Flood Pumping Station

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Flood is a natural event. It occurs when a piece of dry land is submerged under water. It is extremely dangerous, destructive and has the potential to wipe away an entire city or a coastline. Common causes of flooding are high annual rainfalls, river overflow, backwater effect due to tidal intrusion from the sea, tsunami, strong winds in coastal area, inadequate capacity of catchment size, waterway and drainage systems.

There are several types of floods such as flash flood, rapid on set flood, slow on set flood and coastal flood. Flash flood occurs within a very short time. Rapid on set flood is similar to flash flood but it takes a longer time to develop and can last for few days. Slow on set flood is caused by water bodies overflowing their banks. It can spread over many kilometres and move to low lying areas. Coastal flood refers to low-lying land flooded by seawater.

Photo 1: Inland Flooding

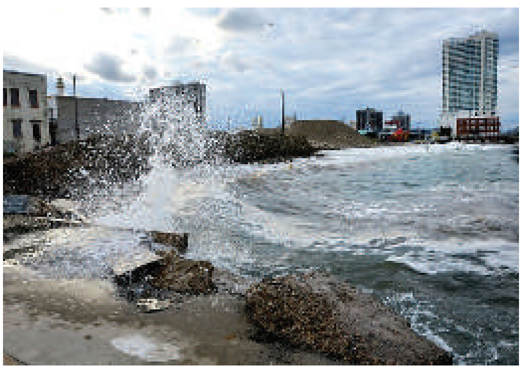

Photo 2: Coastal Flooding

There is no ultimate solution to preventing flood. Over the years, engineers and government technical agencies have been using various preventive flood risk controlling methods including flood pumping station, dam, water gate, diversion canal, self-closing barrier, river defences (such as levee, bunds, reservoirs and weirs) and lastly, coastal defences (such as sea wall, breakwater, beach nourishment and barrier island).

Photo 3: Dam

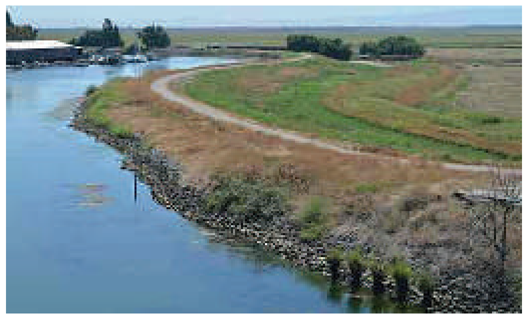

Photo 4: Levee/Bund

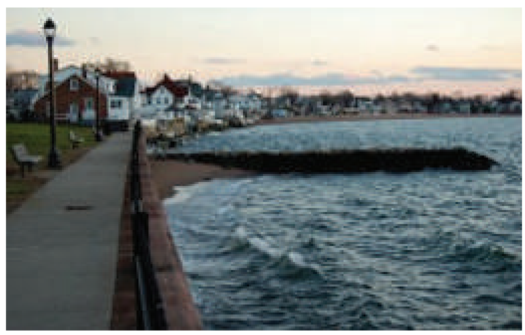

Photo 5: Seawall/Breakwater

Photo 6: Control Gate

PUMPING STATION

Urban drainage and flood water system design in low lying and tidal areas involves a number of special considerations. Because of the difficulty in designing gravity systems in low lying areas, it may be necessary to use a pumping system which requires minimum cost and land acquisition compared to the common civil and structural type of flood defence system. It also helps to maximise the flood area protection coverage and minimise the interior drainage interference.

Photo 7: A Typical Pumping Station

DESIGN REQUIREMENTS OF FLOOD PUMPING STATION

1. SELECTION OF PUMP

Pumps are divided into two categories: Dynamic and displacement. Dynamic pumps, especially the centrifugal type, are commonly used in a flood pumping station. The recommended centrifugal type of pump shall be axial and mixed-flow due to high discharge of flood water. An axial pump operates at low pressure (head is less than 9m) with a high flow rate. It can pump water up to 9,000 litres per second for each operation.

The concept of mixed-flow pump is in between radial and axial flow pumps. Mixed-flow pump experiences radial acceleration, lifts the water and exits the impeller in the range of 0-90 degrees from the axial direction. Hence, a mixed-flow pump is able to operate at higher pressure compared to an axial pump (head is more than 9m) and can deliver a higher discharge of water compared to a typical radial flow pumps.

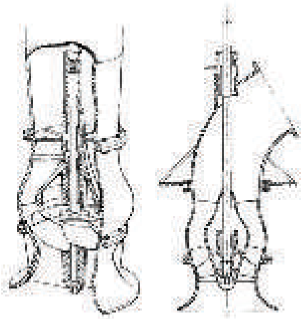

Photo 8: Mixed-Flow Pump

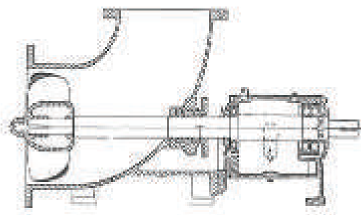

Photo 9: Axial Flow Pump

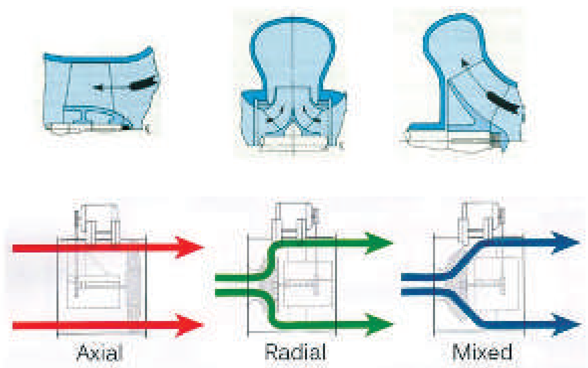

Photo 10: Comparison of Flow Direction Between Axial, Radial and Mixed-Flow Pump

The following criteria need to be established to complete the pump selection. These are as stated below:

a) Total pumping requirement (Flowrate, Q & Total dynamic head, H)
b) NPSH requirement
c) Minimum water level
d) Water-surface elevation
e) Proposed station location
f) Point of discharge
g) Proposed method of operation

In a year, the operating period in a flood pumping station is relatively short, so capital cost is more crucial than operating cost and standby pumps are usually not required unless preferred by the client.

2. GENERAL CONSIDERATIONS FOR PUMPING STATION

A pumping station consists of an inlet area, fore bay and pump bay. The inlet area conveys flood water to the pumping station from the river. Fore bay is designed to guide the flood water to the bay and it prevents non-uniform and unsteady flow. The final zone is the pump bay and flood pumps are placed here.

Flood pattern, inlet, cross flow velocity and boundary geometry are very important when determining the design of the pumping station. According to ANSI/Hydraulic Institute 9.8 – 1998, using basic good pit design precludes the need for model testing. The given velocity as per the relevant code of design shall be fulfilled to avoid sedimentation, build-up of obstruction and to prevent loss and vortices at the pump bay.

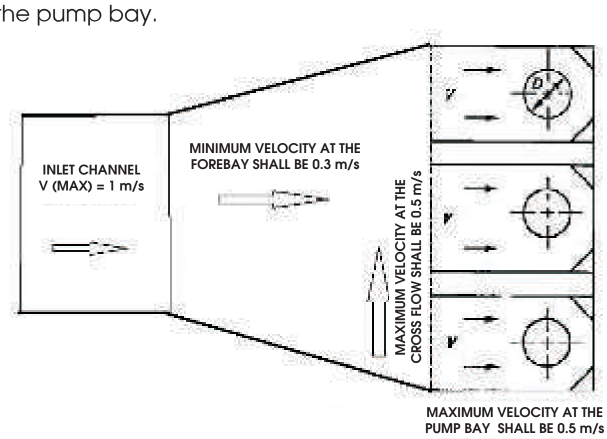

Photo 11: Preferred Flow Pattern

A flood pumping station can have two types of layout: Front and side inlet. The front inlet shall have the incoming water from the frontal area and the side inlet shall have the incoming water from the side way area, and in most cases, is conveyed by a channelled pipeline. The sump design is also crucial to the pump performance. A good sump design prevents excessive variation in velocity with time, entrained air/gas bubbles, excessive pre-swirl of flow entering the pump and finally provides uniform flow distribution at the pump impeller.

The sump design shall consider the submergence of the pump itself. The submergence of the pump shall be equal to or more than the required NPSH. To determine the submergence of the pump, minimum water level for the pump to operate shall be established. Minimum water level shall be the sum of pump submergence and clearance to the bottom of the sump.

Generally, a pumping station has two types of sump intake designs: Open sump intake and enclosed sump intake. The open sump intake design is sensitive to non-uniform flow. If more than 3 pumps are installed, the length of the dividing wall shall be at least 2/3 of the total width of the sump. In some cases, sump length should be increased to 6 times the pipe diameter or more if flow contraction occurs near the sump entrance. On the other hand, an enclosed sump intake design is the least sensitive to the disturbance of the approaching flow. It is the recommended and preferred choice for stations with multiple pumps and with various operating conditions. The enclosed sump intake design reduces disturbances and swirls in the approaching flow.

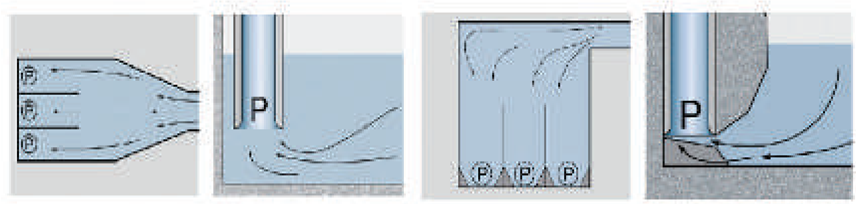

Photo 12: Open Sump Intake Vs Enclosed Intake Design

Flow correction devices also can be used to enhance the performance of the flood pumps. Examples are vertical corner fillet, side wall fillet, back wall corner fillet, floor splitter and vortex suppressor. Floor splitter and back wall corner fillets are used to remove small asymmetries of flow and to prevent the formation of wall vortices. Side wall corner fillet prevents submerged vortices. Vortex suppressor is controlled via a grid system using the principal of boundary layer and separation phenomena. As a result, the approaching flow to the pump units is vortex free, quiet and has a concentrated high velocity flow and steady performance.

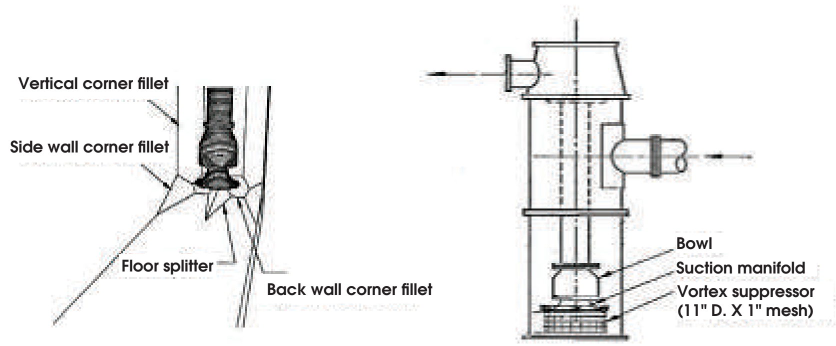

Photo 13: Example of Flow Correction Devices

3. OTHER MECHANICAL COMPONENTS

Besides the pump and station structure, mechanical elements such as gate, trash rack, screens and sludge pump, are equally important to ensure optimum performance of the pumping station. Control gates are required at the outlet to avoid backflow during high tide or high flood levels at the receiving water bodies. Trash racks are provided at the entrance of a pumping station and this is required to remove large sediments. Screens are often installed in conjunction with trash racks to remove smaller debris. A sludge pump is only used when the water at the sump area is removed during the service/maintenance period of the flood pumps.

Photo 14: Gate, Trash Rack & Screens

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4. MODEL TESTING & COMPUTATIONAL FLUID DYNAMIC ANALYSIS

Model testing and CFD analysis are carried out to provide effective solutions to complex hydraulic problems with unmatched reliability. This is recommended for pumping stations which have sumps with geometry obstruction, non-uniform approach flow to the sump and where pump flow is greater than 2,500 l/s per pump or total station flow exceeds 6,200 l/s as well as any deviation from HIS design standard.

A CFD analysis provides more detailed information of the flow field at a fraction of cost per time needed for model tests. A CFD analysis also offers a good understanding of the pumping station hydraulic and provides good comparisons between various design alternatives. ■