

Flood Storage and Some Case Studies

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Presented in this paper are the Flood Storage Concept and its applications, ranging from single lots or small community to the regional levels. Some local cases are quoted for illustration. Since Hong Kong has very few large scale flood storage facilities, some Japanese regional schemes applicable to highly developed urban catchments are also briefly described.

Keywords: Flood Storage, Stormwater Tunnel, Tunnel Trunk Drainage, On-Site Stormwater Detention, Polder Scheme

INTRODUCTION

Flood storage is a common stormwater management approach in controlling the quantity or quality of stormwater runoff. It is particularly useful in areas where the downstream drainage capacity is restricted. Flood storage is finding its application in Hong Kong because the development is moving to the upstream and that there is a need to improve the standard of downstream drainage systems.

CONCEPT OF FLOOD STORAGE

Flood storage is one of the flow regulation techniques in reducing flood risk to the downstream areas of a catchment. It works on the principle of storing a portion of the surface runoff coming from the upstream and allowing a limited flow to the downstream of the catchment. In this way, the flow rate is restricted to stay within the capacity of the downstream drainage system.

Figure 1 illustrates the runoff from an upstream site. It is larger than the downstream drainage capacity, but with flood storage facility, the flow rate can be reduced to eliminate flooding to the downstream. The excessive water flow is diverted into storage ponds and will be re-discharged into the drainage network when the water level subsides. The actual shape of the outflow depends on the flow regulation device, e.g. orifice control, gate valve, or pumping. In general, regulated type storage facility provides the most efficient flood mitigation because it makes possible to start storing flood flow only when the highest permissible flow is reached [13].

Flood storage approach is often used when the capacity of the downstream drainage network is incapable to meet the

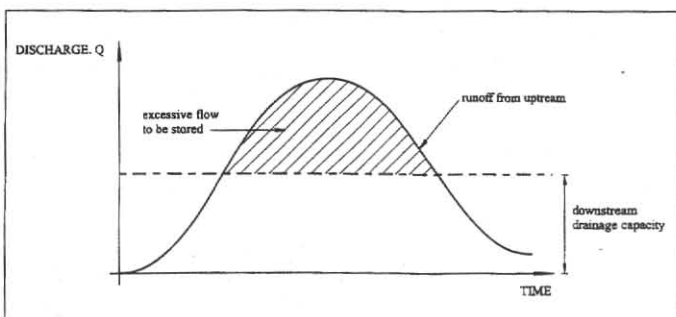


Figure 1 – Flood Storage Concept

increased peak flow rate arising from development upstream. Development usually propagates from the downstream. When the upstream areas are being developed, the downstream areas have already been fully urbanised. Upgrading the drainage network at the downstream areas will cause severe disturbance and is technically difficult due to lack of working space. The storage approach with construction works taken place at the upstream can be a suitable solution.

APPLICATION OF FLOOD STORAGE APPROACH

From the design point of view, storage ponds can be classified into On-line and Off-line storages. They are schematically shown in Figure 2. Increasing the drainage pipe size is a simple application of On-line storage concept and is viable for some overseas countries, e.g. the United Kingdom. However, the rainfall in Hong Kong is much heavier and the spare volume of the drainage pipeline will be rapidly filled up under extreme rain-storm events. Specific facilities with considerable storage volume will be required if the flood storage approach is adopted.

The flood storage concept is not complicated, yet it can be

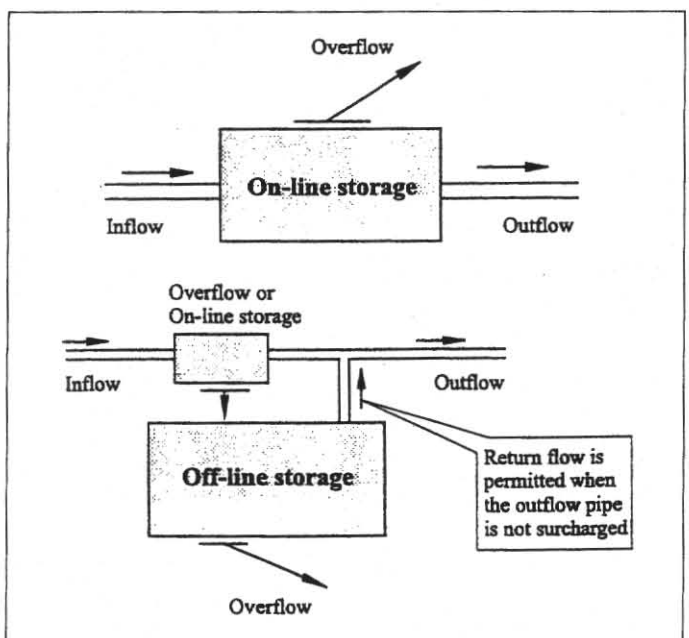


Figure 2 – On-line and Off-line Storage

modified into numerous forms to suit different situations. It is one of the "Best Management Practices" adopted in the United States on flood protection [12]. For illustration of its application, some cases are quoted below. They are grouped according to the size of the community being protected by the schemes, namely, single lots or small communities, and regional scale.

FLOOD STORAGE FOR SINGLE LOTS OR SMALL COMMUNITIES

In Hong Kong, the Drainage Services Department has issued a Technical Circular [5] and an Advice Note [6] to provide guidelines in assessing the drainage impact of developments. These documents apply to private projects requiring permission from the Town Planning Board under the Town Planning Ordinance, or those requiring approval of the Lands Department for lease modification. For development likely to cause drainage impact, the developer must complete a Project Profile, or a more detailed Drainage Impact Assessment Study if necessary. The primary objective of the process is to demonstrate that with implementation of the necessary mitigation measures, the project will not cause unacceptable increase in flood risk to areas upstream of, adjacent to, or downstream of the development.

Flood alleviation by On-site Stormwater Detention (OSD) can be an alternative in avoiding extensive drainage improvement along the downstream drainage network [9]. The OSD approach and OSD facilities applicable to Hong Kong conditions have been discussed in [10]. Flat roof, driveway, sump pit, planter and water pond can all be converted into effective OSD facilities.

OSD approach can be more economic if the OSD facilities are provided for a group of buildings instead of single households. However, grouping the houses together will induce other problems such as sharing of liability and responsibility, especially when the facilities are owned and operated by the house owners in common. The best arrangement is the OSD facility to be built during the development stage and its long term operation and maintenance responsibilities are covered under the Deed of Mutual Covenant. Some OSD facilities have been completed under similar arrangement by private developers in Hong Kong in the recent years.

1) RESIDENTIAL DEVELOPMENT IN SAN TIN, YUEN LONG

An example is the Tai Fu Tai Residential Development Phase II in San Tin, Yuen Long, with a site area of 0.84 ha. According to [3], the site is not subject to flooding under a 200-year return period rainstorm. It is outside the flood fringe of the river network and the development will not obstruct the passage of flood flow in the catchment.

The potential drainage impact of the development will be the increase in peak runoff rate and runoff volume due to paving up of the site. An underground storage tank with volume of 140 m³ is designed to attenuate the peak flow rate and to compensate for the increase in runoff volume [1].

2) RESIDENTIAL DEVELOPMENT AT HA YAU TIN TSUEN, YUEN LONG

Another example is the residential development at Ha Yau Tin Tsuen, Yuen Long, with a development area of 0.68 ha. According to [3], the main part of the site and the adjacent villages lie just below the predicted water level of a flood at 10-year return period.

As a mitigation measure for the development, runoff from the site will be stored up for rainstorms of return period above 10-year until the water level in the Yuen Long Eastern Nullah subsides. A storage volume of 630 m³ with pump capacity of 0.25 m³/s are provided [2]. The drainage conditions of the site will improve in around 2004 when the Yuen Long Bypass Floodway is completed and diverts away the runoff from the upper basin. The catchment associated with the Eastern Nullah will be reduced and the nullah capacity will then meet a flood of 200-year return period. In the coming five years, the probability of occurrence of an extreme rainstorm is relatively low. The mitigation measures can be considered as expedient before the completion of the By-pass Floodway.

POLDER SCHEMES FOR SMALL COMMUNITIES

A polder scheme is a special form of flood storage and is provided to protect villages within the low-lying flood plain areas like Yuen Long. A polder scheme has a storage pond and its layout is very similar to a flood storage scheme, as shown in Figure 3 [4]. A village protected by a polder scheme is surrounded by an embankment so that flood water outside the village cannot get into the polder area. Surface runoff within the polder is stored in a pond and later removed by pumping. During dry weather when the water level outside the polder is low, the runoff will be discharged to the outside by gravity.

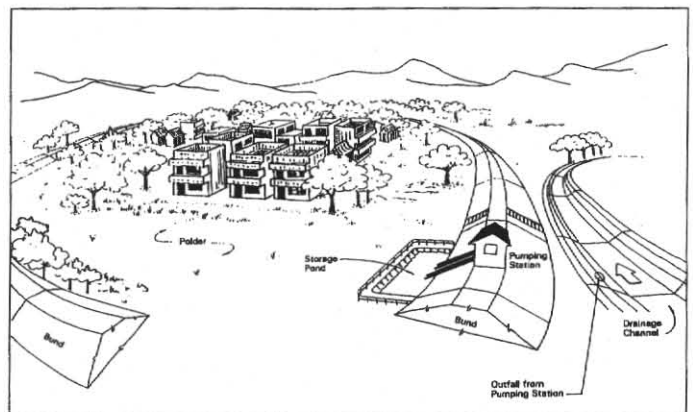


Figure 3 – Polder and Floodwater Pumping Scheme – Schematic View

There are about 15 polder schemes in operation now, and 12 more are planned to be implemented by the Government. The largest existing polder catchments are in Sheung Shui Tsuen and Yuen Long Kau Hui with areas of 26 ha and 21 ha respectively. Other polder catchments are generally less than 10 ha.

A polder scheme differs from a flood storage system in that the storage pond of the former is designed to temporarily hold up the water flow to suit the pump-out rate of the pumps. If the polder storage pond is large enough, it may be converted into a flood storage pond and helps alleviate the downstream drainage conditions. An example is the Sheung Shui Tsuen storage pond which has an area of 0.37 ha.

REGIONAL FLOOD STORAGE

Further saving in cost can be achieved if the flood improvement measures are applied to a regional scale. By providing a regional scheme, local measures are not required in part of the catchment and the resulted savings may outweigh the cost of the scheme itself. Furthermore, with the large capital provision, more options of improvement measures can be available for choice, e.g. by conveyance, by catchment re-distribution, drainage diversion, or

storage. An improved overall cost-effectiveness on flood prevention can be pursued.

In designing regional flood storage facilities, the major consideration will be on the large volume of flow to be catered for. Usually, the facilities can be combined with other water engineering works such as water supplies, irrigation, power generation and navigation. The Three Gorges Dam system is a good example comprising all the above.

In Hong Kong, the catchment sizes are small. They are all less than 115 km² and dam sites are not always available to the larger catchments, e.g. Yuen Long or Indus. The reservoirs in Hong Kong are not intended for flood storage purposes. In fact, the two largest reservoirs, i.e. Plover Cove and High Island are both reclaimed from sea. Their formation levels are low and are not suitable for flood storage.

A regional flood storage facility in Hong Kong is the infield of the racecourse at Happy Valley. The overall concept is to create a flood detention storage within the racecourse to replace the existing area prone to flooding [11]. The infield is designed as an Off-line storage tank and the overland flood will flow into the sports ground and be stored there. For a rainstorm of 200-year return period, the storage volume provided is estimated to be 132,000 m³.

REGIONAL FLOOD STORAGE APPLICATIONS IN JAPAN

Large scale flood storage is commonly used in Japan for flood alleviation purposes [7]. The authors visited several schemes in Yokohama, Tokyo and Osaka in August 97. It is noted that their approach is very suitable for highly urbanised areas like Hong Kong.

Japan has the same problem as Hong Kong in that the downstream areas have been fully developed and upgrading of the drainage systems is almost impossible. Flood storage approach is often adopted and suitable open space like parks and sports fields are converted into storage ponds. The followings are some of the flood storage facilities visited by the authors.

A) BUILDING BASEMENT AS STORAGE

The basement level of a domestic building in Shinjuku is designed as an open flood storage basin for improvement of the Myoshoji River in Tokyo. The schematic layout is shown in Figure 4. The basin can offer a storage volume of 30,000 m³. The Myoshoji River improvement scheme includes

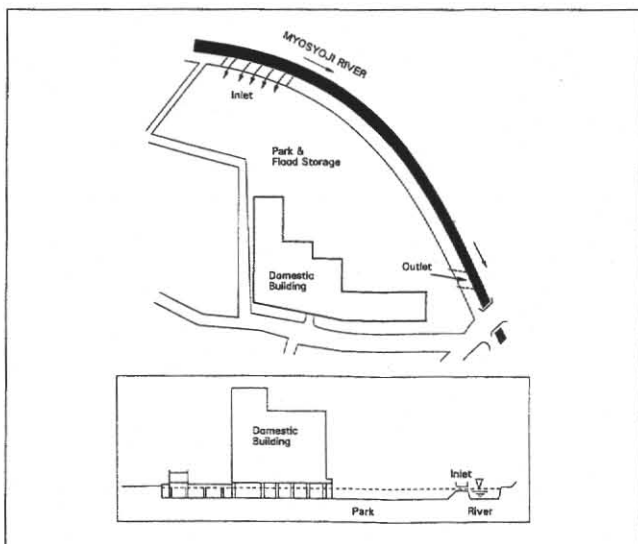


Figure 4 – Myoshoji River Flood Storage, Tokyo

also an underground storage tank and three other open storage as parks. The total storage volume provided is 357,000 m³.

During the dry weather, the basement is a sitting-out area for use of the public. When the water level in the Myoshoji River rises, the excessive runoff will spill over from the river channel into the basement. Such flooding may occur one to two times a year and the duration of flood is a few hours.

B) LARGE UNDERGROUND STORAGE TANK

The Lower Bikuni Flood Regulation Tank is located in Tokyo with a storage volume of 212,000 m³. The plan area is 1.57 ha and the storage depth is 23.5 m. The tank is completely underground, thus freeing the ground surface for the construction of a park. The tank is divided into chambers and only some of them will be wetted during small floods. This will reduce the cleansing and maintenance of the tank after flooding.

Another smaller one visited is the flood regulation tank for improvement of the Myoshoji River in Tokyo. It is partly buried underground with the roof as a sports field. It has a storage volume of 70,000 m³ and will operate when its open storage counterpart as discussed in A) above is full.

C) TUNNEL TRUNK DRAINAGE

With the mastering of the special expertise, engineers in Japan have developed a technique of using large diameter tunnels for flood improvement in the major cities of Japan. The Naniwa Grand Floodway in Osaka is an example and is shown in Figure 5. The Wada-Yayoi Trunk in Tokyo is another example and is discussed in details in [8]. Storm runoff is conveyed through the drainage tunnels to pumping stations,

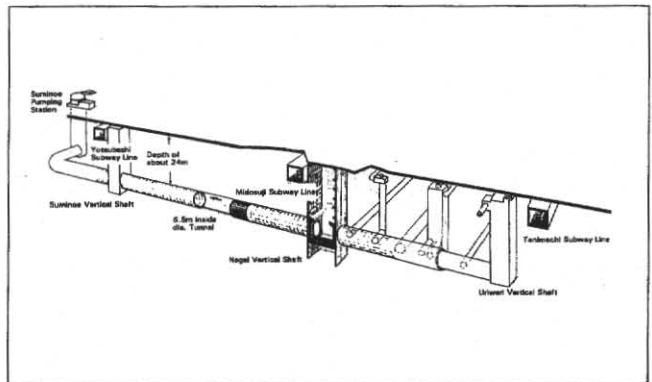


Figure 5 – Typical Drainage Tunnel (Naniwa Grand Floodway, Osaka)

where it will be pumped to the receiving waters. A large volume of flood storage can be provided by these tunnels due to their considerable sizes and lengths. Some of the drainage tunnels visited with brief details are listed below:

Name of Tunnel	City	Diameter (m)	Length (km)	Approx. Depth (m)
Wada-Yayoi Trunk	Tokyo	8.0	2.4	50
Shinhanesuehiro Trunk Sewer	Yokohama	9.5	4.4	53
Naniwa Grand Floodway	Osaka	6.5	8.5	40
Yodo Grand Floodway	Osaka	2.0 - 7.5	22.5	49
Tennoji-Benten Trunk Sewer	Osaka	3.0 - 6.0	7.5	25

DISCUSSION

Hong Kong is a hilly area. Except 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 cost-effective. Construction of drainage pipeline networks should first be considered in the choice of flood improvement measures.

The approach of drainage by conveyance has inherent construction difficulties in highly urbanised area. Any drainage upgrading works will unavoidably disrupt the traffic, and cause great inconvenience and nuisance to the public. Finding space to house the drainage pipeline amongst the congested underground utilities is also a problem.

Storage approach can provide an alternative to the upgrading of drainage pipes in the downstream areas. The provision of storage facilities can be at local or at regional level. OSD approach already finds its application in isolated developments in the rural area where public drains are missing or running out of capacity to meet new developments. Appropriate design guidelines on OSD which suit the local conditions should be established to facilitate the practising engineers.

A regional scheme can relieve the necessity for individual OSD, but it usually consumes large land areas. Since land is very valuable in the urban area, land surface of the scheme should share other uses, such as park or open space. Safety must be thoroughly considered if the open space is subject to flooding as the flood level can rise rapidly under heavy rains.

Tunnel approach is a promising form of underground storage. It requires minimal ground area and causes less disturbance to the public during construction. If the tunnel is deep enough, it can overcome restraints induced by the foundations of the buildings. However, additional pumping effort will be required to raise the stored water to the ground level for discharge.

Regional schemes can be implemented cost-effectively and operated efficiently. However, they are usually large and difficult to implement. A careful balance between the local and regional systems should be established for each catchment so as to achieve the most cost-effective combination.

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DISCLAIMER

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