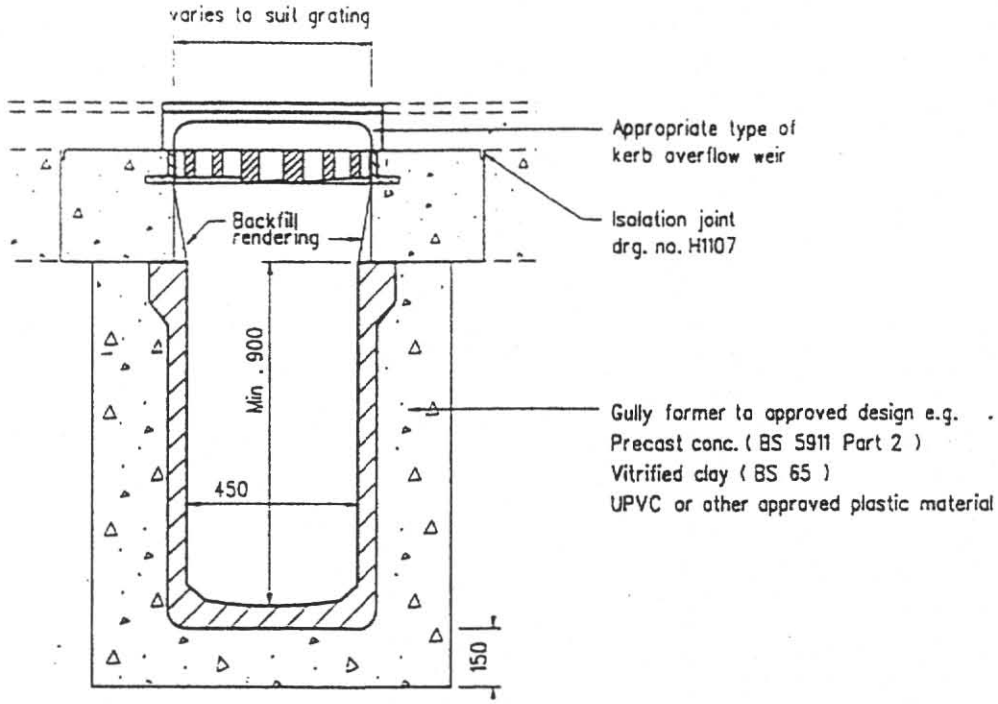
SECTION A-A



PLAN

Note : All dimensions in millimetres

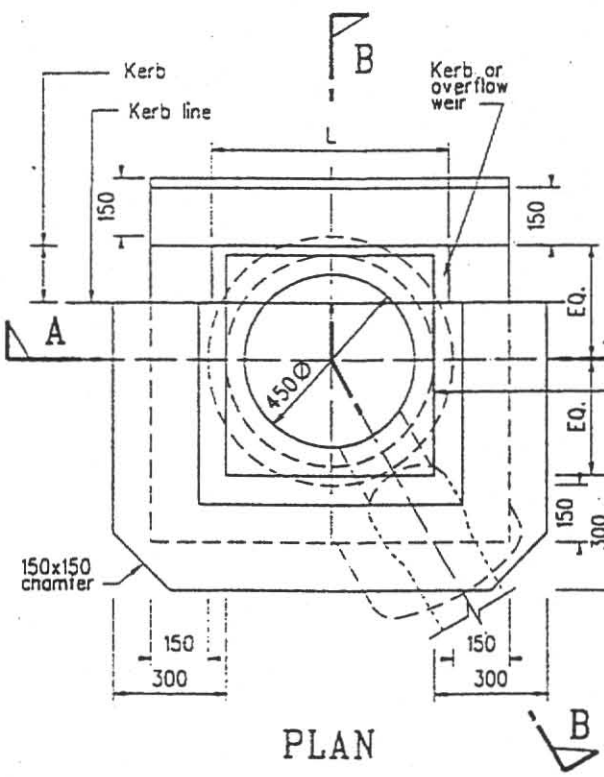
FIG. 4 Typical Details of Catchpits



SECTION A-A

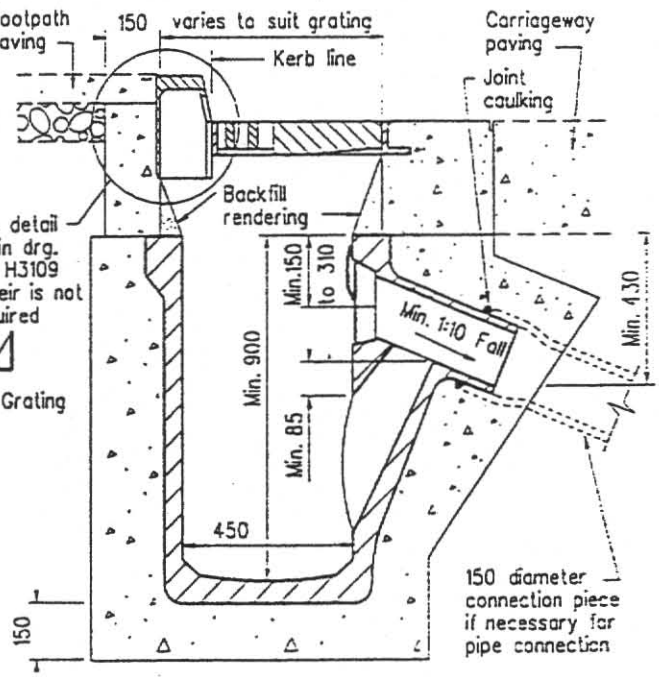
Note :

1. Trapped gullies are only necessary if stormwater carrier drain is likely to be contaminated by sewage i.e. when carrier drain is a combined drain



PLAN

(Only outlines of weir and grating are shown for clarity)



SECTION B-B

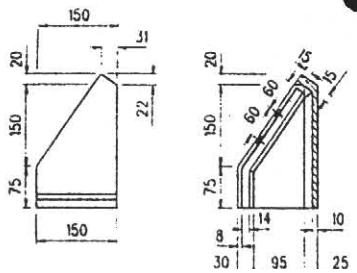
FIG. 5

	Former drg. no H3006 with general revision	June 94
REF.	REVISION	SIGNATURE DATE

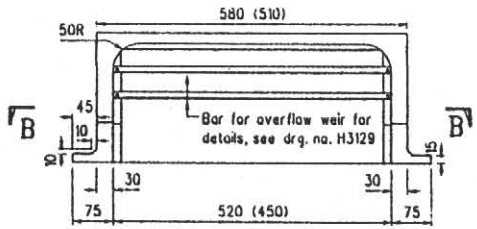
TRAPPED GULLY WITH GULLY FORMER

HIGHWAYS DEPARTMENT

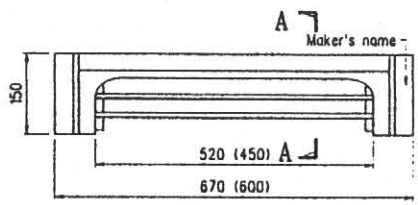
REFERENCE	DRAWING No. CAD
SCALE 1:20	H 3110



SIDE VIEW SECTION A-A



FRONT ELEVATION



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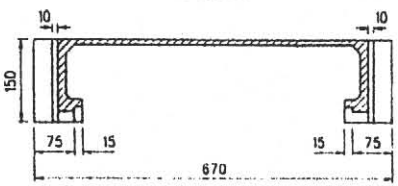

SECTION B-B

Notes :

1. Dimensions are in millimetres.
2. Dimensions in the bracket apply to type PR-325H only.
3. All corners are to be rounded to approximately 2 mm radius.
4. Other than bolts and nuts, material is to be cast iron grade 150 of B.S.1452.

REF.	REVISION	SIGNATURE	DATE
	Former drg. no. H3015/5 with general revising		June 94

KERB OVERFLOW WEIRS TYPE PR-450H AND TYPE PR-325H

HIGHWAYS DEPARTMENT

REFERENCE	DRAWING No.	CAD
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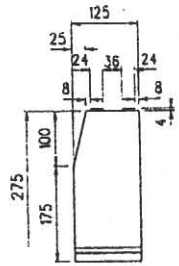
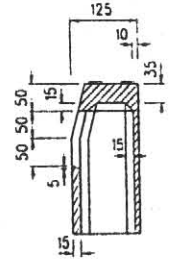
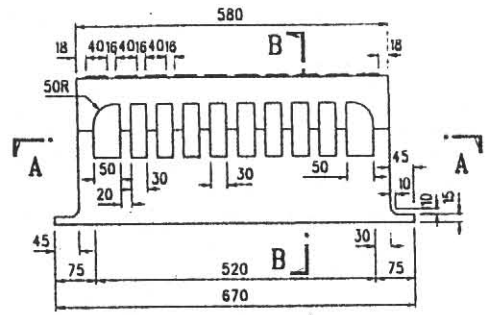
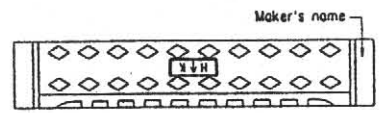




SIDE VIEW SECTION B-B



FRONT ELEVATION



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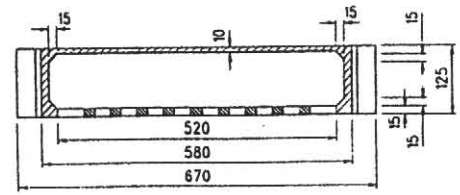

SECTION A-A

Notes :

1. Dimensions are in millimetres.
2. All corners are to be rounded to approximately 2 mm radius.
3. Material is to be cast iron grade 150 of B.S.1452.

FIG. 6

REF.	REVISION	SIGNATURE	DATE
	New issue		June 94

KERB OVERFLOW WEIRS TYPE K1-450V

HIGHWAYS DEPARTMENT

REFERENCE	DRAWING No.	CAD
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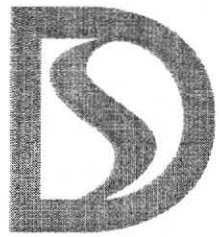

Seminar on Design & Maintenance of Road Drainage Systems to Prevent Flooding

Drainage Services Department
21 April 1998