

12.3 Design Considerations

12.3.1 Location

Economic and design considerations dictate that the pump station be located relatively near the low point of the highway. Hopefully a frontage road or overpass is available for easy access to the station. The station and access road should be located on high ground so that access can be obtained if the highway becomes flooded. Soil borings should be made during the selection of the site to determine the allowable bearing capacity of the soil and to identify any potential problems.

Architectural and landscaping decisions should be made in the location phase for above-ground stations so the station will blend into the surrounding community. Following are some considerations that should be used in the location and design of pump stations.

- Modern pump stations can be architecturally pleasing with a minimum increase in cost.
- Clean functional lines will improve the station's appearance.
- Masonry or a textured concrete exterior can be very pleasing.
- Screening walls may be provided to hide exterior equipment and break up the lines of the building.
- A small amount of landscaping can substantially improve the overall appearance of the site.
- It may be necessary or desirable to place the station entirely underground.
- Ample parking and working areas should be provided adjacent to the station for maintenance and repair vehicles.

12.3.2 Hydrology

Because of traffic safety and flood hazards, pump stations serving major expressways and arterials are usually designed to accommodate a 50-year storm. It is desirable to check the drainage system for the 100-year storm to determine the extent of flooding and the associated risk. Every attempt should be made to keep the drainage area tributary to the station as small as possible. Bypass or pass-through all possible drainage to reduce pumping requirements. Avoid future increases in pumping by isolating the drainage area, i.e., prevent off-site drainage from possibly being diverted to the pump station. Hydrologic design should be based on the ultimate development of the area which must drain to the station.

Designers should consider storage, in addition to that which exists in the wet well, at all pump station sites. For most highway pump stations, the high flows of the inflow hydrograph will occur over a relatively short time. Additional storage, skillfully designed, may greatly reduce the peak pumping rate required. An economic analysis can be used to determine the optimum combination of storage and pumping capacity. Because of the nature of the sites where highway related pump stations are located, it is most often necessary that the storage be located well below normal ground level.

If flow attenuation is required for purposes other than reducing the size of the pump facility and cannot be obtained upstream of the station, consideration may be given to providing the storage downstream of the pump station. This will require large flows to be pumped and thus pump installation and operation costs will be higher.

If storage is used to reduce peak flow rates, a routing procedure must be used to design the system. To determine the discharge rate, the routing procedure integrates three independent elements: the inflow hydrograph, the stage-storage relationship, and the stage-discharge relationship.

12.3.3 Collection Systems

Storm drains leading to the pumping station are usually designed on a flat grade to minimize depth and cost. A minimum grade that produces a velocity of 1 m/s (3 ft/s) in the pipe while flowing one-quarter full is suggested to avoid siltation problems in the collection system. Minimum cover or local head requirements should govern the depth of the uppermost inlets. The inlet pipe should enter the station perpendicular to the line of pumps. The inflow should distribute itself equally to all pumps. Baffles may be required to ensure that this is achieved.

Storm drainage systems tributary to the pump station can be quite extensive and costly. Linear or intermediate storage along the storm drain may be used to reduce peak flows and pipe sizes. For some pump stations, the storage available in the collection system may be significant. However, it is often necessary to provide additional storage near the pump station. This may be done by oversizing the collection system or designing an underground vault.

In a wet-pit station where submersible or screw-type pumps are proposed, consideration of storage in the collection lines may be less critical, due to the less stringent submergence requirements of these alternate types of pumps. Also, submersible pumps can withstand more frequent cycling.

Using grate inlets as screens to prevent large objects from entering the system and possibly damaging the pumps is recommended. This approach has additional advantages of possibly eliminating costly trash racks and simplifying debris removal since debris can be more easily removed from the roadway than the wet well.

12.3.4 Station Types

Basically, there are two types of stations: wet-pit and dry-pit.

Wet-Pit Stations - In the wet-pit station, the pumps are submerged in a wet well or sump with the motors and the controls located overhead. With this design, the stormwater is pumped vertically through a riser pipe. The motor is commonly connected to the pump by a long drive shaft located in the center of the riser pipe. See Figure 12-1 for typical layout. Another type of wet-pit design involves the use of submersible pumps. The submersible pump commonly requires less maintenance and less kilowatts because a long drive shaft is not required. They also allow for convenient maintenance in wet-pit stations because of easy pump removal.

Submersible pumps are now available in large sizes and should be considered for use in all station designs. Rail systems are available which allow removal of pumps without entering the wet well.

Dry-Pit Stations - Dry-pit stations consist of two separate elements: the storage box or wet well and the dry well. Stormwater is stored in the wet well which is connected to the dry well by horizontal suction piping. Centrifugal pumps are usually used. Power is provided by either close-coupled motors in the dry well or long drive shafts with the motors located overhead. The main advantage of the dry-pit station for stormwater is the availability of a dry area for personnel to perform routine and emergency pump and pipe maintenance. See Figure 12-2 for typical layout.

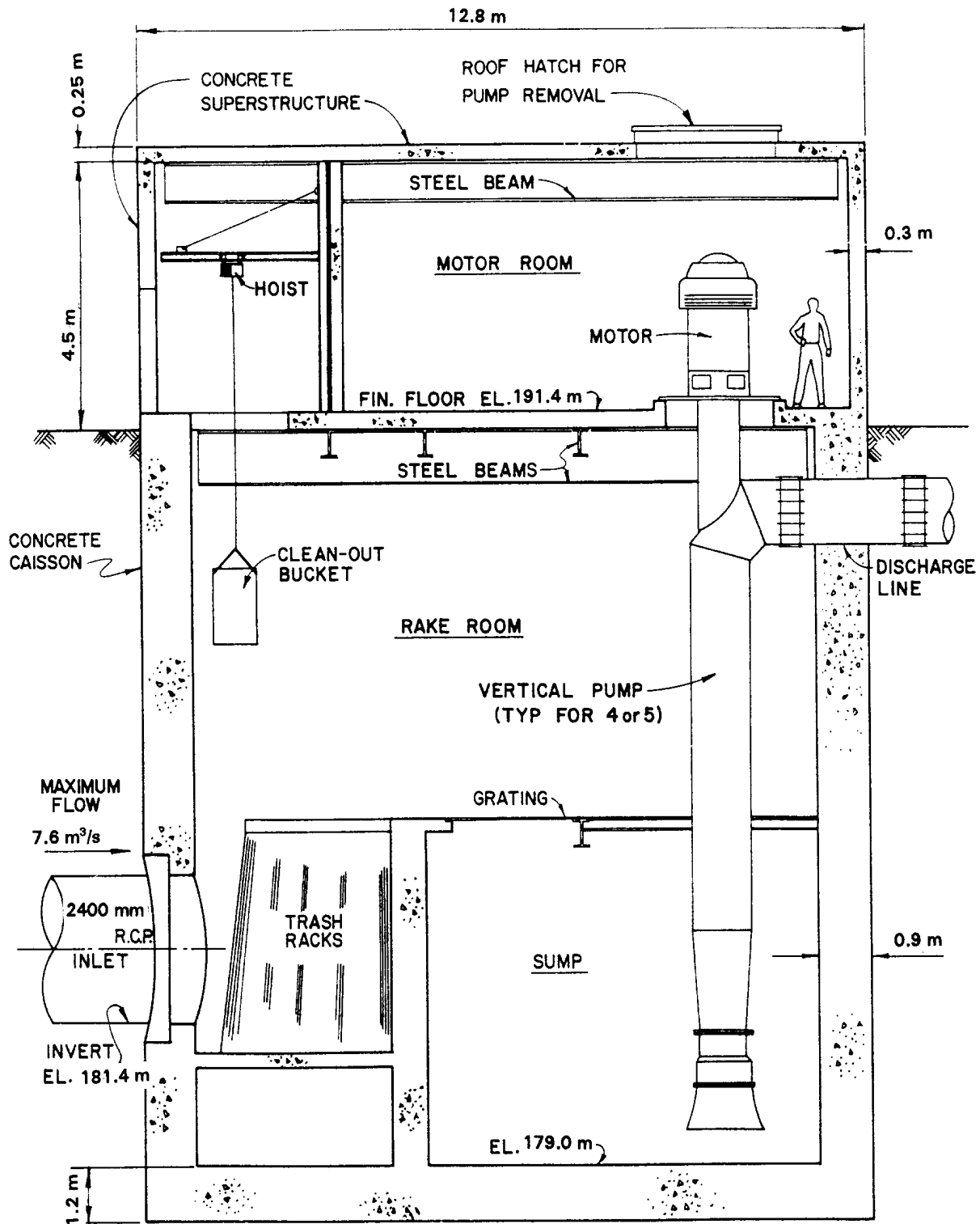


Figure 12-1 Typical Wet-Pit Station

Source: FHWA IP-82-17

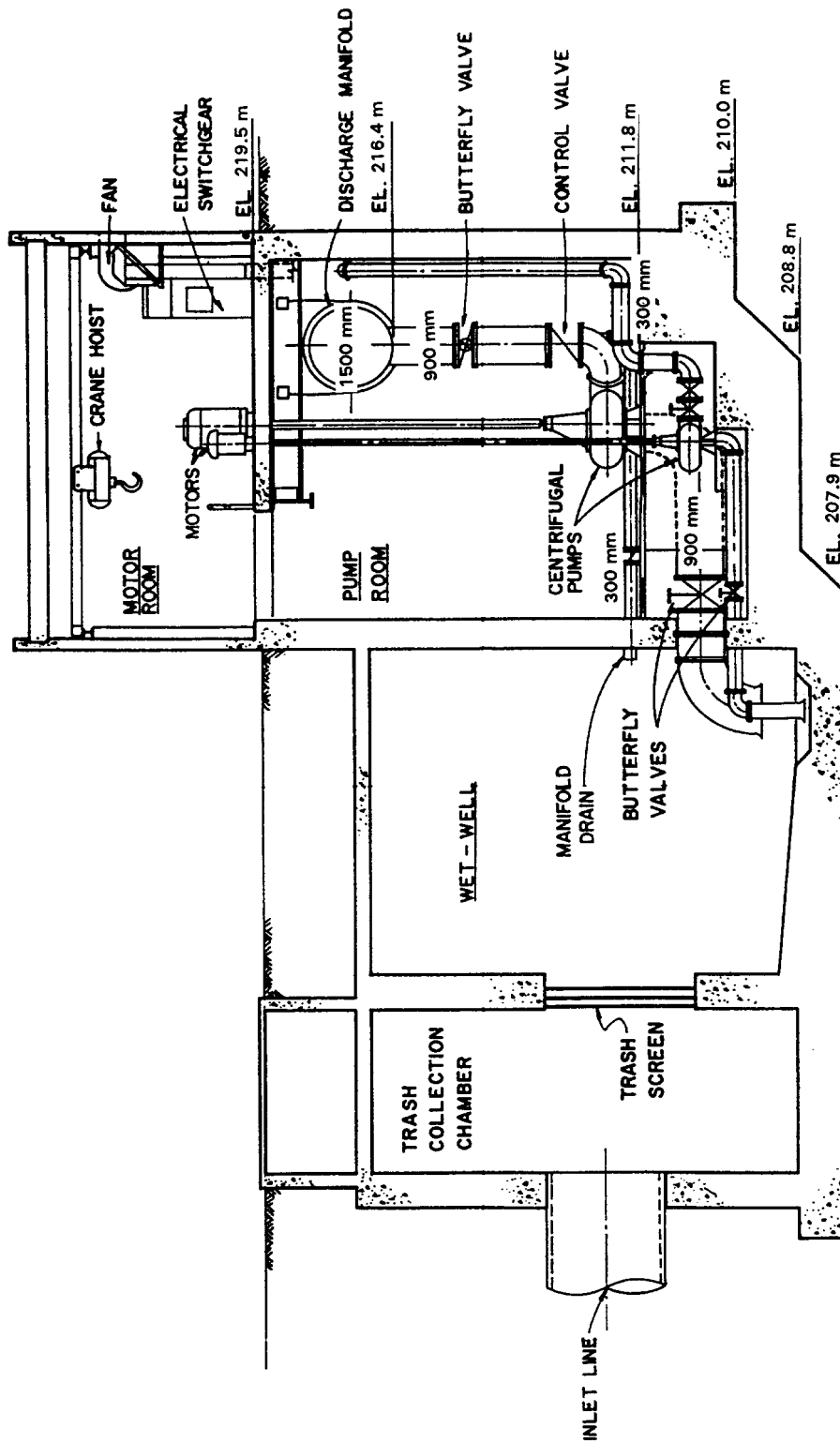


Figure 12-2 Typical Dry-Pit Station

Source: FHWA IP-82-17

12.3.5 Pump Types

The most common types of stormwater pumps are axial flow (propeller), radial flow (impeller) and mixed flow (combination of the previous two). Each type of pump has its particular merits.

Axial Flow Pumps - Axial flow pumps lift the water up a vertical riser pipe; flow is parallel to the pump axis and drive shaft. They are commonly used for low head, high discharge applications. Axial flow pumps do not handle debris particularly well because the propellers will bend or possibly break if they strike a relatively large, hard object. Also, fibrous material will wrap itself around the propellers.

Radial Flow Pumps - Radial flow pumps utilize centrifugal force to move water up the riser pipe. They will handle any range of head and discharge, but are the best choice for high head applications. Radial flow pumps generally handle debris quite well. A single vane, non-clog impeller handles debris the best because it provides the largest impeller opening. The debris handling capability decreases with an increase in the number of vanes since the size of the openings decrease.

Mixed Flow Pumps - Mixed flow pumps are very similar to axial flow except they create head by a combination of lift and centrifugal action. An obvious physical difference is the presence of the impeller "bowl" just above the pump inlet. They are used for intermediate head and discharge applications and handle debris slightly better than propellers.

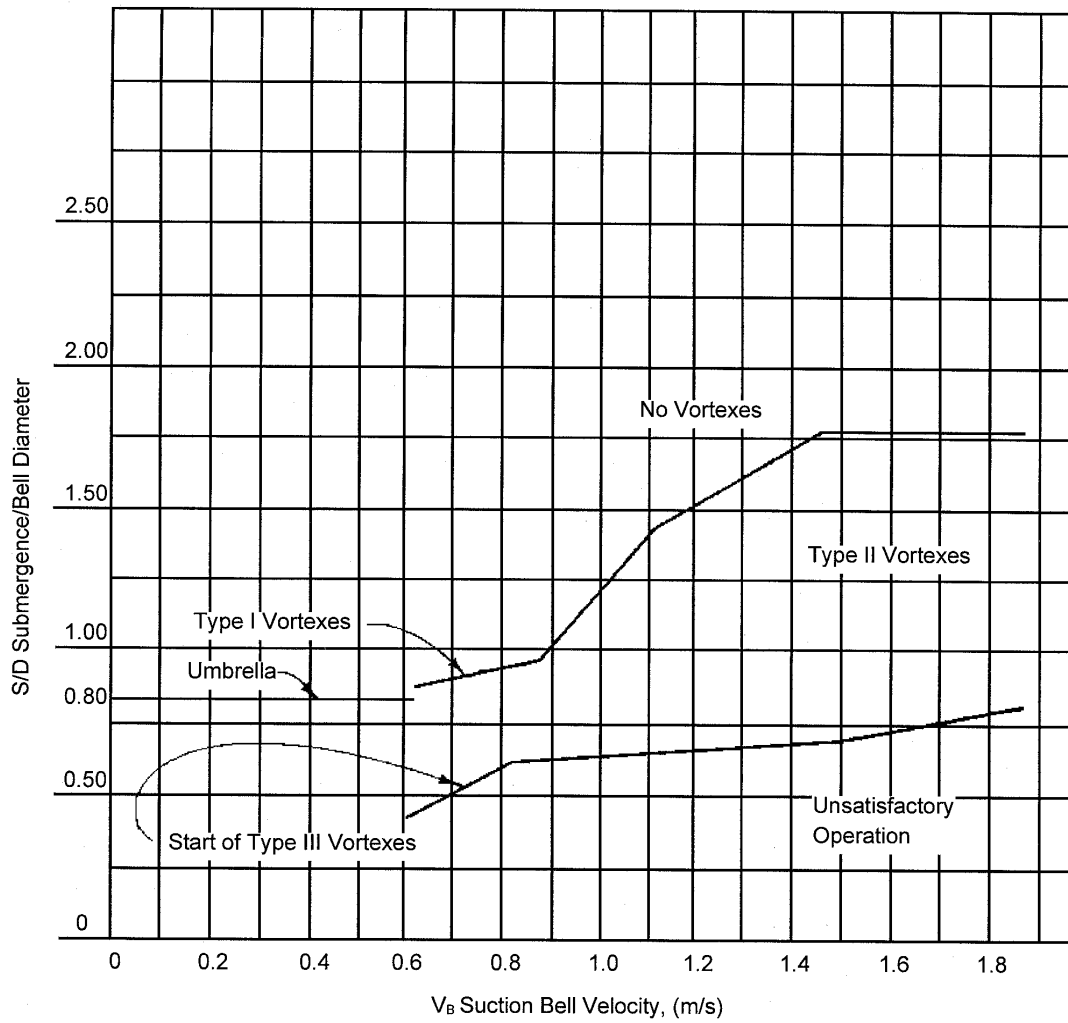
These pumps can be driven by motors or engines housed overhead or in a dry well or by submersible motors located in a wet well. Submersible pumps frequently provide special advantages in simplifying the design, construction, maintenance and, therefore, cost of the pumping station. Use of anything other than a constant speed, single stage, single suction pump would be rare.

The selection procedure is to first establish the criteria and then to select from the options available a combination that clearly meets the criteria. Cost, reliability, operating and maintenance requirements are all important considerations when making the selection. It is difficult and beyond the scope of this Manual to develop a totally objective selection procedure. First costs are usually of more concern than operating costs in stormwater pump stations since the operating periods during the year are relatively short. Ordinarily, first costs are minimized by providing as much storage as possible, with two or three small pumps, electrically-driven.

12.3.6 Submergence

Submergence is the depth of water above the pump inlet necessary to prevent cavitation and vortexing. It varies significantly with pump type and speed and atmospheric pressure. This dimension is provided by the pump manufacturer and is determined by laboratory testing. A very important part of submergence is the required net positive suction head (NPSH) because it governs cavitation. The available NPSH should be calculated and compared to the manufacturer's requirement. Additional submergence may be required at higher elevations. As a general rule, radial flow pumps require the least submergence while axial flow pumps require the most.

One popular method of reducing the submergence requirement (and therefore the station depth) for axial and mixed flow pumps, when cavitation is not a concern, is to attach a suction umbrella. A suction umbrella is a dish-shaped steel plate attached to the pump inlet which improves the entrance conditions by reducing the intake velocities. For umbrella velocities of 0.6 m/s (2 ft/s) or less, a submergence to pump bell diameter ratio of 0.80 can be used. Vortex criteria developed by Dicmas can be used to check the submergence requirements for these pumps (see Figure 12-3).



Phenomenon is not related solely to backwall as illustrated.
 Vortexing occurs at random locations according to pump pit conditions.

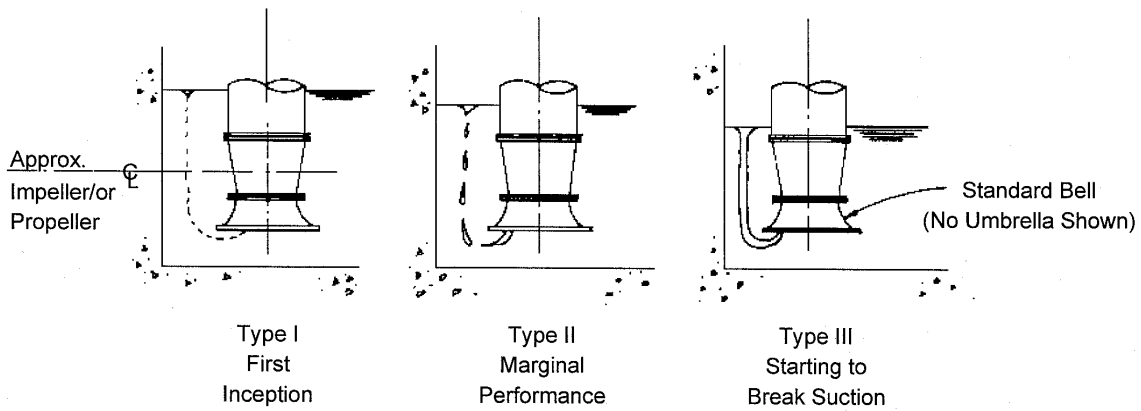


Figure 12-3 Vortex Description And Submergence Requirements

12.3.7 Water-Level Sensors

The water-level sensors activate the pumps and, therefore, are a vital component of the control system. There are a number of different types of sensors that can be used. Types include the float switch, electronic probes, ultrasonic devices, mercury switch and air pressure switch. The location or setting of these sensors controls the starting and stopping of the pump motors. Their function is critical because the pump motors or engines must not start more frequently than an allowable number of times per hour (i.e., the minimum cycle time) to avoid damage. To prolong the life of the motors, sufficient volume must be provided between the pump start and stop elevations to meet the minimum cycle time requirement. The on-off setting for the first pump is particularly important because it defines the most frequently used cycle.

12.3.8 Power

Several types of power may be available for a pump station. Examples are electric motors and gasoline, diesel or natural gas engines. The designer should select the type of power that best meets the needs of the project based on an estimate of future energy considerations and overall station reliability. A comparative cost analysis of alternatives is helpful in making this decision. However, when readily available, electric power is usually the most economical and reliable choice today.

The need for backup power is dependent upon the consequences of failure. The decision to provide it should be based on economics and safety. For electric motors, two independent electrical feeds from the electric utility with an automatic transfer switch may be the cost-effective choice when backup power is required. A standby generator is generally less cost-effective because of its initial costs. Also, standby generators require considerable maintenance and testing to ensure operation in times of need.

For extensive depressed freeway systems involving a number of electric motor-driven stations, a mobile generator may be the cost-effective choice for backup power. A trailer mounted generator can be stored at any one of the pump stations. If a power outage occurs, maintenance forces can move the generator to the affected station to provide temporary power. If a mobile generator is used as the source of backup power, it may be necessary to add additional storage to compensate for the time lag that results in moving the generator from site to site. This lag will typically be 1.0 to 1.5 h from the time the maintenance forces are notified.

12.3.9 Discharge System

The discharge piping should be kept as simple as possible. Pumping systems that lift the stormwater vertically and discharge it through individual lines to a gravity storm drain as quickly as possible are preferred. Individual pump discharge lines are the most cost-effective system for short outfall lengths. Damaging pump reversal could occur with very long forced mains. Check valves should be installed. The effect of stormwater returning to the sump after pumping stops should be considered. Individual lines may exit the pumping station either above or below grade. Frost depth shall be considered while deciding the depth of discharge piping. Frozen discharge pipe could exert additional back pressure on pumps.

It may be necessary to pump to a higher elevation using long discharge lines. This may dictate that the individual lines be combined into a force main via a manifold. For such cases, check valves must be provided on the individual lines to keep stormwater from running back into the wet well and restarting the pumps or prolonging their operation time. Check valves should preferably be located on horizontal layouts rather than vertical, to prevent sedimentation on the downstream side

after the valve closing. Gate valves should be provided in each pump discharge line to provide for continued operation during periods of repair, etc. A cost analysis should be performed to determine what length and type of discharge piping justifies a manifold. Number of valves required shall be kept to a minimum to reduce cost, maintenance and headloss through the system.

12.3.10 Flap Gates And Valving

Flap Gates - The purpose of a flap gate is to restrict water from flowing back into the discharge pipe and to discourage entry into the outfall line. Flap gates are usually not water tight so the elevation of the discharge pipe should be set above the normal water levels in the receiving channel. If flap gates are used, it may not be necessary to provide for check valves.

Check Valves - Check valves are water tight and are required to prevent backflow on forcemains which contain sufficient water to restart the pumps. They also effectively stop backflow from reversing the direction of pump and motor rotation. They must be used on manifolds to prevent return flow from perpetuating pump operation. Check valves should be "non-slam" to prevent water hammer. Types include: swing, ball, dash pot and electric.

Gate Valves - Gate valves are simply a shut-off device used on forcemains to allow for pump or valve removal. These valves should not be used to throttle flow. They should be either totally open or totally closed.

Air/Vacuum Valves - Air/Vacuum valves are used to allow air to escape the discharge piping when pumping begins and to prevent vacuum damage to the discharge piping when pumping stops. They are especially important with large diameter pipe. If the pump discharge is open to the atmosphere, an air-vacuum release valve is not necessary. Combination air release valves are used at high points in force mains to evacuate trapped air.

12.3.11 Trash Racks And Grit Chambers

Trash racks should be provided at the entrance to the wet well if large debris is anticipated. For stormwater pumping stations, simple steel bar screens are adequate. Usually, the bar screens are inclined with bar spacings approximately 40 mm (1.5 in). Constructing the screens in modules facilitate removal for maintenance. If the screen is relatively small, an emergency overflow should be provided to protect against clogging and subsequent surcharging of the collection system. As previously noted, screening large debris at surface inlets may be very effective in minimizing the need for trash racks.

If substantial amounts of sediment are anticipated, a chamber may be provided to catch solids that are expected to settle out. This will minimize wear on the pumps and limit deposits in the wet well. The grit chamber should be designed so that a convenient means of sediment removal is available.

12.3.12 Ventilation

Ventilation of dry and wet wells is necessary to ensure a safe working environment for maintenance personnel. The ventilation system can be activated by a light switch at the entrance to the station. Maintenance procedures should require personnel to wait several minutes after ventilation has started before entering the well. Some owners require the testing of the air in the wet well prior to allowing entry. Safety procedures for working in wet wells should be well established and carefully followed.

If mechanical ventilation is required to prevent buildup of potentially explosive gasses, the pump motors or any spark producing equipment should be rated explosion proof or the fans run continuously.

Heating and dehumidifying requirements are variable. Their use is primarily dependent upon equipment and station type, environmental conditions and station use.

12.3.13 Roof Hatches And Monorails

It will be necessary to remove motors and pumps from the station for periodic maintenance and repair. Removable roof hatches located over the equipment are a cost-effective way of providing this capability. Mobile cranes can simply lift the equipment directly from the station onto maintenance trucks. Monorails are usually more cost-effective for larger stations.

12.3.14 Equipment Certification And Testing

Equipment certification and testing is a crucial element of pump station design. The purchaser has a right to witness equipment testing at the manufacturer's lab. However, this is not always practical. As an alternative, the manufacturer should provide certified test results to the owner. It is good practice to include in the contract specifications the requirement for acceptance testing by the owner, when possible, to ensure proper operation of the completed pump station. The testing should be done in the presence of the owner's representative. If the representative waves the right to observe the test, a written report should be provided to give assurance that the pump equipment meets all performance requirements. Any component that fails should be repaired and retested.

12.3.15 Monitoring

Pump stations are vulnerable to a wide range of operational problems from malfunction of the equipment to loss of power. Monitoring systems such as on-site warning lights and remote alarms can help minimize such failures and their consequences.

Telemetry is an option that should be considered for monitoring critical pump stations. Operating functions may be telemetered from the station to a central control unit. This allows the central control unit to initiate corrective actions immediately if a malfunction occurs. Such functions as power, pump operations, unauthorized entry, explosive fumes and high water levels can be monitored effectively in this manner. Perhaps the best overall procedure to assure the proper functioning of a pump station is the implementation of a regular schedule of maintenance conducted by trained, experienced personnel.

12.3.16 Hazardous Spills

The possibility of hazardous spills is always present under highway conditions. In particular, this has reference to gasoline, and the vulnerability of pump stations and pumping equipment to fire damage. There is a history of such incidents having occurred and also of spills of oils, corrosive chemicals, pesticides and the like having been flushed into stations, with undesirable results. The usual design practice has been to provide a closed conduit system leading directly from the highway to the pump station without any open forebay to intercept hazardous fluids, or vent off volatile gases. With a closed system, there must be a gas-tight seal between the pump pit and the motor room in the pump station. Preferably, the pump station should be isolated from the main collection system and the effect of hazardous spills by a properly designed storage facility upstream of the station. This may be an open forebay or a closed box below the highway pavement or adjacent to it. The closed box must be ventilated by sufficient grating area at each end.